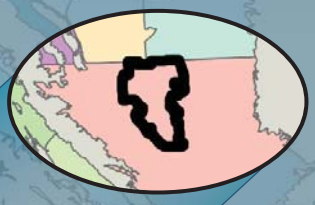
REFERENCES

Semitropic Water Storage District

2012 Groundwater Management Plan

Kern County, California



SEMITROPIC
GROUNDWATER BANKING
WATER STORAGE DISTRICT

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Abbreviations and Acronyms

af	acre-feet
AVWB	Antelope Valley Water Bank
BMOs	basin management objectives
CASGEM	California Statewide Groundwater Elevation Monitoring Program
cfs	cubic feet per second
CVP	Central Valley Project
CWC	California Water Code
District	Semitropic Water Storage District
DWR	Department of Water Resources
EQIP	Environmental Quality Incentives Program
GPSC	General Project Service Charge
ILRP	Irrigated Lands Regulatory Program
KCWA	Kern County Water Agency
mg/l	milligrams per liter
Semitropic	Semitropic Water Storage District
Reclamation	U.S. Bureau of Reclamation
RWMG	Poso Creek Regional Water Management Group
SWP	State Water Project
SWRU	Stored Water Recovery Unit
taf	one-thousand acre-feet
TDS	total dissolved solids
USGS	United States Geological Survey

1 Introduction

In the fall of 2003, Semitropic Water Storage District (Semitropic or District) adopted a groundwater management plan (2003 Plan) under California Water Code §10750 et seq., which were added through enactment of AB-255 (1991), later replaced by AB-3030 (1992), and modified by SB-1938 (2002). To a very large degree, the 2003 Plan formalized the many groundwater management practices that had evolved over many years of operational experience with a significant conjunctive-use project. Further, it affirmed the District's commitment to local control and management. The adopted plan included provision for periodic review, which was recently completed. This review resulted in revisions to the existing plan and adoption of this amended (or updated) groundwater management plan (Plan). Revisions included the following:

- Refine Basin Management Objectives.
- Expand basin management strategies and actions.
- Include accomplishments.
- Update text and figures as appropriate to reflect the most recent available data.
- Reorganize Plan.

Fundamentally, development of a groundwater management plan involves 1) setting an overarching goal; 2) identifying issues of concern within the context of that goal; 3) formulating basin management objectives that address the issues of concern; 4) establishing management strategies and actions to achieve the objectives; and 5) developing an implementation plan which tracks progress in meeting the basin management objectives. Development of this amended groundwater management plan was guided by this logically ordered list of fundamental elements. The remainder of this section addresses the Plan's overarching goal; describes the management area; and includes discussion of statutory authority, requirements, and guidance respecting groundwater management planning.

1.1 Overarching Goal

Preservation and enhancement of the groundwater resource is vital to sustaining the local economies which have been built up in reliance, in whole or in part, on this resource. The goals articulated in the District's 2003 Plan are 1) to preserve the utility of the groundwater resource within its area, both in terms of quantity and quality, 2) to ensure the long-term

sustainability of its water resources, and 3) to preserve and enhance the groundwater resource for the benefit of its landowners . Fundamentally, the District's goals remain unchanged; however, for the purpose of this amended plan, the overarching goal has been consolidated and restated as follows: *to preserve the groundwater resource as an economically viable source of water supply to support overlying uses into the foreseeable future through local control and management*. This goal is the point of beginning for the formulation of the amended groundwater management plan.

1.2 Management Area

The Management Area is defined as the area within the boundaries of the Semitropic Water Storage District, which is that portion of the groundwater basin over which the District has jurisdiction to implement specific management practices. The Semitropic Water Storage District is located in north-central Kern County in the San Joaquin Valley, about 20 miles northwest of the City of Bakersfield (reference Figure 1). In response to a long-term decline in groundwater levels, Semitropic was organized in 1958 to provide supplemental water for irrigation within its boundaries. The total land area within Semitropic is approximately 221,000 acres (or 345 square miles), with about 125,000 acres (or 195 square miles) irrigated. It is noted that the irrigated area varies from year to year, depending on many factors.

The Semitropic Improvement District (reference Figure 1) includes the areas to which imported surface water supplies have been and are being delivered, and adjacent areas receiving benefits from the importation of surface water. The remainder of the District, outside the Improvement District and largely undeveloped for agriculture, receives a lesser benefit from District operations since no surface water is delivered in the area. In practice, the District is regarded as one management area, consisting of the entire District area.

Department of Water Resources (DWR) Bulletin No. 118 --- *California's Groundwater Update 2003* --- delineates the boundaries of groundwater basins and subbasins throughout California. The San Joaquin Valley portion of Kern County (or the Kern County subbasin) is located within the San Joaquin Valley Basin of the Tulare Lake Hydrologic Region, as shown on Figure 2. Figure 3 focuses on Kern County and shows the location of the District in relation to the groundwater basin boundary identified by DWR. In particular, Semitropic is located within DWR Groundwater Basin No. 5-22.14.

As suggested by the boundaries of the groundwater basin, the District shares a common (i.e., hydraulically connected) groundwater resource with neighboring water agencies. Accordingly, water management practices in Semitropic affect neighboring areas and vice versa. Although the District only has authority to enact specific management practices within its boundaries, the District may take actions to protect groundwater supplies from

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R

25S 26S 27S 28S 29S 30S 31S 32S 12N 11N 10N

24W 23W 22W 21W 20W 19W 18W 17W 16W 15W 14W

Delano
McFarland
Wasco
Shafter
Lost Hills
Bakersfield
Arvin
Taft
Tehachapi
Maricopa

Semitropic W.S.D.

Pond-Poso Canal
California Aqueduct
Buttonwillow Ridge Canal
Lerdo Canal
Calloway Canal
Friant-Kern Canal
Cawelo Canal
Beardsley Canal
Kern River
Lake Isabella
Cross Valley Canal
KWBA Canal
Kern River Canal
Alejandro Canal
Arvin Edison Canal
Kern Island Canal
California Aqueduct

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City
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Semitropic W.S.D.

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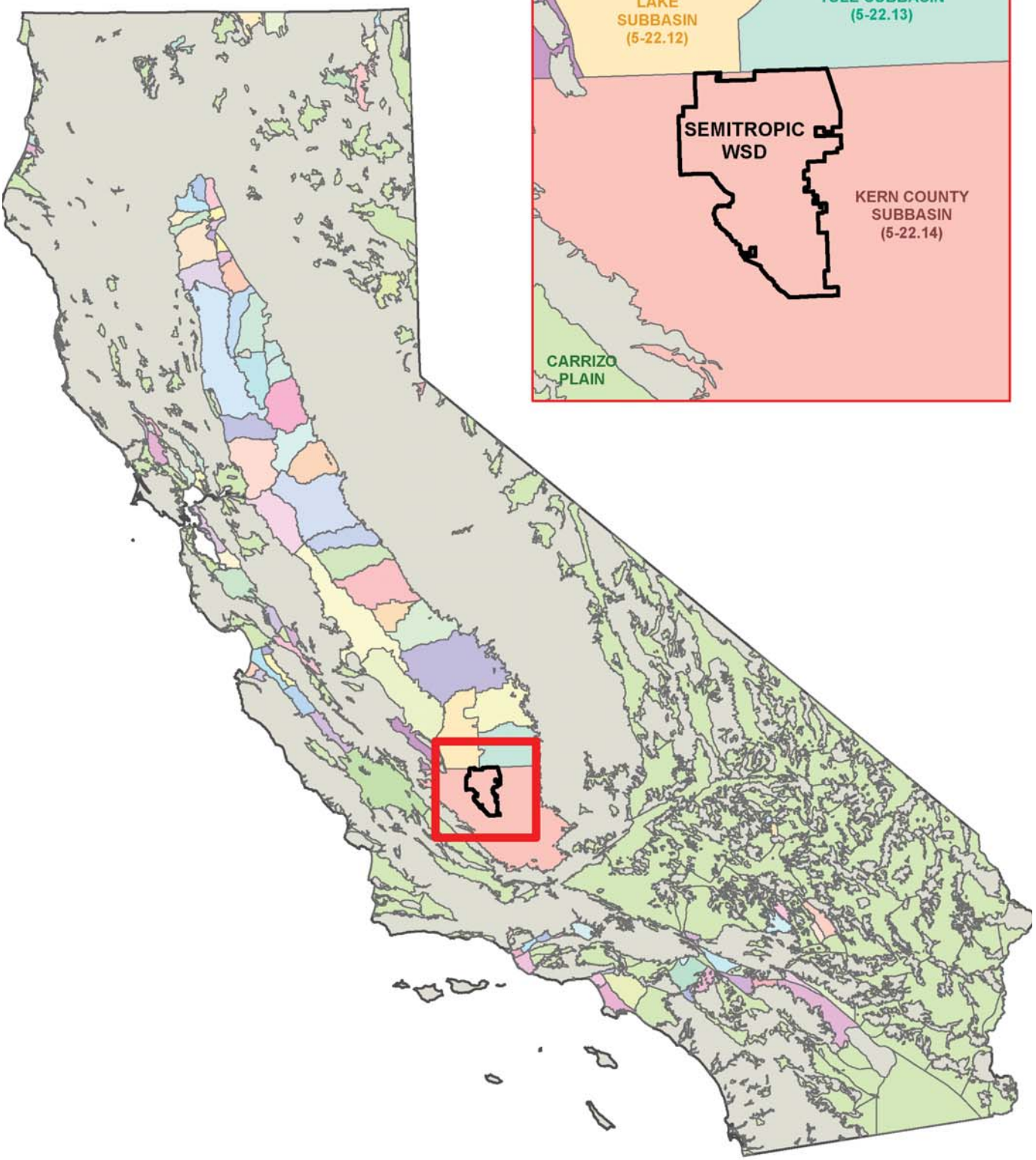
2012 Groundwater Management Plan
Kern County, California

Semitropic Water Storage District

REGIONAL LOCATION

SEPTEMBER 2012 FIGURE 1

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SOURCE: DWR Bulletin 118, v.3, 2003.

2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	Groundwater Basins
Semitropic Water Storage District		March 2012 Figure 2

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25S 26S 27S 28S 29S 30S 31S 32S 12N 11N 10N

24W 23W 22W 21W 20W 19W 18W 17W 16W 15W 14W

Delano
Delano-Earlimart I.D.
Lost Hills W.D.
Southern San Joaquin M.U.D.
Kern-Tulare W.D.
McFarland
Berrenda Mesa W.D.
Lake Isabella
Semitropic W.S.D.
Pond-Poso Canal
Lost Hills
North Kern W.S.D.
Wasco
Cawelo W.D.
California Aqueduct
Buttonwillow Ridge Canal
Shafter-Wasco I.D.
Cawelo Canal
Lerdo Canal
Friant-Kern Canal
Calloway Canal
Shafter
Belridge W.S.D.
Buena Vista W.S.D.
Beardsley Canal
Kern River
Rosedale-Rio Bravo W.S.D.
Bakersfield
Cross Valley Canal
Improvement District No. 4
KWBA Canal
Kern River Canal
Alejandro Canal
Arvin Edison Canal
Kern Delta W.D.
Arvin
Buena Vista W.S.D.
Kern Island Canal
Taft
Tehachapi
Arvin-Edison W.S.D.
Wheeler Ridge-Maricopa W.S.D.
Maricopa
California Aqueduct

City
River, Canal
Township
Section
Semitropic Groundwater Monitoring Committee Member District
San Joaquin Valley Subbasin

SOURCE: San Joaquin Valley Subbasin - DWR, Bulletin 118, Update 2003

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2012 Groundwater Management Plan
Kern County, California

Semitropic Water Storage District

KERN COUNTY GROUNDWATER SUB-BASIN MANAGEMENT PLANNING AREA AND OTHER LOCAL AGENCIES

SEPTEMBER 2012 FIGURE 3

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activities outside of its area. The Plan includes management goals that would affect the groundwater outside District boundaries. As a practical matter, the area of influence is primarily within the Kern County subbasin; however, parts of the Tule and Tulare Lake sub-basins may also be included.

1.3 California Water Code

Part 2.75 of Division 6 of the California Water Code, titled *Groundwater Management*, is the result of legislation passed initially in 1991, and subsequently amended. Presently, Part 2.75 consists of Sections 10750 through 10755.4. In this planning document, specific reference is made to certain sections and some have been reproduced for ease of reference.

1.3.1 Statutory Authority

Development, adoption, and implementation of a groundwater management plan are voluntary. §10753(a) provides that a "local agency" may adopt and implement a groundwater management plan within its service area pursuant to Part 2.75 of the Water Code. Semitropic Water Storage District meets the definition of a "local agency" in that it is a "local public agency that provides water service" (§10752(g)). Implementation of a plan requires that the public agency have the necessary powers. In this regard, Water Code Sections 10750 et seq. provides some additional powers. Most of these powers are already provided under Water Storage District law (Division 14 of the Water Code) and many are already being exercised under the District-approved projects.

1.3.2 Plan Requirements and Guidance

For those agencies electing to develop and implement a groundwater management plan, the Water Code provides guidance respecting the content of a plan. Certain content is required if the agency intends to apply for funding administered by DWR that may be available from time to time; guidance respecting other content is discretionary. DWR Bulletin 118, *California's Groundwater Update 2003*, provides a summary of the guidelines set forth in the Water Code, as well as additional suggestions. Table 1 presents a summary of these guidelines, along with the location in this report where each is addressed.

Table 1: Potential Elements of a Groundwater Management Plan

Components	Location
Water Code Required Components [§10753.7(a)]	
1. Basin Management Objectives (BMOs).	Section 5
2. Monitoring and management of groundwater elevations, groundwater quality, inelastic land subsidence, and changes in surface water flows and quality that directly affect groundwater levels or quality or are caused by pumping.	Section 6
3. Plan to involve other agencies located in the groundwater basin.	Sections 5 & 6
4. Map of groundwater basin boundary, as delineated by DWR Bulletin 118, with agency boundaries that are subject to GMP.	Section 1
5. Adoption of monitoring protocols.	Section 6
6. Documentation of public involvement.	Section 5 & Appendix D
Water Code Discretionary Components [§10753.8]	
1. The control of saline water intrusion.	N/A
2. Identification and management of wellhead protection areas and recharge areas.	Section 5
3. Regulation of the migration of contaminated groundwater.	Section 5
4. The administration of a well abandonment and well destruction program.	Section 5
5. Mitigation of conditions of overdraft.	Section 5
6. Replenishment of groundwater extracted by water producers.	Section 5
7. Monitoring of groundwater levels and storage.	Section 6
8. Facilitating conjunctive use operations.	Section 5
9. Identification of well construction policies.	Section 5
10. The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.	Section 5
11. The development of relationships with state and federal regulatory agencies.	Section 5
12. The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.	Section 5
DWR Bulletin 118 Suggested Components	
1. Establish advisory committee of stakeholders.	Section 5
2. Describe area to be managed.	Sections 1, 3, and 4
3. Describe connection between BMOs, management actions, and water supply reliability.	Section 5
4. Periodic reports on basin conditions and management activities.	Section 6
5. Periodic re-evaluation of Plan.	Section 6

2 Groundwater Management

Groundwater management has been practiced in the San Joaquin Valley for decades, a fact that was documented in a 1979 report initiated by the San Joaquin Valley Agricultural Water Committee, *Water Resources Management in the Southern San Joaquin Valley*. As the report title suggests, groundwater management activities existed under the broader umbrella of water resources management. "Groundwater management plan" was codified in the 1990s with the passage of groundwater management legislation. Accordingly, many agencies who subsequently prepared groundwater management plans, including Semitropic, were formalizing in a standalone planning document many of the activities which had previously been referred to as simply "water resources management".

The plan formulation process included identification and consideration of adjoining or overlapping agencies engaged in groundwater management. This section considers both individual agency groundwater management planning documents and regional management activities.

2.1 Neighboring Groundwater Management Plans

Cal. Water Code §10750(a): *The Legislature finds and declares that groundwater is a valuable natural resource in California, and should be managed to ensure both its safe production and its quality. It is the intent of the Legislature to encourage local agencies to work cooperatively to manage groundwater resources within their jurisdictions.*

Similar to Semitropic, neighboring water districts operate conjunctive-use projects , with most based on the importation of supplemental water supplies from the State Water Project (SWP), the federal Central Valley Project (CVP), or the Kern River. Accordingly, groundwater management is on-going in these districts and is particularly relevant to this plan given the shared (i.e., hydraulically connected) groundwater resource. The status of groundwater management in adjoining or overlapping areas is summarized below by agency (reference Figure 3):

Shafter-Wasco Irrigation District: *Groundwater Management Plan (July 2007)*

- "The District's objective is to preserve the utility of the groundwater resource, both in terms of quantity and quality at the least possible cost to sustain the agricultural production and support urban development within the boundaries of the District." (p 1-1)

- "The Plan will enable the District to establish policies that will serve to enhance the overall management of the water supplies available to the District." (p 2-1)

- The District's Basin Management Objectives are:

    - "To promote and realize groundwater resource protection;

    - To facilitate groundwater resource sustainability;

    - To develop groundwater resource understanding;

    - To develop groundwater basin understanding; and

    - To promote and facilitate information dissemination regarding the groundwater source." (p 4-1)

- "Continued monthly monitoring of six (6) wells and semi-annual monitoring of 64 wells will assist in conclusions as to the status (availability) of the resource." (p 4-3)

- "Documentation in the form of an annual report will be prepared as required to record the results of the management activities monitoring elements of the Plan." (p 7-2)

North Kern Water Storage District: *Groundwater Management Plan (July 1993)*

- North Kern's 1993 plan was prepared to 1) "preserve and enhance the groundwater resource for the benefit of its landowners", 2) "coordinate its activities with those of its neighbors", 3) "review and enhance its existing monitoring activities", and 4) "help assure the long-standing practice of local management". (p 1)

- North Kern is presently in the process of updating its groundwater management plan, which is expected to be complete in 2012.

Buena Vista Water Storage District: *Groundwater Status and Management Plan (Revised May 2002)*

- "It is the goal of Buena Vista Water Storage District to provide the landowners and water users of the District with a reliable, affordable, and usable surface and groundwater supply." (p 1)

- "The District's Groundwater Status and Management Plan describes the District's plan to protect groundwater levels and quality in the present and over the long-term, keep groundwater use costs to a minimum, maintain groundwater control at the local level, document existing conditions, and initiate necessary programs and studies." (p 1)

Rosedale-Rio Bravo Water Storage District: *Groundwater Management Plan*

- Rosedale's plan was prepared to 1) "to preserve and enhance groundwater resources", 2) "enhance existing monitoring activities", and 3) "provide for the continuance of local management". (p 2)

- Rosedale operates a direct recharge project on behalf of its landowners and provides water banking services to third parties. In this context, the District recently adopted a "Policy Regarding Sustainable Groundwater Banking Operations".

City of Wasco: *Urban Water Management Plan Update for 2010 (June 2011)*

- "The City of Wasco currently has only one source of water available to it, groundwater." (p 25)

- "The City of Wasco uses wastewater effluent for agricultural irrigation on City-owned land. The irrigation practice helps to replenish the area groundwater table through deep percolation and reduces groundwater overdraft." (p 26)

- "The City of Wasco has not adopted a groundwater management plan. The City is currently seeking funding to develop its own groundwater management plan." (p 28)

The above-referenced groundwater management planning documents were reviewed and considered in the formulation of this plan, and was a key step in coordinating with the planning efforts of other basin stakeholders. The only adjoining district without an adopted plan is the Southern San Joaquin Municipal Utility District. Summarized in Table 2, located at the end of this section, are the adjoining entities and their adopted management plans.

2.2 Regional Cooperation and Collaboration

As noted near the beginning of this section, §10750(a) of the Water Code "encourage[s] local agencies to work cooperatively to manage groundwater resources". In addition to coordinating with the individual efforts of the above-described districts, this section describes

overlapping agencies with regional extent as well as forums which include several groups of districts who have come together cooperatively and collaboratively for purposes related to groundwater management. Accordingly, the following subsections include discussion of the County of Kern, the Kern County Water Agency, the Semitropic Groundwater Monitoring Committee, and the Poso Creek Regional Water Management Group. Summarized in Table 2 (located at the end of this section) are the adjoining entities and their management plans, along with an indication of which districts are participants in the Semitropic Groundwater Monitoring Committee or the Poso Creek Regional Water Management Group.

2.2.1 County Of Kern

In May of 1989, the Kern County Board of Supervisors adopted Ordinance No. G-5006 concerning the regulation of wells and water systems. By reference, the Ordinance initially adopted certain standards contained in California State Department of Water Resources Bulletin No. 74-81, and Kern Health Department Handbook "UT 50", which have been amended from time to time. This Ordinance governs the construction and reconstruction of wells, including protection of the well head, casing standards and seals between aquifers, as well as procedures to be followed upon abandonment, and is applicable to wells throughout the District and Kern County.

More recently, in a report to the Board of Supervisors regarding County-wide groundwater resource management (2011), the County's Development Services Agency indicated its intent to undertake the following efforts:

- Schedule tri-annual meetings with the Kern County Water Agency staff and prepare water issue and program status reports for the Board of Supervisors.
- Continue to implement water laws and programs and comment on water planning proposals.
- Prioritized participation in water program meetings.

With regard to the last item, this same report listed a number of the local water meetings or forums, which included the Poso Creek Regional Water Management Group (reference Section 2.2.4). Though inactive for the last two to three years, Semitropic has been an active participant in the Water Resources Committee of Kern County, which is advisory to the Kern County Board of Supervisors. Finally, when requested by agencies of Kern County, the District reviews development plans and proposals within its boundaries.

2.2.2 Kern County Water Agency

Semitropic is a "member unit" of the Kern County Water Agency (KCWA), with whom Semitropic contracts for the importation of State Water Project water. Kern County Water Agency was created by special act in 1961 and has boundaries which are coincident with the County of Kern. Though the Kern County Water Agency has not developed a formal regional groundwater management plan, they have engaged in activities integral to groundwater management, which include the following (to name a few):

- Contracting vehicle for the importation of State Water Project Water to Kern County.
- Local clearinghouse for the collection and management of groundwater level data and, to a lesser extent, groundwater quality data.
- Prepares an annual water supply report which includes maps of groundwater levels and the concentration of total dissolved solids; selected groundwater level hydrographs; and estimates of total water supplies and uses.
- Cooperates with DWR in the semi-annual collection of groundwater level measurements in Kern County.

2.2.3 Semitropic Groundwater Monitoring Committee

Semitropic, along with neighboring districts (shown on Figure 3) --- each with its own conjunctive-use project, share a common groundwater basin. For this reason, a groundwater monitoring committee was formed in 1994 in response to implementation of the Semitropic Groundwater Banking Project. This committee includes representatives from Semitropic and five neighboring water agencies; Buena Vista Water Storage District, Rosedale-Rio Bravo Water Storage District, Shafter-Wasco Irrigation District, North Kern Water Storage District, and Southern San Joaquin Municipal Utility District (as shown on Figure 3). It is noteworthy that the committee includes users of State Water Project water, federal Central Valley Project water, and local Kern River water. The responsibilities of the committee are identified in the Memorandum of Understanding and are summarized following:

- Engage a professional groundwater consultant.
- Meet and confer periodically.
- Establish groundwater evaluation methodologies.
- Identify additional monitoring wells and that are considered necessary.

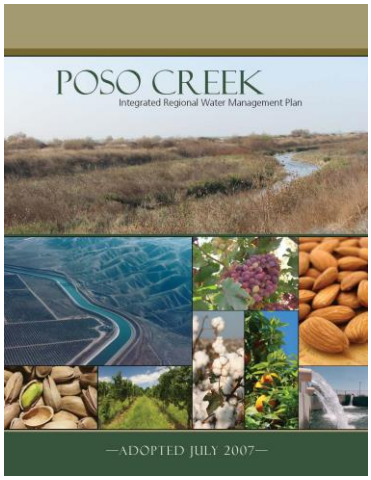
- Prepare annual water balance studies and other interpretive studies.
- Develop criteria for determining the conditions constituting a significant imbalance between the delivery of water for banking and/or nonbanking purposes and withdrawal for such purposes.
- Determine the impacts of the Project by evaluating with and without Project conditions.
- Develop procedures, review data, and recommend Project operational criteria for the purpose of identifying, verifying, avoiding, eliminating or mitigating to the extent practical, the creation of significant imbalances or significant adverse impacts.

The Committee has been meeting as necessary since its inception in 1994. Kenneth D. Schmidt and Associates serves as consultant to the Committee and has been responsible for preparation of a biennial monitoring report. The Committee's consultant has also provided guidance on the location and construction of all of the District's monitor wells.

2.2.4 Poso Creek Regional Water Management Group

In the spring of 2005, efforts were underway to bring several adjoining water agencies together for the purpose of developing an *Integrated Regional Water Management Plan* and, by early 2006, plan development had begun in earnest. By July 2007, the following water agencies had cooperated in the development of a Plan and the boards of directors of these same agencies had adopted the Plan.

- Cawelo Water District
- Delano-Earlimart Irrigation District
- Kern-Tulare Water District
- North Kern Water Storage District
- Semitropic Water Storage District
- Shafter-Wasco Irrigation District



These water agencies, together with the North West Kern Resource Conservation District and a representative of 16 economically-disadvantaged communities with the Poso Creek Region, make up the Poso Creek Regional Water Management Group. The purpose of the Poso Creek Integrated Regional Water Management Plan (Plan) is to provide a framework for (1) coordinating groundwater and surface water management activities through *regiona*l

objectives, and (2) implementing the measures necessary to meet those objectives. The Plan's groundwater-related objectives include the following:

- Maintain groundwater levels at economically viable pumping lifts.
- Protect the quality of groundwater and enhance where practical.
- Enhance monitoring activities to meet groundwater level and water quality goals.

While the Plan includes a number of findings, the overriding conclusion is that surface water supplies available to the Region will be significantly reduced in the future (relative to historical conditions) and that there will be a corresponding decline in groundwater levels as groundwater is used to make up the reduction in surface water supplies if actions are not taken. Therefore, the Poso Creek Regional Water Management Group has recognized that it is imperative that the members work collaboratively to maximize the utility of limited water resources.

Table 2: Summary of Adjoining Entities, Management Plans, and Collaboration

Agency	Common Boundary or Overlap with Semitropic	Groundwater Management Plan	Urban Water Management Plan	Poso Creek Regional Water Management Group	Semitropic Groundwater Monitoring Committee
Buena Vista Water Storage District	✓	✓			✓
Cawelo water District		✓		✓	
Delano-Earlimart Irrigation District		✓		✓	
Kern County Water Agency (KCWA)	✓				
Kern-Tulare Water District		✓		✓	
North Kern Water Storage District	✓	✓		✓	✓
Rosedale-Rio Bravo Water Storage District	✓	✓			✓
Shafter-Wasco Irrigation District	✓	✓		✓	✓
Southern San Joaquin Municipal Utility District	✓				✓
City of Wasco	✓		✓	✓	

3 The District

Semitropic Water Storage District (Semitropic or District) includes a gross area of about 221,000 acres located in northwest Kern County. In any given year, about 125,000 acres are irrigated, which contributes to the $4 to $5 billion of annual agricultural production in Kern County ($4.75 billion in 2010, Kern County Agricultural Commissioner). This section provides background regarding Semitropic Water Storage District, including land use, water supplies, service areas, conjunctive use, water banking, and conservation.

3.1 Formation

Prior to formation of the District and adoption and construction of a project, irrigated agricultural development relied completely on pumped groundwater. As in other areas developed in reliance on pumped groundwater, water levels declined as water was pumped for beneficial use on overlying lands. To address declining groundwater levels, the District was organized in 1958 to develop conjunctive use programs and facilities and, in particular, to import water to supplement the area's water needs.

Groundwater management within the District, as in many areas of California, is rooted in the conjunctive use of surface water and groundwater resources, that is, water supplies from the two sources are integrated to accomplish optimum utilization of each. In the 1960s, District landowners approved implementation of a project, which included construction of main conveyance and distribution system facilities extending from the California Aqueduct (Governor Edmund G. Brown California Aqueduct) of the State Water Project (SWP) to farm delivery locations. The Project was predicated on the conjunctive use of imported SWP water with the underlying groundwater resource. Prior to construction of the facilities, irrigated crops within Semitropic were totally dependent on groundwater pumping. Since the imported water supply is erratic, the District devised a plan of conjunctive use, wherein the underlying groundwater reservoir continues to be used to meet demands for seasonal peaks and to provide irrigation water in times of limited surface supplies. Under the District's Project, some lands received the imported water supply (the so-called Contract Water Service Area) and other lands remained solely dependent on pumped groundwater for irrigation, with the latter benefitting from improved groundwater conditions due to the importation of surface water.

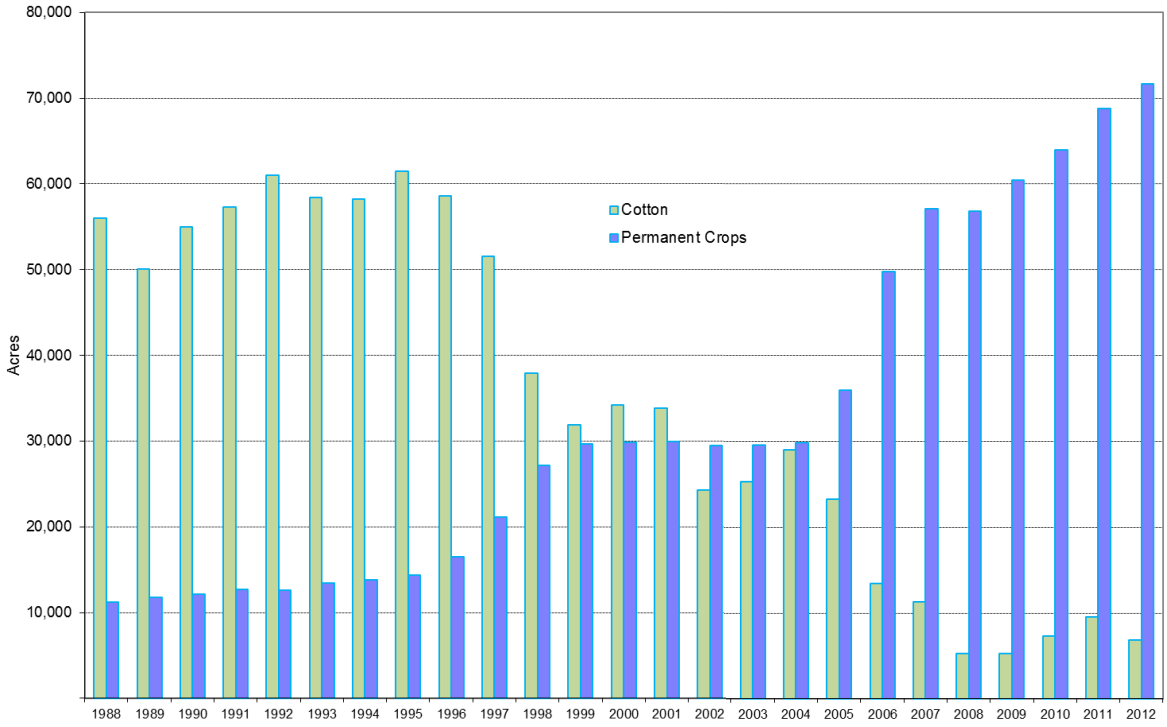
3.2 Land Use

Irrigated agricultural uses dominate the developed lands within Semitropic. Over the last ten years, the cropped farmland in any given year has varied from about 111,000 to 134,000 acres. For the most part, the remainder of the District's 221,000 gross acres are either

grazing land; undeveloped; managed habitat located within the Kern National Wildlife Refuge; or developed to duck clubs.

Cropping patterns have varied over the years. At the time of Semitropic's original project in the 1970s, the preponderance of the cropped acreage was in annual crops, principally cotton, alfalfa (and pasture), and grain. Since that time, there has been a shift away from annual crops in favor of permanent crops. In the 1970s, less than five percent of the cropped acreage was planted to permanent crops. Today, more than one-half of the cropped acreage is planted to permanent crops. As a generalization, the relatively large cotton acreage which persisted until the mid-1990s has since shifted to tree crops --- primarily almonds and pistachios. Figure 4 illustrates the annual changes in cotton acreage and permanent crop acreage over the last 25 years.

Figure 4: Cotton and Permanent Crop Acreage (1988-2012)



The last land use survey conducted by DWR was in 2006 and the resulting land use map is presented in Figure 5. Based on the District's 2012 land use survey, cropped acreage was distributed among the following six crop types/categories:

Deciduous	53%
Alfalfa	18%
Grain/Pasture	16%
Cotton	5%
Vineyard	4%
Truck	3%

While the cropping pattern has changed over time, the total farmed acreage has gone up and down with the economics of farming. It is reasonable to anticipate that the farmed acreage will continue to fluctuate, without any increasing or decreasing trend; however, the significant percentage of permanent crops which has developed over the last several years may reduce the year-to-year fluctuations in farmed acreage going forward.



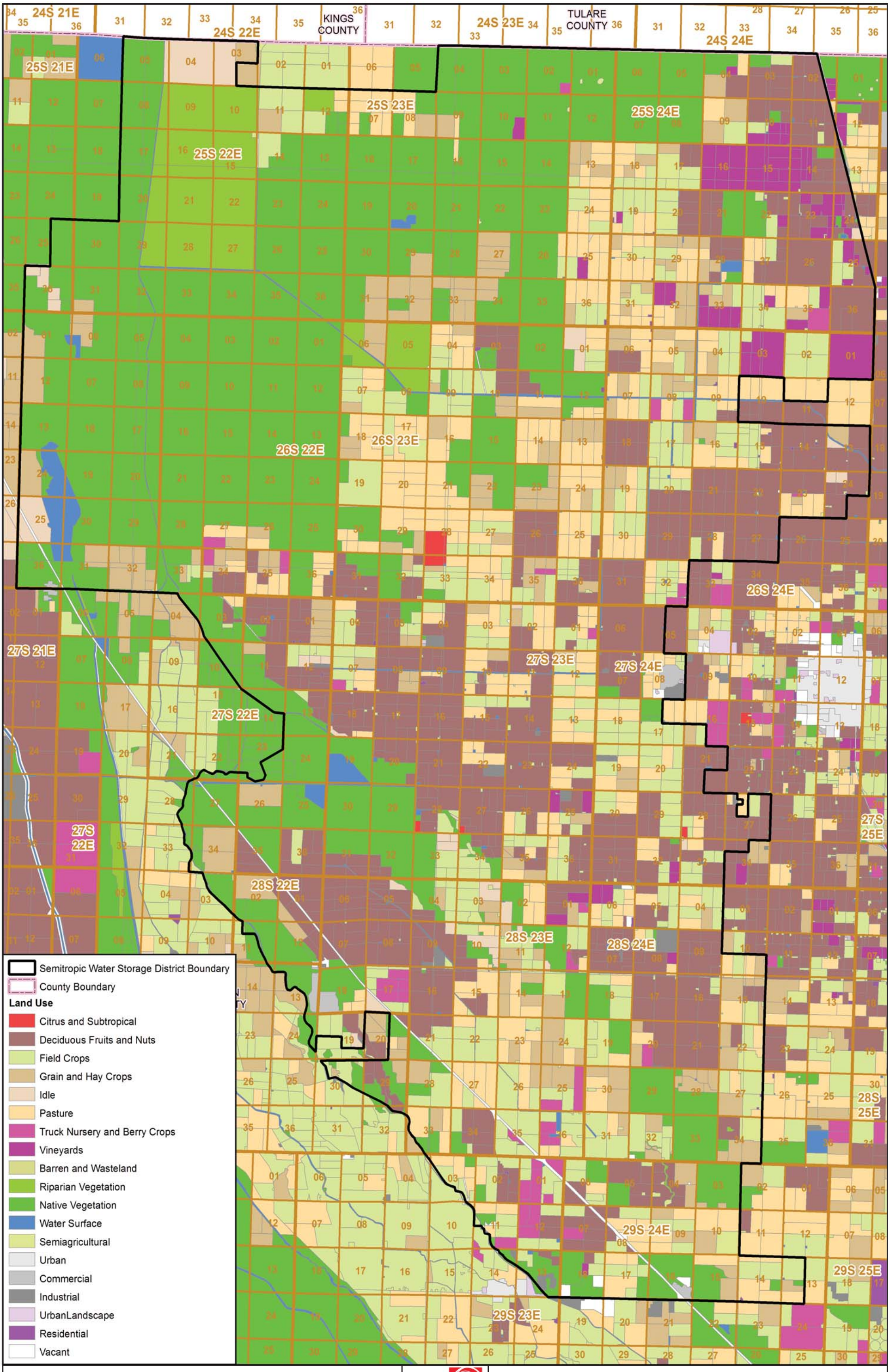
There has been a significant shift from row crops to permanent crops.

The largest city which is proximate to the District is the City of Wasco, which is centered just to the east of the District. Urbanization of District lands has not been an issue to date, and it is unlikely that this will change in the foreseeable future; however, it is noted that the Wasco State Prison is located within the District, and pays the General Project Service Charge in light of its reliance upon improved groundwater conditions as a result of the District's Project.

3.3 Water Supplies and Use

The District's primary source of surface water is imported SWP water, which is conjunctively managed with the underlying groundwater. From time to time --- mostly during "wet" years --- other supplies have been diverted, including Poso Creek, Kern River, and Friant-Kern water. With regard to Poso Creek, the District holds a water rights permit and is party to an agreement with two other agencies (North Kern Water Storage District and Cawelo Water District) which addresses the management and sharing of this infrequent source of supply. Rainfall in the area of the District is minimal, averaging about six inches annually.

For many years, Semitropic's contract with the Kern County Water Agency (KCWA) for SWP water amounted to 158,000 acre-feet of annual entitlement, this was subsequently reduced to 155,000 acre-feet in 1996 in exchange for the District's interest in the Kern Water Bank Authority (which has greatly enhanced the District's water management capabilities). With completion of the necessary diversion and distribution facilities, the District began importing SWP water in 1973; however, shortages in SWP supplies have been more frequent and larger than originally envisioned, owing to the incomplete status of the State Water Project facilities and new and unforeseen regulatory restrictions on export from the Sacramento-San Joaquin River Delta. In particular, the District's SWP water supply has noteworthy restrictions including: (1) the conservation facilities to be constructed as part of the SWP have not been completed, which has the effect of reducing the yield of the District's contract supply of SWP water; (2) Federal and State regulatory agencies have, particularly since the mid 1990s, placed additional constraints on pumping from the SWP's Banks



2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	2006 DWR Land Use
Semitropic Water Storage District	March 2012	Figure 5

Pumping Plant, which were not contemplated, and have resulted in reductions in reliability and yield of the District's contract supply of SWP water; (3) because the annual allocation of water from the SWP during a given year is a moving target until as late as August of that year, District growers must make decisions regarding annual plantings before knowing their water allocation; and (4) while CVP 215 water has been an infrequent and relatively small source of supply, recent actions to "restore" the San Joaquin River are expected to reduce the availability of such supplies in the future. However, any restrictions on the District's surface water supplies that result in a decrease in the available surface water supplies for the year is offset by a commensurate increase in the use of groundwater to meet irrigation water requirements.

The District will continue to preserve and protect the contracts respecting its existing surface water supplies, and will continue to pursue opportunities to supplement these supplies. Additional opportunities could include "spot market" purchases of available surface supplies (which is the District's current practice), increasing the District's ability to import water during the wetter years (through institutional arrangements and/or construction of additional facilities), expanding the District's existing irrigation distribution system to include lands which rely principally on pumped groundwater (reference Section 3.4), acquisition of additional water supplies on a permanent or long-term basis, if and when available.

The total demand for irrigation water is on the order of 450,000 acre-feet each year. Any demand not met with imported supplies is met with pumped groundwater. "Land retirement" would result in a reduction in the demand for irrigation water and the use of pumped groundwater. The District's current annual delivery capability is about 350,000 acre-feet and the ultimate objective is on the order of 400,000 are-feet. Farmers in the District's surface water service areas maintain and use on-farm wells to meet irrigation water requirements to the extent that surface water deliveries are inadequate.

3.4 Service Areas

Implementation of the District's initial irrigation distribution system project in the 1970s involved construction of the facilities necessary to divert water from the California Aqueduct to about 43,000 acres, which is referred to as the Contract Water Service Area. This is the area to which the District's contract for SWP water is dedicated. The remaining irrigated lands continued to rely exclusively on pumped groundwater and were referred to as the Groundwater Service Area. Gradually, over time, improvements were made which provided for the delivery of surface water to about 20,000 acres within the Groundwater Service Area. In general, these lands were proximate to the District's irrigation distribution system and required relatively modest improvements to "connect" to the District's system. Deliveries to these lands is on an as-available basis and they are collectively referred to as the Temporary Water Service Area.

Beginning with implementation of the Semitropic Groundwater Banking Program in the mid 1990s, new distribution systems have been constructed with revenue generated from the banking program to serve an additional 35,000 acres of land that had been in the Groundwater Service Area. Collectively, these lands are referred to as the Intermittent Water Service Area. The absorptive capability corresponding to about two-thirds of this total (or about 23,000 acres) is first available for third-party banking, then for District water supplies, because of the enhancement in delivery capabilities of the area as a result of investment of the banking program. Owing to the first priority for third-party banking, this is referred to as "contractual absorptive capability". The absorptive capability corresponding to the remaining 12,000 acres is referred to as "discretionary absorptive capability", i.e., priority for use of this capacity is completely at the District's discretion.

Similar to the Temporary Water Service Area, surface water deliveries are on an as-available basis; however, surface water must be taken (when available) in lieu of pumping groundwater, and the District has the right to use the groundwater pumping facilities within this area when not needed to meet the irrigation water requirements of these lands. As a result of these improvements, the capability now exists to deliver surface water (as available) to more than 108,000 acres of the irrigated lands within the District in lieu of pumping groundwater. These service areas make up the Surface Water Service Area, which is shown on Figure 6. The Surface Water Service Area and the Groundwater Service Area comprise all of the irrigated lands within the District. It is the District's intent to continue to look for opportunities to expand its surface water distribution system in order to further reduce groundwater pumping in "wet" years when surface water is available.

3.5 Conjunctive Use

Semitropic has conjunctively utilized imported surface water supplies with groundwater since completion of the District's original irrigation distribution system facilities in the mid 1970s. As discussed previously, the foundation of the District's groundwater management is the conjunctive use of surface water and groundwater supplies; integrating the two sources of supply to achieve the optimal use of each. The particulars of the District's conjunctive use program reflect available facilities (for distribution, recharge, and recovery), groundwater basin characteristics, the availability of surface water supplies, and institutional considerations. The District's conjunctive use program includes surface water delivery in lieu of groundwater pumping, direct recharge, groundwater storage and recovery (water banking) for other agencies, water banking in out-of-District projects, as well



Canal-side pumping plant delivers surface water to irrigation in lieu of groundwater pumping.

as exchange arrangements with other water agencies. Further, it depends on available groundwater storage capacity to regulate "wet-year" surface water supplies to "dry" years when that water is necessary to supplement deficiencies in surface supplies.

3.5.1 Groundwater Recharge

Indirect recharge involves the delivery and use of surface water in lieu of pumped groundwater. Sometimes referred to as "in-lieu recharge", this has been the District's mainstay since the first SWP water was imported in the early 1970s. The District's Groundwater Banking Program is also based on in-lieu recharge. The advantage of in-lieu recharge is that the recharge is essentially immediate, as the delivery of one acre-foot of water on the surface immediately displaces one acre-foot of groundwater pumping and does not depend upon percolation and the movement of water in the aquifer. One disadvantage is the fact that the surface water supply must be available on an irrigation demand schedule, with irrigation demands being relatively low during the winter months. In contrast, direct recharge through water spreading ponds or basins can be accomplished during any time of the year, which increases the likelihood of being able to capture unregulated supplies that become available from time to time. Accordingly, Semitropic became a participant in two out-of-District water banking projects in the 1990s, both based on direct recharge (reference Section 3.6). Subsequently, in 2008, about 525 acres of spreading ponds were developed within the District (reference Figure 6).

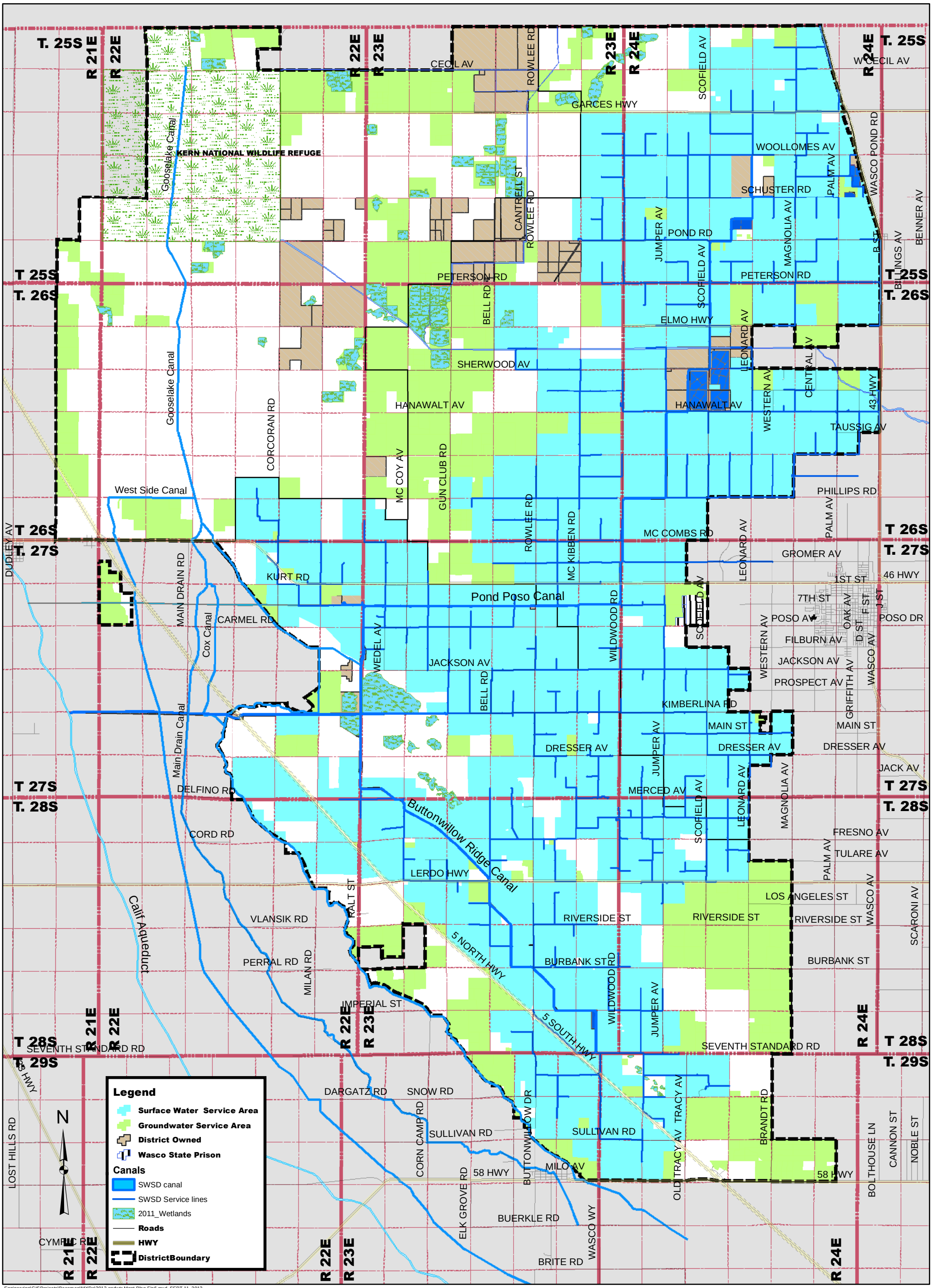


Interbasin structure in Pond-Poso Spreading Grounds

3.5.2 Groundwater Extraction

Extractions within the District are by privately-owned wells and District-owned wells. Recall that about two-thirds of the District's irrigated area is capable of receiving surface water deliveries; however, landowners must maintain wells to meet irrigation demands when surface water supplies are limited or not available. The District maintains wells to supplement the available surface supply to some District lands and for recovery of previously banked water for return to banking partners in years of reduced surface water supplies. The remaining one-third of the District's irrigated area relies exclusively on pumped groundwater. The District's importation of surface water helps to support those landowners who continue to rely on pumped groundwater by reducing the District's overall reliance on the underlying groundwater.

Management of groundwater extractions can be achieved through economic inducement policies. Presently, the District provides an indirect economic inducement through its water-



Engineering\GISProjects\Basemap\MXDs\2012 gndwtr Mgnt Plan Fig6.mxd SEPT 11, 2012

Semitropic Water Storage District

Figure No. 6

pricing policies. In particular, surface water rates are set high enough to promote water conservation, yet reasonable enough to compete with groundwater pumping costs, and thereby discourage the use of groundwater when surface water is available. In addition, it is the District's policy to not allow use of the District's distribution facilities for the wheeling of landowner-pumped groundwater when there are surface water supplies available to turn off wells. The District's General Project Service Charge (GPSC) is intended to result in comparable water costs to growers, whether pumping groundwater or receiving District-delivered water, i.e., such that there is no economic incentive to pump groundwater. Going forward, the District intends to explore more equitable methods to charge for groundwater used, as compared with the GPSC which is applied on a per-acre basis (reference Section 5.4).

In 2005 and 2006, District staff located all wells in the District, which numbered more than 1,240 wells at that time. In order to keep this effort "current", it will be necessary to work with the County of Kern to receive notice of permits to both construct and abandon wells.

3.6 Water Banking

Water banking involves the regulation of wet-year surface water supplies in dewatered groundwater storage for subsequent recovery during times of water supply deficiencies. The storage is achieved through either indirect and direct recharge. Indirect recharge is based on the delivery of surface water for irrigation in lieu of pumping groundwater for irrigation.

The preponderance of direct recharge is based on the surface spreading and percolation of water supplies in basins or ponds. Surface delivery in lieu of groundwater pumping motivated the District to enter into long-term contracts for SWP water in the early 1970s. Deliveries made in this manner are also referred to as "in-lieu" recharge. This aspect of the District's program relies on its extensive system of irrigation distribution facilities (constructed specifically for the purpose of delivering the SWP water). In this regard, Semitropic has expanded its delivery capability from about one-third of the irrigated acreage (in the late 1970s) to about two-thirds at present, with plans to increase that percentage. In addition, the District banks water outside of its immediate (or Management) area through its participation in the Kern Water Bank and the Pioneer Project (both of these water banking projects are located on the Kern River fan). These projects rely on direct recharge and are used as an additional source of supply in "dry" years. In addition, the District is a majority participant in the development of the Semitropic-Rosamond Water Bank Authority. All of these banking projects are more particularly described in the subsections which follow.

3.6.1 Semitropic Groundwater Banking Project

In 1988, Semitropic initiated a study of a groundwater banking program which was ultimately included as a part of the District's 1992 Improvements Project. This has developed into the Semitropic Groundwater Banking Project, which is a long-term water

storage project designed to optimize the distribution and use of water resources between the District and its banking partners.

The original District projects were planned and designed to deliver supplemental surface water to farms relying exclusively on groundwater. Imported surface water from the SWP and the associated reduction in groundwater pumping have helped to stabilize groundwater conditions in Semitropic, which in turn have helped maintain a viable agricultural economy in the area. The Groundwater Banking Project is a continuation of Semitropic's efforts to make the best use of the underlying groundwater resource, including unused storage capacity.

Semitropic has long-term contracts with several water banking partners**;** including the Metropolitan Water District of Southern California, Santa Clara Valley Water District, Zone 7 Water Agency**,** Alameda County Water District, Newhall Land and Farming Company, San Diego County Water Authority, and the City of Tracy. Semitropic receives SWP or CVP surface water from its banking partners in years of ample supplies and delivers it to landowners for irrigation use in lieu of groundwater pumping. Groundwater which otherwise would have been pumped remains in storage, credited to the account of the banking partner. In times of surface water shortages, the water may be withdrawn by the banking partner. At that time, Semitropic will return the banked water to the California Aqueduct, either from its supply of SWP water by exchange, and/or by pumping of District and landowner wells. At the end of 2011, the District held more than 900,000 acre-feet in groundwater storage on behalf of its banking partners. This storage has a significant, positive impact on groundwater levels.

Certain operational criteria have been put in place to assure that District landowners and landowners in neighboring districts are not adversely impacted as a result of the Project; these include the following:

- Only water stored under the banking agreement may be withdrawn from Semitropic's groundwater basin. Water must first be stored before it is withdrawn.
- Semitropic will retain a minimum quantity of its SWP supply to maintain the quality of water delivered to farmers within its service area.
- The District will retain about ten percent of the water delivered as an allowance for aquifer and operational losses.
- The District will not pump more water from the wells on a given farm than the total of all prior surface water deliveries to that farm for banking purposes.
- A network of monitor wells, solely for monitoring purposes, has been constructed to supplement the network of production wells, and thereby enhance groundwater monitoring.

- Within a particular area, withdrawal of stored water is prohibited if such withdrawals would cause the average groundwater levels over a three-year period to be 15 feet lower than the average groundwater levels which would have prevailed without the project over the same three-year period, except for the Stored Water Recovery Unit, where this criteria can be exceeded with appropriate mitigation.

- Groundwater monitoring data are reviewed by a Monitoring Committee composed primarily of representatives from surrounding water districts.

As part of the Project, the District has constructed additional distribution facilities, new wells for recovery of stored groundwater, and facilities to transfer water back to the California Aqueduct. In particular, distribution facilities have been built to serve intermittent surface water supplies (for groundwater banking) to more than 23,000 acres. With regard to the recovery of stored groundwater, it is noted that the District has agreements in place for the use of a large network of privately-owned wells in order to supplement District-owned wells and to provide the operational flexibility necessary to spatially distribute the pumping to avoid impacts and to manage the quality of the water delivered into the California Aqueduct.

In addition to the water banking aspects of the Project, distribution facilities which are being constructed as part of the Project can be used for non-banking purposes. In particular, these facilities will allow Semitropic to acquire KCWA Agricultural Pool Water, when available, and deliver it to District lands. The water banking facilities will also allow the District to pump groundwater and deliver it for the benefit of farmers within Semitropic. On a limited basis, the District will be able to provide water to farmers who may have groundwater quality problems, peaking problems, well outages, and other emergency needs.

3.6.2 Kern Water Bank Authority

Upon implementation of the Monterey Agreement in 1996 by the California Department of Water Resources and the State Water Contractors, Semitropic obtained a 6.67 percent share of the Kern Water Bank Authority. With a gross area of about 20,000 acres, the Kern Water Bank is located to the south of the District, astride the Kern River. It is a direct recharge-based project, with about 7,000 acres of spreading basins. To the extent there has been unused recharge or recovery capacity, Semitropic has at times exercised considerably more than its share of this project's capacity.

3.6.3 Pioneer Project

The Pioneer Project is operated by the Kern County Water Agency as a direct recharge-based water banking project, located on the Kern fan, adjacent to the Kern Water Bank. There are "recharge participants" and "recovery participants"; the former are vested with a first priority right to the use of the recharge facilities, and the latter are vested with a first priority right to

the use of the recovery facilities. Semitropic is a "recovery participant" with a 14 percent share of the Project's recovery capacity. This is a minimum amount; rather, to the extent there is unused capacity, it is also available for District use. Semitropic's right to use of the Project's recharge capacity is second to the "recharge participants".

3.6.4 Semitropic-Rosamond Water Bank Authority

Formation of the Semitropic-Rosamond Water Bank Authority in 2007 had the effect of combining the assets of the Antelope Valley Water Bank (AVWB) with those of the Stored Water Recovery Unit (SWRU), which is an expansion of Semitropic's Groundwater Banking Project. The AVWB is planned to provide up to 500,000 acre-feet of storage capacity, 100,000 acre-feet of delivery capacity annually, and 100,000 acre-feet of recovery and return capacity annually. The SWRU will provide up to 650,000 acre-feet of additional storage capacity, 50,000 acre-feet of delivery capacity annually, and 200,000 acre-feet of recovery and return capacity annually.

Semitropic has a 57 percent share of the combined project, which is only partially built out at this time. The Antelope Valley operations are based on direct recharge through spreading ponds. Located at the south end of Kern County, the Antelope Valley provides some geographic diversification to the District's water banking activities, and additional operational flexibility.

3.7 Conservation

The District's water banking operations --- both in-District and out-of-District --- are based on regulating or conserving "wet-year" water for use during "dry" years. In addition, the District's conservation practices are evidenced in its water-pricing policies and in its financial support of water use education; for example, the Water Association of Kern County at the local level, and the Water Education Foundation at the State level. The water-pricing policies encourage the use of surface water supplies when available in lieu of pumped groundwater, thereby conserving the underlying groundwater resource. The District practices conservation in its operations and encourages and supports conservation at the on-farm level by providing financial support to the North West Kern Resource Conservation District-DWR Mobile Laboratory. In 2006, the District prepared an Agricultural Water Management Plan in accordance with guidelines prepared by the Agricultural Water Management Council, which considered a number of efficient water management practices identified by the Council. Most recently, the District participated in a Natural Resources Conservation Service program[1] which provided financial assistance to District growers to implement on-farm water conservation measures. In this regard, there has been a considerable shift in irrigation practices to low-volume methods of application.

[1] Environmental Quality Incentives Program (EQIP)

4 The Basin

As a prerequisite to developing a management plan --- with basin management objectives, strategies, and actions --- it is necessary to first characterize the basin, so as to set the stage for identification of issues of concern related to the groundwater management goal. Accordingly, this section includes discussion of the underlying aquifer system, recharge, water levels, water quality, and subsidence.

4.1 Groundwater Basin Characteristics

Boundaries for California groundwater basins and subbasins are designated by Department of Water Resources (DWR) Bulletin No. 118, California's Groundwater Update 2003. The portion of Kern County that lies within the San Joaquin Valley is designated as the Kern County subbasin (Groundwater Basin Number: 5-22.14). This subbasin is located in the part of the San Joaquin Valley Basin known as the Tulare Lake Hydrologic Region. The District position within the Tulare Lake Hydrologic Region is depicted on Figure 7. To the east of the District, a series of faults effectively prevent significant hydraulic connection between the valley aquifer and the groundwater in the dissected uplands. Historically, groundwater levels beneath the Kern River to the south, are sufficiently high enough to effectively keep groundwater south of the river from flowing across to the north. In the northern part of the District, clays of the Tulare Lakebed effectively create a groundwater flow barrier to the west and northwest. To the northeast, groundwater flows between the Kern County subbasin and the Tule subbasin and, to a lesser extent, to the Tulare Lake subbasin. The extent of the interconnection is not certain; however, groundwater elevations and a persistent groundwater depression in northern Kern County indicate that effective groundwater interaction does occur with areas located immediately north of the Kern County boundary.

Within the boundaries discussed above, several thousands of feet of sediments have been deposited in an asymmetrical northwest-to-southeast-trending trough, as shown on Figure 8 (reference the location of cross section A-A' on Figure 7).

beneficial use. To the east, fresh water recharges the Kern River Formation, primarily from the Kern River, Poso Creek, Deer Creek, White River, and through extensive leakage from conveyance facilities which parallel the Friant-Kern Canal.

The Tulare Formation contains several thick, regionally extensive clay layers. The most extensive of the clay layers, the Corcoran member of the Tulare Formation, Corcoran Clay or E-clay, A cross section (B-B') through the District is shown in (reference Figure 7 for location). This cross section parallels the regional cross section (A-A') shown in reference Figure 7 for location), but shows more detail within the Tulare and Kern River formations. Groundwater within the District occurs in several different aquifers. Five major aquifers or zones are recognized. These are: , an , a a transition zone, and a lower saline aquifer (also reference for a northwest to southeast trending cross section, with location depicted on Figure 7).

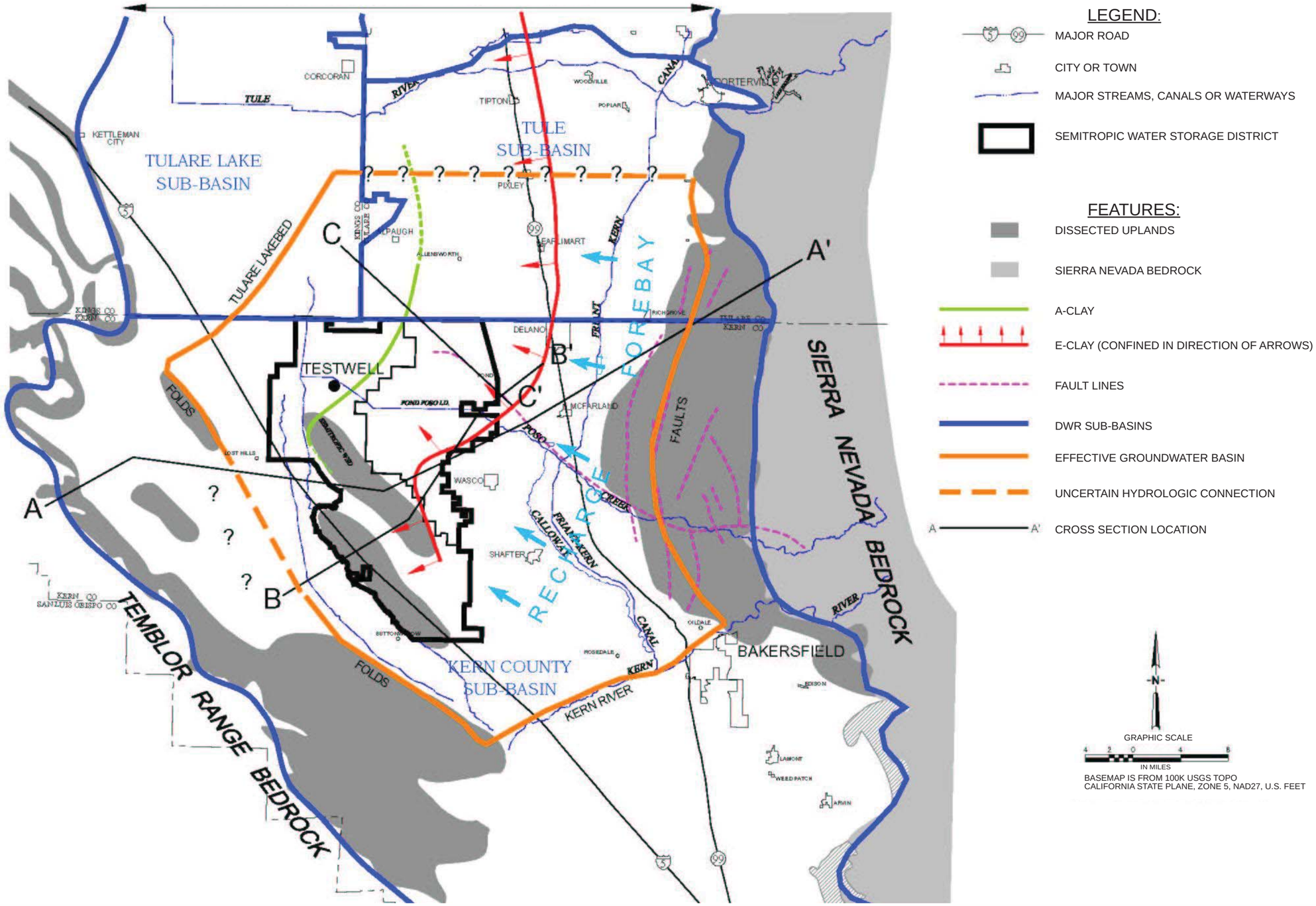
In the southeast and east part of the District, the E-clay thins, splits as it nears the surface, and becomes hydraulically ineffective as it merges into the "forebay" --- the unconfined part of the main aquifer that is hydraulically connected to the main confined aquifer.

The dip is generally west-northwest. To the south and east, the E-clay is absent and the entire aquifer consists of a thickened production zone, The upper portions are unconfined, the lower portions are semi-confined, and the base of fresh water drops to about 1,800 feet below the surface.

4.1.1 Perched Zone

A 5-20 foot-deep, perched aquifer is located in the western part of the basin as shown on Figure 11 (i.e., the areas of shallow groundwater highlighted in color). The area affected by perched conditions changes yearly to some extent depending on hydrologic conditions. The extent of this zone in 2010 is shown on Figure 11. Some perching may occur on the A-clay.

TULARE LAKE HYDROLOGIC REGION



LEGEND:

- MAJOR ROAD
- CITY OR TOWN
- MAJOR STREAMS, CANALS OR WATERWAYS
- SEMITROPIC WATER STORAGE DISTRICT

FEATURES:

- DISSECTED UPLANDS
- SIERRA NEVADA BEDROCK
- A-CLAY
- E-CLAY (CONFINED IN DIRECTION OF ARROWS)
- FAULT LINES
- DWR SUB-BASINS
- EFFECTIVE GROUNDWATER BASIN
- UNCERTAIN HYDROLOGIC CONNECTION
- A — A' CROSS SECTION LOCATION

N

GRAPHIC SCALE

4 2 0 4 8

IN MILES

BASEMAP IS FROM 100K USGS TOPO
CALIFORNIA STATE PLANE, ZONE 5, NAD27, U.S. FEET

2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	Illustrative Map of Effective Groundwater Basin
Semitropic Water Storage District	March 2012	Figure 7

DWR BASIN BOUNDARY

EFFECTIVE GROUNDWATER BASIN

GROUNDWATER MANAGEMENT AREA

A

A'

N.45 E. | N.80W | N.87W. | N.78W | N.53E. | N.62E. | N.68E

NORTH ANTELOPE HILLS

LOST HILLS

SEMITROPIC RIDGE

SAN JOAQUIN VALLEY FRESH WATER

ELEV. IN FEET

0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
19,000
20,000
21,000
22,000
23,000

ALLUVIUM
SALINE
TULARE
SAN JOAQUIN
ETCHEGOIN
REEF RIDGE
ANTELOPE
McDONALD
DEVILWATER
GOULD-BUTTONBED
MEDIA
CARNEROS
UPPER SANTOS
LOWER SANTOS
"PHACOIDES" SHALE
SALT CREEK
KERN RIVER
FIRST MYA ZONE
CHANAC
SANTA MARGARITA
GRANITIC BASEMENT
MIOCENE UNDIFFERENTIATED
ROUND MOUNTAIN
OLCESE
FREEMAN - JEWETT
PYRAMID HILLS
VEDDER
REEF RIDGE
FRUITVALE
ROUND MTN.
OLCESE
FREEMAN-JEWETT
VEDDER
TUNEY
McCLURE
KREYENHAGEN UNDIFFERENTIATED
WALKER (?)
POND FAULT
BASEMENT COMPLEX
POINT OF ROCKS
GREELEY FAULT
SEMITROPIC ANTICLINE FAULT
LOWER MIOCENE UNDIFF.
EOCENE UNDIFFERENTIATED
AGUA
CRETACEOUS
TD 11,080
TD 21,496 CRETACEOUS
TD 15,866
TD 9,937
TD 3,370
TD 4,493

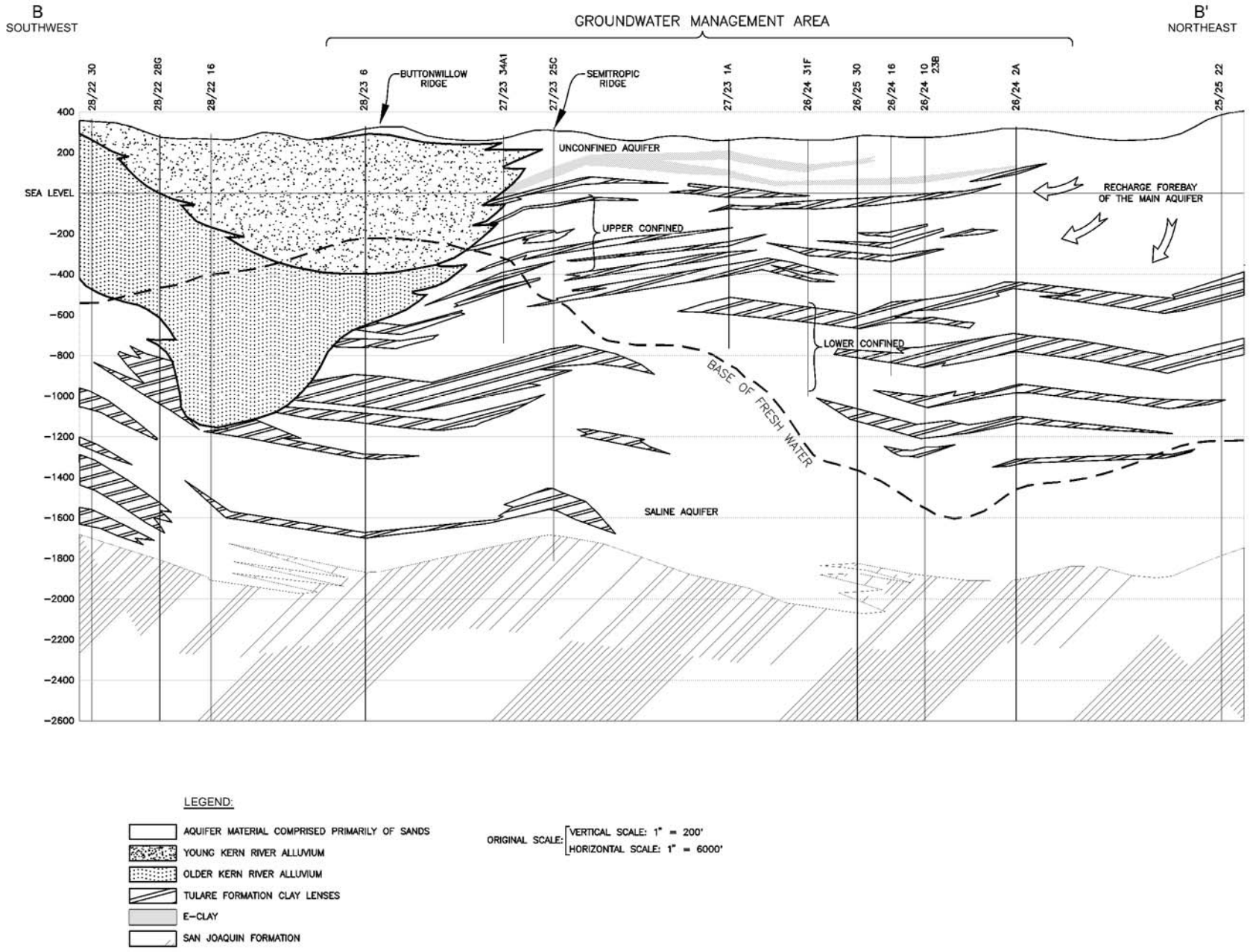
LOWER MIOCENE UNDIFFERENTIATED:
- MEDIA
- CARNEROS
- UPPER SANTOS
- AGUA
- LOWER SANTOS
- "PHACOIDES"
- SALT CREEK

EOCENE UNDIFFERENTIATED:
- KREYENHAGEN UNDIFFERENTIATED
- POINT OF ROCKS
- CANOAS
- MABURY

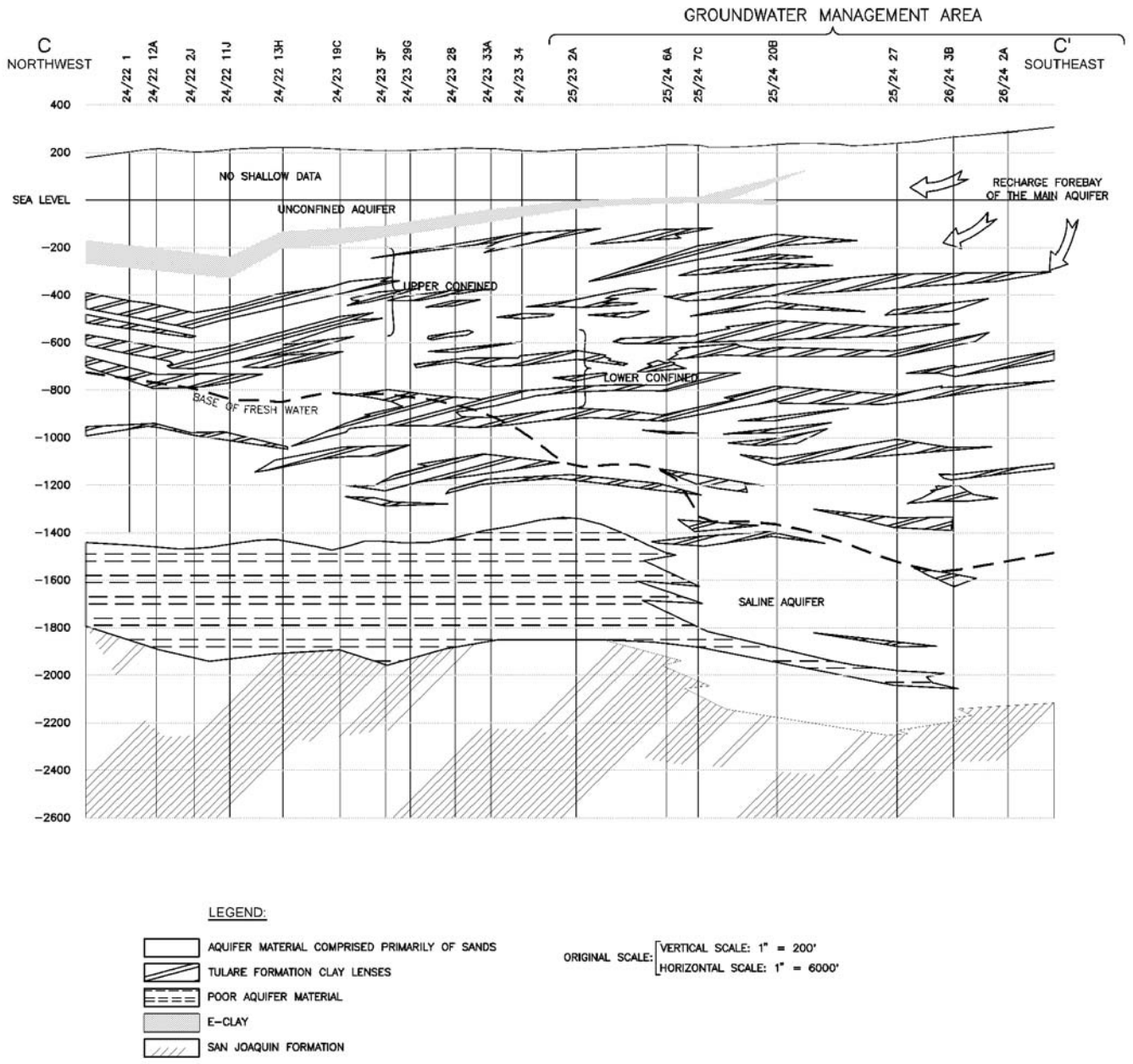
Horizontal Scale in Miles
Vertical Scale in Feet
Approximate Vertical Exaggeration: 5X

REF: *The portion of this profile west of Lost Hills is from cross-section A-A' of Geologic Map of Tomblor Range in Guidebook To Geology & Oilfields, Westside Southern San Joaquin Valley, 1968: Pacific Sections A.A.P.G., S.E.G., and S.E.P.M.*

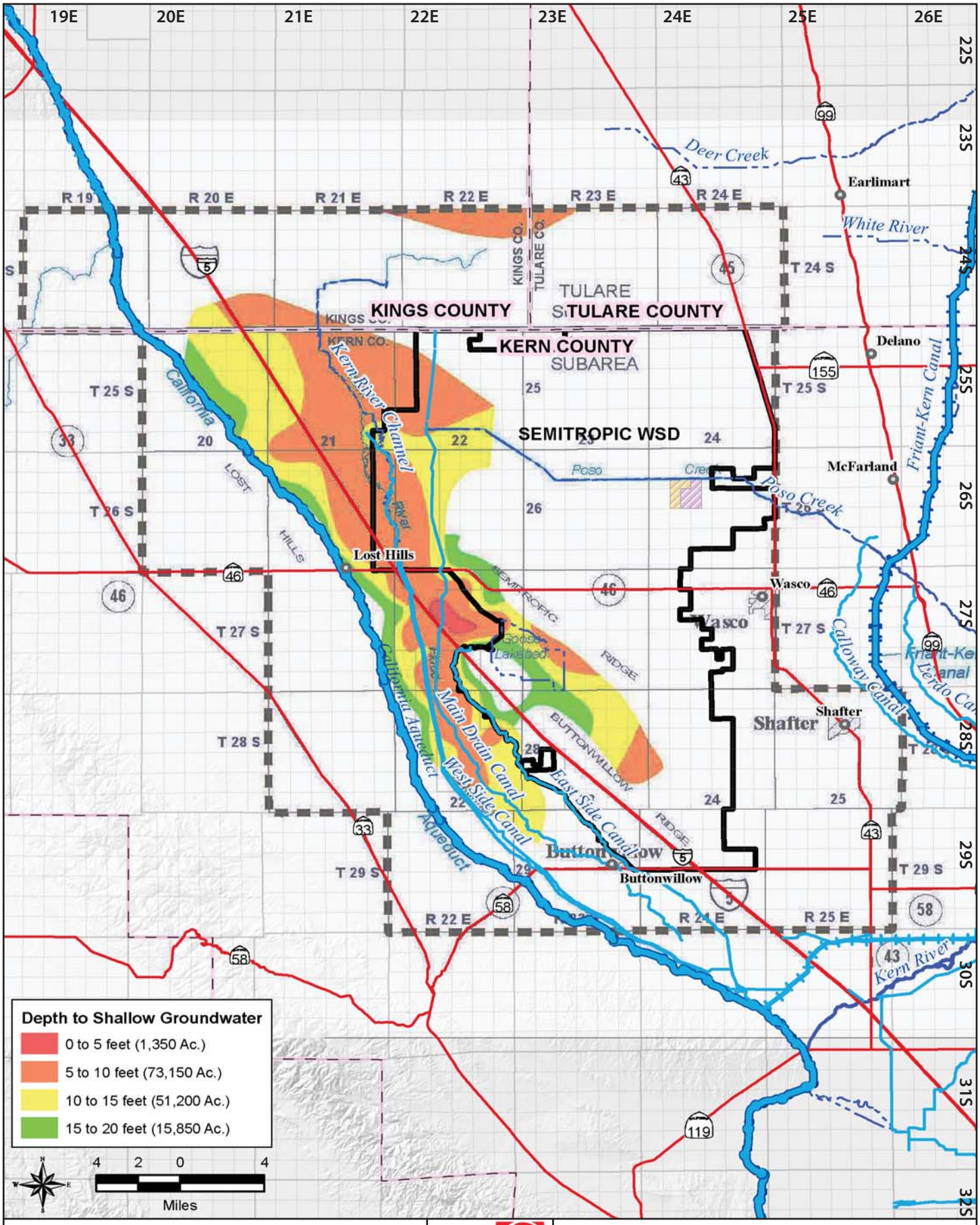
2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	Regional West-to-East Cross Section A - A'
Semitropic Water Storage District		March 2012 — Figure 8



2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	Cross-Section B - B' Through Semitropic WSD
Semitropic Water Storage District		March 2012 — Figure 9



2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	Cross-Section C - C' Through Semitropic WSD
Semitropic Water Storage District		March 2012 — Figure 10



2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	Areas of Shallow Groundwater (2010)
Semitropic Water Storage District		March 2012 Figure 11

4.1.2 Unconfined Zone

The upper, unconfined aquifer when compared to the production zone consists of generally poor quality water. The unconfined aquifer lies above the E-clay which thickens with proximity to the Tulare Lakebed and is thin and indistinguishable from the sediments of the "main" aquifer in the forebay area along the eastern and southern boundaries of the District.

4.1.3 Production Zone

Beneath the E-clay is the District's upper production zone of the "main" aquifer - a confined, fresh, sodium-bicarbonate aquifer. The production zone is approximately 325 feet thick and consists of oxidized sediments. The sediments are tan, yellow, olive-gray, and occasionally deep orange, indicating exposure to previous surface weathering. Most sand units are poorly to moderately well sorted sand, the coarsest size being small pebbles. The top and base sediments are thick, fining-upward sands with several discontinuous sands occurring between. The salinity is estimated at about 300 milligrams per liter (mg/l). There is a 50-foot geochemical transition zone where oxidized sediments interfinger with reduced sediments. Below 800 feet, reduced blue-gray to blue-green sediments dominate, and the lowest part contains characteristically green-black sediments. A 100-foot-thick, coarse-grained sand forms the base of the production zone.

4.1.4 Transition Zone

Below the production zone is a couple of hundred feet of aquifer that ranges from about Few wells within the District are constructed in this layer and it is not considered part of the "main aquifer". The depth to the base of fresh water varies significantly along the western edge of the District and is as high as a few hundred feet in some locations. An aquifer test was conducted in the northwest part of the District (reference Figure 7, "Testwell"), with monitors placed in the upper, lower, and transition zones. Testing indicates that there is poor hydraulic connection between the transition layer and the main aquifer in that area.

4.1.5 Saline Zone

An 800-foot thick high sodium chloride aquifer underlies the transition zone. Below 1,250 feet, reduced black-green, coarse sediments dominate. Little is known of the salinity of the deeper regions.

4.2 Recharge

Replenishment of groundwater underlying the District occurs naturally and indirectly through the delivery of available surface water supplies in lieu of pumping groundwater (i.e., such

deliveries are to lands that have developed in reliance on pumped groundwater), referred to as *in-lieu recharge.* Additionally, irrigation water not consumed by evapotranspiration of cropped lands percolates to the underlying groundwater, referred to as *return flows.*

Recharge to both the confined and semi-confined aquifers occurs principally as subsurface inflow from the semi-confined aquifer forebay, located to the south and east of Semitropic. Recharge to the semi-confined aquifer system also includes deep percolation of excess applied irrigation water, and less frequently from Poso Creek surface flows during wet years. Deer Creek, the White River, and small drainages along the dissected hills also add a small amount of recharge to the valley aquifer. The importation of surface water to the forebay area has been ongoing for decades. Shallow clay layers, particularly in the northwest portion of the District, restrict the percolation of surface water, and have formed areas of perched water.

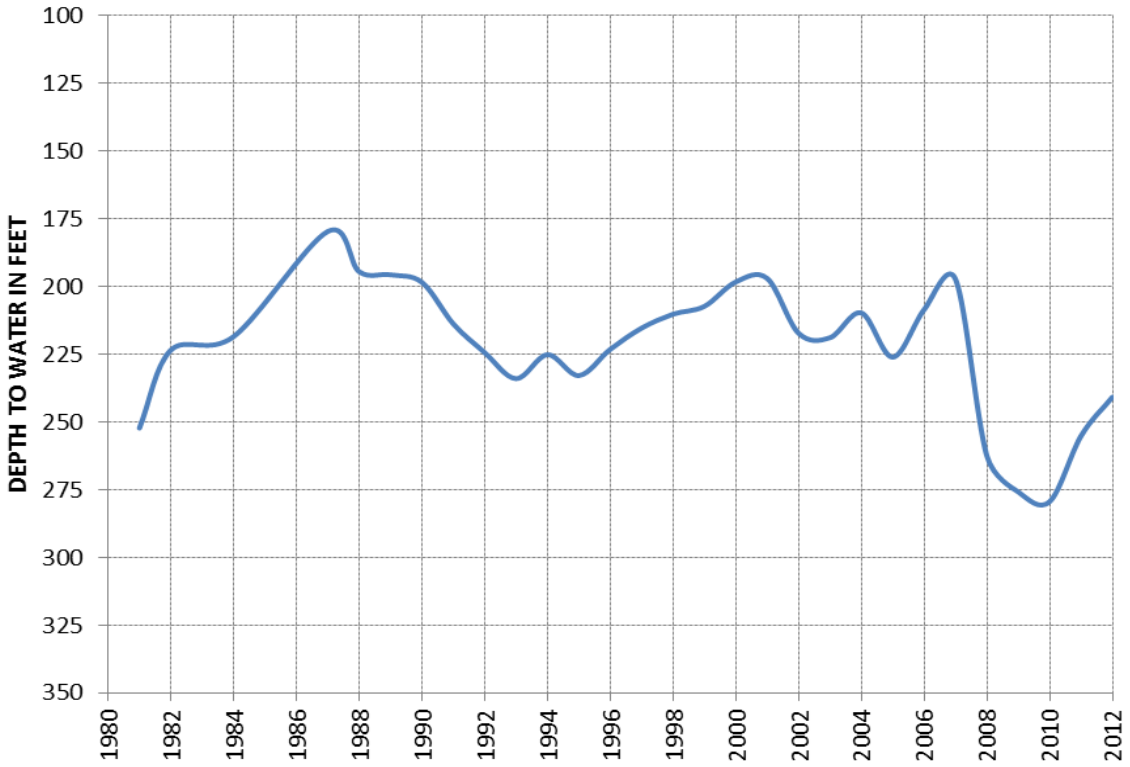
The principal component of recharge in "dry" years is seepage from irrigation water, whereas, in "wet" years, intentional surface recharge and in-lieu recharge are the principal components. As the number of groundwater recharge facilities increases over the years, the natural recharge becomes a smaller portion of total recharge. Programs developed throughout Kern County have contributed significantly to basin recharge, and are critical to maintaining groundwater levels and water quality. The District's management goals reflect the continuing role of these programs in enhancing groundwater recharge to the basin.

4.3 Water Levels

Long-term hydrographs indicate that relatively stable groundwater conditions prevailed in the District area until the mid 1940s. Subsequently, increased pumping caused water levels to decline at a rate of about 8 feet per year, with seasonal fluctuations approaching 100 feet per year. These declines continued until initiation of surface water deliveries in the mid 1970s. The commencement of groundwater banking activities in the early 1990s further enhanced groundwater recharge. Figure 12 illustrates the water level fluctuations averaged over the area of the District.

An elliptical, north-to-south groundwater low has formed along the basin axis beneath the District. Ridges of high groundwater are maintained east of the District and under the Kern River, however, these ridges appear to break down slightly in critically dry years. Groundwater levels have been relatively stable in recent years, with fluctuations of about 50 feet; declining during "dry" periods, and increasing during "wet" periods. Flow directions and water levels are shown on Figure 13 for Spring 2011 conditions.

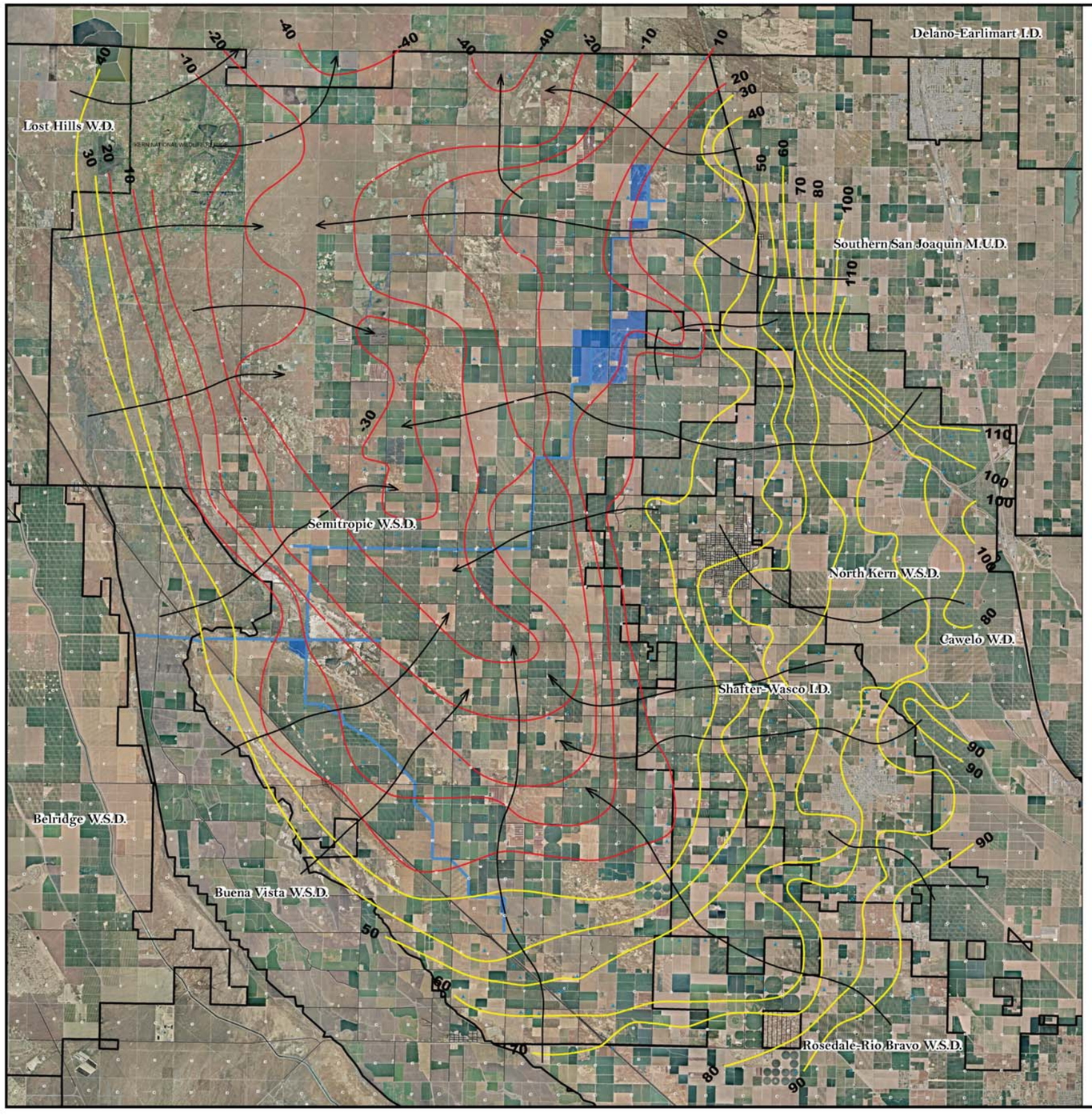
Figure 12: Average Groundwater Level Fluctuations



4.4 Water Quality

The main production zones beneath the District are of good water quality; however, three areas of potentially poor quality are found within the District and the groundwater basin; shallow groundwater, deep groundwater, and west-side groundwater. The high salinity shallow groundwater is only characteristic where there is perched water; however, the transition zone and saline water below the production zone are typical of the entire District. Prevention of migration from the poor quality areas to the high quality areas is a critical management goal of the District.

Groundwater of poor quality, typically a sodium chloride or sodium chloride-sulfate type with high concentrations of dissolved solids and chlorides, can be found extensively along the west side of the San Joaquin Valley. "Stabilization" of groundwater levels beneath most of the District has served to limit migration of poor quality groundwater into the District from the west.



N

Water-Level Elevations And Direction of Groundwater Flow For the Forbay Area and Lower Zone (Spring 2011)

Legend

+23 Well & Water-Level Elevation (Feet)

Direction of Groundwater Flow

+80 Water-Level Elevation Contours (ft. Relative to M.S.L.) For Forebay Area.

-20 Water-Level Elevation Contours (ft. Relative to M.S.L.) For Lower Zone.

1 0.5 0 1 2 3
Miles

Source: Kenneth D. Schmidt and Associates

2012 Groundwater Management Plan		Water-Level Elevations for the Forebay Area and Lower Zone (Spring 2010)
Semitropic Water Storage District		March 2012 — Figure 13

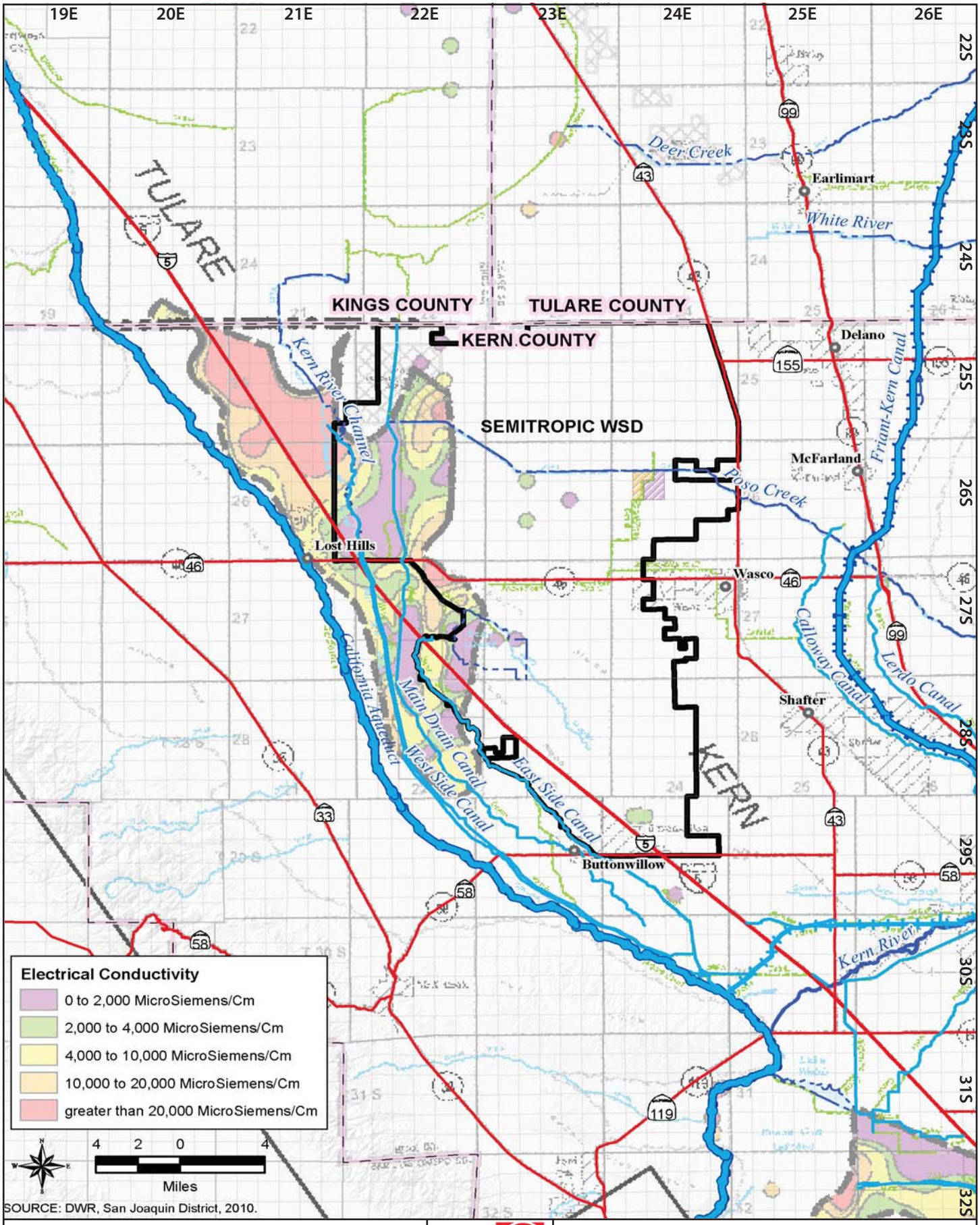
Groundwater of poor quality also can be found in the unconfined aquifer, particularly with perched water. Figure 14 illustrates the electrical conductivity of shallow groundwater. Some areas of the unconfined aquifer are significantly saline, others brackish, due to "spills" from the perched zone, leakage through domestic well borings, and deep seepage of irrigation water. The E-clay largely prevents this water from entering the main aquifer. Accurate identification of the E-clay, proper and sufficient length of annular seals through the E-clay, and proper materials and methods of well construction are critical to maintaining good water quality in the main aquifer. Figure 15 shows the distribution of total dissolved solids concentrations in the main or deep zone.

Some groundwater of poor quality can be found in the main aquifer, principally in the deeper zones of the Tulare Formation. The depth to the base of fresh water varies significantly across the District. Pockets of connate saline water may also be trapped in shallower zones under the Buttonwillow and Semitropic ridges. The District has reviewed extensive geologic data and District wells are constructed sufficiently above the saline boundary to maintain water quality.

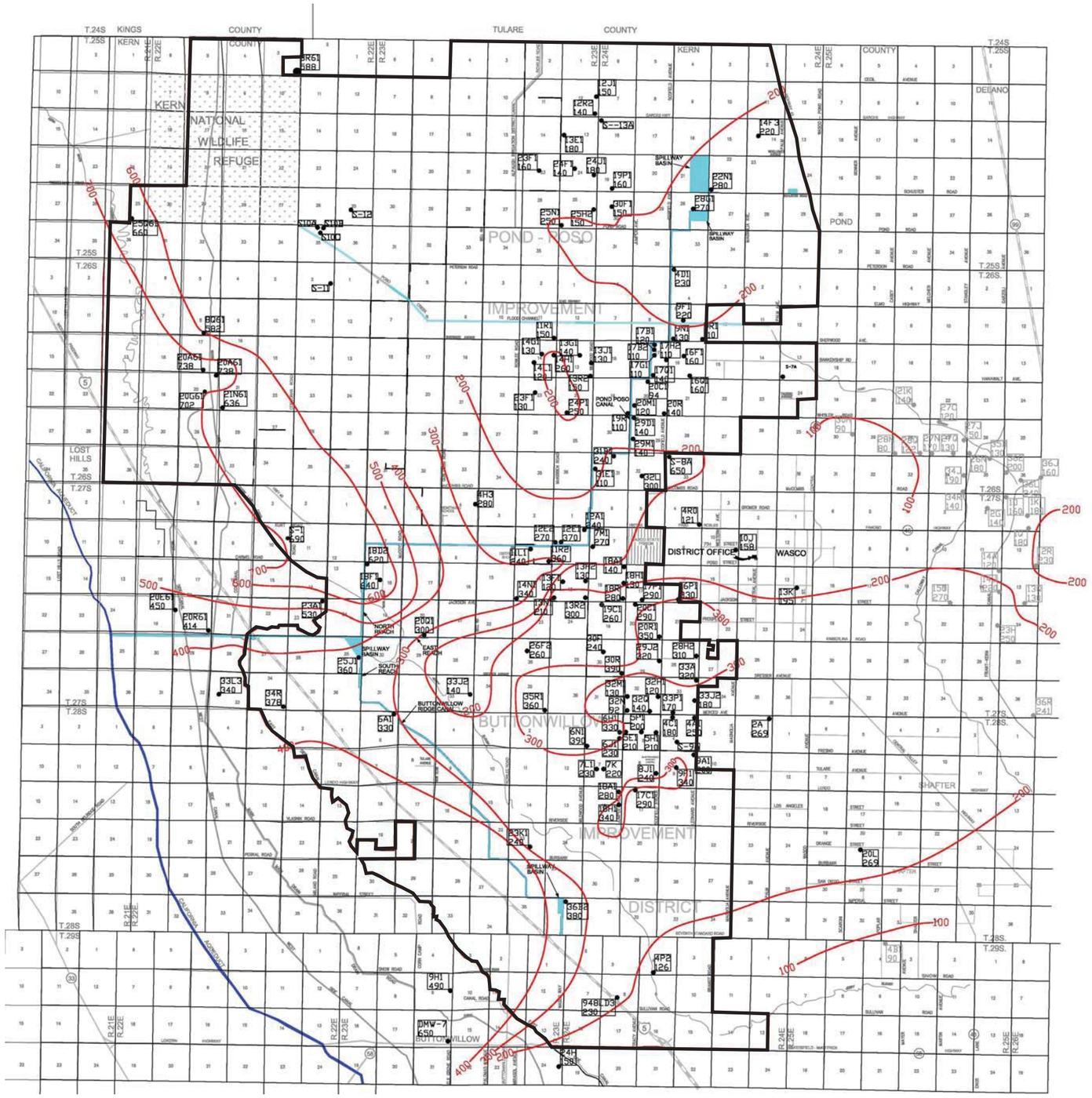
4.5 Subsidence

Land subsidence in the Tulare Basin region has been caused primarily by the compaction of fine-grained sediments following long-term withdrawal of groundwater in excess of recharge. Land subsidence can be characterized as either elastic, which is related to coarse-grained materials, or non-elastic, which is related to fine-grained materials. Clay compaction is permanent (non-elastic subsidence) and aquifer storage is lost, while coarse-grained unconfined aquifer materials rebound (elastic subsidence). Non-elastic compaction appears to happen more readily when wells are perforated only in the confined part of the aquifer system, beneath a significant clay layer or layers, because a larger head differential is created which imparts greater stresses on the aquifer materials.

In the southern San Joaquin Valley, land subsidence has been studied in the area extending from Wasco on the south to Tulare on the north. The greatest amount of subsidence is along State Highway 99 between the communities of Pixley (to the northeast) and Delano (to the east). However, some historical subsidence is located just to the east of the District, principally in the area lying north of State Highway 46, where from 1926 to 1962, the maximum subsidence is indicated to be about four feet, with an average of about two and one-half feet over the area north of Highway 46 (USGS, 1969). In 1988, the California Department of Water Resources surveyed a line of benchmarks which included the alignment of Highway 46 east of the District. Based on this survey, subsidence for the period extending from 1962 to 1988 is suggested to have been about one foot near the intersection of Highways 46 and 99 and is essentially zero near Wasco (at the eastern edge of the District).



2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	Electrical Conductivity In Shallow Groundwater (2010)
Semitropic Water Storage District		March 2012 Figure 14



EXPLANATION

4A1 250 — WELL IDENTIFICATION, TDS CONCENTRATION (mg/l)

200 — CONTOUR OF TDS CONCENTRATION (mg/l)

SEMITROPIC WATER STORAGE DISTRICT

N

SCALE OF MILES
1 0 1 2 3

Source: Kenneth D. Schmidt and Associates

2012 Groundwater Management Plan		Total Dissolved Solids in Deep Groundwater (March - November 2007)
Semitropic Water Storage District		February 2012 — Figure 15

In 1975, the San Joaquin Nuclear Project Feasibility Study Report (LADWP 1975) evaluated historical subsidence and the potential for future subsidence for an area in the west-central part of the District. The report concluded that about one foot of subsidence occurred from 1962 to 1974 as the confined aquifer water levels declined about 80 feet. Since 2006, the District has maintained a borehole extensometer located about five miles north of this area in order to be alerted to any future subsidence.

5 The Plan

Cal. Water Code §10752(d): *"Groundwater management plan" or "plan" means a document that describes the activities intended to be included in a groundwater management program.*

As previously stated, the overarching goal of formulating and implementing this plan is preservation of the groundwater resource as a source of water supply to support overlying uses into the future through local control and management. Consistent with this goal, this section articulates basin management objectives, strategies, and actions, which collectively comprise *The Plan*. Implementation of the plan is addressed in Section 6.

5.1 Statutory Requirements

As noted in Section 1, the Water Code provides guidance respecting the content of a plan. DWR Bulletin 118, *California's Groundwater Update 2003*, provides a summary of the guidelines set forth in the Water Code, as well as additional suggestions. Table 1 (located in Section 1) presents a summary of these guidelines, along with the location in this report where each is addressed. Not only do these guidelines address plan content, they also address public and agency involvement, which is discussed in the following subsection.

5.1.1 Public and Agency Involvement

Public involvement for developing this amended groundwater management plan included published notices in the Bakersfield Californian, the newspaper with the widest circulation in Kern County. In particular, these included the following:

- Notice of hearing to consider adoption of a Resolution of Intention to prepare an amended groundwater management plan. [CWC§10753.2(a)]
- Publish Resolution of Intention [CWC§10753.3(a)]
- Notice regarding how to participate in development of the plan [CWC§10753.4(b)]
- Notice of second hearing to consider adoption of an amended groundwater management plan. [CWC§10753.5(a)]

In addition, the District's Board of Directors held regularly scheduled monthly meetings which were open to the public, with time set aside for public comment, and agendas are provided on the District's website. The Proofs of Publication for the published Notices are located in Appendix D, along with copies of meeting minutes and other documentation related to the plan development and adoption process.

As discussed in Section 2, there are two principal forums for local agency involvement and collaboration; the Semitropic Groundwater Monitoring Committee and the Poso Creek Regional Water Management Group (RWMG). The following table indicates the member districts of each group:

Table 3: Monitoring Committee and Poso Creek RWMG Participants

Agency	Poso Creek Regional Water Management Group	Semitropic Groundwater Monitoring Committee
Buena Vista Water Storage District		✓
Cawelo Water District	✓	✓
Delano-Earlimart Irrigation District	✓	
Kern-Tulare Water District	✓	
North Kern Water Storage District	✓	✓
North West Kern Resource Conservation District	✓	✓
Rosedale-Rio Bravo Water Storage District		✓
Semitropic Water Storage District	✓	✓
Shafter-Wasco Irrigation District	✓	✓
Southern San Joaquin Municipal Utility District		✓
16 Communities, including the City of Wasco	✓	✓

The locations of these agencies are shown on Figure 3. Collectively, these agencies represent over 500,000 acres overlying that portion of the Kern County groundwater subbasin lying north of the Kern River. This Plan update was included on the regular meeting agenda for each group and was addressed in noticed meetings of each. As noted in the above table, many of the districts are common to each group. Effectively, the two groups served the role of a "technical advisory committee".

5.2 Issues of Concern

Consideration of groundwater conditions in the basin has given rise to *issues of concern*, which include the following, and for the most part are described and discussed in further detail in Section 4:

Surface Water Supplies: Reduction in the historical amount of surface water diverted into the District and the Region. DWR Bulletin 160-09[2] articulated some of the "challenges" facing the Tulare Lake Basin, which include the following:

a. "Sacramento-San Joaquin River Delta water quality needs and environmental needs are reducing the export volume of water pumped and available in the Tulare Lake region ---the new biological opinions for endangered species in December 2008 reduced export pumping 20-30 percent.

b. Changes in the OCAP[3] could worsen water delivery reliability issues of imported water from the CVP and SWP and along with the growing acreage of permanent crops.

c. The San Joaquin River Settlement will impact water diverted into the Friant-Kern Canal, possibly as much as 15 percent of supply [on average] as interim flows begin in fall 2009."

Furthermore, according to the 2011 "Draft Delivery Reliability Report" as prepared by the State of California, Natural Resources Agency, Department of Water Resources, "Under future conditions the average annual delivery of Table A water estimated for this 2011 Report is 2,466 taf/year, about 1% less than the 2,487 taf/year estimate for the future conditions scenario presented in the 2009 report." This is equivalent to a long-term future average reliability of 60 percent.

In addition, projects have been proposed which, if implemented, would have the effect of reducing the amount of Kern River water historically diverted into the Region.

Groundwater Levels: Decline in groundwater levels as a result of 1) reductions in historically available surface water supplies and a corresponding increase in the use of groundwater, particularly with the shift to permanent crops (both within the District and the region); and 2) increased groundwater pumping in unorganized areas adjacent to the District (generally located to the north and northeast, as well as to the east of the south part of the District) which rely exclusively on pumped groundwater for irrigation to support permanent crops.

Subsidence: Land surface subsidence which could be induced by the extraction of groundwater.

[2] DWR, Bulletin 160-09, California Water Plan Update 2009, Tulare Lake, Integrated Water Management, Volume 3, Regional Reports

[3] "OCAP" refers to Operations Criteria and Plan for the State Water Project and changes to the OCAP may be dictated by new biological opinions, such as those mentioned in item (a).

Salt Load: Increasing concentration of salts over time in the absence of a means to remove salts from the basin.

Water Banking: Balancing the positive effects of recharge with the additional pumping stress on the aquifer during times of recovery.[4]

Groundwater Quality: Migration of groundwater from areas of relatively poor water quality (generally from the west) to areas of relatively better water quality (at least in part as a result of reduced surface water supplies); and degradation of water quality from leakage through abandoned wells (which is being addressed through the Kern County well ordinance). Within the District, constituents of concern for agriculture are primarily related to salinity (and include chloride), while arsenic and nitrates are constituents of concern with regard to drinking water supplies.

5.3 Basin Management Objectives

Cal. Water Code §10753.7(a)(1): *Prepare and implement a groundwater management plan that includes basin management objectives for the groundwater basin that is subject to the plan. The plan shall include components relating to the monitoring and management of groundwater levels within the groundwater basin, groundwater quality degradation, inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin.*

In the above citation, the Water Code identifies five areas within which it is appropriate to consider and formulate objectives which are tailored to the specific management area. Given the Plan's overarching goal and the issues of concern which have been identified, the following Basin Management Objectives (BMO) have been formulated for the District's portion of the basin:

- ✓ Groundwater Levels: Maintain groundwater levels at economically viable pumping lifts for the overlying agricultural uses.
- ✓ Groundwater Quality: Protect groundwater quality in general and minimize increases in salinity.
- ✓ Inelastic Land Surface Subsidence: Avoid conditions conducive to inelastic land surface subsidence.
- ✓ Changes in Surface Flow: Protect and preserve surface water rights and contracts.

[4] This is addressed in part by a Groundwater Rule which was adopted as part of the implementation of the District's water banking project.

- ✓ Changes in Surface Water Quality: Protect and preserve surface water quality.

It is the intent of this Plan that meeting these objectives would result in a sustainable groundwater resource for present and future beneficial uses. While the overall goal of the Plan may remain relatively unchanged over time, it is expected that the objectives will be revisited from time to time and modified as appropriate in response to changed conditions.

5.4 Basin Management Strategies and Actions

In order to achieve the above-stated basin management objectives, consideration was given to numerous strategies, many of which are set forth in Cal. Water Code §10753.8.

Cal. Water Code §10753.8*: A groundwater management plan may include components relating to all of the following:*

(a) The control of saline water intrusion.

(b) Identification and management of wellhead protection areas and recharge areas.

(c) Regulation of the migration of contaminated groundwater.

(d) The administration of a well abandonment and well destruction program.

(e) Mitigation of conditions of overdraft.

(f) Replenishment of groundwater extracted by water producers.

(g) Monitoring of groundwater levels and storage.

(h) Facilitating conjunctive use operations.

(i) Identification of well construction policies.

(j) The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.

(k) The development of relationships with state and federal regulatory agencies.

(l) The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

Many of the above-listed strategies are applicable to the Semitropic management area, and a given strategy may support one or more of the basin management objectives. Further, each of these strategies requires that specific management actions be established. Based on consideration of available management strategies, specific management actions have been

established and are listed following, along with a notation as to which of the basin management objectives are supported by that action. In addition, each action is identified as either existing or planned (by the boxes and checkmarks in the margin). No priority is intended by the order in which the actions are listed.

	Table 4. Management Strategies and Actions	*Basin Management Objectives*					
		Groundwater Levels	Groundwater Quality	Land Subsidence	Surface Water Flow	Surface Water Quality	
☑	Maximize use of available surface water supplies for irrigation and spreading; use water pricing, water exchanges, and water banking as appropriate.	✓	✓	✓	✓		
☑	Develop water exchanges and/or water banking arrangements that result in a net increase in District water supplies, i.e., over and above an allowance for "losses".	✓	✓	✓			
☑	Protect the physical recharge interface in spreading ponds by minimizing vehicular travel and trampling, and by maintaining/mowing grass on the pond bottoms.	✓		✓			
☑	Promote water use efficiency through financial support of the North West Kern RCD-DWR Mobile Laboratory and by encouraging landowners to take advantage of this resource by requesting field irrigation evaluations.	✓					
☑	Operate and maintain District wells in a manner that protects the wellhead.		✓				
☑	Actively participate in local water resource management forums, including the Semitropic Groundwater Monitoring Committee and the Poso Creek Regional Water Management Group.	✓	✓	✓	✓	✓	
☑	Remain vigilant with respect to water transfer, exchange, and banking arrangements which have the potential to adversely affect the common groundwater resource.	✓	✓	✓			
☐	Formally request local agencies to add Semitropic to their distribution list for any CEQA or NEPA documents.	✓	✓	✓	✓	✓	
☐	Formally request the U.S. Bureau of Reclamation to add Semitropic to their distribution list for any NEPA documents for projects located within the San Joaquin Valley portion of Kern County, and monitor their website for release of NEPA documents.	✓	✓	✓	✓	✓	
☑	Oppose proposed projects with the potential to adversely affect Poso Creek supplies in terms of quantity and quality (and the corresponding water rights).	✓	✓	✓	✓	✓	
☐	Consider expanding the District's website to include data respecting groundwater levels and quality.	✓	✓				
☑	Annually file statements of diversion and use of Poso Creek water with DWR.				✓		
☐	Request to receive copies of annual or other periodic reporting prepared by adjacent districts under their adopted groundwater management plans.	✓	✓	✓	✓	✓	
☑	Preserve the yield of the District's contract for imported State Water Project water through participation in the efforts of the Kern County Water Agency, the State Water Contractors, and the Coalition for a Sustainable Delta.	✓		✓	✓		

	Table 4. Management Strategies and Actions	Basin Management Objectives				
		Groundwater Levels	Groundwater Quality	Land Subsidence	Surface Water Flow	Surface Water Quality
☑	Support measures that will improve the reliability of the SWP. The District will continue to support the Bay-Delta Conservation Plan process to the extent that the solution is economically feasible for agriculture.	✓		✓	✓	
☑	Purchase wet-year water that is available from time to time, including SWP "Article 21" water, CVP-Friant "Section 215" water, and local Kern River water.	✓		✓	✓	
☑	Purchase and import additional SWP water which is available from time to time (on an annual basis) through the Kern County Water Agency (KCWA). In this regard, support KCWA efforts to keep SWP entitlement within Kern County and available at a price affordable to agriculture.	✓		✓	✓	
☑	Continue the development of the District's water banking capabilities.	✓		✓	✓	
☑	Continue to support the development of in-lieu recharge projects in order to accommodate the delivery and use of available surface water supplies in lieu of pumped groundwater, including expansion of main conveyance facilities to and from the California Aqueduct, as well as irrigation distribution system facilities.	✓		✓	✓	
☑	Participate in water banking projects located outside of the District's area which are based on direct recharge in order to provide a place to store and reregulate surface supplies that are available at times of relatively "low" irrigation demands.	✓		✓	✓	
☑	Facilitate the importation of surface water supplies to neighboring water agencies relying on the common groundwater resource.	✓		✓	✓	
☑	Encourage the use of surface water in lieu of pumped groundwater when available (e.g., through water-pricing policies and contracts for intermittent water deliveries).	✓		✓	✓	
☑	Comply with, and encourage landowner compliance with, Kern County Ordinance No. G-5006, including sanitary well seal, annular well seal, and well abandonment requirements.		✓			
☐	Make guidelines available to landowners for well construction and maintenance methods to minimize risk of corrosion, encrustation, casing failure, siphoning of pesticides , wellhead spills of toxics and other actions that have potential to cause aquifer contamination.		✓			
☐	Seek partners that would help finance the treatment of drainage water in localized areas and any otherwise "unusable" water, all with the objective of developing useable supplies.		✓			
☐	Test water quality before completing new wells so that perforations are not placed in zones of poor water quality.		✓			

	Table 4. Management Strategies and Actions	Basin Management Objectives				
		Groundwater Levels	Groundwater Quality	Land Subsidence	Surface Water Flow	Surface Water Quality
☐	Continue gathering data to update and refine the estimate of the location of the base of fresh water and pockets of poor water quality, and to enhance the understanding of the hydrologic character of the western edge of the District.		✓			
☐	Make technical information available to landowners which will help ensure that their operations protect the main aquifer from migration of poor quality water located to the west, above the E-clay, and below the production zone.		✓			
☐	Contact Kern County Environmental Health on a regular basis to stay current with the status of known contaminant sites.		✓			
☐	Consider development of local shallow groundwater supplies with relatively "high" concentrations of nitrates for irrigation to reduce nitrates within the basin.		✓			
☐	Consider blending groundwater with relatively "high" concentrations of TDS with other supplies such that the blended supply is useable for irrigated agriculture.		✓			
☐	Contact agencies north of the Kern County line to attempt to obtain the same level of information obtained in Kern County concerning groundwater quality, contaminant sites, water level and quality monitoring, and groundwater management.	✓	✓	✓		
☑	Provide redundancy and flexibility in groundwater production facilities so that the spatial distribution of pumping can be altered to some extent from year to year in response to observed fluctuations in groundwater levels.	✓		✓		
☑	Maintain an existing agreement with two upstream water agencies (namely; North Kern Water Storage District and Cawelo Water District) for sharing of the waters of Poso Creek.	✓		✓	✓	
☐	Maintain the District's existing water diversion permit on Poso Creek, and convert it to a license at the appropriate time.				✓	
☑	Only water stored under a banking agreement may be withdrawn from Semitropic's groundwater basin. Water must first be stored before it is withdrawn.	✓		✓		
☑	Under its third-party water banking arrangements, Semitropic will retain a minimum quantity of its SWP supply to maintain the quality of water delivered to farmers.					✓
☑	The District will retain about ten percent of the water delivered for banking by third parties to account for aquifer and operational losses.	✓		✓		
☑	The District will not pump more water from the wells on a given farm than the total of all prior surface water deliveries to that farm for banking purposes.	✓		✓		
☑	Construct monitor wells as necessary to monitor the in-District water banking operations.	✓	✓	✓		

	Table 4. Management Strategies and Actions	Basin Management Objectives				
		Groundwater Levels	Groundwater Quality	Land Subsidence	Surface Water Flow	Surface Water Quality
☑	Withdrawal of previously banked water would be prohibited if such withdrawals would cause the average groundwater levels over a three-year period to be 15 feet lower than the average groundwater levels which would have prevailed without the project over the same three-year period, unless otherwise mitigated.	✓		✓		
☑	Evaluate alternative methods of levying the District's General Project Service Charge.	✓		✓		
☑	Continue to support voluntary land retirement as a means of reducing local demands upon the groundwater basin.	✓		✓		
☐	Encourage and support delivery of surface water supplies (when available) to largely unorganized lands located adjacent to the District which rely exclusively on pumped groundwater for irrigation.	✓	✓	✓		

Implementation of selected conjunctive-use measures and actions is illustrated on the timeline presented on Figure 16.

5.4.1 New Basin Management Strategies

Since adoption of the District's 2003 Groundwater Management Plan, the District has commenced implementation of new strategies which include unbalanced water banking arrangements and land retirement. In addition, the District intends to explore an alternative method of levying its General Project Service Charge.

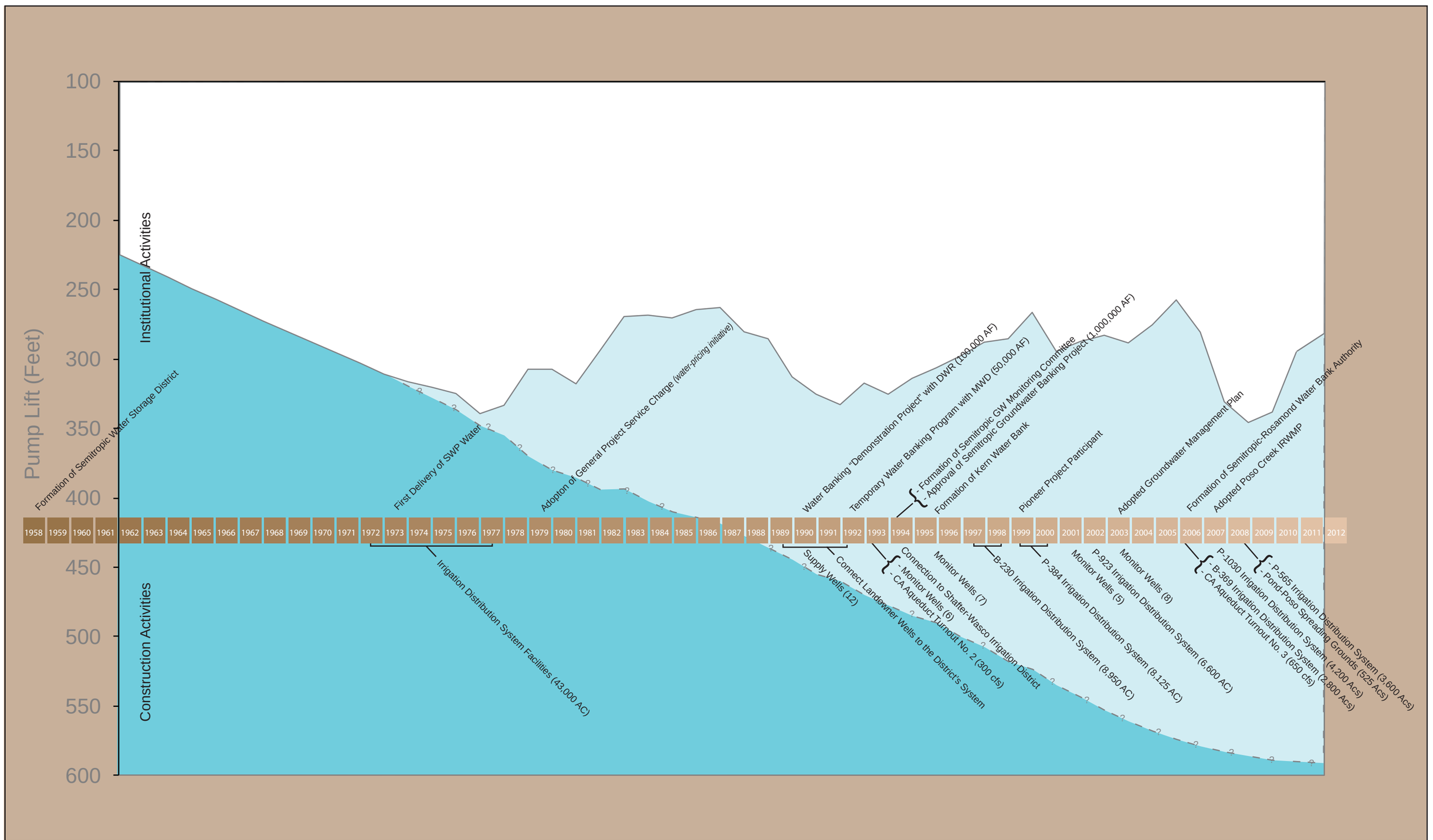
5.4.1.1 Unbalanced Water Banking Arrangements

With regard to unbalanced water banking arrangements, the District has "recently" entered into two water management programs whereby for every two acre-feet delivered for storage in Semitropic, the District is only obligated to return one acre-foot, which results in one acre-foot being left behind, thereby increasing Semitropic's water supply; one such program is with neighboring Buena Vista Water Storage District (2011), and one with Kern-Tulare Water District. Under a balanced or bucket-for-bucket arrangement, ten percent has been left behind as an allowance for "losses".

5.4.1.2 Land Retirement

Most of the District's groundwater management strategies are focused on "supply"; in particular, maximizing the use of available surface water supplies in lieu of pumping groundwater. In contrast, "land retirement" is a strategy that is focused on "demand" for (or use of) water. Land retirement refers to permanently retiring land with a dependence upon groundwater from irrigated agricultural uses, thereby reducing groundwater pumping and conserving groundwater resources for the benefit of District landowners. This strategy has only recently been implemented in view of the significant regulatory constraints that have been placed on water deliveries from the Sacramento-San Joaquin River Delta, which is the District's primary source of surface water supplies. The availability of supplies --- both SWP contract supplies and other supplies --- has been significantly impaired. Reductions in surface water supplies have resulted in a corresponding increase in the reliance on pumped groundwater to meet irrigation demands. Recall, from the discussion in Section 2, that this was identified in the Poso Creek IRWMP (2007) as the number one challenge facing the region, which caused it to be included in the *issues of concern* (presented in Section 5.2).

As presently formulated, the District's land retirement program is strictly voluntary (i.e., it is predicated on having a willing seller); applies only to land which overlies the useable groundwater basin and is developed to irrigated agricultural uses with a dependence upon groundwater; and depends on available funding to effect the purchase, as well as other alternatives available to the District at the time. In order to partially offset purchase costs, consideration will be given to the inclusion of purchased lands in a habitat conservation program or other beneficial uses not reliant upon groundwater.



2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	Timeline of Selected Water Resource Management Actions
Semitropic Water Storage District		March 2012 — Figure 16

5.5 Conjunctive Use Accomplishments

The essence of the District's conjunctive use strategies is to maximize the use of available surface water supplies in lieu of pumped groundwater, which is reflected in many of the above-listed *management actions*. Semitropic has implemented a number of conjunctive-use measures --- both structural and non-structural --- over and above the District's original project, which was implemented in the 1970s. These measures include the following:

Increased In-Lieu Recharge Capability
(i.e., turn off wells when surface water is available to maximize the use of surface water)

- Temporary Water Service Area (deliver non-contract surface water, when available, to lands outside of the Contract Water Service Area which are proximate to the District's main conveyance facilities and require relatively modest improvements to effect surface water deliveries)
    - 20,000 acres
- Construct additional irrigation distribution systems (to deliver surface water, when available, to lands otherwise reliant on pumped groundwater)
    - 23,000 acres ("contractual absorptive capability", i.e., first priority is third-party water banking)
    - 12,000 acres ("discretionary absorptive capability", i.e., District has first priority)
- Increase capacity to divert water from California Aqueduct (to support delivery of as-available surface water supplies to an expanded surface water service area)
    - SWP Turnout No. 2 (300 cfs)
    - SWP Turnout No. 3 (600 cfs)
- Increase main conveyance capacity (through canal enlargement, canal lining, and enlargement of pipe siphons at canal road crossings)

Increased Direct Recharge Capability
(Direct recharge complements in-lieu recharge by providing a place to store water which is independent of irrigation demand, inasmuch as certain water supplies are often available at times of "low" irrigation demand.)

- Kern Water Bank (30,000 af/yr min.)
- Pioneer Project (20,400 af/yr min.)
- In-District spreading ponds (525 net acres existing; 980 acres planned)

Added Surface Storage Capability

- Goose Lake (4,000 – 5,000 af/yr)
- Spreading Ponds (1,650 af existing; 3,050 af planned)

Added Inter-District Conveyance Capacity
(To facilitate mutually beneficial water banking and exchange arrangements with neighboring water districts, including access to alternative sources of water supplies.)

- Buena Vista Water Storage District (60 cfs)
- Shafter-Wasco Irrigation District (30 - 35 cfs each way)
- North Kern Water Storage District (30 – 40 cfs each way)

Implemented Third-Party Water Banking
(The District takes delivery of (i.e., banks) "wet-year" water which is used to turn off wells, and subsequently recovers and returns groundwater during "dry" years. Aside from banking revenues which have funded most the above-described physical improvements, there are water-level benefits as a result of water banking activity.)

- Ten percent leave behind (90 percent of gross deliveries for banking is subject to return, leaving 10 percent behind for the benefit of the basin)

- Water in storage (to the extent there is banked water in storage, there is a corresponding water-level benefit, i.e., this is water that would not be in the basin were it not for water banking)

- "Wet-year" water purchases which are facilitated by water-banking revenues

Developed Well Assets

(Aside from supporting the District's water banking program, well assets allow the District to maximize the import of available surface water supplies early in the year by providing the ability to meet water delivery obligations to the Contract Water Service Area later in the year, if required)

- District-owned wells
- Landowner Pumping Agreements
- Landowner wells in ILSA
- Pioneer Project
- Kern Water Bank

Three figures have been prepared to illustrate the accomplishments of the District's conjunctive-use initiatives: 1) surface water service area over time (Figure 17), 2) annual diversion of surface water over time (Figure 18), and 3) groundwater pumping lifts over time (Figure 19).

As shown on Figure 17, the surface water service area has more than doubled from the original design and buildout of 43,000 acres. The District's absorptive capability attributable to irrigation demand is directly proportional to the size of the surface water service area; accordingly, the absorptive capability attributable to irrigation has also more than doubled.

The actual diversions of surface water for irrigation over time reflect both build up of the absorptive capability and the hydrology (or available supplies), and is illustrated on Figure 18 (with the line indicating the maximum annual diversion to date).

Figure 17: Development of Surface Water Service Area (1970 - 2010)

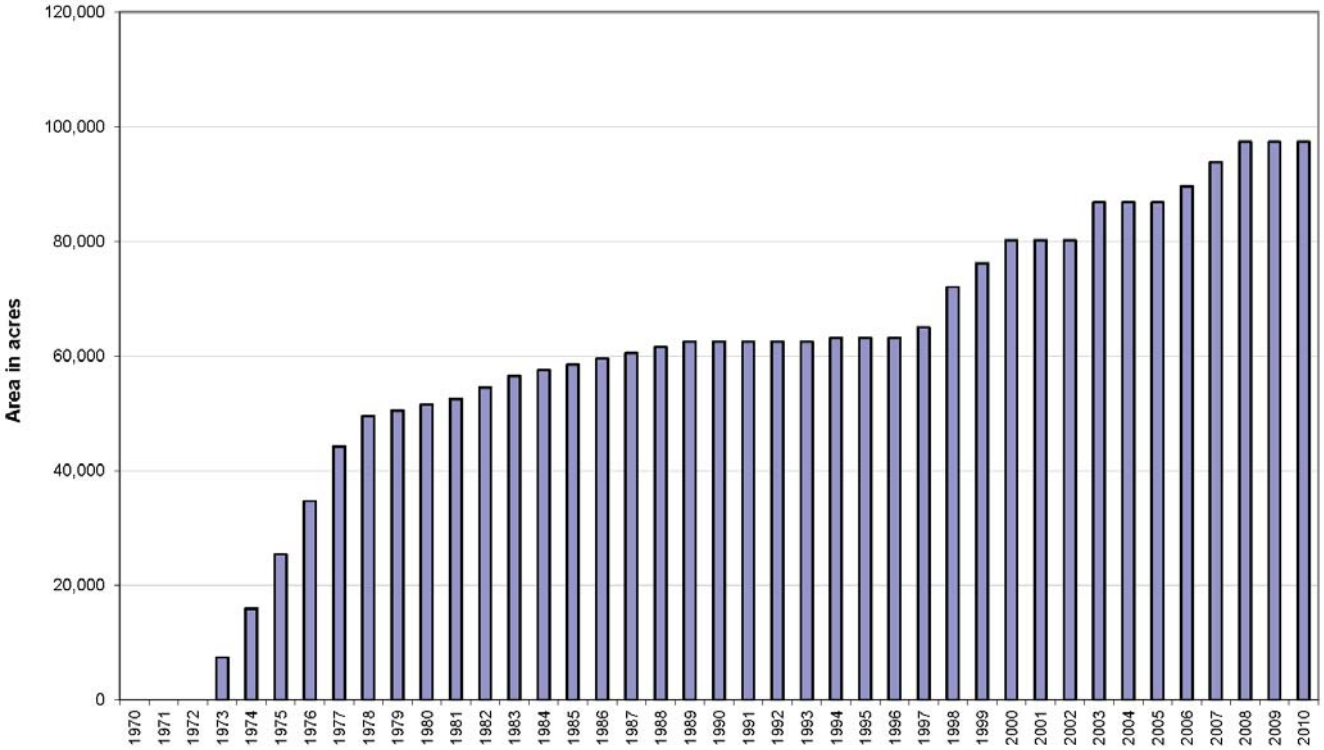
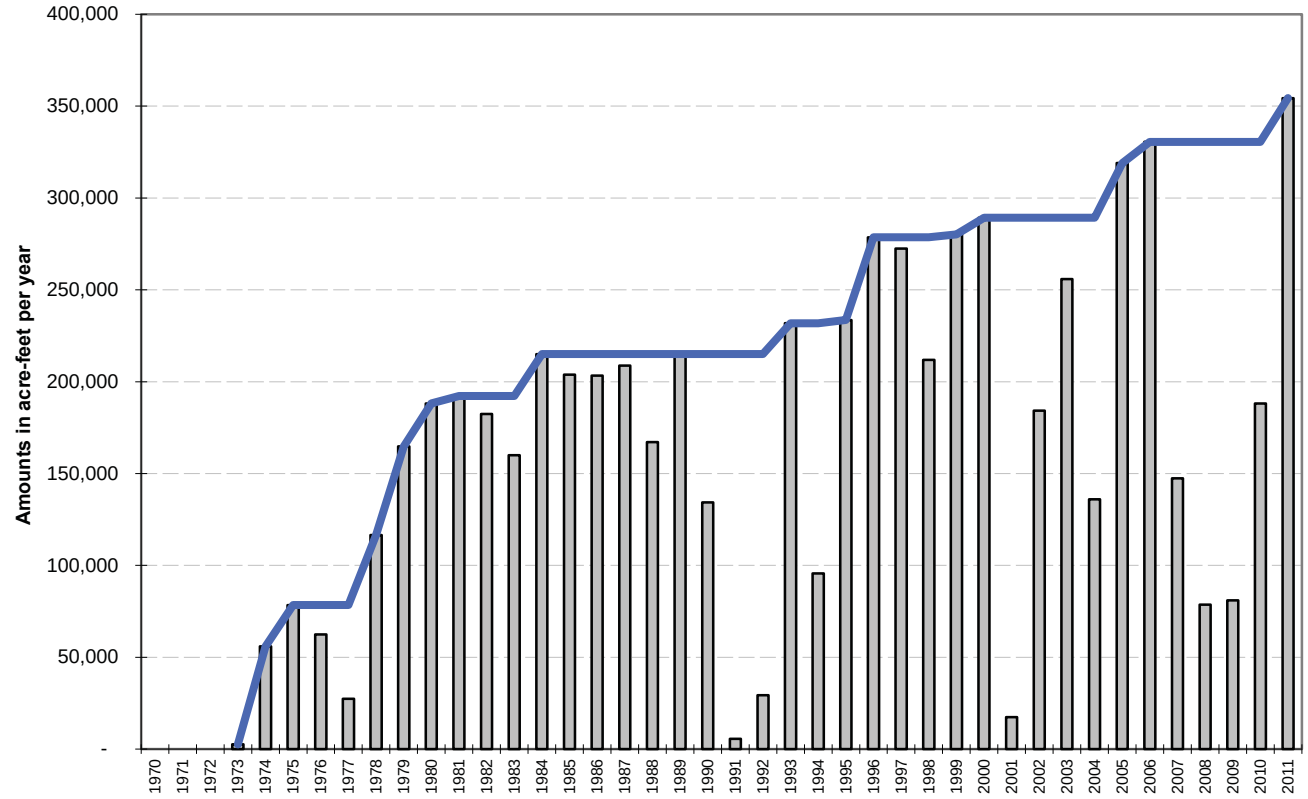
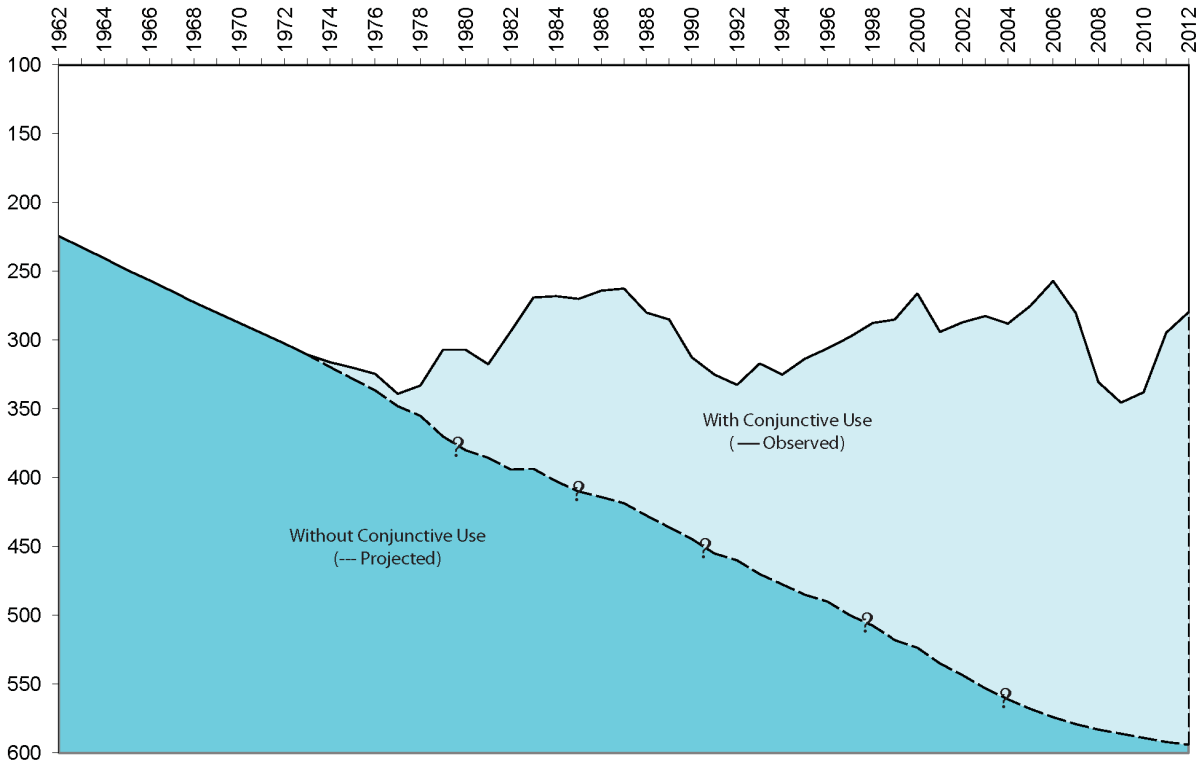


Figure 18: Surface Water Diversions to Semitropic WSD (1970 - 2011)



The fluctuation of groundwater levels over time is the ultimate measure of the effectiveness of the conjunctive-use measures which the District has implemented. Accordingly, Figure 19 illustrates the annual fluctuation of groundwater pumping lifts.

Figure 19: Groundwater Pumping Lifts



As shown on Figure 19, a steady decline in groundwater levels preceded the District's importation of a supplemental surface water supply. Since that action and subsequent enhancements to the District's conjunctive-use program, groundwater levels have been relatively stable in recent years; generally declining during "dry" periods, and increasing during "wet" periods.

Owing to the significant capital costs involved in constructing additional irrigation distribution system facilities, expansion of the District's surface water service area has been slowly occurring over time as funding has been available (reference Figure 6); more recently, in-District spreading capability has become operational. Accordingly, much of the benefit of these significant improvements in the District's ability to absorb available supplies has yet to be realized. However, the benefits also depend on the availability of supplies, which has been adversely impacted --- primarily through judicial and regulatory actions.

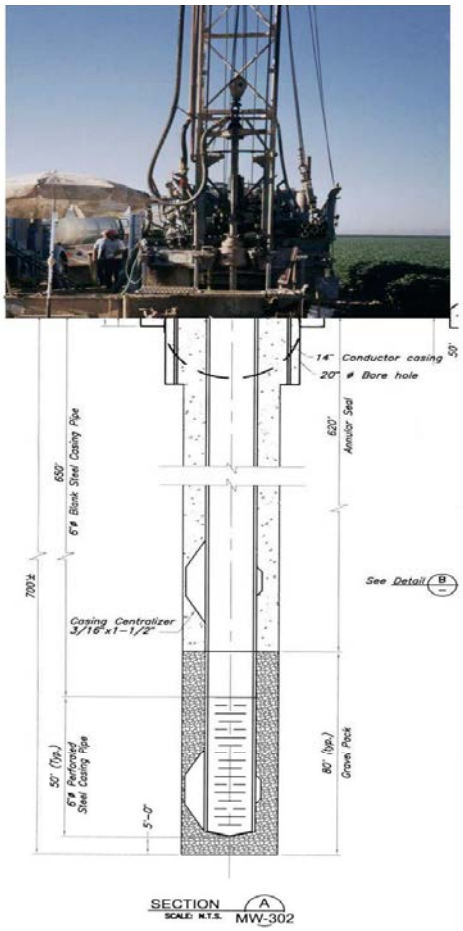
6 Plan Implementation

Cal. Water Code §10752(e): *"Groundwater management program" or "program" means a coordinated and ongoing activity undertaken for the benefit of a groundwater basin, or a portion of a groundwater basin, pursuant to a groundwater management plan adopted pursuant to this part.*

Plan implementation includes the following elements, each of which is addressed in this section:

- Monitoring
- Reporting
- Agency Coordination and Stakeholder Involvement
- Plan Review and Update

6.1 Monitoring



"Typical" Monitor Well under construction.

Management of the groundwater resource is dependent on good basic data respecting both geology and hydrology. The purpose of this element of the Management Plan is to characterize the conditions within the groundwater basin, both to provide a measure of the accomplishments relative to the *Basin Management Objectives* and to identify and implement specific programs that become needed in response to changing conditions in the basin. Monitoring includes collecting the basic data and analyzing these data to characterize the basin and would be subject to modification, as needed, to reflect changes or additions in the programs implemented under the Management Plan. Monitoring is essential to gauging Plan performance and making future management decisions.

Implementation of the Semitropic Groundwater Banking Project involved the establishment of a Groundwater Monitoring Committee (in 1994) to develop and oversee a groundwater

monitoring program. The Monitoring Program addresses existing monitoring activities, proposed monitoring activities (at the time the document was prepared), and data management and interpretation (a copy of this Program is included in Appendix A). Subsequently, in 1996, a sampling plan was prepared for use by Semitropic and the adjoining districts. The sampling plan "…provides the acceptable procedures to be used for measuring water levels and collecting, preserving, and analyzing water samples …" (a copy of the sampling plan is included in Appendix B). In addition to Semitropic, the Committee includes representatives from five neighboring water agencies (reference Figure 4 for their relative locations). The Kern County Water Agency and the California Department of Water Resources are interested parties and participate in Committee activities from time to time.

6.1.1 Water Levels

Groundwater level data are the most important singular barometer of the "health" of the basin. Selected District-owned and privately-owned supply wells have been routinely measured since commencement of District operations in the mid-1970s; however, the total number of wells measured in any given year has varied as a result of individual site conditions, which include access and whether the well is being pumped at the time of the field visit. Typically, water levels are measured twice a year, in both the "spring" and "fall", with the timing of these measurements intended to capture the annual water level high and low, respectively. These data have been made available to the Kern County Water Agency and the Department of Water Resources.

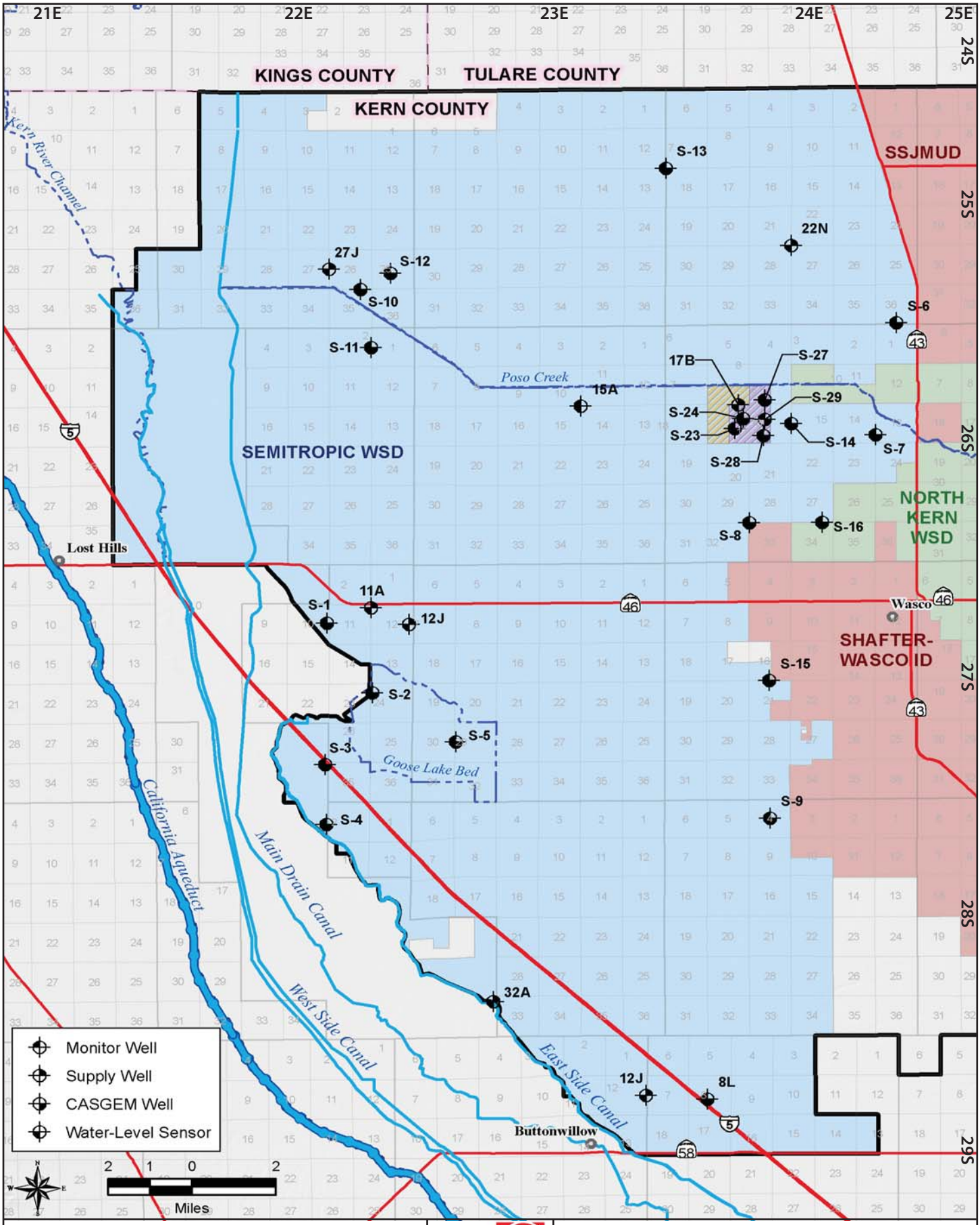
For many years, the monitoring network consisted almost exclusively of supply wells, most of them active. In 1992, two monitor wells were constructed by the Department of Water Resources which are the southernmost monitor wells in the District. Since that time, the District has constructed 25 dedicated monitor wells at 16 sites (exclusive of those located in the spreading grounds) as shown on Figure 20. Most recently, 19 monitor wells were constructed at 5 sites within the District's Pond-Poso Spreading Grounds. Table 5 summarizes the perforated intervals, installed equipment, and monitoring/sampling frequency for these monitor wells. The network will be reviewed periodically in order to provide sufficient areal coverage to prepare representative water-level elevation and depth contour maps. Measurement of water levels will continue to be performed in both spring and fall in order to show seasonal variations in water levels. Using the same wells for monitoring over a long-term period (to the extent practical), will facilitate the preparation of meaningful water-level change maps and hydrographs.

State legislation passed in 2009 resulted in the development and implementation of the California Statewide Groundwater Elevation Monitoring Program (CASGEM) by the Department of Water Resources. The Program is intended to annually collect and house sufficient water level data to identify seasonal and long-term trends in water levels throughout the State's groundwater basins, and make that data readily available to the public. Semitropic responded to DWR's solicitation for participating Monitoring Entities by

preparing and submitting a monitoring plan. As a result, Semitropic is a CASGEM Monitoring Entity, with 22 monitor well sites in the Program. The locations of these wells are indicated on Figure 20 and the District's CASGEM monitoring plan is included as Appendix C. Three of Semitropic's immediate neighbors are also Monitoring Entities; Buena Vista Water Storage District, Rosedale-Rio Bravo Water Storage District, and Shafter-Wasco Irrigation District.



Surface enclosure for Monitor Well S-6



2012 Groundwater Management Plan	GEI Consultants Bookman-Edmonston Division	Monitor Wells
Semitropic Water Storage District		March 2012 Figure 20

Table 5: Summary of Monitor Wells

District Well No.	aka	Location T-R-S	Well Type	Year Constructed	Perforated Interval (ft bgs)	Water Level Sensor	Water Level Measurement Frequency	Sampling Pump	Sampling Frequency
S-1		27S-22E-10J	M	1994		✓	2		1
S-2		27S-22E-24D	M	1994		✓	2		1
S-3		27S-22E-34A	M	1994		✓	2		1
S-4		28S-22E-3H	M	1994		✓	2		1
S-5		27S-23E-29M	M	1994		✓	2		1
S-6		25S-24E-36Q	M	1995	381 - 431	✓	2	✓	
S-7A		26S-24E-13N	M	1995	550 - 600	✓	2	✓	1
S-7B		26S-24E-13N	M	1995	330 - 380	✓	2		
S-8A		26S-24E-33D	M	1995	637 - 687	✓	2	✓	1
S-8B		26S-24E-33D	M	1995	392 - 432	✓	2		
S-9A		28S-24E-4L	M	1995	660 - 690	✓	2	✓	1
S-9B		28S-24E-4L	M	1995	357 - 407	✓	2		
					420 - 460				
S-10A		25S-22E-35B	M	1999	490 - 700	✓	2		
					740 - 890				
S-10B		25S-22E-35B	M	1999	1250 - 1260		2		
S-10C		25S-22E-35B	M	1999	1080 - 1090		2	✓	1
S-11		26S-22E-2J	M	2001	550 - 700	✓	2		
S-12		25S-22E-25L	M	2001	510 - 740	✓	2		
		25S-22E-27J	S			✓	2		
S-13A		25S-24E-18D	M	2003	660 - 690	✓	2	✓	1
S-13B		25S-24E-18D	M	2003	390 - 430	✓	2	✓	
PP1029 DGW		25S-24E-22N	S			✓	2		
		26S-23E-15A1	M			✓	2		
		26S-23E-15A2	M			✓	2		
S-14A		26S-24E-16J	M	2003	670 - 710	✓	2	✓	1
S-14B		26S-24E-16J	M	2003	430 - 480	✓	2	✓	
PP754 DGW		26S-24E-17B	S			✓	2		
		27S-22E-11A	S			✓	2		
		27S-22E-12J	S			✓	2		
S-15A		27S-24E-16P	M	2003	550 - 600	✓	2	✓	1
S-15B		27S-24E-16P	M	2003	400 - 450	✓	2	✓	
S-16A		26S-24E-27Q	M	2003	620 - 670	✓	2	✓	1
S-16B		26S-24E-27R	M	2003	370 - 410	✓	2	✓	
S-23A	03M 50	26S24E17J001M	M	2008	30-50		4		
S-23B	03M 90	26S24E17J002M	M	2008	70-90		4		
S-23C	03M 300	26S24E17J003M	M	2008	280-300	✓	4	✓	4
S-23D	03M 800	26S24E17J004M	M	2008	780-800	✓	4	✓	4
S-24A	04M 50	26S24E17H002M	M	2008	30-50		4		
S-24B	04M 90	26S24E17H003M	M	2008	70-90		4		
S-24C	04M 300	26S24E17H004M	M	2008	280-300	✓	4	✓	4
S-24D	04M 800	26S24E17H005M	M	2008	780-800	✓	4	✓	4
S-27A	07M 50	26S24E09P001M	M	2008	30-50		4		
S-27B	07M 90	26S24E09P002M	M	2008	70-90		4		
S-27C	07M 300	26S24E09P003M	M	2008	280-300	✓	4	✓	4
S-27D	07M 800	26S24E09P004M	M	2008	780-800	✓	4	✓	4
S-28A	08M 50	26S24E16P001M	M	2008	30-50		4		
S-28B	08M 90	26S24E16P002M	M	2008	70-90		4		
S-28C	08M 300	26S24E16P003M	M	2008	280-300	✓	4	✓	4
S-28D	08M 800	26S24E16P004M	M	2008	780-800	✓	4	✓	4
S-29A	MW1A	26S24E16F003M	M	2006	40-60		4		
S-29B	MW1B	26S24E16F002M	M	2006	80-100		4		
S-29C	MW1C	26S24E16F001M	M	2006	210-230		4		
		28S-23E-32A	S			✓	2		
		29S-23E-12J	S			✓	2		
948L02		29S-24E-8L02	M	1992	525 - 625	✓	6-12		2
948L03		29S-24E-8L03	M	1992	360 - 440	✓	6-12		2

(1) Well Type: M = Monitor; S = Supply
(2) Measurement and sampling frequencies are the number of times per year

Water level data are used to evaluate groundwater movement, storage conditions, and pumping costs. Maps showing contours of equal water-level elevation indicate the direction of groundwater movement and (in conjunction with knowledge of the aquifer transmissivity) also can be used to quantify estimates of groundwater underflow entering and leaving the Management Area. Maps of depth to groundwater can provide insight into the distribution of pumping lifts (and so assist in estimating pumping costs). Maps showing changes in groundwater levels (when used in conjunction with data on specific yield) can be used to estimate changes in groundwater storage. In addition to these water level maps, hydrographs of water level fluctuations in selected wells provide information on seasonal and long-term fluctuations of water levels.

6.1.2 Water Quality

Water quality monitoring, including water sampling and testing, will identify the suitability of groundwater for various uses. Under the District's current program, water samples are collected annually from all wells connected to the District system on a three-year cycle, whereby one-third of the wells is tested every year. Historically, water quality testing has been (typically) limited to standard agricultural-type analyses; however, in more recent years, additional testing (e.g., Title 22) has been included for some wells. Testing will become more extensive (both in terms of the number of tests and the constituents which are included in the tests) in the future to monitor the quality of water which is pumped into the California Aqueduct during periods of recovery and return of previously banked water. In this regard, the District has developed a (spreadsheet) model to manage the quality of the blended groundwater supply which is discharged into the Aqueduct (i.e, the discharge is the result of blending the pumpage from numerous wells located throughout the District). To support this management tool, the District developed a large water quality database in 2001, when water was being returned to the Aqueduct. Groundwater pumped into the District's distribution system is also sampled and analyzed in order to monitor water quality at times when significant quantities of groundwater are being delivered by the District to its growers.



Cluster of four monitor wells; each is completed at a different depth, and two are equipped with sampling pumps.

The collected data will not only be used to make real-time water management decisions during periods of groundwater discharge into the Aqueduct, but will provide the basis for identification of long-term water quality trends. If trends indicating degradation are suggested, the District would be in a position to identify the likely source(s) and significance of the degradation, and to make an assessment of whether arrest or correction of the

degradation is within the District's control. Significance would be a function of the constituent, the magnitude of the degradation, then current standards, and the areal extent of the degradation.

Similar to the water level network, the monitoring network for water quality consists of production wells, as well as dedicated monitor wells. The monitor wells shown on Figure 20 are used to monitor both water levels and water quality.

In recent years, water quality data have been managed through the use of electronic spreadsheets. With the significant increase in water quality data which will be developed in the future, a better data management system is needed to facilitate the analysis and interpretation of the collected data.

Additionally, the District is a member of the Kern River Watershed Coalition Authority, which is in turn a member of the Southern San Joaquin Water Quality Coalition, and in that capacity participates in, and contributes financially to, a Regional Water Quality Control Board program to monitor and improve surface water quality associated with agricultural activities. The Regional Board is in the process of promulgating a broader Irrigated Lands Regulatory Program (ILRP) to address both surface water and groundwater quality and, if Regional Board conditions are reasonable, the District may be involved in the future with implementation of the broader program.

6.1.3 Recharge and Pumpage

Data are collected annually that allow for quantification of the various elements of the hydrologic inventory, and support further analysis of the impact of management actions through the use of tools such as groundwater modeling. Principal components of the inventory include the amount of water recharged, and the quantity of groundwater pumped. The recharge is principally comprised of the deliveries of imported water, which are measured. Most of the groundwater pumping on the other hand, is not measured, with the exception of pumping by District-owned wells. Accordingly, data respecting crop acreages, crop evapotranspiration, and precipitation are collected to support a reasonable estimate of on-farm pumping.

6.1.4 Land Subsidence

Historically, the District did not attempt to measure land surface subsidence; rather, it relied on infrequent studies by state and federal agencies. The last such study was conducted by the Department of Water Resources in 1988, which involved releveling of an east-west line generally following the alignment of State Highway 46. This resurvey indicated that 1 to 2 feet of subsidence had occurred since 1962. Because subsidence observed between 1962 and 1970 was of this magnitude, it appears that reasonably "stable" conditions have resulted from the importation and delivery of surface water by the District, which commenced in the 1970s, as well as neighboring water agencies.

The District is considering an expansion of its groundwater banking project, which would include the construction and operation of a well field. In anticipation of this expansion, the District constructed a borehole extensometer in the area of the proposed well field with the help of grant funds under the Local Groundwater Assistance Act. At such time as this expansion goes forward, mitigation measures to address the potential for subsidence to occur during periods of significant, concentrated extraction will include land surface surveys across the well field and nearby areas prior to operation of the well field, and consultation with the Department of Water Resources and other appropriate agencies to implement measures to mitigate subsidence should it be detected.

6.2 Data Management, Interpretation, and Reporting

The Monitoring Program, included as Appendix A, addresses data management and interpretation and is not reproduced in this section. Rather, that discussion is supplemented in this section. In 2004, the District acquired the same database software which is used by the Kern County Water Agency to manage its groundwater data. This database was initially populated with the data in KCWA's database for District's area. Recall that the Semitropic Groundwater Monitoring Committee has retained a consulting hydrogeologist to annually prepare groundwater level and quality maps and hydrographs. Also with regard to data interpretation, the District has developed a groundwater flow model to assist in the evaluation of water level impacts of water management actions, considering both past and prospective actions.

Finally, documentation, in the form of a monitoring report, will be prepared as required to present the results of the monitoring program. The contents of the monitoring report could include:

- Maps showing spring and/or fall water elevations;
- Maps showing spring and/or fall depths to water;
- Map showing change in water levels from spring of the current year to spring of the previous year;
- Water-level hydrographs for selected key wells;
- Map showing areas of impaired water quality;
- Graphs of water quality over time for selected key wells; and
- Assessment of effectiveness of basin management objectives and other project activities.

Most of the above-cited items are addressed in a biennial report prepared by the Groundwater Monitoring Committee's consulting hydrogeologist.

6.3 Public and Agency Involvement

While the Management Area is limited to the boundaries of Semitropic, the underlying groundwater system is part of a much larger groundwater basin, i.e., it is hydraulically connected with the groundwater underlying neighboring water agencies. In particular, recall that Semitropic is situated within the Kern County subbasin of the San Joaquin Valley Basin of the Tulare Lake Hydrologic Region. Figure 3 shows the boundary of the Kern County subbasin, along with the boundaries of Semitropic and neighboring water agencies. It is in this context that efforts respecting public and agency involvement are coordinated.

Going forward, public and agency involvement will be primarily coordinated through the following:

- District website
- District Board meetings
- Semitropic Groundwater Monitoring Committee
- Poso Creek Regional Water Management Group

The District's Board of Directors holds regularly scheduled monthly meetings which are open to the public, with time set aside for public comment. The agendas and minutes for these meetings are posted on the District's website (www.semitropic.com).

To date, the Monitoring Committee has coordinated the collection and presentation of water level and water quality data among the six participating water agencies. In this regard, the Committee has retained a consulting hydrogeologist to prepare both water level and water quality maps and hydrographs. These are reviewed at Committee meetings and ultimately included in a Biennial Monitoring Report. In addition, the Monitoring Committee has been, and will continue to be, a forum for discussion and consideration of proposed projects which may affect the common groundwater resource.

The Poso Creek Regional Water Management Group has been very effective in bringing several districts together in order to leverage their efforts on several water resources management fronts, but particularly with regard to improving water supply reliability. In this regard, all of the districts share a common groundwater basin and a common groundwater management strategy --- maximize the use of surface water supplies available to the districts in the region. The group completed and adopted an Integrated Regional Water Management Plan in 2007, and efforts are underway to update that plan. Aside from the participating water districts, cities within the region have been invited to participate more actively, including the City of Wasco. The Poso Creek RWMG has been meeting regularly and its meetings are open to the public.

Section 5 presented a number of management actions, several of which illustrate the inter-agency involvement and collaboration that are planned going forward:

- Actively participate in the Poso Creek Regional Water Management Group.
- Actively participate in the Semitropic Groundwater Monitoring Committee (which includes five neighboring water agencies).
- Support the Poso Creek RWMG's initiative to work with the U.S. Bureau of Reclamation on completing environmental documentation which will facilitate water banking and exchange arrangements in the region.
- Seek support from neighboring water agencies for the cooperative development of a regional groundwater model.
- Evaluate additional interties between the District's conveyance and distribution system facilities and those of neighboring water agencies to enhance water exchange capabilities.
- Share groundwater level and quality data with the Kern County Water Agency.
- Support the Kern County Water Agency's efforts to improve its groundwater database.
- Participate in CASGEM as a monitoring entity.
- Continue to coordinate the collection of water level and water quality data with neighboring water agencies through the Semitropic Groundwater Monitoring Committee. This would include following a uniform sampling and testing protocol.
- Continue to participate in the Irrigated Lands Regulatory Program so long as Regional Board conditions are reasonable and in the best interest of the District and its landowners.

6.4 Plan Review

The District's Board of Directors will review the Groundwater Management Plan every five years, or sooner if indicated by basin monitoring or other changed conditions. While the Plan's overarching goal would not likely change, basin management objectives may be refined and specific management actions could change.

Appendix A

A Monitoring Program

PROPOSED GROUNDWATER MONITORING PROGRAM
SEMITROPIC GROUNDWATER BANKING PROGRAM

prepared for

Semitropic Water Storage District
Buena Vista Water Storage District
North Kern Water Storage District
Rosedale-Rio Bravo Water Storage District
Shafter-Wasco Irrigation District
Southern San Joaquin Municipal Utility District

by

Kenneth D. Schmidt and Associates
Groundwater Quality Consultants
Fresno, California

June 1994

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FRESNO, CALIFORNIA 93704
TELEPHONE (209) 224-4412

June 1, 1994

To Members of the Groundwater
Monitoring Committee:

Submitted herewith is the proposed groundwater monitoring program for the Semitropic groundwater banking program. I appreciate the cooperation of all of you in contributing to this effort.

Sincerely yours,

Ken Schmidt

Kenneth D. Schmidt

KDS/pt

MAY 2 6 1994

PROPOSED GROUNDWATER MONITORING PROGRAM
SEMITROPIC GROUNDWATER BANKING PROGRAM

INTRODUCTION

The proposed Semitropic WSD-MWD water-banking project essentially involves two major components. First groundwater would be stored or banked through an in-lieu recharge program, whereby canal water would be delivered as a source of irrigation water to replace groundwater that would otherwise have been pumped. Later, groundwater would either be extracted from this storage account by a number of District and landowner wells and delivered into the California aqueduct and exported from the area, or surface water would be exchanged with the MWD and groundwater pumped from those wells and delivered in the contract service area of the District.

The primary purposes of the proposed groundwater monitoring program are to determine: 1) changes in water levels due to the in-lieu recharge and groundwater extraction project, and 2) changes in groundwater quality due to the project. In late 1993, an informal association of the Kern County districts most directly concerned with the proposed Semitropic WSD banking program was formed. The following districts were included:

Semitropic Water Storage District

Buena Vista Water Storage District

North Kern Water Storage District

Rosedale-Rio Bravo Water Storage District

Shafter-Wasco Irrigation District

Southern San Joaquin Municipal Utility District

The districts listed other than Semitropic WSD essentially surround

the Semitropic WSD. The initial task of this group was to develop a groundwater monitoring program that would be suitable to all of the participants.

EXISTING MONITORING

Each of the subject districts provided information on the monitoring that they now routinely do, including crop surveys and pumpage, water levels, and water sampling and analyses. In addition, information on monitoring programs by the California Department of Water Resources (DWR) and Kern County Water Agency (KCWA) was obtained. This information is summarized in this section. For each district, crop surveys, pumpage, and intentional recharge activities are first discussed. This is followed by a discussion of water-level monitoring and groundwater quality monitoring.

Semitropic WSD

Crop Surveys and Pumpage

Crop surveys are done by the District annually. Values for applied water per acre of each crop are used to determine the total amount of applied water. Groundwater pumpage from landowner wells has been determined by deducting the amount of canal deliveries from the irrigation water requirement. Pumpage from District wells is measured regularly with totalizing flowmeters. For extractions from landowner wells associated with the banking project, the pumpage of each well to be used would be measured monthly with a totalizing flowmeter.

Water Levels

Water-levels in from 125 to 150 supply wells are measured by the District annually in January. Water-level sounders are used to measure most of the wells, although an acoustic probe is used for some wells. In addition, DWR measures water levels in 22 other wells semi-annually (January and September), and KCWA measures water levels in 58 other wells semi-annually (January and September). Information on the depths and perforated intervals of all of these wells has been compiled and tabulated by the District. There is one multi-completion monitor well installed by DWR in the south part of the District that is regularly monitored by DWR. In 1993-94, the District installed five single-completion monitor wells in the west part of the District, and these are to be regularly monitored, similar to that described for the monitor wells in the adjacent Buena Vista WSD. The District also collects pump tests on about 100 wells each year to evaluate pumping lifts in the District. Contour maps are prepared annually for pumping lift and periodically for water-level elevations in the District.

Groundwater Quality

Routine monitoring of groundwater quality by the District commenced in 1988. Water samples are now collected from about 50 to 75 wells during the summer pumping season. The samples are analyzed for major cations and anions, pH, electrical conductivity, and boron.

Buena Vista WSD

Crop Surveys and Pumpage

The District prepares an annual crop survey and map, and based on irrigation requirements and surface water deliveries, the groundwater pumpage is estimated. The estimated groundwater pumpage in the District since 1983 has ranged from almost nothing in 1983-84 and 1985 to 92,000 acre-feet in 1992.

Water Levels

The District has located all landowner irrigation wells and plotted the locations on a District map. Water levels in 50 of these wells are measured quarterly and water-level elevations are determined and tabulated. Information on the perforated intervals of these wells has not been compiled, however most of them are believed to range in depth from about 400 to 500 feet, and some are perforated as shallow as 100 feet in depth. The historical water-level record for these wells extends back about 50 years.

The District now has 14 monitor wells within its boundaries. The three southernmost wells, south of Buttonwillow, are double completion wells and were installed by DWR to monitor the Kern Fan water banking project and have been routinely monitored by DWR since 1992. Five single-completion monitor wells were installed by the District in late 1991 in the north part of the District, primarily to monitor the potential easterly migration of poor quality groundwater from the west. These wells range in depth from about 230 to 370 feet and are usually perforated over the lower 20

to 50 feet in depth. In 1993-94, three new single completion monitor wells were installed by the District in the area north of Buttonwillow to supplement gaps in the existing District monitor network. These wells ranged in depth from about 415 to 450 feet and were perforated over the lower 30 to 40 feet. Water levels in the monitor wells are measured monthly and water-level elevations are determined and compiled.

The District also has a number of shallow piezometers for the purpose of monitoring shallow groundwater levels. Water levels in these wells are also measured quarterly.

Groundwater Quality

Water samples are collected from the irrigation wells whenever they are pumping during the quarterly water-level measurement round for analyses of major cations and anions and irrigation water constituents. Water samples are collected quarterly from the monitor wells by DWR for analysis. The analyses are also primarily for irrigation water constituents. For the shallow piezometers, electrical conductivity is also determined on samples collected quarterly.

North Kern WSD

Crop Surveys, Pumpage, and Recharge

The District performs crop surveys about every four years. Monthly pumpage from each District well is determined from a combination of monthly pump rating and hour meter readings. The

District operates three spreading works and measures the diversions of canal water to these. Annually, estimates of landowner well pumpage are made by comparing canal deliveries, District pumpage, and crop irrigation requirements.

Water Levels

The District has located and mapped all landowner irrigation wells in the District. It historically did not monitor any of these wells, however is now measuring many on a semi-annual basis. There are about 70 District water supply wells. Water levels in these wells are measured semi-annually (late February-early March and late September-early October), and water-level elevations are determined and compiled. Airlines and an air pressure gage are used to measure the water levels. These devices were first calibrated by independent measurements with an electric sounder. Information on the depths and perforated intervals of the District wells is available. The District has not installed any monitor wells.

In the area within several miles of the boundary with the Semitropic WSD, the DWR measures water levels semi-annually (January and September) in eight landowner wells.

Groundwater Quality

The District collects water samples from each District well once during the summer pumping period in years when the wells are in use for analyses of irrigation water constituents. During periods when the District wells are not used, they are not sampled.

Rosedale-Rio Bravo WSD

Crop Surveys, Pumpage, and Recharge

The District operates a groundwater recharge project. The average surface water delivery to landowners is about 10,000 acre-feet per year. The District has no irrigation wells. Regular crop surveys are not done by the District. The last District crop survey was completed in October 1987. At about that time, an estimate of landowner well pumpage was made, based on canal deliveries and irrigation water requirements. The District is planning to perform a crop survey in 1994.

Water Levels

The District measures water levels in 23 landowner wells on a monthly basis. Measurements for some of these wells extend back prior to 1976. Information on the depths of most of these wells is available, and most range from about 150 to 500 feet deep. The monthly measurements for each well are averaged and tabulated. The District has not installed any monitor wells. However, the DWR recently installed four double-completion monitor wells in the District and these wells are measured routinely, as part of the Kern Fan water banking project. The shallow completion casings are typically perforated from about 350 to 450 feet in depth and the lower completion casings from about 600 to 700 feet in depth. Information from this monitoring has not yet been received by the District.

In the area within several miles of the boundary with the

Semitropic WSD, the DWR measures water levels in five other landowner wells semi-annually (January and September) and the KCWA measures water levels in one additional landowner well semi-annually (January and September).

Groundwater Quality

The District does not do groundwater quality monitoring. DWR regularly collects samples from several of their monitor wells in the District and analyzes them for irrigation water constituents.

Shafter-Wasco I.D.

Crop Surveys and Pumpage

The District performs a crop survey each year and consumptive use values are applied for each crop. Surface water deliveries to the farms are also determined and tabulated. Groundwater pumpage is then estimated from the difference between surface water deliveries and crop requirements. In 1992, about 44,000 acre feet of surface water was delivered and about 40,000 acre-feet of groundwater was pumped. Under average conditions, groundwater pumpage is about 28,000 acre-feet per year.

Water Levels

The District measures water levels in about 70 landowner wells on a semi-annual basis, and six of these are measured on a monthly basis. An acoustic well probe has been used for the water-level measurements since 1982. The District has not installed any

monitor wells. The District is in the process of mapping all landowner irrigation wells in the District.

In the area within several miles of the boundary with the Semitropic WSD, the DWR measures water levels semi-annually (January and September) in seven other landowner wells.

Groundwater Quality

Recently, the District began a water quality monitoring program for 12 landowner domestic wells in the District. Electrical conductivity, TDS, and pH are determined on samples collected semi-annually. For four of the 12 wells, more comprehensive analyses are performed on samples collected annually. These analyses include major cations and anions, boron, iron, manganese, copper, and zinc. There are seven City of Wasco wells in the District, and comprehensive water quality monitoring pursuant to DOHS regulations is regularly performed on water samples collected from each of these wells.

Southern San Joaquin MUD

Crop Surveys and Pumpage

The District does an annual crop survey. The District has no wells and does not estimate landowner pumpage.

Water Levels

The District measures water levels semi-annually in 25 landowner wells. Information on depths and perforated intervals of

these wells is not presently available. The District has not installed any monitor wells.

In the area within several miles of the boundary with the Semitropic WSD, the KCWA measures the water level in one other landowner well semi-annually (January and September).

Groundwater Quality

The District does not conduct water quality monitoring of wells in the District.

Summary

Figure 1 shows the locations of wells in which water levels are regularly measured. In the Semitropic WSD, locations of such wells throughout the District are shown. In the adjacent Districts, only such wells within several miles of the boundary with the Semitropic WSD are shown. Also provided is a summary of the state number for each well and the frequency of water-level measurements. Figure 2 shows the locations of wells which are regularly sampled. As for water-level monitoring, locations of all such wells in the Semitropic WSD are shown, whereas in the adjacent Districts, locations of only wells within several miles of the boundary with the Semitropic WSD are shown. Also provided is a summary of state numbers for these wells and the frequency of sampling. Monitor wells, landowner wells, and District wells within the area specified are included.

PROPOSED MONITORING

The proposed monitoring is divided into that to be conducted 1) within the Semitropic WSD and 2) within adjacent Districts.

Semitropic WSD

The monitoring to be conducted in the District is divided into: 1) District and landowner wells to be used for extraction, 2) monitor wells, and 3) other landowner wells in the District.

Extraction Wells

Pumpage from each of these wells as part of the banking project is to be measured on at least a monthly basis with totalizing flowmeters. In addition, depth to water would be measured on at least a semi-annual basis. Comprehensive (Title 22) drinking water analyses are to be run on water samples collected, within the past five years of each time of use, from each of these wells when they are being used to return water to the California Aqueduct. During extraction periods, water samples would be collected annually for analyses of electrical conductivity. Samples from about one third of these wells would then be selected for irrigation water analyses.

Monitor Wells

In 1993-94, the District installed five single-completion monitor wells in the west part of the District. Along with the existing single-completion Buena Vista WSD monitor wells, there

appears to be adequate monitor well coverage along the west side of the Semitropic WSD. One double completion monitor well measured by DWR in the south part of the District would also be incorporated into the program.

Consideration of the locations of wells proposed to be used for extraction and the in-lieu areas indicates that new monitor wells are desirable along the east edge of the District. Because of the large number of active landowner irrigation wells in the District that are not to be used as part of the banking project and other active landowner irrigation wells adjacent to the District, it is proposed that two sets of monitor wells would be installed in the east part of the District. One set (interior) would be located close to areas of dense District extraction wells to be used for the banking project, generally several miles west of the easterly boundary of the Semitropic WSD. Monitoring of this set of wells would be used to primarily show the influence of pumping of the extraction wells for the banking project. A second set of wells (boundary) would be located close to the easterly boundary of the Semitropic WSD. Monitoring of this set of wells would be used to help differentiate between the drawdown caused by pumpage of extraction wells for the banking project and that caused by pumping of other wells, particularly those in adjacent Districts to the east. Also, the effects of the in-lieu recharge component would be assessed at these boundary monitor wells. A total of five interior monitor well sites are proposed. The locations of these wells are generally in areas of dense extraction wells. A total of seven

monitor well sites are proposed along the eastern boundary of the Semitropic WSD. The locations of these wells were also selected to aid in monitoring the in-lieu areas.

Figure 1 shows the locations of existing and proposed monitor wells. Presently, single-completion monitor wells about 400 feet deep are proposed for the sites north of Sherwood Avenue. This would be supplemented with monitoring of deeper wells in adjacent areas (such as at the Pond School and Delano Prison, if the owners allow). South of Sherwood Avenue, double-completion wells are proposed. At these sites, one casing would be perforated opposite strata from about 350 to 450 feet deep and another opposite strata from about 650 to 750 feet deep. Continuous water-level recorders would be operated in the easterly monitor wells during extraction periods. Otherwise, quarterly water-level measurements would be made. Water samples would be collected from these monitor wells annually, by pumping with a submersible pump. The wells would be pumped for about four hours prior to collecting the water samples for chemical analyses. The samples would be analyzed for irrigation water constituents (including nitrate).

Other Wells

Approximately 50 other landowner wells in the existing water-level monitoring network would be incorporated into this program. These wells would be located near proposed extraction wells or in in-lieu areas.

Buena Vista WSD

The eight District monitor wells west of the Semitropic WSD would be incorporated into the program. In addition, six landowner wells now being monitored by the District east of the West Side Canal would be incorporated into the program. These wells are within several miles of the boundary with the Semitropic WSD. An attempt would be made to determine the depths and perforated intervals of these wells. The locations of these wells are also shown in Figure 1.

North Kern WSD

Two District supply wells that are within several miles of the boundary with the Semitropic WSD would be incorporated into the program. In addition, the eight 12 landowner wells measured by DWR would be included. An attempt would be made to determine the depths and perforated intervals of the wells measured by DWR. Also, about eight landowner wells would be selected for annual sampling for analyses of irrigation water constituents, including nitrate. In addition, pump tests would be obtained annually, if possible, for about one dozen private landowner wells in the area within several miles of the boundary with the Semitropic WSD.

Rosedale-Rio Bravo WSD

Three of the landowner wells measured by the District and one landowner well measured by the DWR would be incorporated into the program. These wells are all within several miles of the boundary

with the Semitropic WSD. An attempt would be made to determine the depths and perforated intervals of these wells, and also to map active irrigation wells in the District within three miles of proposed extraction and in-lieu areas. The five landowner wells measured by the DWR and one by the KCWA semi-annually within several miles of the boundary with the Semitropic WSD would be incorporated into the program.

About nine landowner wells within several miles of the boundary with the Semitropic WSD would be selected for annual sampling. These would be large capacity, irrigation wells, with known perforated intervals. The analyses would be for irrigation water analyses, nitrate, DBCP, and EDB.

Shafter-Wasco I.D.

Ten landowner wells measured by the District and seven landowner wells measured by DWR would be incorporated into the program. These wells are also within several miles of the boundary with the Semitropic WSD. An attempt would be made to determine the depths and perforated intervals of these wells. In addition, pump tests would be obtained annually from about one dozen landowner wells, if possible, within several miles of the boundary with the Semitropic WSD.

Southern San Joaquin MUD

Eight of the landowner wells measured by the District and one landowner well measured by the KCWA semi-annually would be

incorporated into the program. These wells are generally within several miles of the boundary with the Semitropic WSD. An attempt would be made to determine the perforated intervals of these wells, and also to map active irrigation wells in the District within three miles of proposed extraction and in-lieu areas. In addition, two other deep wells in the District would be added into the program, with owner approval. They include the new Pond School well and the Delano Prison well. Both of these wells have deep annular seals and are perforated only opposite deep deposits, and would serve as useful wells for monitoring, to supplement information from the single completion wells.

About nine landowner wells would be selected for annual sampling. These wells would have known perforated intervals. The analyses would be for irrigation water constituents (including nitrate).

Coordination of Monitoring

It would be highly useful to coordinate monitoring schedules, between the various districts, DWR, and the KCWA, to optimize the value of monitoring for this program. Presently, there appears to be some overlap of monitoring programs, and some differences in the times when the water levels are measured, procedures for measurements, times when water samples are collected, sampling procedures, types of analyses, and in other aspects.

In terms of water levels, measurements in the westerly monitor wells should be coordinated between Semitropic WSD and the Buena

Vista WSD. In terms of District and landowner wells, water levels should be measured semi-annually (spring and fall) during the same week if possible. Information from the water-level recorders and monthly measurements in some wells should be used to determine exactly when these measurements are made. The spring measurement would coincide with the shallowest annual level, and the fall measurement with the deepest (non-pumping) annual level. The semi-annual measurements would also be done during the same week that the monitor wells are measured.

The times of water sampling should be coordinated. Annual samples from large-capacity wells should be collected during heavy pumping periods, probably during July. The monitor wells should be sampled during the same month. Also, if possible, a uniform list of constituents to be analyzed should be developed, with one exception. DBCP and EDB concentrations would also be monitored in the Rosedale-Rio Bravo WSD, because of the high levels previously found.

DATA MANAGEMENT AND INTERPRETATION

The goal of this part of the monitoring program is to compile, plot, and map the accumulated data in a manner so that the hydrogeologic and water quality impacts of the proposed banking program can be clearly demonstrated. Following are some proposed data management techniques.

Water Levels

Semi-annual water-level elevation contour maps would be prepared by an experienced hydrogeologist (not a computer). Initially, two sets of maps would be prepared. One would be for strata above approximately 350 to 400 feet in depth. Another would be for strata below this depth. Eventually, it may be desirable to subdivide the wells which are measured into three or more depth intervals. Besides water-level elevation contours, flowlines indicating the direction of groundwater flow would also be shown on the maps.

Water-level hydrographs would be prepared for all measured wells. For previously measured wells, these would extend back to the original measurements. On each hydrograph, the state well number, local number or owner's identification, and the depth and perforated interval would be shown.

Information on pumping lifts from pump tests in key areas would also be compiled and reviewed. The water-level information would be reviewed annually, and recommendations provided on changes in the monitoring program, if any are necessary.

Pumpage and Recharge

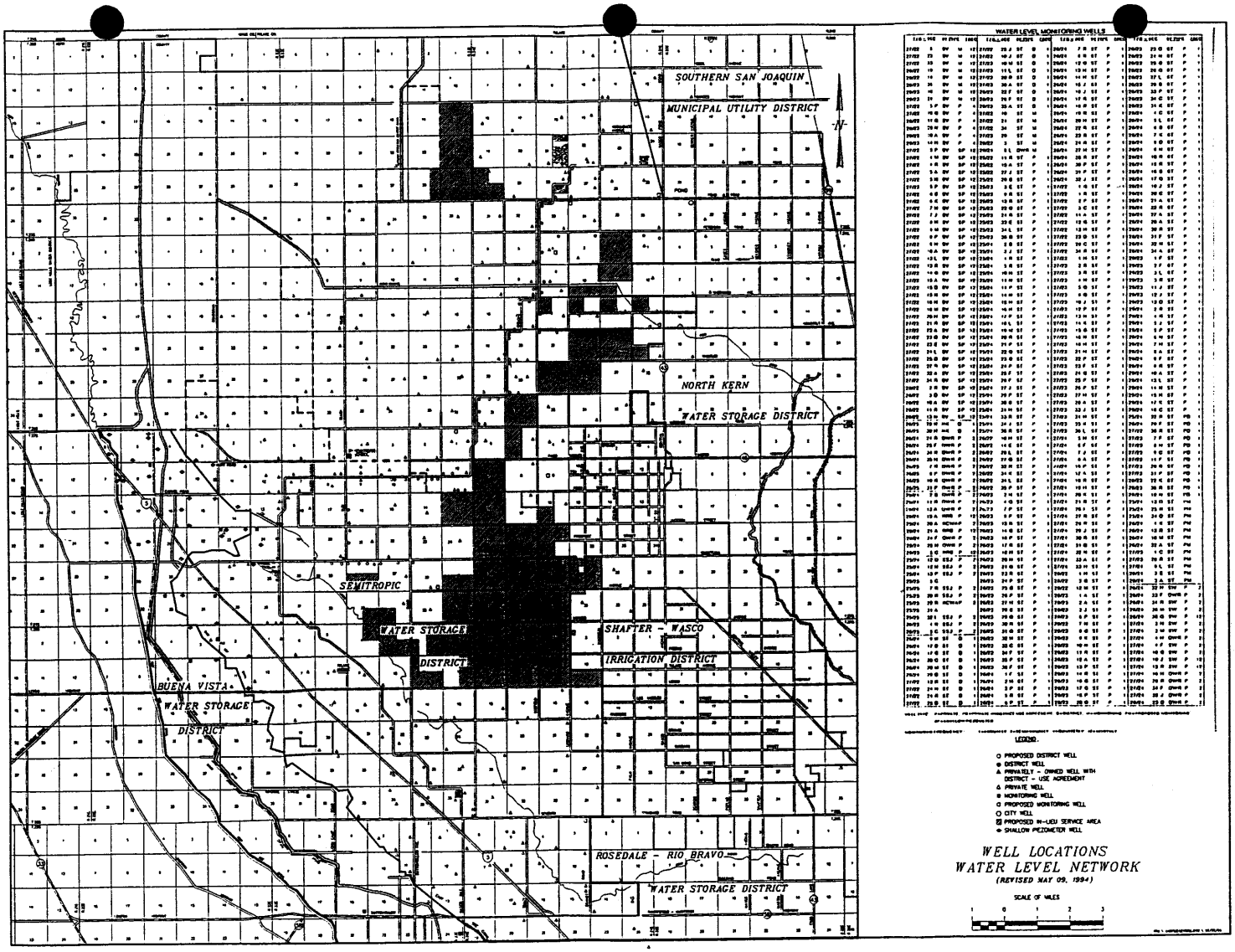
Information on extractions for the water-banking program, and amounts of in-lieu recharge in the Semitropic WSD would be compiled annually. In addition, estimates of pumpage and intentional recharge in the surrounding districts would be compiled. This information would be used in evaluating water-level trends.

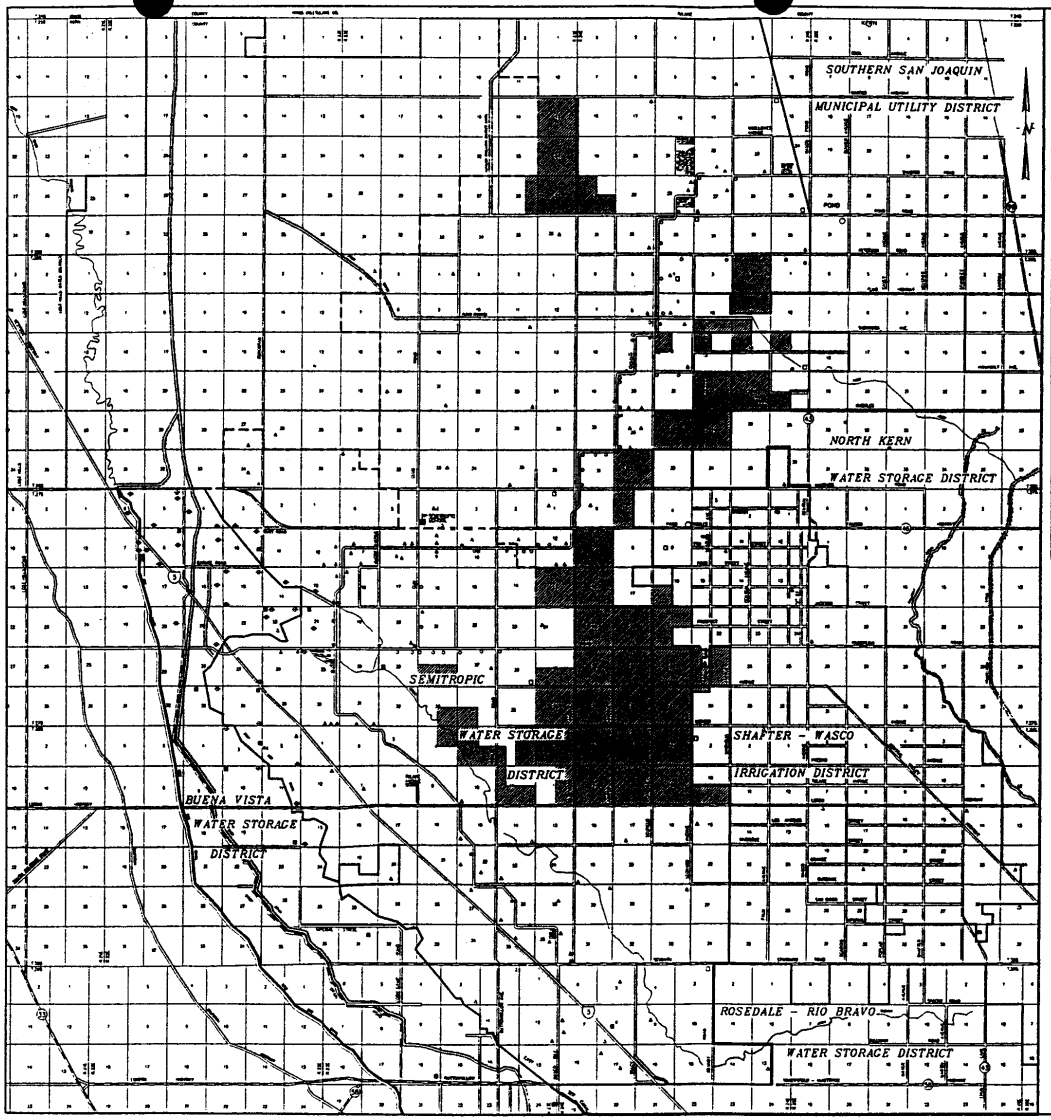
Chemical Quality

Maps would initially be prepared annually, showing concentrations of key constituents in water from sampled wells. Electrical conductivity, boron, and nitrate would likely be shown. As for water levels, it may be possible to prepare one map for the shallower groundwater (above a depth of about 350 to 400 feet) and another for the deeper groundwater. After several years, the frequency of preparing these maps might be decreased to biennial or triennial. In addition, more than two depth intervals might be mapped.

Hydrographs would also be prepared for key constituents, such as electrical conductivity, boron, and nitrate. For wells previously monitored, these would extend back to the initial sampling.

This information would be reviewed and interpreted with respect to water-level changes, in-lieu recharge, and extraction pumpage for the proposed project.


SOUTHERN SAN JOAQUIN
MUNICIPAL UTILITY DISTRICT
N
NORTH KERN
WATER STORAGE DISTRICT
SEMITROPIC
WATER STORAGE
DISTRICT
SHAFTER - WASCO
IRRIGATION DISTRICT
BUENA VISTA
WATER STORAGE
DISTRICT
ROSEDALE - RIO BRAVO
WATER STORAGE DISTRICT
WATER LEVEL MONITORING WELLS
LEGEND
PROPOSED DISTRICT WELL
DISTRICT WELL
PREVIOUSLY - OWNED WELL WITH DISTRICT - USE AGREEMENT
PRIVATE WELL
MONITORING WELL
PROPOSED MONITORING WELL
CITY WELL
PROPOSED IN-LIEU SERVICE AREA
SHALLOW PIEZOMETER WELL
WELL LOCATIONS
WATER LEVEL NETWORK
(REVISED MAY 09, 1994)
SCALE OF MILES
1 0 1 2 3



WATER QUALITY MONITORING WELLS

T/R - SEC	BY	TYPE	FREQ
27/22	B	BV	M	4
27/22	23	BV	M	4
27/22	33	BV	M	4
28/22	10	BV	M	4
28/22	14	BV	M	4
29/23	31	BV	M	4
29/23	10	BV	M	4
28/23	24	BV	M	4
27/22	3 F	BV	SP	12
27/22	4 M	BV	SP	12
27/22	4 R	BV	SP	12
27/22	5 A	BV	SP	12
27/22	5 H	BV	SP	12
27/22	5 P	BV	SP	12
27/22	6 B	BV	SP	12
27/22	6 K	BV	SP	12
27/22	7 H	BV	SP	12
27/22	7 J	BV	SP	12
27/22	8 H	BV	SP	12
27/22	8 M	BV	SP	12
27/22	8 P	BV	SP	12
27/22	9 H	BV	SP	12
27/22	10 A	BV	SP	12
27/22	13 L	BV	SP	12
27/22	13 R	BV	SP	12
27/22	14 G	BV	SP	12
27/22	15 A	BV	SP	12
27/22	15 O	BV	SP	12
27/22	15 N	BV	SP	12
27/22	16 H	BV	SP	12
27/22	16 M	BV	SP	12
27/22	20 H	BV	SP	12
27/22	21 R	BV	SP	12
27/22	23 A	BV	SP	12
27/22	23 D	BV	SP	12
27/22	23 E	BV	SP	12
27/22	24 L	BV	SP	12
27/22	25 D	BV	SP	12
27/22	27 R	BV	SP	12
27/22	33 A	BV	SP	12
27/22	34 R	BV	SP	12
28/22	2 R	BV	SP	12
28/22	3 Q	BV	SP	12
28/22	10 A	BV	SP	12
28/22	11 R	BV	SP	12
28/22	13 N	BV	SP	12
28/23	26 N	NK	D	4
28/23	36 H	NK	D	4
25/25	5 C			
26/25	31 A			
27/22	10	ST	M	
27/22	24	ST	M	
27/22	34	ST	M	
27/23	29	ST	M	
28/22	3	ST	M	
29/24	8 L	DWR	M	
28/23	13 M	ST	P	1
25/23	36 Q	ST	P	1
25/24	11 M	ST	P	1
25/24	17 A	ST	P	1
25/24	36 R	ST	P	1
26/22	26 L	ST	P	1
26/22	27 Q	ST	P	1
26/22	34 K	ST	P	1
26/23	4 H	ST	P	1
26/23	6 H	ST	P	1
26/23	11 R	ST	P	1
26/23	20 F	ST	P	1
26/23	21 Q	ST	P	1
26/23	23 R	ST	P	1
26/23	31 Q	ST	P	1
26/23	33 H	ST	P	1
26/23	35 P	ST	P	1
26/24	3 H	ST	P	1
26/24	16 R	ST	P	1
26/24	23 R	ST	P	1
26/24	26 R	ST	P	1
27/22	23 K	ST	P	1
27/23	4 F	ST	P	1
27/23	4 Q	ST	P	1
27/23	24 E	ST	P	1
27/23	28 P	ST	P	1
27/23	27 J	ST	P	1
27/24	6 F	ST	P	1
27/24	16 R	ST	P	1
27/24	26 H	ST	P	1
27/24	36 P	ST	P	1
26/23	2 H	ST	P	1
26/23	12 A	ST	P	1
26/23	2 A	ST	P	1
26/24	3 H	ST	P	1
26/23	7 K	ST	P	1
26/23	10 N	ST	P	1
26/23	14 R	ST	P	1
26/23	20 P	ST	P	1
26/23	23 N	ST	P	1
26/23	27 C	ST	P	1
26/23	32 A	ST	P	1
26/24	4 J	ST	P	1
26/24	7 H	ST	P	1
26/24	15 E	ST	P	1
26/24	17 P	ST	P	1
26/24	28 A	ST	P	1
29/23	3 R	ST	P	1
29/23	12 R	ST	P	1
29/24	7 E	ST	P	1
29/24	7 M	ST	P	1
29/24	8 P	ST	P	1
29/24	9 F	ST	P	1
29/24	13 L	ST	P	1
29/24	17 E	ST	P	1
29/24	17 K	ST	P	1
25/24	13 D	ST	PM	
25/24	25 R	ST	PM	
25/24	34 D	ST	PM	
26/24	4 K	ST	PM	
26/24	13 R	ST	PM	
26/24	16 M	ST	PM	
26/24	32 A	ST	PM	
27/22	1 C	ST	PM	
27/23	36 R	ST	PM	
27/24	9 L	ST	PM	
26/24	3 E	ST	PM	
29/24	3 A	ST	PM	
26/24	26 P	SW	P	2
27/24	4 R	SW	P	2
27/24	10 J	SW	P	2
27/24	13 K	SW	P	2
27/24	27 F	SW	P	2
27/25	19 N	SW	P	2
26/24	2 A	SW	P	2
26/25	4 B	SW	P	2
26/25	14 Q	SW	P	2
26/25	19 Q	SW	P	2
26/25	20 L	SW	P	2
26/25	24 L	SW	P	2
27/24	4	WSC	CY	

WELL TYPE : P=PRIVATE; D=DISTRICT; M=MONITORING; PM=PROPOSED MONITORING; CY=CITY; SP=SHALLOW PIEZOMETER

MONITORING FREQUENCY : 1=ANNUALLY; 2=SEMIANNUALLY; 4=QUARTERLY; 12=MONTHLY

LEGEND

- ○ PROPOSED DISTRICT WELL
- ● DISTRICT WELL
- ▲ PRIVATELY - OWNED WELL WITH DISTRICT - USE AGREEMENT
- △ PRIVATE WELL
- ■ MONITORING WELL
- ◇ PROPOSED MONITORING WELL
- ○ CITY WELL
- ▩ PROPOSED IN-LIEU SERVICE AREA
- ⊕ SHALLOW PIEZOMETER WELL

WELL LOCATIONS
WATER QUALITY NETWORK

(REVISED MAY 09, 1994)

SCALE OF MILES

1 0 1 2 3

Appendix B

B Sampling Plan

SAMPLING PLAN FOR GROUNDWATER MONITORING FOR SEMITROPIC WSD WATER BANKING PROGRAM

Draft Report - For Review Purposes Only

Prepared for:

Semitropic Water Storage District
and Adjoining Districts

Prepared by:

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Groundwater Quality Consultants
Fresno, California

September 1996

RECEIVED-BFL

SEP 1 3 1996

BOOKMAN-EDMONSTON ENGINEERING, INC.

SAMPLING PLAN FOR GROUNDWATER MONITORING FOR SEMITROPIC WSD WATER BANKING PROGRAM

INTRODUCTION

A groundwater monitoring program was proposed for the Semitropic WSD Groundwater Banking Program in June 1994. This proposed monitoring program was subsequently included in a Memorandum of Understanding (MOU) between the project participants and the adjoining districts, and the program was commenced. Two of the most important components in the monitoring program are water-level measurements and sampling and analyses of water from wells. The measured and/or sampled wells include 1) monitor wells, 2) supply wells, 3) shallow piezometers, and 4) unused wells. A number of different entities are involved in conducting the monitoring. It is desirable to have a plan which provides the acceptable procedures to be used for measuring water levels and collecting, preserving, and analyzing water samples for this program. This plan is intended to be used as a guideline, that can be periodically updated, as modifications are made to the monitoring program. The discussion is divided into 1) water levels, and 2) water sampling. Separate discussions are generally provided for the different types of wells monitored.

A diagram should be maintained showing how to find the well, and its precise location from roads and other landmarks. Also,the precise location of the measuring point for water levels and the sampling point for water sample collection should be documented.

WATER LEVELS

There are five devices that are commonly used for measuring water levels in wells. These are: 1) steel tape, 2) electric sounder, 3) acoustic device, 4) airline, and 5) continuous recorders. Each of these is briefly described, and their applicability to specific situations is also discussed. An example of a water-level measurement field record is attached.

Steel Tapes

First, about five to ten feet of the lower end of the steel tape is chalked with carpenter's chalk. The procedure is then to lower the tape, with a weight on the bottom to keep it plumb inside the well, to below the water level. The point at the top of the well from which the water level is measured is termed the measuring point (MP) or reference point (RP). Once the end of the tape reaches the water level, the tape is run farther in until the next marker on the tape (normally at five or ten foot intervals) is reached (the run). The tape is then carefully withdrawn from the well, and the wetted extent of the tape (the cut) is precisely measured. An engineer's tape (graduated in tenths and hundredths of a foot), is used to measure this distance. This value is then added to, or subtracted from, the value previously read when the tape was fully extended into the well (the run). The date and time of measurement, the run and cut, and the calculated depth to water below the MP are carefully recorded. Water-level measurements should be made to the nearest tenth of a foot. If any nearby

(i.e., within a quarter of a mile or so) large-capacity wells are pumping at the time of the measurement, this information is also recorded. Oil is commonly present on top of the water in many irrigation wells. If oil is present, this should be recorded. Steel tapes are most useful for shallow water levels (i.e., less than about 50 to 100 feet), and for wells that do not have falling water, which precludes accurate water-level measurements with a tape. After each well is measured, the wetted part of the tape should be wiped clean with a cloth, particularly if oil was encountered in the well.

Electric Sounders

Both single and double-line electric sounders can be used to measure water levels. The single-line sounder requires metal at the surface for grounding. Electric sounders are frequently used for deep water-level measurements and where falling water is present in wells. The approach is to lower the sounding line and tip into the well until the water level is reached, which is normally indicated by observing a reading on the voltmeter. The line is then raised until the voltmeter reading returns to the reading for above the water level, and the sounding line is then again lowered in the well, until the water level is again reached. The exact point on the sounding line at the M.P. is noted. An engineer's tape is then used to measure the distance from this point to the nearest marker. This distance is added to or subtracted from the nearest depth marker reading on the sounding line to determine the

depth to water. Water-level measurements should be made to the nearest tenth of a foot. The date, time, and depth to water should be recorded. When oil is present on top of the water, it may be difficult to obtain an accurate reading of the top of the oil by this method. However, with care, both the distance to the top of the oil and top of the water can usually be measured with an electric sounder.

If metal clips are used as the depth markers on the sounding line, the distances between the markers should be carefully measured with a steel tape before each measurement round. If the markers are movable, they should be adjusted to the precise depths as measured, or a correction applied to the measurements. The necessary periodic calibrations of the sounders should also be recorded in the field book. The electric sounding wire and sounding tip should be cleaned after use in each well, if oil is present in the well.

Acoustic Devices

Acoustic devices generally measure the depth to water by timing the travel of a sound wave to the water level from the surface. These devices are not as accurate as steel tapes or electric sounders. They are unnecessary in most situations where water levels are less than 200 feet deep. They are especially useful for deep water levels (about 500 feet or greater), and in cases where an electric tape or electric sounder cannot readily be used to measure the depth to water (i.e., in cases of several

casing reductions in the well). These devices should be calibrated during each sampling round, by also measuring the water level in at least one well with a steel tape or recently calibrated electric sounder. Care should be taken in using these devices. This method doesn't allow delineation of an oil layer in a well. If oil is present on top of the water, the depth measured is for the top of the oil. Because of this and other factors, acoustic devices are not generally recommended, except if tapes or electric sounders cannot be feasibly utilized for measuring the water level.

Airlines

Airline measurements are also not as accurate as steel tapes or electric sounders. These are used primarily in water supply wells that are equipped with permanent pumps. An airline is first installed in the well next to the pump column, to an adequate depth below the water level. Air pressure is then used to temporarily blow the water out of the airline. The pressure required to do this is recorded, and, if necessary, converted to feet (14.7 psi equals 34.0 feet of water). This value is then deducted from the airline setting, to determine the depth to water. Measurements are probably only accurate to the nearest half a foot. Care should be taken to use a uniform elevation of the airgage (i.e., a specific distance above the ground surface) each time. The use of airlines is especially applicable in some large-capacity supply wells, where a steel tape or electric sounder cannot be readily inserted between the well casing and pump column. Some of the limitations of the

airline approach include:

1. the airline may leak, if the joints aren't completely sealed.
2. sometimes the airlines aren't set to the depth recorded (i.e., one or two joints are lost track of during installation).

Airlines should be periodically calibrated by also measuring the water level with a steel tape or calibrated electric sounder. In general, airlines should only be used where a steel tape or electric sounder cannot be readily used (i.e., such as in cases where there is not enough room between the pump column and inside of the well casing). When measurements are made, the pressure readings should be carefully recorded. The length of the airline and the depth to water calculation should be provided. The MP elevation relative to the ground surface should be measured each time. When calibrations are made, they should be documented in the field book.

Continuous Recorders

Both float type-recorders with the associated charts and pressure transducers with digital readouts are commonly used. Measurements for both of these approaches should be periodically calibrated, normally at least monthly, by measuring with a steel tape or recently calibrated electric sounder. There are some situations that can be encountered, such as falling water, which can render these devices inoperative. Instructions for proper use of these devices are normally provided by the manufacturer. Regu-

lar maintenance and calibration are necessary.

WELL SAMPLING

Water samples are collected from supply wells, monitor wells, and piezometers. The supply wells to be sampled have permanent pumps. Some of the monitor wells have permanent pumps and some would be sampled with portable pumping equipment. Piezometers are generally sampled by bailing with a hand bailer or a hand pump. An electrical conductivity probe can be used to directly measure the electrical conductivity of water in the shallow piezometers.

Monitor Wells

For monitor wells, the static water level is first measured. The amount of water inside the well (including the gravel pack) is then calculated (the water column length times the cross sectional area). The well is then pumped long enough to remove five well volumes, before collecting water samples for laboratory analysis. If possible, the field water temperature, pH, and electrical conductivity should be periodically measured during pumping. The pumping rate should also be periodically measured by timing the filling of a container of known volume (i.e., five or ten gallons). Normal submersible pumps (i.e., those commonly used for domestic wells) are adequate for the water sampling to be done as part of this program. All field measurements, including dates and times, should be carefully recorded in a field book.

Supply Wells

Different approaches are generally used for supply wells than for monitor wells, because the sampling results for supply wells depend highly on the previous pumping history. For actively used large-capacity wells, several hours of pumping are normally adequate to obtain samples representative of the formation water. For wells that have been pumping for an unknown duration, field measurements of water temperature, pH, and electrical conductivity over a period of 15 or 20 minutes can verify that conditions are stabilized. However, for large-capacity wells that have been idle for extended periods (i.e., months or longer) substantial pumping is often necessary before representative water samples can be obtained. From several days to a week of pumping is often necessary for such wells. This is particularly true for wells with perforations extending over large intervals, and for wells with falling water. In sampling such wells, it is extremely useful to periodically measure the water temperature, pH, and electrical conductivity during pumping (i.e., several times a day). After values of these parameters stabilize, representative water samples can usually be obtained. Notes should be kept in the field book on the date and time of field measurements and water sample collection, and the pumping history of the well (the approximate hours or days of pumping), in cases where the well had been idle prior to pumping. An example of a field parameter measurement record is attached.

Piezometers

Electrical conductivity probes can be used to directly measure the electrical conductivity of shallow groundwater (less than 50 feet deep). In general, once the probe is lowered to the sampling location (usually the midpoint between the water level and the bottom of the well, measurements should be recorded about every half a minute until the values stabilize. For laboratory analyses of constituents, small diameter hand bailers or a hand pump can be used for shallow groundwater (above a depth of about 100 feet). In this case, the static water level should be measured, and the amount of water in the piezometer determined. At least three well volumes should be removed from the well before collecting samples for laboratory analyses. In this case, if possible, water temperatures, pH, and electrical conductivity should be periodically measured in the field.

Sample Preservation

The samples for analyses of inorganic chemical constituents should be collected as follows:

- The location from which the sample is collected should be documented.
- The tap or spigot should be allowed to run for at least one minute before collecting the water sample.
- The required sample bottles are: one liter untreated polyethylene, one liter polyethylene treated with nitric acid, and 100 ml polyethylene treated with sulfuric acid.

- The untreated polyethylene bottle should be rinsed twice with the water to be sampled, then filled until it overflows, then tightly capped.
- The treated bottles should be filled to near the top, then tightly capped. These bottles should then be shaken several times to thoroughly mix the acid with the water.
- The sample bottles should be labeled and preserved.
- The appropriate sample transmittal and analysis request forms should be completed.

Table 1 provides the specific preservatives and holding times required for inorganic chemical constituents. In general, all samples should be kept in a cooled ice chest or refrigerated and delivered to the laboratory within several days of collection. An example of an analysis request form is attached.

Analytical Methods

Methods of analyses for the inorganic chemical constituents are provided in Table 2. Alternative methods may be submitted for review.

Quality Control

Quality control for field activities include duplicate samples, replicate measurements, and calibrated equipment. Duplicate samples are collected to check for precision of the analysis. One duplicate sample should be collected per sampling round. The duplicate sample would be collected, packaged, sealed and analyzed

TABLE 1 - CONTAINERS, PRESERVATIVES, AND HOLDING TIMES FOR WATER SAMPLING AND ANALYSES

Constituent	Sample Size (ml)	Preservative	Holding Time
Electrical Conductivity	100	None	28 days
pH	25	None	Analyze Immediately
Total Diss. Solids Residue at 180°C	100	None	7 days
Metals	500	HNO_3 to pH <2	6 months
Nitrate	100	H_2SO_4 to pH <2 Cool, 4°C	48 hours

All containers are polyethylene. Electrical conductivity and pH should also be measured in the field, if possible.

TABLE 2 - ANALYTICAL METHODS FOR INORGANIC CHEMICALS IN WATER

Chemical Constituent	EPA Analytical Method	Type of Analysis	Ref	Approximate Minimum Reporting Level
Calcium	200.7	I.C.P.	2	1 mg/l
Magnesium	200.7	I.C.P.	2	1 mg/l
Sodium	200.7	I.C.P.	2	1 mg/l
Potassium	200.7	I.C.P.	2	1 mg/l
Carbonate	310.1	Titrimetric	1	3 mg/l
Bicarbonate	310.1	Titrimetric	1	3 mg/l
Chloride	325.2	Auto. Colorimetric	1	1 mg/l
Sulfate	375.2	Auto. Colorimetric	1	1 mg/l
Nitrate	353.2	Auto. Colorimetric	1	1 mg/l
Total Dissolved Solids	160.1	Gravimetric	1	10 mg/l
pH	150.1	Electrometric	1	0.1
Electrical Conductivity	120.1	Probe	1	10 micromhos/cm
Boron	200.7	I.C.P.	2	0.1 mg/l

Reference 1: Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020

Reference 2: "Inductively Coupled Plasma-Atomic Emission Spectrometric Method of Trace Elements Analysis of Water and Waste", Method 200.7 modified by CLP Inorganic Data/Protocol Review Committee.

Type of Analysis: F.A.A.: Flame Atomic Absorption
I.C.P.: Inductively Coupled Plasma

Alternative acceptable methods are provided in Standard Methods.

in an identical manner as the other samples. However, it should not be identified as a duplicate sample. In this way, the identity of the duplicate sample would be unknown to the laboratory personnel performing the analysis. The field measurements use replicate measurements, calibration of equipment, and comparing previously collected data to determine the internal quality of the data collected.

The following procedures for checking the correctness of chemical analyses are applicable specifically to water samples for which the major constituents have been analyzed. This include pH, electrical conductivity, total dissolved solids (TDS), and major anions and cations. Concentrations of the major constituents (in milligrams per liter) are summed to approximate the total dissolved solids (TDS) concentration as follows:

$$TDS = Na + K + Ca + Mg + CO_3 + 0.5\ HCO_3 + Cl + SO_4 + SiO_2 + NO_3$$

This calculated value of TDS is checked against the TDS residue at 180°C. Because silica is not usually determined, the residue value of TDS should be greater than the calculated value. Common silica concentrations in groundwater in the area are from 20 to 40 mg/l. It should be noted that for waters high in calcium sulfate, the TDS residue at 180°C cannot be expected to agree closely with the calculated value, because of water that is contained in the gypsum molecule, and this is not lost during evaporation at 180°C.

The sum of the anions and cations, when expressed as milliequivalents per liter, should balance within an acceptable tolerance. Following are the conversion factors that are used to

determine milliequivalents per liter for each major cation and anion:

Ca ÷ mg/l by 20	CO_3 ÷ mg/l by 30
Mg ÷ mg/l by 12.15	HCO_3 ÷ mg/l by 61
Na ÷ mg/l by 23	SO_4 ÷ mg/l by 48
K ÷ mg/l by 39.1	Cl ÷ mg/l by 35.5
	NO_3 ÷ mg/l by 62

The acceptable difference is based on the percentage difference defined as follows:

$$\% \text{ difference} = 100 \frac{\Sigma \text{ cations} - \Sigma \text{ anions}}{\Sigma \text{ cations} + \Sigma \text{ anions}}$$

From Standard Methods, the criteria for acceptance are as follows:

Anion Sum (meq/L)	Acceptable % Difference
0-3.0	± 0.2
3.0-10.0	± 2
10.0-800	± 2-5

Also, the ratio of the TDS in mg/l to the electrical conductivity in micromhos/cm at 25°C should be about 0.65. Values less than 0.55 or greater than 0.75 are suspect.

WATER-LEVEL MEASUREMENT FIELD RECORD

KENNETH D. SCHMIDT & ASSOCIATES
Groundwater Quality Consultants

Project: _____

Well Location: (- -) _____ Local No.: _____

Land Surface Elevation (feet): _____

Measuring Point Elevation (feet): _____

Date/Time Measured: _____ Measured By: _____

Measuring Device: _____

Pumping History: _____

_____

Measuring Point Description:

_____

_____

_____

_____

Diagram of Well & Meas. Pt.

Water-Level Measurement:

Run (feet)	Cut (feet)	Depth to Water From Meas. Pt. (feet)

Water-Level Elevation (feet): _____

Optional

Well Use: _____

Casing diameter (inches): _____

Cased Depth (feet): _____

Perforated Interval (feet): _____

Type of Pump: _____

Diagram of Well Location

Notes:

FIELD PARAMETERS MEASUREMENT RECORD

KENNETH D. SCHMIDT & ASSOCIATES
Groundwater Quality Consultants

Project: _____

Well No.: _____

Date: _____

Measured By: _____

TIME (hr)	TIME (min)	Temperature (°F)	Elec. Cond. (at 25°C)	pH	Notes

Lab. No. _____

Customer _____

er No. _____ Date Rec'd _____ By _____

Description _____

Ca _____ epm _____ ppm

Mg _____ epm _____ ppm

Na _____ epm _____ ppm

K _____ epm _____ ppm

Hardness as $CaCO_3$ _____ ppm _____ gr/gal

OH _____ epm _____ ppm

CO_3 _____ epm _____ ppm

HCO_3 _____ epm _____ ppm

E.C. Reading _____ = _____ K x 10^6 Res _____

Cl _____ epm _____ ppm

SO_4 _____ epm _____ ppm

NO_3 _____ ppm

NO_3-N _____ ppm

F _____ ppm

Fe _____ ppm

Mn _____ ppm

As _____ ppm

Cu _____ ppm

Zn _____ ppm

MBAS _____ ppm

Color _____ Color Units

Odor _____

rb. _____

pH _____

TDS _____ ppm

TRACE ELEMENTS

Ba _____

Cd _____

Cr _____

Pb _____

Hg _____

Se _____

Ag _____

Appendix C

C CASGEM Monitoring Plan

Semitropic Water Storage District
Addendum to the Groundwater Elevation Monitoring Plan
Specifically for DWR's CASGEM Program
December 2011

The Semitropic Water Storage District monitoring Plan was prepared by Kenneth D. Schmidt in September 1996. For purposes of the DWR CASGEM Program the District has modified the plan to include the following specific wells and components:

Well network location(s) – Twenty-two wells sites with 46 measurements, as listed in Table 1.

Map(s) of the well network – A map showing the location of the well(s) is included as Figure 1 - Well Network Location.

Monitoring Schedule – Measure water level twice per year, spring and fall

Field Measurement Methods – Measurement method will be by wire sounder, tape and/or transducer, reference point is sounding tube or top of casing, as indicated in Table 1, and measurements are recorded on field sheets and entered into a spreadsheet.

Role of operating Agency – The District is a wholesale water supplier for agricultural growers.

Monitoring Plan rationale – The District has selected the above-referenced sites to regularly and systematically monitor groundwater elevations that demonstrate seasonal and long-term trends and for the District to commit to monitoring the water level of groundwater wells. Historically, in addition to these wells, the District provides spring and fall measurements from Grower-owned wells and District production wells to the DWR and Kern County Water Agency for their use in demonstrating seasonal and long-term trends.

The District has followed and implemented monitoring protocols developed by the DWR and the Bureau of Reclamation which are appropriate for the local groundwater basin conditions that include:

- step-by-step instructions to establish the Reference Point,
- methods for recording measurements,
- methods to ensure the measurement of static (non-pumping) groundwater conditions,
- step-by-step instructions to measure depth to water, and
- standardized forms for recording measurements.

This following information is recorded in a field form, which was designed by the Bureau of Reclamation:

- location (State Well Number),
- date,
- measuring device used,
- field representative name,
- well status (pumping/not pumping and no measurement/questionable measurement)
- remarks/comments

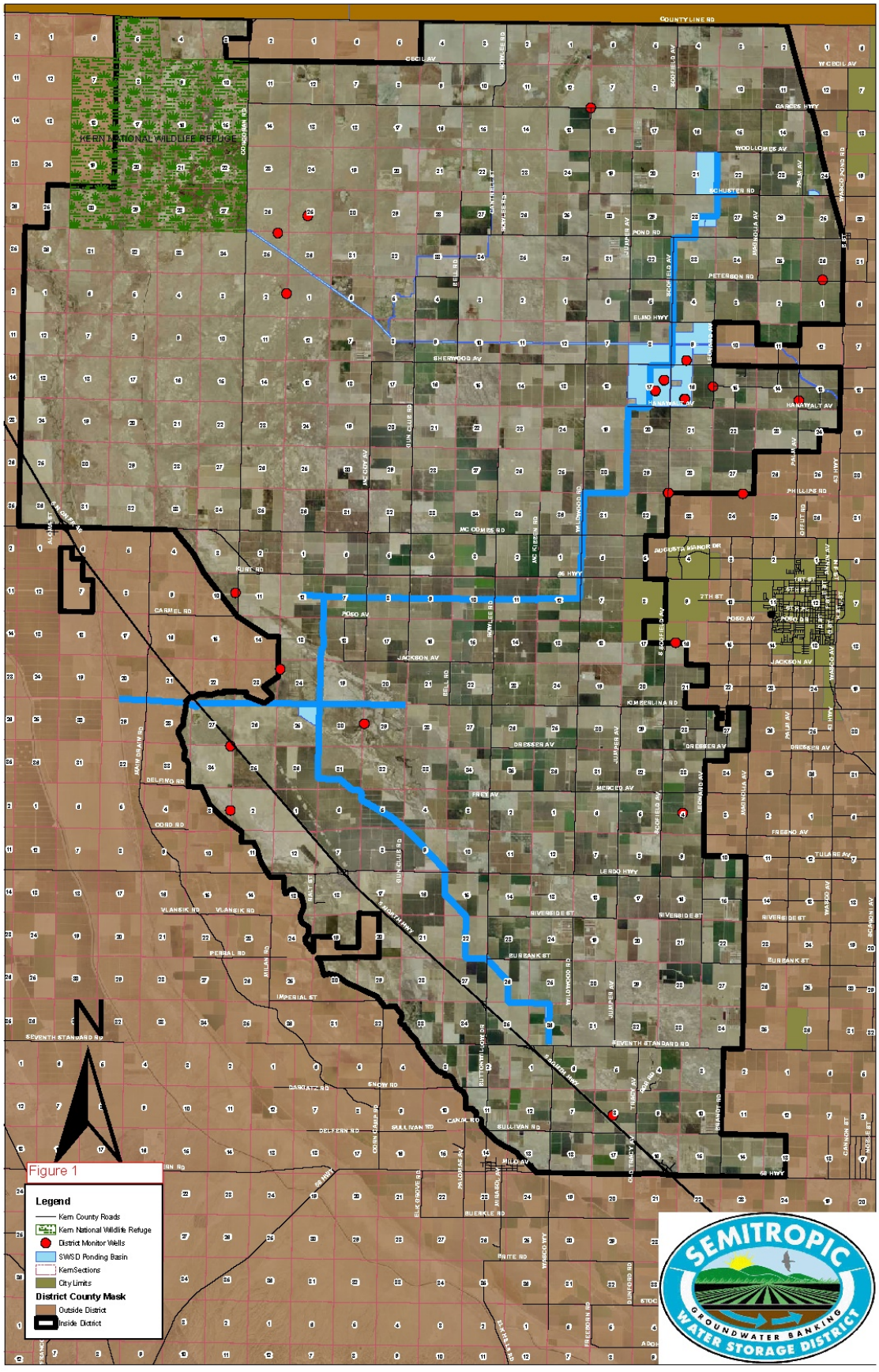
The District submitted detailed well information for the wells selected for the CASGEM Program, including:

- Local well ID and/or State Well Number
- Reference Point Elevation (feet, NAD83)
- Reference Point description
- Ground Surface Elevation (feet NAD83)
- Method of determining elevation
- Accuracy of elevation method
- Well Use
- Well Status (active or inactive)
- Well coordinates (decimal lat/long, NAD83)
- Method of determining coordinates
- Accuracy of coordinate method
- Well Completion type (single or multi-completion)
- Total depth (feet)
- Top and bottom of screened intervals (up to 10 intervals)
- Well Completion Report number
- Groundwater basin of well (or subbasin or portion)
- Written description of well location
- Any additional comments

The District anticipates it will submit the following groundwater elevation information for the selected well(s) during each round of monitoring:

- Well identification number
- Measurement date
- Reference point elevation of the well (feet) using NAD83 vertical datum
- Elevation of land surface datum at the well (feet) using NAD83 vertical datum
- Depth to water below reference point (feet) (unless no measurement was taken)
- Method of measuring water depth
- Measurement Quality Codes. (If no measurement is taken, a specified “no measurement” code, must be recorded. Standard codes will be provided by the online system. If a measurement is taken, a “no measurement” code is not recorded.) (If the quality of a measurement is uncertain, a “questionable measurement” code can be recorded. Standard codes will be provided by the online system. If no measurement is taken, a “questionable measurement” code is not recorded.)
- Measuring agency identification
- Measurement time (PST/PDT with military time/24 hour format)
- Comments about measurement, if applicable

Figure 1 – Monitor well sites



CASGEM Online System

Welcome: Ron Eid

Home Notifications Well Information View Map Reports My Profile Sign Out

Public: Basin Summary

Monitoring Entity Details

Monitoring Entity Name	Semitropic Water Storage District
Monitoring Entity Address	P.O.Box 8043, Wasco, CA
Contact Person	Paul Oshel, (661) 758-5113
Authority Type	Local Agency Pursuant to WC Part 2.75

Basin Information

Region of Basin	7-Tulare Lake
Basin Number and Name	5-22.14-Kern County
Basin Portion Name	Semitropic Water Storage District
Cooperating Agency	

Basin Shape Files

Shape File	Download
DistrictBoundaryCopy 11112011152152.shp	Download
DistrictBoundaryCopy 11112011152152.dbf	Download
DistrictBoundaryCopy 11112011152152.prj	Download
DistrictBoundaryCopy 11112011152152.shx	Download

Required Documents

File Name	File Category	Date	Remarks	Download
Cover.pdf	Copy of current groundwater management plan	12/22/2010	our notice on intentis under Section 10927(c) as we have an 3030plan	Download
Authority Designation.doc	Statement that the entity will comply with the requirements of WC Part 2.11	12/22/2010		Download
Cover.pdf	Statement describing the ability or qualifications of the entity to conduct the groundwater monitoring functions required	1/4/2011		Download
Groundwater Monitoring and Sampling Plan 09062011153440.pdf	Monitoring Plan Document describing the basin details	9/6/2011	Written plan text	Download
Distrist Map with Mon Wells 12 17 2010 09062011154753.pdf	Monitoring Plan Document describing the basin details	9/6/2011	Map of District and Monitoring Wells	Download

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Wells

Local Well Designation	Basin	Portion	State Well Number	CASGEM Well Number	Well Use	Depth	View On Map
948L03 Cluster2 of 2	Kern County	Semitropic Water Storage District	29S24E08L003M	354189N1194216W002	Observation	440	View On Map
948L02 Cluster1 of 2	Kern County	Semitropic Water Storage District	29S24E08L002M	354189N1194216W001	Observation	625	View On Map

1 2 3 Page size: 20 46 items in 3 pages

Local Well Designation	Basin	Portion	State Well Number	CASGEM Well Number	Well Use	Depth	View On Map
S-29B (aka MW1B)	Kern County	Semitropic Water Storage District	26S24E16F002M	356684N1193954W002	Observation	100	View On Map
S-29C (aka MW1C)	Kern County	Semitropic Water Storage District	26S24E16F001M	356684N1193954W003	Observation	230	View On Map
S-29A (aka MW1A)	Kern County	Semitropic Water Storage District	26S24E16F003M	356684N1193954W001	Observation	60	View On Map
S-28D (aka 03M 800)	Kern County	Semitropic Water Storage District	26S24E16P004M	356625N1193958W001	Observation	800	View On Map
S-28B (aka 08M 90)	Kern County	Semitropic Water Storage District	26S24E16P002M	356625N1193959W002	Observation	90	View On Map
S-28C (aka 03M 300)	Kern County	Semitropic Water Storage District	26S24E16P003M	356625N1193959W003	Observation	300	View On Map
S-28A (aka 08M 50)	Kern County	Semitropic Water Storage District	26S24E16P001M	356625N1193959W001	Observation	50	View On Map
S-27D (aka 07M 800)	Kern County	Semitropic Water Storage District	26S24E09P004M	356757N1193954W001	Observation	800	View On Map
S-27C (aka 07M 300)	Kern County	Semitropic Water Storage District	26S24E09P003M	356756N1193953W003	Observation	300	View On Map
S-27B (aka 07M 90)	Kern County	Semitropic Water Storage District	26S24E09P002M	356756N1193953W002	Observation	90	View On Map
S-27A (aka 07M 50)	Kern County	Semitropic Water Storage District	26S24E09P001M	356756N1193953W001	Observation	50	View On Map
S-24C (aka 04M 300)	Kern County	Semitropic Water Storage District	26S24E17H004M	356688N1194045W003	Observation	300	View On Map
S-24B (aka 04M 90)	Kern County	Semitropic Water Storage District	26S24E17H003M	356688N1194045W002	Observation	90	View On Map
S-24D (aka 04M 800)	Kern County	Semitropic Water Storage District	26S24E17H005M	356688N1194046W001	Observation	800	View On Map
S-24A (aka 04M 50)	Kern County	Semitropic Water Storage District	26S24E17H002M	356688N1194045W001	Observation	50	View On Map
S-23D (aka 03M 800)	Kern County	Semitropic Water Storage District	26S24E17J004M	356652N1194081W001	Observation	800	View On Map
S-23C (aka 03M 300)	Kern County	Semitropic Water Storage District	26S24E17J003M	356651N1194080W001	Observation	300	View On Map
S-23B (aka 03M 90)	Kern County	Semitropic Water Storage District	26S24E17J002M	356651N1194081W002	Observation	90	View On Map

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Back

Local Well Designation	Basin	Portion	State Well Number	CASGEM Well Number	Well Use	Depth	View On Map
S-16B Cluster 2 of 2	Kern County	Semitropic Water Storage District	26S24E27R002M	356305N1193711W001	Observation	410	View On Map
S-15B Cluster 2 of 2	Kern County	Semitropic Water Storage District	27S24E16P003M	355725N1193941W002	Observation	450	View On Map
S-15A Cluster 1 of 2	Kern County	Semitropic Water Storage District	27S24E16P002M	355725N1193941W001	Observation	600	View On Map
S-13B Cluster 2 of 2	Kern County	Semitropic Water Storage District	25S24E18D002M	357609N1194367W001	Observation	430	View On Map
S-14B Cluster 2 of 2	Kern County	Semitropic Water Storage District	26S24E16J002M	356668N1193841W002	Observation	480	View On Map
S-14A Cluster 1 of 2	Kern County	Semitropic Water Storage District	26S24E16J001M	356668N1193841W001	Observation	715	View On Map
S-13A Cluster 1 of 2	Kern County	Semitropic Water Storage District	25S24E18D001M	357609N1194366W001	Observation	690	View On Map
S-11	Kern County	Semitropic Water Storage District	26S22E02J001M	356956N1195623W001	Observation	700	View On Map
S-12	Kern County	Semitropic Water Storage District	25S22E25L001M	357228N1195538W001	Observation	740	View On Map
S-10C Multi-C 3 of 3	Kern County	Semitropic Water Storage District	25S22E35B002M	357169N1195665W003	Observation	1100	View On Map
S-10A Multi-C 1 of 3	Kern County	Semitropic Water Storage District	25S22E35B003M	357169N1195665W001	Observation	900	View On Map
S-10B Multi-C 2 of 3	Kern County	Semitropic Water Storage District	25S22E35B001M	357169N1195665W002	Observation	1270	View On Map
S-9A Cluster 1 of 2	Kern County	Semitropic Water Storage District	28S24E04L001M	355219N1193943W001	Observation	690	View On Map
S-9B Cluster 2 of 2	Kern County	Semitropic Water Storage District	28S24E04L002M	355219N1193943W002	Observation	407	View On Map
S-8B Cluster 2 of 2	Kern County	Semitropic Water Storage District	26S24E33D002M	356305N1194021W002	Observation	432	View On Map
S-7B Cluster 2 of 2	Kern County	Semitropic Water Storage District	26S24E13N002M	356625N1193483W002	Observation	380	View On Map
S-8A Cluster 1 of 2	Kern County	Semitropic Water Storage District	26S24E33D001M	356305N1194021W001	Observation	687	View On Map
S-6	Kern County	Semitropic Water Storage District	25S24E36Q001M	357036N1193392W001	Observation	431	View On Map

1 2 3 Page size: 20 46 items in 3 pages

Back

Local Well Designation	Basin	Portion	State Well Number	CASGEM Well Number	Well Use	Depth	View On Map
S-4	Kern County	Semitropic Water Storage District	28S22E03H001M	355205N1195821W001	Observation	445	View On Map
S-3	Kern County	Semitropic Water Storage District	27S22E34A001M	355423N1195825W001	Observation	300	View On Map
S-2	Kern County	Semitropic Water Storage District	27S22E24D001M	355687N1195623W001	Observation	448	View On Map
S-1	Kern County	Semitropic Water Storage District	27S22E10J001M	355944N1195814W001	Observation	340	View On Map

1 2 3 Page size: 20 46 items in 3 pages

Back

Appendix D

D Public Involvement Documentation

PROOF OF PUBLICATION

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JUN 23 2011

The BAKERSFIELD CALIFORNIAN
P. O. BOX 440
BAKERSFIELD, CA 93302

SEMITROPIC WATER STGE & BNKNG
15411 ROWLEE RD
WASCO, CA 93280

Ad Number:	12406148	**PO #:**	S.W.S.D.
Edition:	TBC	**Run Times**	2
Class Code	Legal Notices		
Start Date	6/14/2011	**Stop Date**	6/21/2011
Billing Lines	18	**Inches**	108.92
Total Cost	$ 196.32	**Account**	1SEM05
Billing Address	SEMITROPIC WATER STGE & BNKI 15411 ROWLEE RD WASCO,CA 93280		

--

STATE OF CALIFORNIA
COUNTY OF KERN

I AM A CITIZEN OF THE UNITED STATES AND A RESIDENT OF THE COUNTY AFORESAID: I AM OVER THE AGE OF EIGHTEEN YEARS, AND NOT A PARTY TO OR INTERESTED IN THE ABOVE ENTITLED MATTER. I AM THE ASSISTANT PRINCIPAL CLERK OF THE PRINTER OF THE BAKERSFIELD CALIFORNIAN, A NEWSPAPER OF GENERAL CIRCULATION, PRINTED AND PUBLISHED DAILY IN THE CITY OF BAKERSFIELD COUNTY OF KERN,

AND WHICH NEWSPAPER HAS BEEN ADJUDGED A NEWSPAPER OF GENERAL CIRCULATION BY THE SUPERIOR COURT OF THE COUNTY OF KERN, STATE OF CALIFORNIA, UNDER DATE OF FEBRUARY 5, 1952, CASE NUMBER 57610; THAT THE NOTICE, OF WHICH THE ANNEXED IS A PRINTED COPY, HAS BEEN PUBLISHED IN EACH REGULAR AND ENTIRE ISSUE OF SAID NEWSPAPER
AND NOT IN ANY SUPPLEMENT THEREOF ON THE FOLLOWING DATES, TO WIT: 6/14/11
6/21/11

ALL IN YEAR 2011

I CERTIFY (OR DECLARE) UNDER PENALTY OF PERJURY THAT THE FOREGOING IS TRUE AND CORRECT.

Jessi Brice

DATED AT BAKERSFIELD CALIFORNIA
6/21/11

Solicitor I.D.: 0

First Text
Semitropic Water Storage DistrictNOTICE

Ad Number 12406148

Semitropic Water Storage District

NOTICE OF HEARING

NOTICE IS HEREBY GIVEN, that on June 28, 2011, commencing at 1:00 p.m. the Board of Directors of the Semitropic Water Storage District will consider whether to adopt a Resolution of Intention to amend its September 22, 2003 Groundwater Management Plan. The hearing will be held at the District's offices located at 1101 Central Avenue, Wasco, California. It is contemplated that the Resolution of Intention and amended Groundwater Management Plan prepared in furtherance thereof will include as a component confirming a program of the District and its Semitropic Improvement District to acquire lands that otherwise would have continued to be farmed and utilized groundwater, and for the District to cease activities on such lands which utilize groundwater in order to conserve groundwater resources, for the benefit of the landowners within the District's Semitropic Improvement District.
DATED: June 13, 2011
/s/ Wilmar L. Boschman, Assistant Secretary
June 14, 21, 2011 (12406148)

BEFORE THE BOARD OF DIRECTORS

THE SEMITROPIC WATER STORAGE DISTRICT

IN THE MATTER OF: **RESOLUTION NO.** ST 11- 4

RESOLUTION OF INTENTION OF SEMITROPIC WATER STORAGE DISTRICT TO AMEND ITS GROUNDWATER MANAGEMENT PLAN

WHEREAS, with adoption of Resolution ST 03- 7 adopted September 22, 2003, this Board adopted a Groundwater Management Plan pursuant to part 2.75 of Division 6 of the California Water Code, acting for and on behalf of itself and its Improvement Districts ("District"); and

WHEREAS, on June 28, 2011, the District did hold a public hearing, noticed as required by law, concerning adoption of an amended Groundwater Management Plan, and based on the discussion at said hearing, the Board believes amending its Groundwater Management Plan would be in the best interest of the District and its landowners and water users.

BE IT RESOLVED BY THE BOARD OF DIRECTORS AS FOLLOWS:

1. The foregoing findings are true and correct;
2. It is the intention of the District to draft an amended Groundwater Management Plan in accordance with part 2.75 of Division 6 of the California Water Code and the District's consultant and staff are authorized and directed to proceed with drafting such Amended Plan.
3. This Resolution shall be deemed a resolution of intention in accordance with Water Code Section 10753.2, and it shall be published in accordance Water Code Section 10753.3.

4. After such Amended Plan has been prepared, the District will conduct a second public hearing in accordance with Water Code Section 10753.5 et seq. to determine whether to adopt such Amended Plan.

5. The Amended Plan shall address, among other things, the District's ongoing and future program to acquire lands that otherwise would continue to be farmed and utilize groundwater and for the District to cease activities on such lands which would utilize groundwater in order to, among other things, reduce groundwater pumping and conserve groundwater resources.

6. The Board authorizes and directs the General Manager to execute all documents and to take any other actions necessary and advisable to carry out the purposes of this Resolution.

ALL THE FOREGOING, being on motion of Director Waterhouse, seconded by Director Tracy, was hereby authorized by the following vote, to wit:

AYES:	Directors Fabbri, Howard, McCarthy, Portwood, Tracy Waterhouse and Wegis;
NOES:	None
ABSTAIN:	None
ABSENT:	None

I HEREBY CERTIFY that the foregoing is a true copy of the Resolution of the Board of Directors of Semitropic Water Storage District as duly passed and adopted by said Board of Directors at an adjourned meeting held this 28 day of June, 2011.

WITNESS my hand and official seal of said Board of Directors this 28th day of June, 2011.

Asst. Secretary of the Board of Directors

COPY

PROOF OF PUBLICATION

RECEIVED
AUG 18 2011
S.W.S.D.

The BAKERSFIELD CALIFORNIAN
P. O. BOX 440
BAKERSFIELD, CA 93302

SEMITROPIC WATER STGE & BNKNG
1101 CENTRAL AVE
WASCO, CA 93280

Ad Number:	12478901	**PO #:**	
Edition:	TBC	**Run Times**	
Class Code	Legal Notices		
Start Date	8/9/2011	**Stop Date**	8/16/2011
Billing Lines	62	**Inches**	373.13
Total Cost	$ 668.88	**Account**	1SEM05
Billing Address	SEMITROPIC WATER STGE & BNKI 1101 CENTRAL AVE WASCO,CA 93280		

--

STATE OF CALIFORNIA
COUNTY OF KERN

I AM A CITIZEN OF THE UNITED STATES AND A RESIDENT OF THE COUNTY AFORESAID: I AM OVER THE AGE OF EIGHTEEN YEARS, AND NOT A PARTY TO OR INTERESTED IN THE ABOVE ENTITLED MATTER. I AM THE ASSISTANT PRINCIPAL CLERK OF THE PRINTER OF THE BAKERSFIELD CALIFORNIAN, A NEWSPAPER OF GENERAL CIRCULATION, PRINTED AND PUBLISHED DAILY IN THE CITY OF BAKERSFIELD COUNTY OF KERN,

AND WHICH NEWSPAPER HAS BEEN ADJUDGED A NEWSPAPER OF GENERAL CIRCULATION BY THE SUPERIOR COURT OF THE COUNTY OF KERN, STATE OF CALIFORNIA, UNDER DATE OF FEBRUARY 5, 1952, CASE NUMBER 57610; THAT THE NOTICE, OF WHICH THE ANNEXED IS A PRINTED COPY, HAS BEEN PUBLISHED IN EACH REGULAR AND ENTIRE ISSUE OF SAID NEWSPAPER
AND NOT IN ANY SUPPLEMENT THEREOF ON THE FOLLOWING DATES, TO WIT: 8/9/11
8/16/11

ALL IN YEAR 2011

I CERTIFY (OR DECLARE) UNDER PENALTY OF PERJURY THAT THE FOREGOING IS TRUE AND CORRECT.

Jessi Brice

DATED AT BAKERSFIELD CALIFORNIA

8/16/11

Solicitor I.D.: 0

First Text
BEFORE THE BOARD OF DIRECTORSTHE SEMITR

Ad Number 12478901

BEFORE THE BOARD OF DIRECTORS

THE SEMITROPIC WATER STORAGE DISTRICT

IN THE MATTER OF: **RESOLUTION NO. ST 11-4**

RESOLUTION OF INTENTION OF SEMITROPIC WATER STORAGE DISTRICT TO AMEND ITS GROUNDWATER MANAGEMENT PLAN

WHEREAS, with adoption of Resolution ST 03-7 adopted September 22, 2003, this Board adopted a Groundwater Management Plan pursuant to part 2.75 of Division 6 of the California Water Code, acting for and on behalf of itself and its Improvement Districts ("District");
and

WHEREAS, on June 28, 2011, the District did hold a public hearing, noticed as required by law, concerning adoption of an amended Groundwater Management Plan, and based on the discussion at said hearing, the Board believes amending its Groundwater Management Plan would be in the best interest of the District and its landowners and water users.

BE IT RESOLVED BY THE BOARD OF DIRECTORS AS FOLLOWS:

1. The foregoing findings are true and correct;
2. It is the intention of the District to draft an amended Groundwater Management Plan in accordance with part 2.75 of Division 6 of the California Water Code and the District's consultant and staff are authorized and directed to proceed with drafting such Amended Plan.
3. This Resolution shall be deemed a resolution of intention in accordance with Water Code Section 10753.2, and it shall be published in accordance Water Code Section 10753.3.
4. After such Amended Plan has been prepared, the District will conduct a second public hearing in accordance with Water Code Section 10753.5 et seq. to determine whether to adopt such Amended Plan.
5. The Amended Plan shall address, among other things, the District's ongoing and future program to acquire lands that otherwise would continue to be farmed and utilize groundwater and for the District to cease activities on such lands which would utilize groundwater in order to, among other things reduce groundwater pumping and conserve groundwater resources.
6. The Board authorizes and directs the General Manager to execute all documents and to take any other actions necessary and advisable to carry out the purposes of this Resolution.

ALL THE FOREGOING, being on motion of Director Waterhouse, seconded by Director Tracy, was hereby authorized by the following vote, to wit:

AYES: Directors Fabbri, Howard, McCarthy, Portwood, Tracy Waterhouse and Wegis;

NOES: None

ABSTAIN: None

ABSENT: None

I HEREBY CERTIFY that the foregoing is a true copy of the Resolution of the Board of Directors of Semitropic Water Storage District as duly passed and adopted by said Board of Directors at a Special meeting held this 28 day of June, 2011.

WITNESS my hand and official seal of said Board of Directors this 28th day of June, 2011.
/s/ Wilmar L. Boschman Asst. Secretary of the Board of Directors
August 9, 16, 2011 (12478901)

1101 Central Avenue, P.O. Box 8043, Wasco, California 93280-0877

Telephone: (661) 758-5113 Bakersfield: (661) 327-7144
Facsimile: (661) 758-3219 Email: mail@semitropic.com
Website: www.semitropic.com

NOTICE OF PREPARATION OF AMENDED GROUNDWATER MANAGEMENT PLAN SEMITROPIC WATER STORAGE DISTRICT

NOTICE is hereby given that interested parties may participate in Semitropic Water Storage District's (District) development of an amended groundwater management plan pursuant to Part 2.75 (commencing at Section 10750) of Division 6 of the California Water Code. In particular, interested parties may participate by any or all of the following means: (1) attend a meeting of the District's Board of Directors (which typically meets at 12:30 p.m. on the second Wednesday of the month at the District's office) to provide comment and/or indicate area of interest; (2) submit comments and/or indicate area of interest in writing; (3) submit a written request to receive notice of meetings and availability of a draft plan; or (4) make an appointment to meet with the District's General Manager. The District's office may be reached at (661)-758-5113 or at 1101 Central Avenue, Wasco, CA. The District's mailing address is P.O. Box 8043, Wasco, CA 93280-0877.

Semitropic Water Storage District
Semitropic Groundwater Banking Project
Monitoring Committee

Buena Vista Water Storage District
North Kern Water Storage District
Rosedale-Rio Bravo Water Storage District

Semitropic Water Storage District
Shafter-Wasco Irrigation District
Southern San Joaquin Municipal Utility District

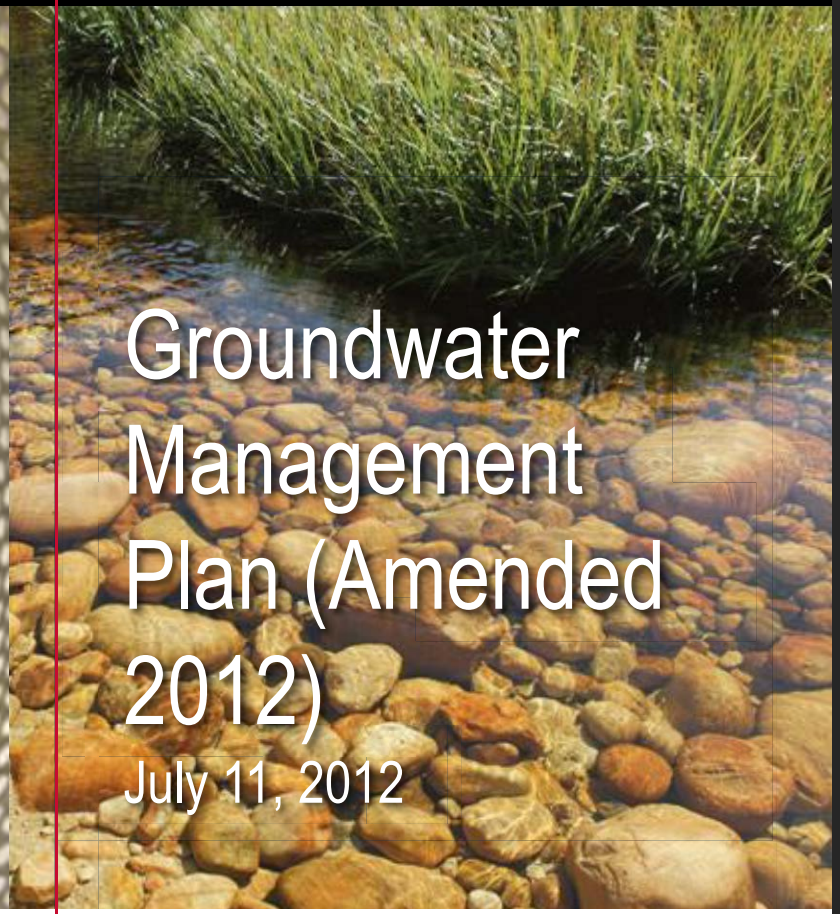
March 1, 2012 – 10:00 a.m.
Semitropic Water Storage District Board Room
Attendee's are welcome to call in on a conference line.
Phone: (877) 841-9268 Participant Code: 738207

DRAFT Agenda

1. Call to order
2. Minutes of November 3, 2011 meeting
3. Project operations
   a. Recharge
   b. Recovery
   c. Modeling
4. Project updates
   a. SWRU construction (Phase 2)
   b. Pond-Poso Spreading Grounds
5. Data collection/reporting
   a. Spring 2012 water-level measurements
   b. Water-level sensors
   c. Water sampling/testing
6. Biennial Groundwater Monitoring Report
   a. 2007-2008
   b. 2009-2010
7. Poso Creek IRWMP
8. [redacted]
   a. North Kern Update
   [redacted]
9. Treasurer's Report
10. New business
11. Next meeting
12. Adjourn

consulting engineers and scientists





Groundwater Management Plan (Amended 2012)

July 11, 2012

GEI Consultants



Background

- California Water Code (*Section 10750, et seq*)
  - AB-255 (1991)
  - AB-3030 (1992)
  - SB-1938 (2002)

- Semitropic's 2003 GWMP

GEI Consultants



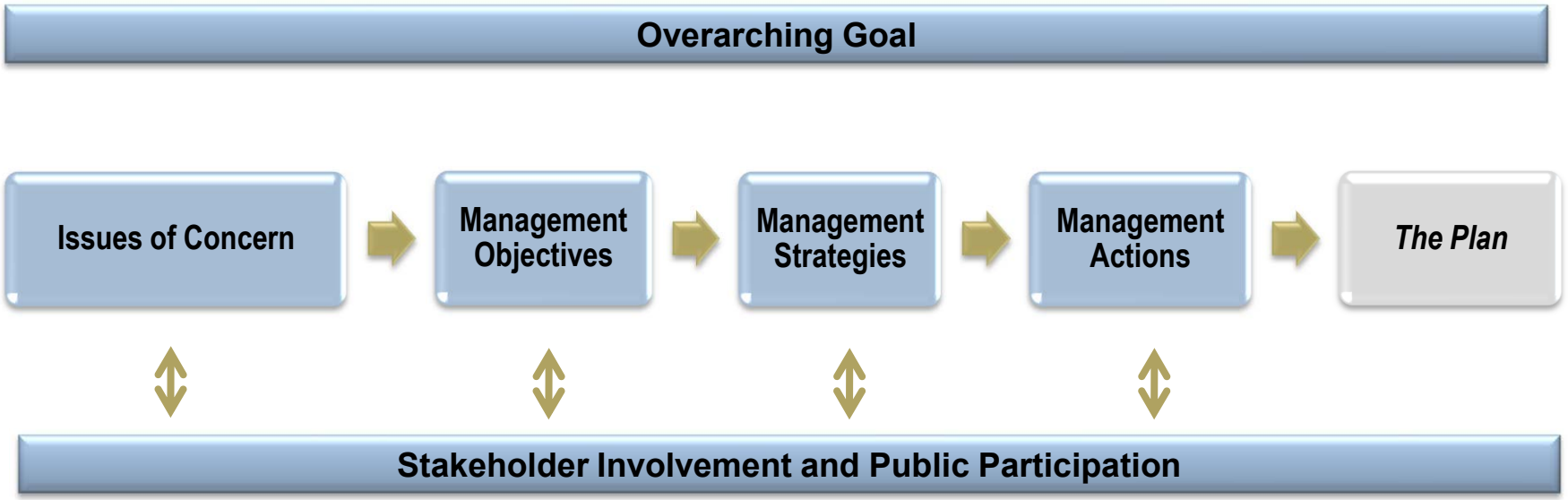
GWMP Outline

- Introduction
- Groundwater Management
- The District
- The Basin
- The Plan
- Plan Implementation

GEI Consultants



Plan Development



GEI Consultants



Management Objectives Must Consider …

- Groundwater Levels
- Groundwater Quality
- Land Subsidence
- Surface Water Flows
- Surface Water Quality

GEI Consultants



Example for "*Surface Water Flows*"

Overarching Goal

Issue of Concern:

Reduction in SWP Supplies

Management Objective:

Surface Water Flows

Management Strategy:

Maximize Use of Available Supplies

Management Actions:

-- Pricing

-- Exchanges

-- Absorptive Capability

-- Banking

The Plan

GEI Consultants



Plan Implementation

- Monitoring
- Data Management, Interpretation, and Reporting
- Public and Agency Involvement
- Plan Review

GEI Consultants



The 2012 Amended GWMP

- Notice of Intent (June 2011)
- Administrative DRAFT
- Review by Staff and Counsel
- Revised Administrative DRAFT

GEI Consultants

Semitropic Water Storage District
Semitropic Groundwater Banking Project
Monitoring Committee

Buena Vista Water Storage District
North Kern Water Storage District
Rosedale-Rio Bravo Water Storage District

Semitropic Water Storage District
Shafter-Wasco Irrigation District
Southern San Joaquin Municipal Utility District

August 16, 2012 – 10:00 a.m.
Semitropic Water Storage District Board Room
Attendee's are welcome to call in on a conference line.
Phone: (877) 841-9268 Participant Code: 738207

DRAFT Agenda

1. Call to order
2. Minutes of March 1, 2012 meeting
3. Project operations
   a. Recharge
   b. Recovery
   c. Modeling
4. Project updates
   a. SWRU construction (Phase 2)
   b. Pond-Poso Spreading Grounds
5. Data collection/reporting
   a. Fall 2012 water-level measurements
   b. Water-level sensors
   c. Water sampling/testing
6. Biennial Groundwater Monitoring Report
   a. 2007-2008
   b. 2009-2010
7. Poso Creek IRWMP
8. [redacted]
9. Treasurer's Report
10. New business
11. Next meeting
12. Adjourn

PROOF OF PUBLICATION

The BAKERSFIELD CALIFORNIAN
P. O. BOX 440
BAKERSFIELD, CA 93302

SEMITROPIC WATER STGE & BNKNG
1101 CENTRAL AVE
WASCO, CA 93280

Ad Number:	12942715	**PO #:**	2nd hearing
Edition:	TBC	**Run Times**	2
Class Code	Legal Notices		
Start Date	9/26/2012	**Stop Date**	10/3/2012
Billing Lines	25	**Inches**	150.92
Total Cost	$ 271.50	**Account**	1SEM05
Billing Address	SEMITROPIC WATER STGE & BNKI 1101 CENTRAL AVE WASCO,CA 93280		

--

STATE OF CALIFORNIA
COUNTY OF KERN

I AM A CITIZEN OF THE UNITED STATES AND A RESIDENT OF THE COUNTY AFORESAID: I AM OVER THE AGE OF EIGHTEEN YEARS, AND NOT A PARTY TO OR INTERESTED IN THE ABOVE ENTITLED MATTER. I AM THE ASSISTANT PRINCIPAL CLERK OF THE PRINTER OF THE BAKERSFIELD CALIFORNIAN, A NEWSPAPER OF GENERAL CIRCULATION, PRINTED AND PUBLISHED DAILY IN THE CITY OF BAKERSFIELD COUNTY OF KERN,

AND WHICH NEWSPAPER HAS BEEN ADJUDGED A NEWSPAPER OF GENERAL CIRCULATION BY THE SUPERIOR COURT OF THE COUNTY OF KERN, STATE OF CALIFORNIA, UNDER DATE OF FEBRUARY 5, 1952, CASE NUMBER 57610; THAT THE NOTICE, OF WHICH THE ANNEXED IS A PRINTED COPY, HAS BEEN PUBLISHED IN EACH REGULAR AND ENTIRE ISSUE OF SAID NEWSPAPER
AND NOT IN ANY SUPPLEMENT THEREOF ON THE FOLLOWING DATES, TO WIT: 9/26/12
10/3/12

ALL IN YEAR 2012

I CERTIFY (OR DECLARE) UNDER PENALTY OF PERJURY THAT THE FOREGOING IS TRUE AND CORRECT.

Terri Brice

DATED AT BAKERSFIELD CALIFORNIA
10/3/12

Solicitor I.D.: 0

First Text
NOTICE OF PUBLIC HEARINGON ADOPTION OF C

Ad Number 12942715

NOTICE OF PUBLIC HEARING
ON ADOPTION OF GROUNDWATER MANAGEMENT PLAN
BY SEMITROPIC WATER STORAGE DISTRICT

NOTICE is hereby given that (a) Semitropic Water Storage District has prepared a draft groundwater management plan pursuant to Part 2.75 (commencing at Section 10750) of Division 6 of the California Water Code; (b) copies of the draft plan may be downloaded from the District website under Customer Service/Notices at www.semitropic.com or obtained for the cost of reproduction at the office of the Semitropic Water Storage District, located at 1101 Central Avenue, Wasco, CA; and (c) a public hearing will be held on October 10, 2012, at 2:00 p.m. at the office of the Semitropic Water Storage District to determine whether to adopt the plan. Written comments may be sent to the District at P.O. Box 8043, Wasco, CA 93280-0877 and must be received by or before 3:00 p.m. on October 9, 2012.

To a large extent, the plan is consistent with the District's long-standing groundwater monitoring and management practices. In addition to providing relevant background regarding the District and the basin, the plan includes identification of issues of concern; basin management objectives, strategies, and actions; and monitoring activities and reporting.

Dated: September 20, 2012

/s/ Wilmar L. Boschman, Assistant Secretary

September 26, October 3, 2012 (12942715)

RECEIVED
OCT 04 2012
S.W.S.D.

EXHIBIT B

BEFORE THE BOARD OF DIRECTORS OF
SEMITROPIC WATER STORAGE DISTRICT ON BEHALF OF IT'S SELF
AND SEMITROPIC IMPROVEMENT DISTIRCT

IN THE MATTER OF: **RESOLUTION NO. ST 12-04**

ADOPTION OF 2012 AMENDED GROUNDWATER MANAGEMENT PLAN

WHEREAS, with adoption of Resolution No. ST 03-07 on September 22, 2003, the Board of Directors of the Semitropic Water Storage District, acting on behalf of itself and its Semitropic Improvement District (collectively the "District") adopted a Groundwater Management Plan pursuant to California Water Code Sections 10750, et seq., and

WHEREAS, adoption of a Groundwater Management Plan is in furtherance of and consistent with the District's adopted project approved by the landowners and the historical operation of the District; and

WHEREAS, Part 2.75 of Division 6 of the California Water Code permits the adoption and implementation of groundwater management plans to encourage authorized local agencies to manage groundwater resources within their service areas; and

WHEREAS, the District is an authorized local agency and may therefore adopt and implement such a groundwater management plan; and

WHEREAS, a first public hearing was held on June 28, 2011, to discuss the amendment of the above referenced 2003 groundwater management plan; and

WHEREAS, the District passed, and subsequently published, Resolution ST 11-04 of Intention to amend its Groundwater Management Plan; and

WHEREAS, the District's consultant prepared an Amended Groundwater Management Plan at the direction of the District Board of Directors; and

WHEREAS, following notice as required by law having been given, a second public hearing was held on October 10, 2012, in accordance with the California Water Code Section 10753.5, et seq. to consider adoption of the proposed Amended Groundwater Management Plan and no comments were submitted nor formal protests were submitted on such proposed 2012 Amended Groundwater Management Plan; and

WHEREAS, the Board believes that the adoption of the proposed 2012 Amended Groundwater Management Plan is in the best interests of the District and its landowners;

NOW, THEREFORE, BE IT RESOLVED that:

(1) The foregoing findings, and each of them, are true and correct.

(2) The District approves and adopts the 2012 Amended Groundwater Management Plan in accordance with Part 2.75 of Division 6 of the California Water Code, as prepared by the District's consultant.

(3) The Board hereby authorizes the officers and staff of the District to execute all documents and take any other action necessary or advisable to carry out the purpose of this resolution.

All the foregoing being on motion of Director Waterhouse, seconded by Director Fabbri, and authorized by the following vote, to wit:

AYES: Directors Fabbri, Howard, McCarthy, Portwood, Tracy, Waterhouse and Wegis

NOES: None

ABSTAIN: None

ABSENT: None

I HEREBY CERTIFY that the foregoing resolution is the resolution of said District as duly passed and adopted by said Board of Directors on the10th day of October, 2012.

WITNESS my hand and seal of said Board of Directors this 10th day of October, 2012.

Assist. Secretary of the Board of Directors


SEMITROPIC
GROUNDWATER BANKING
WATER STORAGE DISTRICT

QUADRIENNIAL GROUNDWATER MONITORING REPORT FOR THE SEMITROPIC WATER STORAGE DISTRICT WATER BANKING PROJECT (2011-2014)

prepared for:
Semitropic Water Storage District
Buena Vista Water Storage District
North Kern Water Storage District
Rosedale-Rio Bravo Water Storage District
Shafter-Wasco Irrigation District
Southern San Joaquin Municipal Utility District

by
Kenneth D. Schmidt and Associates
Groundwater Quality Consultants
Bakersfield, California

May 2017

KENNETH D. SCHMIDT AND ASSOCIATES
GROUNDWATER QUALITY CONSULTANTS
3701 PEGASUS DRIVE, SUITE 112
BAKERSFIELD, CALIFORNIA 93308
TELEPHONE (661) 392-1630

May 3, 2017

Mr. Jason Gianquinto, Manager
Semitropic Water Storage District
P.O. Box Z
Wasco, CA 93280

Re: Water Banking Project Quadriennial
Groundwater Monitoring Report
for 2011-14

Dear Jason:

Submitted herewith is the quadriennial groundwater monitoring report for 2011-14 for the Semitropic Water Storage District Water Banking Project. I appreciate the cooperation of Isela Medina of the District, and Ron Eid of GEI Consultants in providing information and preparing the illustrations, and the other districts in providing information on water-banking activities and results of groundwater monitoring.

Sincerely Yours,

Kenneth D. Schmidt

KDS/td

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QUADRIENNIAL GROUNDWATER MONITORING REPORT FOR THE SEMITROPIC WATER STORAGE DISTRICT WATER BANKING PROJECT (2011-2014)

INTRODUCTION

Except for two demonstration projects that were conducted in the early 1990's, the Semitropic Water Banking Project began in 1995. One demonstration project was conducted with the State of California in 1990, and another with the Metropolitan Water District of Southern California (MWD) in 1993. Through 2014, the Semitropic Banking Project entailed delivery of surface water to irrigated lands to reduce groundwater pumping. Water has been delivered to lands in "in-lieu" areas, through newly developed distribution systems, and also to lands in the existing District service area. This water has then been accrued in water banking accounts, to be later placed in the California Aqueduct. This was done either through a release of entitlement or a direct pumpback of groundwater to the Aqueduct. The first biennial monitoring report was for 1995-96 and was submitted in May 1998. The second report was for 1997-98 and was submitted in October 1999. The third report was for 1999-00 and was submitted in October 2003. The fourth report was for 2001-02 and was submitted in January 2005. The fifth report was for 2003-04 and was submitted in May 2007. The sixth report was for 2005-06 and was

submitted in May 2011. The seventh report was for 2007-2008 and was submitted in August 2015. The eight report was for 2009-10 and was submitted in September 2016. The monitoring committee decided to combine the reports for 2011-12 and 2013-14 into one quadriennial report.

WATER BANKING ACTIVITIES

There were six original banking partners (Metropolitan Water District (MWD), Santa Clara Valley Water District (SCVMD), Accounts 1 and 2 of Alameda County Water District (ACWD), Zone 7 of ACWD, Vidler Water Company (Vidler), and San Diego County Water Authority (SDCWA). ACWD is a single entity with two accounts. Zone 7 of ACWD is a different banking partner and for this program is treated as a separate entity. The total amount of groundwater storage capacity that had been identified for water banking purposes as of July 1994 was one million acre-feet. In January 2000, Semitropic WSD (SWSD) expanded the water banking capacity by 650,000 acre-feet (to a total of 1,650,000 acre-feet) with the addition of the Stored Water Recovery Unit (SWRU). By 2001, Newhall Land & Farming had become the seventh banking partner. In 2002, the Castaic Lake Water Agency became a lower priority banking partner. In 2005, Irvine Ranch Water District, and Zone 7 were added as part of the SWRU. The following banking partners

were added as part of the SWRU: Poso Creek Water Company, LLC (2007), SDCWA (2008), City of Tracy (2010), Homer, LLC (2012, Harris Farms, Inc. (2013), and Shows Family Farms, LP (2014). The following became lower priority banking partners: Buena Vista Water Storage District (2010), Homer (2011), and Kern-Tulare Water District (2012).

Table 1 shows the history of water banking activity through 2014. The State of California banked 91,663 acre-feet in 1990, as part of a one-time demonstration program, and withdrew 41,499 acre-feet in 1992, 10,033 acre-feet in 1997, 10,033 acre-feet in 2008 and 10,330 acre-feet in 2009. As of the end of 2014, the following net amounts remain in storage, MWD 194,010 acre-feet, SCVWD 227,550 acre-feet, ACWD Account No. 1 40,351 acre-feet, ACWD Account No. 2 82,996 acre-feet, ACWD Zone 7 71,809 acre-feet, SDWA Account No. 1 16,117 acre-feet, Newhall Land & Farming 32,507 acre-feet, Castaic Lake Water Agency 35,970 acre-feet, Poso Creek Water Co. 31,967 acre-feet, the City of Tracy 6,100 acre-feet, Buena Vista WSD 3,100 acre-feet, the Kern-Tulare Water District 584 acre-feet, Homer-1 7,554 acre-feet and Homer-2 4,900 acre-feet. By the end of 2014, a total of 775,578 acre-feet of water remained in storage within the project. All of these amounts are net values after a ten percent deduction for project losses, and also after any recovery of banked water has been accounted for.

TABLE 1-HISTORY OF WATER BANKING ACTIVITY

SEMITROPIC WATER STORAGE DISTRICT

History of Water Banking Activity {Stored water after losses, and (Recovery)} acre-feet

	BANKING PARTNER		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014		EOY 2014 Total
Original Banking Project	State of California	STATE	91,663		(41,499)					(10,033)											(10,033)	(10,033)	0					Put Take Transfer	20,065
	Metropolitan Water District of So. Cal.	MWD				45,377		45,000	85,500	112,500	35,550	68,265	0	0 (31,500)	0	63,846 (10,000)	0 (98,368)	28,090	0	0 (136,000)	0 (92,054) (16,117)	0 (56,175)	66,600	134,111	40,500	0 (56,000)	0 (35,115)	Put Take Transfer	194,010
	Santa Clara Valley Water District	SCVWD							40,500	31,500	21,420	27,000	21,357	0 (30,000)	2,980	29,700	0	80,120	57,632	3,323 (20,000)	5,967 (10,000)	0 (33,453) (10,000)	46,791	59,828	0 (17,000)	0 (45,000)	0 (35,115)	Put Take Transfer	227,550
	Alameda County Water District - 1	Alameda - 1							5,580	9,000	3,402	14,490	12,042	0	625	2,439	0	0	7,940	0 (5,000)	0 (10,000)	0 (3,083)	3,976	3,977	3,979	0 (4,000)	0 (5,016)	Put Take Transfer	40,351
	Alameda County Water District - 2	Alameda - 2												0 4,763	1,250	14,481	7,200	27,270	16,762	926	0	0	2,324	15,283	2,771	0 0	0 (10,034)	Put Take Transfer	82,996
	Zone 7	Zone 7									5,373	20,619	21,546	4,500 (1,807)	12,858	5,850	5,166	5,166	5,166	645	0 (7,000)	0	2,700	5,171	0	0 (4,000)	0 (10,144)	Put Take Transfer	71,809
	Vidler Water Company	Vidler									0	6,291	6,246 (3,691)	0 (7,417)	0	0	0	7,765	1,058	0	0	0 (10,253)						Put Take Transfer	(0)
	San Diego Water Authority - 1	San Diego - 1																			0 16,117	0	0	0	0	0	0	Put Take Transfer	16,117
	Newhall Land & Farming Co.	Newhall												2,654	0	0	0	15,680	1,941	0	1,446	0 0	1,446	1,446	1,446	1,446	0 (4,950) 9,950	Put Take Transfer	32,507
Lower Priority	Castaic Lake Water Agency	CLWA													21,600	0	29,270	0	0	0	0	0 (4,950)	0	0		0	0 (9,950)	Put Take Transfer	35,970
	Homer 1	Homer 1																						7,554		0	0	Put Take Transfer	7,554
	Buena Vista Water Storage District	BVWSD																					3,600	4,500	(5,000)	0	0	Put Take Transfer	3,100
	Kern Tulare Water District	KTWD																							1,185 (601)	0	0	Put Take Transfer	584
SWRU	Irvine Ranch Water District	Irvine																1,508	1,334 (2,842)									Put Take Transfer	0
	City of Tracy	Tracy																		900 (100)	0 (100)	0 0	0	0	5,400	0 0	0 0	Put Take Transfer	6,100
	Poso Creek Water Company LLC	Poso Creek																10,156	2,000	17,131 (5,000)	0 (12,779)	0 0 20,253	0	9,949	0	0 (3,000)	0 (6,742)	Put Take Transfer	31,967
	San Diego Water Authority - 2 (STWB & AVWB)	San Diego - 2																								0	0	Put Take Transfer	0
	Homer - 2	Homer 2																							9,900	7,000 (7,000)	(5,000)	Put Take Transfer	4,900
	Harris Ranch	Harris																								2,244 (2,244)	3,572 (3,572)	Put Take Transfer	0
	Total Stored (Total Recovered) Total Transferred	TOTAL	91,663 0 0	0 0 0	0 (41,499) 0	45,377 0 0	0 0 0	45,000 0 0	131,580 0 0	153,000 (10,033) 0	65,745 0 0	136,665 0 0	61,191 (3,691) 0	4,500 (63,307) 0	39,313 0 0	116,316 (10,000) 0	41,636 (98,368) 0	175,755 0 0	93,834 (2,842) 0	22,925 (166,100) 0	7,413 (141,966) 0	0 (107,694) 0	127,437 0 0	241,818 0 0	65,181 (22,601) 0	10,690 (121,244) 0	3,572 (115,688) 0		775,578

Numbers inside parentheses () are negative and are removed from storage account. Numbers not in parentheses are positive and are added to account.

Shaded areas are for closed accounts

Figure 1 shows the location of water distribution systems where the banked water was delivered and banked water was recovered as of 2014. There were 22 systems in the District as of 2014. Appendix A contains a breakdown of where the banked water and recovered water were allocated in 2011, 2012, 2013, and 2014. The allocation of banked water within each system excludes entitlement deliveries and is proportioned to the total amount of banked water delivered divided by the sum of all other deliveries except entitlement.

In 2011, 241,818 acre-feet of water were stored and no water was recovered. In 2012, 65,181 acre-feet were stored and 22,601 acre-feet were recovered. In 2013, 10,690 acre-feet were stored and 121,244 acre-feet were recovered. In 2014, 3,572 acre-feet were stored and 115,688 acre-feet were recovered.

In 2011, the corresponding allocation of banked water (241,818 acre-feet) was 22% to the north systems, 43% to the central systems, and 36% to the south systems.

In 2012, the corresponding allocation of banked water (241,818 acre-feet) was 22% to the northern systems and the Poso Creek recharge facility, 41% to the central systems, and 37% to the southern systems. In 2012, allocation of recovered water (22,601 acre-feet) was 19% to the northern water systems, 46% to the central systems, and 35% to the southern systems.

In 2013, the corresponding allocation of banked water (10,690

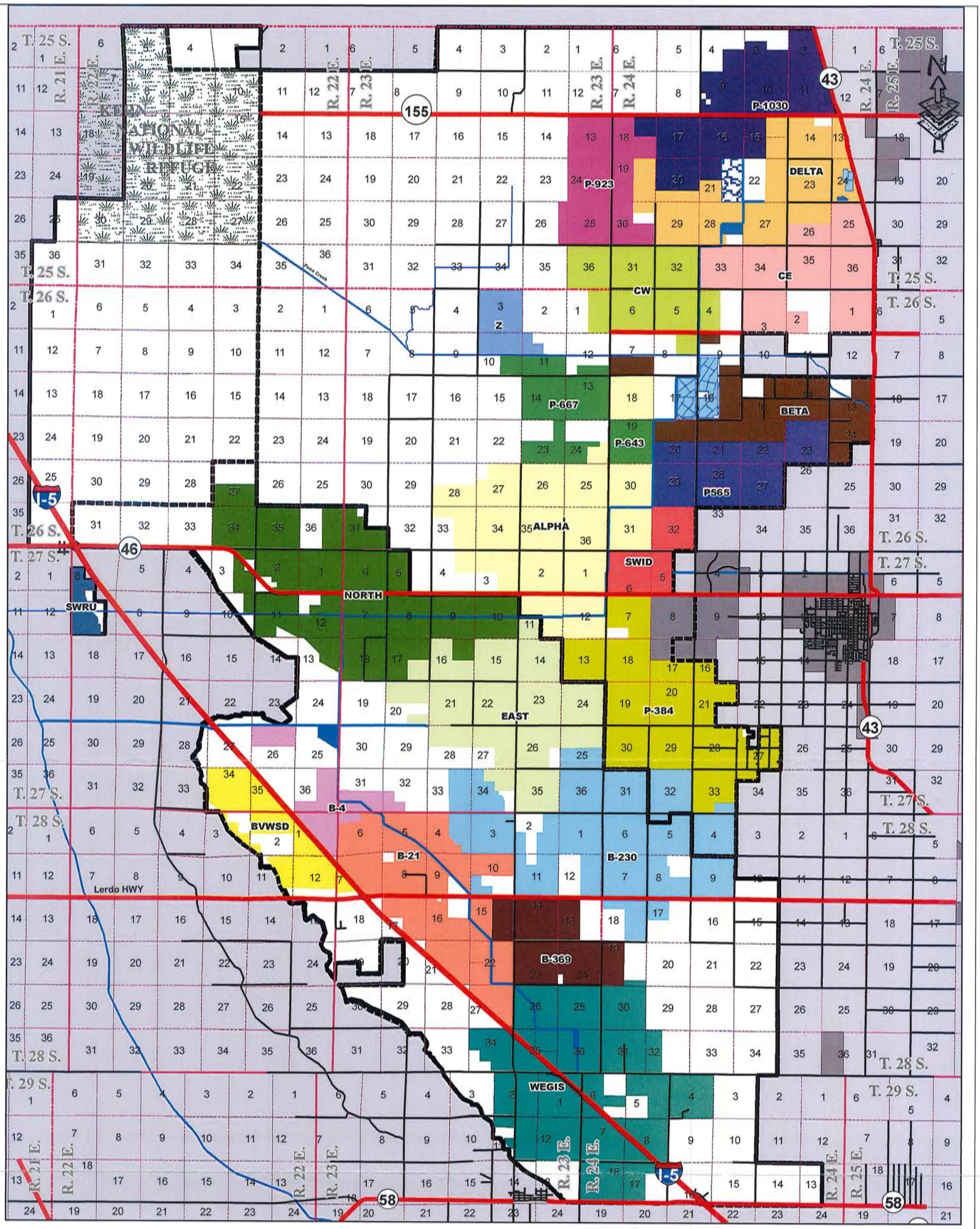


FIGURE 1
SEMITROPIC WATER STORAGE DISTRICT
SYSTEM MAP

0 0.5 1 2 3 4 5 Miles

Dec 2016

Legend

- DistrictBoundary
- Improvement District Boundary
- Transportation
- Canals, Pipelines, and Aqueduct
- Distribution System

SEMITROPIC GROUNDWATER BANKING WATER STORAGE DISTRICT

\GIS Projects\System Routes\DistributionBanking\Water figure 1 09-10 Dec 1, 2016

acre-feet) was 23% for the north systems, 45% for the central systems, and 32% for the southerly systems. For the recovered water (121,244 acre-feet), the allocation was 18% to the northerly systems, 57% to the central systems, and 25% to the southerly systems.

In 2014, the allocation of the banked water (3,572 acre-feet) was 14% to the northerly systems, 54% to the central systems, and 32% to the southerly systems. For the recovered water (115,688 acre-feet), 18% was allocated to the northerly systems, 58% to the central systems, and 24% to the southerly systems.

SUBSURFACE GEOLOGIC CONDITIONS

There are several subsurface geologic trends that are important in terms of groundwater monitoring for this project. First, one major aquifer had been assumed to be present in most of the area south of Seventh Standard Road and east of Wasco (the forebay area). The fine-grained strata that are present in this area had been assumed to not function as effective confining beds. Water levels in shallow and deep water-producing strata in the forebay area tend to be at about the same depth at most locations during periods of minimal pumping. In contrast, within much of the part of the SWSD that is north of Seventh Standard Road, at least one significant confining bed is present. This bed ave-

rages about 300 feet in depth, and contributes to significant differences in water levels with depth at most locations. To the northwest, closer to the Tulare Lake bed, this clay is equivalent to the Corcoran Clay. For purposes of the monitoring program, two aquifers have been assumed to be present in this part of the study area. The upper zone is above this confining bed and the lower zone is below it. Because of this, two different series of water-level elevation maps have been prepared. In most of the area east of the SWSD, water levels for the shallow groundwater (i.e., above a depth of 300 feet) are not available. However, recent subsurface geologic data indicate that a clay layer is also present in much of the North Kern WSD at a comparable depth as to that in the SWSD. In the future, if more information on shallow water levels in the area east of SWSD becomes available, it may be possible to subdivide the water levels in that part of the forebay into two aquifers.

Another important trend in the subsurface is that fine-grained deposits and high salinity groundwater are present in much of the area generally along and west of Interstate 5, north of Seventh Standard Road. Because of these conditions, there is little pumping of groundwater in this area, and groundwater levels are shallow (near the land surface). Water levels in wells in

this area generally correspond to those that are above the widespread confining layer located farther to the east.

GROUNDWATER MONITORING PROGRAM

A Memorandum of Understanding (MOU) was reached between the SWSD and the surrounding entities in July 1994. As part of this MOU, a monitoring committee was established to develop, review, and oversee a groundwater monitoring program. The goal of this program is to develop information so that possible adverse impacts of the water banking project can be mitigated to the extent possible. Members of the monitoring committee represent the SWSD and five adjoining districts. The SWSD banking partners, the Kern County Water Agency, and the California Department of Water Resources are interested parties and participate in committee activities. Ken Schmidt was retained as a groundwater specialist to develop and oversee the monitoring program, and to prepare periodic reports on the results of monitoring. Impacts of the SWSD Groundwater Banking Program are to be evaluated through interpretation of the results of monitoring, and through a groundwater model being developed by GEI Consultants, Inc.

Activities of the committee commenced in Summer 1994, and a groundwater monitoring program was proposed in June 1994. This

plan contained the details of water-level and groundwater quality monitoring, and included two maps, showing the wells to be monitored for water levels and chemical quality. Monitoring pursuant to this plan commenced in Spring 1995. A sampling plan was subsequently developed in September 1996, which presented the recommended procedures to be used for the monitoring, to the extent feasible.

To date, the groundwater monitoring comprised the following:

1. Water level measurements in numerous water supply and monitor wells (normally at least semi-annually).
2. Installation of a number of new monitor wells.
3. Continuous water-level measurements from transducers in 22 monitor wells and supply wells in the SWSD.
4. Monthly water-level measurements in some wells.
5. Operation of a compaction recorder (extensometer) associated with the SWRU.
6. Annual water quality sampling of selected actively used water supply wells, and periodic sampling of some monitor wells.

Interpretive procedures for the groundwater monitoring have included:

1. Preparation of water-level elevation maps (for the deep and shallow groundwater). The direction of groundwater

flow has also been indicated on these maps.

2. Water-level hydrographs have been prepared for many wells, including ones with long-term records.
3. Water-level change maps have been prepared, including for Spring 1995-Spring 2014, for use in evaluating the water banking activities.
4. Maps of total dissolved solids (TDS) in the shallow and deep groundwater have been prepared.
5. TDS hydrographs have been prepared for selected monitor wells.
6. Nitrate, arsenic, uranium, and hexavalent chromium maps have been prepared for groundwater.

Land subsidence has been monitored by the SWSD at a compaction recorder southeast of the Kern National Wildlife Refuge since 2006. Land surface elevations have also been monitored for several years at the Wasco Airport, as part of a program by the U.S. Geological Survey.

In addition to the water-level and groundwater quality monitoring, activities of the SWSD and the adjoining entities that affect groundwater conditions has been obtained and compiled. Included are diversions of surface water into each District, crop surveys and estimates of crop consumptive use, and where availa-

able, groundwater pumpage. Knowledge of this information is essential in order to determine changes in groundwater conditions due to this water banking project. A groundwater model is used by GEI Consultants, Inc. to compare the with and without Semitropic banking project conditions.

MONITOR WELLS

A double completion monitor well (948L) was installed in the south part of the SWSD in 1994 as part of the Kern-Fan Water bank project monitoring project. As of 2010, there were two westerly series of monitor wells, which were single completion wells near the westerly boundary of SWSD with the Buena Vista WSD. One series (DMW-1 through DMW-7) was installed west of the boundary in the Buena Vista WSD, and the other (S-1 through S-5) to the east, in the SWSD. Except for S-1, the remaining S-series monitor wells tap the lower zone. Another Buena Vista WSD monitor well (DMW-8) is located south of the SWSD about a mile south of Seventh Standard Road. The first easterly series monitor wells (S-6 through S-9) were installed at four sites along the east side of the SWSD by the District in Summer 1995. Double completion monitor wells were installed at three of these sites and a single completion well was installed at the fourth site (S-6). Both shallow and deep wells in the easterly series

were designed to tap strata below the regional 300-foot clay layer, because this is where most of the recovery pumpage was expected to be from. The deeper wells were completed beneath a significant local clay layer (below a depth of 550 feet). The shallow completion easterly wells generally tapped strata about 350 to 400 feet deep and above this local clay layer. Continuous water-level recorders were subsequently installed in many of the monitor wells.

As part of the SWRU in the northwest part of the SWSD, one triple completion monitor well (S-10) was installed in Spring 1999. Two casing hammer test wells were installed in this vicinity and converted to deep monitor wells (S-11 and S-12) in November 2001. Additional monitor wells were installed at four other sites (S-13, 14, 15, and 16) in the easterly area in 2003. At each of these sites, double completion wells were completed, similar to the previous easterly monitor wells. Figure 2 shows the locations of these monitor wells. Continuous water-level recorders have been installed in a number of monitor wells and supply wells and the location are also shown in Figure 2. There records are especially valuable, since they clearly indicate the shallow and deepest levels for each year.

A series of single completion monitor wells (DMW) was installed along the east edge of the Buena Vista WSD, generally

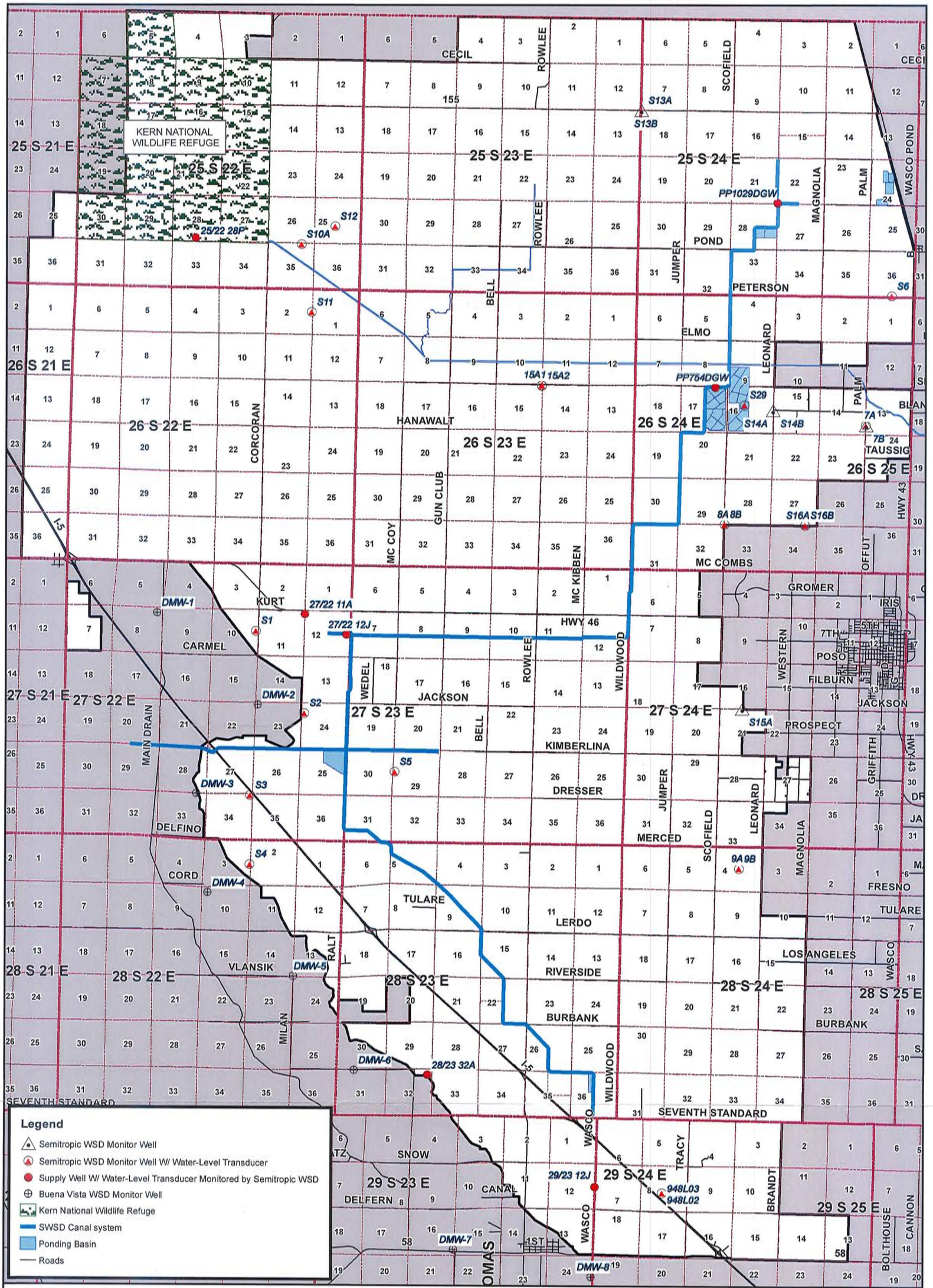


Figure 2
Location of Semitropic WSD and Buena Vista WSD Monitor Wells

Engineering\GIS Projects\Basemap\MXDs\Figure 2 SWSD and BVWSD Mon Well Location Map. Aug 11, 2016 JLK

opposite from the single completion monitor wells installed by the SWSD to the east.

WATER LEVELS

Figure 3 shows the locations of wells used for water-level monitoring. Wells used in the monitoring program have been periodically modified as more information has been obtained, in order to enhance the utility of the monitoring program.

Lower Zone and Forebay

Water-Level Elevations and Direction of Groundwater Flow

The Spring 1995 water-level elevations indicated that water levels in wells tapping strata below the 300-foot clay in the SWSD closely matched those in the forebay area (approximately south of Seventh Standard Road and east of the Central Valley Highway or Wasco Avenue). Most groundwater inflow into SWSD from the forebay area to the east apparently comes from below the 300-foot deep confining bed. Groundwater beneath the 300-foot deep clay layer is confined beneath the District and to the east in much of the North Kern WSD. Thus water-level elevation contour maps have been prepared for the strata below the 300-foot confining bed in the SWSD and for the adjacent upgradient forebay area to the east and south. A different designation (color) has

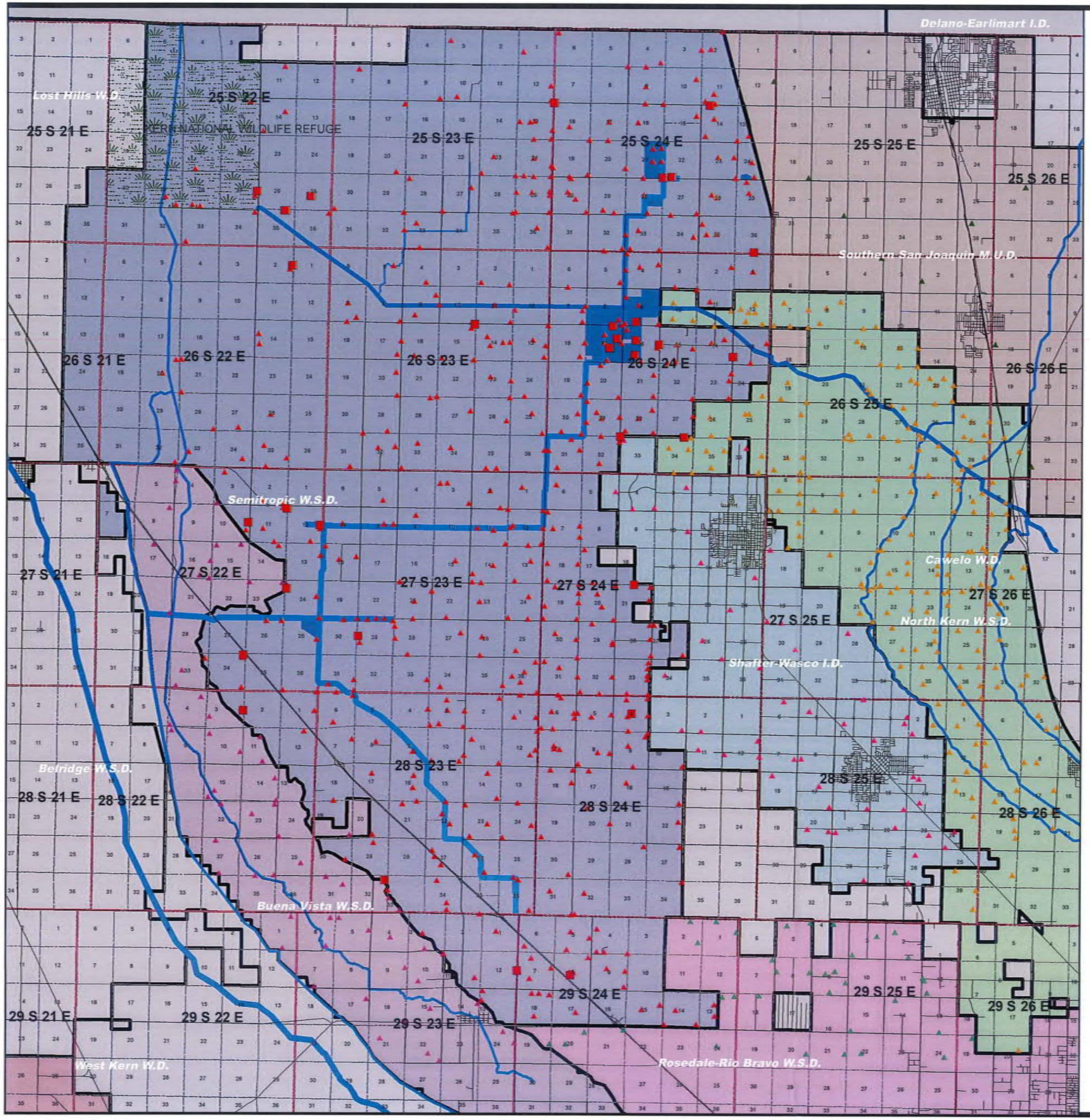


Figure 3
Location of Wells in Water-Level Network

been used for the water-level elevation contours in the forebay area than farther downgradient in the District.

Figures 4, 5, 6, and 7 show water-level elevations and the direction of groundwater flow in the lower zone and forebay area for Spring 2011, 2012, 2013, and 2015. Water-level elevations for specific wells used in preparing the contours are also provided. A map is not provided for Spring 2014, because of the extensive pumping that was being undertaken at that time, which made it impossible to obtain representative static water-level measurements.

In Spring 2011, there was a widespread north-south trending cone of depression, in which water-level elevations were below mean sea level. Water levels were more than 40 feet below mean sea level to the north, near County Line Road. To the east near Highway 43 and north of Shafter, water elevations were about 50 feet above sea level. Beneath the northeast part of the study area, water levels were more than 100 feet above mean sea level. Beneath the southeastern-most part of the study area, water-level elevations exceeded 90 feet above mean sea level in Spring 2011. The direction of groundwater flow was into the SWSD, except along the north boundary of the District in an area about ten miles wide, where groundwater flowed out of the District.

In Spring 2012, there also an extensive north-south trending cone of depression, where water-level elevations were below sea

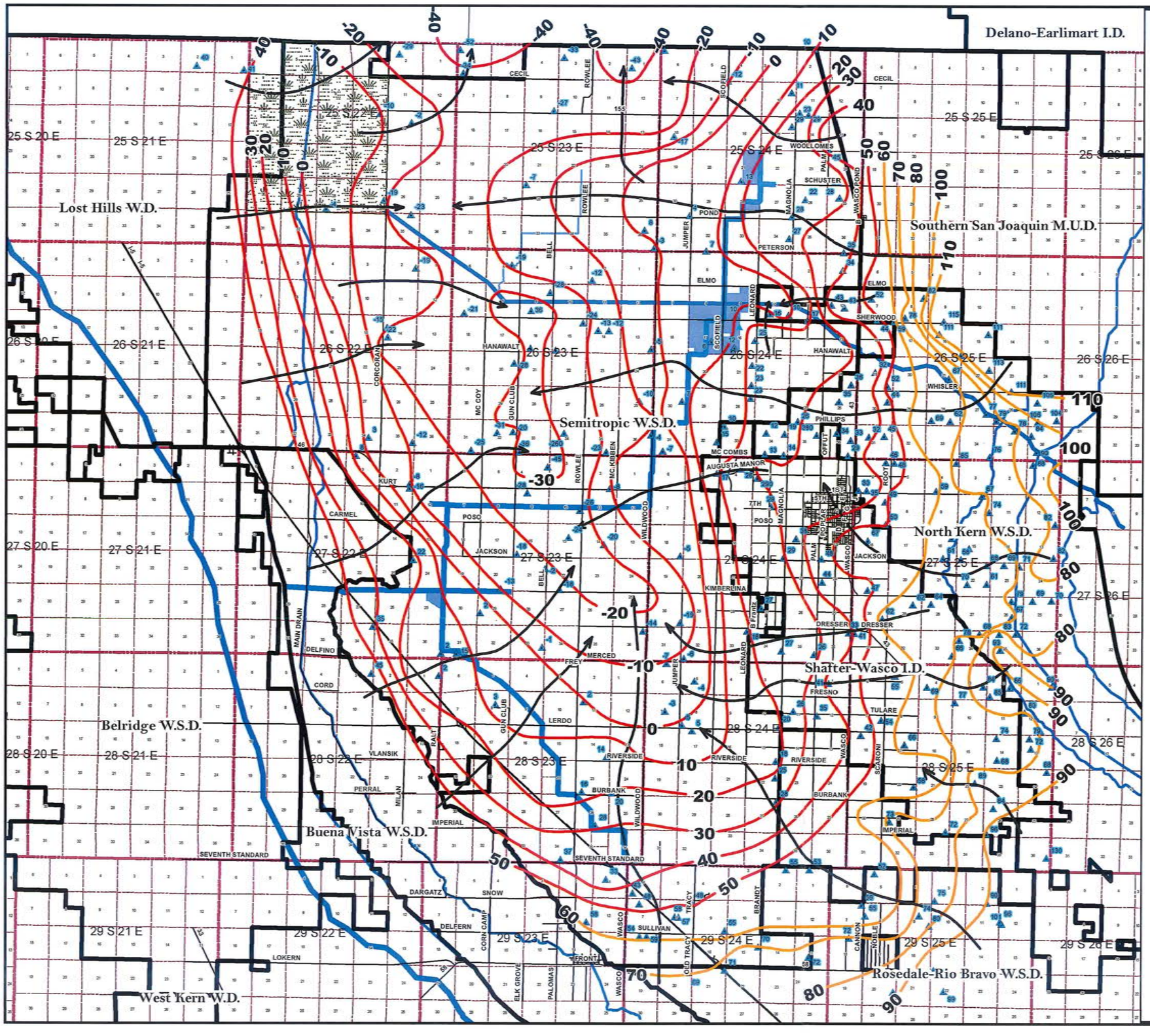


FIGURE 4-

Water-Level Elevations And Direction of Groundwater Flow For the Forbay Area and Lower Zone (Spring 2011)

Legend

- 23 — Well & Water-Level Elevation (Feet)
- Direction of Groundwater Flow
- 80 — Water-Level Elevation Contours (ft. Relative to M.S.L.) For Forebay Area.
- -20 — Water-Level Elevation Contours (ft. Relative to M.S.L.) For Lower Zone.

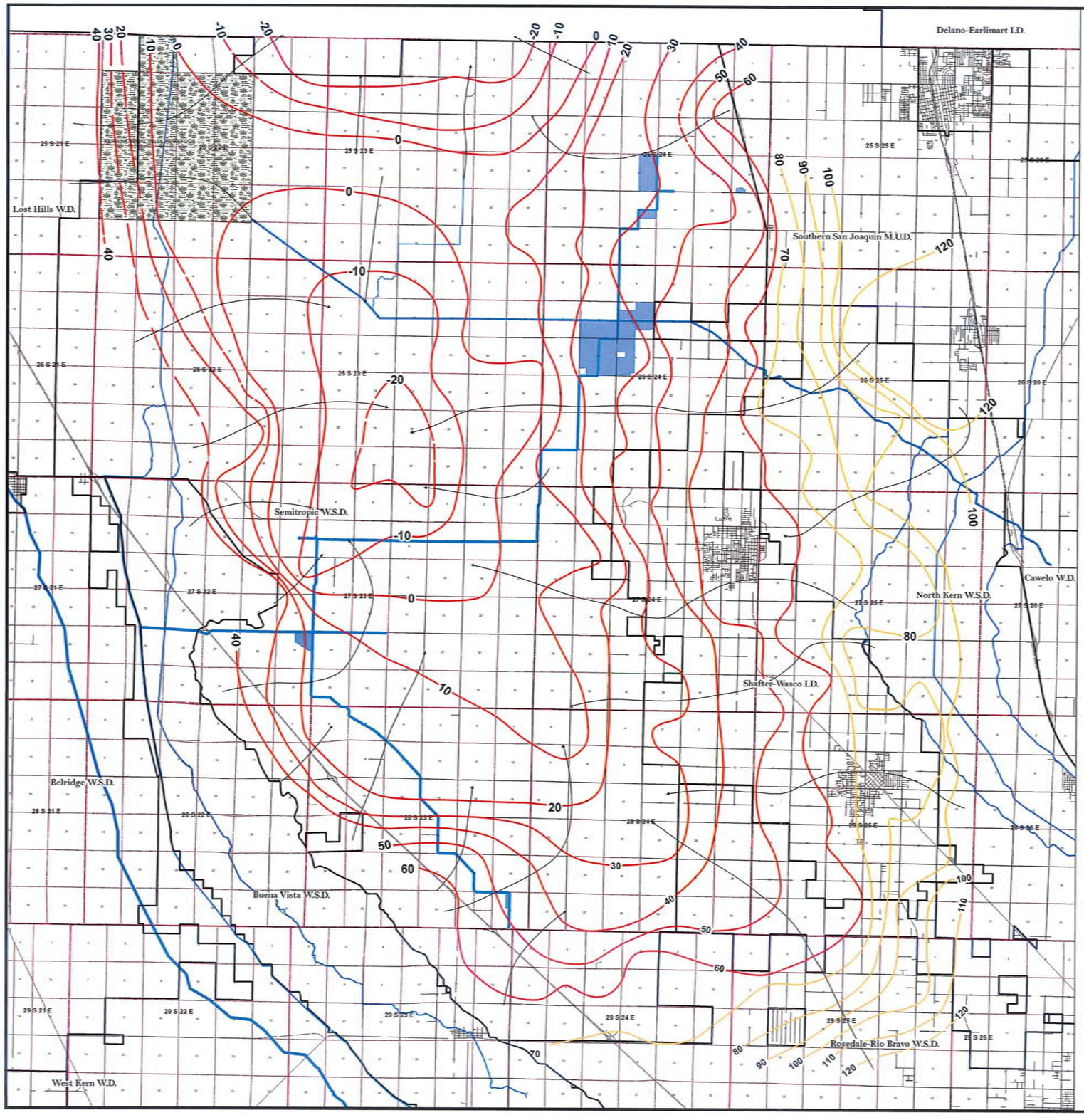


Figure 5

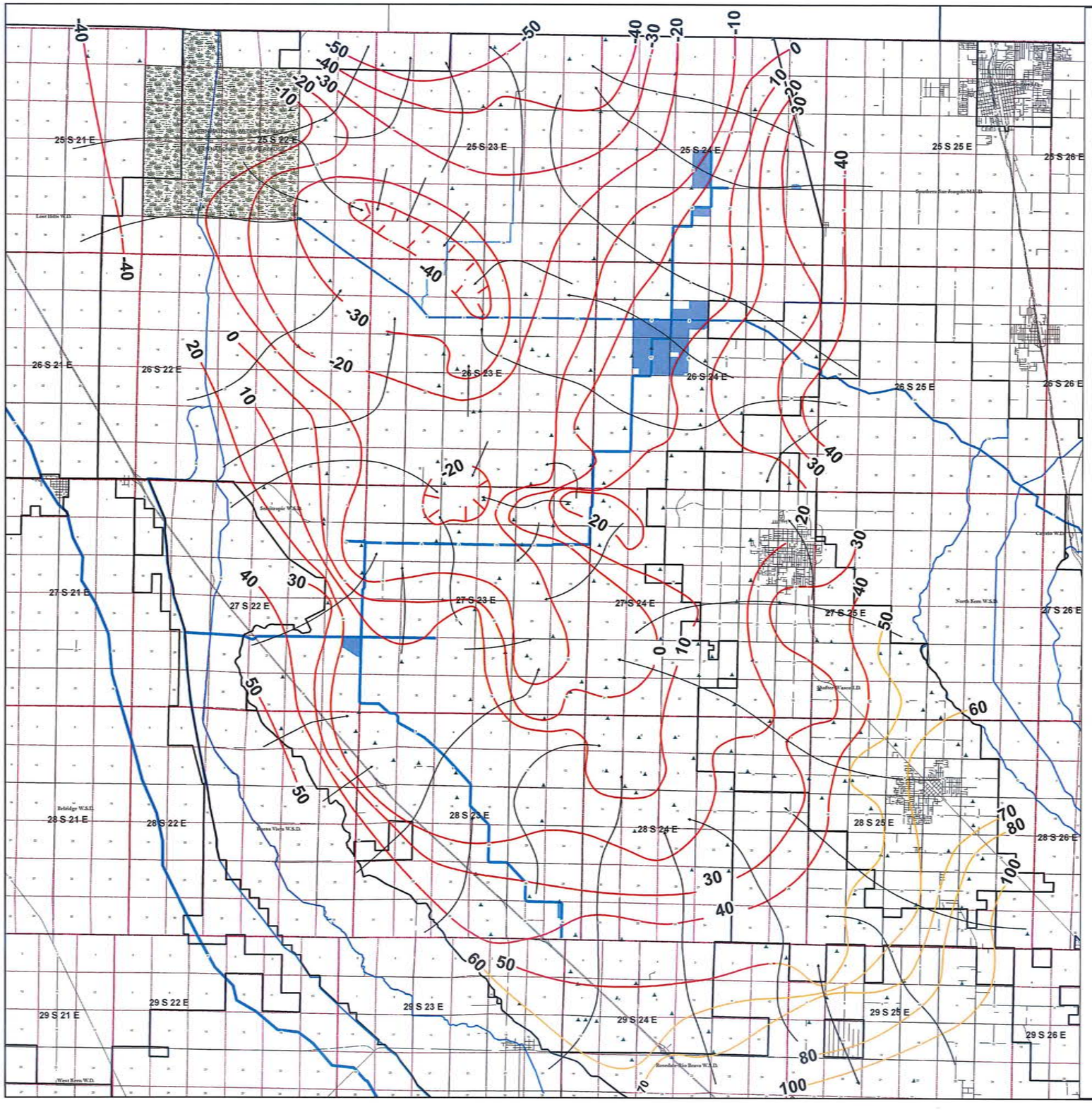
Water-Level Elevations And Direction of Groundwater Flow For the Forbay Area and Lower Zone (Spring 2012)

Legend

- Well Location
- Direction of Groundwater Flow
- 80 — Water-Level Elevation Contours (ft. Relative to M.S.L.) For Forebay Area.
- -20 — Water-Level Elevation Contours (ft. Relative to M.S.L.) For Lower Zone.

2 1 0 2 4 6

Miles



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Figure 6

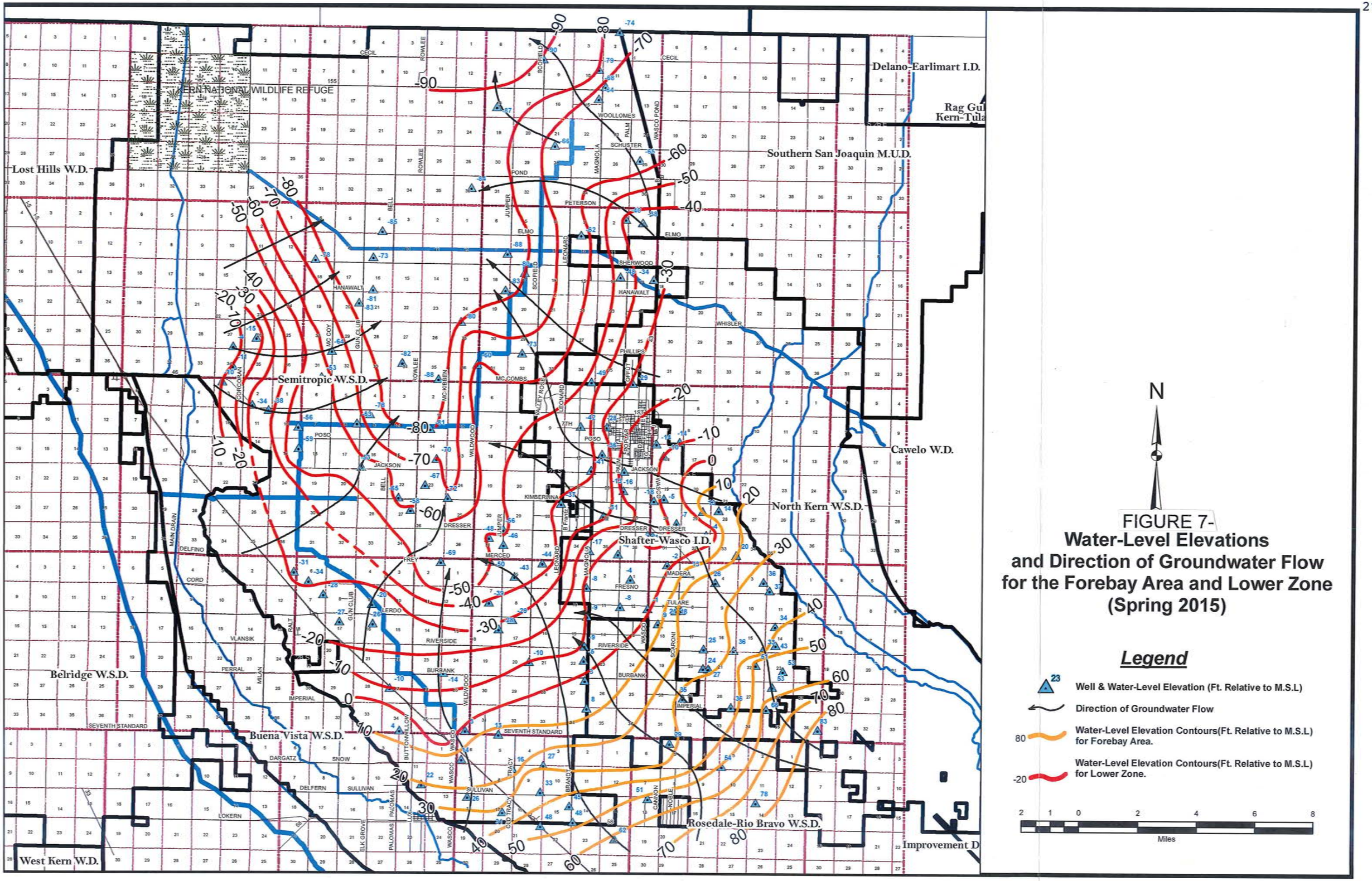
Water-Level Elevations and Direction of Groundwater Flow for the Forebay Area and Lower Zone (Spring 2013)

Legend

- Well Location
- Direction of Groundwater Flow
- 80 — Water-Level Elevation Contours(Ft. Relative to M.S.L) for Forebay Area.
- -20 — Water-Level Elevation Contours(Ft. Relative to M.S.L) for Lower Zone.

2 1 0 2 4 6 8

Miles


KERN NATIONAL WILDLIFE REFUGE
Lost Hills W.D.
Belridge W.S.D.
Semitropic W.S.D.
Buena Vista W.S.D.
West Kern W.D.
Delano-Earlimart I.D.
Rag Gul
Kern-Tula
Southern San Joaquin M.U.D.
Cawelo W.D.
North Kern W.S.D.
Shafter-Wasco I.D.
Rosedale-Rio Bravo W.S.D.
Improvement D
CECIL
ROWLEE
SCOFIELD
WOOLLOMES
PALM
WASCO POND
SCHUSTER
MAGNOLIA
POND
PETERSON
BELL
JUMPER
ELMO
LEONARD
SHERWOOD
HANAWALT
WHISLER
PHILLIPS
MC COY
GUN CLUB
MC COMBS
MC KIBBEN
VALLEY ROSE
OFFUT
7TH
POSO
WILDWOOD
JACKSON
KIMBERLINA
DRESSER
MERCED
FREY
CORD
DELFINO
MAIN DRAIN
LERDO
RIVERSIDE
BURBANK
IMPERIAL
SEVENTH STANDARD
BUTTONWILLOW
DARGATZ
SNOW
DELFERN
SULLIVAN
LOKERN
RALT
VLANSIK
PERRAL
MILAN
CONCORAN
HIGHWAY 99
MADERA
FRESNO
TULARE
SCARONI
TRACY
BRANDT
CAMPION
NORRIS
OLD TRACY
PALOMAS
LUX
BLK GROVE
WASCO
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
N
FIGURE 7-
Water-Level Elevations
and Direction of Groundwater Flow
for the Forebay Area and Lower Zone
(Spring 2015)
Legend
Well & Water-Level Elevation (Ft. Relative to M.S.L)
Direction of Groundwater Flow
80
Water-Level Elevation Contours(Ft. Relative to M.S.L)
for Forebay Area.
-20
Water-Level Elevation Contours(Ft. Relative to M.S.L)
for Lower Zone.
2 1 0 2 4 6 8
Miles

level. The lowest water-level elevations were more than 20 feet below sea level, near the north boundary of the District and in the central part of the District. To the east, near Highway 43 and north of Shafter, water-level elevations were about 60 to 70 feet above sea level. The highest water-level elevations, exceeding 120 feet above sea level, were in the northeast and southeast parts of the study area. The direction of groundwater flow in the deep zone was into the SWSD, except along the north boundary of the District in an area about nine miles wide, where groundwater flowed out of the District.

In Spring 2013, there was also a large cone of depression beneath the north part of the District. Water-level elevations were about 20 feet above sea level near the south edge of this depression and about 50 feet below sea level near the north edge of the District. Along Highway 43 north of Shafter, water level elevations were about 40 feet above sea level. The highest water-level elevations exceeded 70 feet above sea level beneath the southeast part of the study area. Information on water levels was lacking beneath the northeast part of the study area. The direction of groundwater flow in the deep zone was into the District, except along the north boundary of the District in an area about eight miles wide, where groundwater flowed out of the District.

In Spring 2015, there was a large cone of depression beneath the north and central parts of the district. Water-level elevations were more than 30 feet below sea level in this depression. The lowest water levels were more than 90 feet below sea level near the north end of the District. These were the deepest spring levels yet determined. There was a lack of water-level measurements in the northwest and northeast parts of the study area. Water-level elevations along Highway 43 north of Shafter ranged from near sea level to the south to more than 70 feet below mean sea level to the north. The highest water-level elevations (more than 80 feet above mean sea level) were in the southeast part of the study area.

Water-Level Changes

Figure 8 shows the water-level changes in the forebay area and lower zone between Spring 1995 and Spring 2015. No water-level rises were indicated during this period. Water levels fell up to about 30 feet beneath most of the Semitropic WSD. The amount of decline in the SWSD generally increased to the north. The largest water-level declines were beneath T25S/RE23, T25S/R24E, T26S/R23E, and T26S/R24E, which correspond to the northerly systems and the north part of the central systems.

Appendix B contains water-level hydrographs for wells in the

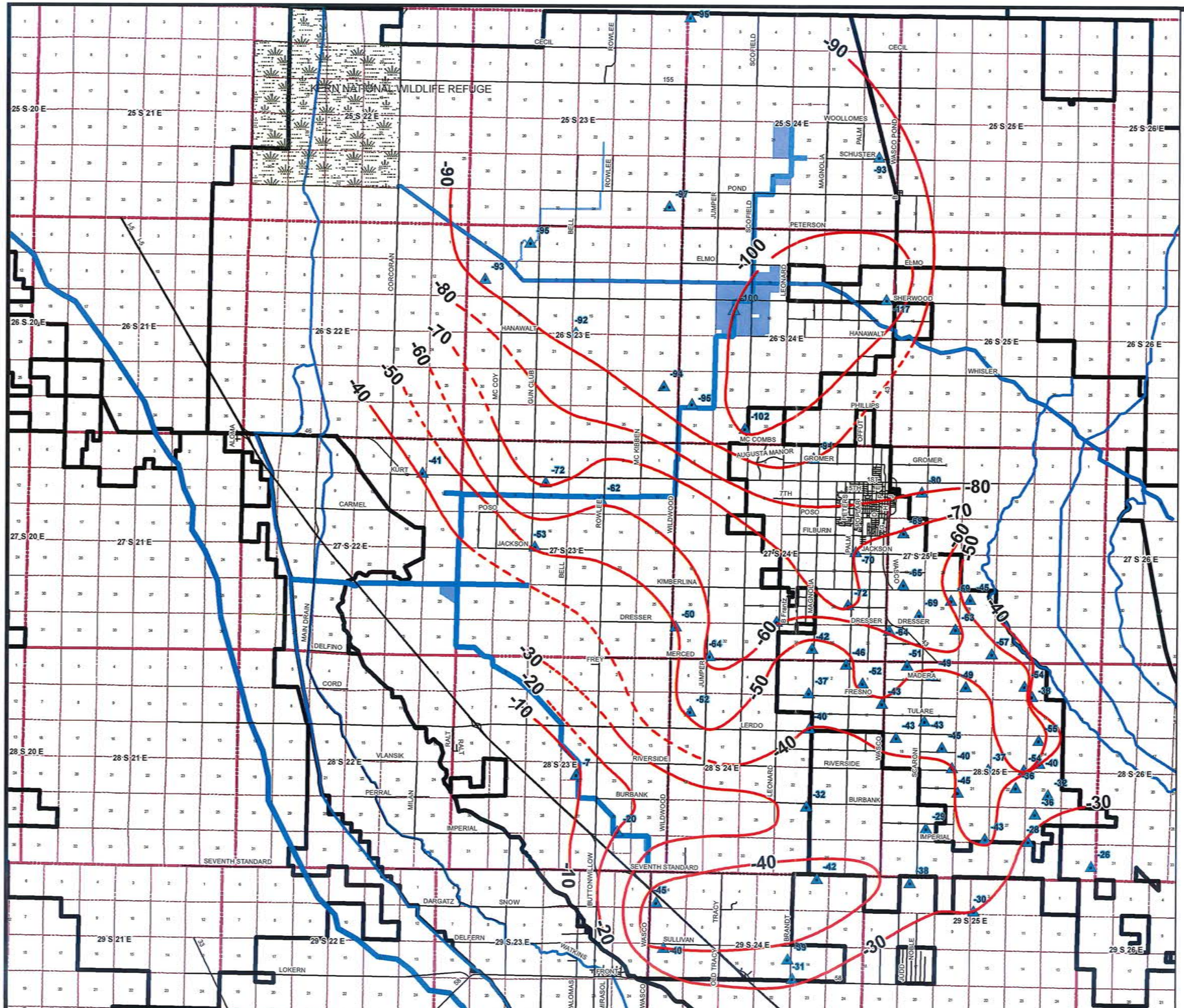


FIGURE 8-

Water-Level Changes For The Forebay Area & Lower Zone (Spring 1995 - 2015)

Legend

- Well & Water-Level Change (Feet)
- \+ Water-Level Rise
- \- Water-Level Decline
- -10 Contour of Water-level Change (Feet)

area. Water-level hydrographs are available for wells in the Southern San Joaquin MUD, North Kern WSD, Shafter-Wasco I.D., and Rosedale-Rio Bravo WSD in the forebay Area. GEI Consultants provided long-term hydrographs for 22 lower zone wells in the SWSD. Records for some of these extend back to about 1970, and most extend back to about 1990-96. Transducer measurements are available for 12 of the District lower zone monitor well sites since 2006. The SWSD prepares hydrographs for these, and records for these (including manual measurements) extend back to 1990-91. In addition, the District has installed transducers in a number of other wells and hydrographs are provided for these.

The North Kern WSD provided water-level hydrographs for 13 wells in the study area. KDSA printed out DWR long-term water-level hydrographs for 21 wells in the Shafter-Wasco I.D. KDSA printed out similar hydrographs for four wells in the Southern San Joaquin MUD. Buena Vista WSD provided water-level hydrographs for five lower zone wells in the study area, and these extend back to the early 1990's. The Rosedale-Rio Bravo WSD provided hydrographs for five wells in the forebay area, and some records extend back to about 1980.

2011-15. Water levels in the lower zone fell during this four-year period in most parts of the SWSD. This was expected, as

2011 and 2012 were years of extensive banking, and 2013 and 2014 were years of extensive recovery pumping. The largest declines (exceeding 80 feet) were primarily in the P-384, P-565, and P-667 systems. The smallest declines (less than 30 feet) were along the west part of the District north of Kimberlina Road. Declines of about 60 feet were present in the Beta System and east of the Kern National Wildlife Refuge.

Near the northwest part of the Kern WSD, water levels also fell during the four-year period. Water-level declines exceeded 100 feet in two wells along Highway 43 north of Wasco. Declines of about 80 feet were present in several wells northeast of Wasco. The smallest water-level declines (less than 50 feet) were in the area east of Wasco.

In the Shafter-Wasco I.D., water levels fell about 30 to 70 feet in the forebay area during this four-year period. The declines were greater to the northwest, north of Kimberlina Road. The smallest declines (less than 40 feet) were generally in the area south of Lerdo Highway.

In the Rosedale-Bravo WSD, water levels fell from about 20 to 30 feet in the forebay area during the four-year period.

Long-Term. In this report a number of hydrographs that were termed "short-term" in previous biennial reports are grouped

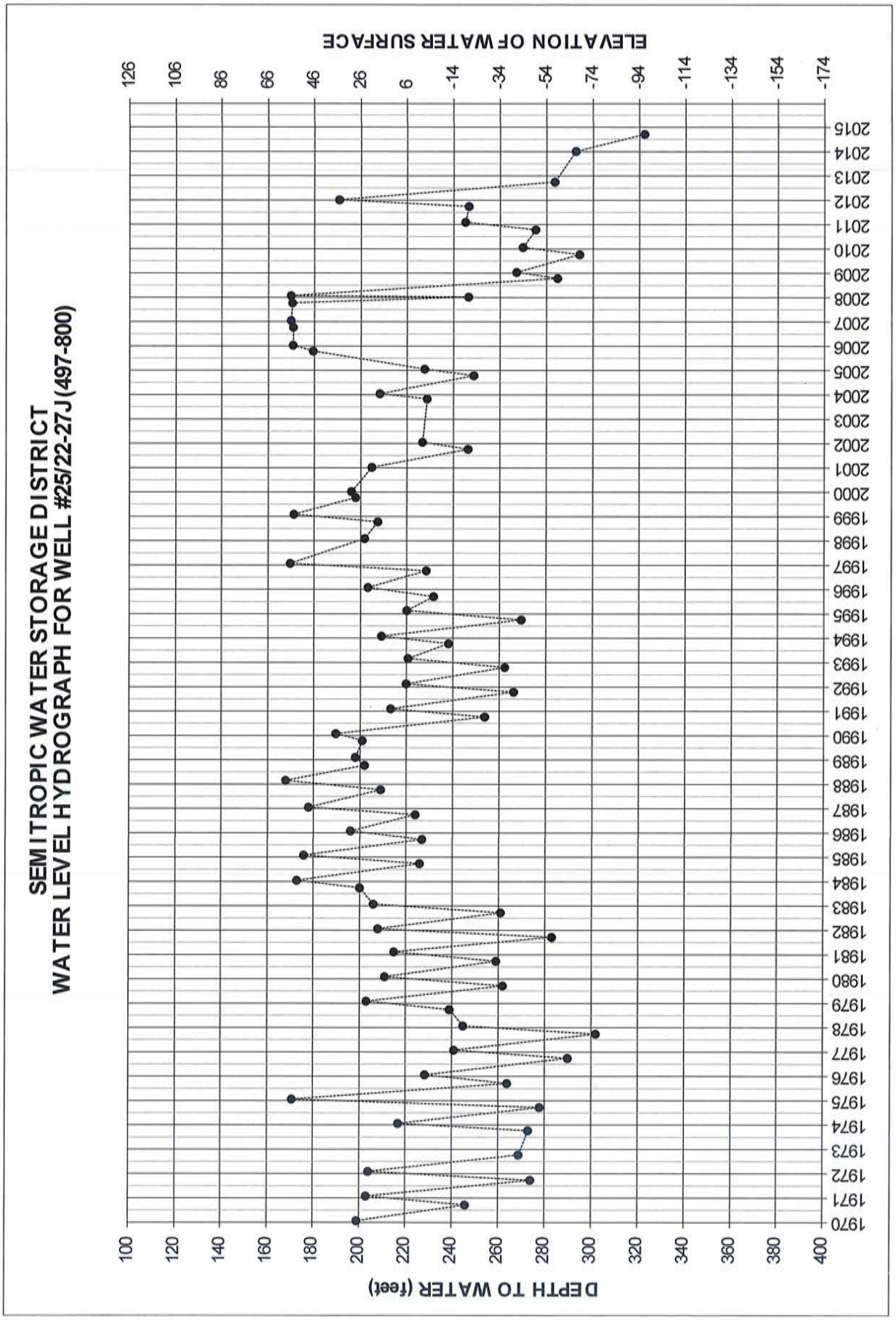


FIGURE 9-TYPICAL WATER-LEVEL HYDROGRAPH FOR THE LOWER ZONE

under long-term, as many of these hydrographs now extend for more than two decades. A typical water-level hydrograph for the lower zone in the SWSD is shown in Figure 9. Well T25S/R22E-27J is located west of Corcoran Road and north of Pond Road, in the northwest part of the District. The casing in this well is perforated from 497 to 800 feet in depth. Water-level records for this well extend from 1970 to 2011. Seasonal water-level declines have ranged from about 30 to about 130 feet. The water levels in this well were falling through 1977. Since then, water levels rose through 1984, then were relatively stable through 1991, and rose after 1994. In Spring 2004, depth to water was near the shallowest of record (near the 1988 and 1996 levels). However, the water level fell substantially after Spring 2008 to the lowest level of record in late 2014 (more than 320 feet deep).

Water-level trends from Spring 1995-Spring 2015 were evaluated for 13 wells in or near the North Kern WSD. Hydrographs for most of the wells indicated rising water levels through Spring 1997, falling water levels from Spring 1997 to Spring 2005, rising water levels through Spring 2007, substantial declines by Spring 2008, then rising or stable water levels through Spring 2011. Water-levels then fell through early 2015.

Water-level trends for 1995-2015 were evaluated for four

wells in the Southern San Joaquin Municipal Utility District. Water-level measurements and hydrographs were obtained from the DWR data base. Water levels generally declined from the 1930's through the mid 1950's, then rose through the late 1980's, then fell during the 1989-93 drought, recovered through about 2007, then fell thereafter.

Water-level trends for 1995-2015 were evaluated for about a dozen wells in the Shafter-Wasco I.D. Water levels had fallen through 1992-94 during the prolonged drought. Water levels then rose through 2001, then fell through 2005. Water levels then rose through 2007, declined significantly by Spring 2008, and then rose or were stable through 2011. After 2011, water levels in these wells fell through early 2015.

Water-level trends for 1995-2015 were evaluated for five wells in the Rosedale-Rio Bravo WSD. Water levels in these wells rose through 2001, then fell through 2005, the rose through 2007, then fell through early 2015. Well T29S/R24E-21A is located in Rosedale-Rio Bravo WSD, near Interstate 5 and Highway 58. Water-level measurements for this well extend from 1981 to 2015 (Figure 10). Seasonal fluctuations have normally been about ten feet. Over the long-term, the water level has risen during wet periods (i.e. the mid-1980's) and fallen during droughts (1989-93 and 2007-15). The shallowest water levels were in the late

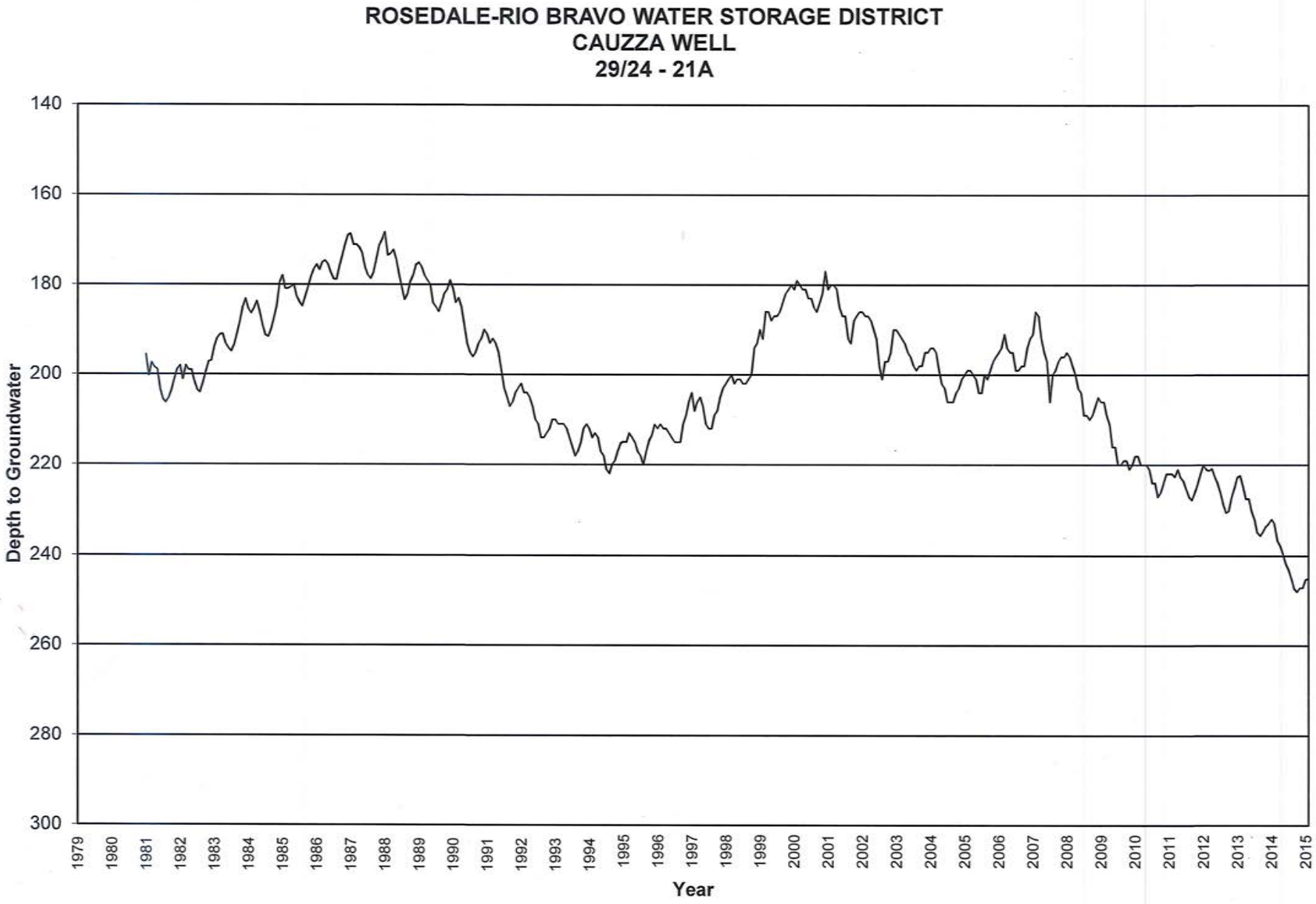


FIGURE 10-TYPICAL WATER-LEVEL HYDROGRAPH FOR THE FOREBAY AREA

1980's near the end of a wet period and the deepest were in the mid-1990's and during 2009-2014. The water-level rises from 1997-2001 and declines after Spring 2007 were partly due to water banking activities of the Kern Fan projects. Overall, the water level in this well has fallen over the long term, particularly since 2007.

Transducer Measurements for Westerly SWSD Wells. Frequent water-level measurements are available for these wells since 1995. Water levels in S-2, located near Jackson Avenue, have ranged from about 160 to 255 feet deep. The shallowest water levels were in 2006 and the deepest water levels were in early 2015. The water-level decline between Spring 2013 and Spring 2015 was about 53 feet, which was slightly less than that between Spring 2007 and Fall 2008. Water levels in this well were relatively stable through 2007 and then declined thereafter. S-3 is located about one mile west and two miles south of S-2. Depth to water in this well has ranged from about 190 to 250 feet. The shallowest water levels were in 1999 and early 2007. The deepest water levels were in late 2014 and early 2015. Overall, the water level fell between 2007 and 2009, was relatively stable through 2013, and then fell since then. S-4 is located about one and a half miles south of S-3. Depth to water has ranged

from about 175 to 233 feet. The shallowest water levels were in early 2001 and in early 2007. The deepest water levels were in 2013-15. Water levels were relatively stable in this well prior to 2007, and then fell thereafter. S-5 is located three miles east and half a mile north of S-3. Depth to water in this well has ranged from about 180 to 300 feet. The shallowest water levels were in early 2001, and early 2007. The deepest water levels were in 2014-15. Water levels in this well were relatively stable prior to 2007 and declined thereafter. Water levels in this well are more indicative of confined conditions and more pumpage from the lower aquifer, as reflected by greater water-level variations than in the S-series wells that are farther north.

Transducer Measurements for Easterly SWSD Monitor Wells. S-6 is located at Peterson Road, about half a mile west of the Central Valley Highway. Depth to water has ranged from about 170 to more than 370 feet. The shallowest water levels were during 1996-2001 and in Spring 2007 and the deepest during 2008-10 and 2014-15. Water levels in this well were relatively stable prior to 2007, and then declined thereafter. S-7B is located about three miles south of S-6 and one mile west of the Central Valley Highway. Depth to water has ranged from about 158 to 277 feet. The

shallowest water levels were in early 2006 and early 2007. The deepest water levels were in 1995 and during 2013-15. Over the long-term, water levels have been relatively stable in this well since 1995. S-8A is located four miles west of the Central Valley Highway and two miles north of Highway 46. Depth to water has ranged from about 200 to almost 435 feet. The shallowest water levels were during 1998-2001, and during early 2007. The deepest water levels were in Summer 2008, 2009, and 2014. Water levels in this well were relatively stable prior to 2007 and have fallen since then. S-9A is located half a mile south of Merced Avenue and three and a half miles west of the Central Valley Highway. Depth to water has ranged from about 230 feet to 340 feet. The shallowest water levels were in 2000-01 and Spring 2007. The deepest water levels were in late Fall 2005, the Summers of 2008-10, and in 2014-15. Water levels in this well were relatively stable prior to 2007, and have declined since then.

Well T25S/R24E-22N (PP 1029 DGN) is a supply well perforated from 401 to 890 feet in depth. Records are available from 2007-2011. Depth to water has ranged from about 160 to 400 feet. The drawdown between Spring 2007 and Summer 2010 was 240 feet. Water-level measurements aren't available after early 2011, because of restricted access to well sounding port. Water levels in all of

these wells are indicative of confined conditions.

Transducer Measurements for Northwesterly SWSD Wells. S-10A is located near Pond Road and Corcoran Road. Depth to water has ranged from about 180 to 340 feet. The shallowest water levels were in 2000-01 and early 2007. The deepest water levels were in the Summers of 2008-10 and in 2014. Water levels in this well were relatively stable until 2007 and have declined since then. S-11 is located about half a mile east and one and a half miles south of S-10A. Depth to water has ranged from about 180 to 333 feet. The deepest water levels were during 2007-2010 and 2013-15. Water levels in this well were relatively stable prior to 2007, and then fell thereafter. Water levels in these wells appear to be influenced by SWSD banking activities and also by pumping from irrigation wells that are used for the newly developed orchards in the area.

Transducer Measurements for Southerly SWSD Well. MW-948L3 is located about half a mile north of Sullivan Road near I-5. Depth to water has ranged from about 195 to 290 feet. The shallowest water levels were during 2000, early 2001, and in early 2007. The deepest water levels were in Summer of 2007-10 and in 2014-15. Water levels in this well were relatively stable from 2008-12, then fell during 2013-15.

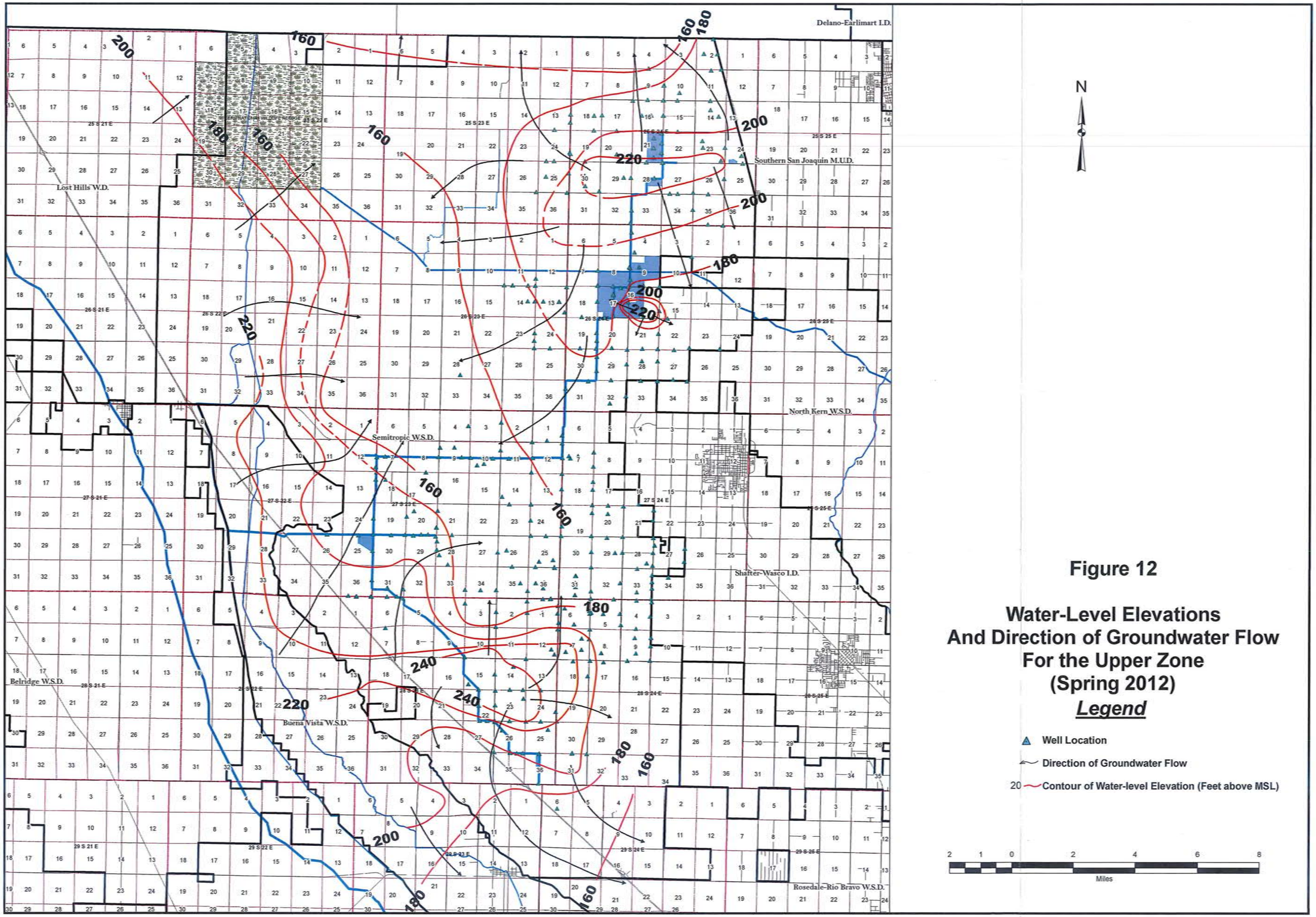
Upper Zone

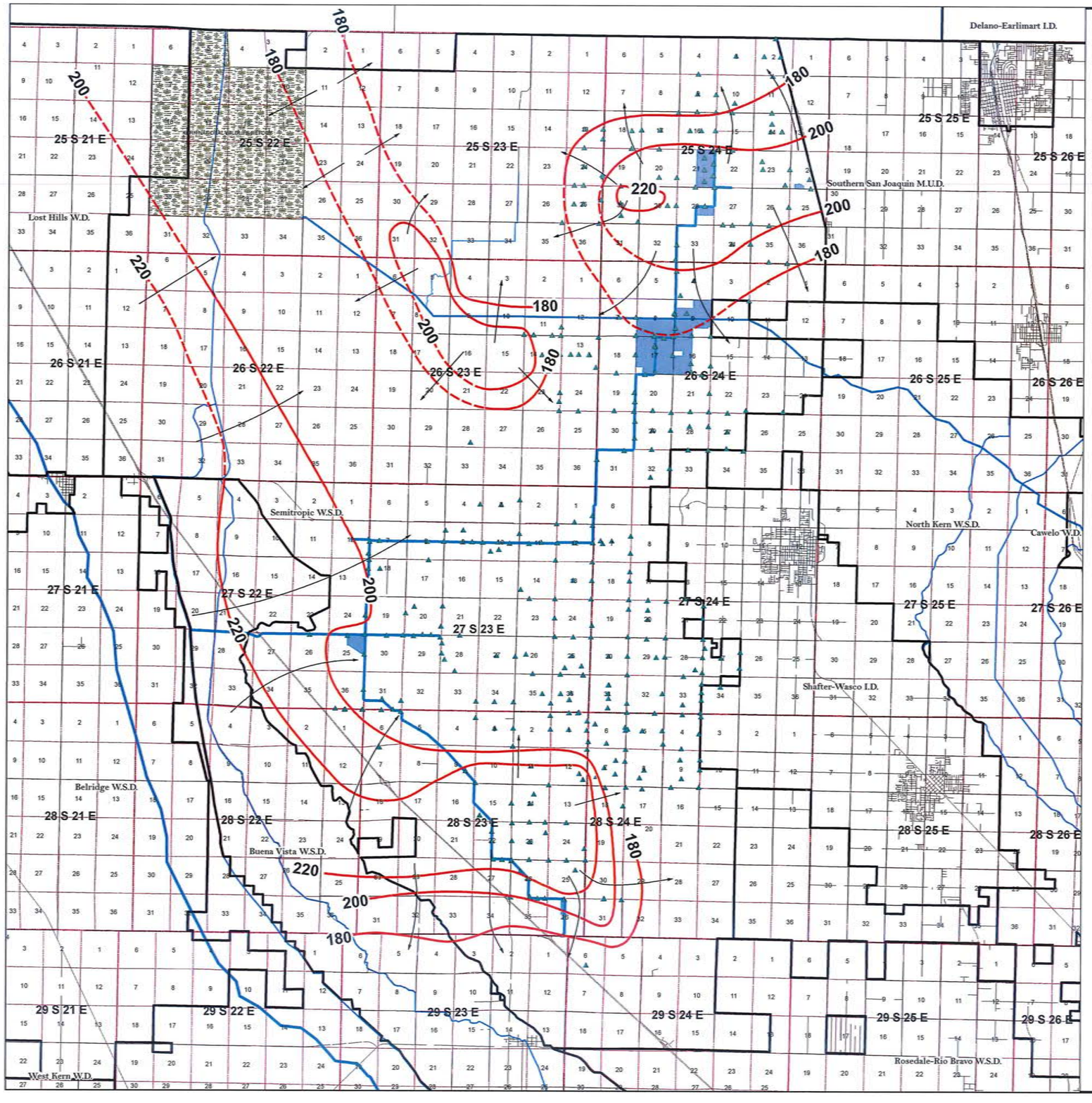
Water-Level Elevations and Direction of Groundwater Flow

Figures 11, 12, 13, and 14 show water-level elevations and the direction of groundwater flow in the upper zone for Spring 2011, 2012, 2013, and 2015. It was not possible to prepare a map for Spring 2014, due to extensive pumping at that time. In Spring 2011, water-level elevations in the upper zone exceeded 200 feet over a large area near and west of the west boundary of the SWSD, and beneath the northeast part of the District. In Spring 2009, the groundwater ridge in the area west of Pond was elongated from the southwest to northeast, as shown in previous maps. Groundwater in the upper zone was flowing out of the District to the north and south, and into the District from the west.

Generally similar water-level elevations were present in Spring 2012 as in 2011. The recharge ridge west of Pond was still evident. However, groundwater flow to the north was more predominant in Spring 2012. Groundwater in the upper zone was flowing into the District from the west, and out of the District to the north and south.

In Spring 2013 the same overall trends were present as in Spring 2012. Groundwater continued to flow into the SWSD from the west in the area north of Seventh Standard Road. Groundwater flowed out of the District to the north and south.


Delano-Earlimart I.D.
Southern San Joaquin M.U.D.
Lost Hills W.D.
North Kern W.S.D.
Semitropic W.S.D.
Shafter-Wasco I.D.
Belridge W.S.D.
Buena Vista W.S.D.
Rosedale-Rio Bravo W.S.D.
N
Figure 12
Water-Level Elevations
And Direction of Groundwater Flow
For the Upper Zone
(Spring 2012)
Legend
Well Location
Direction of Groundwater Flow
20 Contour of Water-level Elevation (Feet above MSL)
2 1 0 2 4 6 8
Miles



N

Figure 13

Water-Level Elevations And Direction of Groundwater Flow For the Upper Zone (Spring 2013)

Legend

- Well Location
- Direction of Groundwater Flow
- 180 — Water-Level Elevation Contours(Feet above M.S.L) for Upper Zone.

2 1 0 2 4 6 8

Miles

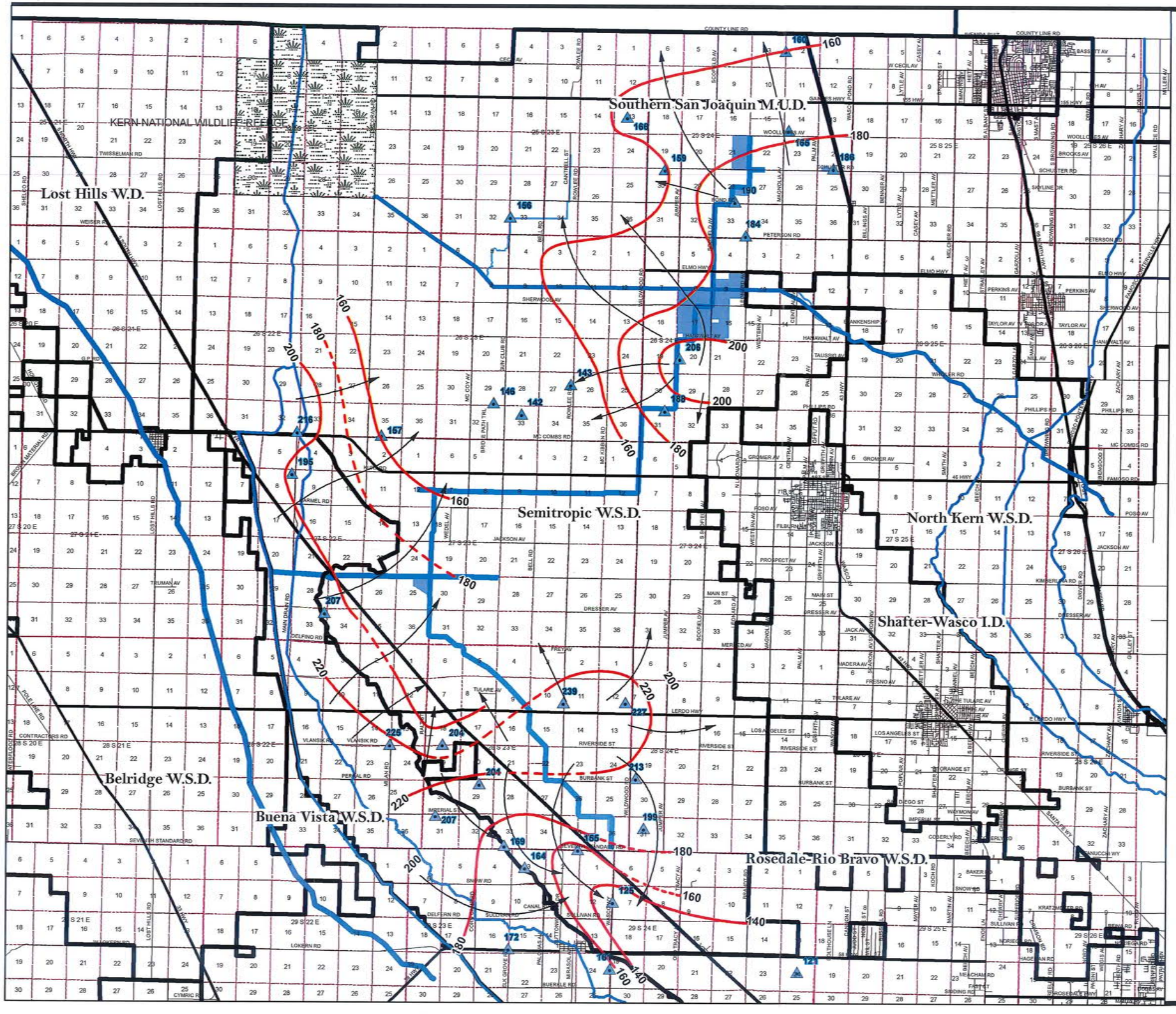


FIGURE 14-
Water-Level Elevations And Direction of Groundwater Flow For the Upper Zone (Spring 2015)

Legend

- 227 — Well & Water-Level Elevation (Feet above MSL)
- Direction of Groundwater Flow
- 100 — Contour of Water-level Elevation (Feet above MSL)

In Spring 2014, the same trends were apparent. Groundwater was flowing with the SWSD from the west in the area near Vlansik Road. The recharge ridge west of Pond was wider. Groundwater was flowing out of the District to the north and south.

Water-Level Changes

2011-15. Throughout the SWSD, water levels in the upper aquifer fell during this period, except in two areas, one of which was northwest of Wasco. Water-level rises in most wells were from 10 to 20 feet. One area was in the SWID system, the east part of the Alpha System, and in the P565 system. Another was in the B-369, B-21, and west part of the B-230 systems.

In the Buena Vista WSD, water levels in most wells fell during 2011-15. The declines usually ranged from about 5 to 30 feet, and were generally the greatest in the part of the area south of Lerdo Highway. Water-level declines in the SWSD in the part of the district north of McCombs Road usually ranged from about 10 to 50 feet, and were greatest in the Alpha and P-667 Systems. In the part of the SWSD south of Kimberlina Road and north of 7th Standard Road, the declines were usually less than 20 feet. In the part of the District south of 7th Standard Road, declines in most wells ranged from about 30 to 40 feet. These declines were in the south part of the Wegis System.

Long-Term. Comparison of the Spring 1995 and Spring 2015 water-level elevation maps for the upper zone indicates a predominance of water-level rises, usually ranging from about 13 to 33 feet. The largest rises (exceeding 25 feet), were near Poso Creek and the SWSD intentional recharge facility. Water-level rises ranging from about 10 to 20 feet were present in most of T25S. Water-level rises of less than 10 feet were common along the west edge of the SWSD and in much of the adjoining BVWSD. There were water-level declines of from 5 to 10 feet in several wells, but these appear to be anomalous.

The Buena Vista WSD provided water-level hydrographs for eight monitor wells which tap the upper zone, and the records extend back to the early to mid-1990's. Overall these hydrographs indicate relatively stable levels over the long-term. For DMW-2, the water levels rose for 1992 through 1998, were relatively stable from 1999 through 2006, fell from 2001-2008, then rose during 2009-10. For DMW-4 water level rose from 19992-1996, were relatively stable from 1996-2006, fell from 2005 to 2008, then rose after 2001. For DMW-7, water levels rose from 1994-98, then gradually fell through early 2011. For DMW-8, water levels rose from 1994 through 1997, were then relatively stable through 2000, slightly declined through 2007, then fell about 40 feet during 2007, then rose after early 2009. For

DMW-10A, water levels rose from about 140 feet in 1995 to about 90 feet in 2000, fell to about 120 feet by early 2005, were relatively stable through early 2008, then generally fell. The deepest levels were in 2008. For Well DMW-12B, water levels rose from 1995 to 1998, were relatively stable during 1998-2000, fell from 2001 to 2004, rose during 2006-07, fell during later 2007, recovered, and then declined after early 2008.

Figure 15 is a typical water-level hydrograph for a well tapping the upper zone in the central part of the SWSD. Well T27S/R24E-33A is located near Leonard and Dresser Avenues, southwest of Wasco. The casing in this well is perforated from 230 to 374 feet in depth. Although some perforations in this well may be below the 300-foot clay, the water-level fluctuations are typical of the upper zone. Prior to 2007, seasonal fluctuations were usually less than 20 feet. The overall trend has been rises during wet periods (the mid-1980's), and declines during droughts (1988-1993, 2007-09, and 2012-15). The water level in this well rose between Spring 1995 and Spring 2001, and then was relatively constant through 2007, before falling about 60 feet in 2007, between early 2007 and early 2009. The water level then recovered by early 2012, and has fallen since then.

Transducer Measurements. Transducer measurements are available

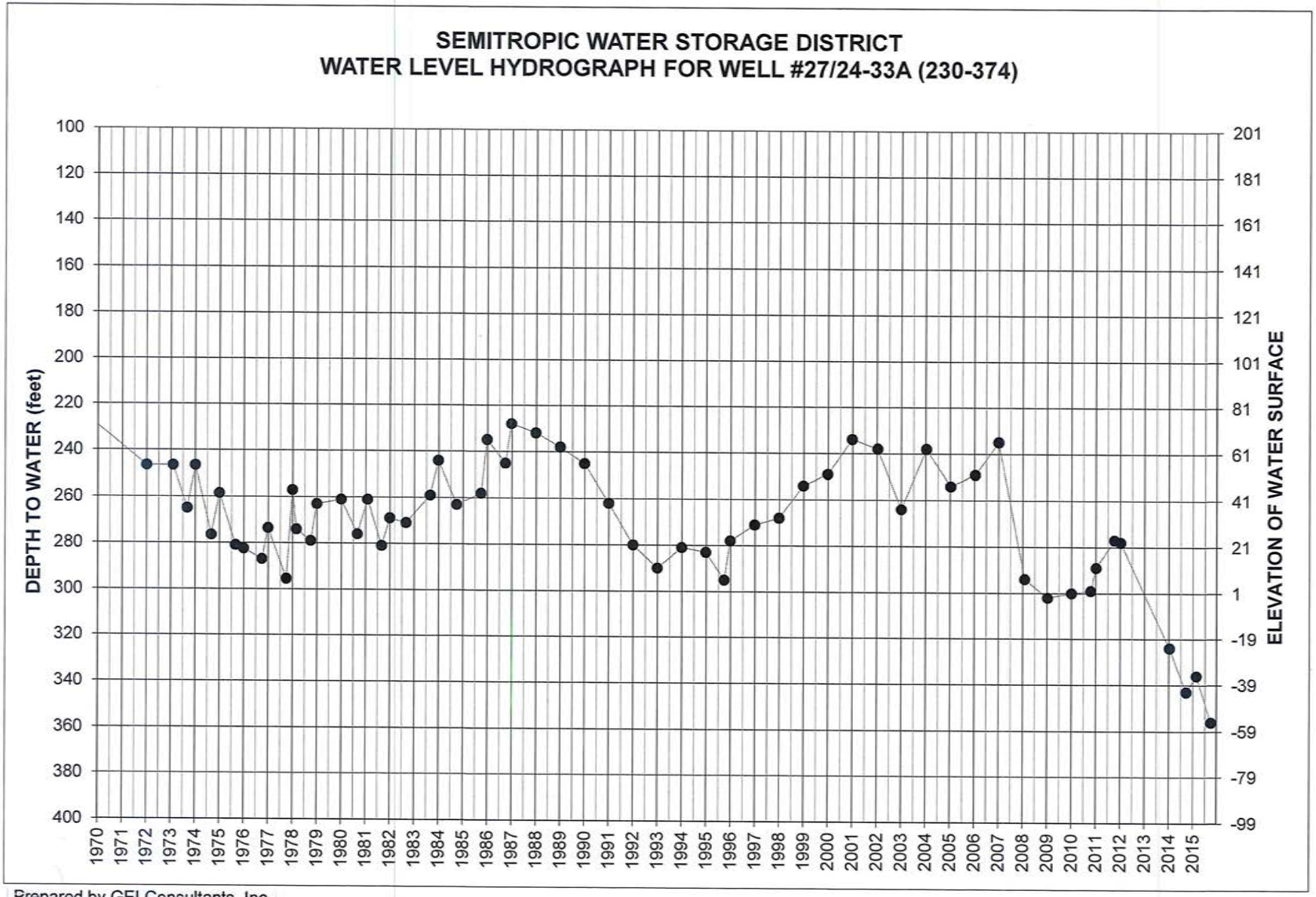


FIGURE 15-TYPICAL WATER-LEVEL HYDROGRAPH FOR THE UPPER ZONE

for SWSD monitor well S-1, located south of Highway 46 and west of Corcoran Road. Depth to water in this well has ranged from about 15 to 50 feet. Measurements for this well indicate that the shallowest water levels were during 1997-2000 and in 2006. After 2006 and through 2009, the water level in this well fell almost 20 feet, apparently due to increased pumping in this area. After early 2010, the water level rose about 10 feet through 2012, then fell through early 2015.

GROUNDWATER QUALITY

Both water supply wells and monitor wells have been periodically sampled as part of this monitoring program. Figure 16 shows the locations of wells which have been sampled as part of this program. Each entity that conducts well sampling arranges for the chemical analyses for the area within its jurisdiction. The only entities that did not conduct groundwater sampling as part of this program were the Rosedale-Rio Bravo WSD and Southern San Joaquin MUD. During wet periods, most of the water supply wells are not in operation and are generally not sampled. In Spring 2007, the Semitropic WSD sampled a number of water supply wells in the District to obtain more information on the quality of water that was to be recovered. Extensive water sampling was also done in 2013.

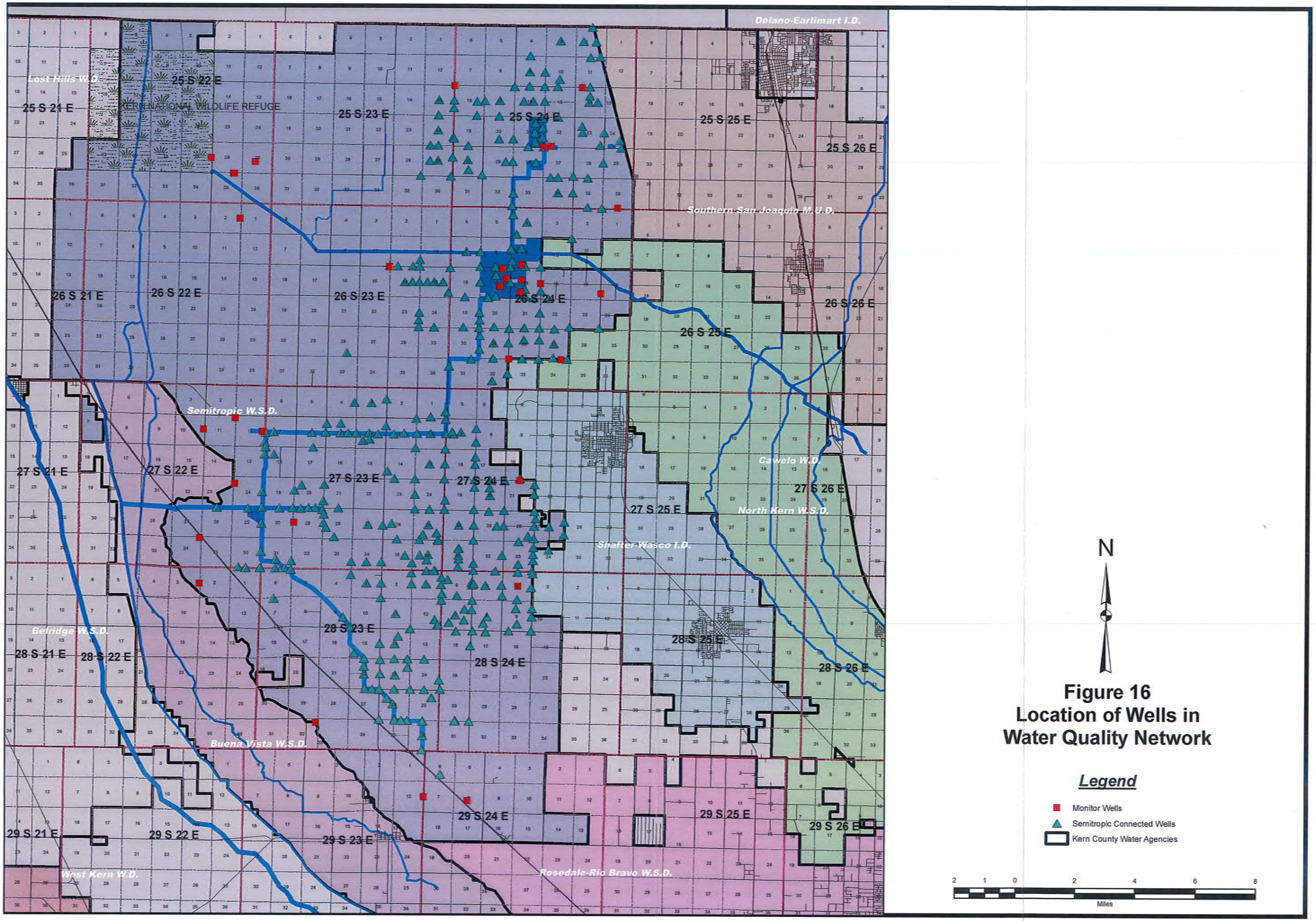


Figure 16
Location of Wells in Water Quality Network

Total dissolved solids (TDS) was selected for initial evaluations, particularly because of a concern about possible enhanced migration of high salinity groundwater from the west due to banking activities. Nitrate was selected because a fairly large area of shallow high nitrate groundwater is present in part of and east of the SWSD. This was considered one of the most important inorganic chemical constituents in terms of drinking water quality. Arsenic became a greater concern when the maximum contaminant level (MCL) for drinking water was lowered from 50 to 10 ppb. Uranium is also of concern because of localized high activities in groundwater in some parts of the area. Hexavalent chromium was also mapped for this report, because of the development of a new MCL for this constituent and the presence of high concentrations in some wells in the District.

There are generally significant differences in concentrations of TDS and constituents such as nitrate between the shallow and deep groundwater in the study area. For salinity (TDS), separate maps are thus prepared for the shallow and deep groundwater. For nitrate, low concentrations are present in the deep groundwater, and where concentrations are high, they are usually for wells tapping shallower groundwater. Arsenic concentrations are generally higher in the deeper groundwater, as compared to in the shallow groundwater. Uranium activities are expected to be higher in the shallow groundwater, which is often oxidized.

Total Dissolved Solids

Shallow Groundwater

Figure 17 shows TDS concentrations in shallow groundwater, generally above a depth of about 300 feet, in the study area for February-October, 2013. It should be noted that "shallow" as used herein, refers to water-producing strata below a depth of about 50 feet, and not to groundwater within 50 feet or less of the land surface, such as in part of the Buena Vista WSD. The shallowest groundwater can be of much higher salinity than the underlying groundwater. TDS concentrations in the shallow groundwater have generally been less than 500 mg/l in most of the central part of the SWSD. The TDS concentrations in shallow groundwater exceeded 1,000 mg/l beneath the westernmost part of the study area, except beneath most of the Buena Vista WSD south of Seventh Standard Road. In the area north of Buttonwillow, the boundary of this higher salinity groundwater becomes progressively farther west to the north.

Several high salinity areas have been delineated by previous well sampling programs in the east part of the study area. Most of the information was derived from Kern County Water Agency water quality maps, as provided in annual reports. TDS concentrations exceeded 1,500 mg/l in the shallow groundwater beneath several areas. The northerly area was primarily north of Pond

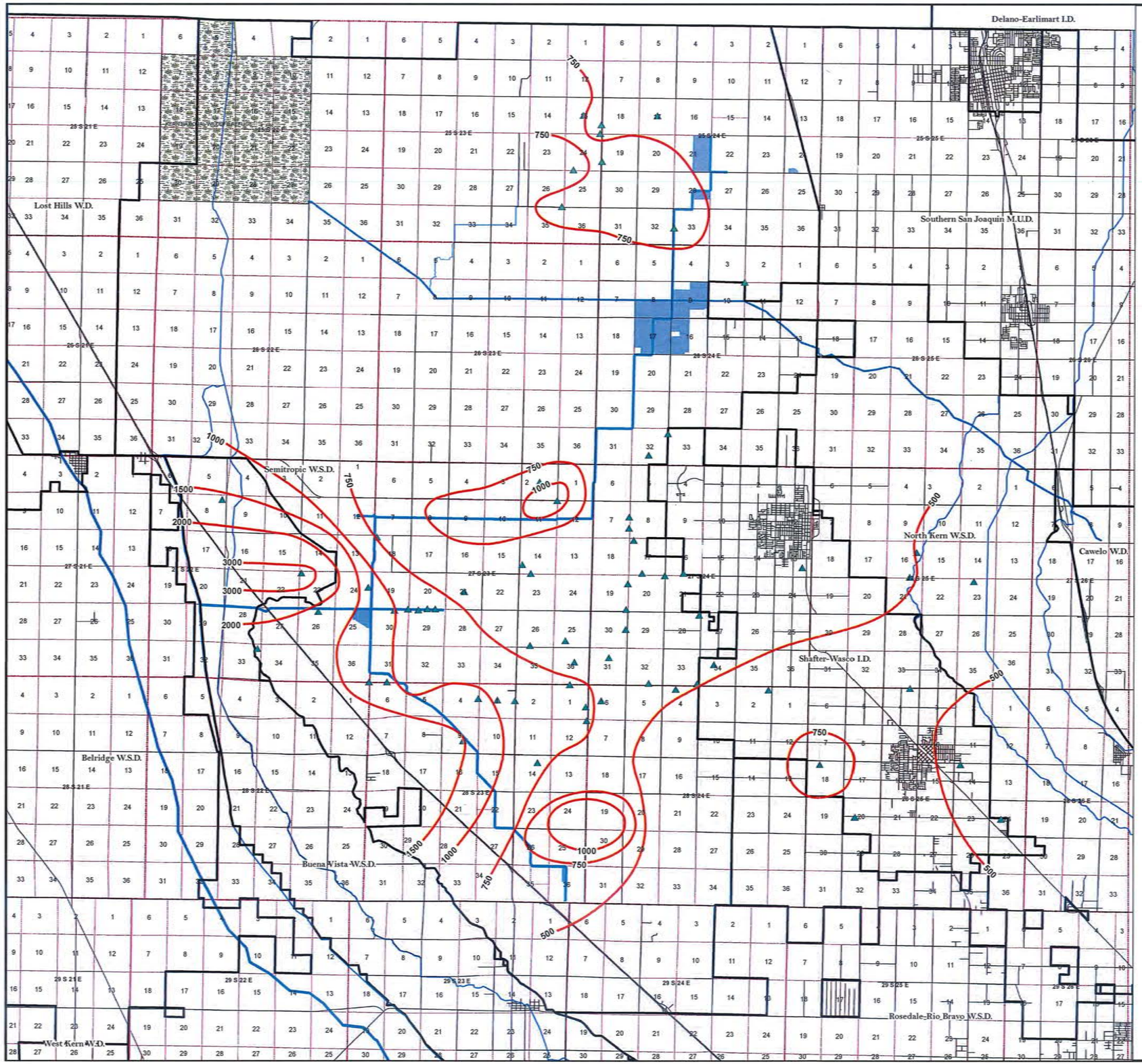


FIGURE 17-

Total Dissolved Solids in Shallow Groundwater (February - October, 2013)

Legend

▲ Location of Well sample site

200 ~ Contour of Total Dissolved Solids Concentration (mg/L)

1 0.5 0 1 2 3 4
Miles

Road and south of Cecil Avenue, southwest of Delano. The western half of this area was in the SWSD and the eastern half in the Southern San Joaquin MUD. The second area was primarily beneath Wasco, and extended south to near Merced Avenue. This high TDS area was bounded by low salinity (less than 500 mg/l TDS) groundwater to the west, south, and north. The third high TDS area was located along the Central Valley Highway, primarily between Merced Avenue and Seventh Standard Road. This area was elongated from northwest to southeast, and was primarily in the Shafter-Wasco Irrigation District. The southerly high TDS area was bounded by low TDS groundwater to the southwest, north, and northeast. As of 2013, there were remnants of the high TDS concentrations in the northerly and southerly areas, but sampling results were limited due to a lack of wells tapping the upper zone in the eastern part of the study area.

Changes in Salinity in Westerly Monitor Wells. Appendix C contains electrical conductivity hydrographs for the eight Buena Vista WSD monitor wells tapping the upper zone along the west boundary of the study area. Analyses for DMW-1, located southeast of Lost Hills, indicate an increasing trend for electrical conductivities between 1992 and 2009. After 2009, the electrical conductivities decreased. Analyses for DMW-2, located about

two miles south of Highway 46 and west of the Eastside Canal, indicate a slight TDS increase during 1992-2000, except for one anomalous sample, then a significant decrease during 2001-03. Then the conductivities slightly increased through 2008, and have been relatively stable since then.

Analyses for DMW-3 indicate a significant increase in electrical conductivity during 2002-03. This well is located about three miles north of Lerdo Highway and east of the Eastside Canal. Electrical conductivities of water from this well were relatively stable after 2003. Analyses for DMW-4, located about one mile north of Lerdo Highway and west of the Eastside Canal, indicate increasing electrical conductivities through 1995, followed by relatively constant values through 1999. Electrical conductivities then increased through 2001, then decreased, and were relatively stable through 2013.

Analyses for DMW-5, which is located about one mile south of Lerdo Highway and west of the Eastside Canal, indicate increasing electrical conductivities during 1991-95. After 1995, the conductivities slightly increased through 2004 and then were stable through 2013. This well is in an area of relatively low salinity groundwater in the upper zone, between Lerdo Highway and Seventh Standard Road. Analyses for DMW-6 indicate large fluctuations in TDS concentrations before 1997, and increasing

concentrations through 2006. Since that time, electrical conductivities have decreased. This well is also in the area of low salinity groundwater in the upper zone.

DMW-7 and 8 are located between Seventh Standard Road and Highway 58. Records for DMW-7 indicate relative stable electrical conductivities through 2000. The conductivities increased during 2001 and then gradually decreased to near the pre-existing concentrations by 2005. Since then, the concentrations increased through 2008, and then decreased. The electrical conductivities in water from DMW-8 decreased from 1994 to 1999, and has been relatively stable since then. This may be associated with recharge from water-banking projects on the Kern Fan.

The overall trend during 1998-2013 for the northwestern most part of the Buena Vista WSD was increasing electrical conductivities in water from most of the monitor wells. South of Seventh Standard Road, electrical conductivities in water from two Buena Vista WSD monitor wells generally stayed about the same.

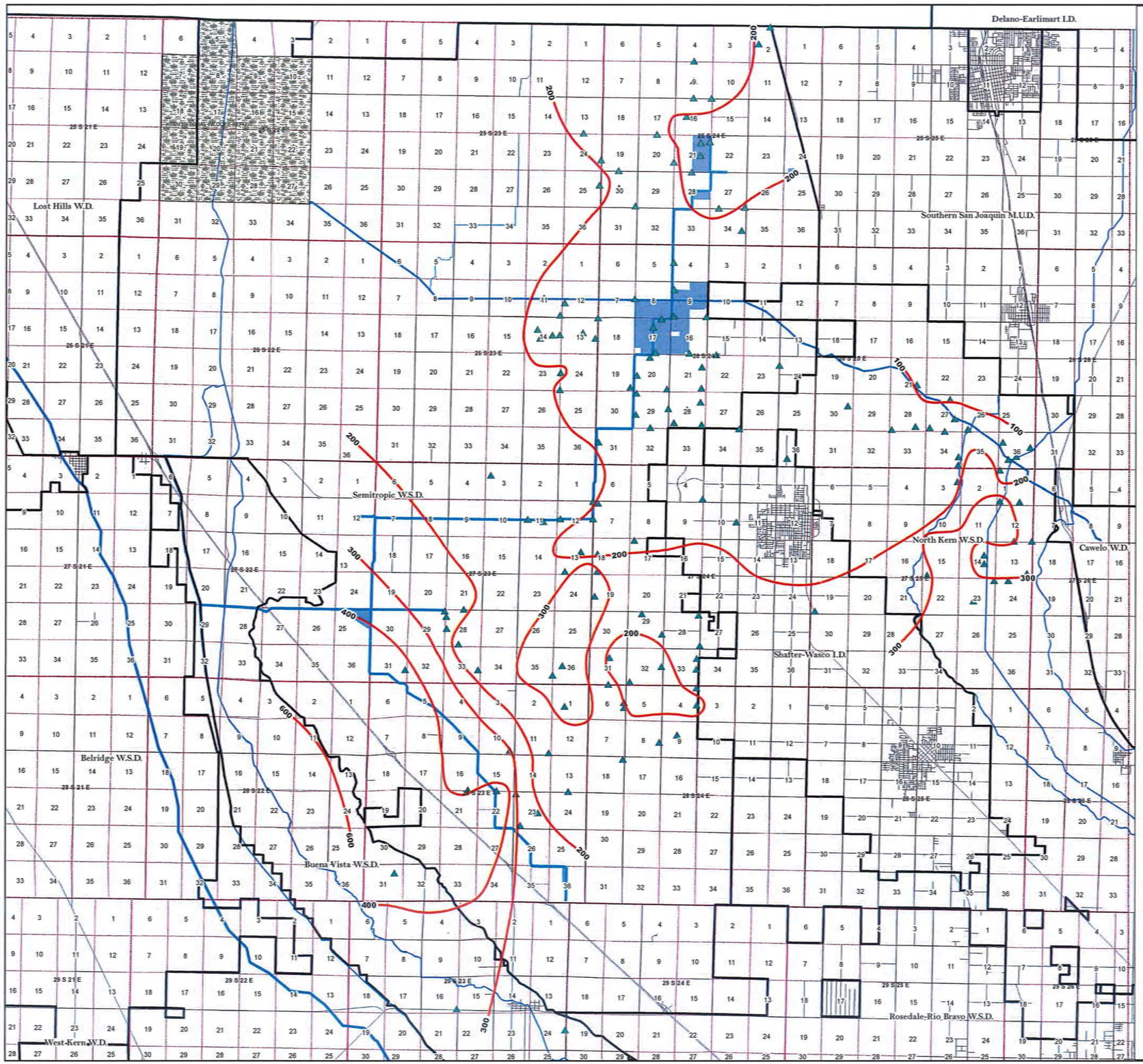
The five westerly monitor wells in the SWSD were sampled annually during Summer 1994-95 and 1998-2003. Analyses indicate that TDS concentrations in water from the northerly of these wells (S-1) generally increased during this period. Updated information is not available.

Deep Groundwater

Figure 18 shows TDS concentrations in the deep groundwater for February-October 2013. Little information is available on the TDS concentrations in deep groundwater in the area west of the Main Drain, because of the lack of deep wells in this area. In 2013, low TDS concentrations were less than 500 mg/l in the deeper groundwater beneath most of the District, except near the southwesternmost part. TDS concentrations were less than 200 mg/l in a large area northwest of Wasco, near Wasco, and to the east in part of the NKWSD.

Nitrate

Figure 19 shows nitrate concentrations in the groundwater, based on sampling during February-October, 2013. Nitrate concentrations beneath the westerly part of the study area were non-detectable in 2013, in about the same area as shown by the results of sampling in 2007, as reported in previous biennial reports. Most of this area was west of Gun Club Road and north of Lerdo Highway, and southwest of I-5 farther to the south. The areas of non-detectable nitrate concentrations are indicated to be where reducing or anaerobic conditions are prevalent in the groundwater.



N

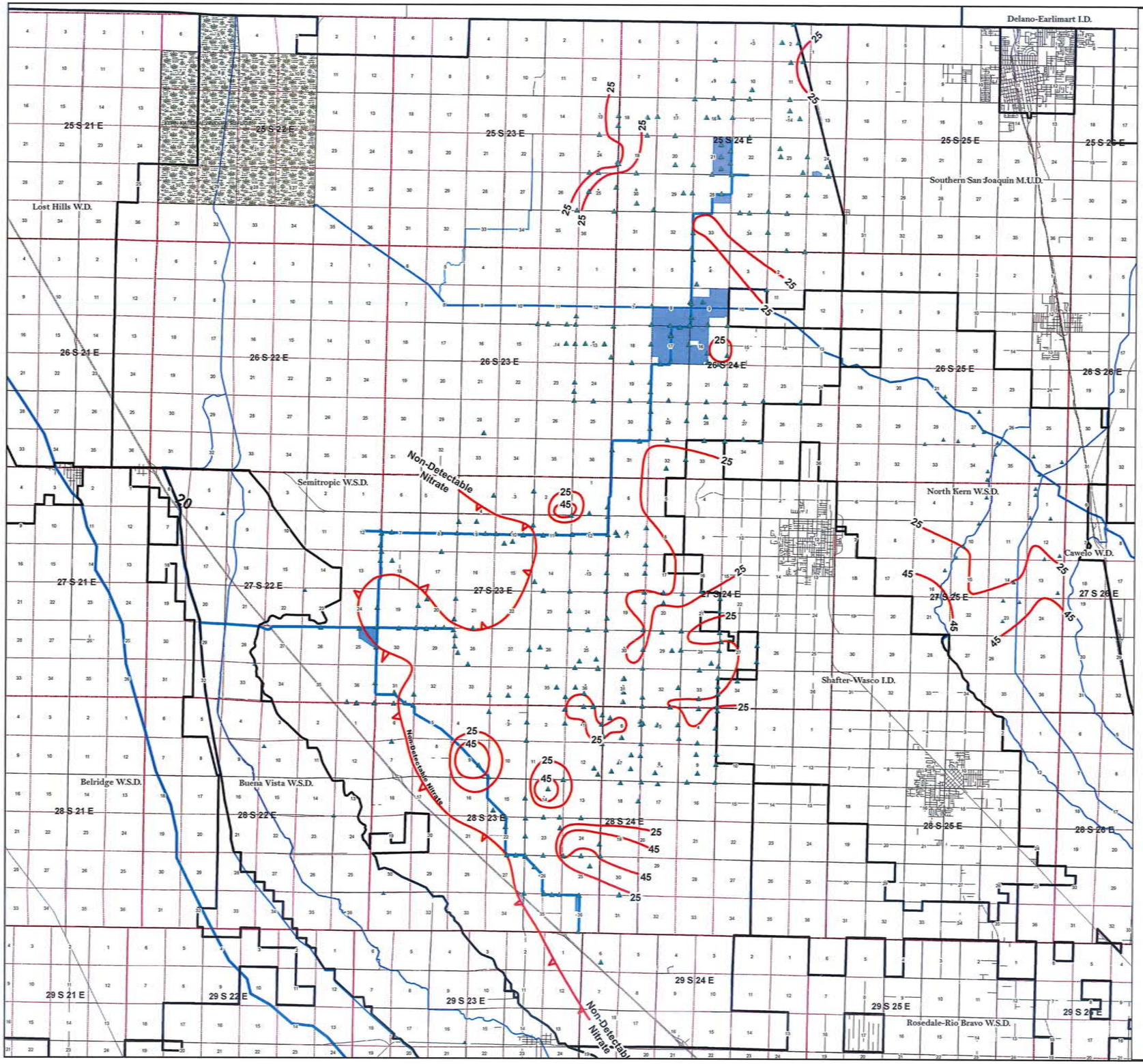
FIGURE 18-
Total Dissolved Solids in Deep Groundwater (February - October, 2013)

Legend

▲ Location of Well sample site

200 ~ Contour of Total Dissolved Solids Concentration (mg/L)

1 0.5 0 1 2 3 4
Miles



N

Figure 19

Nitrate Concentrations in Groundwater (February - October 2013)

Legend

- Location of Well sample site
- 45 Contour of Nitrate Concentration (mg/l)

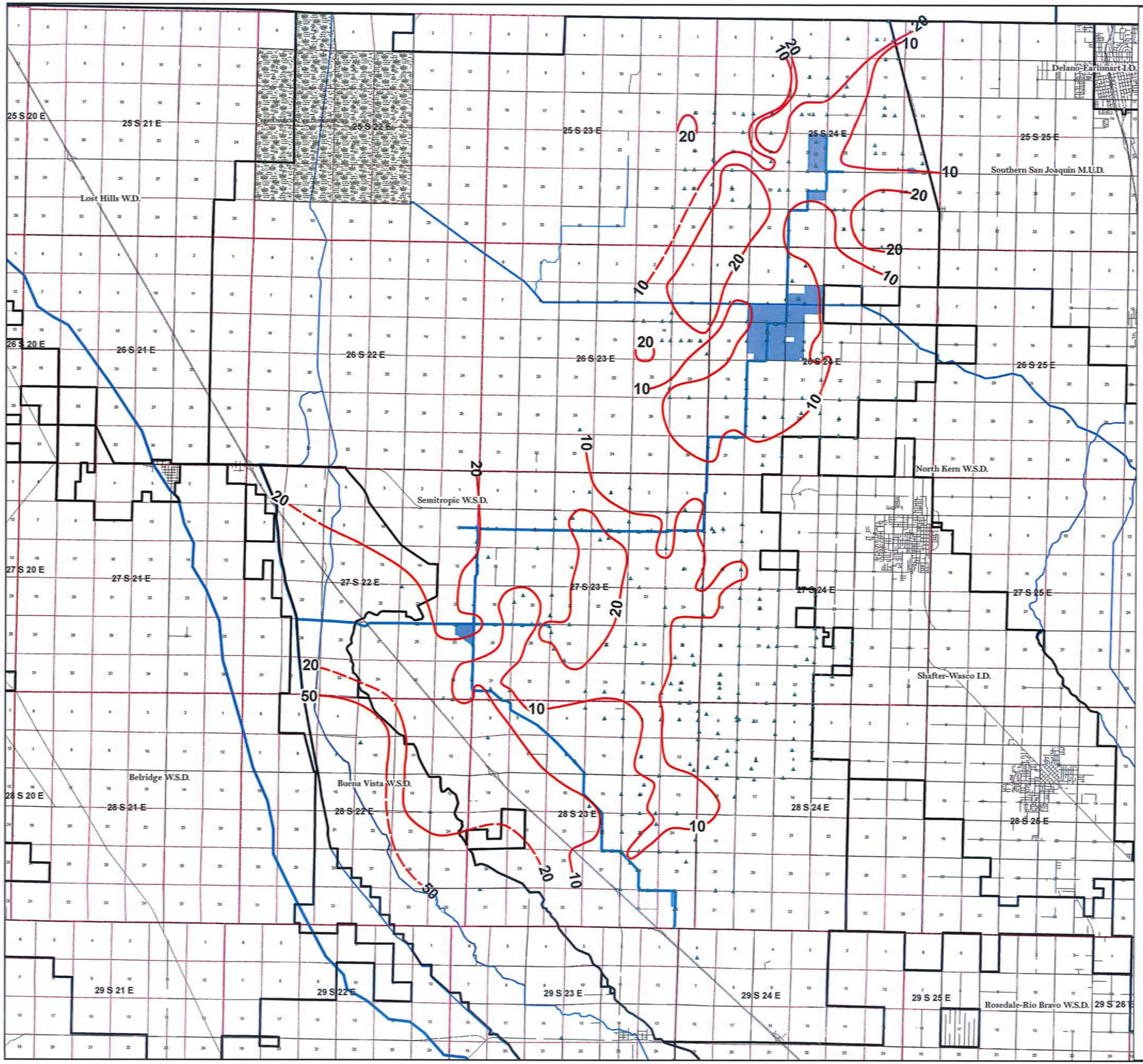
2 1 0 2 4 6 8

Miles

The only identified part of the study area where nitrate concentrations in the shallow groundwater were known to exceed the MCL in 2013 were relatively small areas west and southwest of Wasco. There is a lack of documentation of high nitrate concentrations in the east part of the area as of 2013, due to a lack of sampling of wells that tap the upper zone.

Arsenic

Arsenic concentrations were determined in water from a number of supply wells and monitor wells in the SWSD during February-October, 2013 (Figure 20). The MCL for arsenic in drinking water is 10 ppb. The lowest arsenic concentrations in groundwater in 2013 were generally beneath the east part of the District, usually in the area south of T25S. Analyses for arsenic for the 2013 sampling weren't available for the northwest part of the District. In contrast, the highest arsenic concentrations in 2007 were in groundwater to the southwest, where they exceeded 20 ppb, and in some cases 50 ppb. Results of previous sampling indicated that arsenic concentrations were generally somewhat higher in groundwater beneath the northwest part of the District, where the 300-foot clay is present. Also, arsenic concentrations generally increased toward the old Tulare lake-bed, a regional trend previously noted in the San Joaquin Valley by the U.S. Geological Survey. Most of the data points shown in Figure 20 are for the deep groundwater, and lower arsenic concentrations



N

Figure 20

Arsenic Concentrations in Groundwater (February - October 2013)

Legend

▲ Location of Well sample site

20 ~ Contour of Arsenic Concentration (ppb)

2 1 0 2 4 6 8

Miles

are indicated to be present in the shallow groundwater.

Hexavalent Chromium

Hexavalent chromium concentrations for samples collected during February-October, 2013 are shown in Figure 21. The MCL for hexavalent chromium is 10 parts per billion (ppb). There is a fairly large area northwest of Wasco where hexavalent chromium concentrations exceeded the MCL. This area was generally in approximately the same area as where arsenic concentrations exceeded the MCL in 2013. There were two other smaller areas southwest of Wasco where hexavalent chromium concentrations exceeded the MCL. Those were also generally where arsenic concentrations also exceeded the MCL.

Uranium

Figure 22 shows uranium activities in water from wells sampled during February-October, 2013. The MCL for uranium in drinking water is 20 picocuries per liter. Uranium activities were less than 5 picocuries per liter beneath most of the SWSD. However, uranium activities exceeded 20 picocuries per liter in a northwesterly trending area west of Shafter and in two other nearby small areas. Uranium activities exceeded 30 picocuries per liter in one well in the north part of the District. Uranium activities exceeded 10 picocuries per liter in several other localized areas.

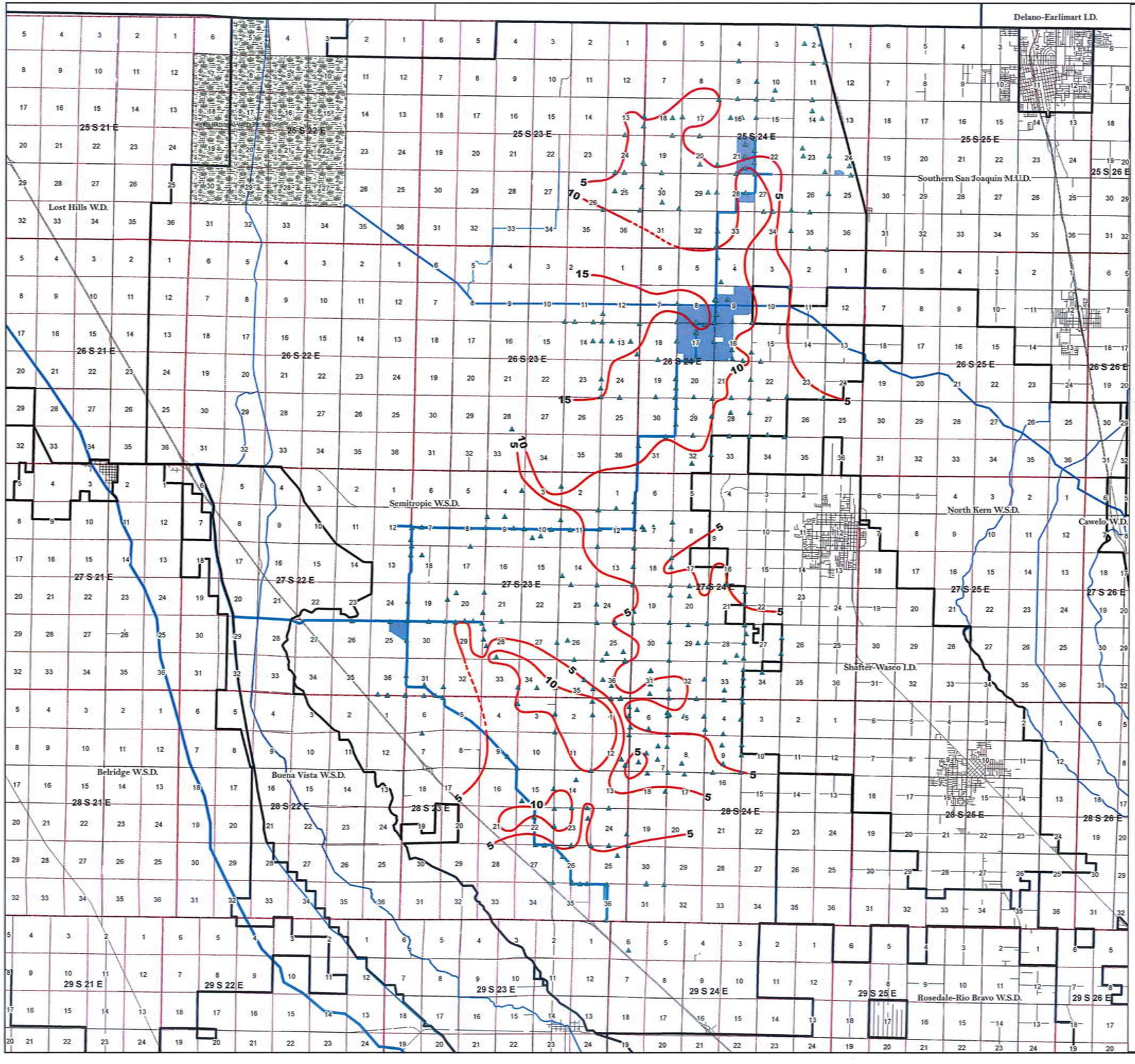


Figure 21

Hexavalent Chromium in Groundwater (February - October 2013)

Legend

▲ Location of Well sample site

15 ~ Contour of Hexavalent Chromium Concentration (ppb)

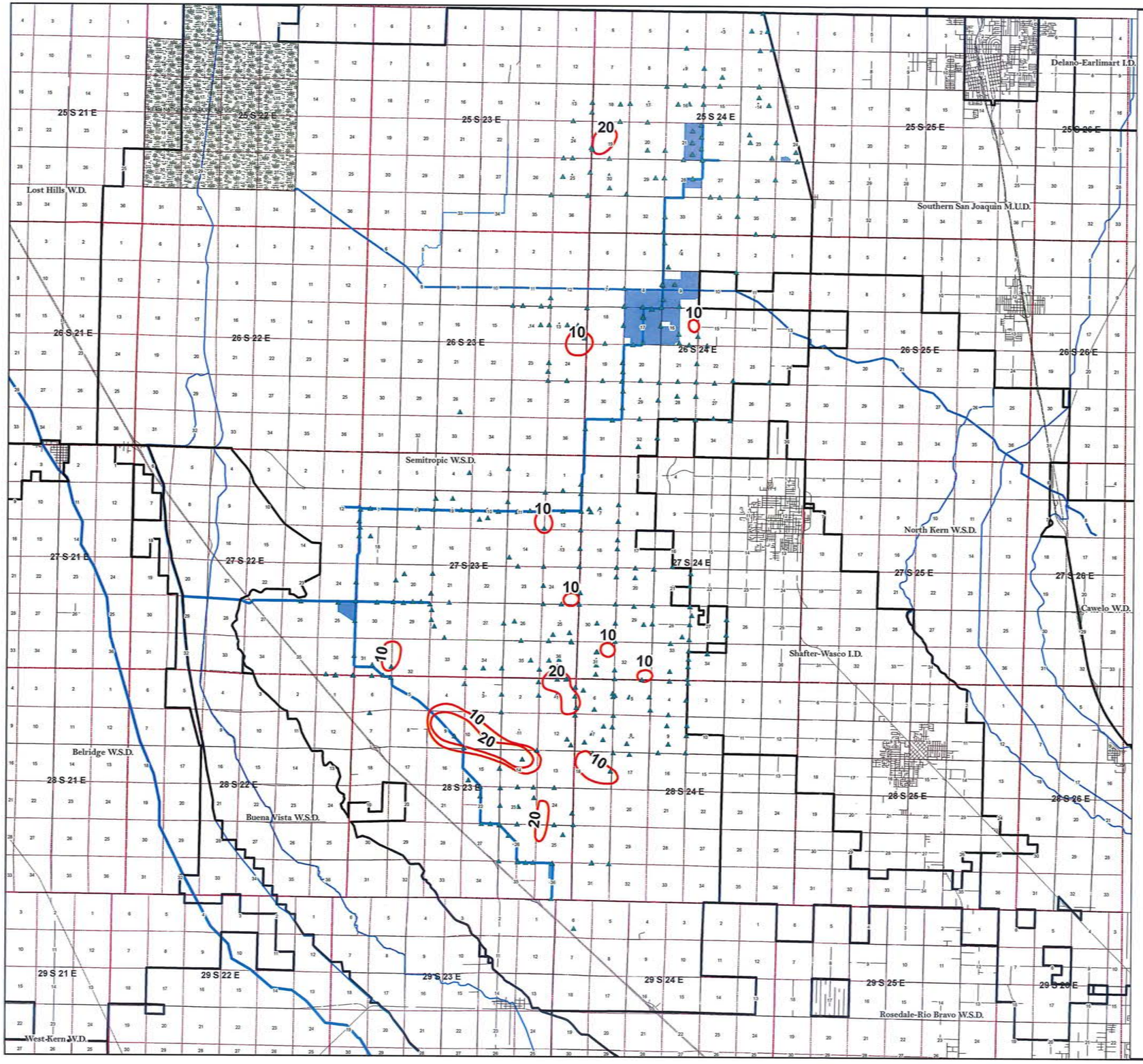


Figure 22

Uranium Activities in Groundwater (February - October 2013)

Legend

- ▲ Location of Well sample site
- 20 ~ Contour of Uranium Activity (pCi/l)

2 1 0 2 4 6 8

Miles

OTHER ACTIVITIES AFFECTING THE WATER BUDGET

Appendix D contains information on surface water deliveries, intentional recharge, crop consumptive use, and estimated pumpage (where available) for the SWSD and adjoining entities for 2011 and 2014. Following is a summary of this information.

Southern San Joaquin MUD

The average delivery of surface water by the District was 112,400 acre-feet per year from 1965-2014. Deliveries were 132,500 acre-feet in 2011, or 18 percent above average, 142,000 acre-feet in 2012, or 26 percent above average, 58,200 acre-feet in 2013, or 48 percent below average, and 60,100 acre-feet in 2014, or 47 percent below average.

Groundwater pumpage in the District is not measured or estimated.

North Kern Water Storage District

The average long-term delivery of surface water by the District was 175,800 acre-feet per year during 1954-2014. Deliveries in 2011 were 340,700 acre-feet (including in-district canal losses), 203,200 acre-feet of which were for intentional recharge. Deliveries in 2012 were 153,400 acre-feet (including in-district canal losses), of which about 7,300 acre-feet were

for intentional recharge. Deliveries in 2013 were 133,300 acre-feet (including in-district canal losses), of which about 1,000 acre-feet were for intentional recharge. Deliveries in 2014 were 126,900 acre-feet (including in-district canal losses), of which about 3,700 acre-feet were for intentional recharge. Deliveries of surface water for these four years were thus 195, 85, 75, and 70 percent, respectively, of the long-term average. None of the District wells are in the study area. Pumpage from private wells is not measured or estimated. Crop surveys were performed, but consumptive use for these four years was not determined.

Rosedale-Rio Bravo WSD

The estimated total surface water diversion into the District was about 276,700 acre-feet in 2011, of which about 260,000 acre-feet were delivered to intentional recharge facilities in the District. The estimated total surface water diversion into the District was about 37,600 acre-feet in 2012, of which about 37,600 acre-feet were delivered to intentional recharge facilities in the District. There were no surface water diversions into the District in 2013 and 2014. The average surface water diversion from 1962 to 2014 was about 64,700 acre-feet per year. Thus the

estimated surface water diversions in 2011 were about 428 percent, and in 2012 were about 58 percent of the long-term average. The estimated groundwater pumpage in the District was 79,800 acre-feet in 2011, 98,100 acre-feet in 2012, 134,700 acre-feet in 2013, and 149,600 acre-feet in 2014. The crop consumptive use in the District was determined to be 72,400 acre-feet in 2011, 73,600 acre-feet in 2012, 74,600 acre-feet in 2013, and 76,300 acre-feet in 2014, based on crop surveys conducted in those years.

Shafter-Wasco Irrigation District

The average farm delivery of surface water by the District from 1988 to 2014 was about 53,000 acre-feet. Surface water deliveries were 74,100 acre-feet in 2011 (40 percent above average), 33,900 acre-feet in 2012 (36 percent below average), 24,100 acre-feet in 2013 (55 percent below average), and 5,900 acre-feet in 2014 (89 percent below average). Groundwater pumpage in the District was not measured or estimated for this period. Crop surveys were performed, but consumptive use of crops for the four years was not determined.

Buena Vista WSD

The average surface water supply by the District was 136,600

acre-feet per year from 1970-2014. Surface water supplies were about 164,200 acre-feet in 2011 (21 percent above average), 105,500 acre-feet in 2012 (22 percent below average), 55,700 acre-feet in 2013 (60 percent below average). There were no surface water supplies in 2014. The estimated groundwater pumpage in the District was 8,000 acre-feet in 2011, 44,700 acre-feet in 2012, 75,000 acre-feet in 2013, and 100,400 acre-feet in 2014. The average crop consumptive use in the District from 1970 to 2014 was 107,100 acre-feet. The estimated crop consumptive use was 129,800 acre-feet in 2011, 115,200 acre-feet in 2012, 114,600 acre-feet in 2013, and 100,400 acre-feet in 2014. The average consumptive use for these four years was 115,000 acre-feet per year.

Semitropic WSD

From 1976 through 2014, the District's total surface water supplies averaged about 171,000 acre-feet annually. During the four years which are the subject of this report, annual surface water inflow ranged widely; from a low of about 7,500 acre-feet in 2014 to a high of about 353,000 acre-feet in 2011. The following table summarizes the annual surface water inflow, banked water, evapotranspiration of applied water, estimates of water use, and groundwater pumpage.

Water Supplies, Water Use, and Groundwater Pumping
(acre-feet)

	2011	2012	2013	2014
Surface Water Inflow	353,000	204,900	46,500	7,500
Banked Water (net)	244,000	66,400	10,700	3,600
ET of Applied Water	342,600	338,100	336,600	331,600
Applied Water:				
(e=90%)	380,700	375,700	373,900	368,500
(e=80%)	428,300	422,700	420,700	414,600
Deliveries to Irrigation	316,000	192,000	75,200	37,700
Pumpage:				
On-Farm				
(e=90%)	64,700	183,700	298,700	330,800
(e=80%)	112,300	230,600	345,500	376,900
District	0	0	115,700	144,600
Total				
(e=90%)	64,700	183,700	414,400	475,400
(e=80%)	112,300	230,600	461,200	521,500

The estimated annual consumptive use (or evapotranspiration, or "ET") of applied water was based on the District's annual crop survey and unit values of the consumptive use of applied water from Burt (2005)[1]. Assuming that the average irrigation efficiency ("e") may range from 80 to 90 percent, the estimated

[1]Charles M. Burt, Ph.D., P.E., August 18, 2005, Expert Report on Friant Service Area. The unit values are indicated to be averages for 1999-2003; ET Zone 15; with adjustments for bare spots and decreased vigor.

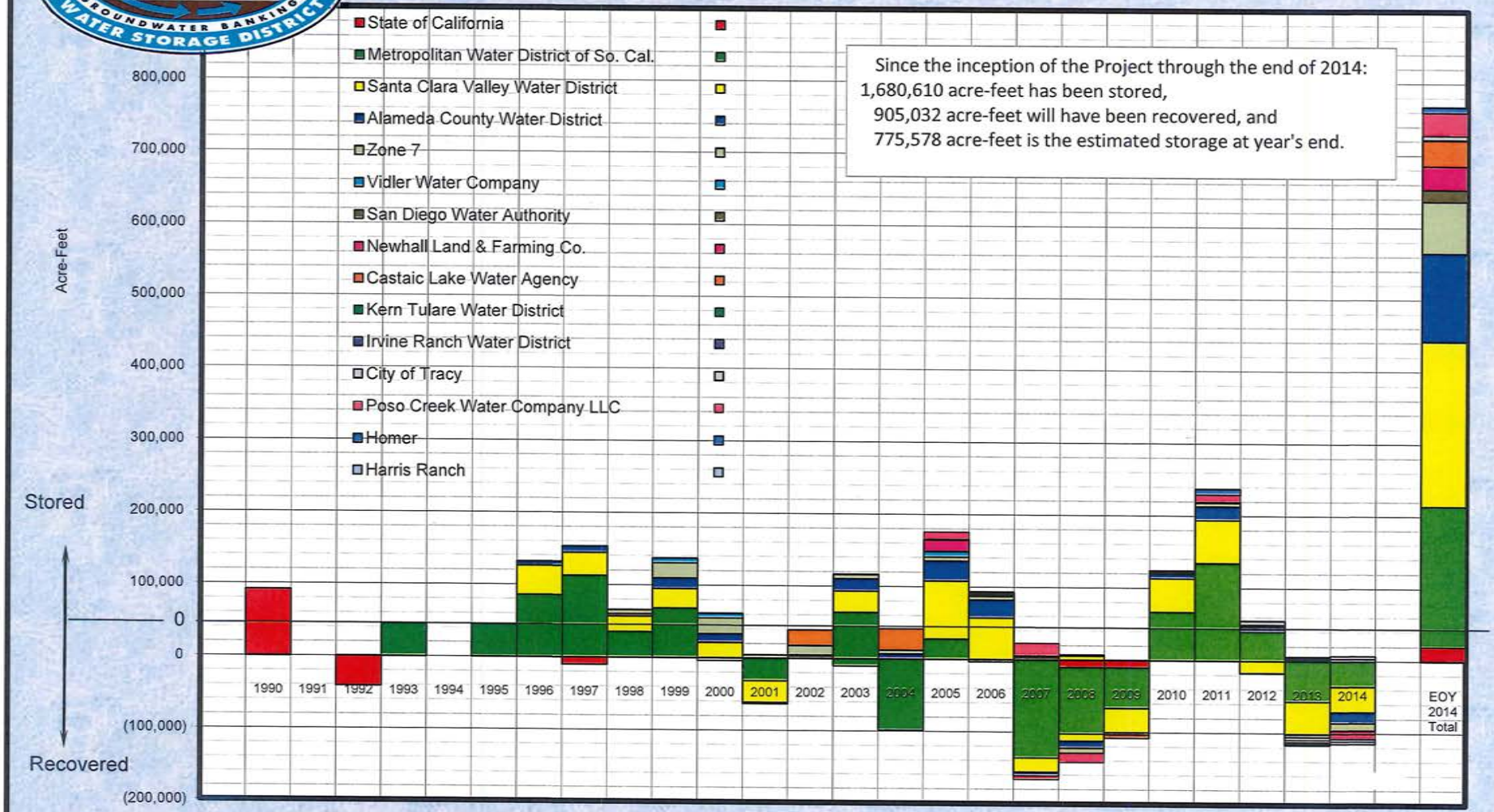
applied water is also expressed as a range. District deliveries to irrigation include surface water and District-pumped groundwater. Accordingly, on-farm pumping is estimated as the difference between the applied water and District deliveries to irrigation. District pumping includes pumping for in-District delivery and use as well as for delivery into the California Aqueduct when returning banked water to banking partners.

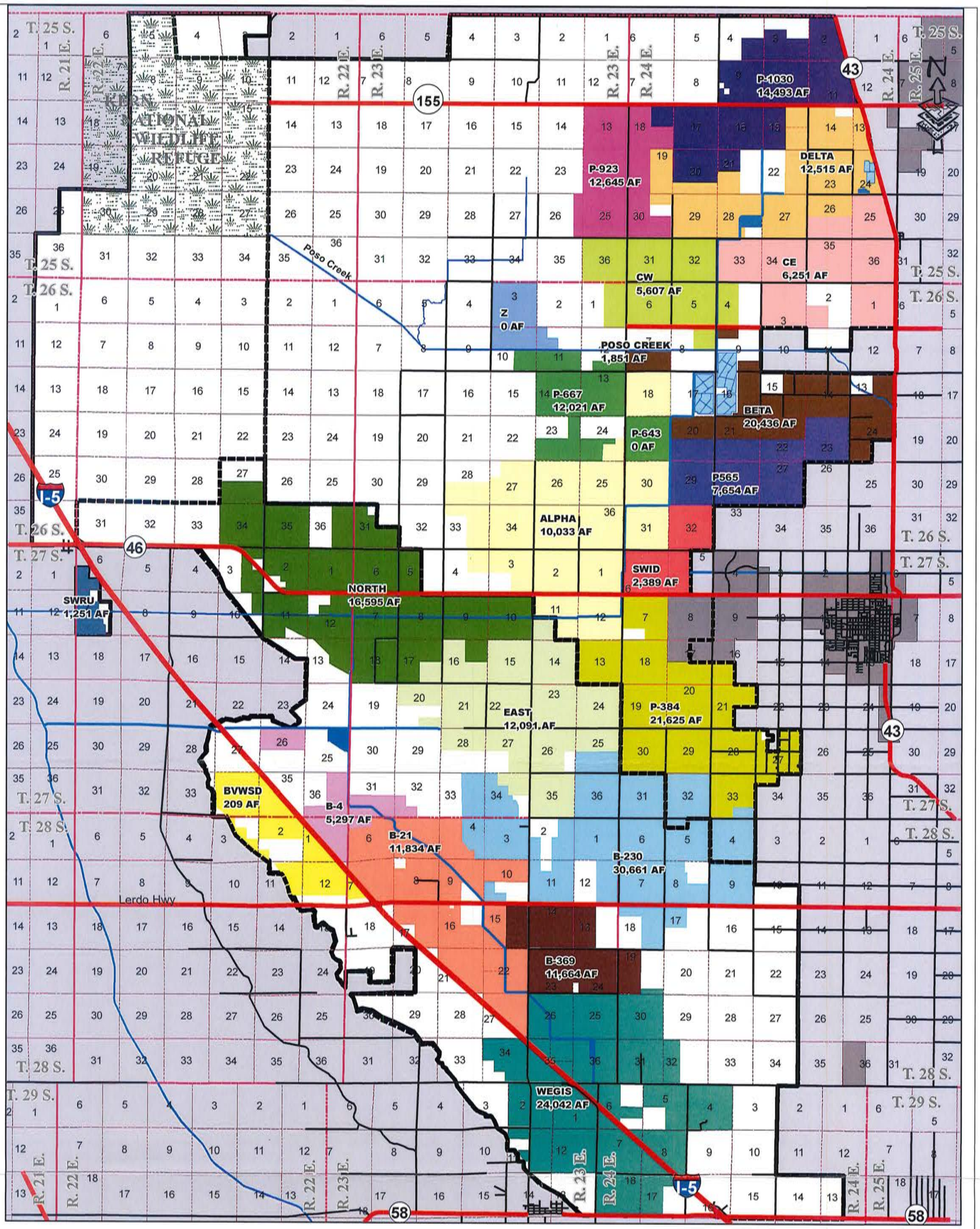
APPENDIX A

WATER-BANKING OPERATIONS

SEMITROPIC GROUNDWATER BANKING WATER STORAGE DISTRICT

History of Water Banking Activity





SEMITROPIC WATER STORAGE DISTRICT

DISTRIBUTION OF 2011 BANKING WATER
241,818 ACRE-FEET STORED
- 0 ACRE-FOOT RECOVERED

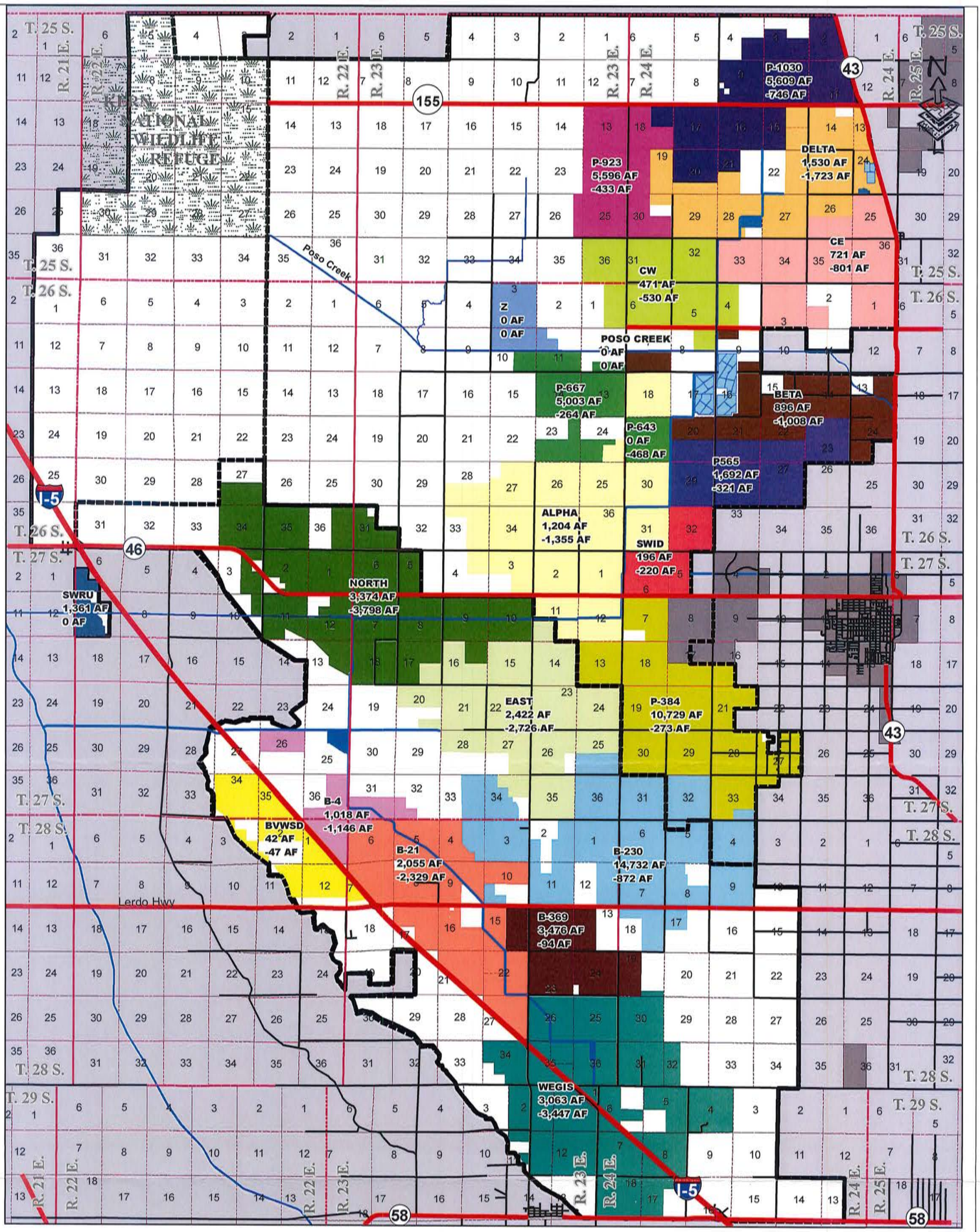
0 0.5 1 2 3 4 5 Miles

Legend

- DistrictBoundary
- Improvement District Boundary
- Transportation
- Canals, Pipelines, and Aqueduct
- Distribution System

SEMITROPIC GROUNDWATER BANKING WATER STORAGE DISTRICT

\GIS Projects\System Routes\DistributionBankingWater2011 Nov 29, 2016



SEMITROPIC WATER STORAGE DISTRICT

DISTRIBUTION OF 2012 BANKING WATER
65,181 ACRE-FEET STORED
- 22,601 ACRE-FOOT RECOVERED

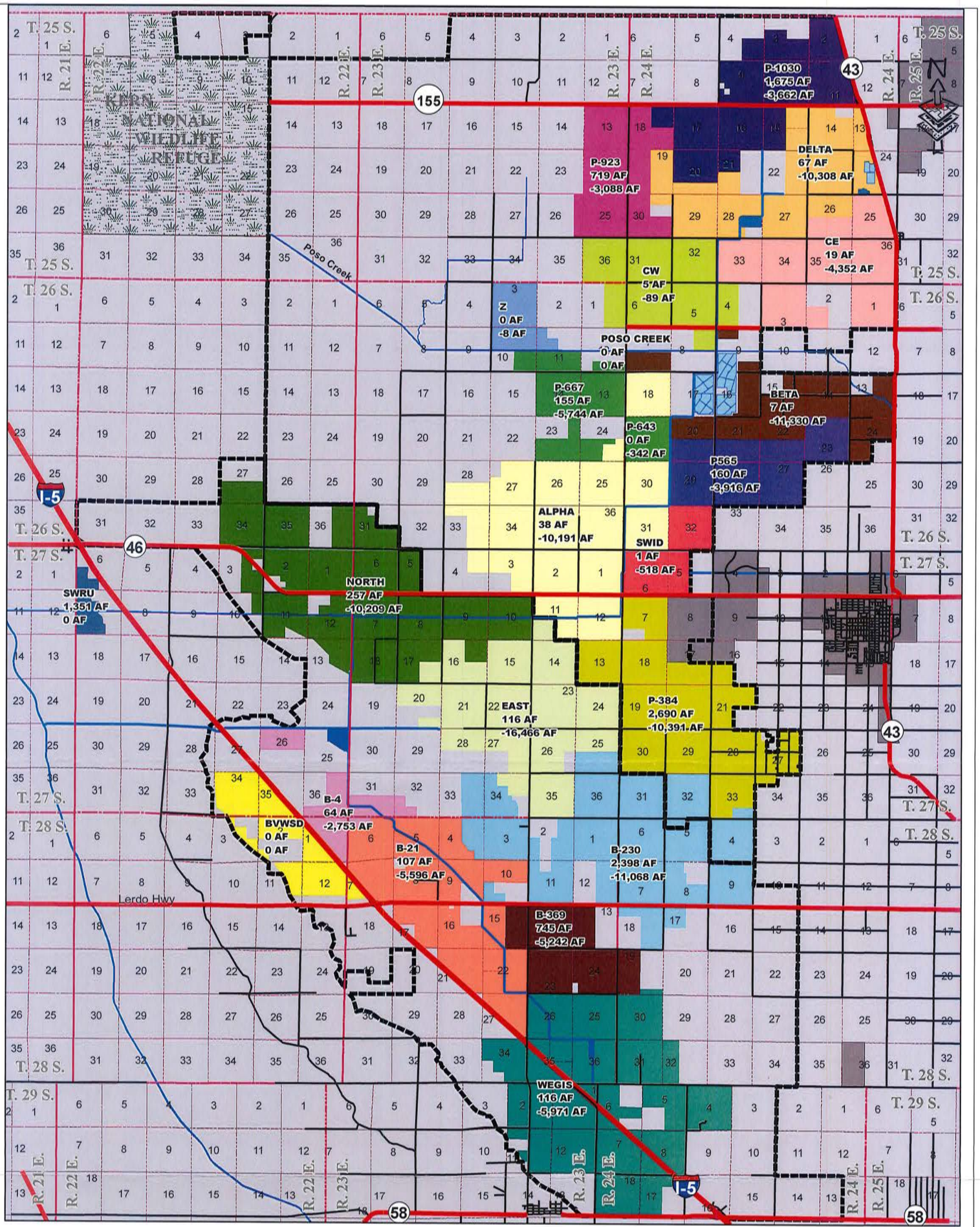
0 0.5 1 2 3 4 5 Miles

Legend

- DistrictBoundary
- Improvement District Boundary
- Transportation
- Canals, Pipelines, and Aqueduct
- Distribution System

SEMITROPIC GROUNDWATER BANKING WATER STORAGE DISTRICT

\GIS Projects\System Routes\Distribution\Banking\Water2012 Nov 29, 2016



SEMITROPIC WATER STORAGE DISTRICT

DISTRIBUTION OF 2013 BANKING WATER
10,690 ACRE-FEET STORED
- 121,244 ACRE-FOOT RECOVERED

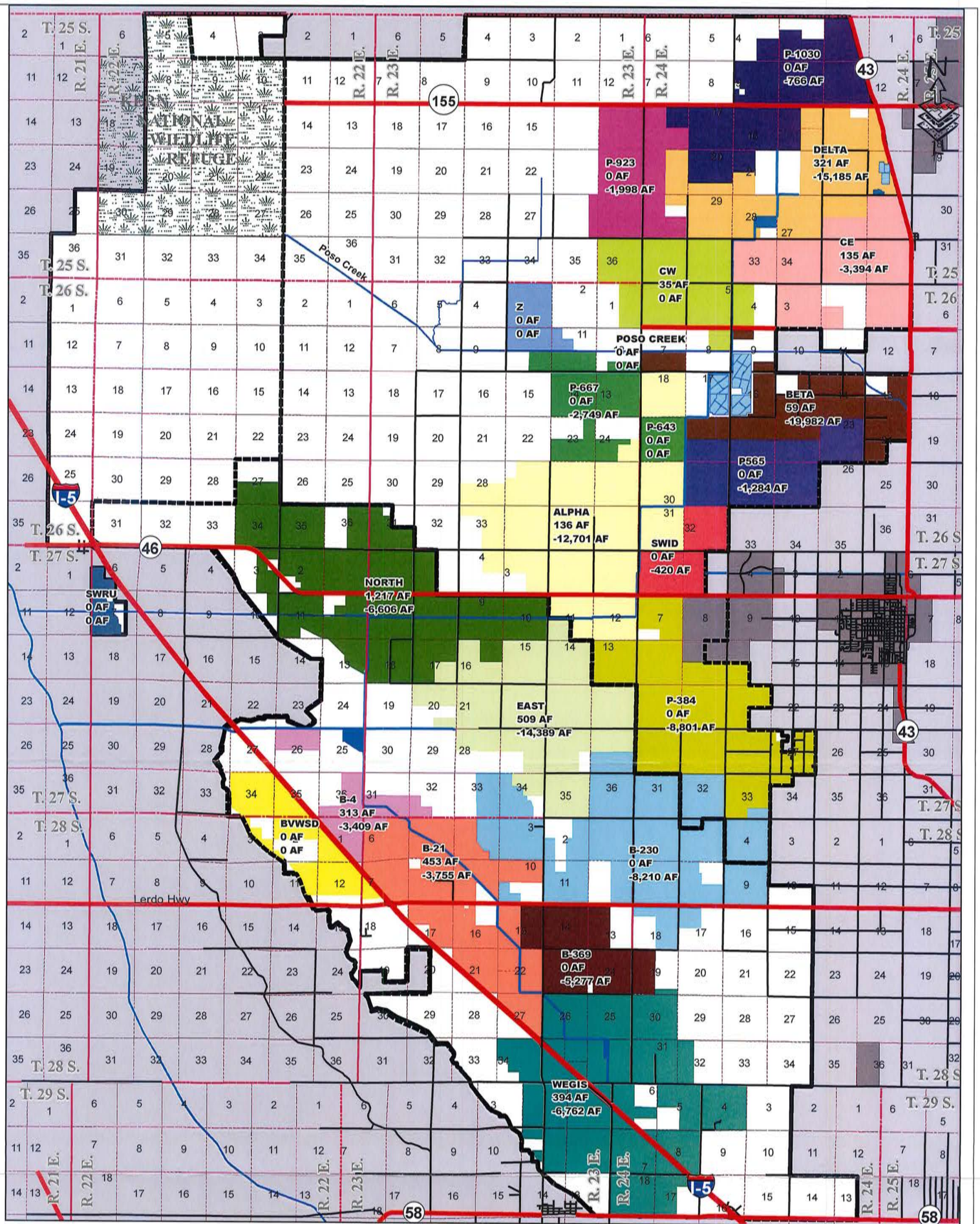
0 0.5 1 2 3 4 5 Miles

Legend

- DistrictBoundary
- Improvement District Boundary
- Transportation
- Canals, Pipelines, and Aqueduct
- Distribution System

SEMITROPIC GROUNDWATER BANKING WATER STORAGE DISTRICT

\GIS Projects\System Routes\DistributionBanking\Water2013 Nov 29, 2016



SEMITROPIC WATER STORAGE DISTRICT

DISTRIBUTION OF 2014 BANKING WATER
3,572 ACRE-FEET STORED
- 115,688 ACRE-FOOT RECOVERED

0 0.5 1 2 3 4 5 Miles

Legend

- DistrictBoundary
- Improvement District Boundary
- Transportation
- Canals, Pipelines, and Aqueduct
- Distribution System

SEMITROPIC GROUNDWATER BANKING WATER STORAGE DISTRICT

\GIS Projects\System Routes\DistributionBankingWater2014 Nov 29, 2016

APPENDIX B

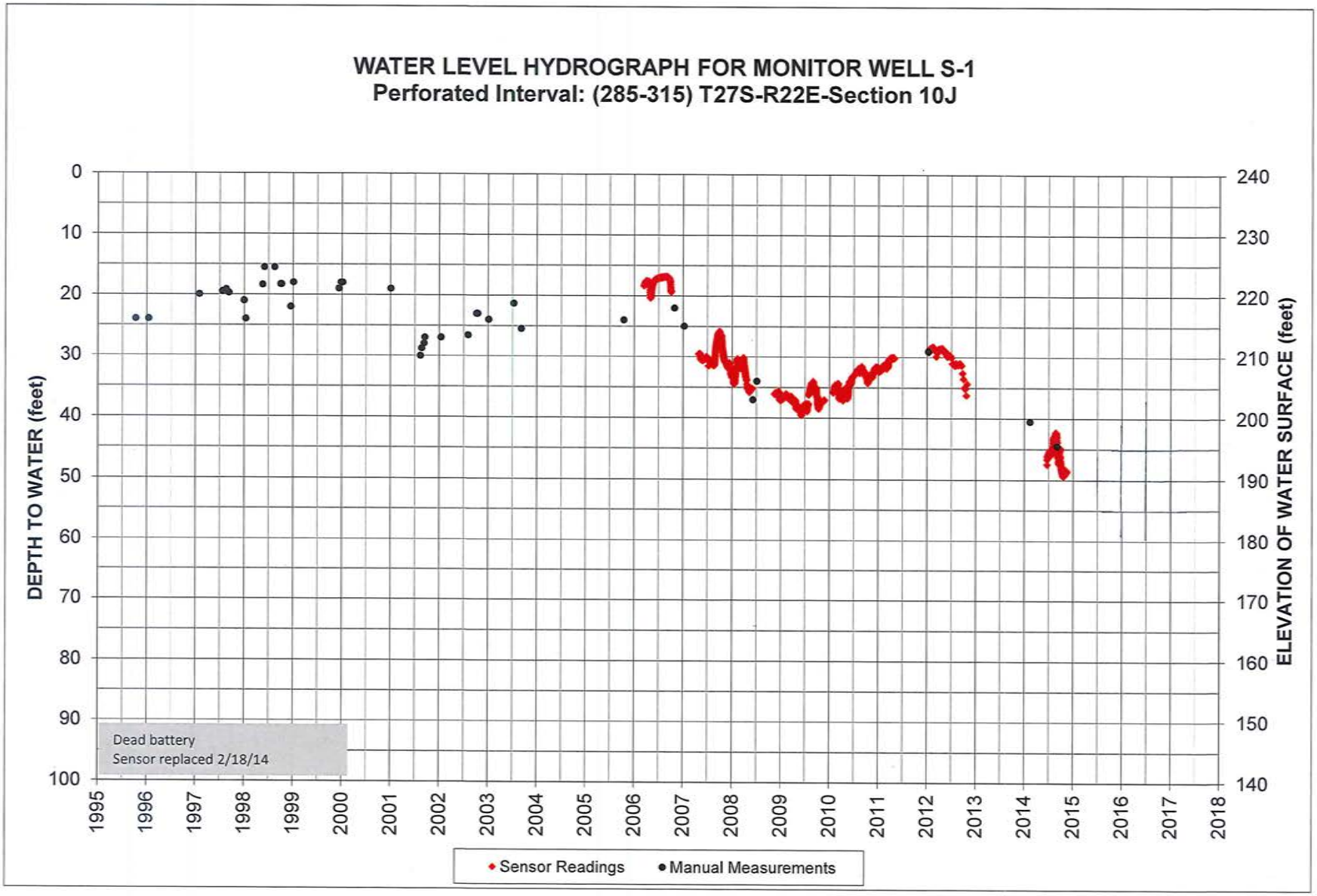
WATER-LEVEL HYDROGRAPHS

SEMITROPIC WATER STORAGE DISTRICT

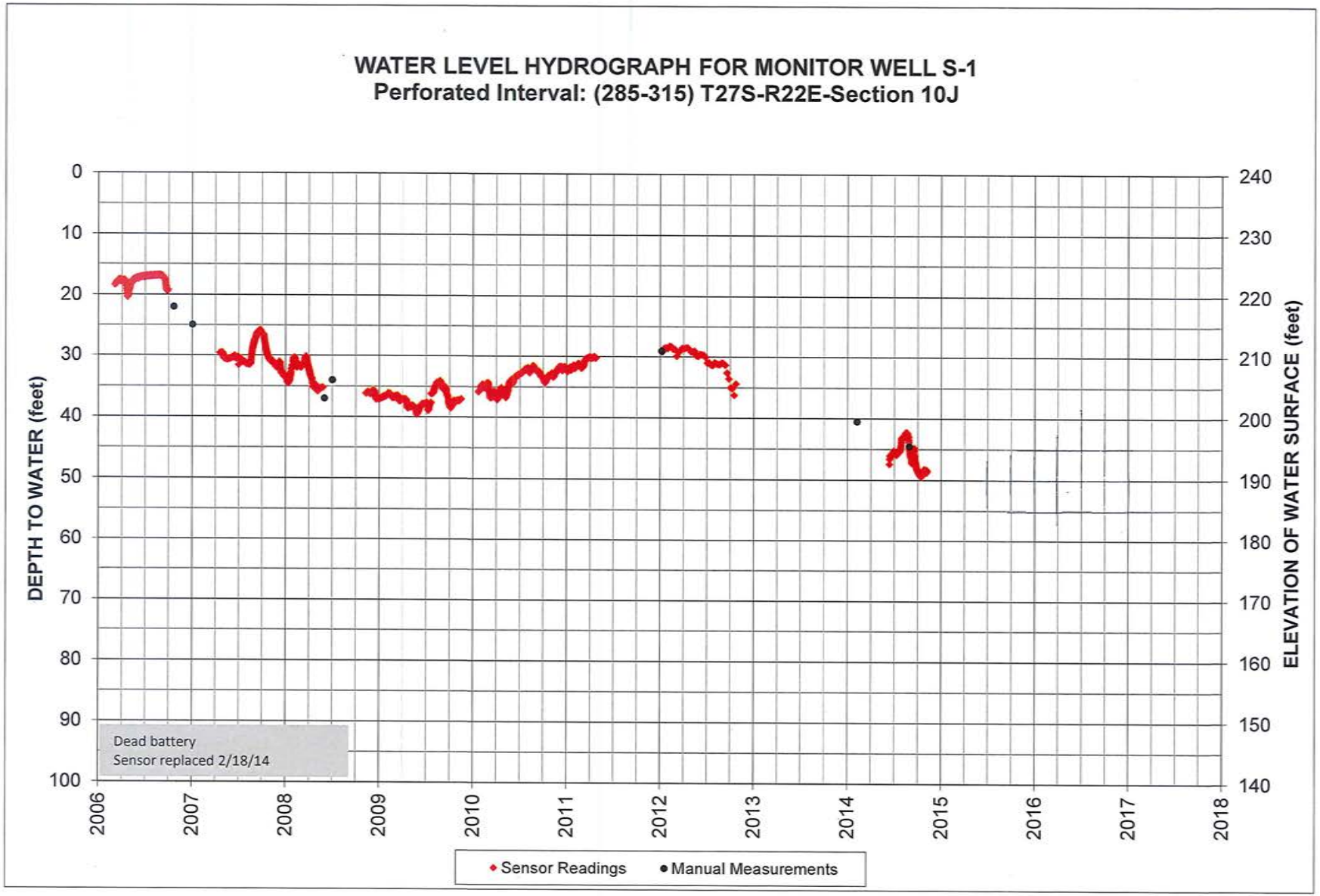
Monitor Wells

Well Characteristics

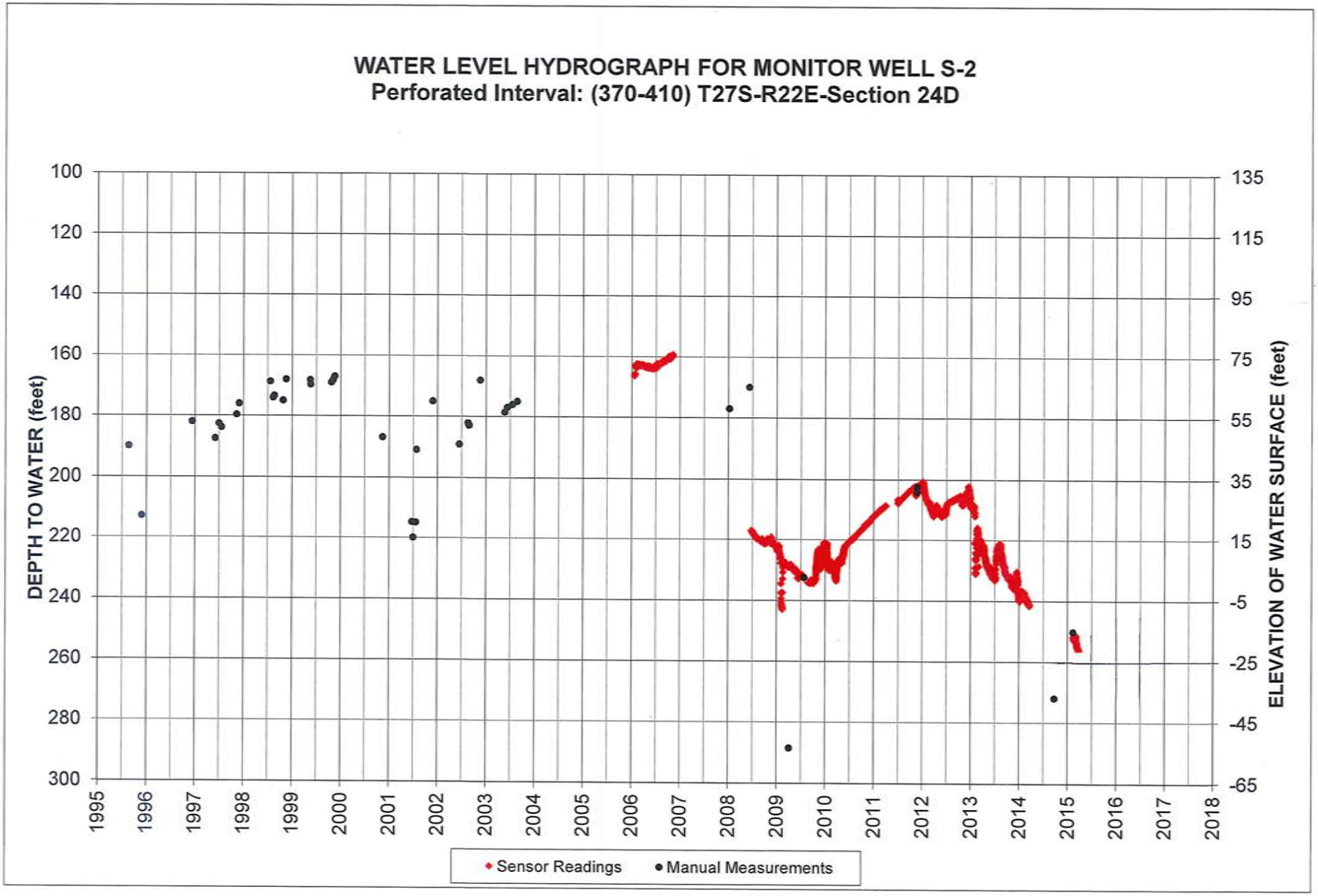
Well No.	Location T-R-S	Type of Well Monitoring -or- Production	Installed Transducer Serial Number	Year Well Constructed	RP Elevation (ft MSL)	Boring Depth (ft)	Completed Depth (ft)	Perforated Interval (ft)	Annular Seal Interval (ft)	Casing		Water Level Sounder Measurement Frequency	Sampling Pump	Sampling Frequency
										Diameter (in)	Material			
948L02	29S-24E-8L02	Monitor Well	105000	1992	295		625	525 - 625		6		6-12		2
948L03	29S-24E-8L03	Monitor Well	104970	1992	295		440	360 - 440		6		6-12		2
S-1	27S-22E-10J	Monitor Well	104935	1994	240	422	340	285-315		5.761	Sch.80 PVC	2		1
S-2	27S-22E-24D	Monitor Well	104939	1994	235	500	448	370-410		5.761	Sch.80 PVC	2		1
S-3	27S-22E-34A	Monitor Well	104942	1994	262	500	300	240-270		5.761	Sch.80 PVC	2		1
S-4	28S-22E-3H	Monitor Well	104996	1994	248	501	445	390-420		5.761	Sch.80 PVC	2		1
S-5	27S-23E-29M	Monitor Well	104999	1994	242	500	430	380-410		5.761	Sch.80 PVC	2		1
S-6	25S-24E-36Q	Monitor Well	104958	1995	282	450	431	381 - 431	0 - 356	6	3/16-in. Steel	2	X	
S-7A	26S-24E-13N	Monitor Well	104957	1995	297	700	600	550 - 600	0 - 520	6	1/4-in. Steel	2	X	1
S-7B	26S-24E-13N	Monitor Well	104959	1995	297	380	380	330 - 380	0 - 310	6	3/16-in. Steel	2		
S-8A	26S-24E-33D	Monitor Well	104956	1995	276	700	687	637 - 687	0 - 600	6	1/4-in. Steel	2	X	1
S-8B	26S-24E-33D	Monitor Well	104941	1995	276	432	432	392 - 432	0 - 362	6	3/16-in. Steel	2		
S-9A	28S-24E-4L	Monitor Well	104978	1995	297	700	690	660 - 690	0 - 640	6	1/4-in. Steel	2	X	1
S-9B	28S-24E-4L	Monitor Well	104998	1995	297	407	407	357 - 407	0 - 322	6	3/16-in. Steel	2		
S-10A	25S-22E-35B	Monitor Well	104968	1999	222		900	420 - 460 490 - 700 740 - 890		4		2		
S-10B	25S-22E-35B	Monitor Well	no transducer	1999	222		1270	1,250 - 1,260		4		2		
S-10C	25S-22E-35B	Monitor Well	no transducer	1999	222		1100	1,080 - 1,090		4		2	X	1
S-11	26S-22E-2J	Monitor Well	104937	2001	222	900	700	550 - 700		6 & 8	1/4-in. Steel	2		
S-12	25S-22E-25L	Monitor Well	104962	2001	217	940	740	510 - 740		6 & 8	1/4-in. Steel	2		
S-13A	25S-24E-18D	Monitor Well	no transducer	2003	222	695	690	660 - 690	0 - 630	6	1/4-in. Steel	2	X	1
S-13B	25S-24E-18D	Monitor Well	no transducer	2003	222	430	435	390 - 430	0 - 370	6	3/16-in. Steel	2	X	
S-14A	26S-24E-16J	Monitor Well	no transducer	2003	274	715	710	670 - 710	0 - 640	6	1/4-in. Steel	2	X	1
S-14B	26S-24E-16J	Monitor Well	no transducer	2003	274	485	480	430 - 480	0 - 410	6	3/16-in. Steel	2	X	
S-15A	27S-24E-16P	Monitor Well	no transducer	2003	295	605	600	550 - 600	0 - 520	6	1/4-in. Steel	2	X	1
S-15B	27S-24E-16P	Monitor Well	no transducer	2003	295	455	450	400 - 450	0 - 380	6	3/16-in. Steel	2	X	
S-16A	26S-24E-27Q	Monitor Well	100993	2003	295	675	670	620 - 670	0 - 590	6	1/4-in. Steel	2	X	1
S-16B	26S-24E-27R	Monitor Well	114335	2003	295	415	410	370 - 410	0 - 350	6	3/16-in. Steel	2	X	
26S-23E-15A1	26S-23E-15A1	Monitor Well	101667	1974	229.3		350	310-350	0-80	6.625 (O.D.)				
26S-23E-15A2	26S-23E-15A2	Monitor Well	104977	1974	229.8		237	80-237	0-25	6.625 (O.D.)				



Semitropic Water Storage District
(Manual data from the KCWA)

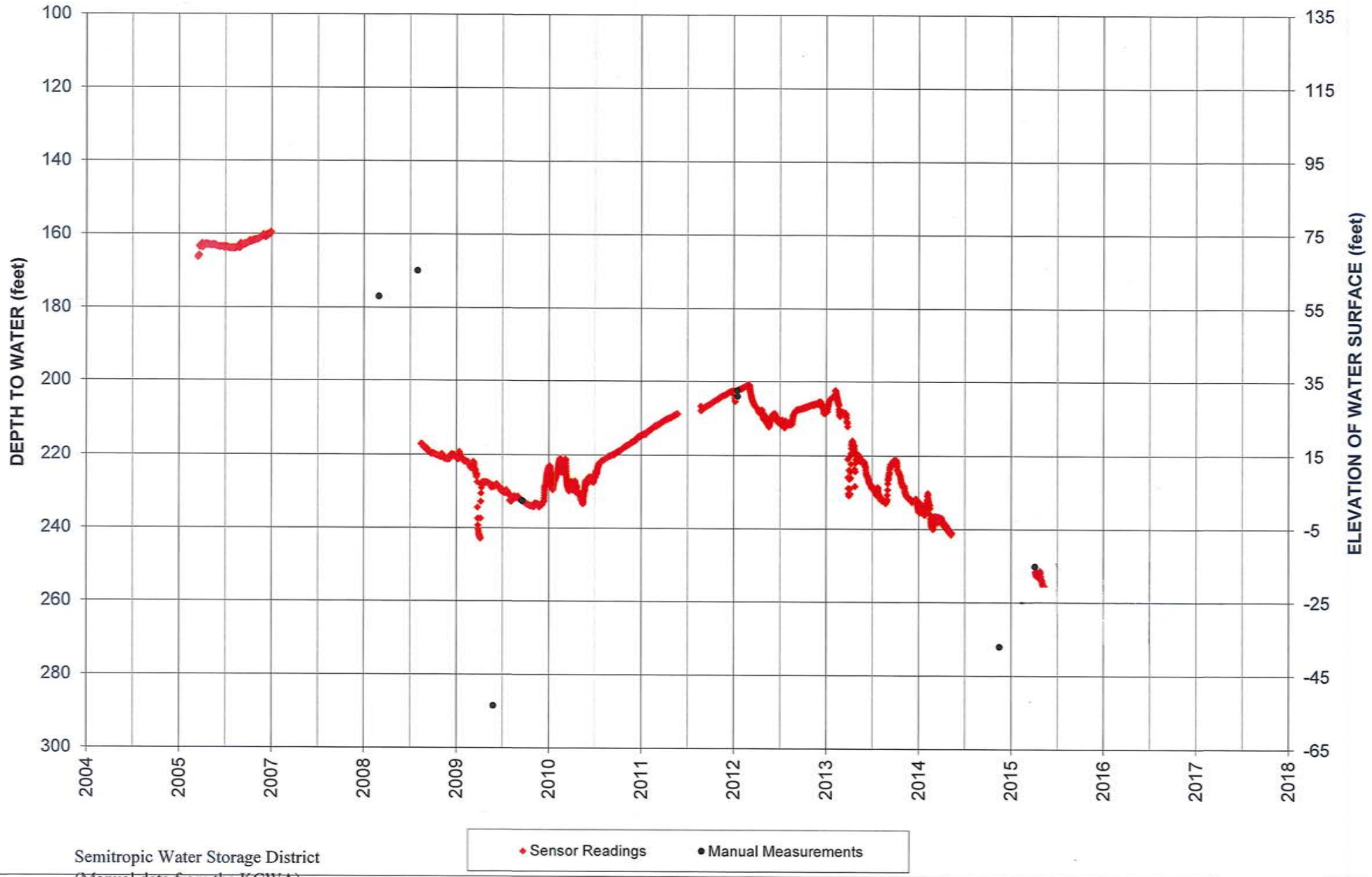


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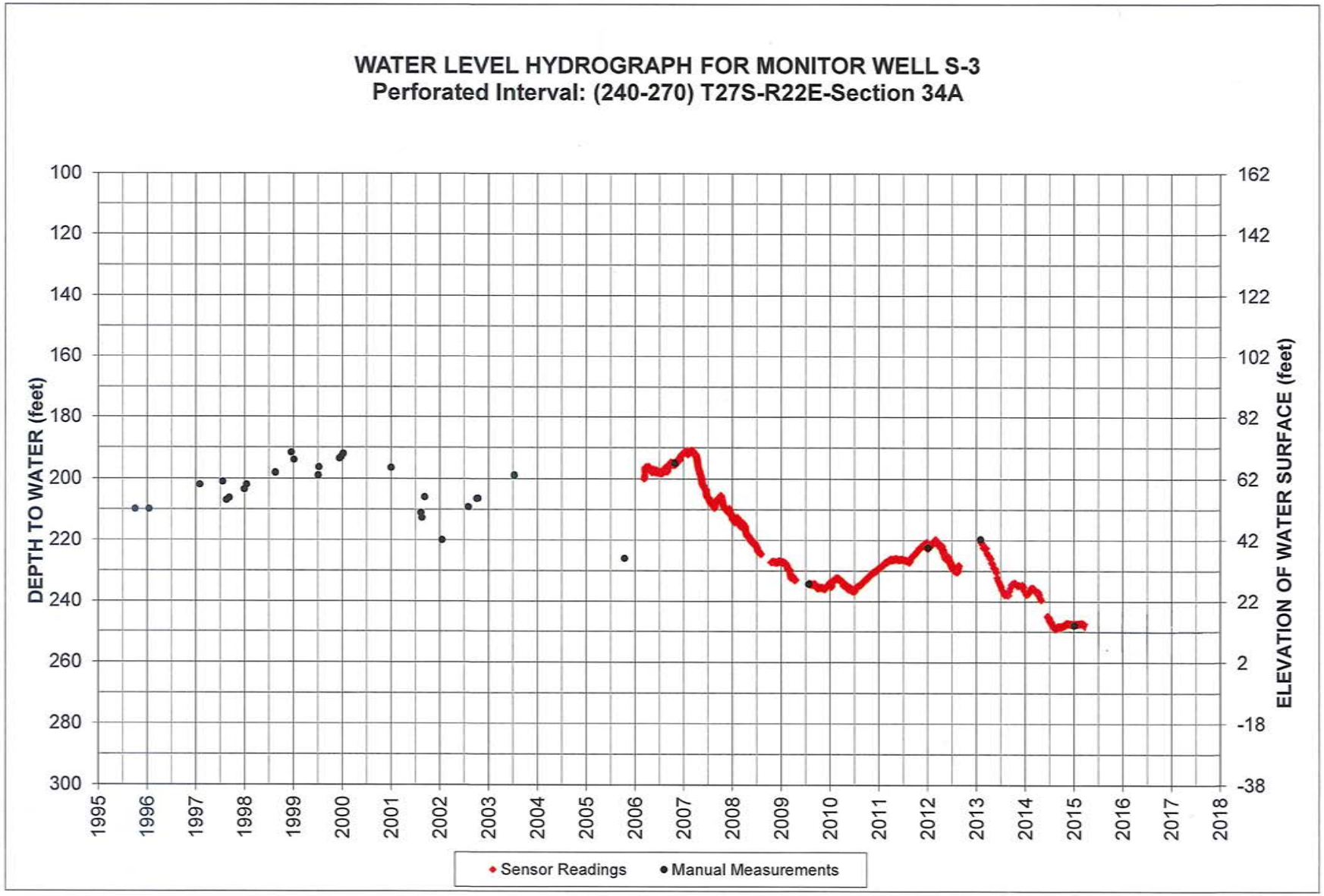


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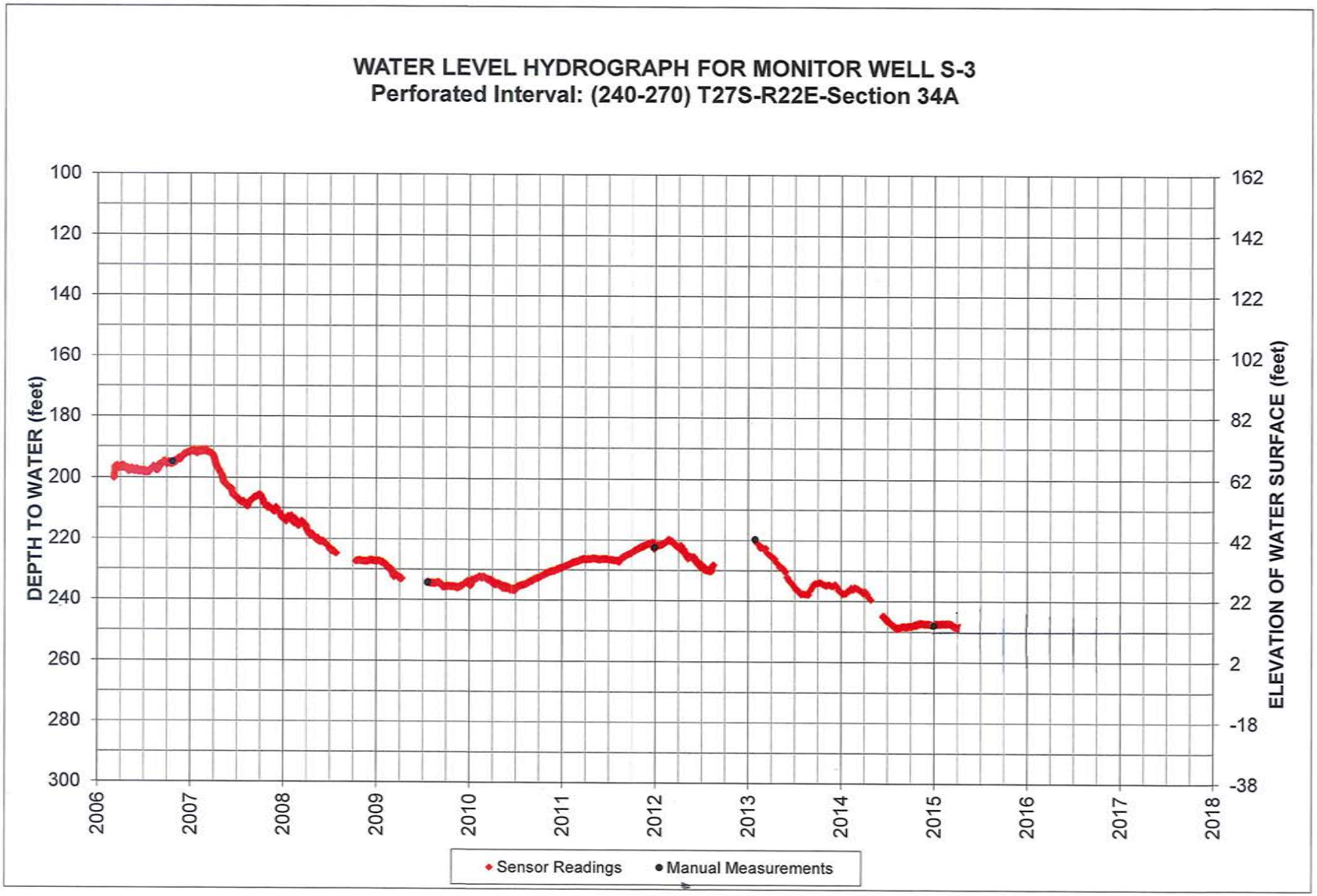
WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-2
Perforated Interval: (370-410) T27S-R22E-Section 24D



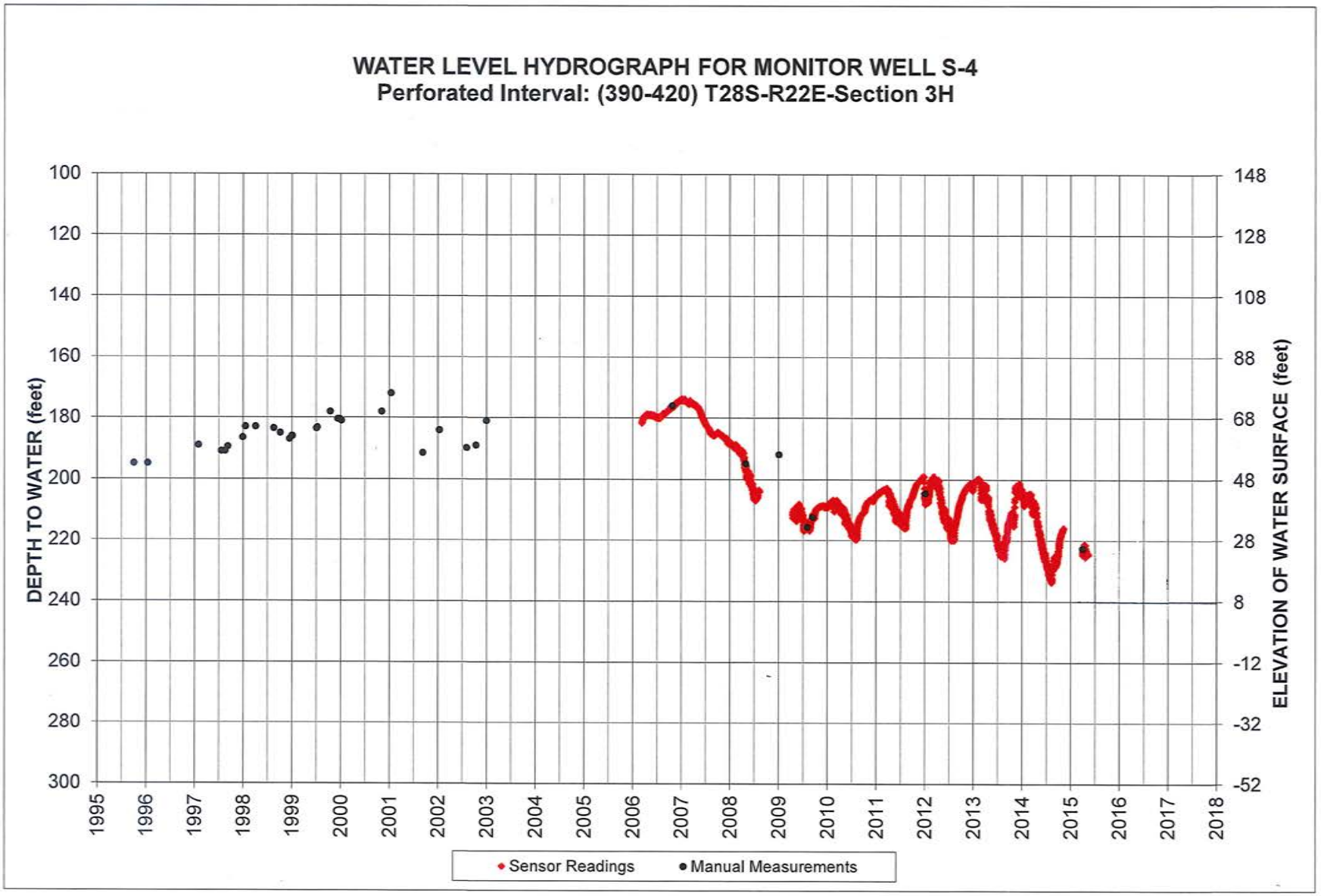
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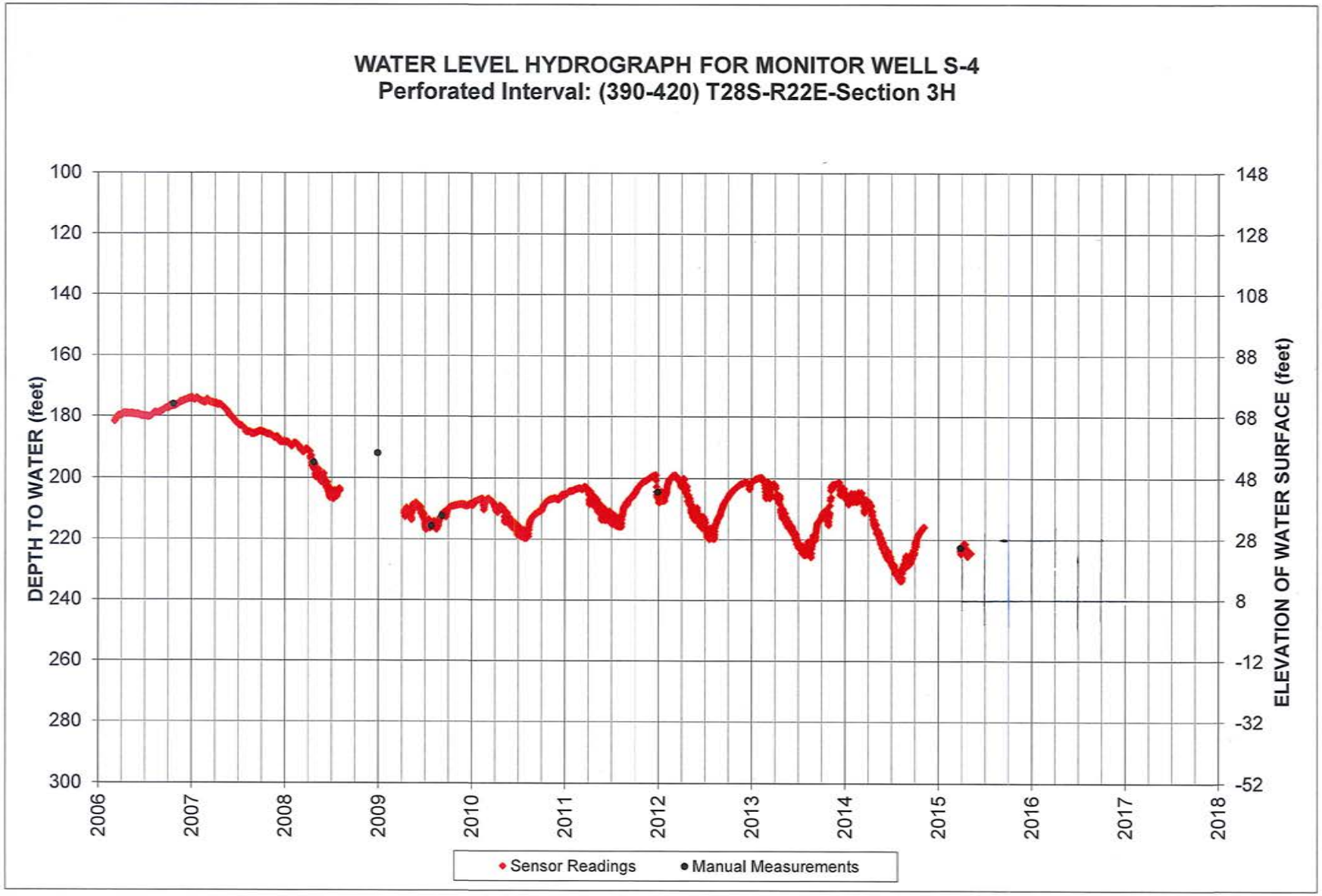
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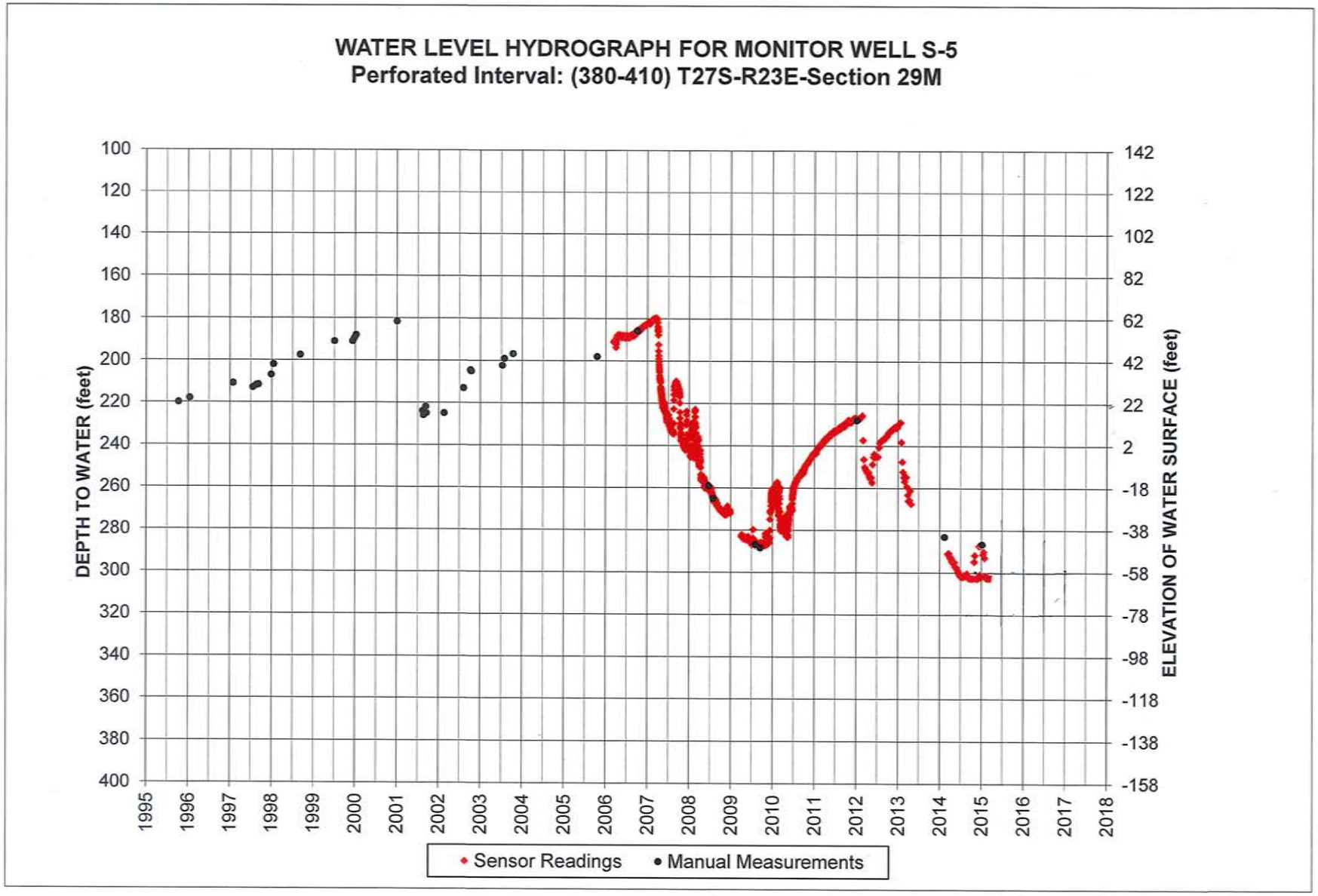
Semitropic Water Storage District
(Manual data from the KCWA)



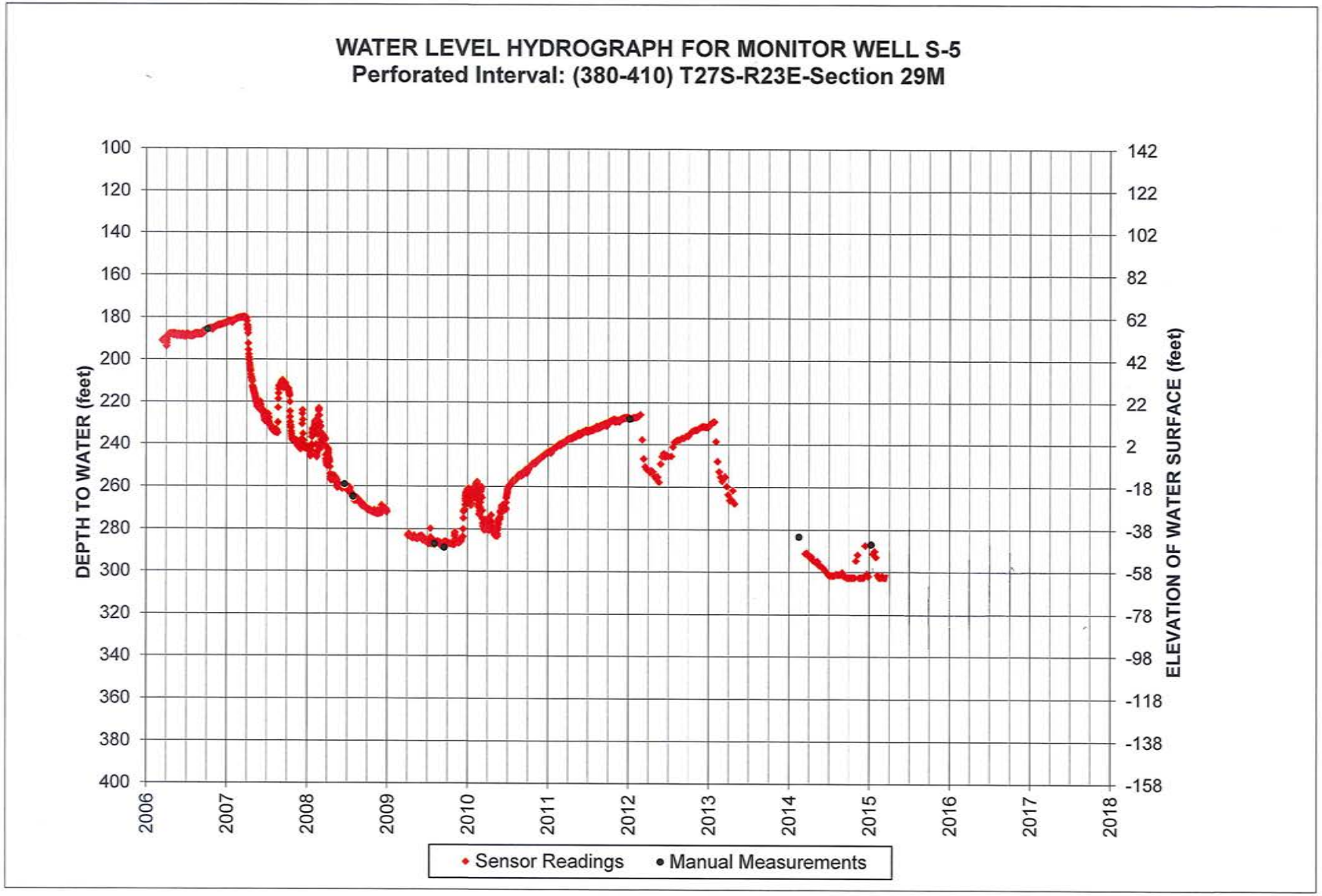
Semitropic Water Storage District
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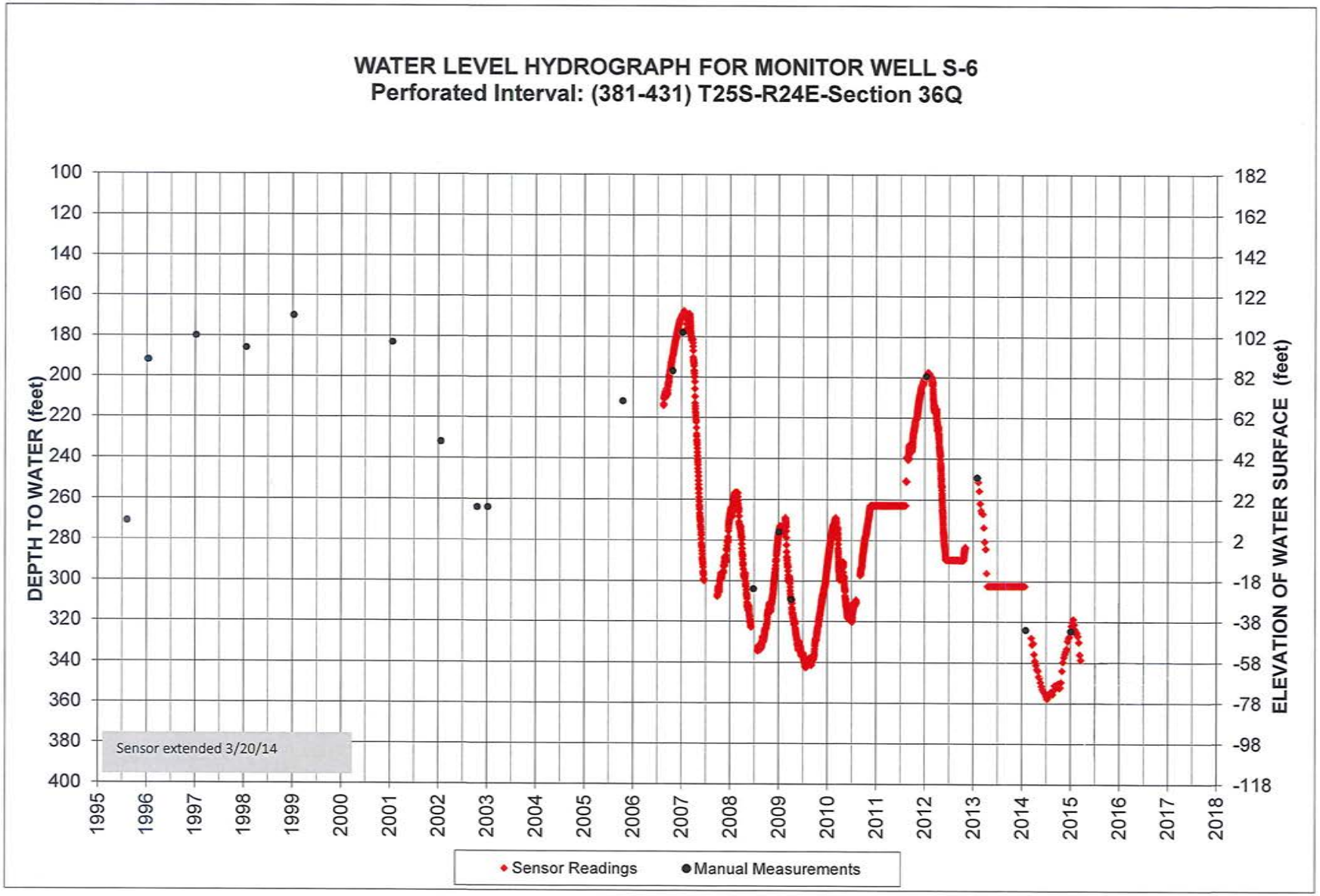
Semitropic Water Storage District
(Manual data from the KCWA)



Semitropic Water Storage District
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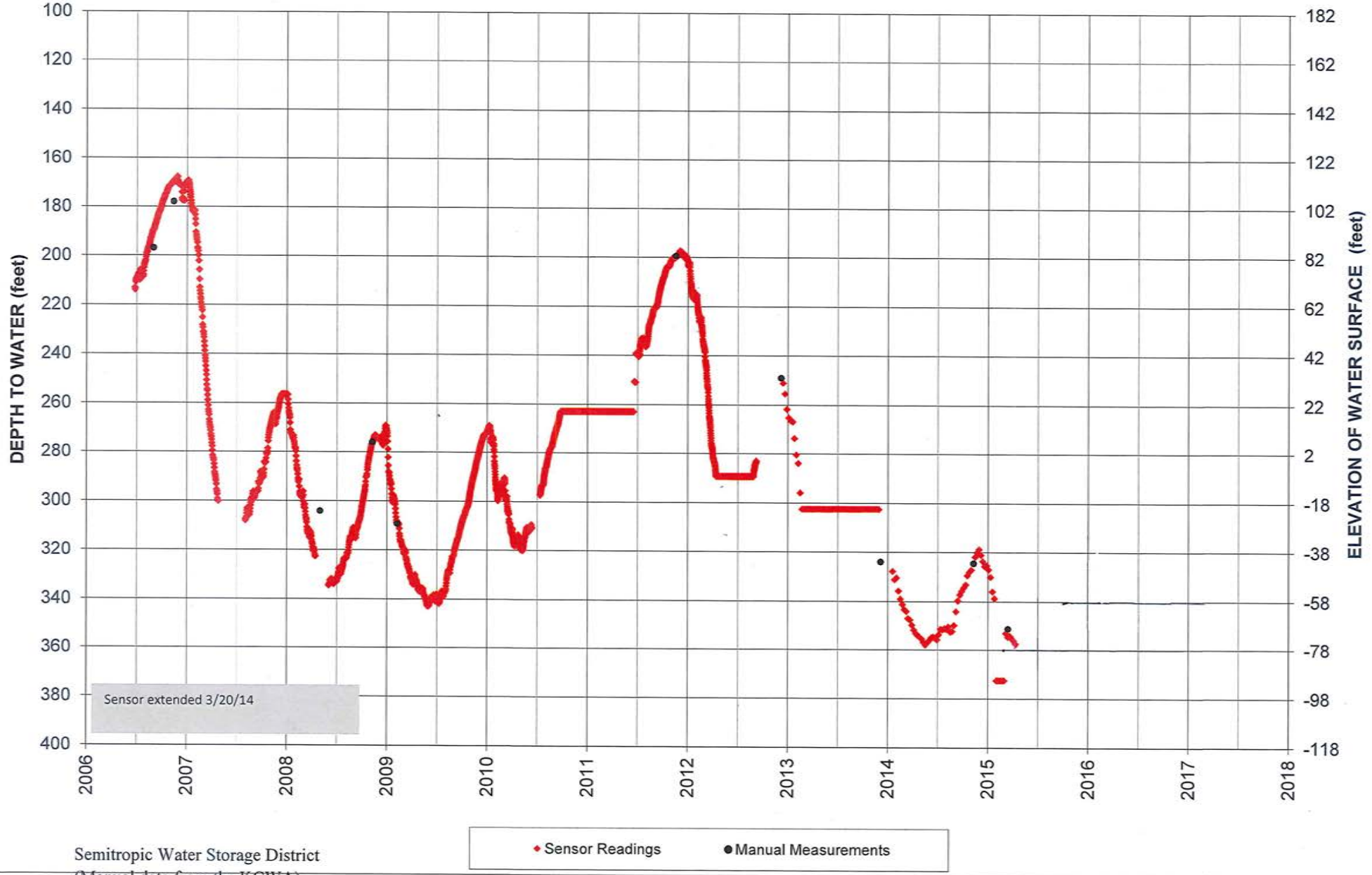


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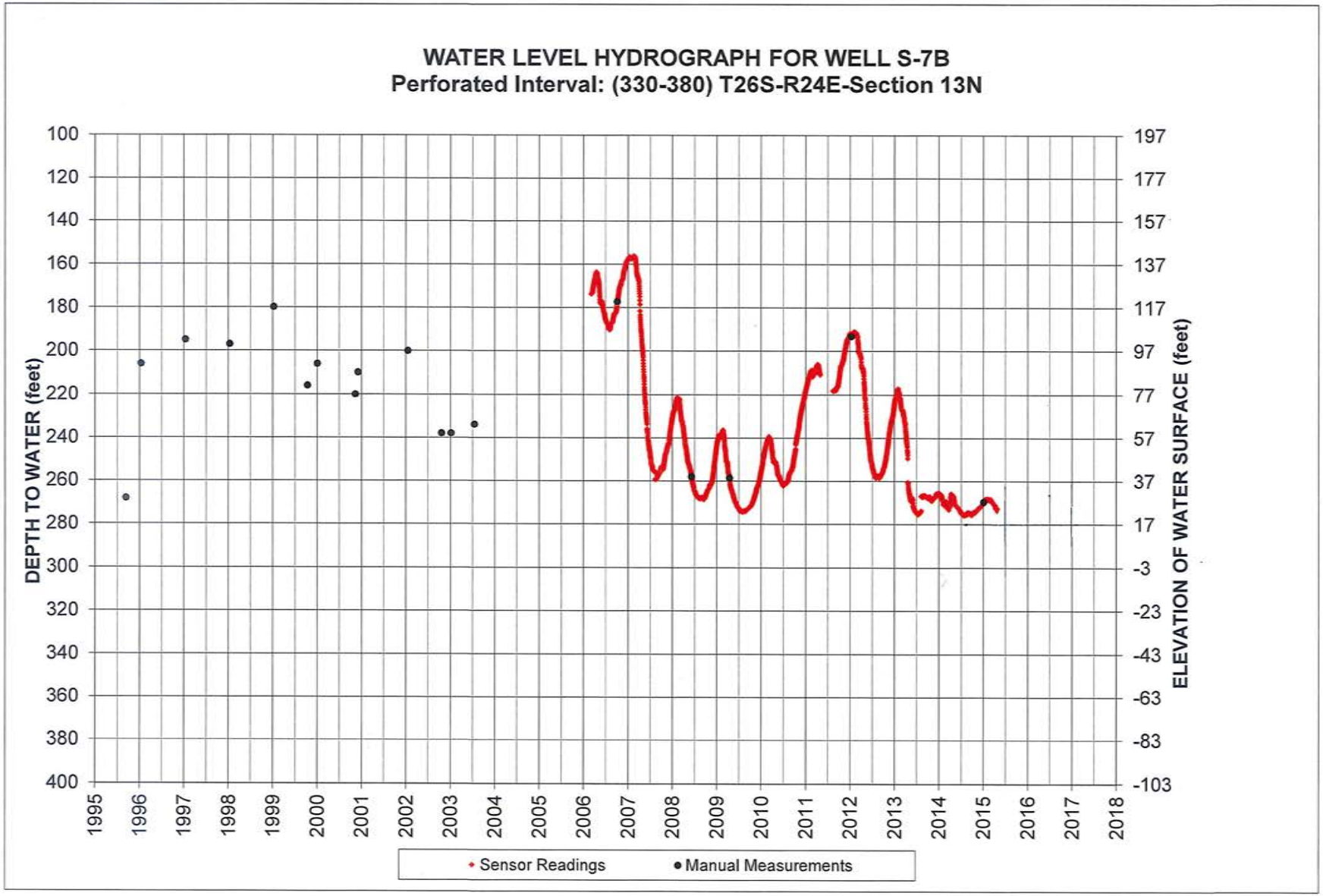


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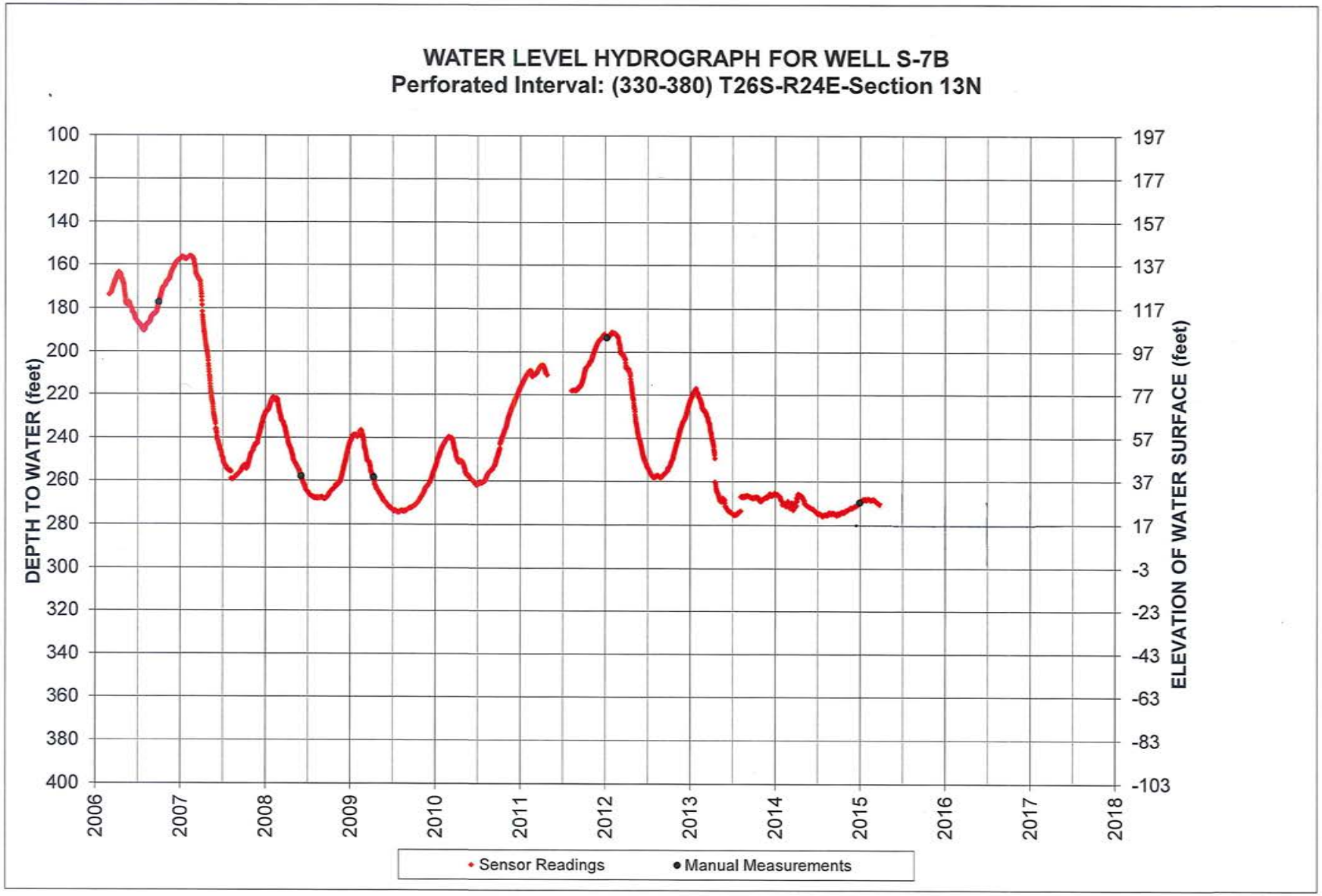
WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-6
Perforated Interval: (381-431) T25S-R24E-Section 36Q



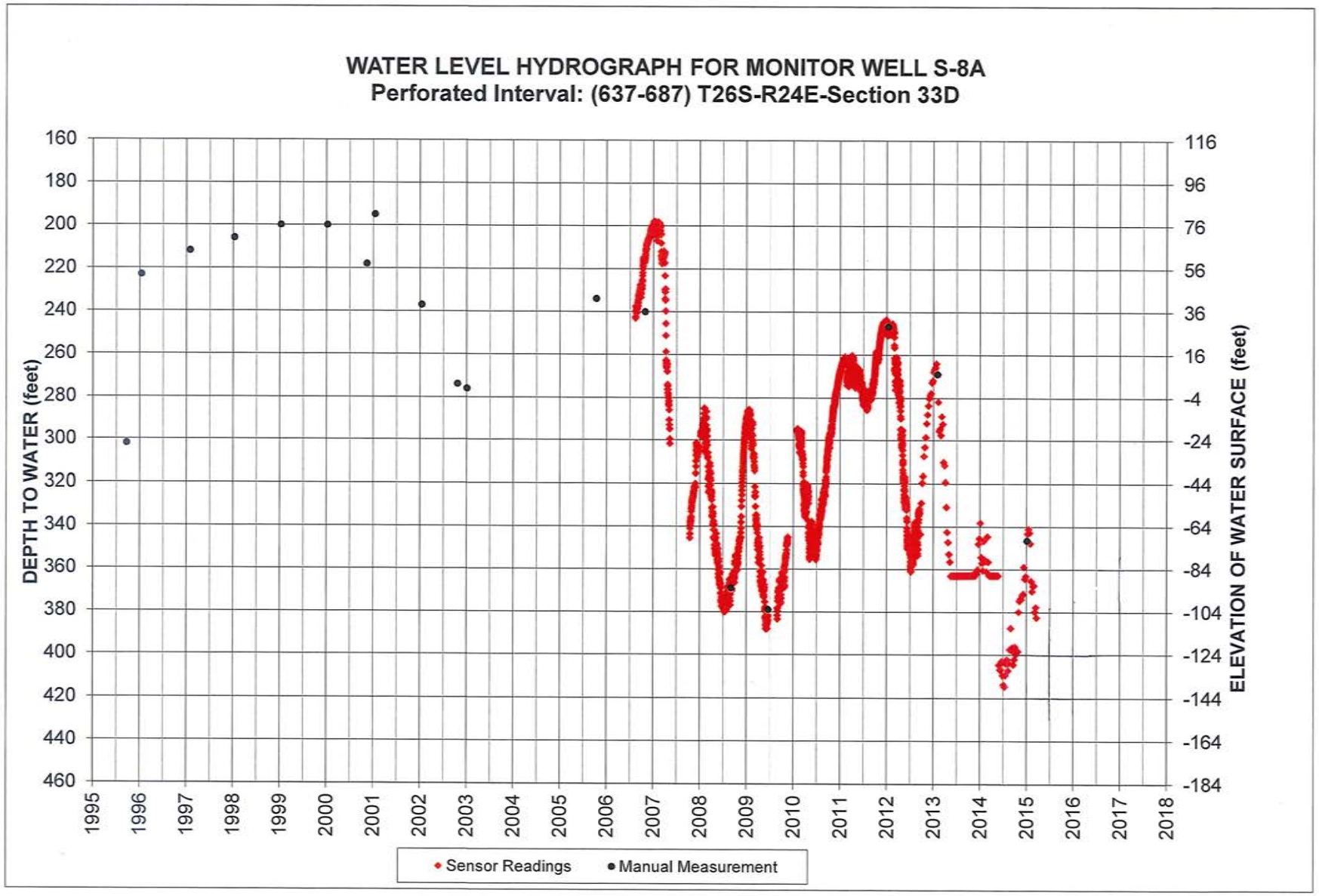
Semitropic Water Storage District
(Manual data from the KCWA)



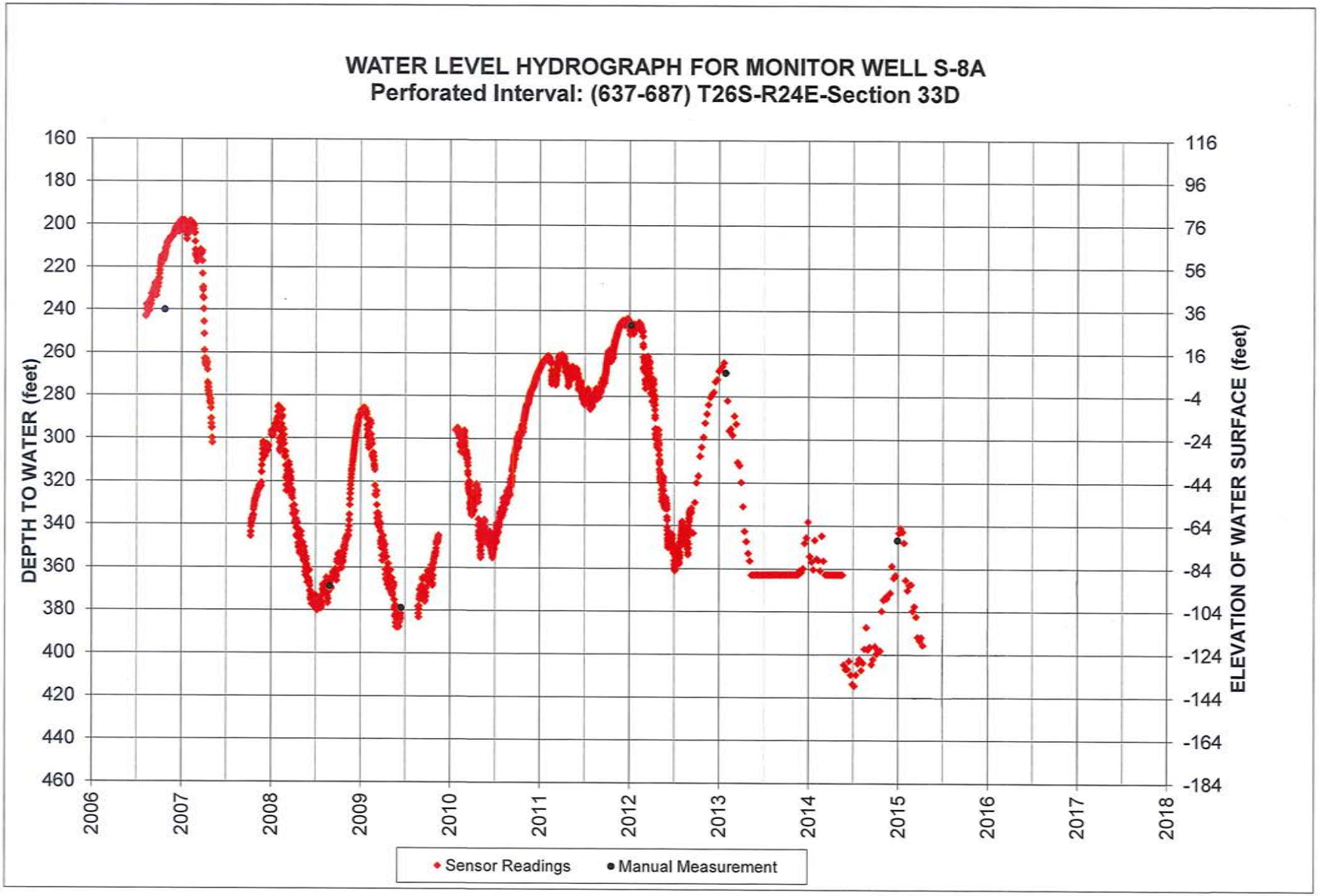
Semitropic Water Storage District
(Manual data from the KCWA)



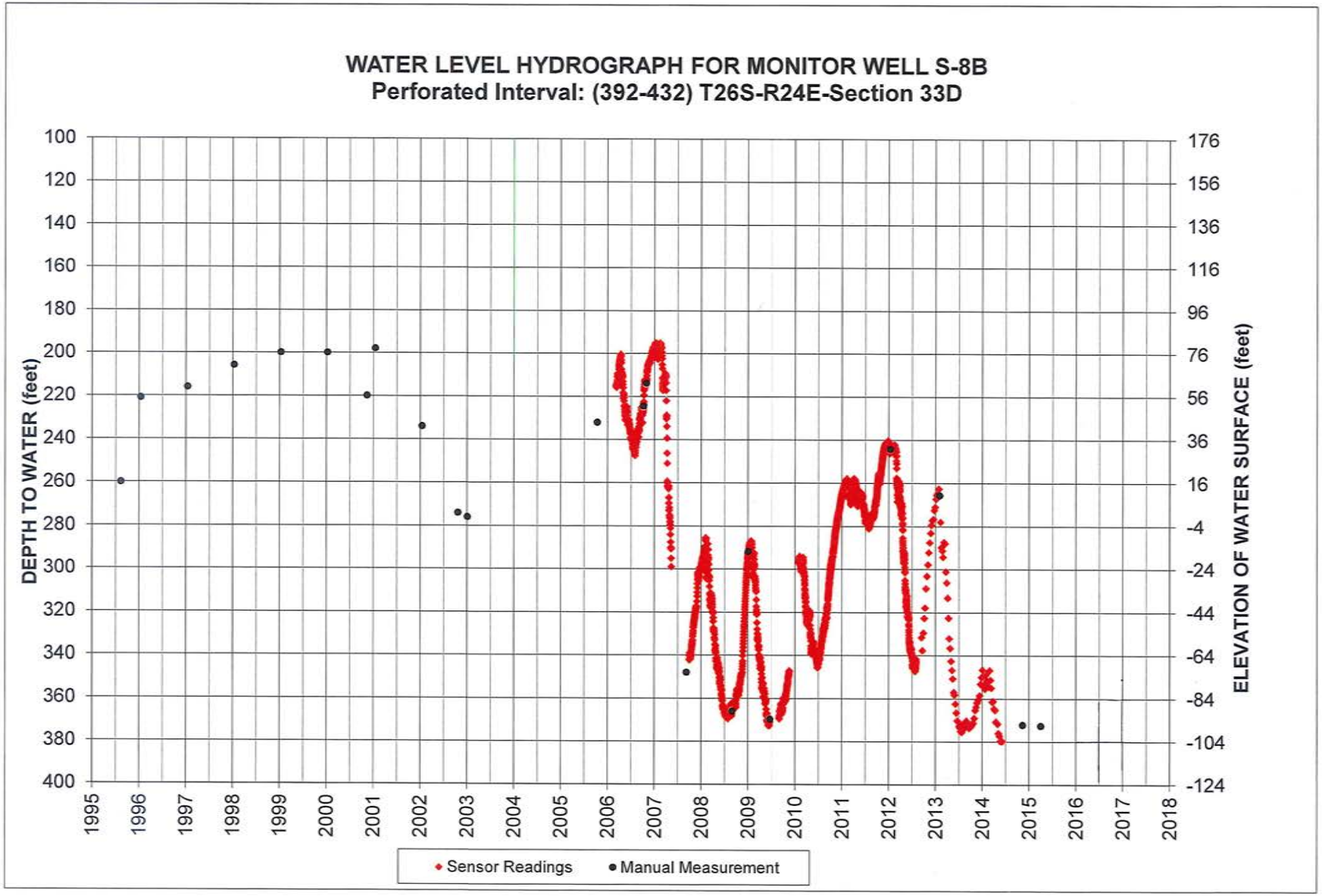
Semitropic Water Storage District
(Manual data from the KCWA)



Semitropic Water Storage District
(Manual data from the KCWA)

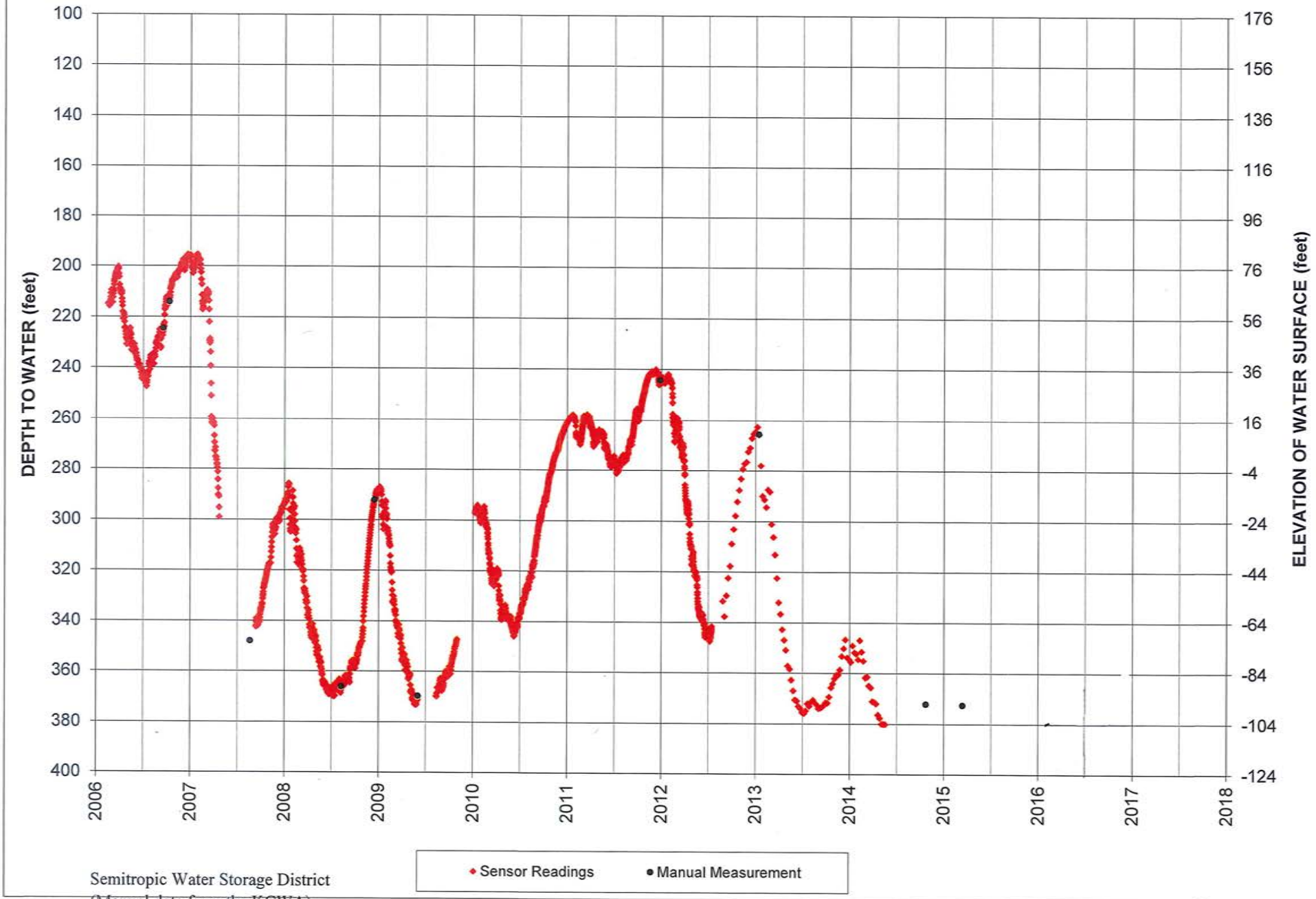


Semitropic Water Storage District
(Manual data from the KCWA)

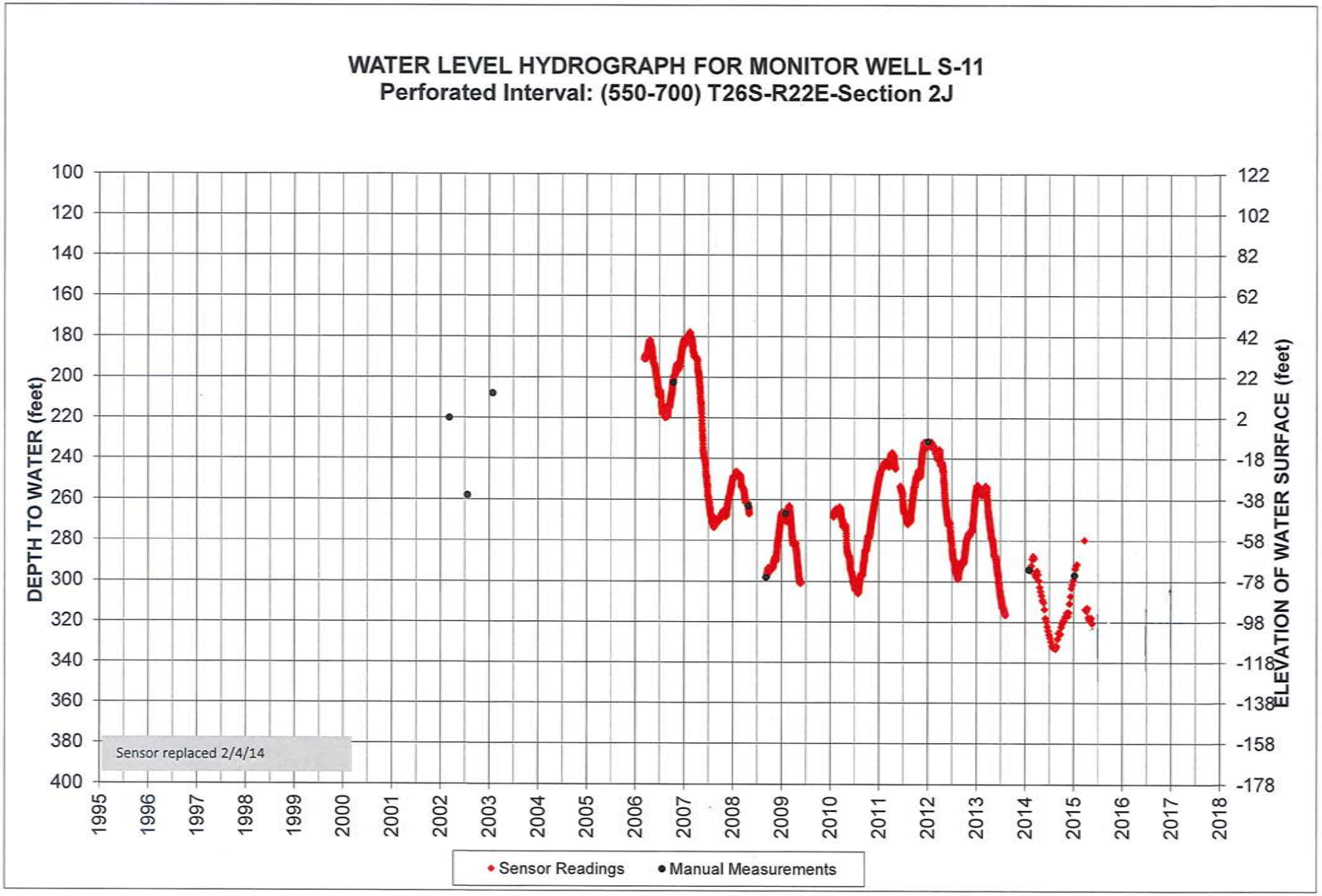


Semitropic Water Storage District
(Manual data from the KCWA)

WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-8B
Perforated Interval: (392-432) T26S-R24E-Section 33D

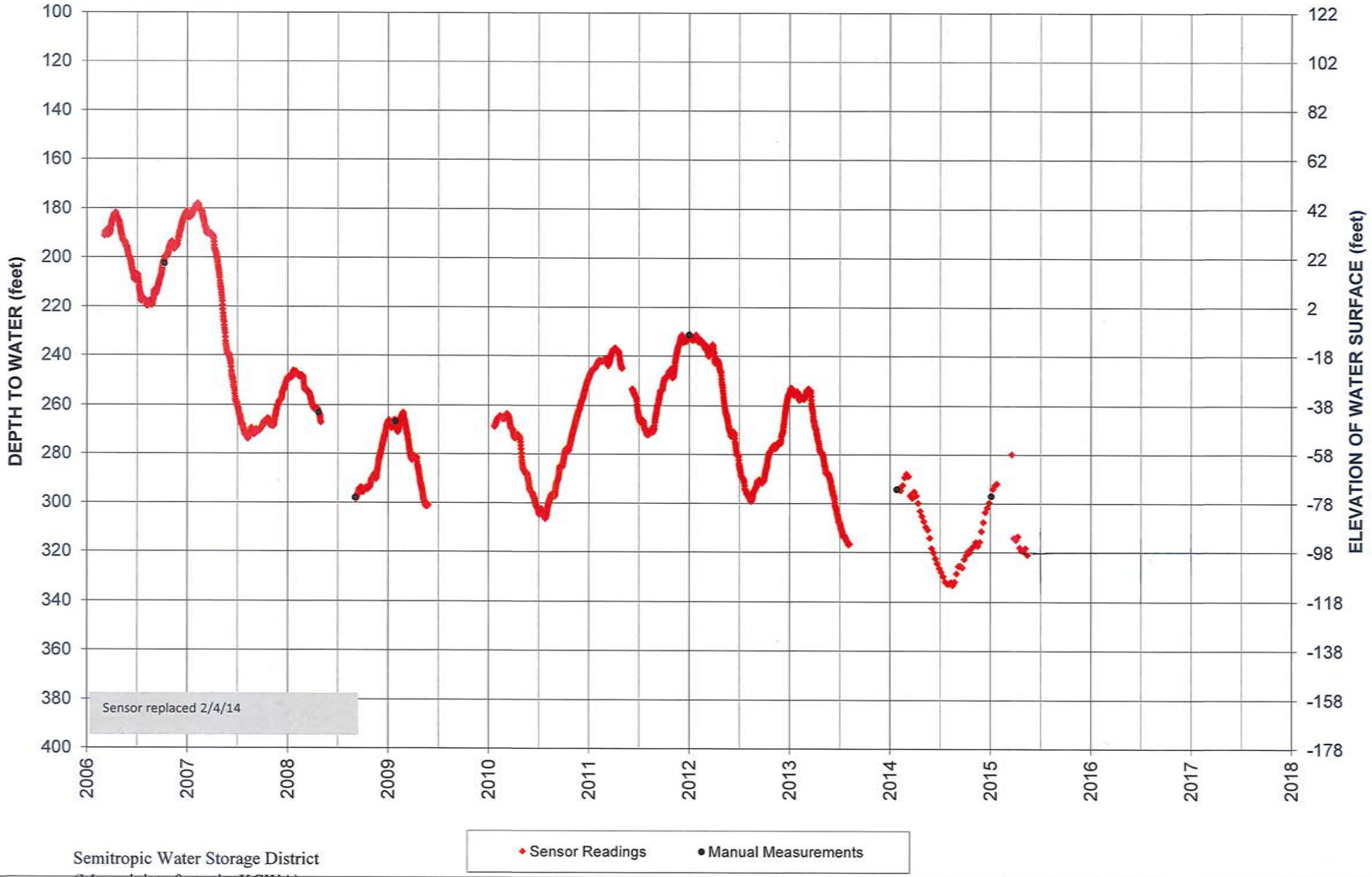


Semitropic Water Storage District
(Manual data from the KCWA)

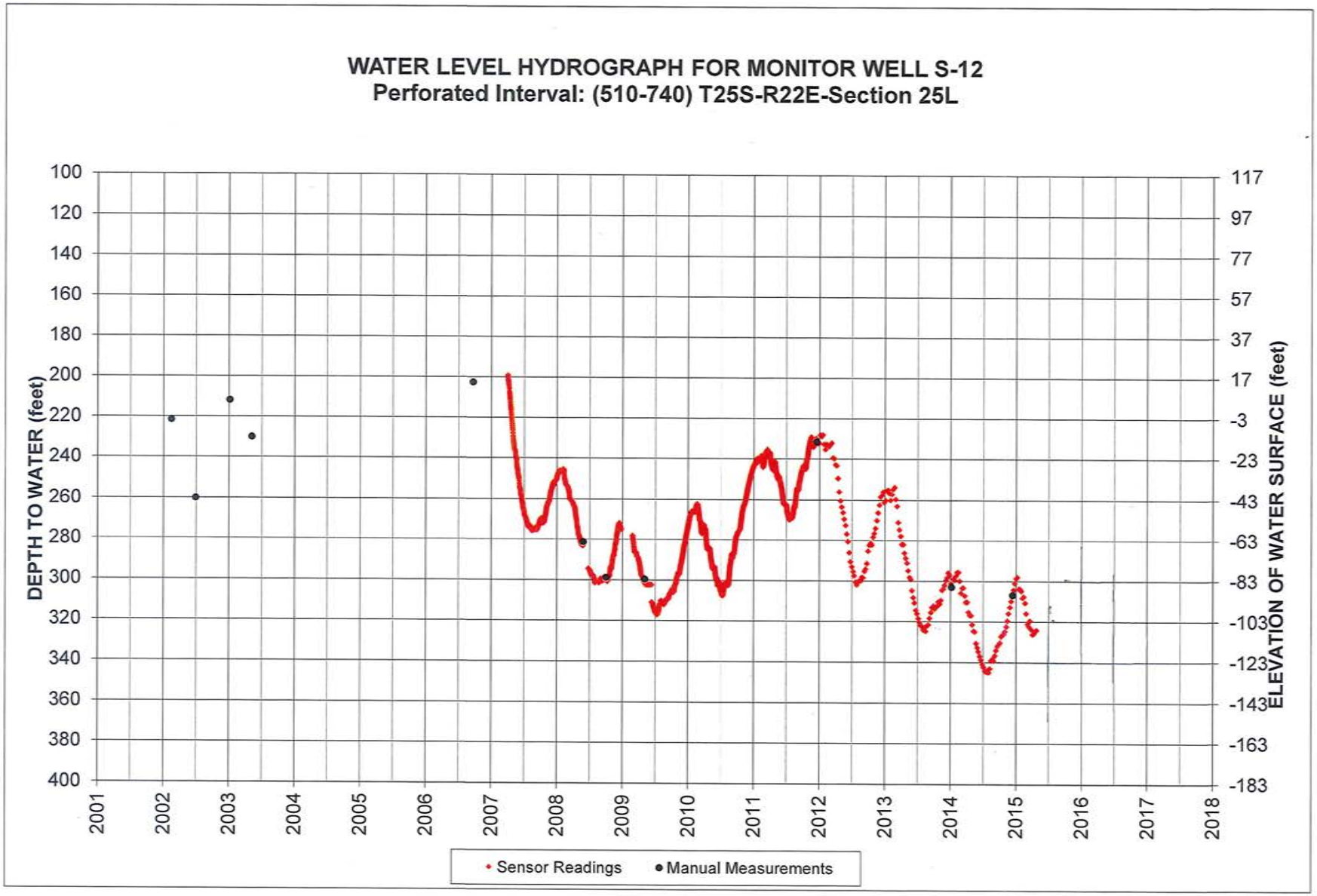


Semitropic Water Storage District
(Manual data from the KCWA)

WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-11
Perforated Interval: (550-700) T26S-R22E-Section 2J

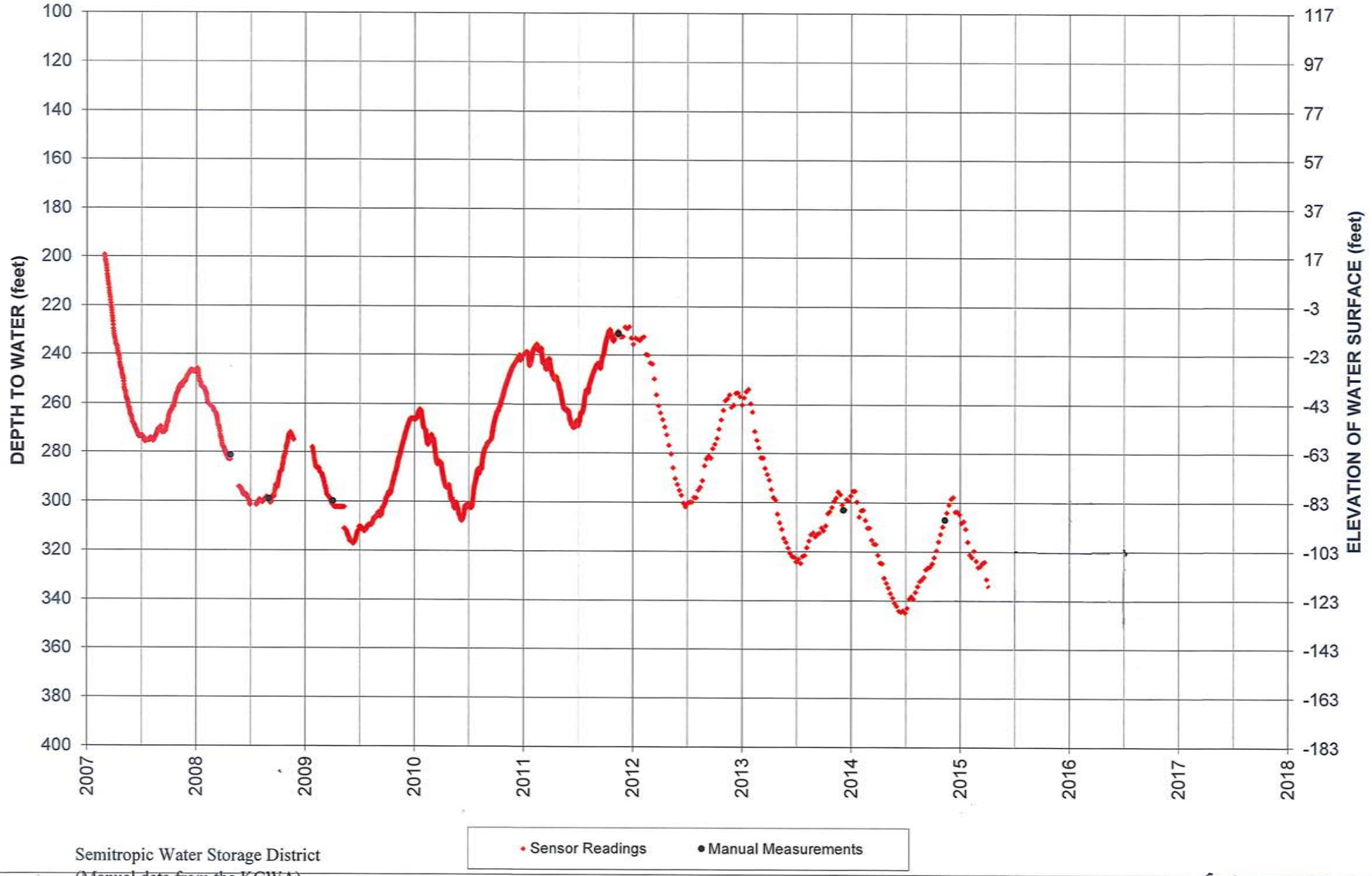


Semitropic Water Storage District
(Manual data from the KCWA)

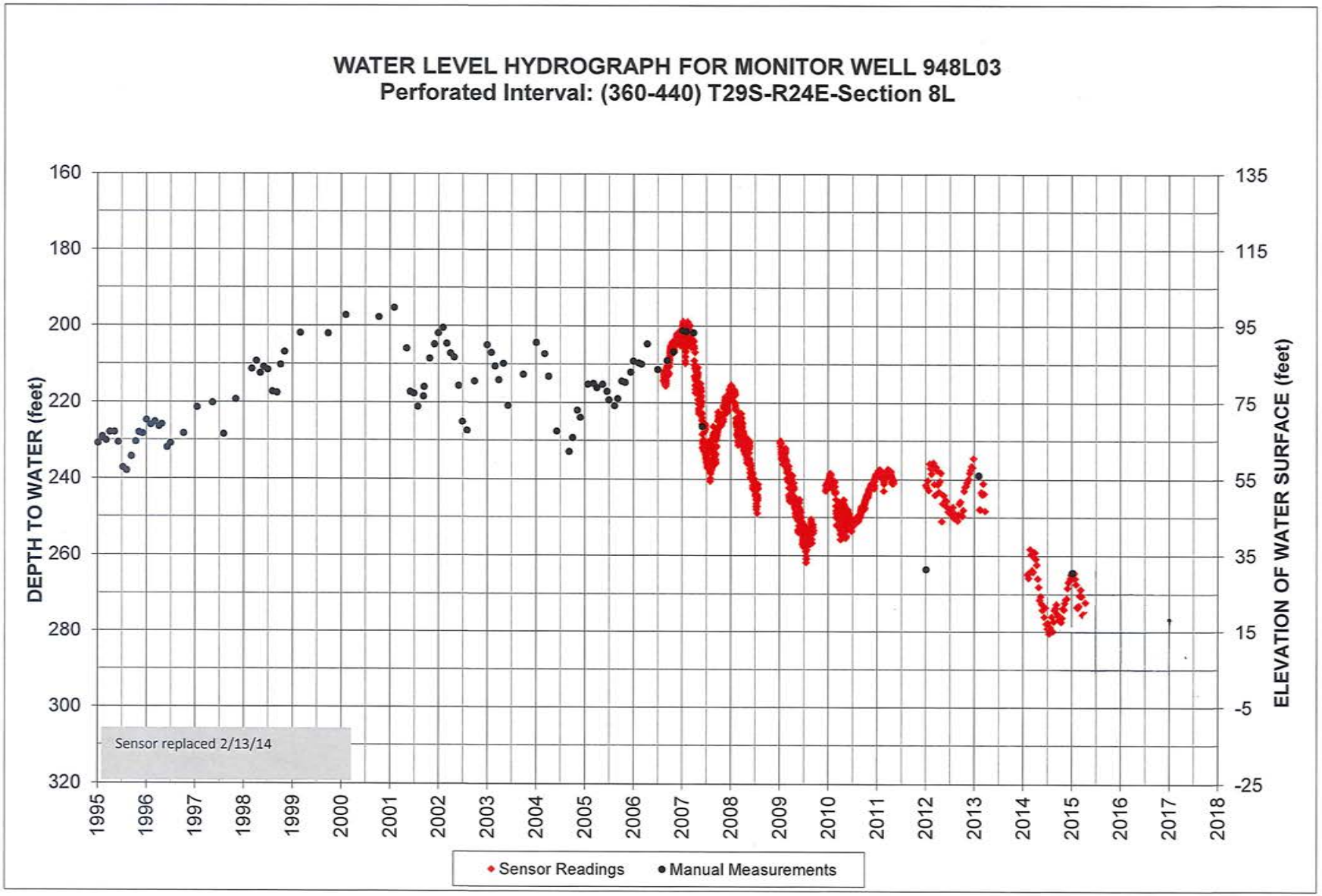


Semitropic Water Storage District
(Manual data from the KCWA)

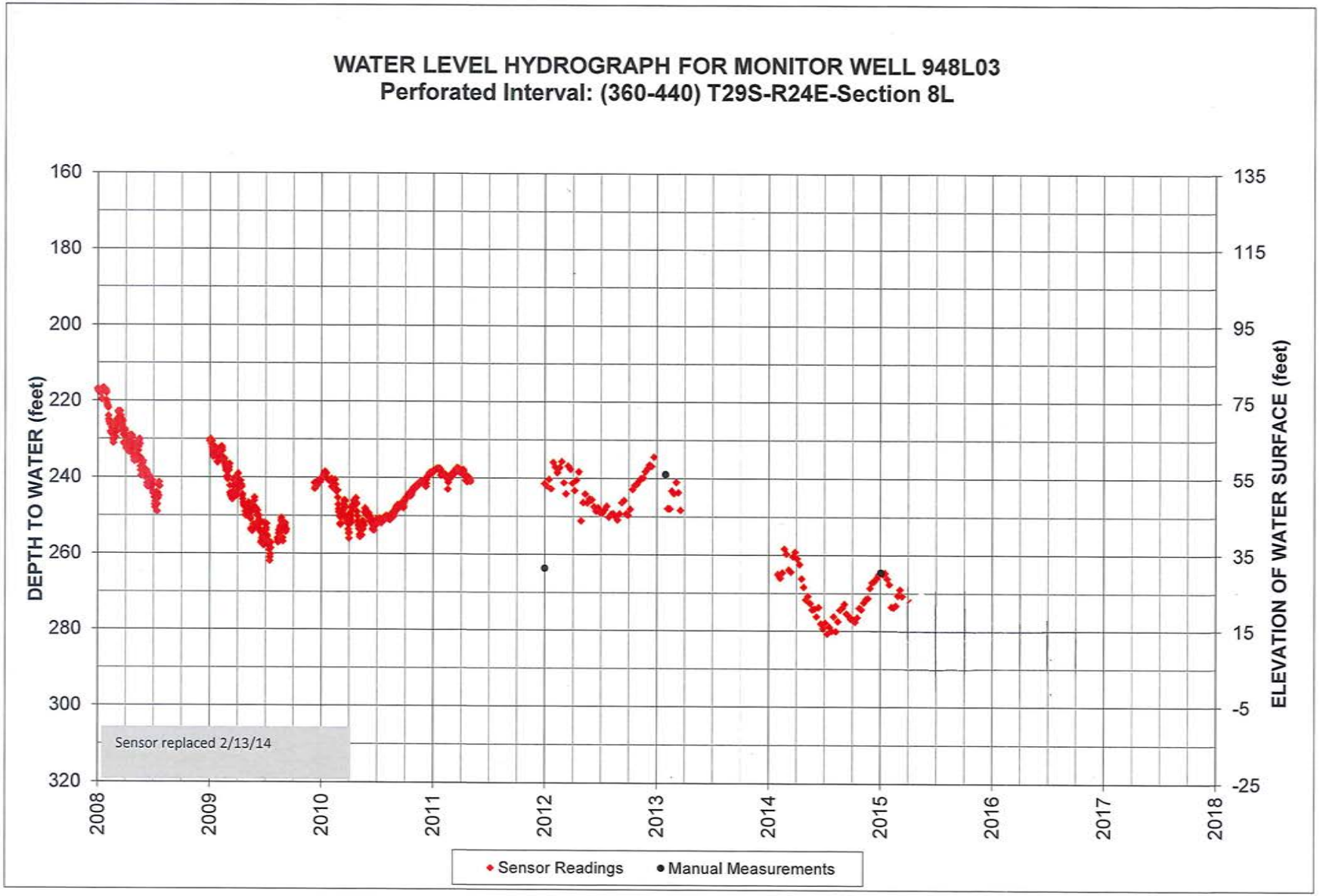
WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-12
Perforated Interval: (510-740) T25S-R22E-Section 25L



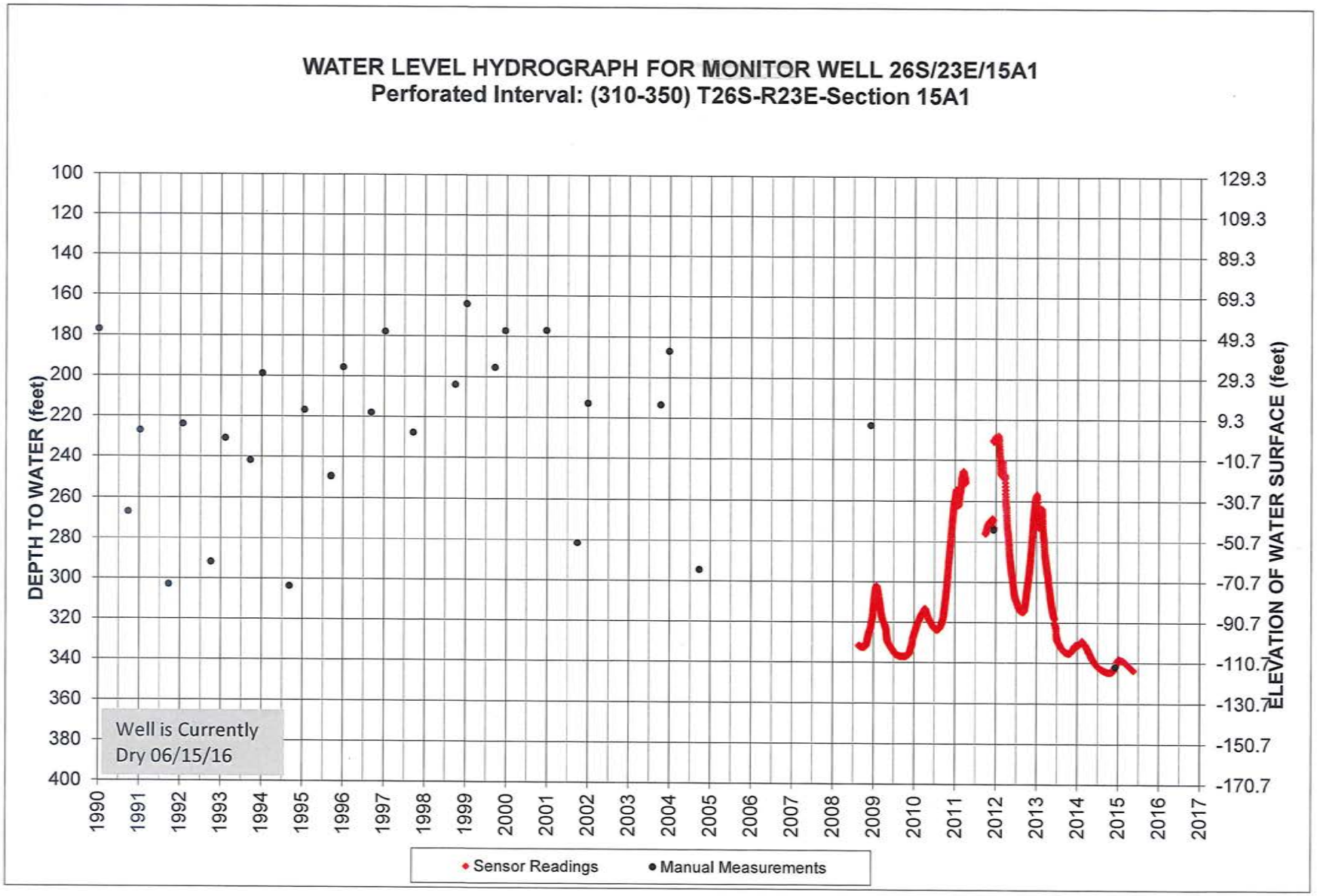
Semitropic Water Storage District
(Manual data from the KCWA)



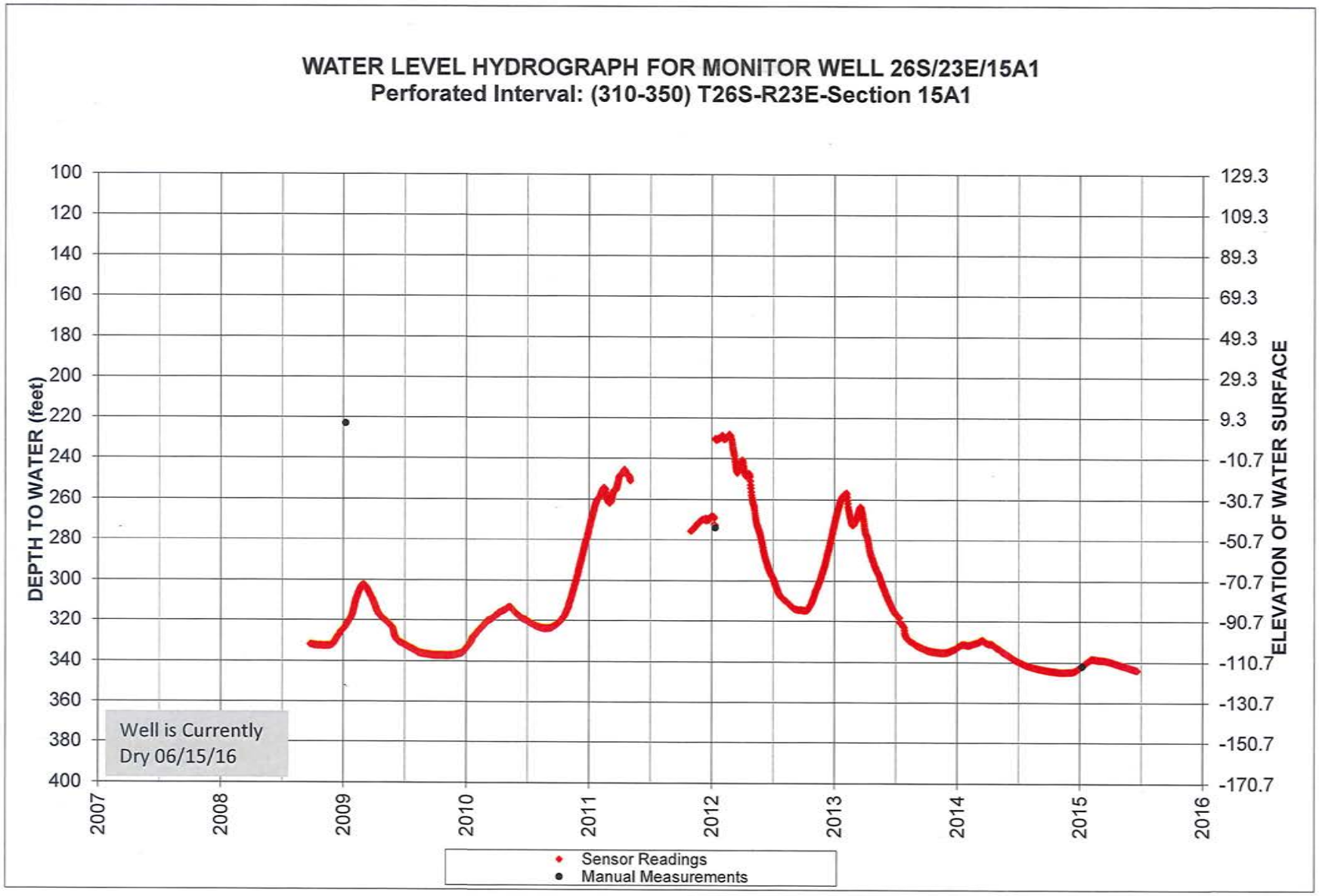
Semitropic Water Storage District
(Manual data from the KCWA)



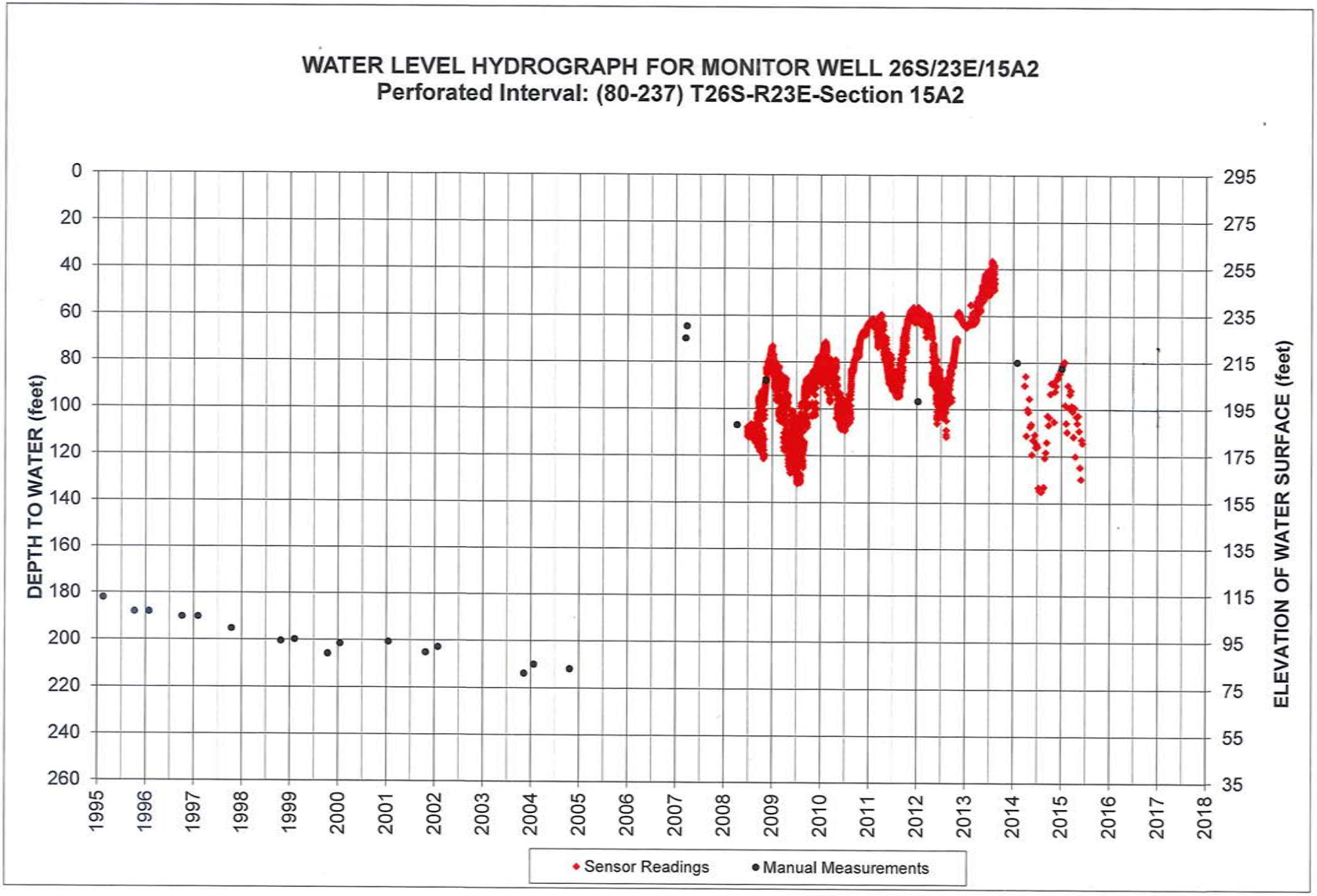
Semitropic Water Storage District
(Manual data from the KCWA)



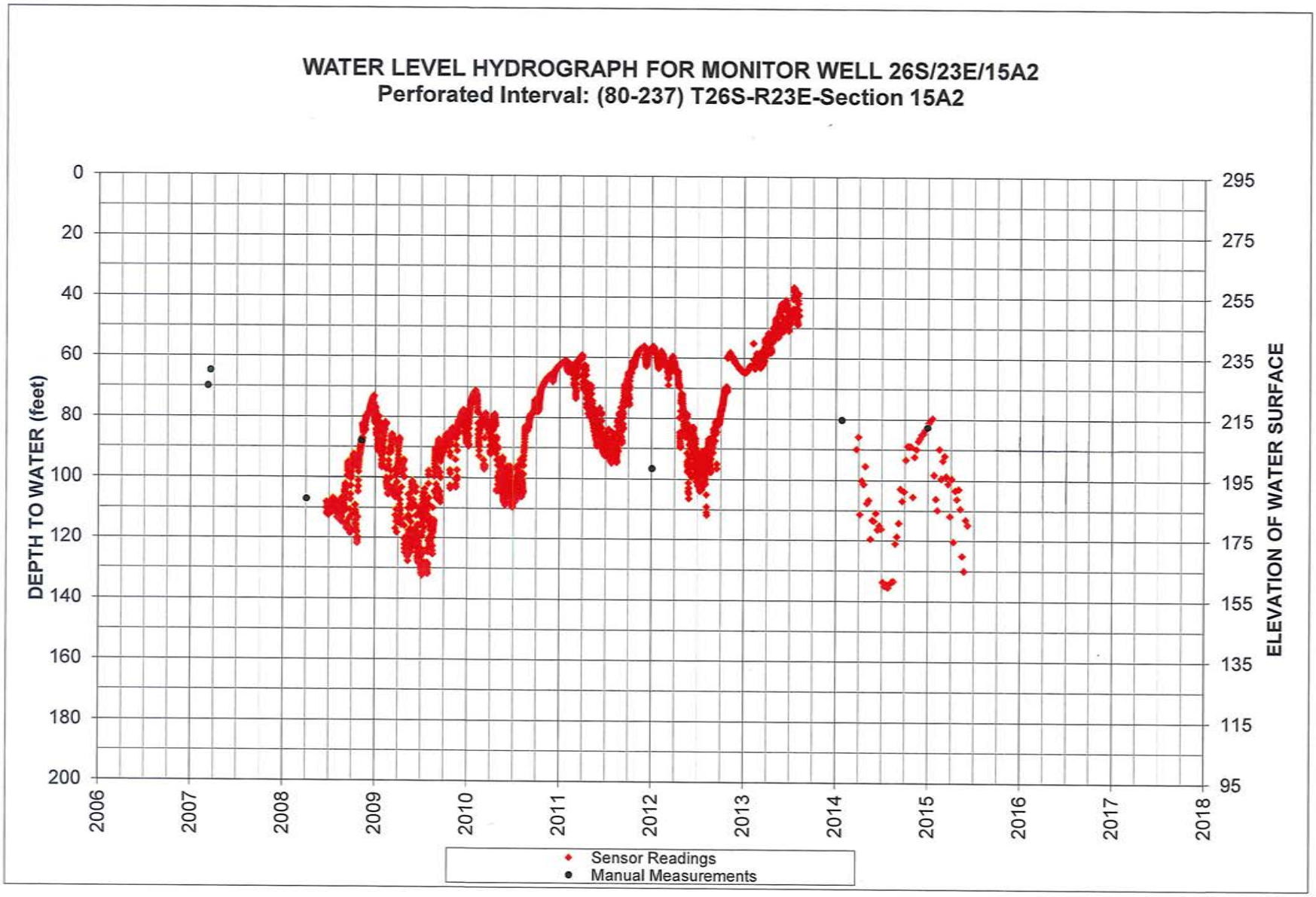
Semitropic Water Storage District
(Manual data from the KCWA)



Semitropic Water Storage District
(Manual data from the KCWA)



Semitropic Water Storage District
(Manual data from the KCWA)



Semitropic Water Storage District
(Manual data from the KCWA)

Supply Wells

SEMITROPIC WSD

DISTRICT WELLS

Well Number		Perforated Interval from	to
26/24-9N		470	840
26/24-17B	(a)	450	790
26/24-17G		450	810
26/24-20C	(a)	440	830
26/24-20M	(a)	440	820
26/24-29D	(a)	460	830
26/24-29M	(a)	410	910
27/22-25D	(a)	242	516
27/22-25J		262	565
27/23-10J		442	633
27/23-30A		204	484
28/23-22F		413	645
28/23-26F		420	690
28/23-35A	(a)	400	670

(a) Not included for lack of "recent" data.

SEMITROPIC WSD

PRIVATE WELLS

Well Number		Perforated Interval from	to
25/24-36R		404	1005
26/22-35P	QM (2012 & 2015)		
26/24-27H		450	805
27/22-12G	(a)	219	416
27/23-28A	(a)	200	625
27/24-20K		300	700
28/22-1H			
28/23-7H	(a)	300	495
28/23-11R		288	510
28/23-16G		240	416
28/23-34K	(a)	226	459
28/24-32N	(a)	68	420
29/23-12J	(a)	150	504

(a) Not included for lack of "recent" or anomalous data.
QM – Questionable Measurements.

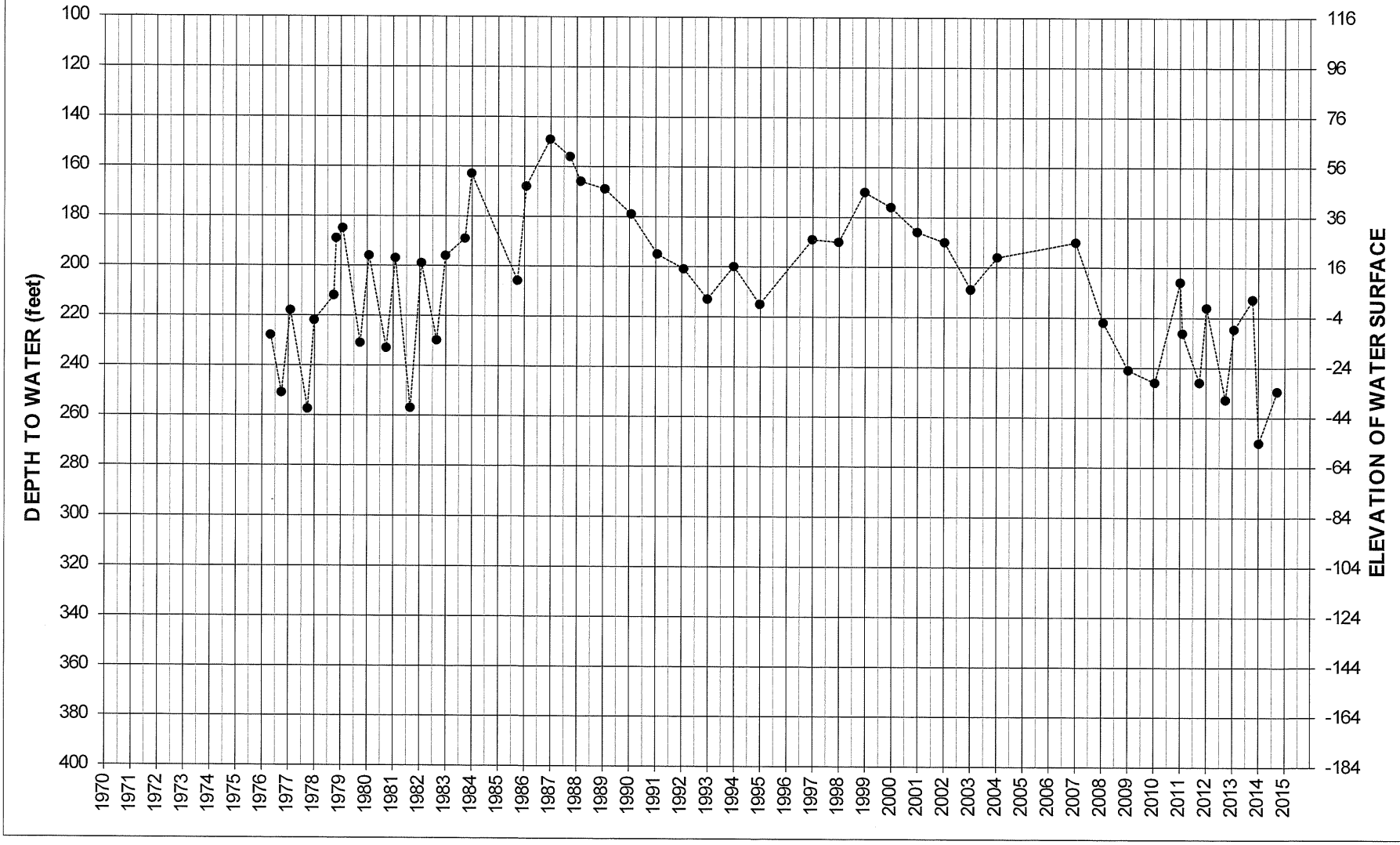
SEMITROPIC WSD

PRIVATE WELLS

Well Number	Perforated Interval from	to	Well Number	Perforated Interval from	to
25/22-15A	230	320	27/23-4H (a)	300	600
25/22-27J	497	800	27/23-15G (a)	371	602
			27/23-16N	300	600
25/23-3E (a)			27/23-26P (a)	350	750
25/23-22Q (a)			27/23-33J	300	840
25/23-24R	499	1200			
			27/24-5H	260	730
25/24-2B	400	700	27/24-6F	400	700
25/24-25F	500	1200	27/24-16P	350	716
			27/24-31D (a)		
26/22-14E	299	544	27/24-33A (a)	230	374
26/22-34L (b)	200	400			
			28/24-4C		
26/23-13R	450	807	28/24-10R		
26/23-21Q (b)	350	702	28/24-28A	204	504
26/24-8R	410	820			
26/24-23R	300	472			

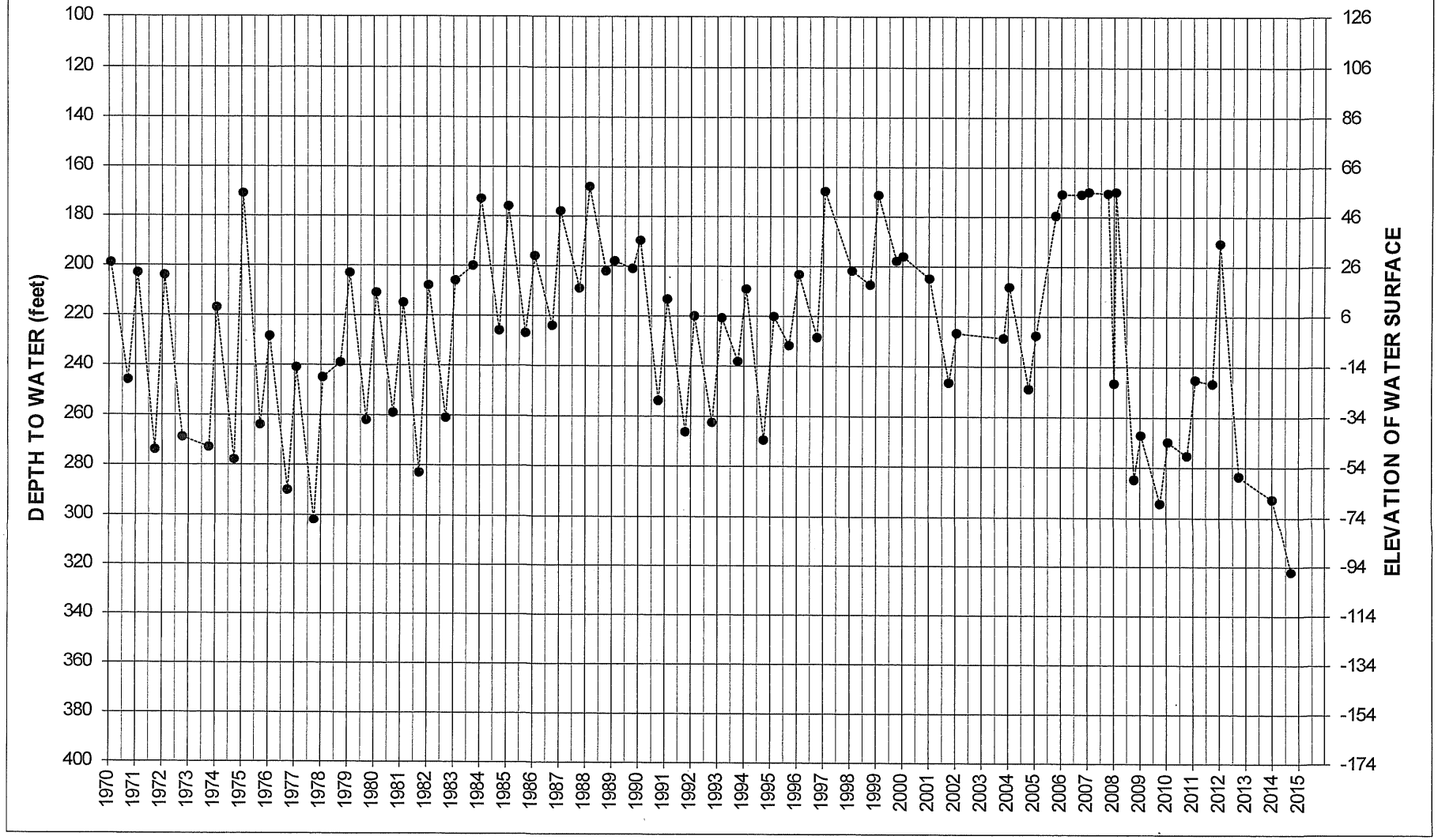
(a) Not included for lack of "recent" or anomalous data.
(b) Abandoned.

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/22-15A (230-320)



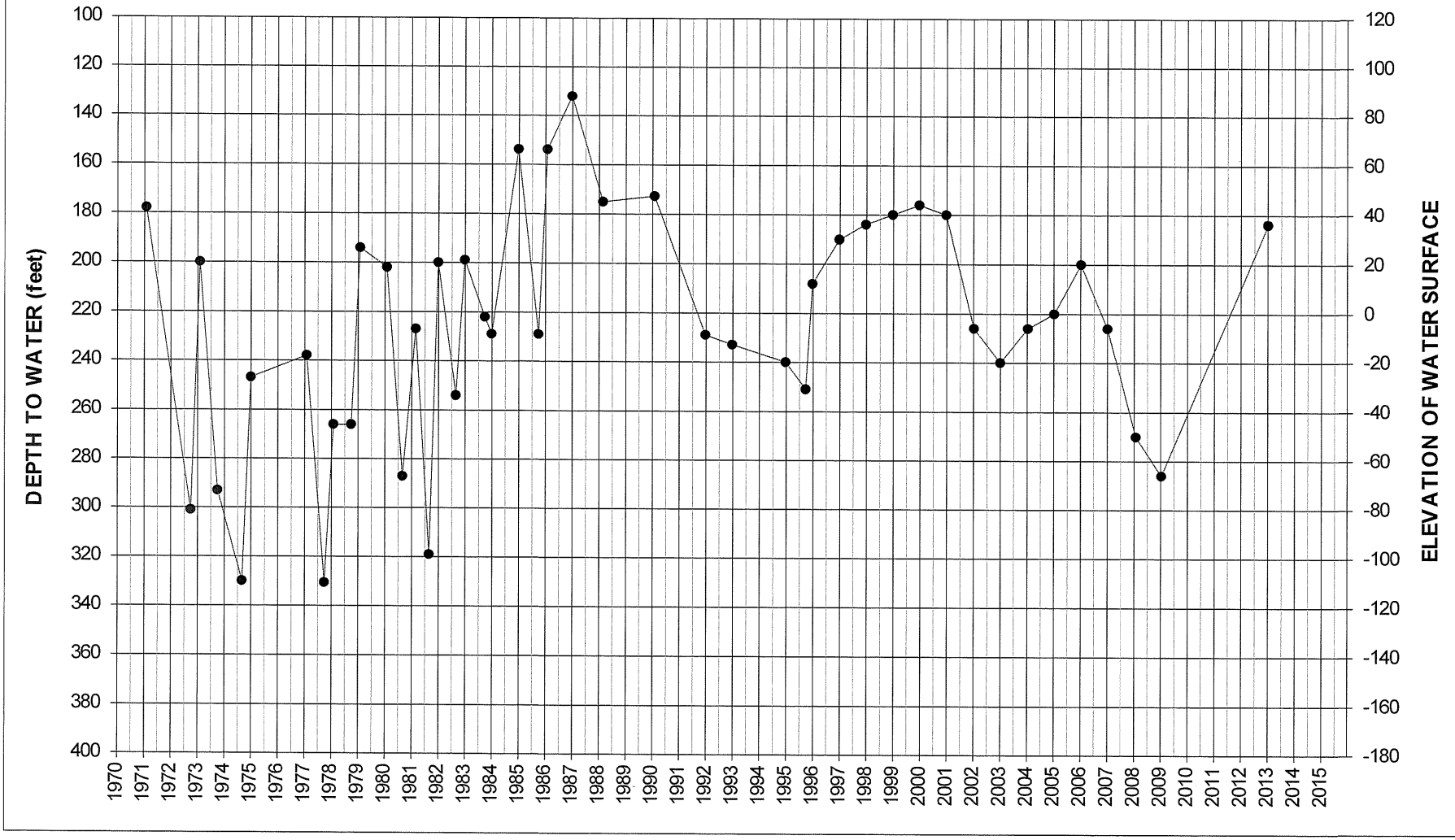
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/22-27J(497-800)



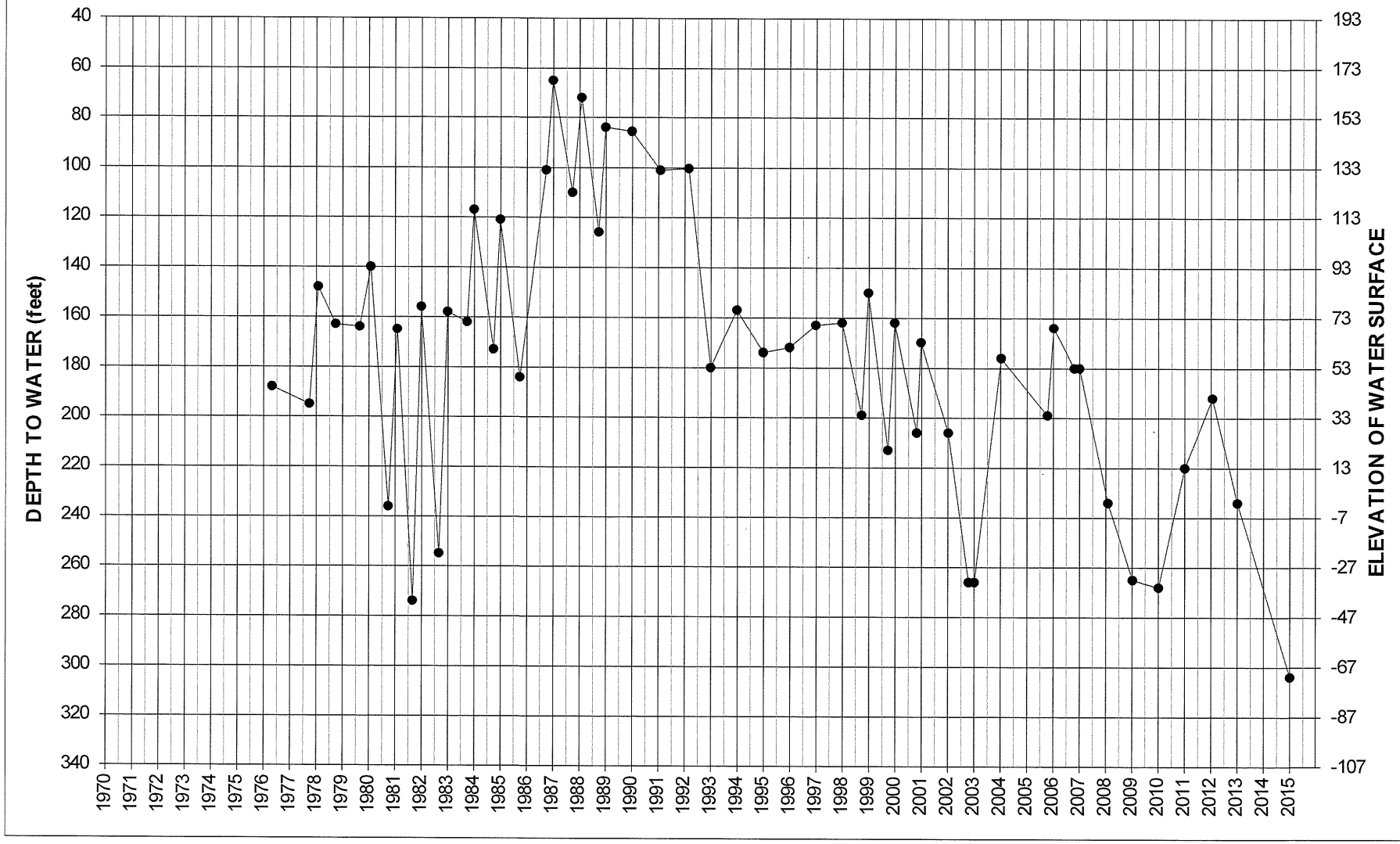
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/23-24R (499-1200)



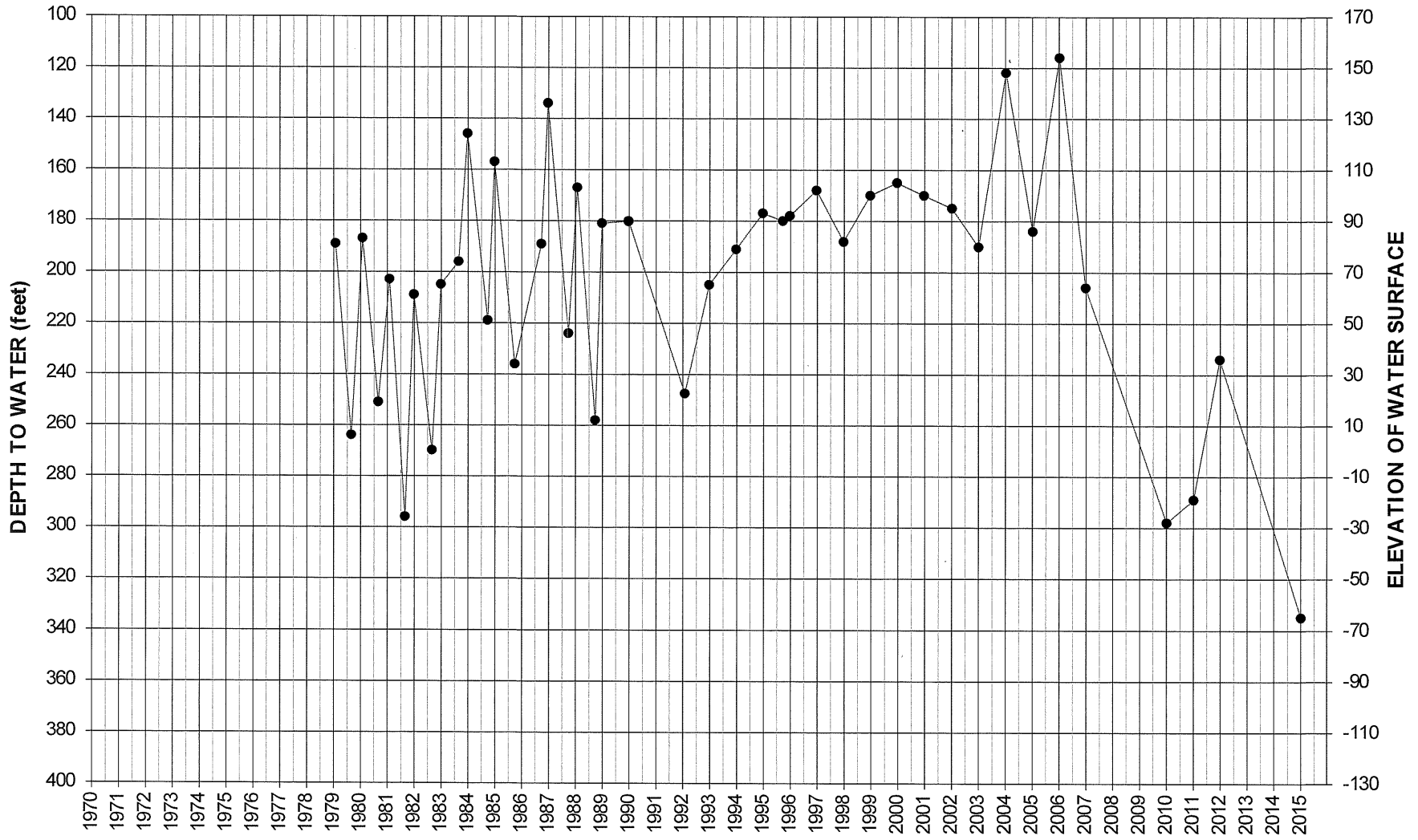
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/24-2B (400-700)



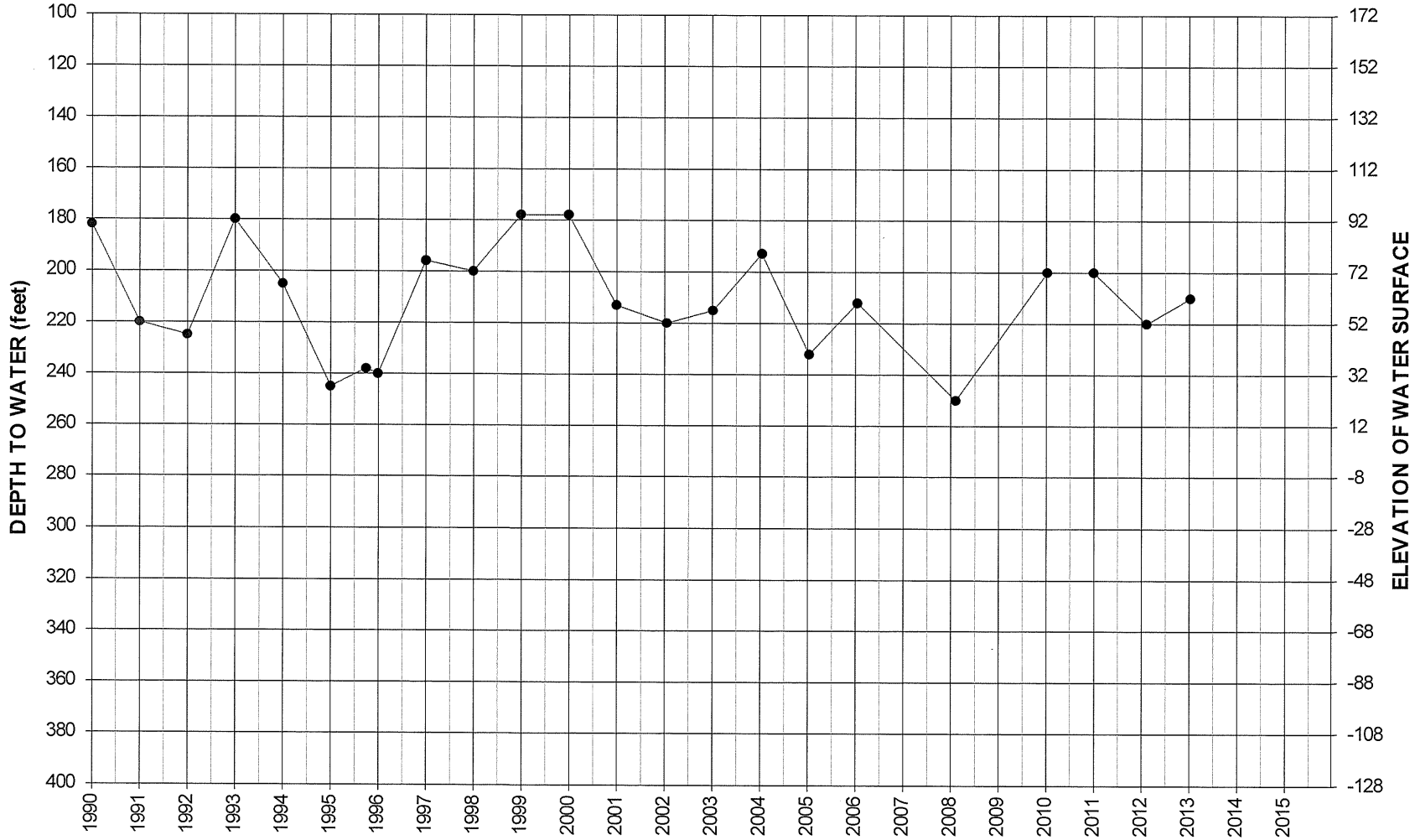
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/24-25F (500-1200)



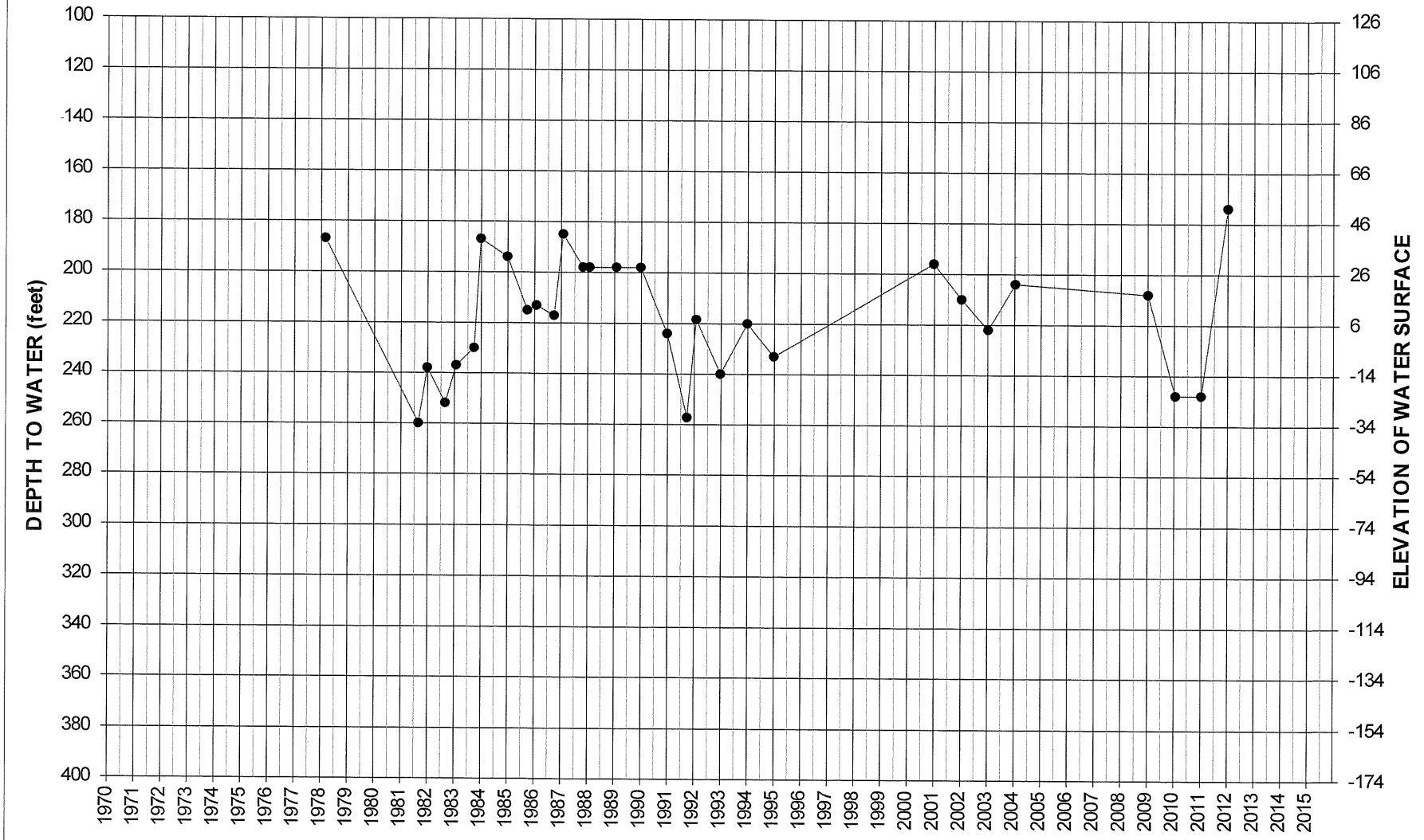
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/24-36R (404-1005)



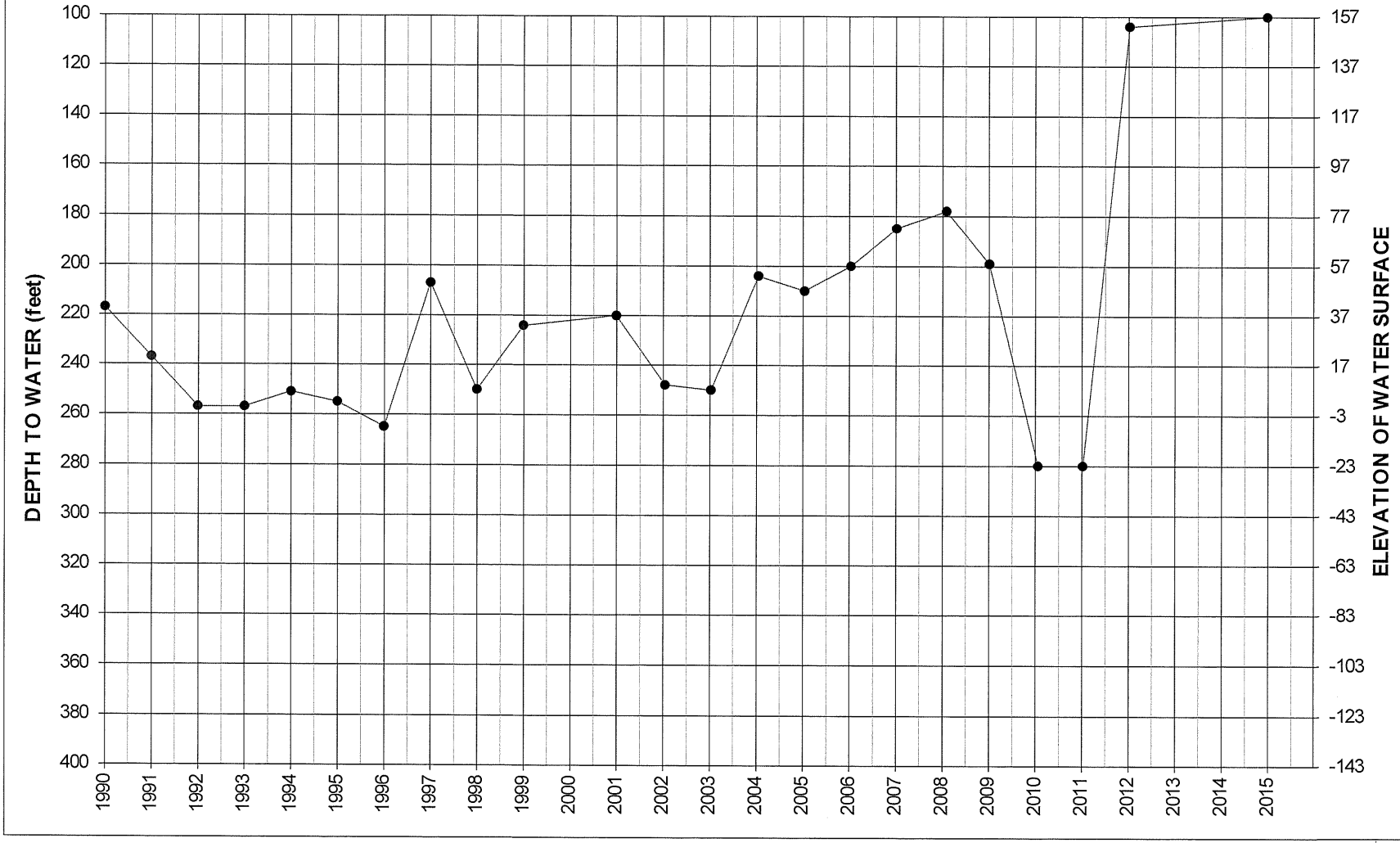
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/22-14E (299-544)



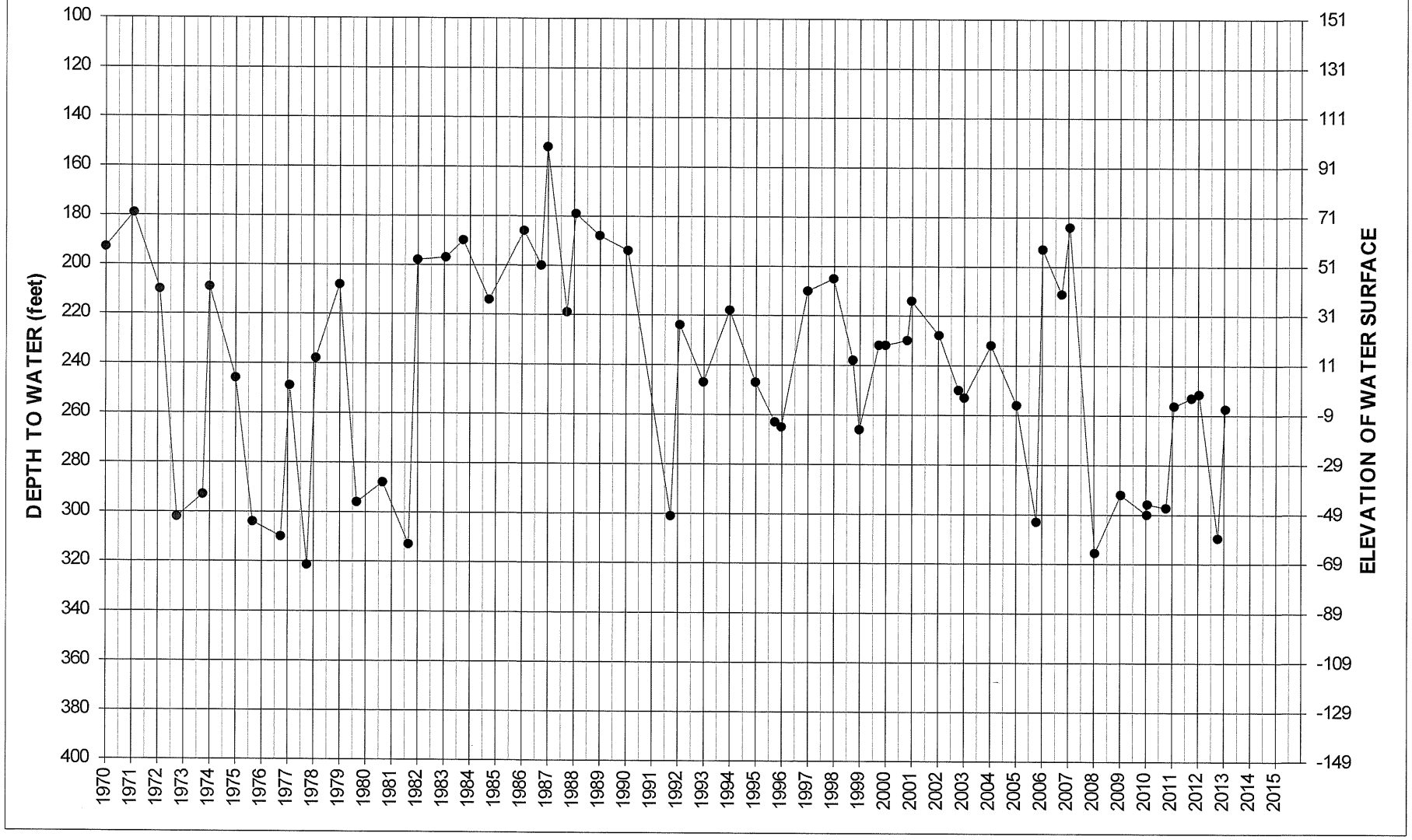
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/22-35P



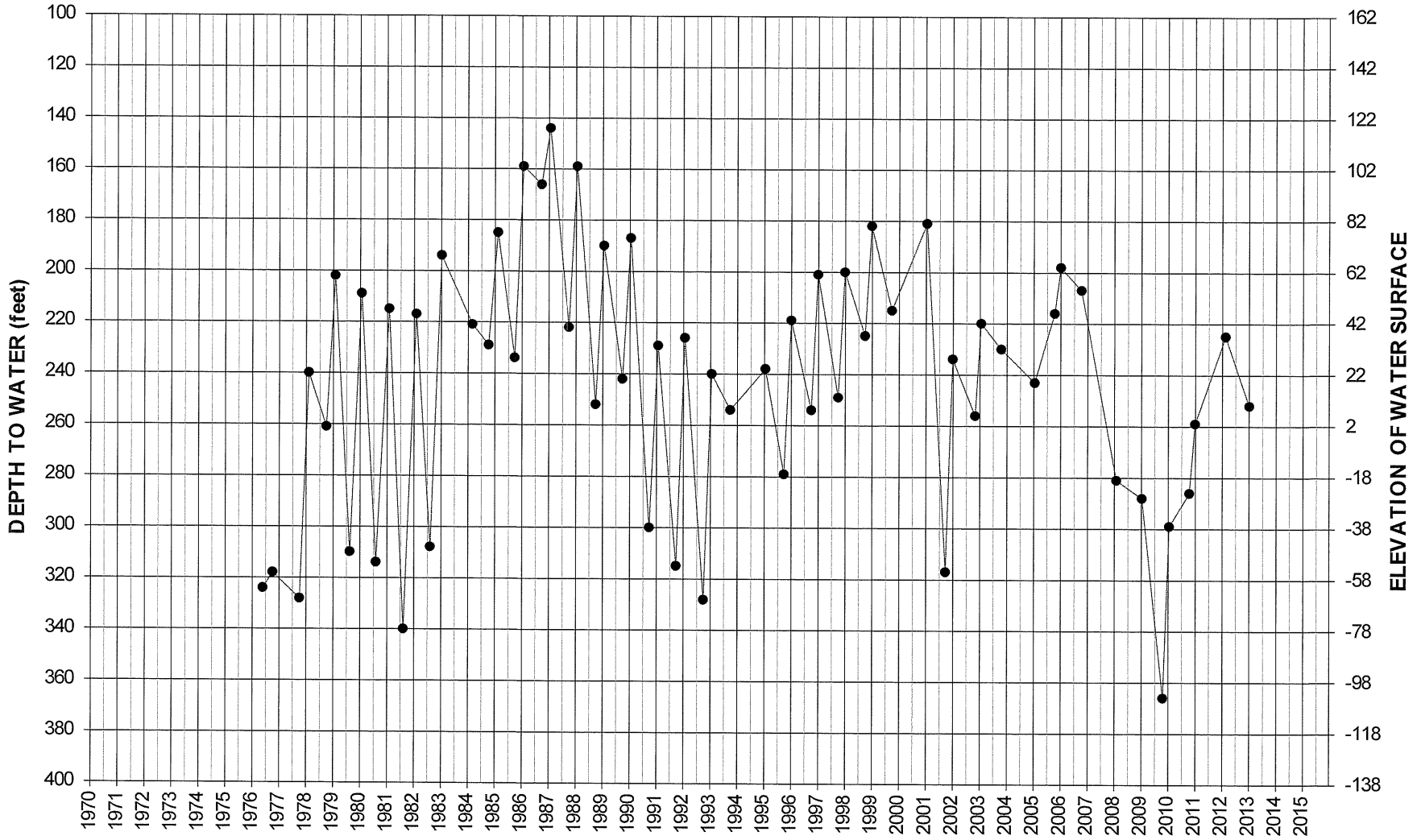
GEI Consultants
Bloomman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/23-13R (450-807)



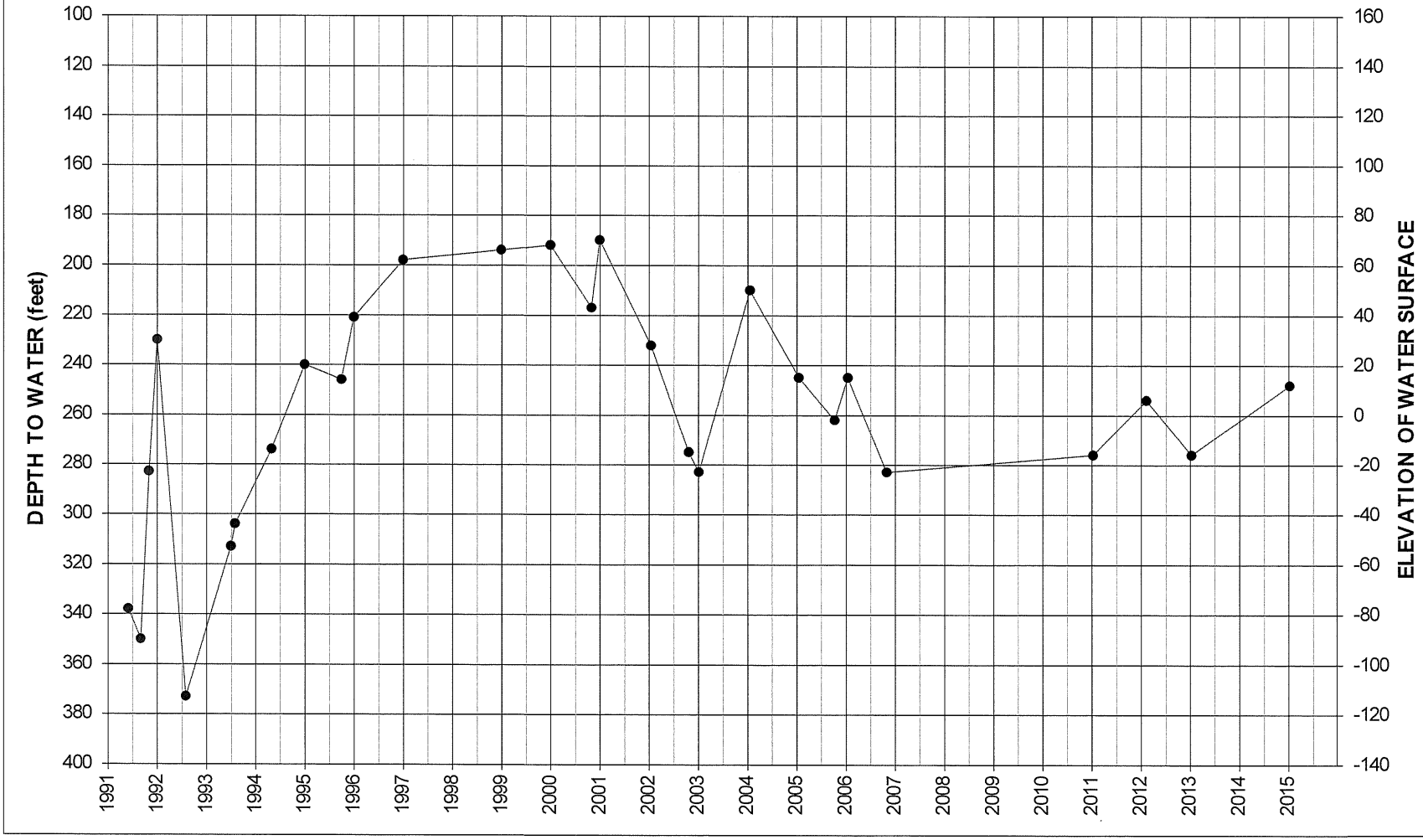
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-8R (410-820)



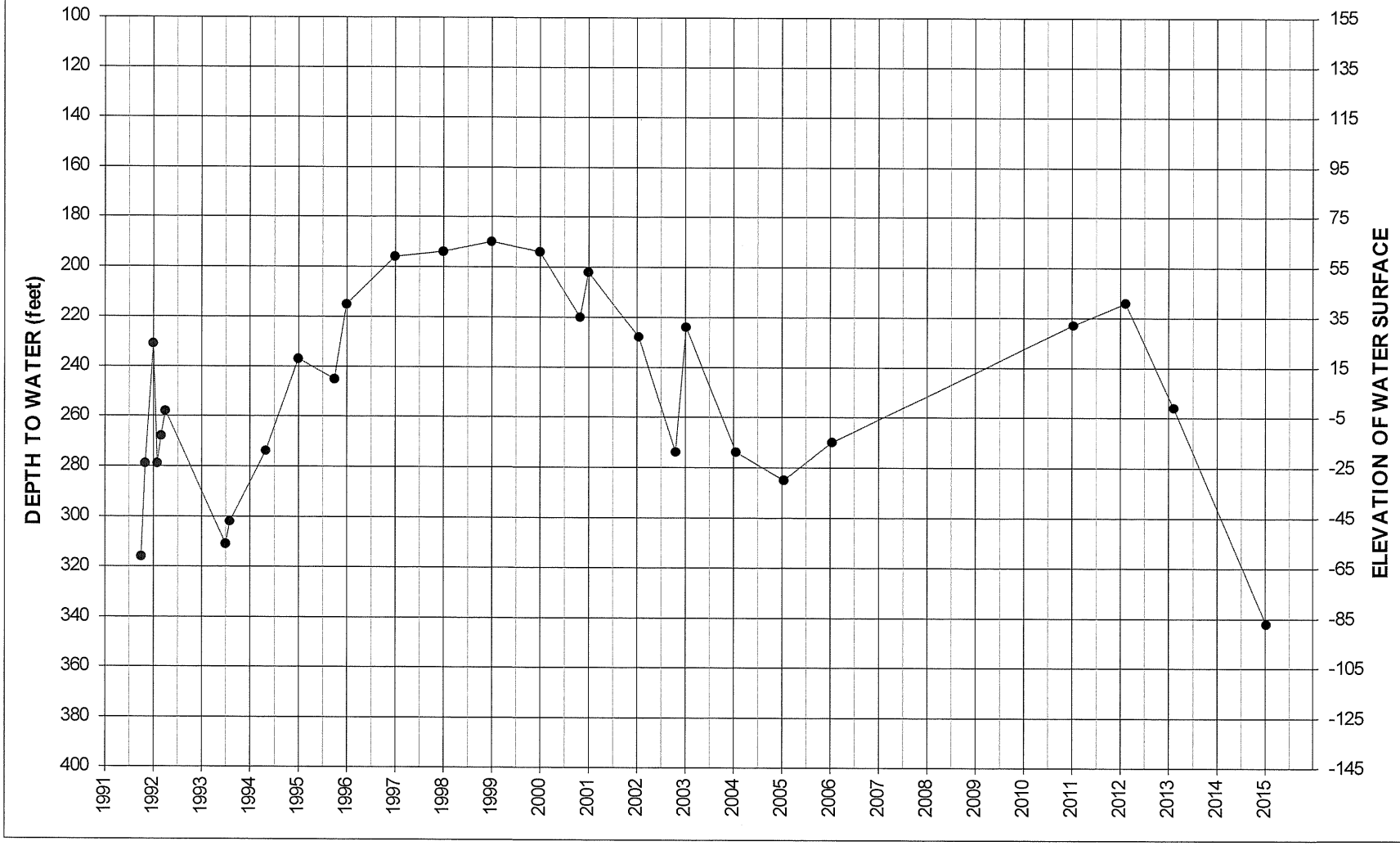
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER WELL HYDROGRAPH FOR WELL #26/24-9N (470-840)



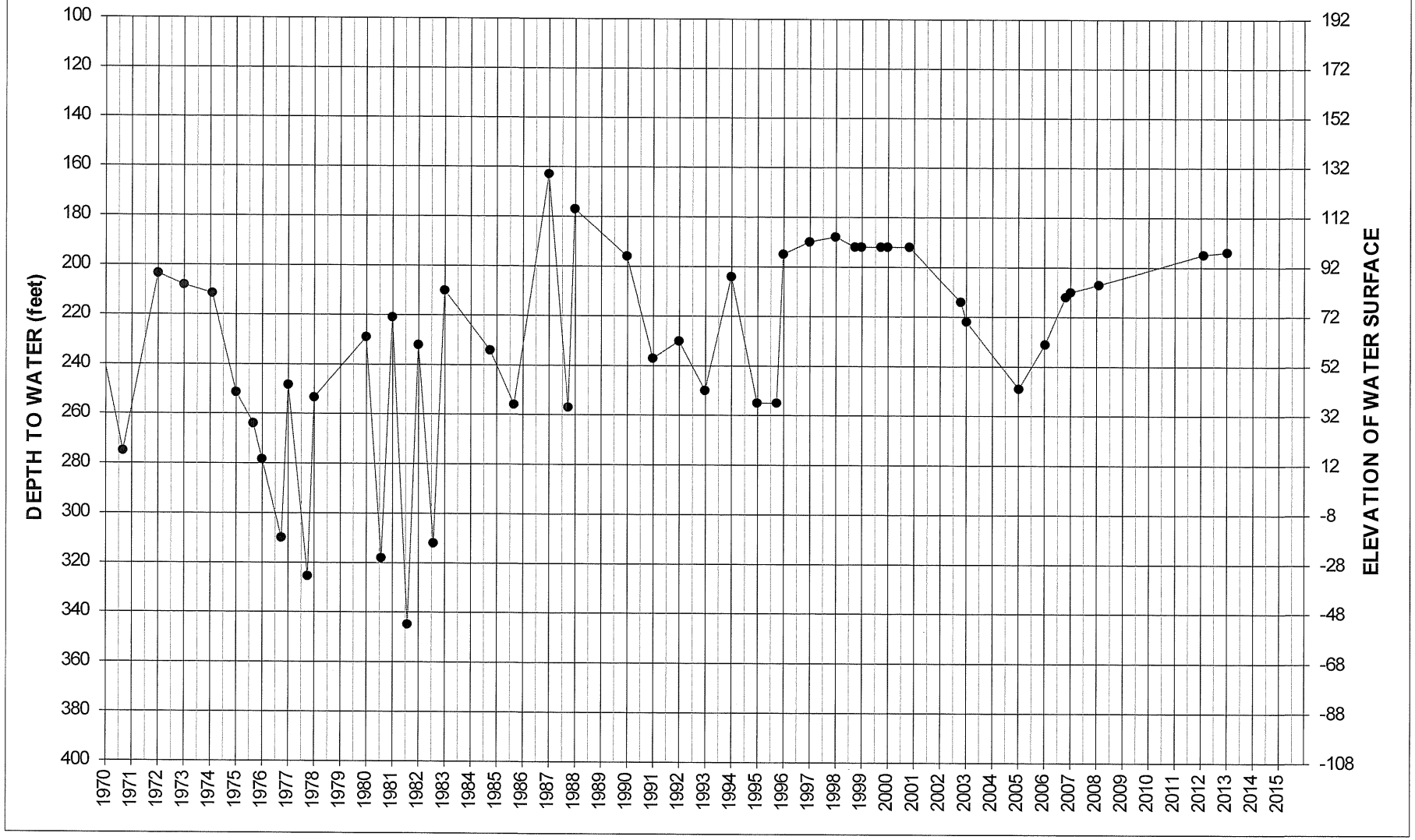
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-17G (450-810)



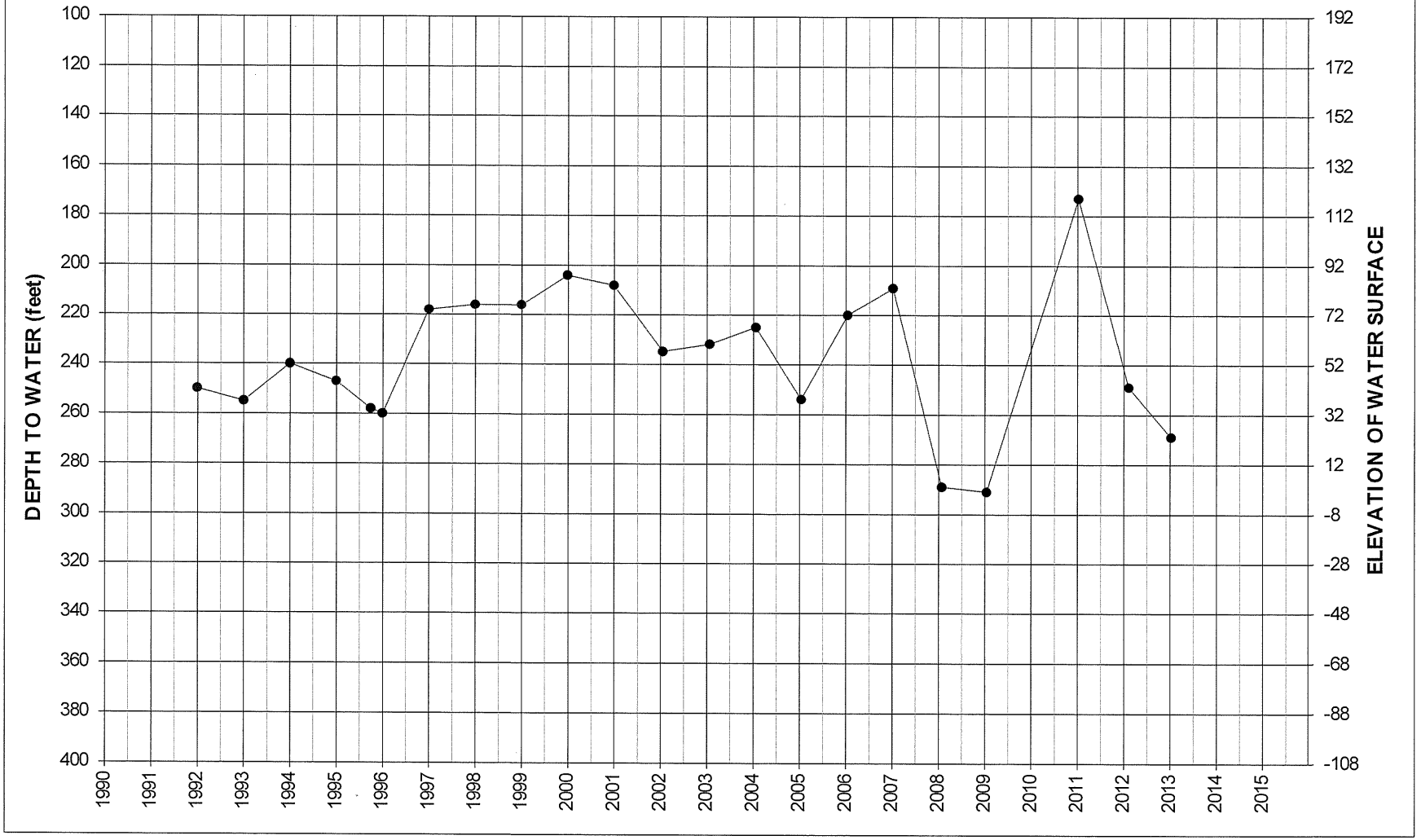
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-23R (300-472)

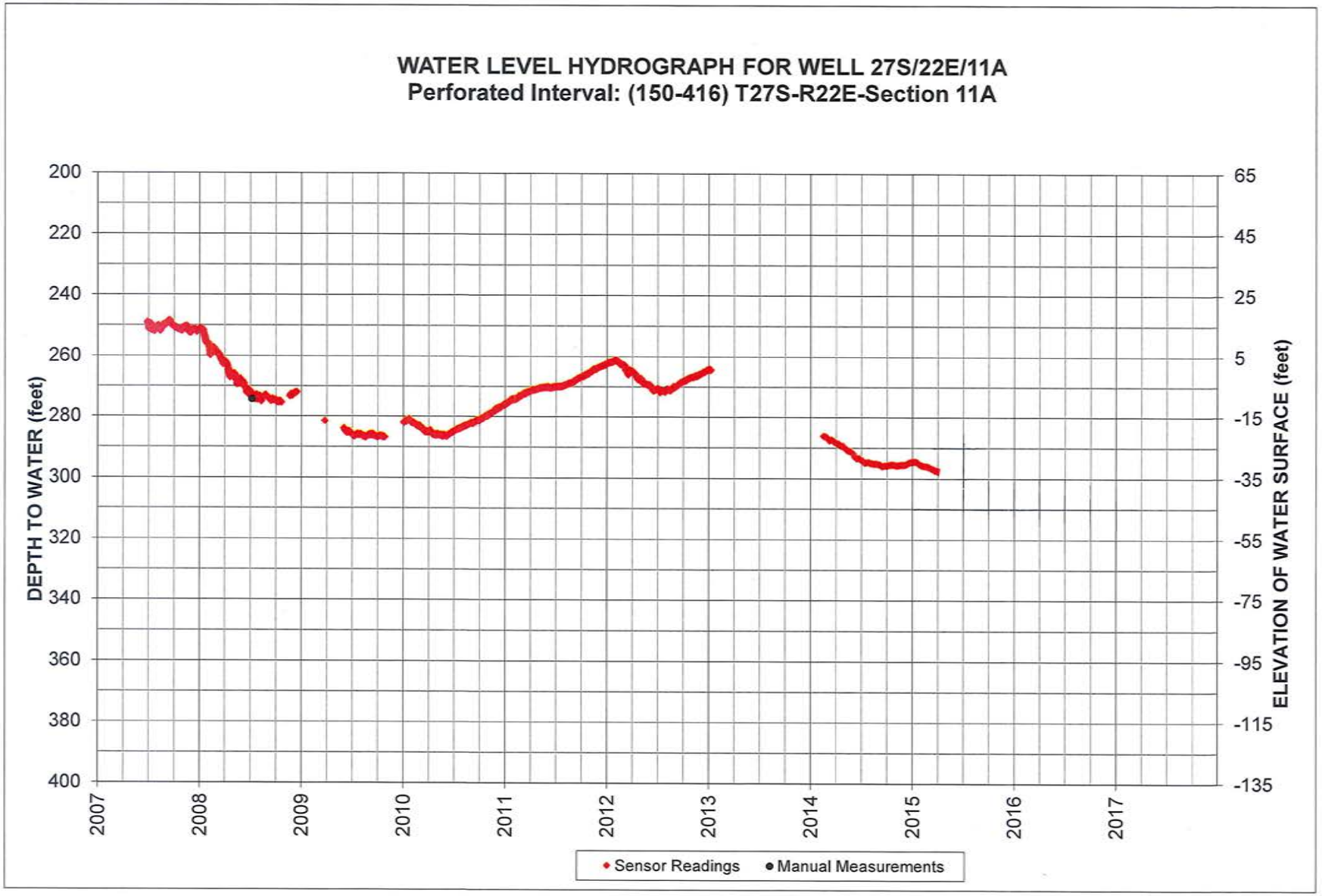


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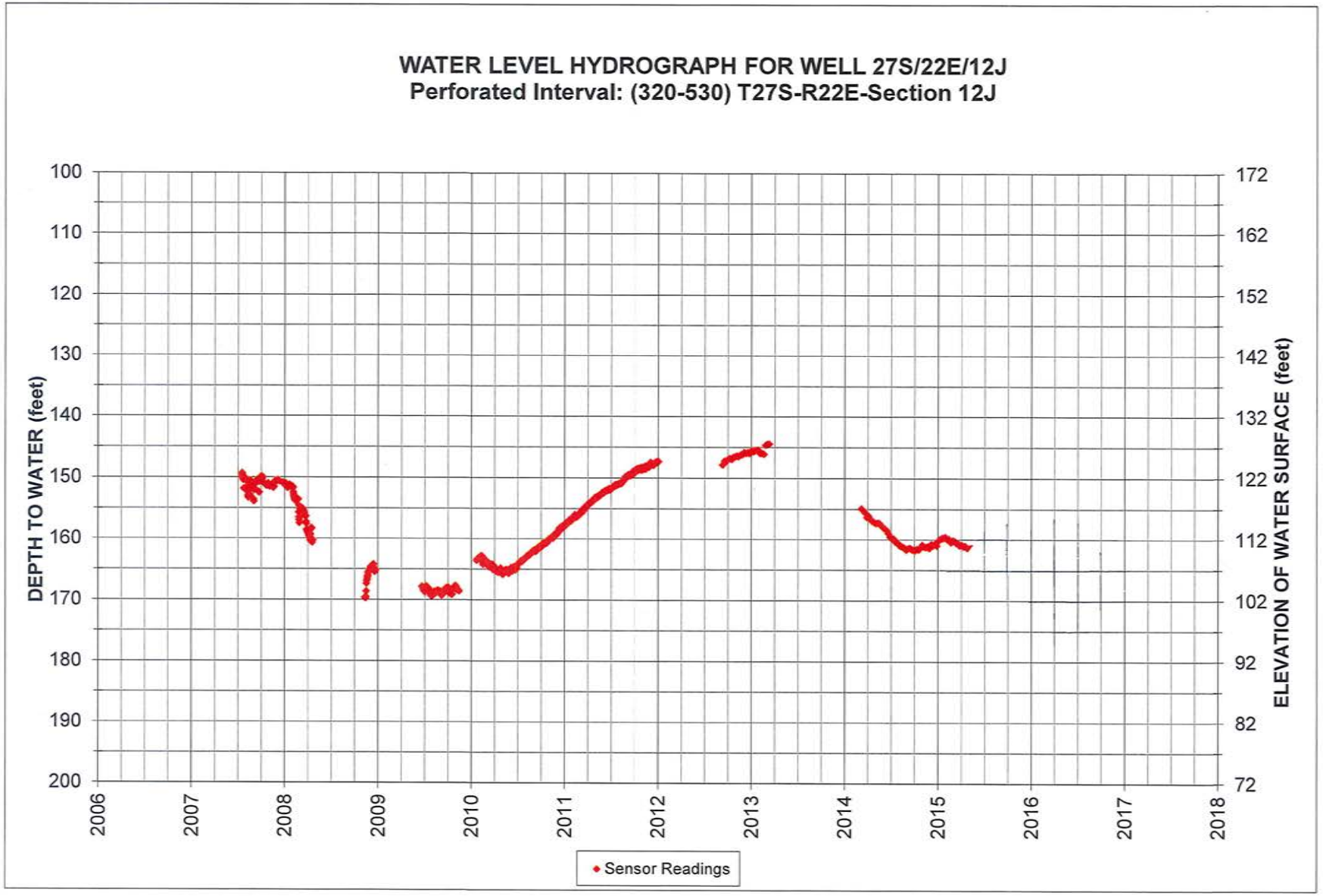
SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-27H (450-805)



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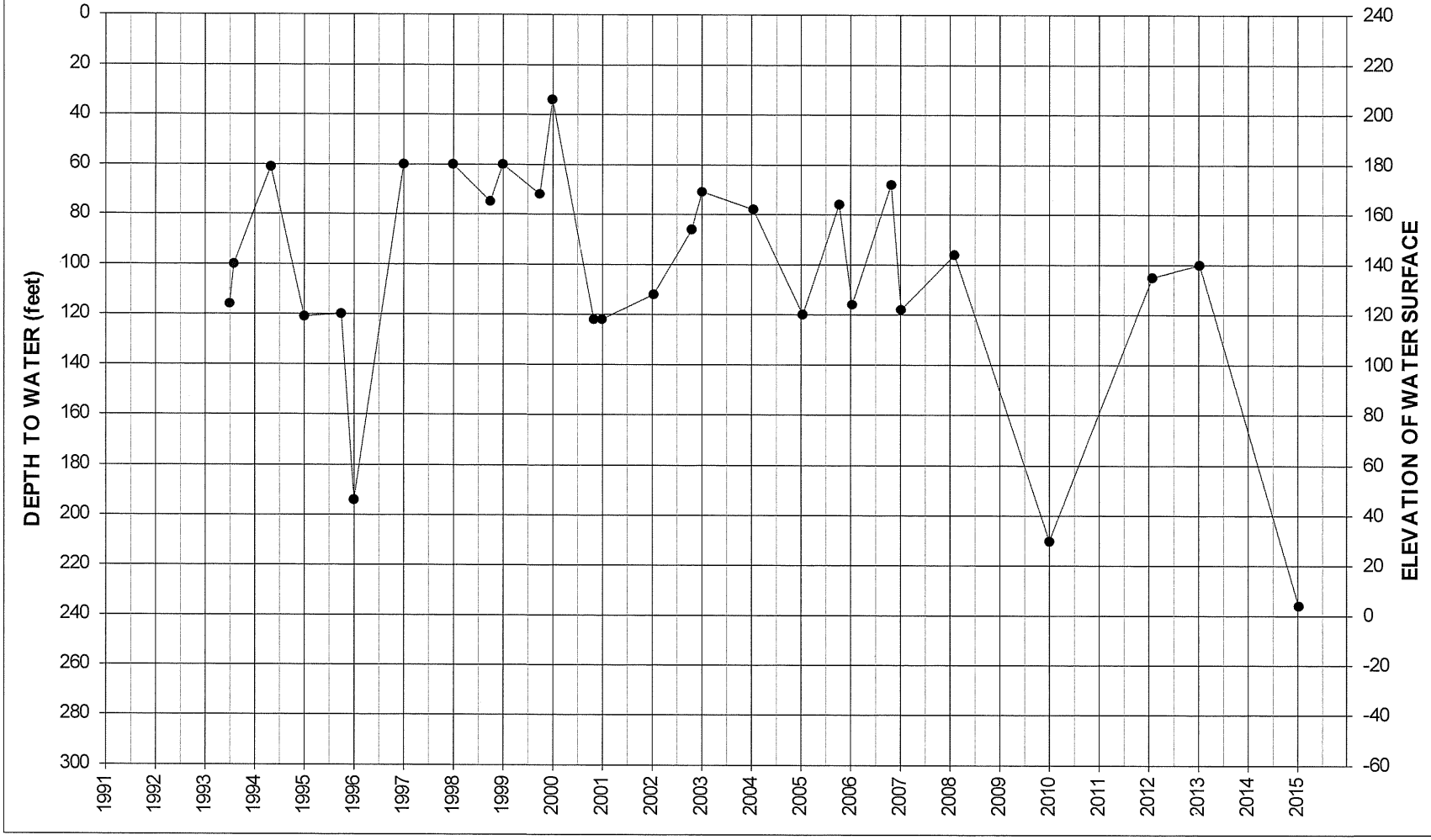


Semitropic Water Storage District
(Manual data from the KCWA)



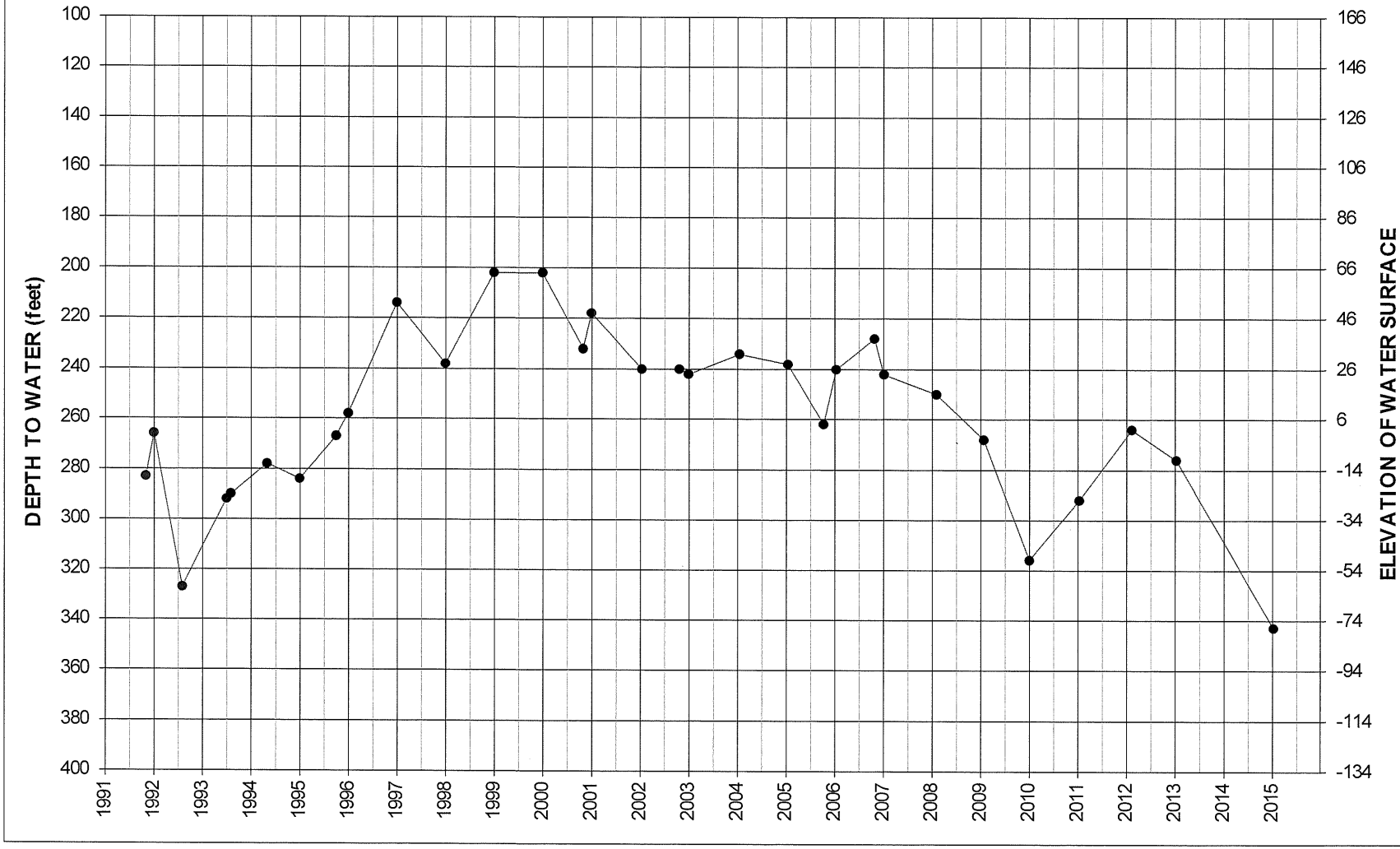
Semitropic Water Storage District

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/22-25J (262-565)



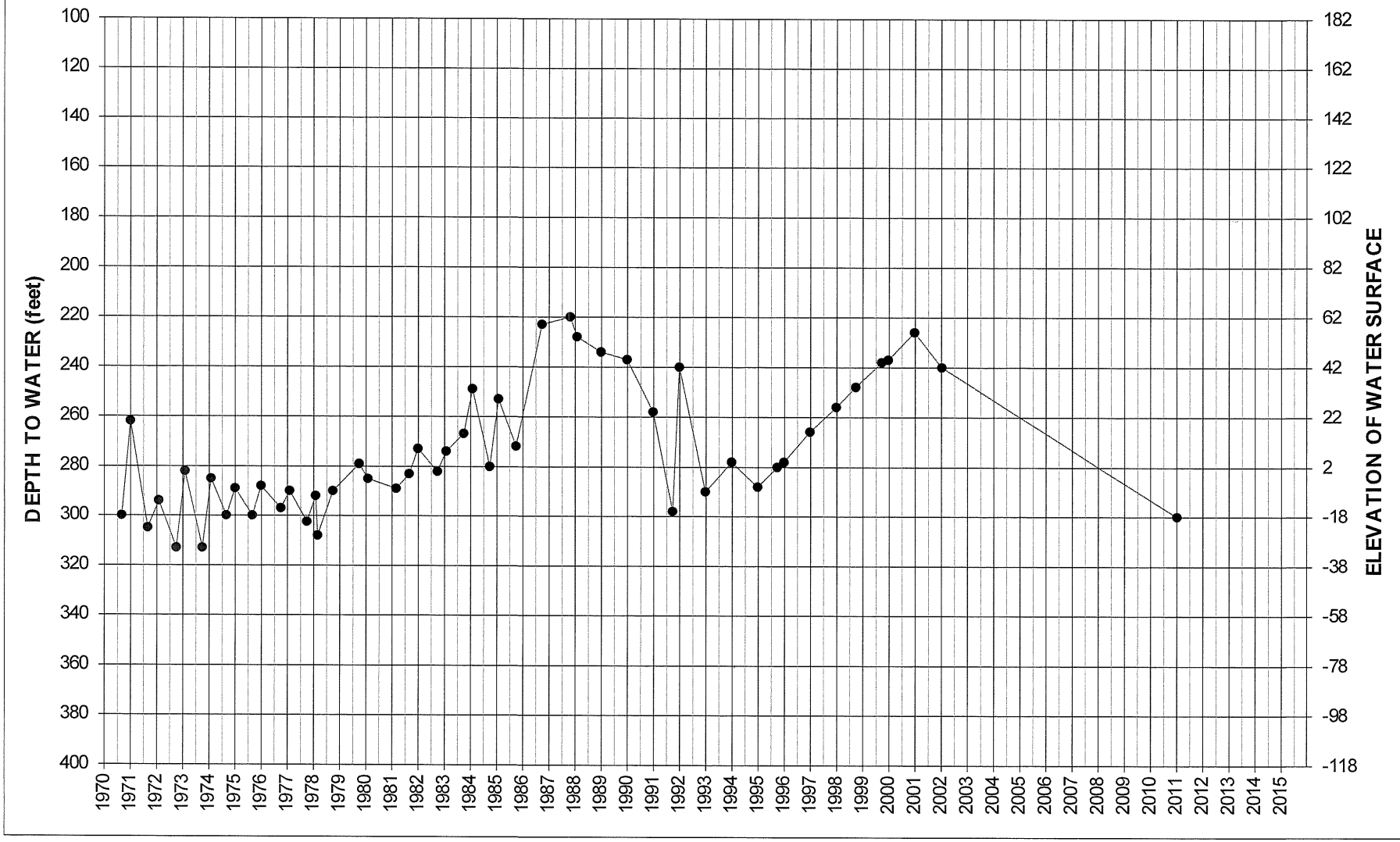
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Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-10J (442-633)



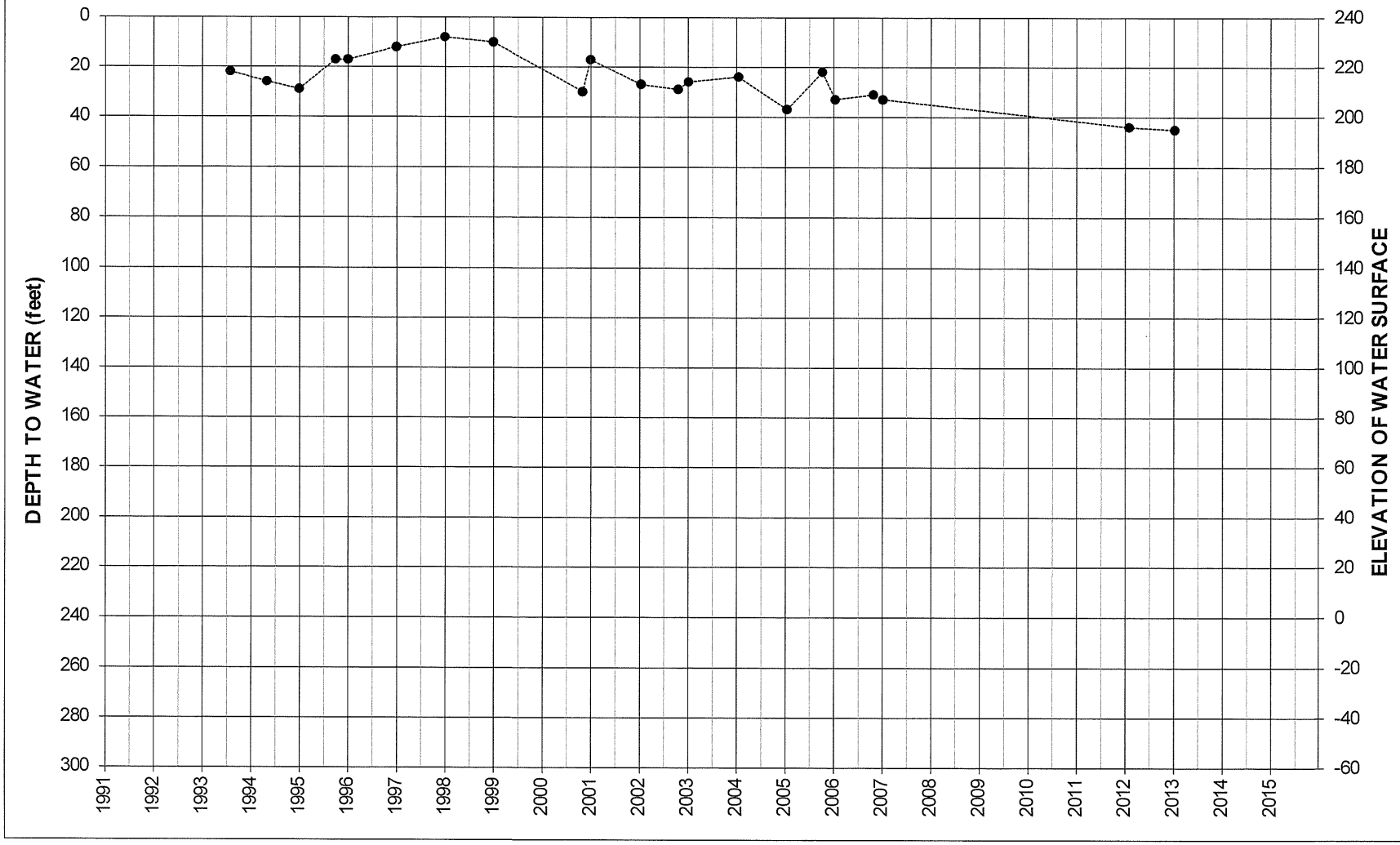
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-16N (300-600)



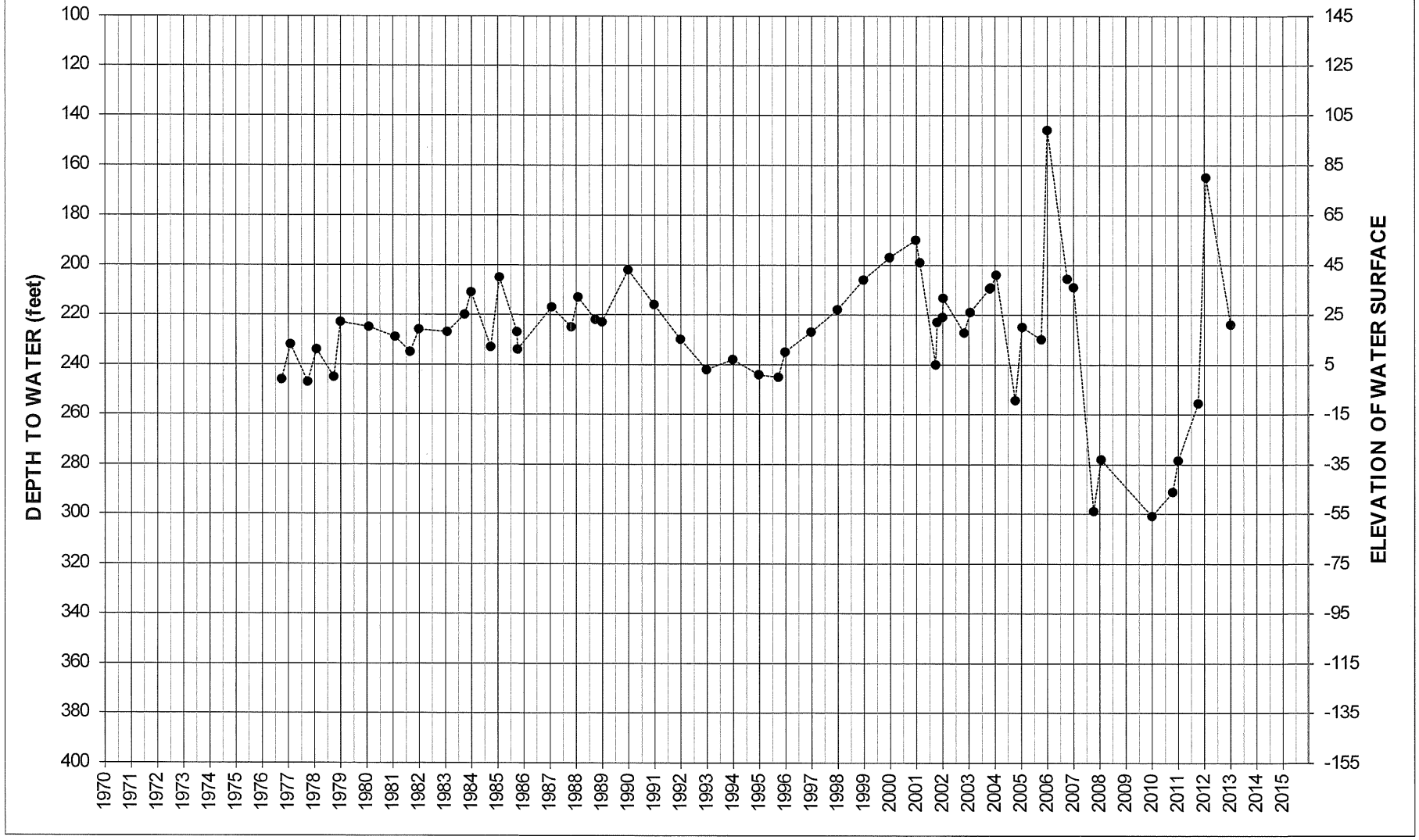
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-30A (204-484)



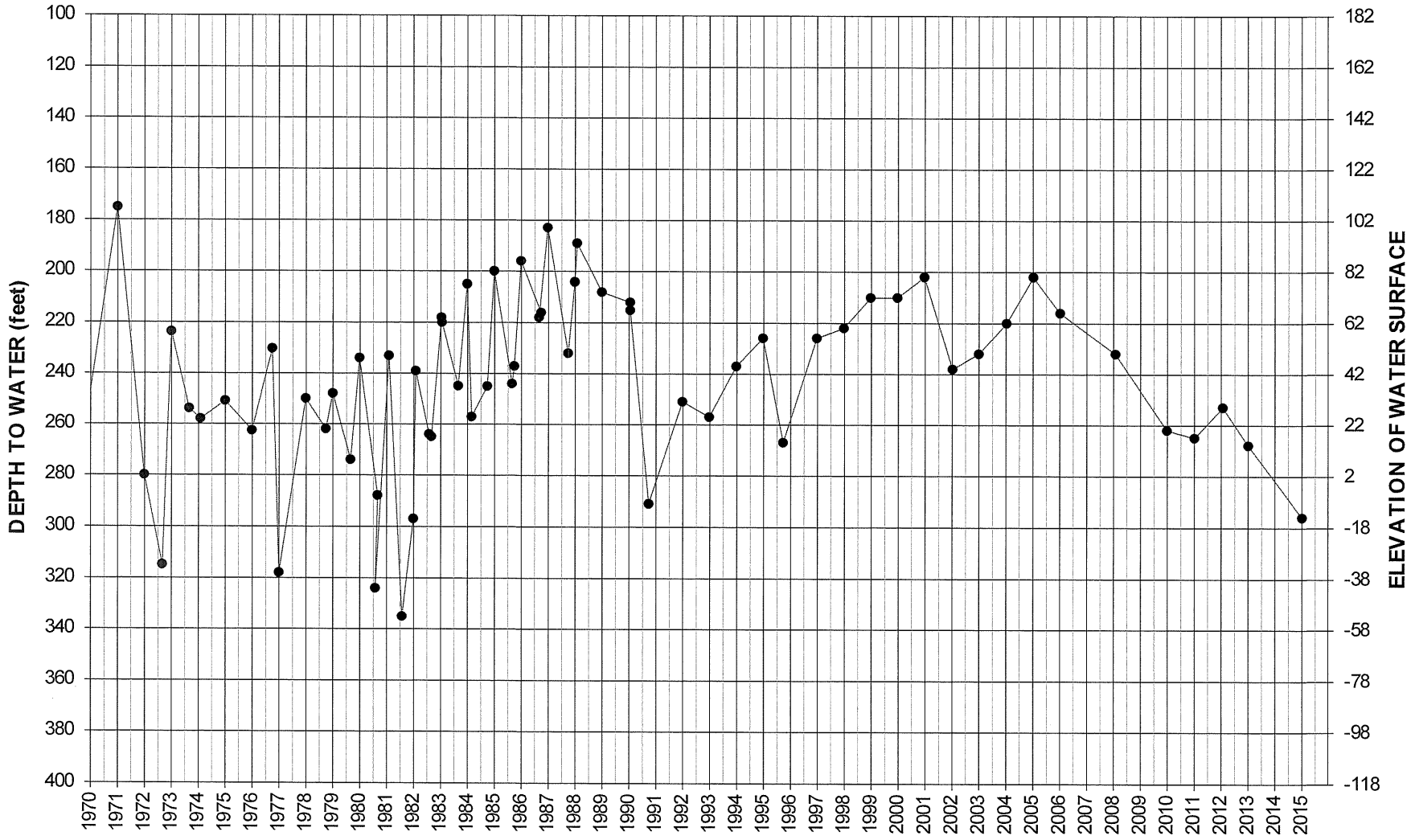
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-33J(300-840)



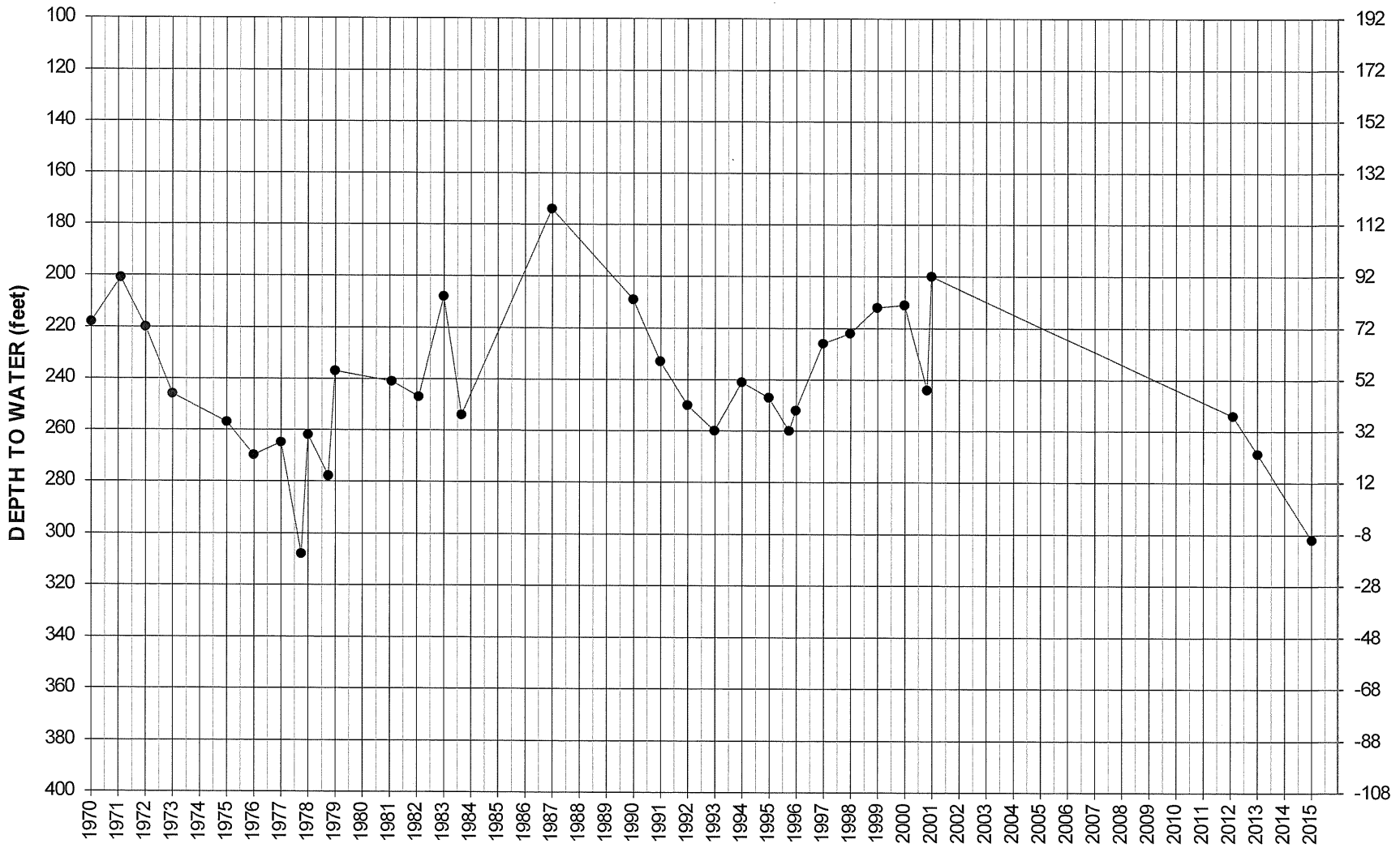
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/24-5H (260-730)



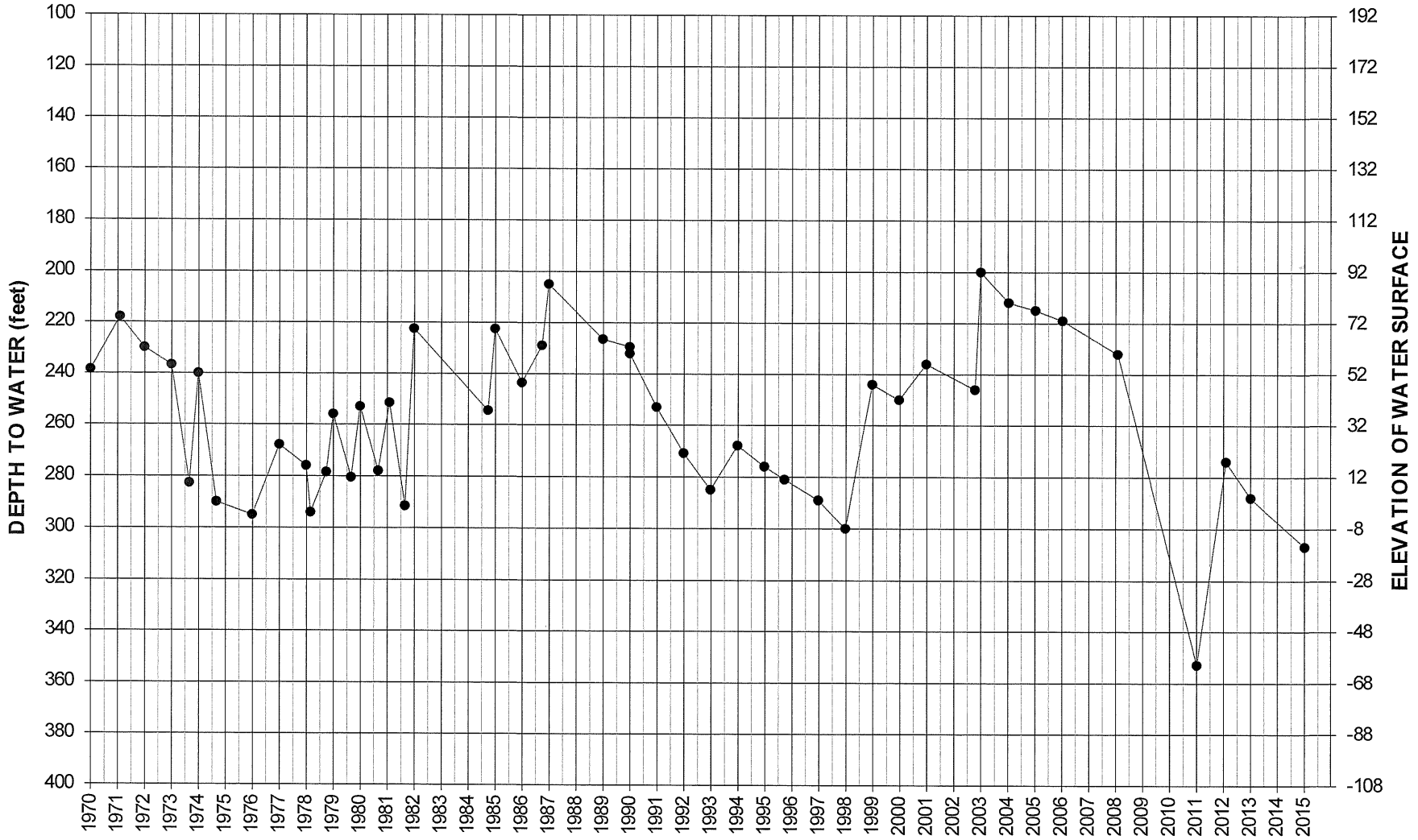
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Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/24-6F



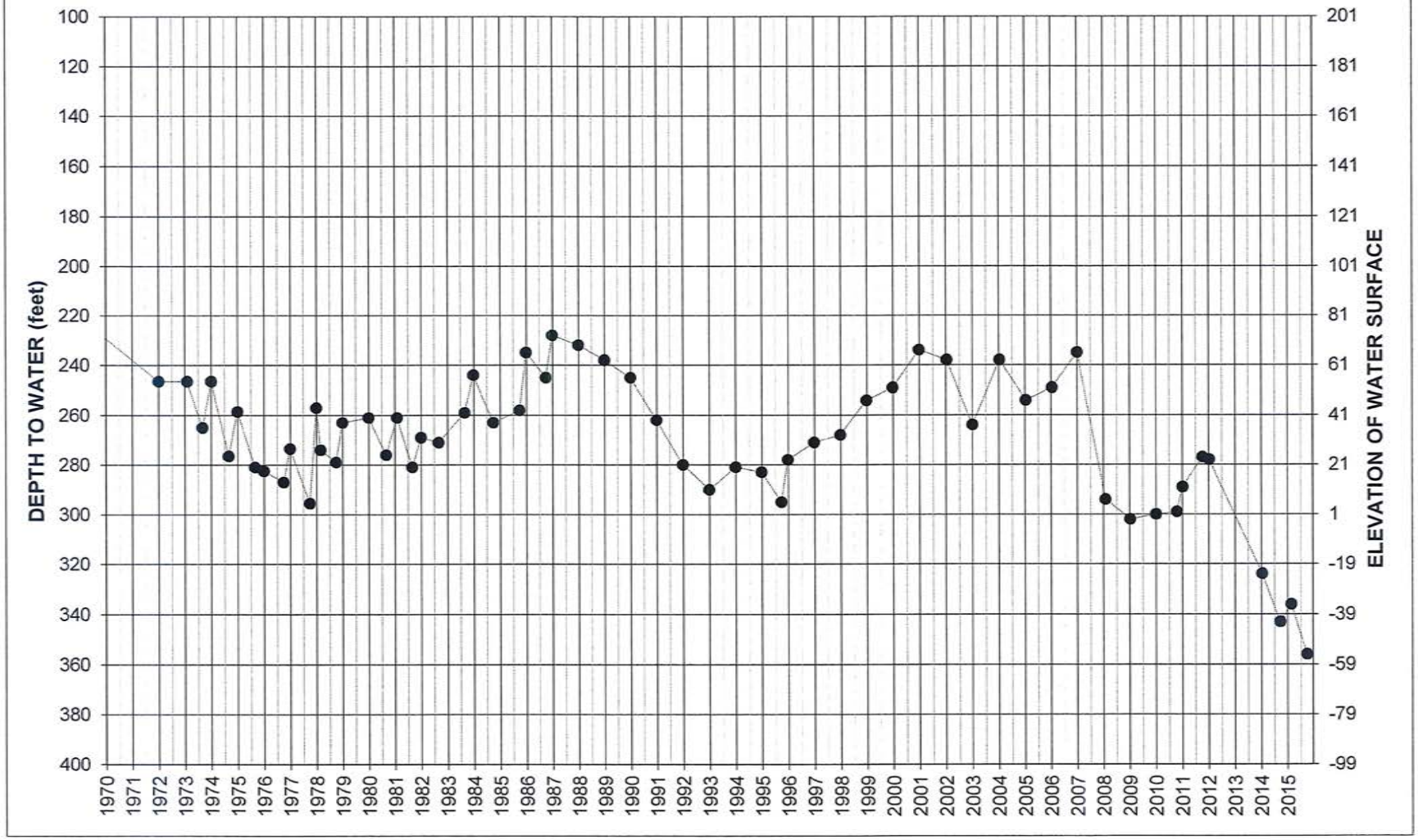
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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/24-16P (350-716)

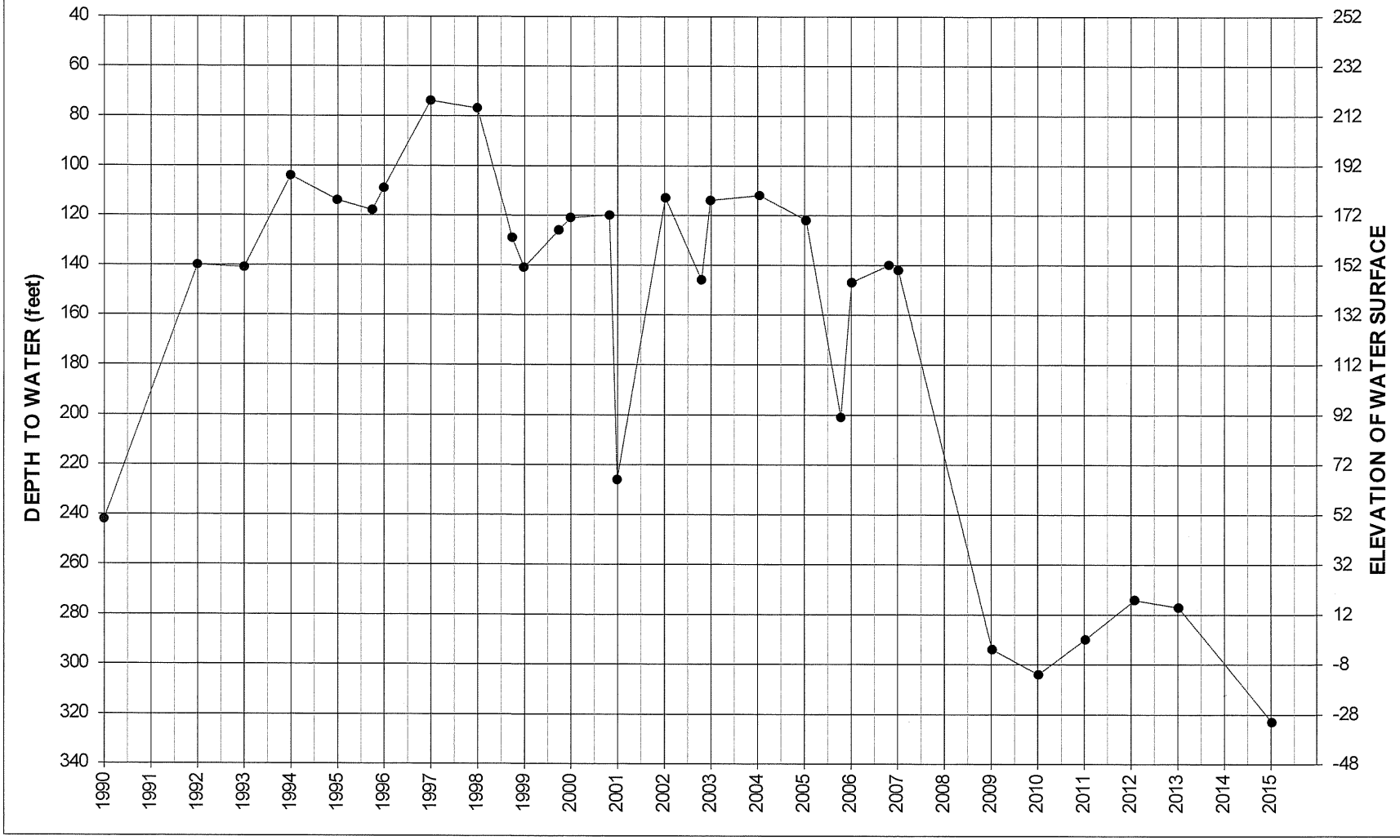


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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/24-33A (230-374)

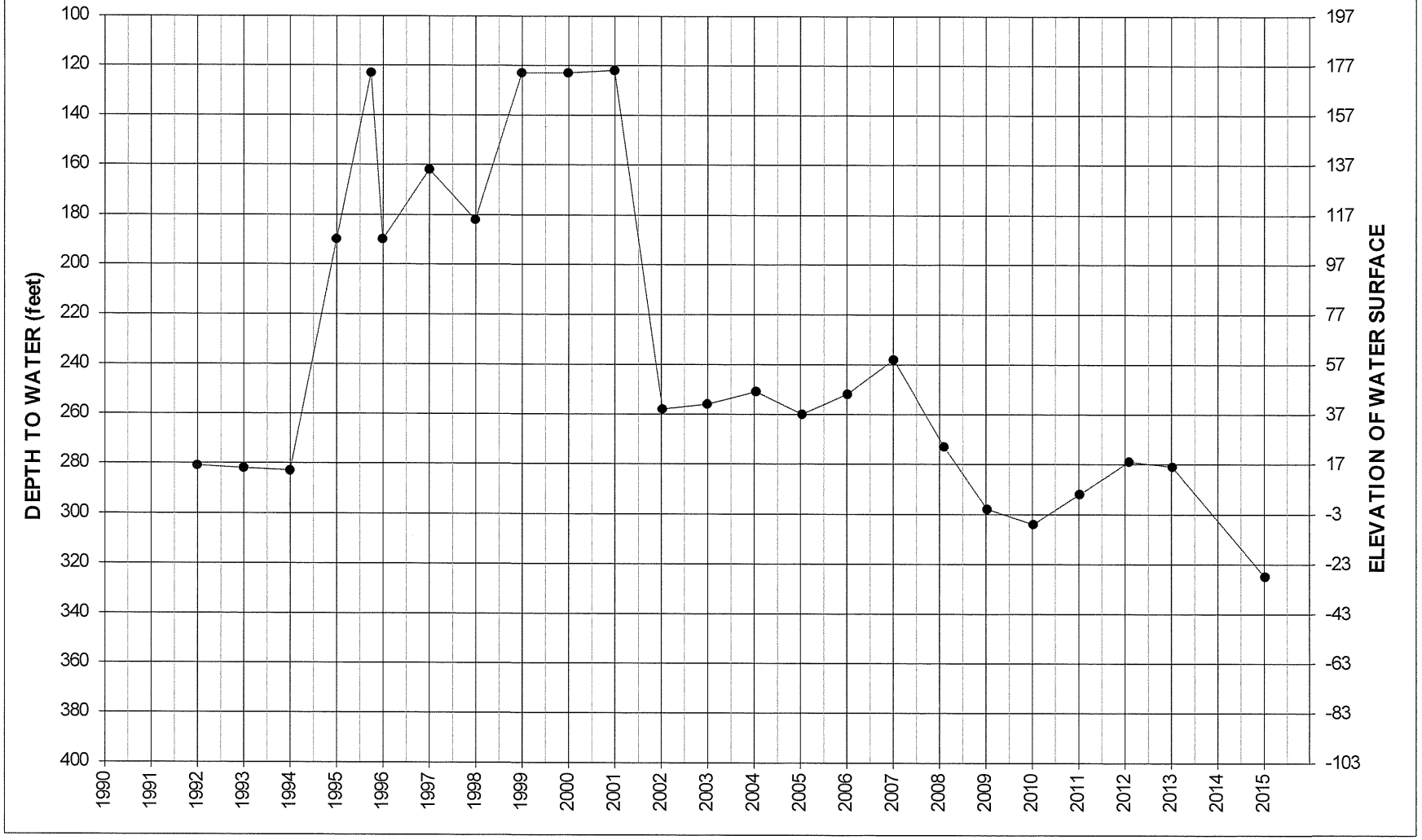


SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/22-1H



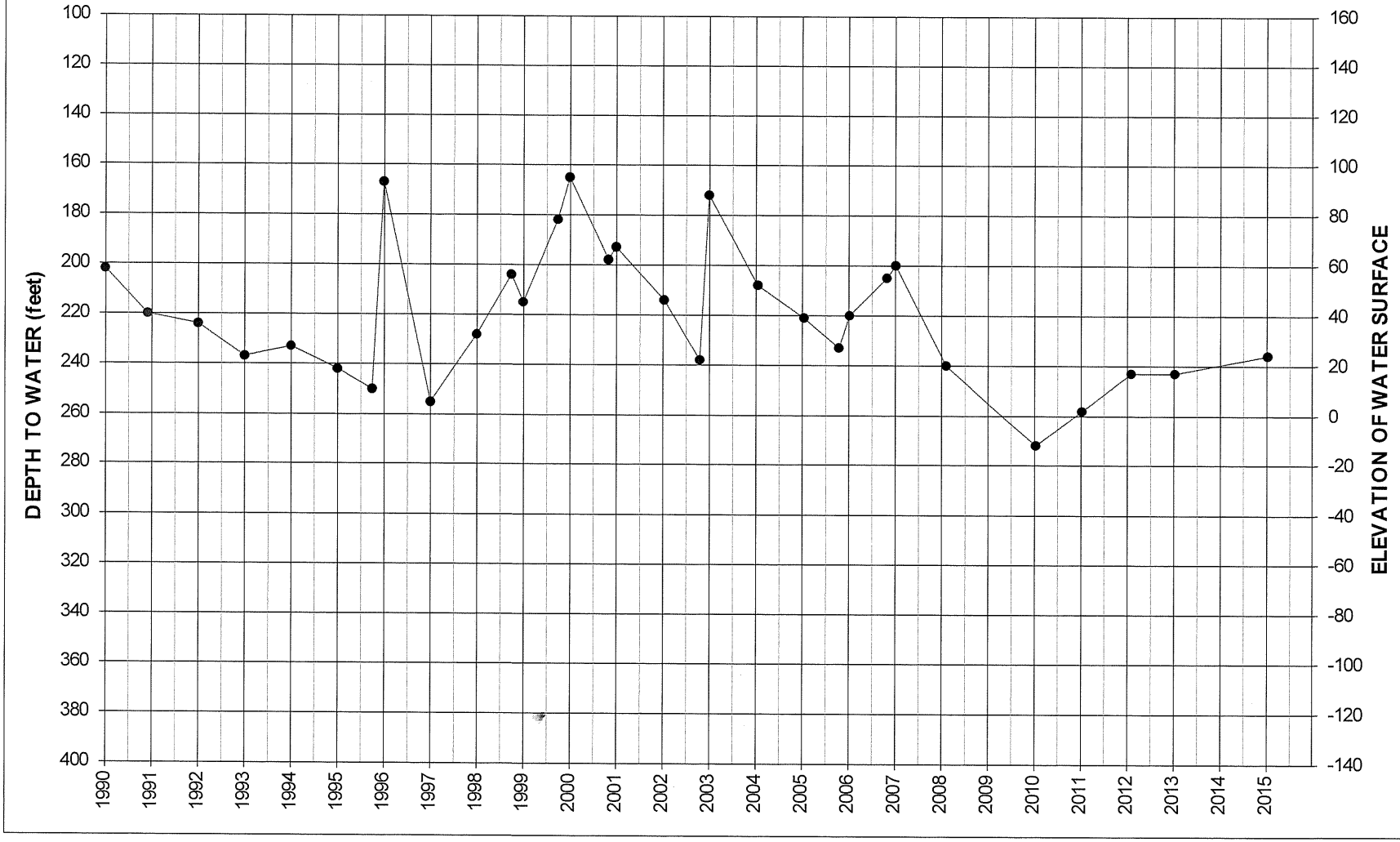
GEI Consultants
Bakersfield-Edmonton Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-7H (300-495)



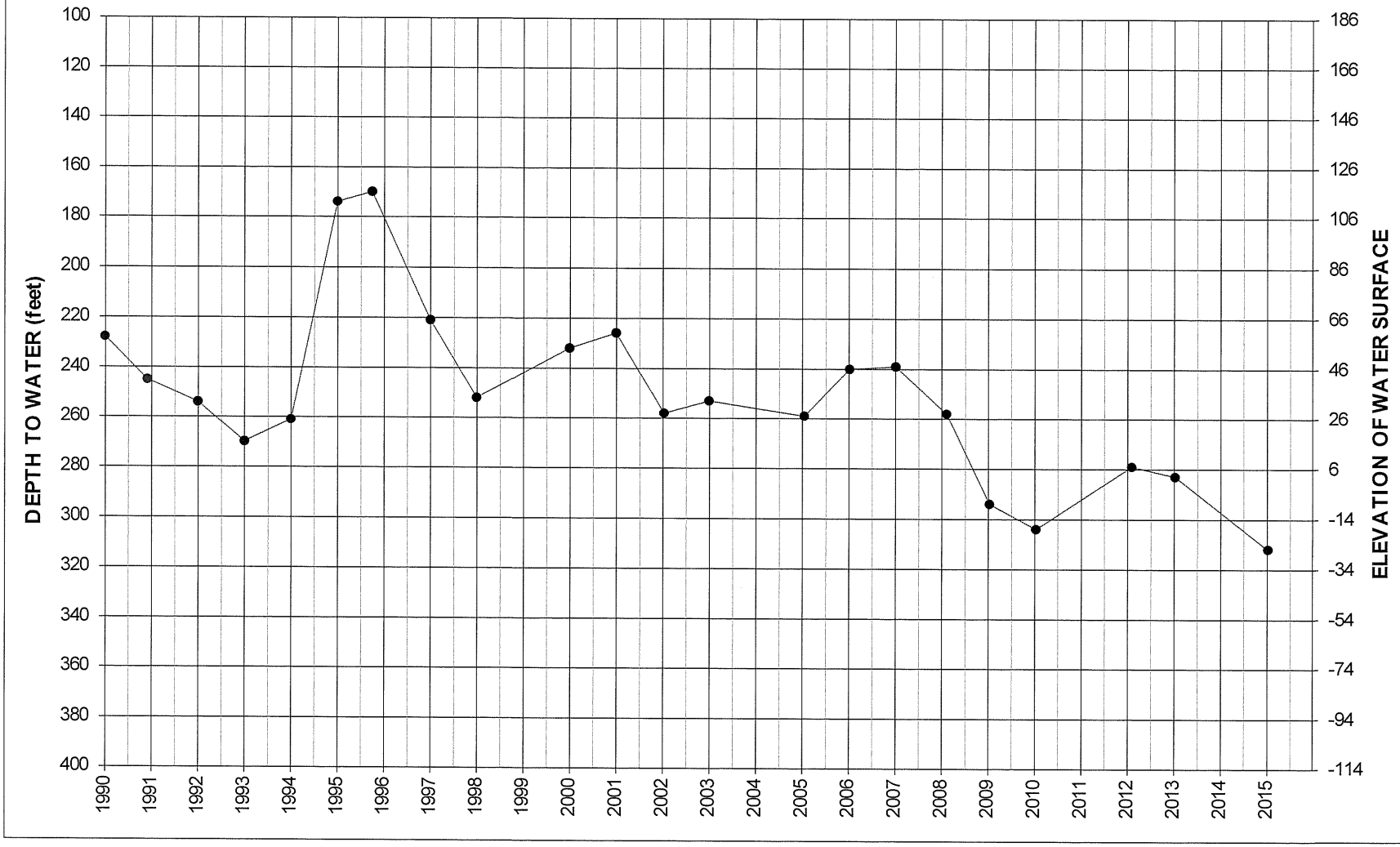
GEI Consultants
Bockman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-11R (288-510)



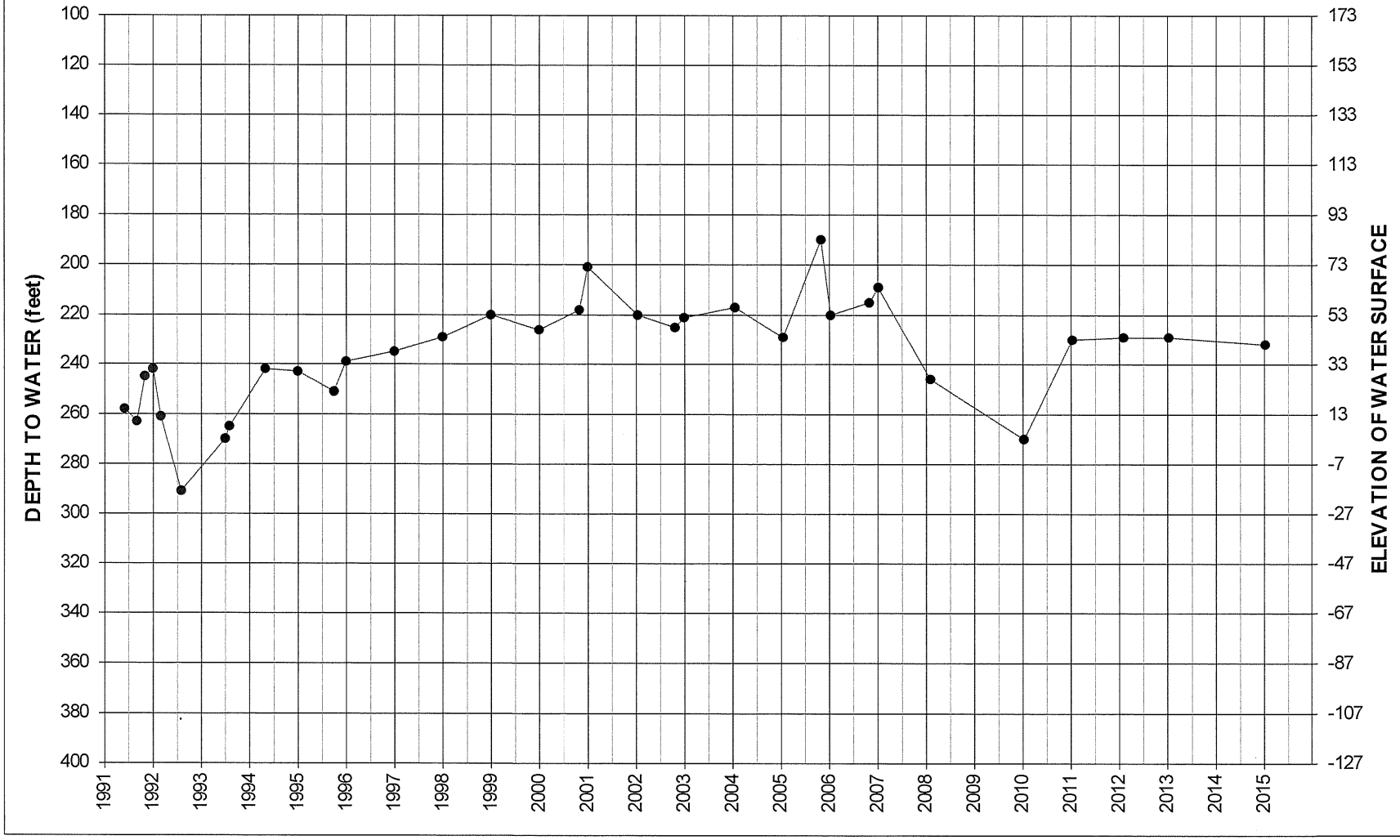
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-16G (240-416)



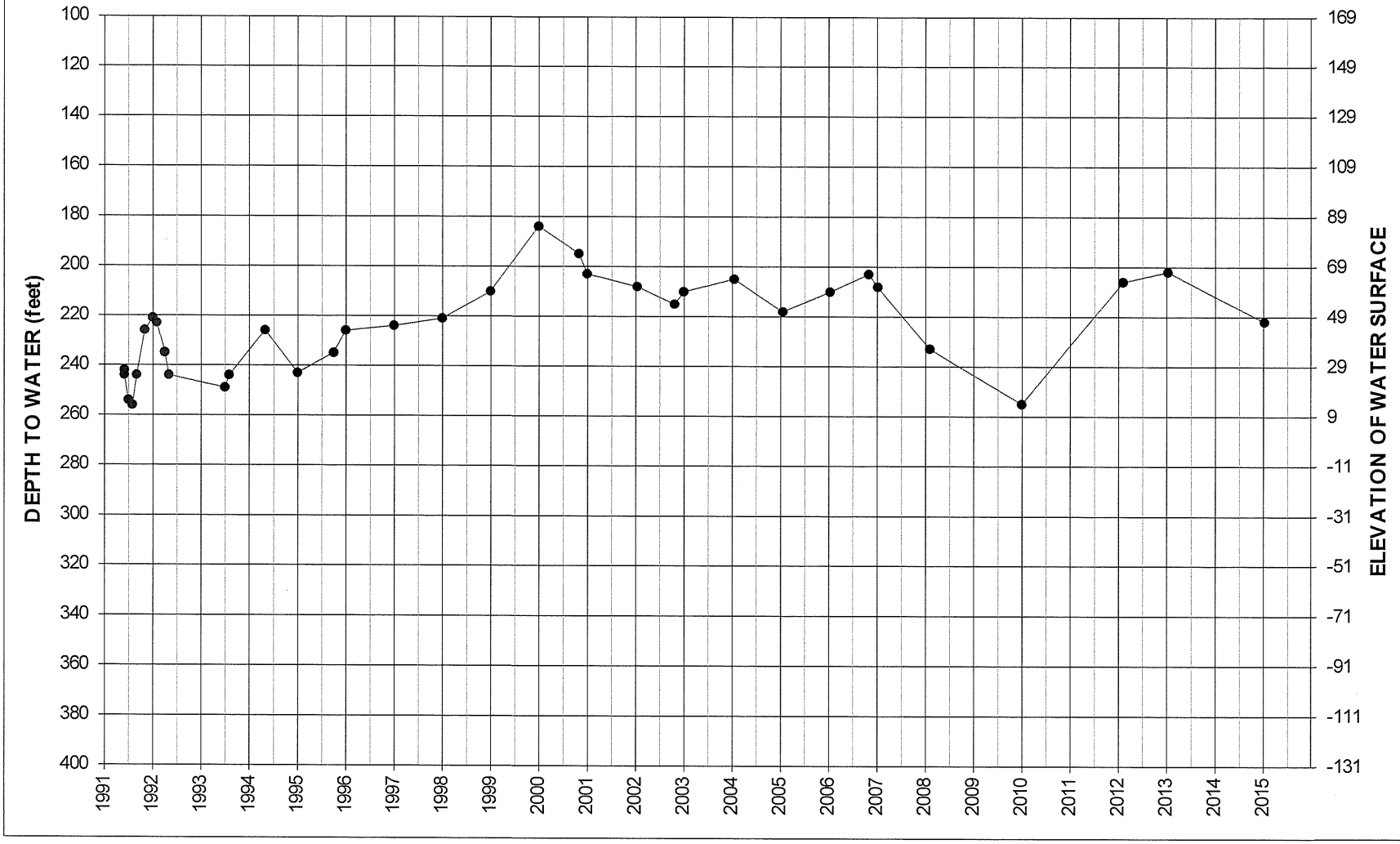
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Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-22F (413-645)



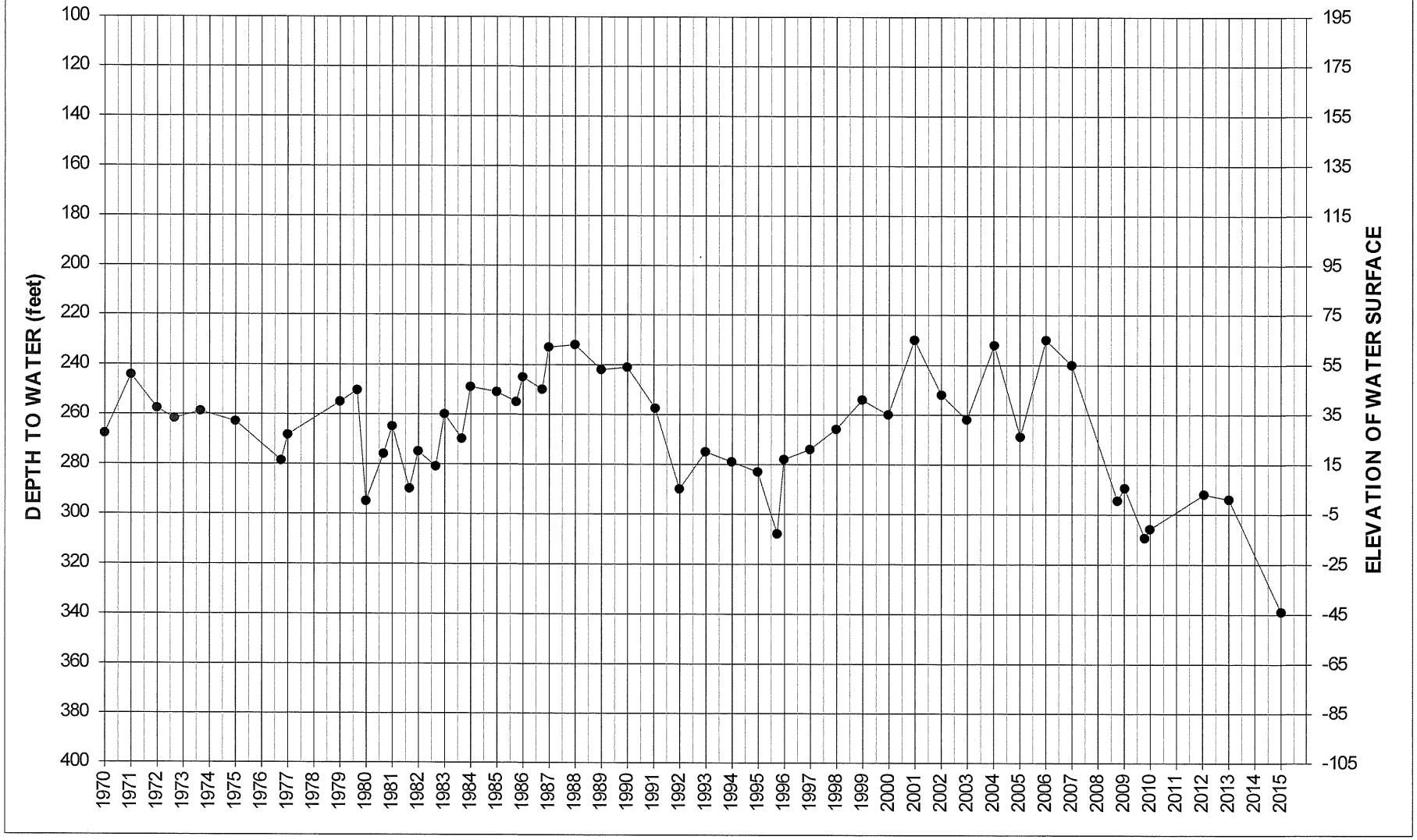
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-26F (420-690)



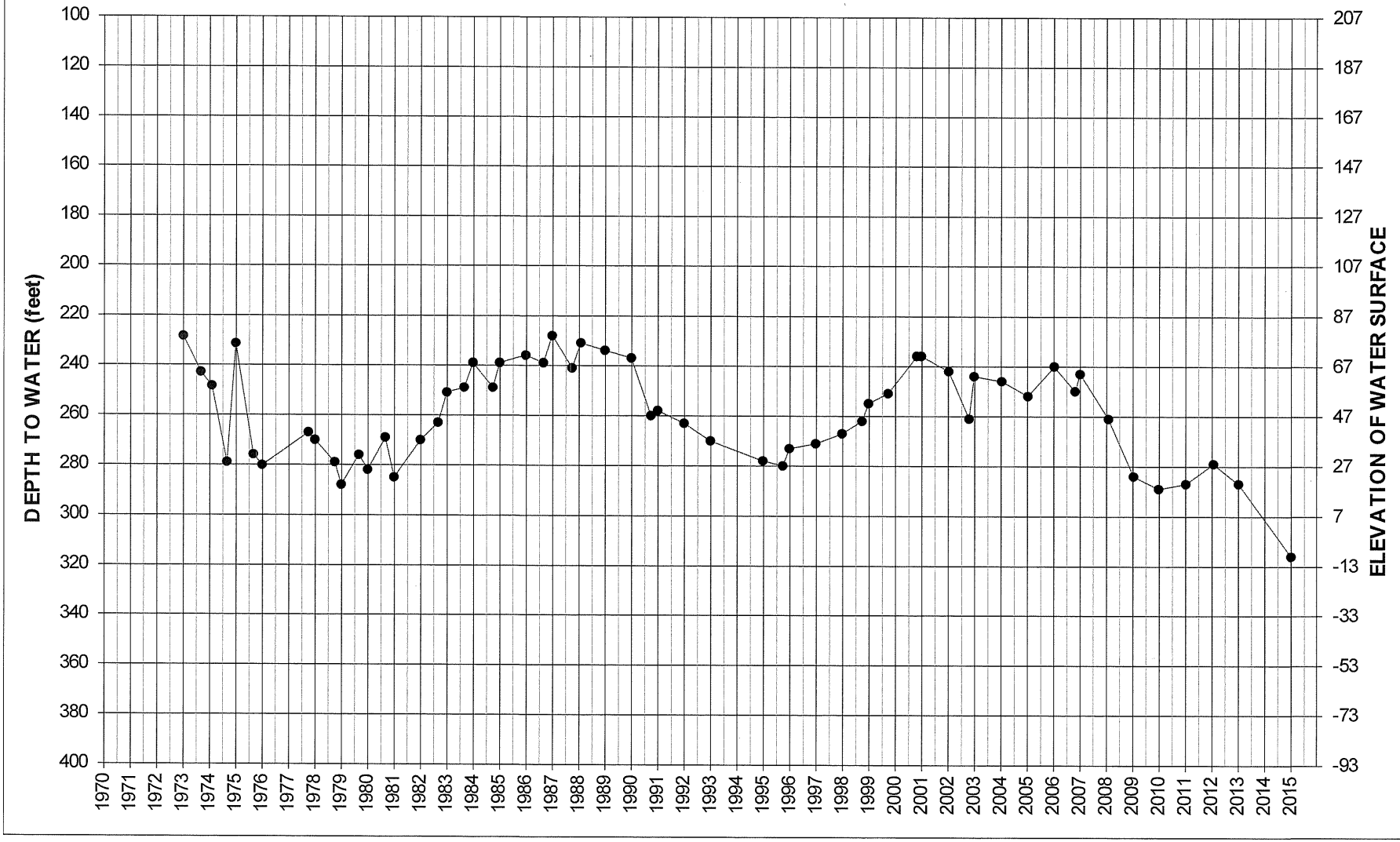
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/24-4C



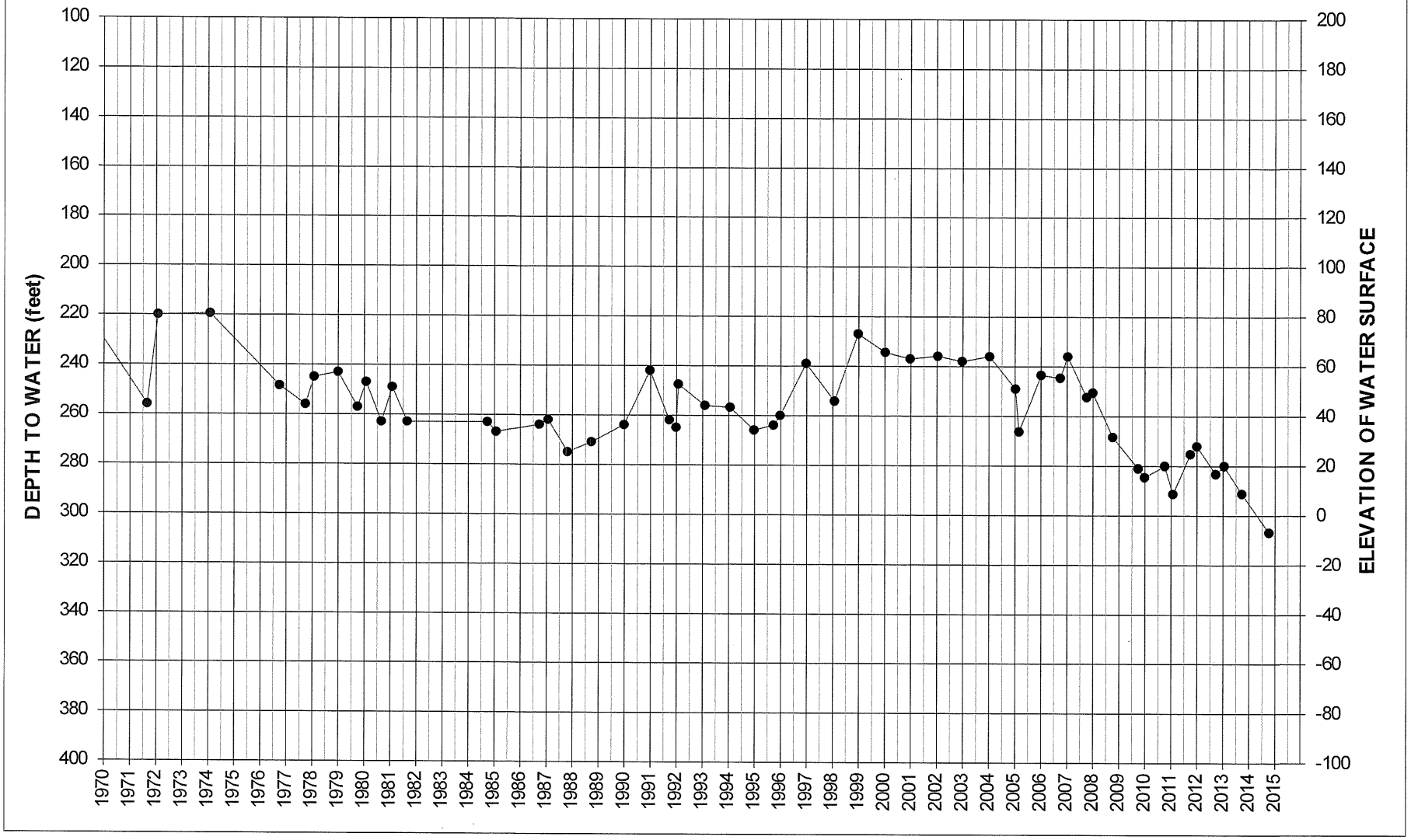
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/24-10R



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Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/24-28A (204-504)



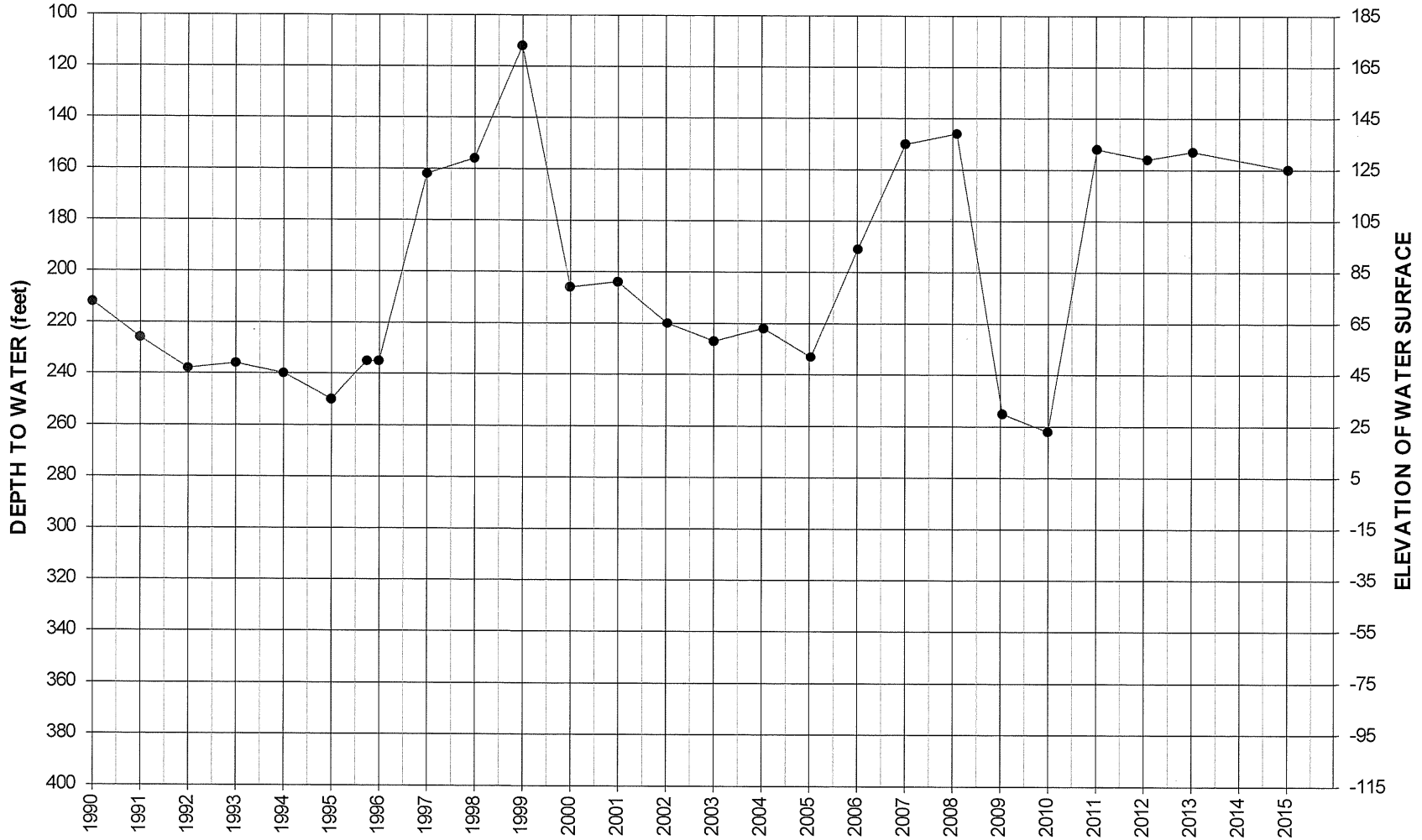
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/24-32N (68-420)

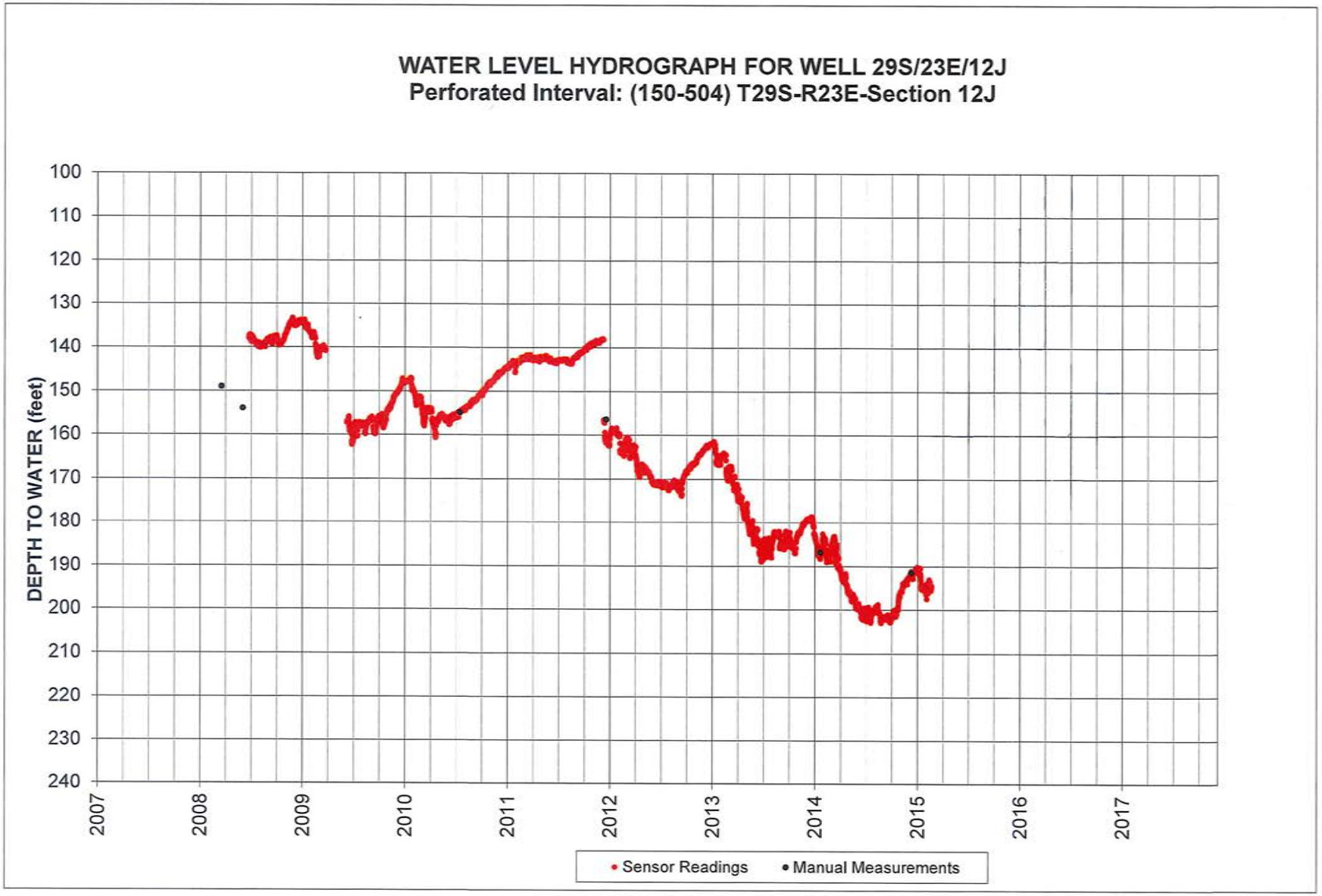


GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #29/23-12J (150-504)

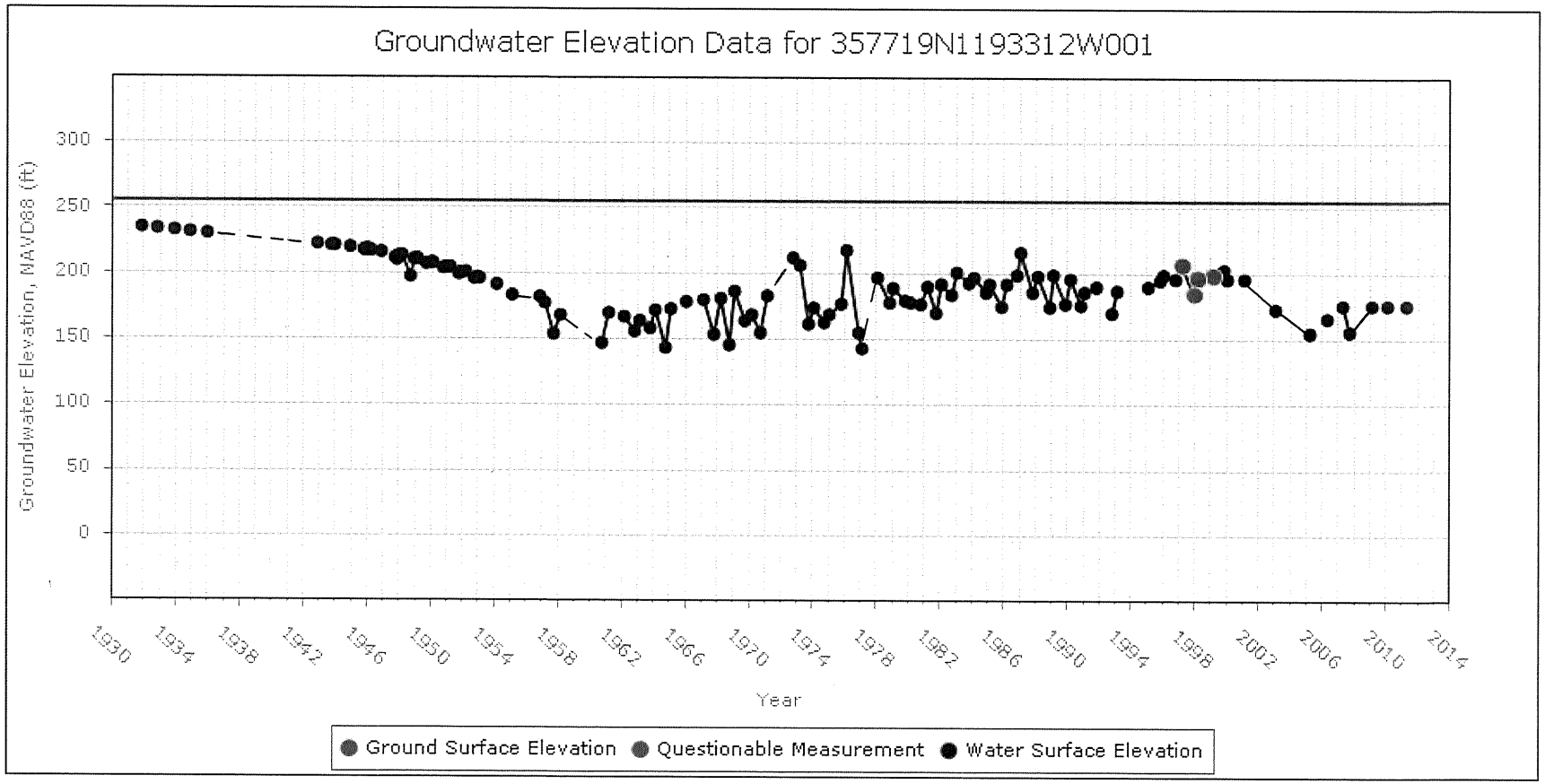


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Bookman-Edmonston Division

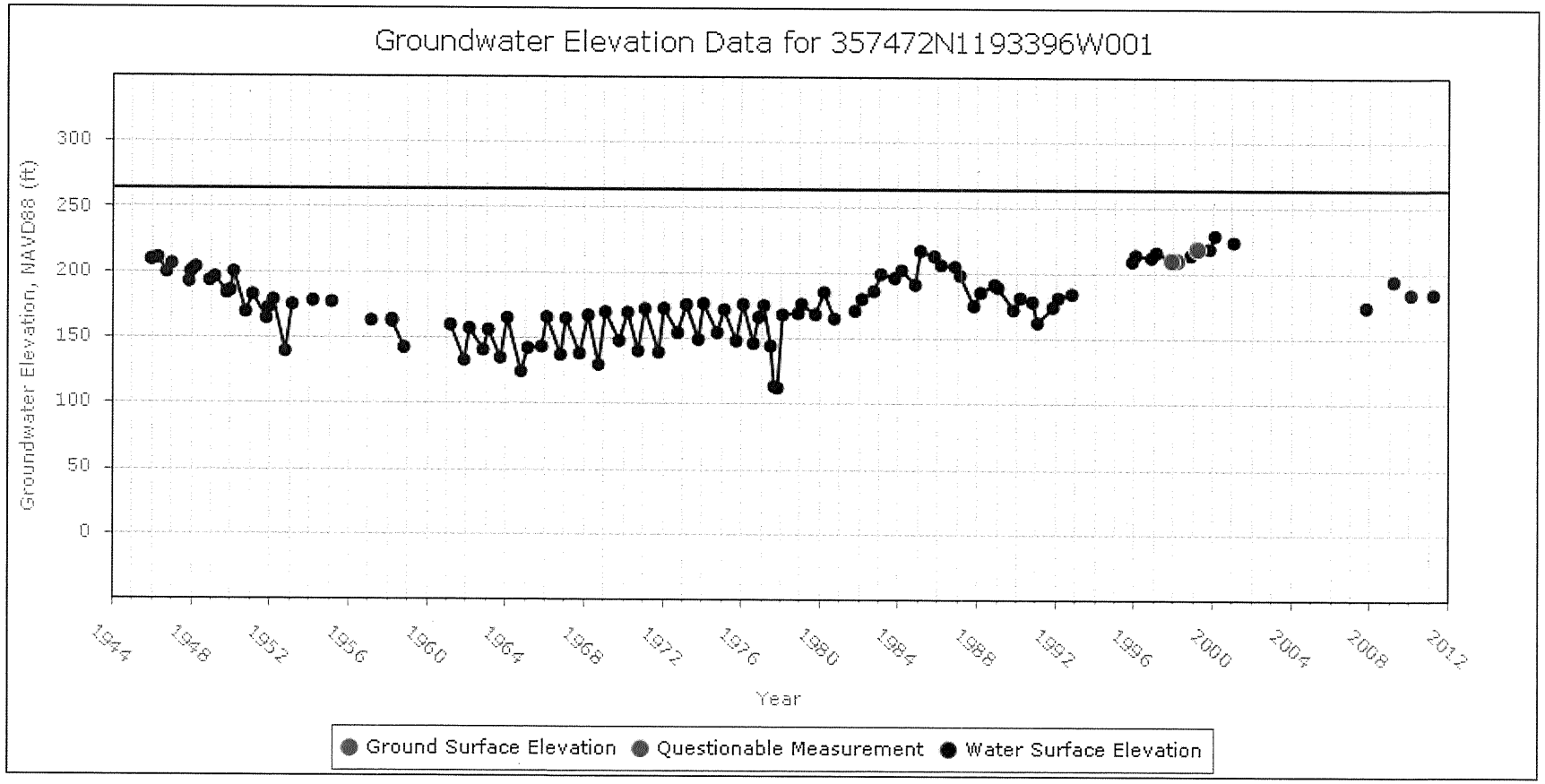


Semitropic Water Storage District
(Manual data from the KCWA)

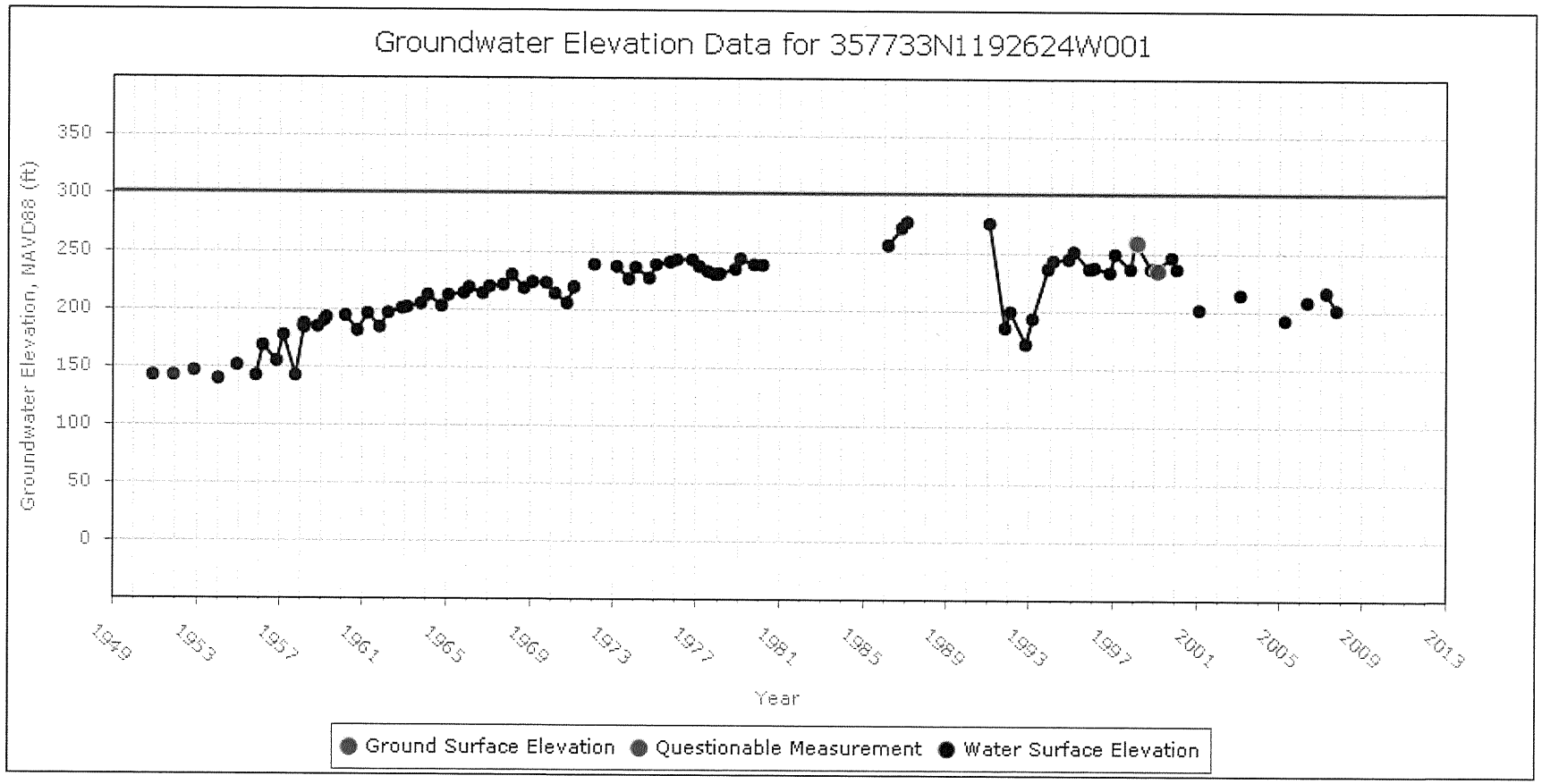
SOUTHERN SAN JOAQUIN MUNICIPAL
UTILITY DISTRICT



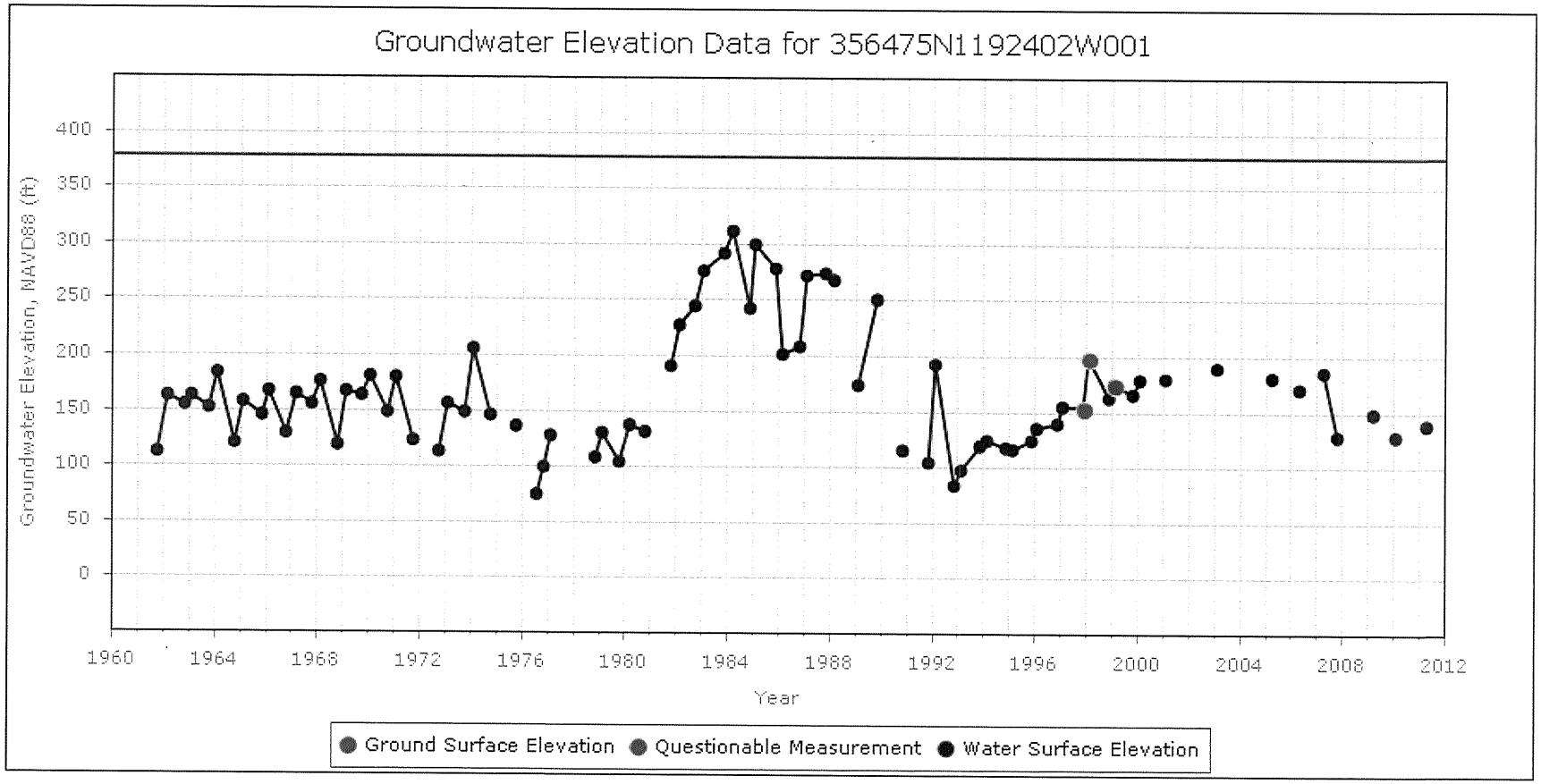
WATER-LEVEL HYDROGRAPH FOR WELL T25S/R24E-12H1



WATER-LEVEL HYDROGRAPH FOR WELL T25S/R24E-13P2



WATER-LEVEL HYDROGRAPH FOR WELL T25S/R25E-10J1



WATER-LEVEL HYDROGRAPH FOR WELL T26S/R25E-24P1

Last edited by: DA LOAD on 6/8/2016 4:52:00 PM

NORTH KERN WATER STORAGE DISTRICT

North Kern Water Storage District
DISTRICT WELLS

Well Number	Perforated Interval	
	from	to
26/25-21K	340	900
26/25-26N	400	800
26/25-27B		
26/25-28Q	340	800
26/25-30H	340	800
26/25-34R	340	800
26/25-35B	340	800
26/25-36E	336	800
27/25-01N	336	800
27/25-03H	340	800
27/25-10L	342	800
27/25-16H		
27/25-23C	341	803

North Kern Water Storage District
PRIVATE WELLS

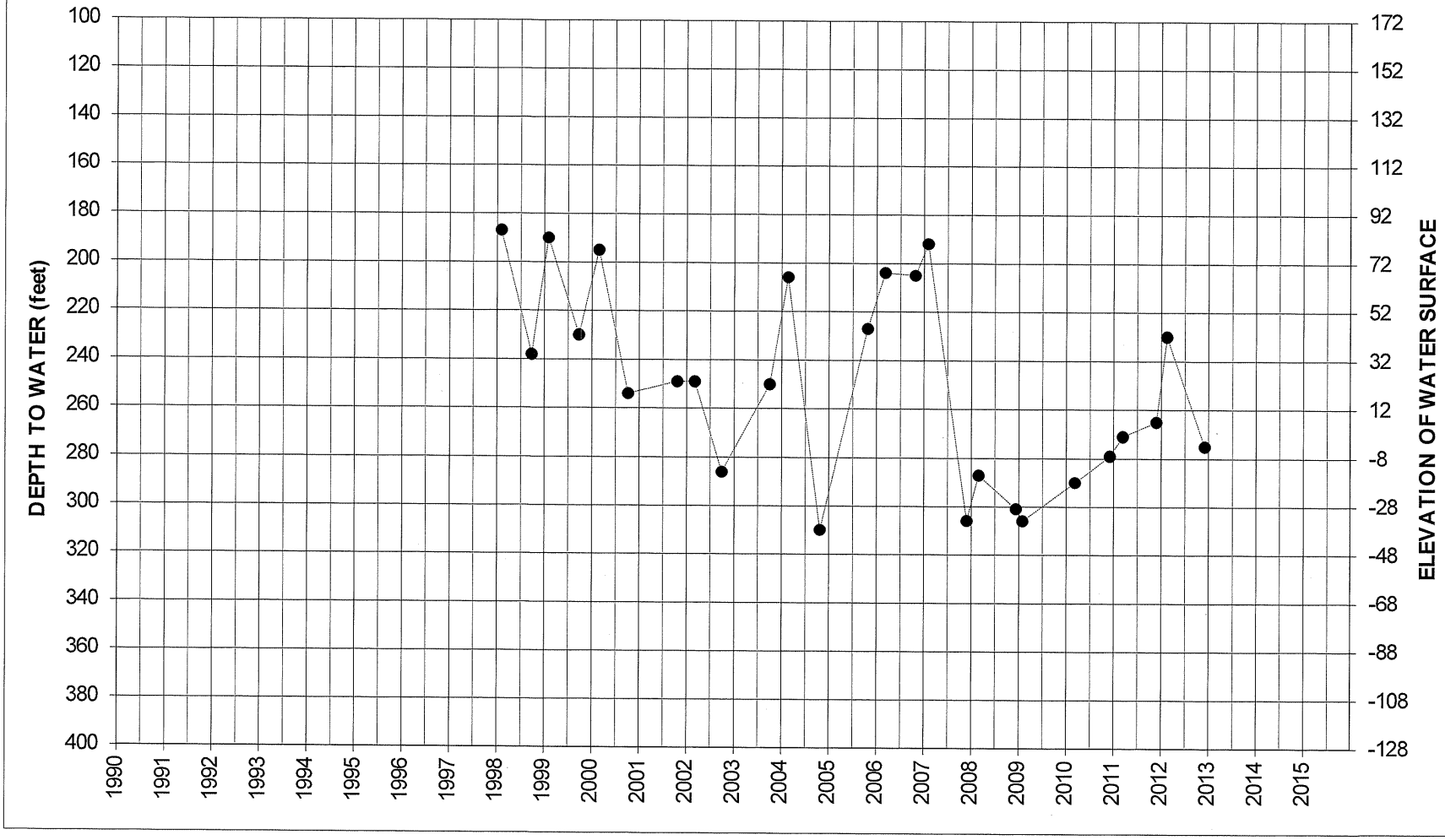
Well Number	**Perforated Interval** from	to
26/25-07R		
26/25-08P		
26/25-09R		
26/25-15R		
26/25-16R		
26/25-19R		
26/25-22H		
26/25-23R		
26/25-25R		
26/25-31R		
27/25-03J (a)		
27/25-04H		
27/25-05H		
27/25-07L (a)		
27/25-10J		
27/25-12F (a)		
27/25-14G (a)		
27/25-15J		
27/25-21K		
27/25-22J		
27/25-24C		
27/25-25J		
27/25-26K		
27/25-27C		
27/25-34A		
27/25-35L		
27/25-36J		

(a) Not included; no recent measurements.

North Kern Water Storage District
PRIVATE WELLS

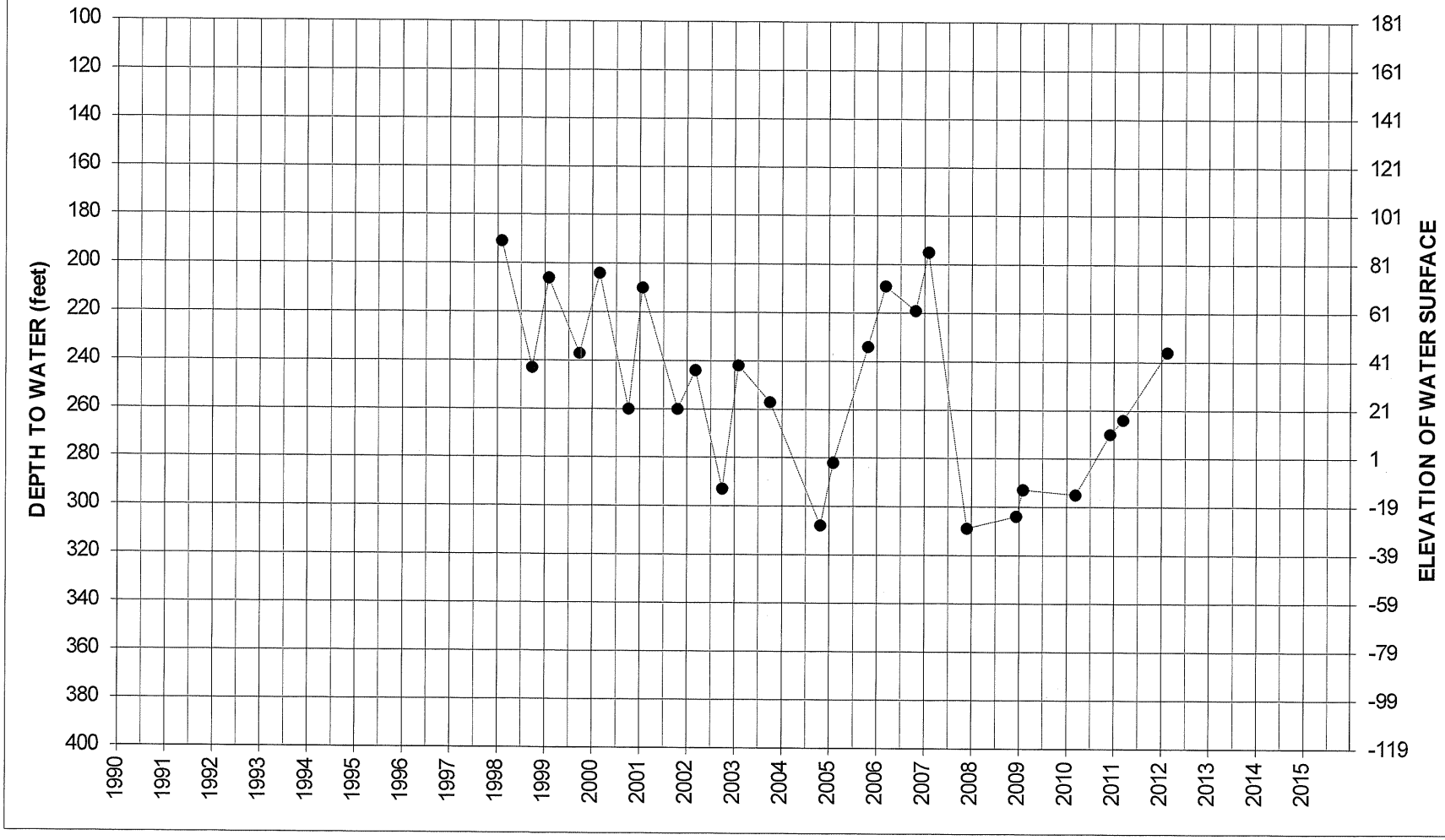
Well Number	**Perforated Interval** from	to
26/24-10F		
26/24-11P		
26/24-12R		
26/24-25F		
26/24-26P		
26/24-34P		
26/24-35F		
26/24-36J		
27/25-06N		
28/25-01C		
28/25-02A		
28/25-12Q		
28/25-13F		

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-10F



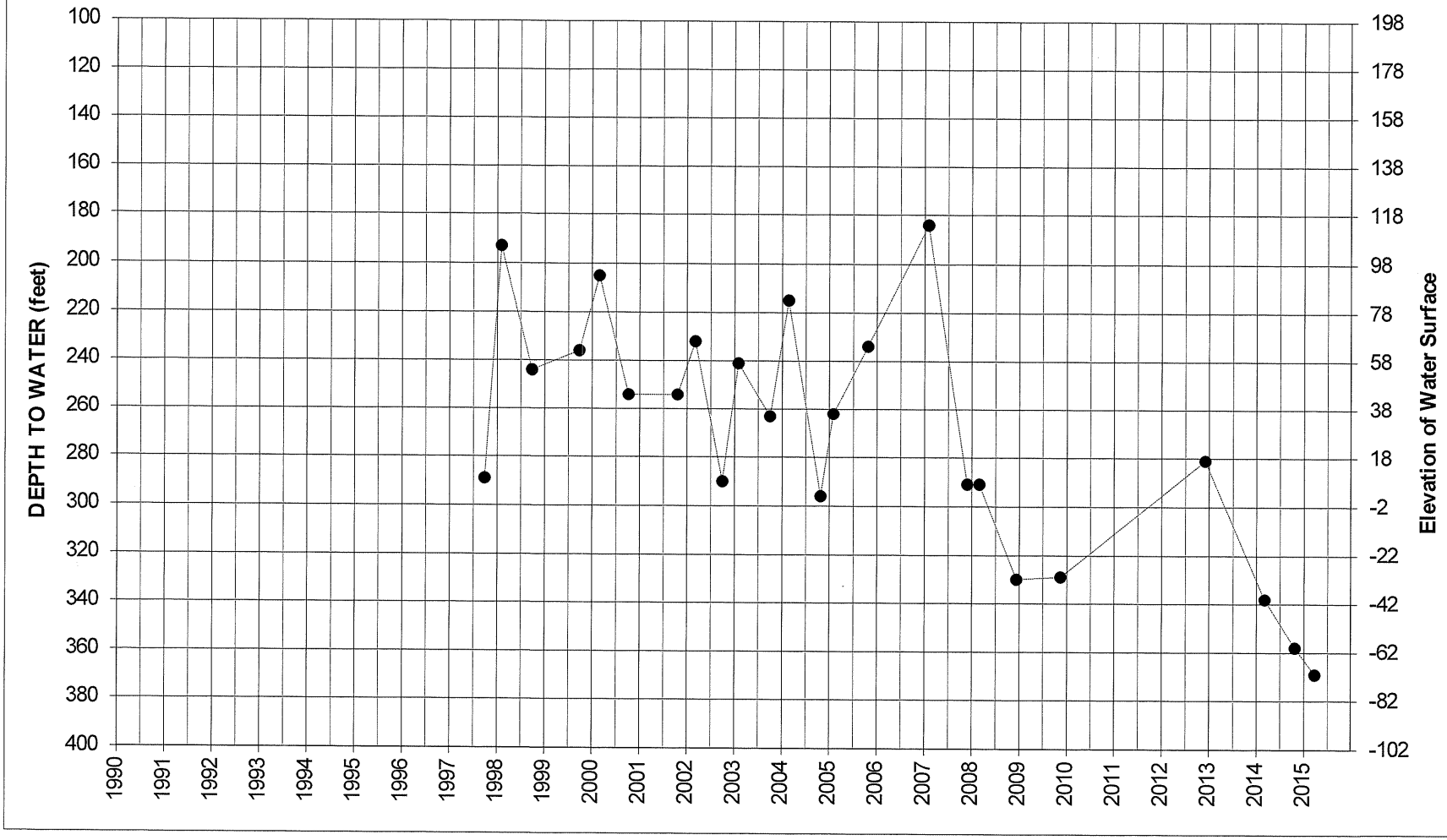
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-11P



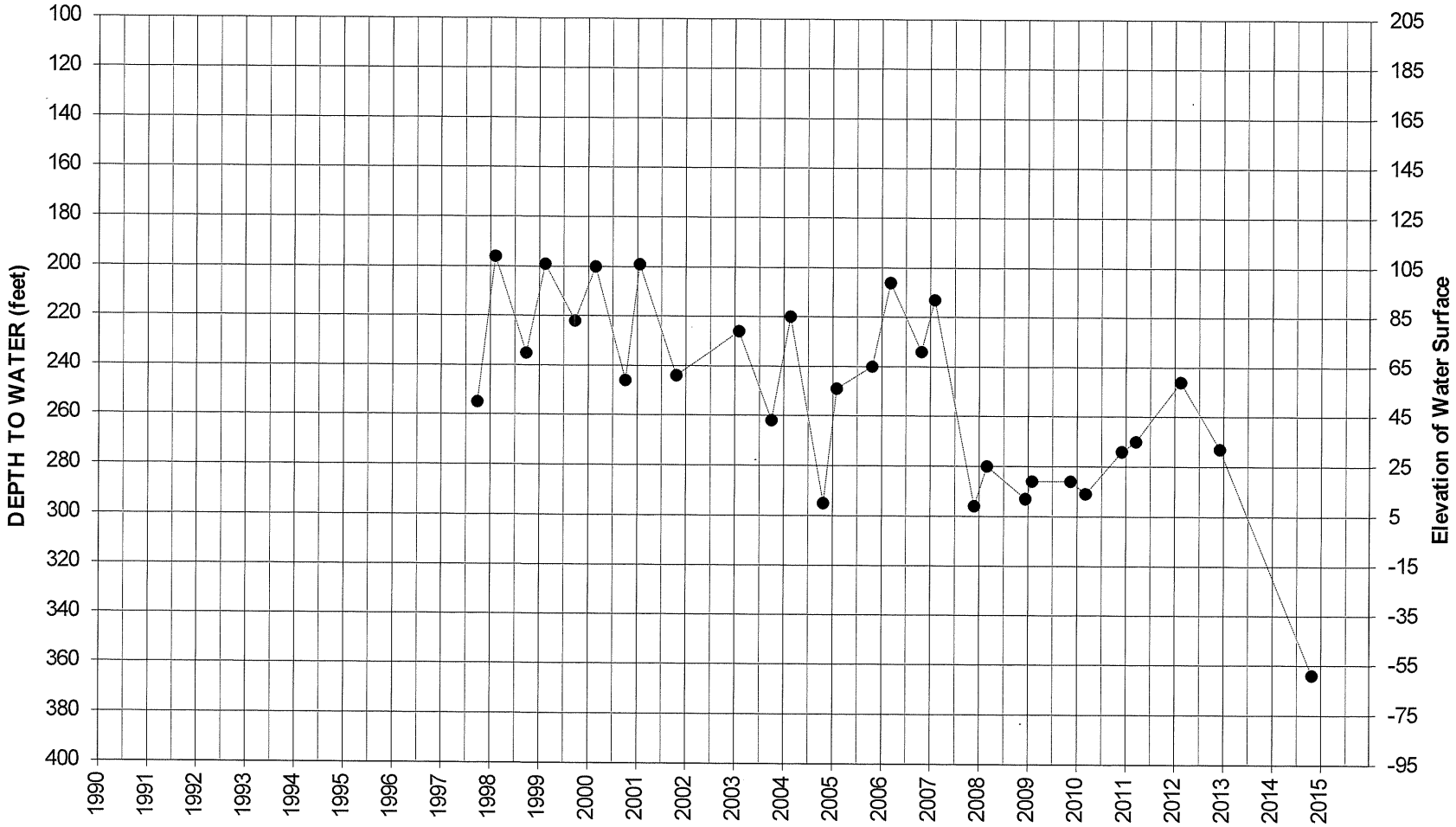
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-12R



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Bookman-Edmonston Division

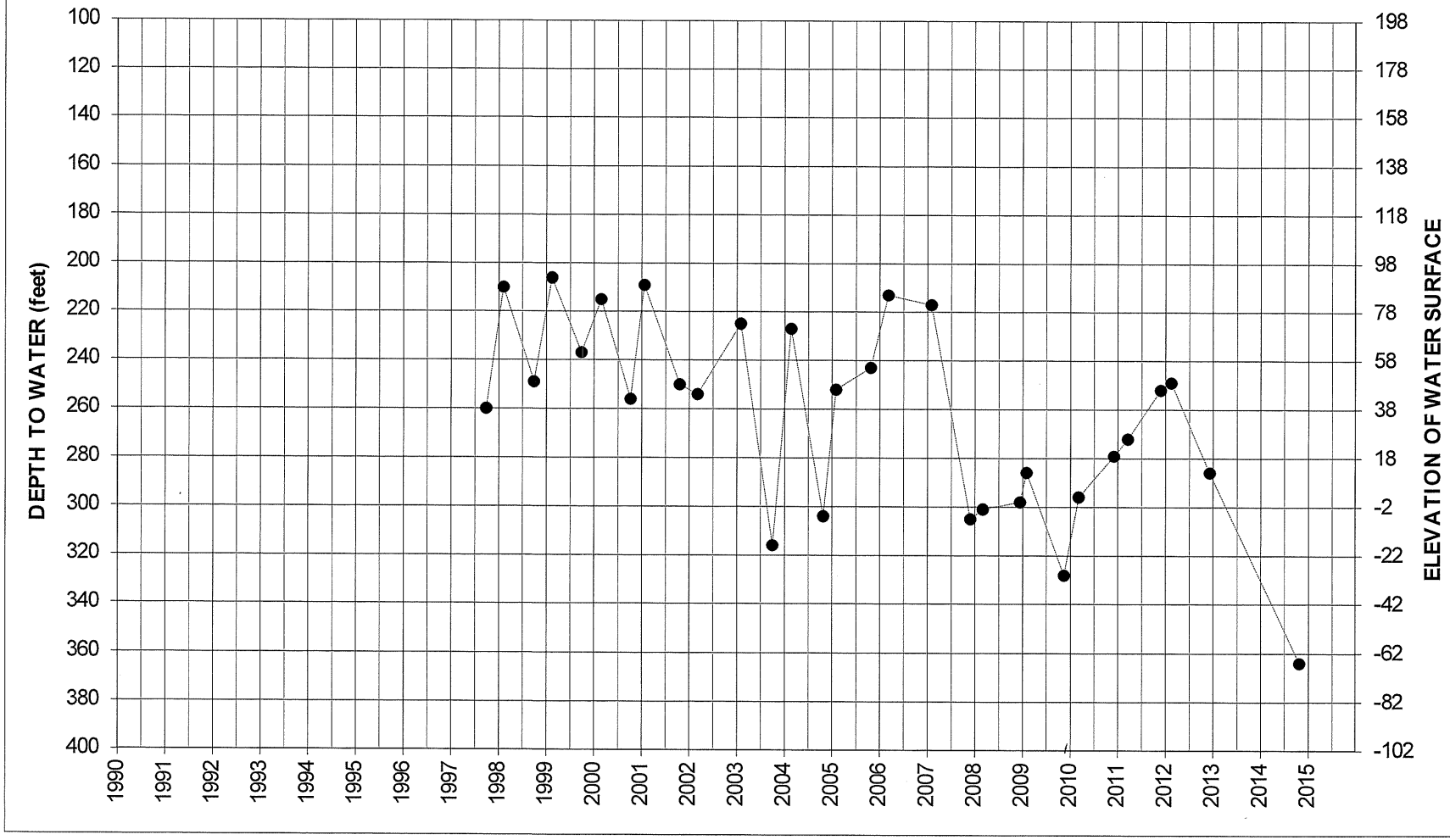
NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-25F



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Boodman-Edmonston Division

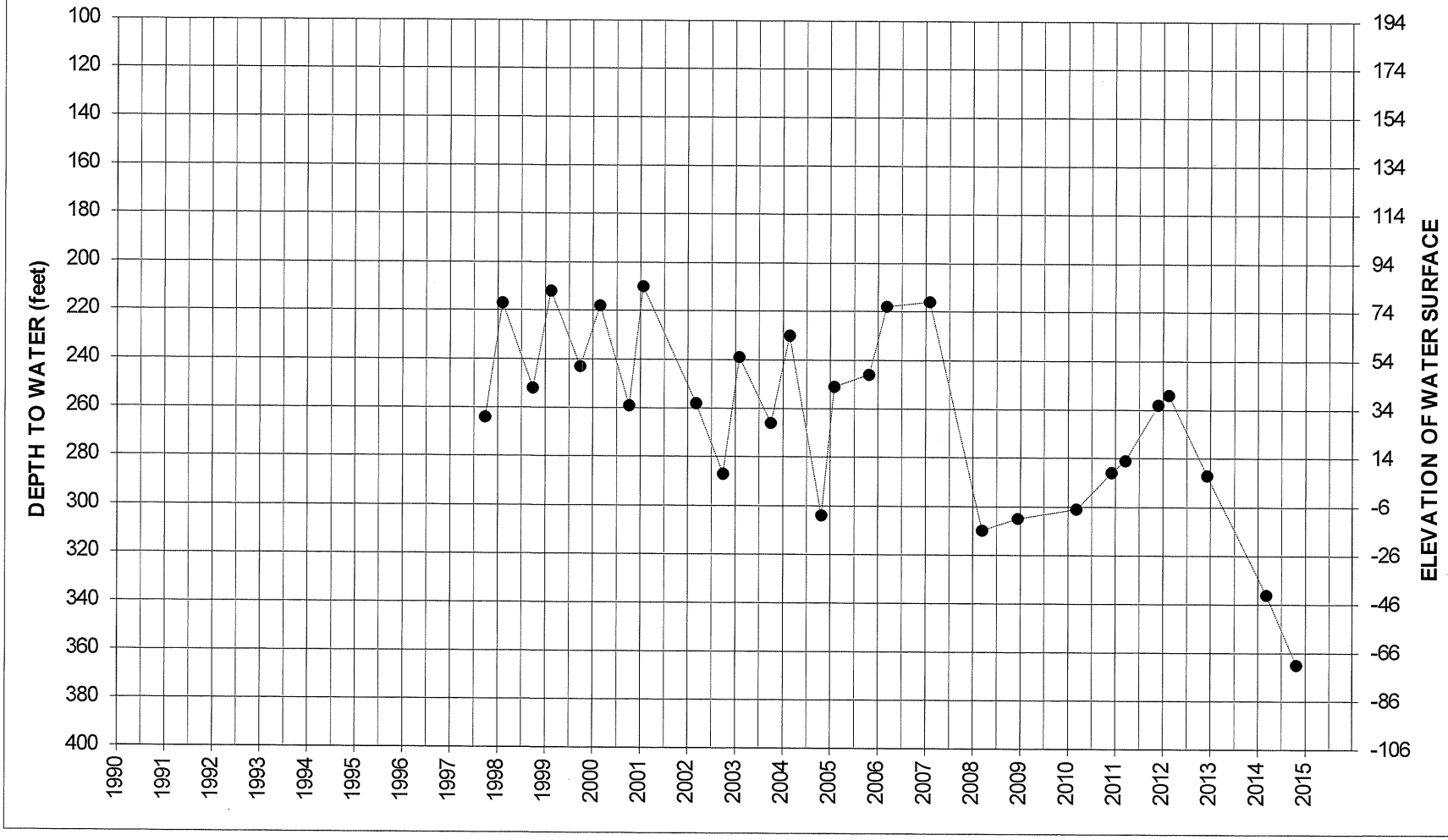
June 2010

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-26P



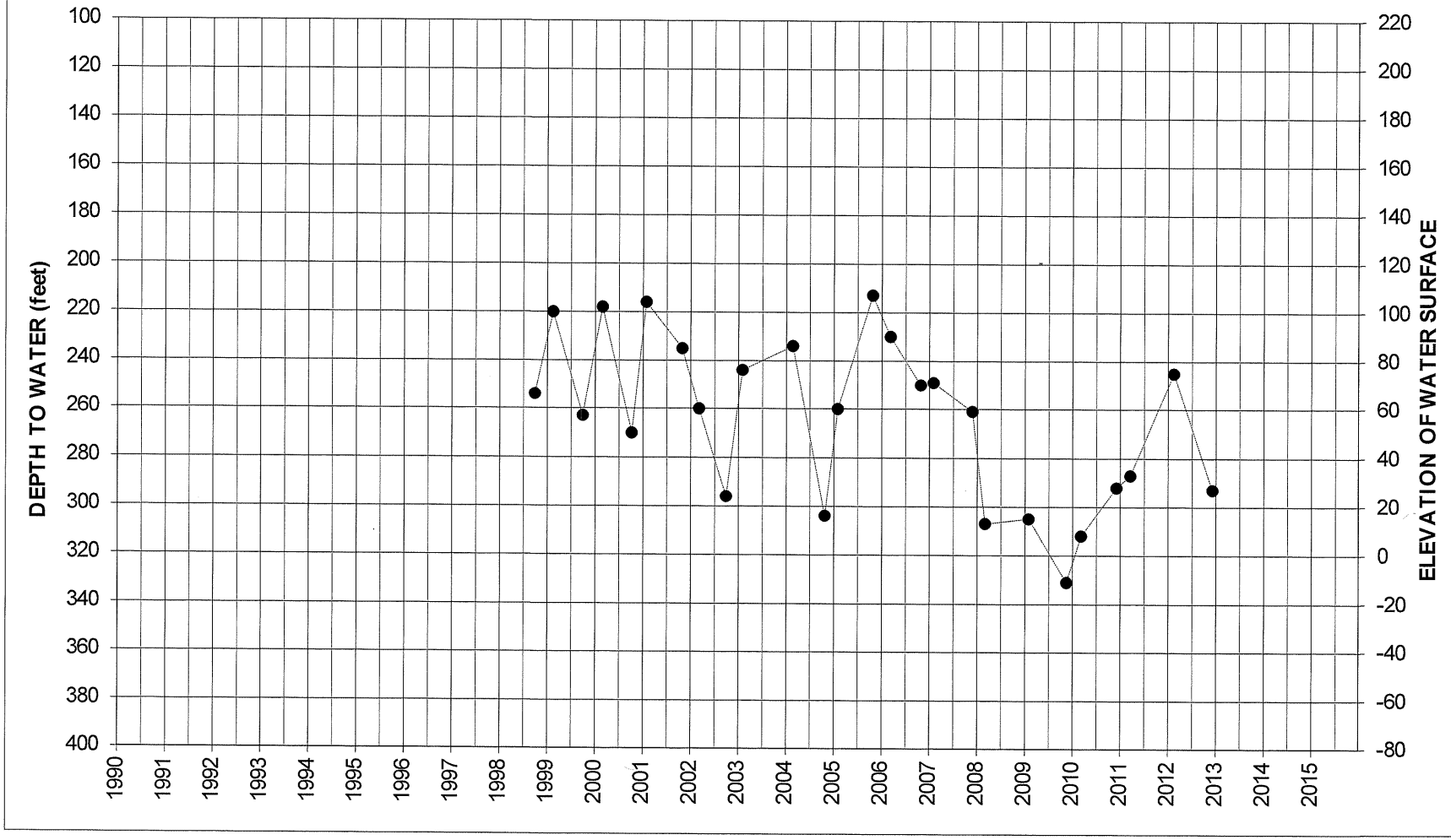
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-34P



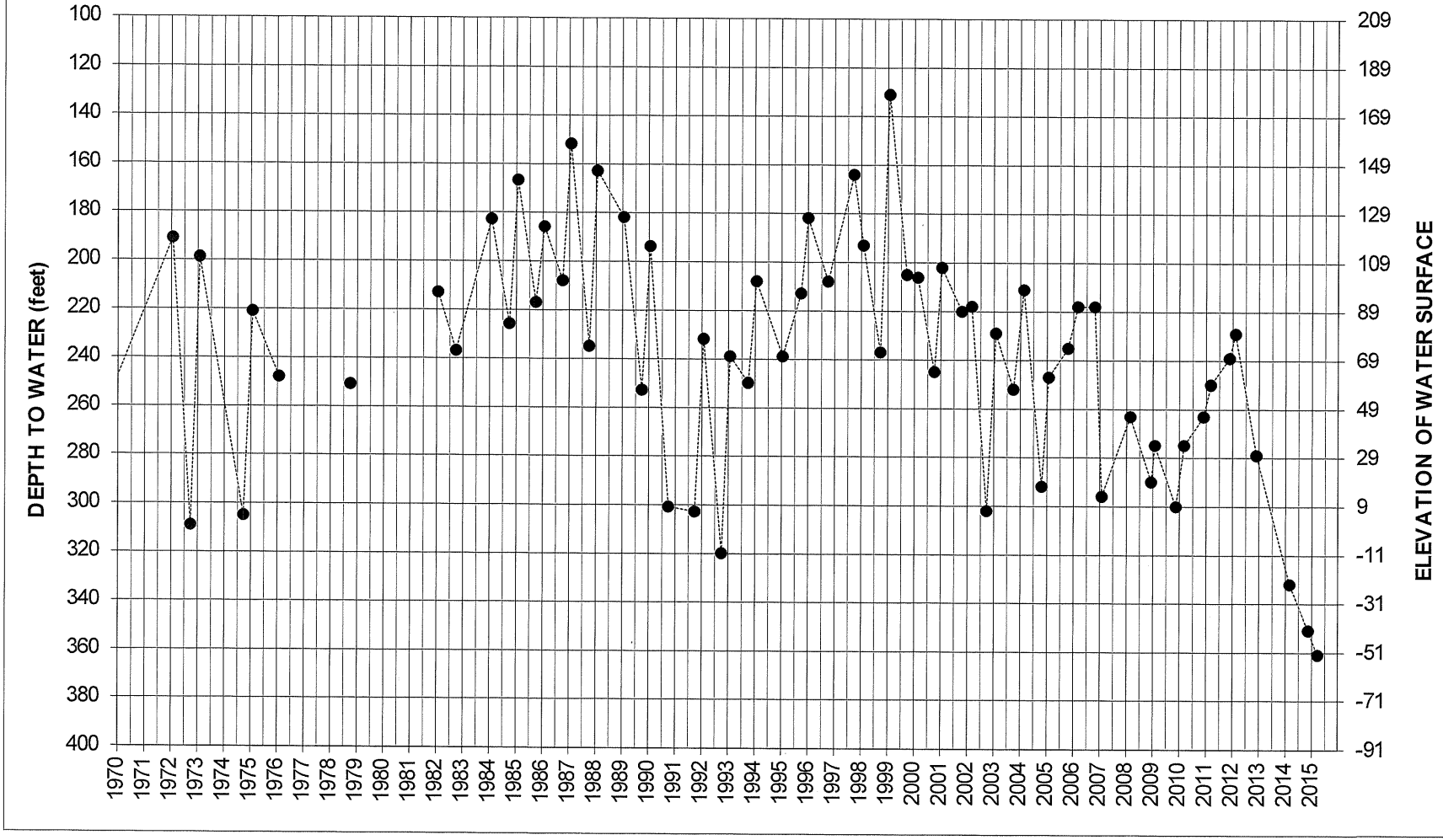
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-36J



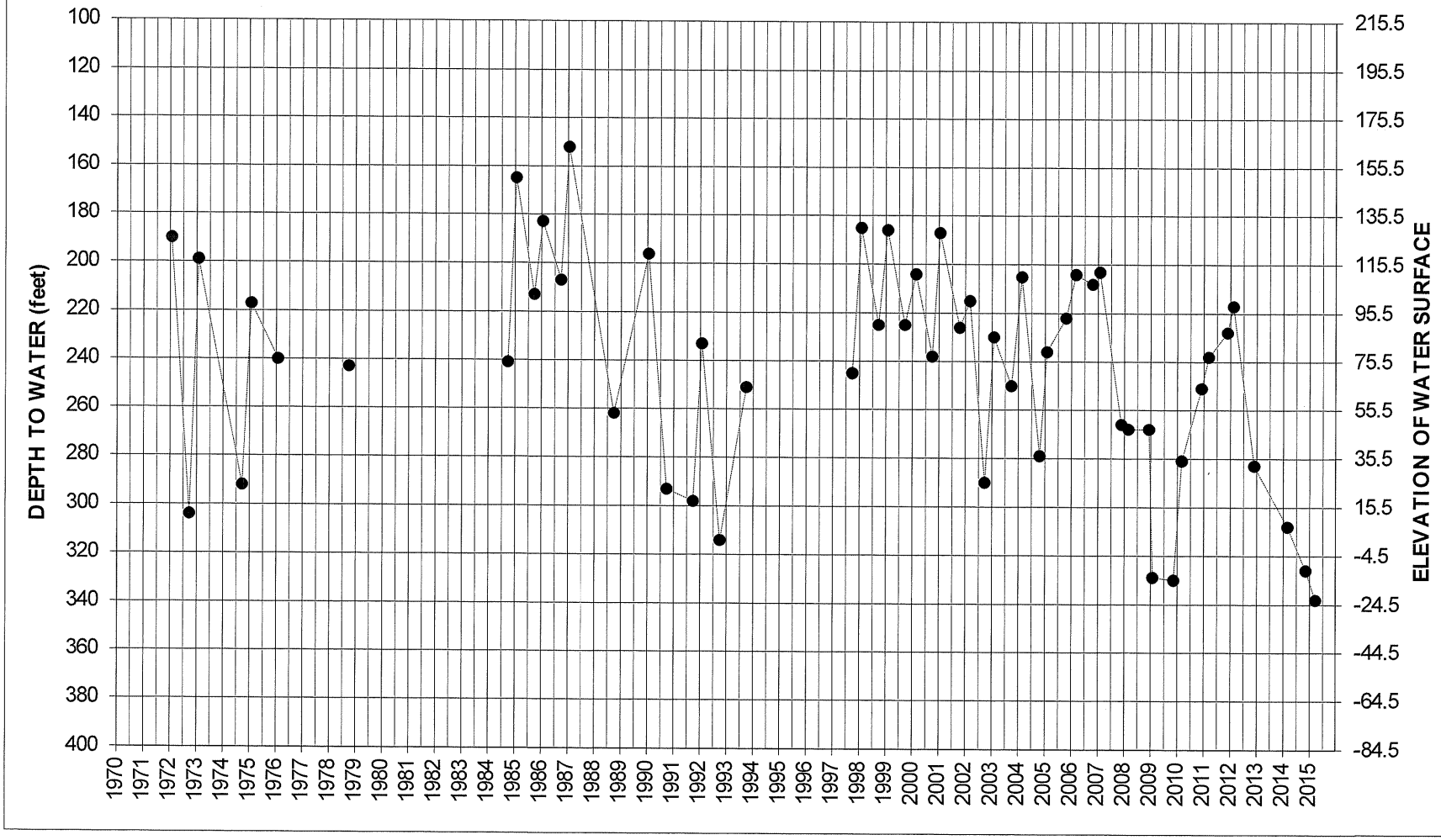
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-07R



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Bookman-Edmonston Division

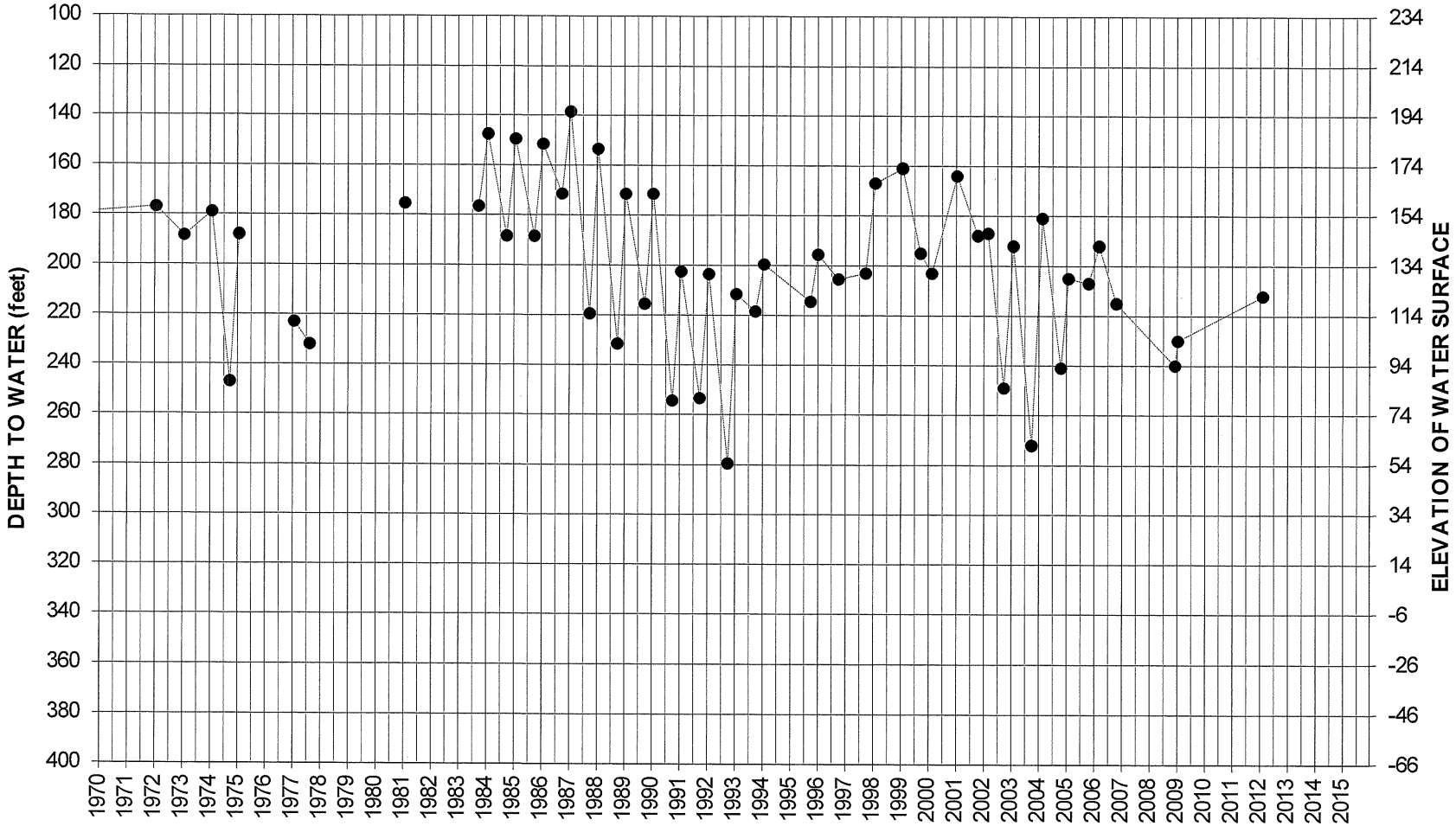
NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-08P



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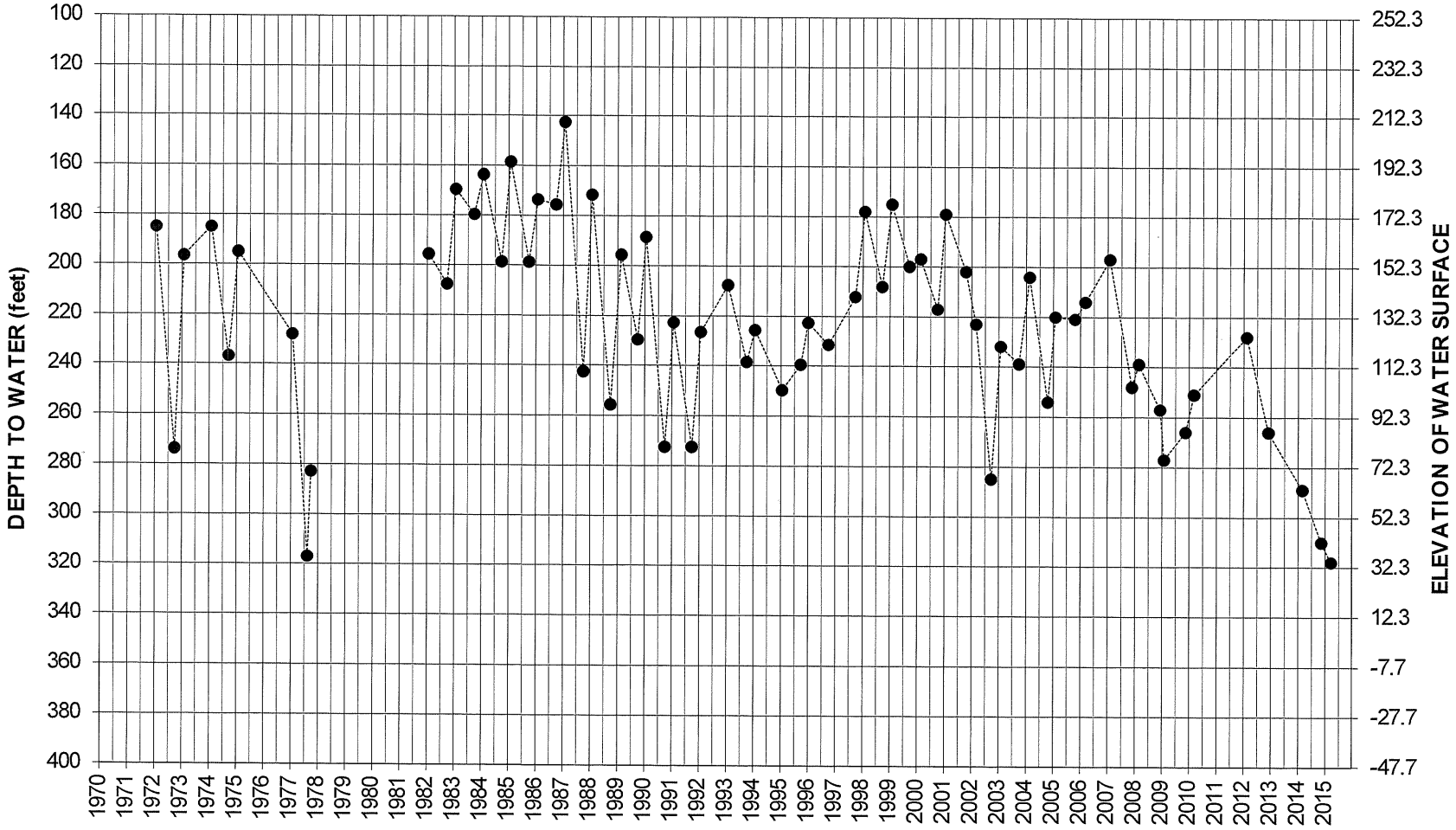
June 2010

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-09R



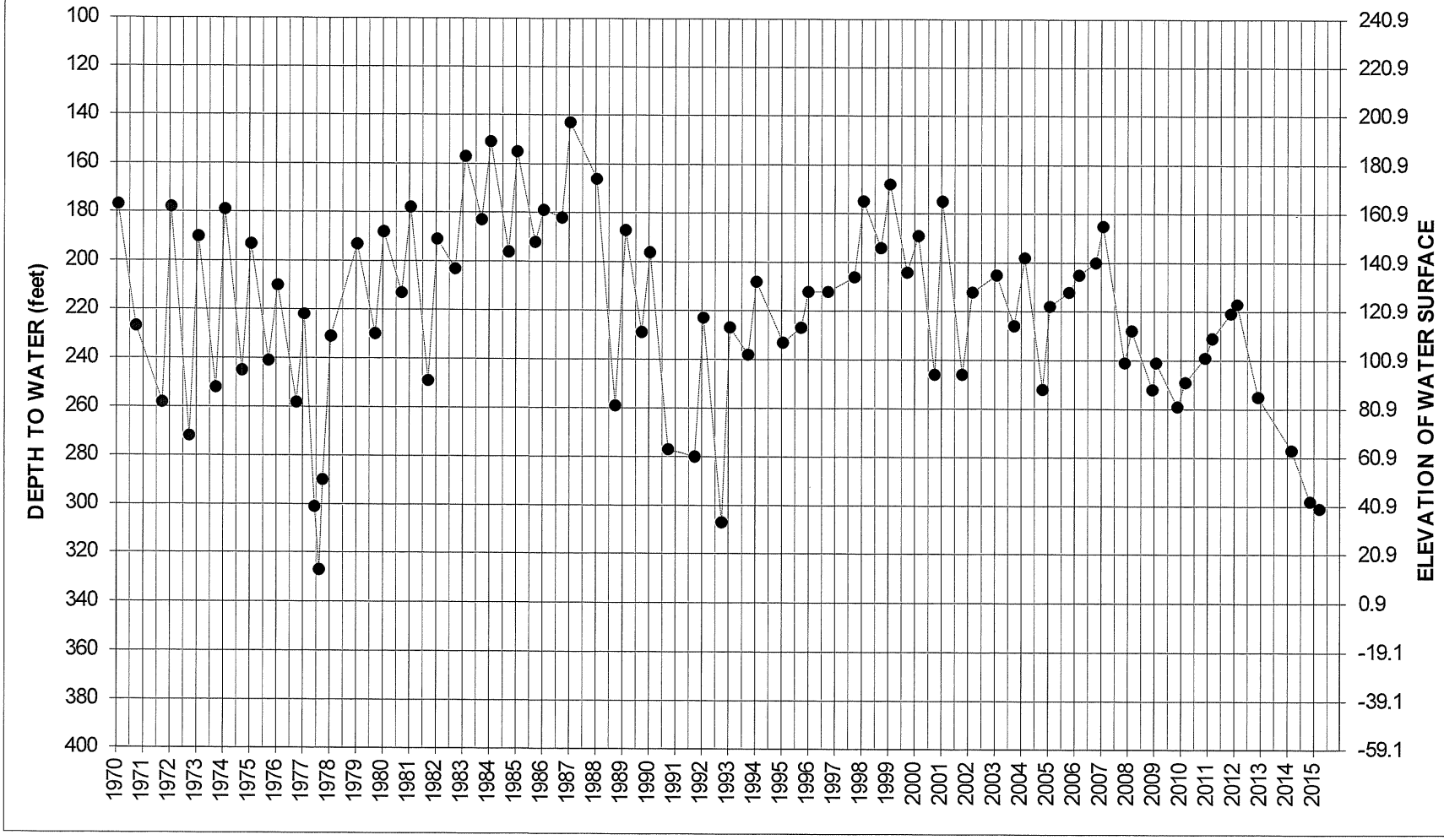
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-15R



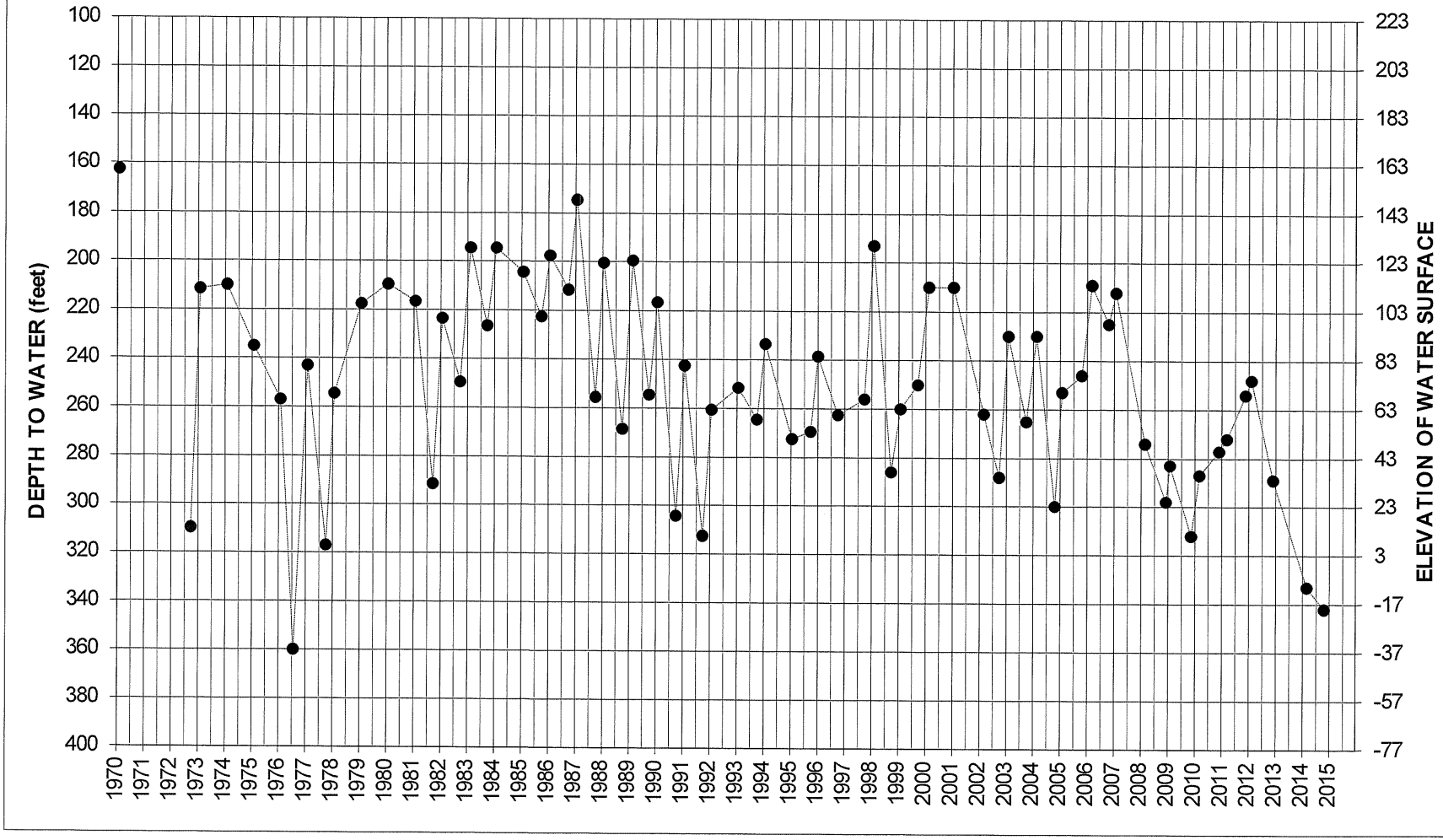
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-16R



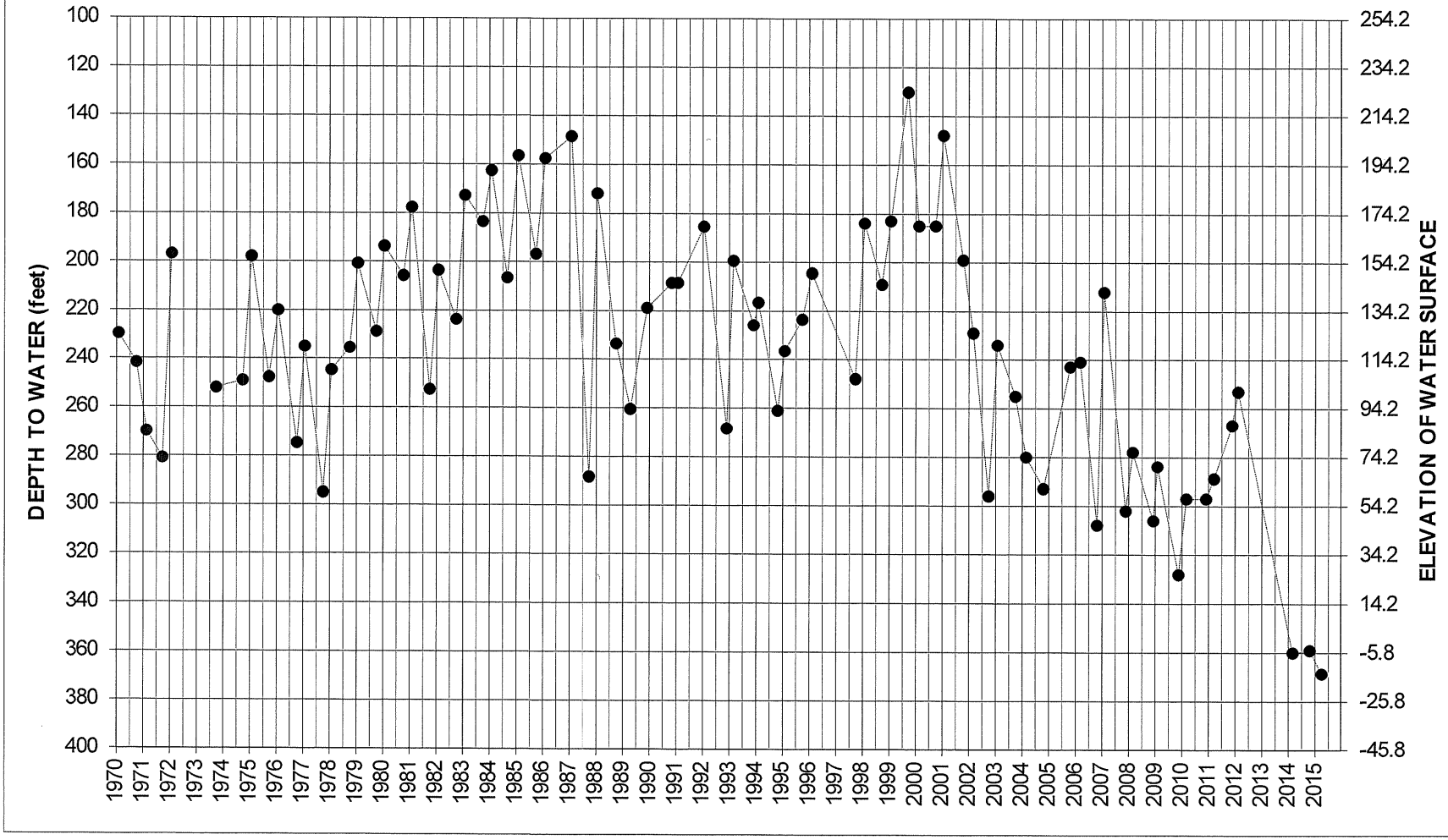
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-19R



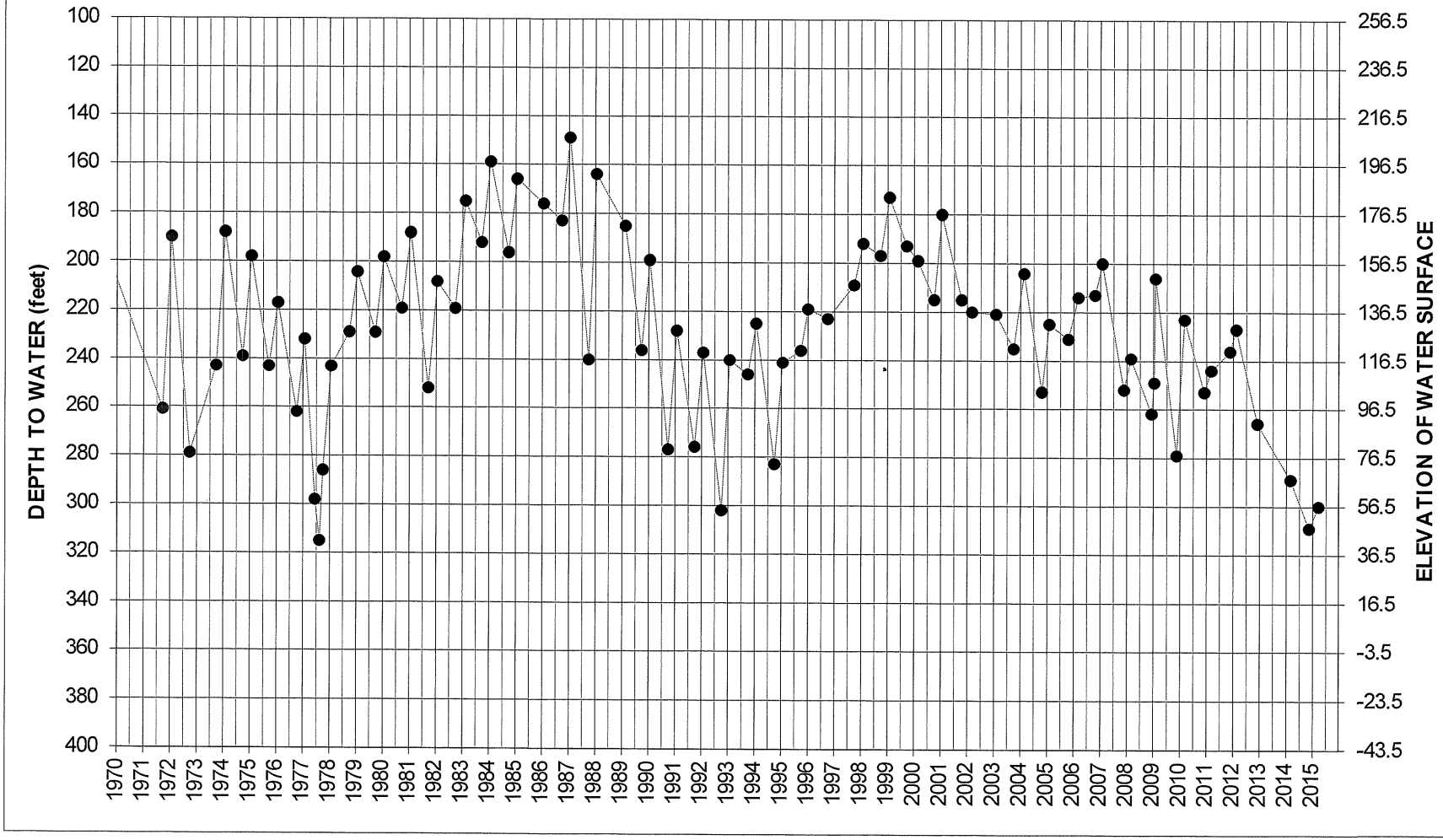
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-21K (340-900)



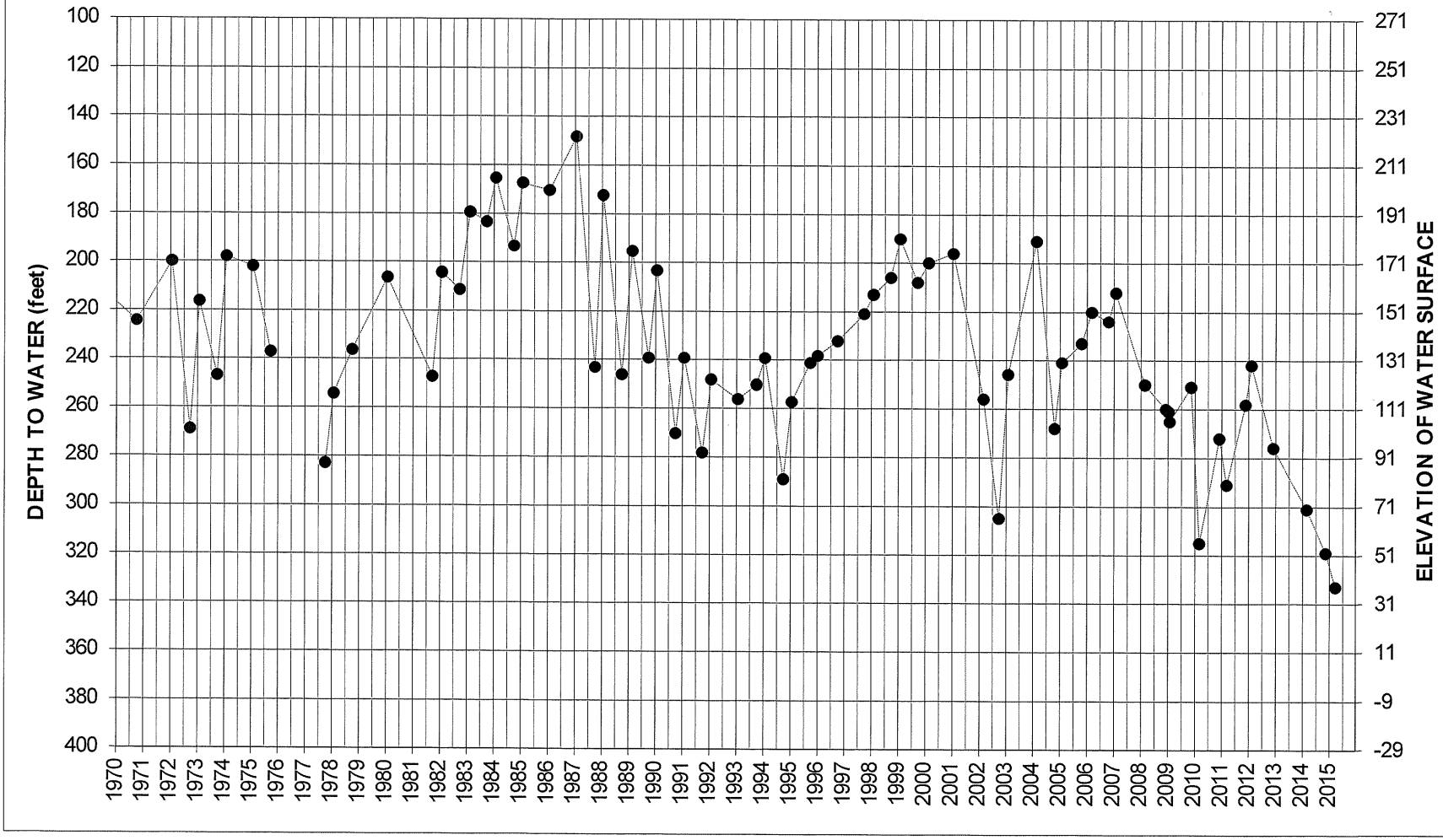
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-22H



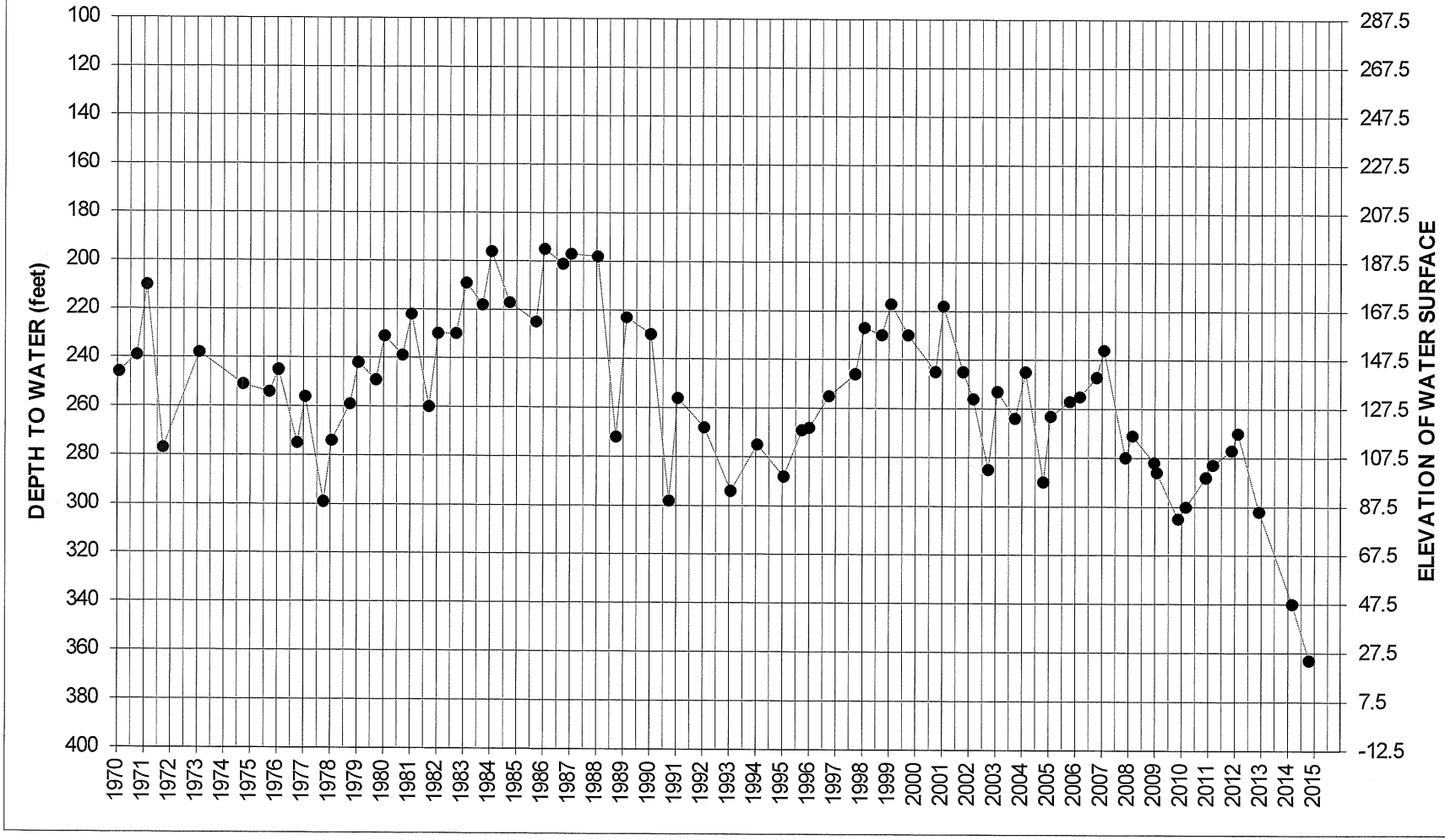
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-23R



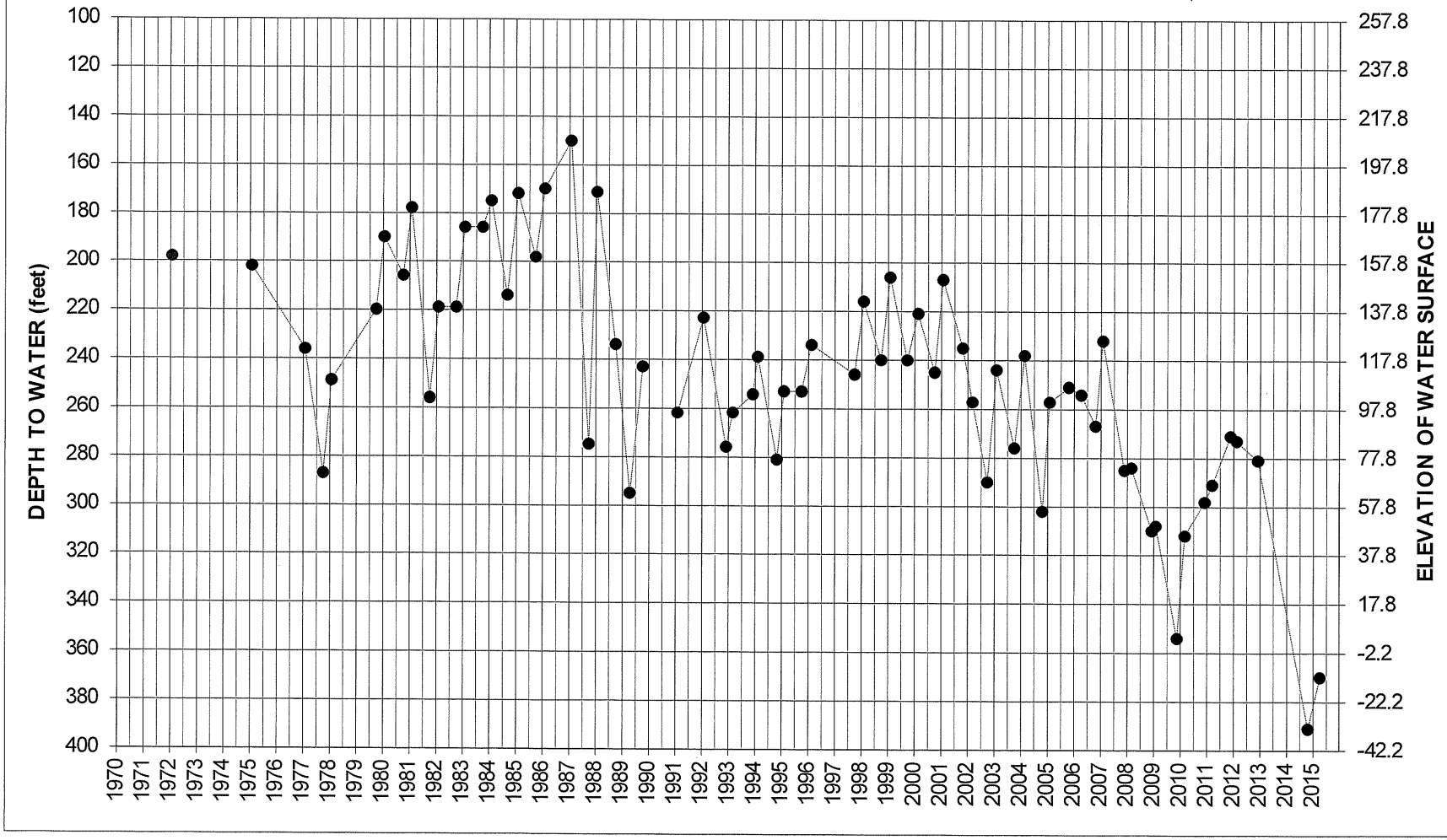
GEI Consultants
Boulmen-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-25R



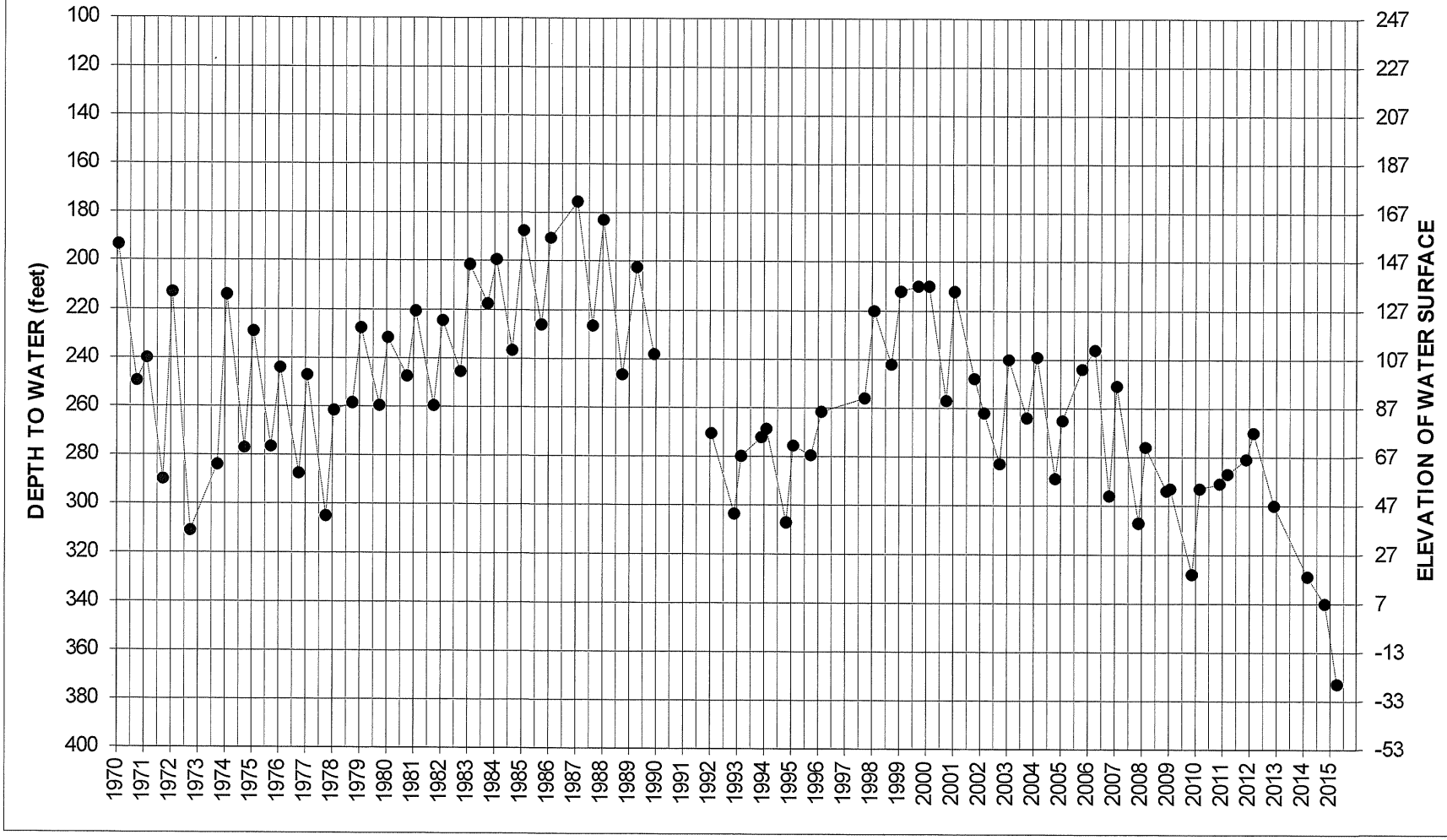
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-27B



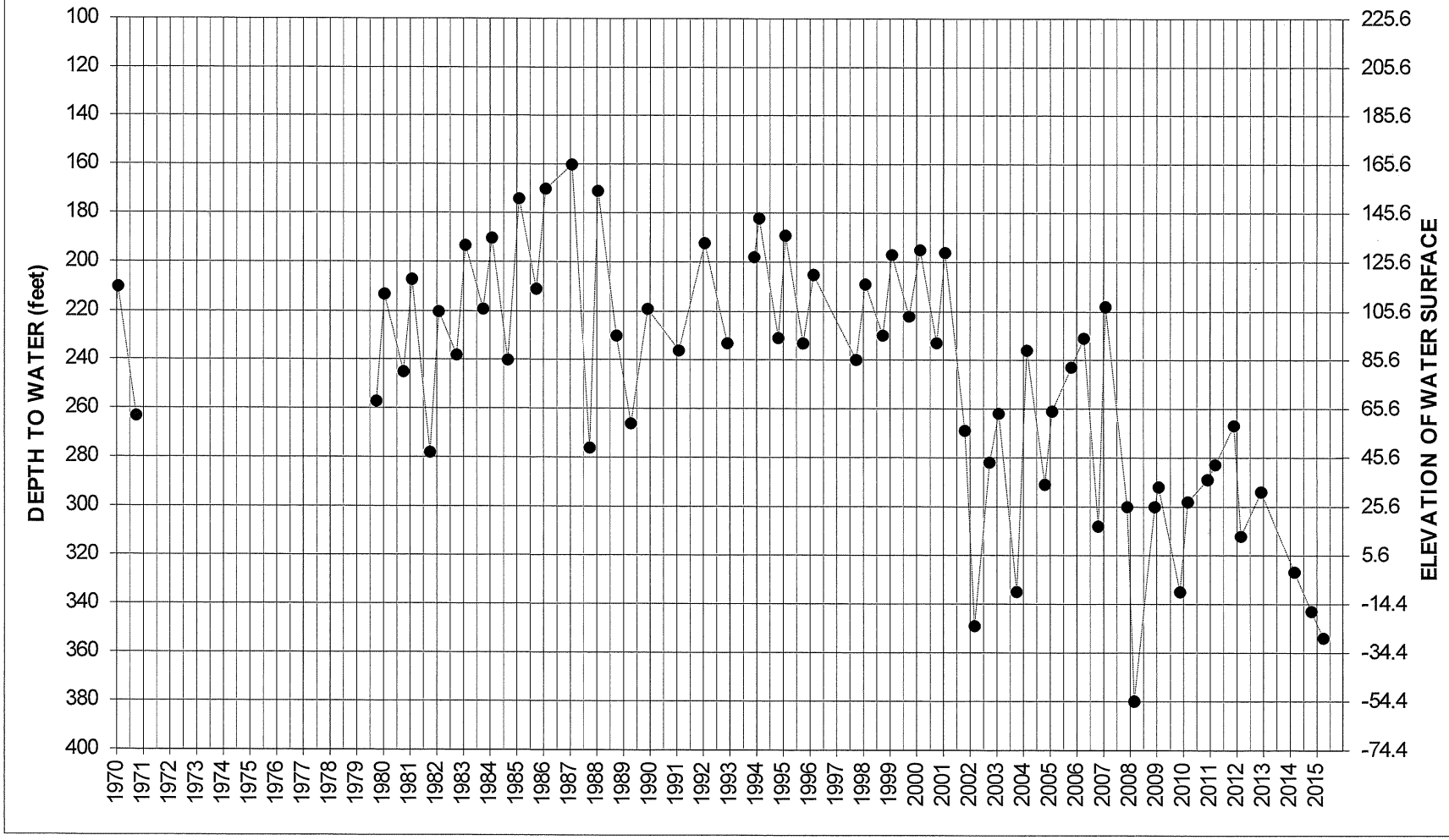
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-28Q (340-800)



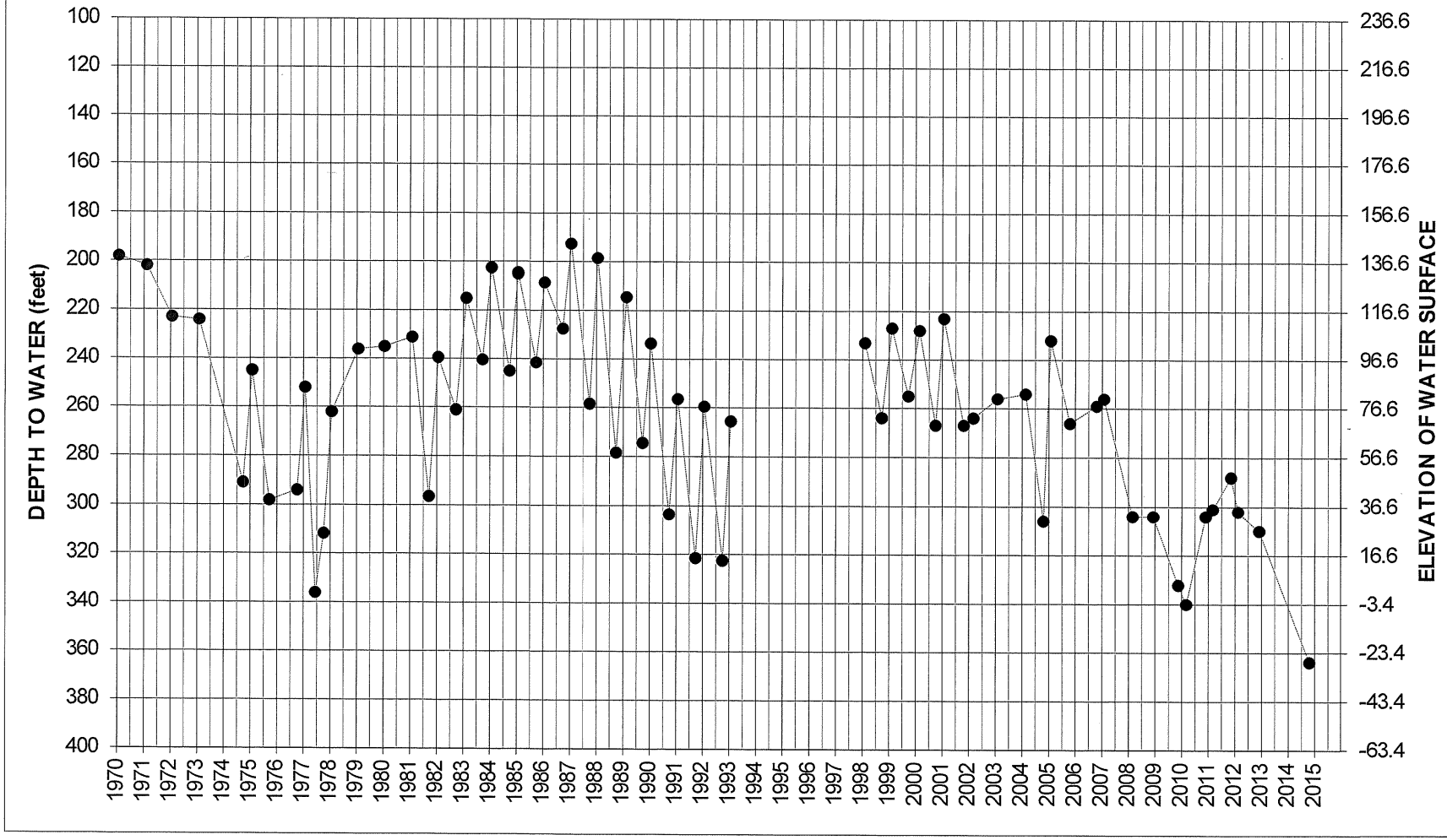
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-30H (340-800)



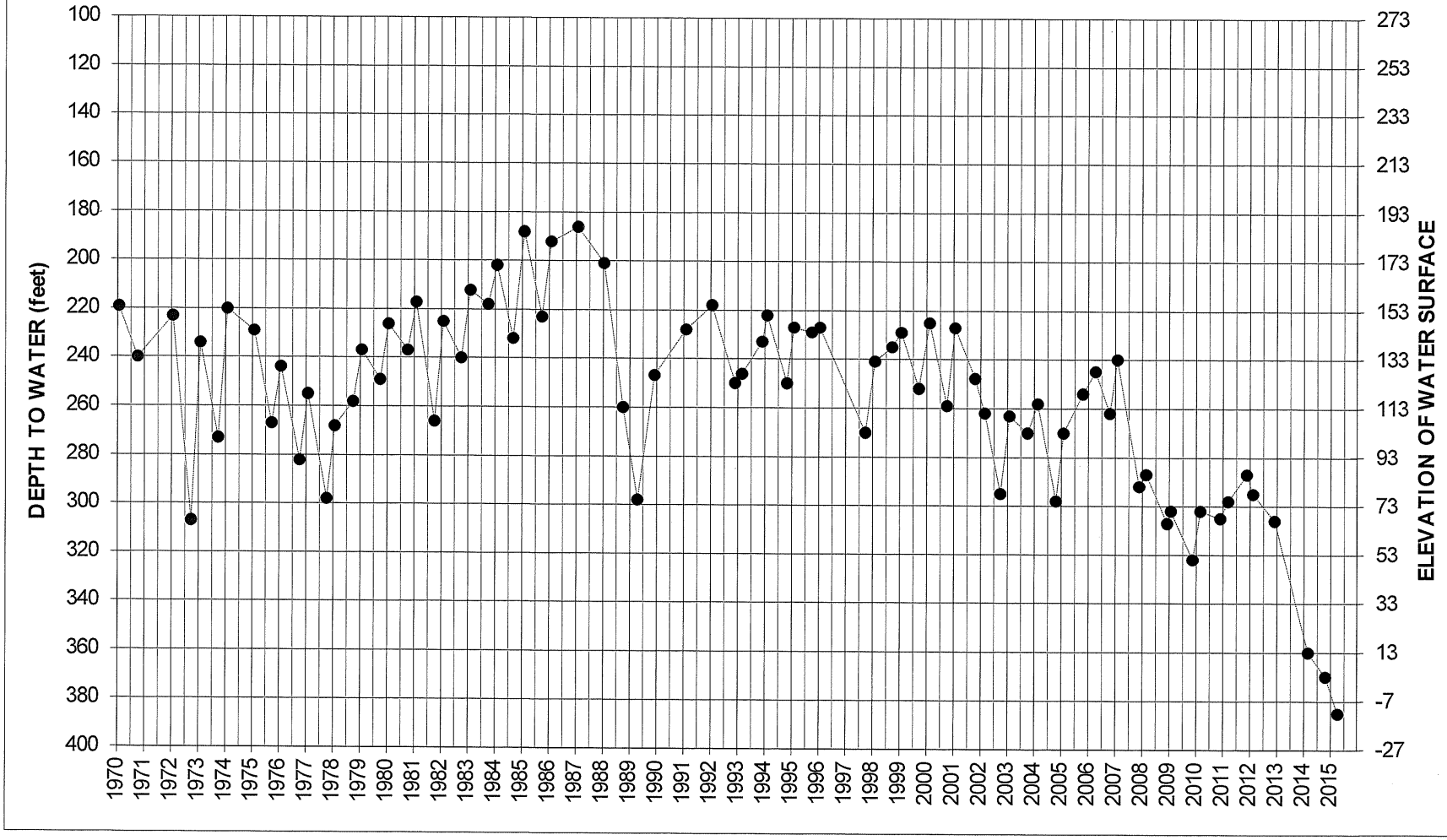
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-31R



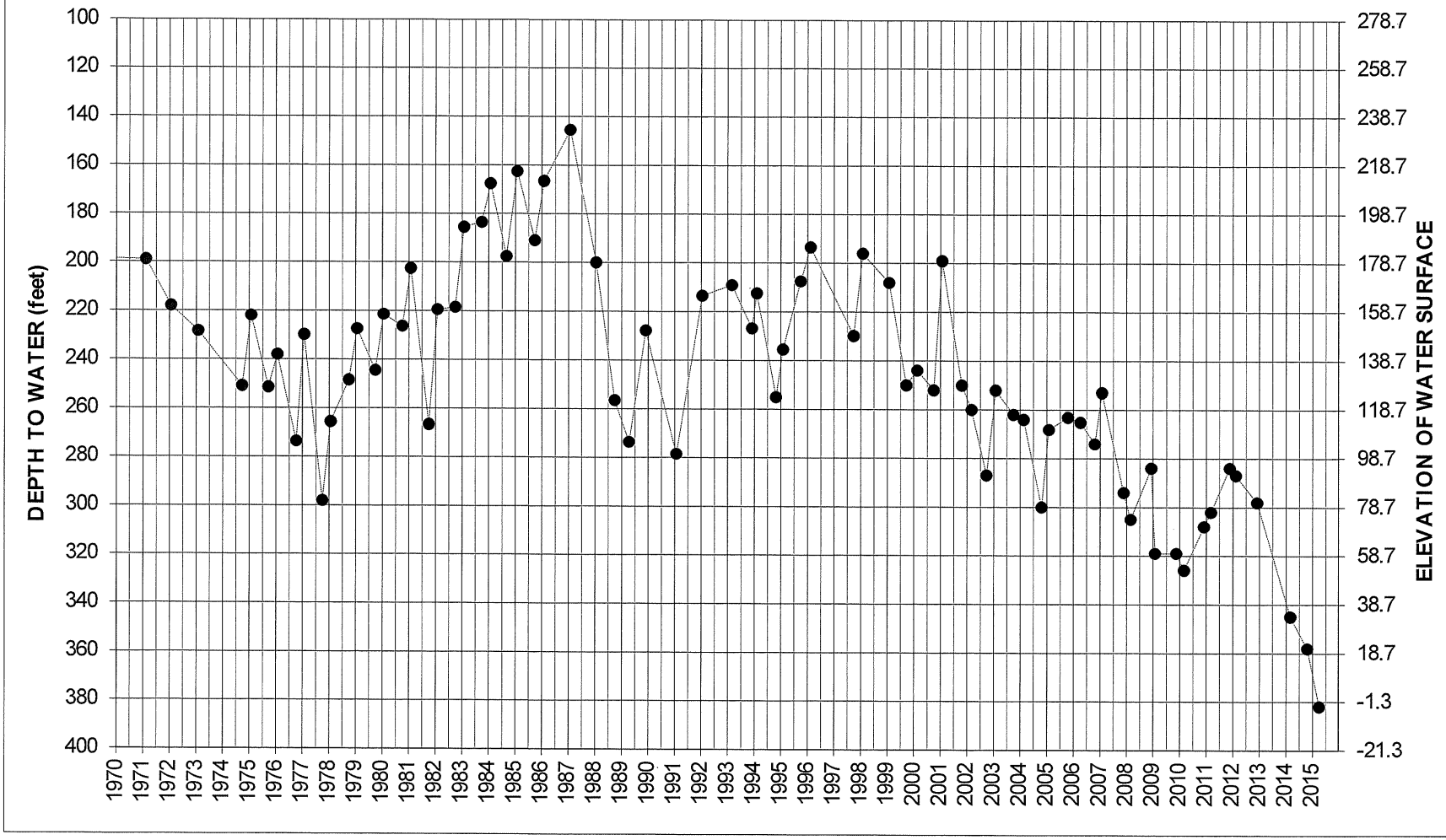
GEI Consultants
Boellman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-34R (340-800)



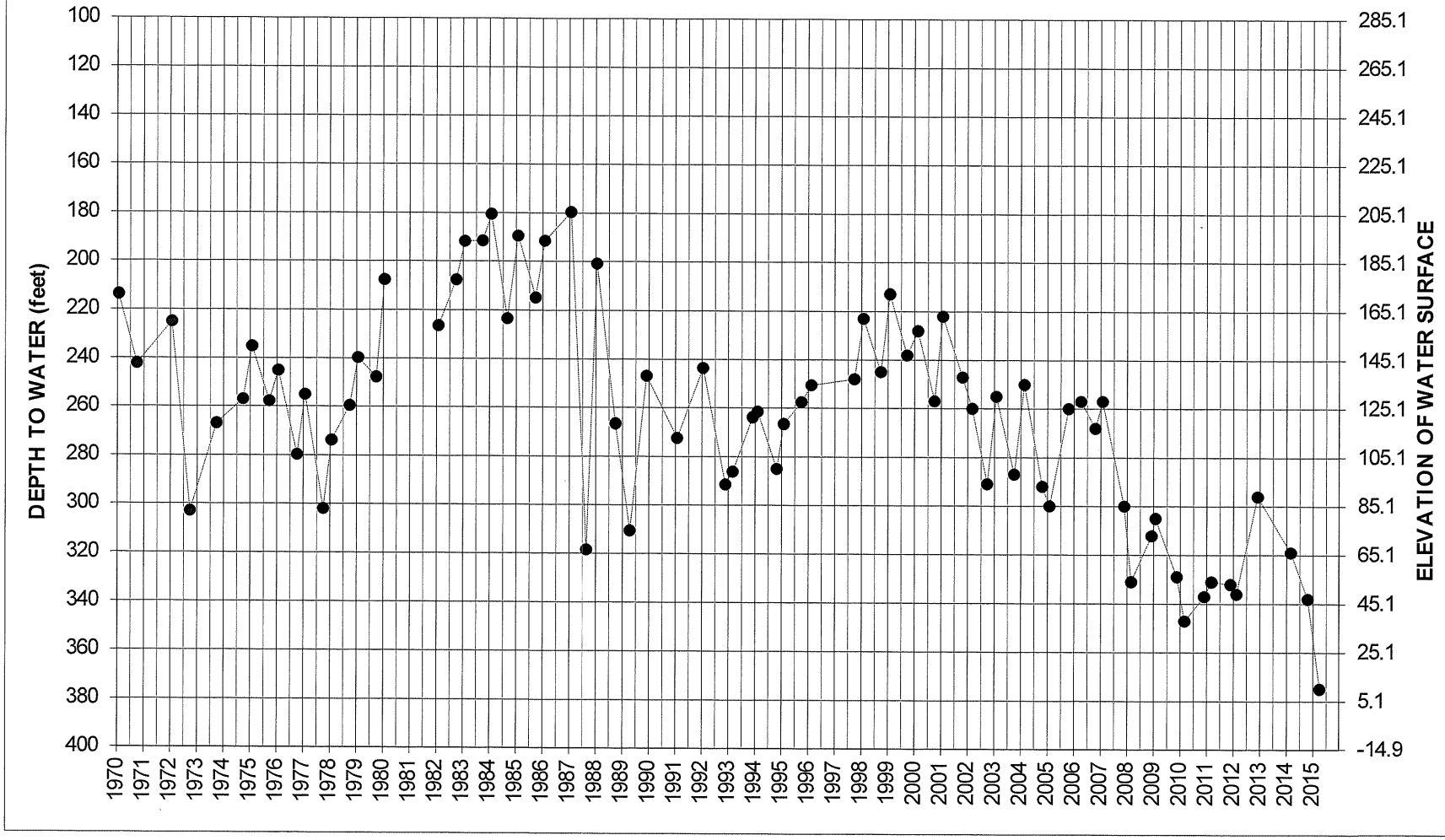
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-35B (340-800)



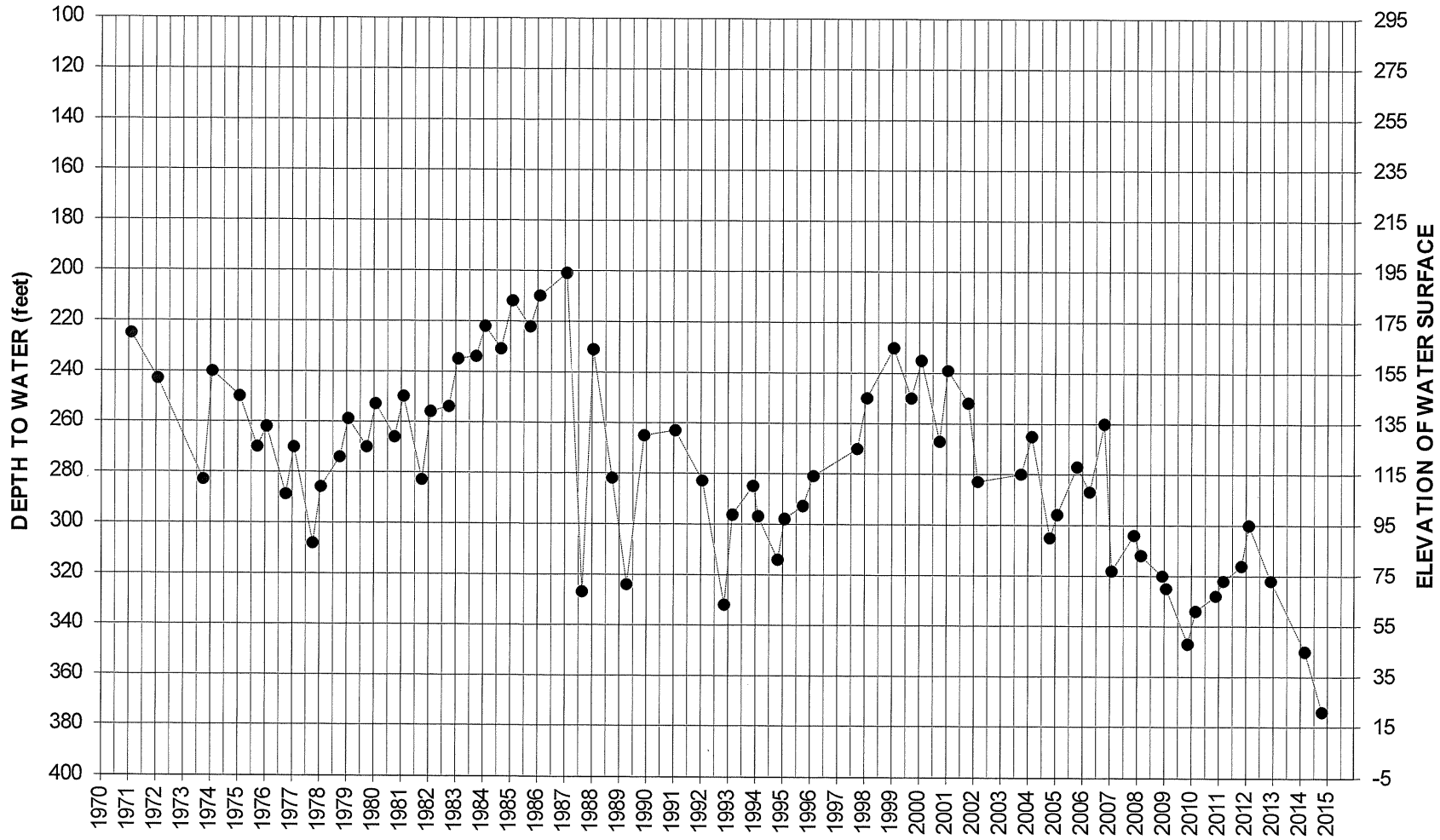
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-36E (336-800)



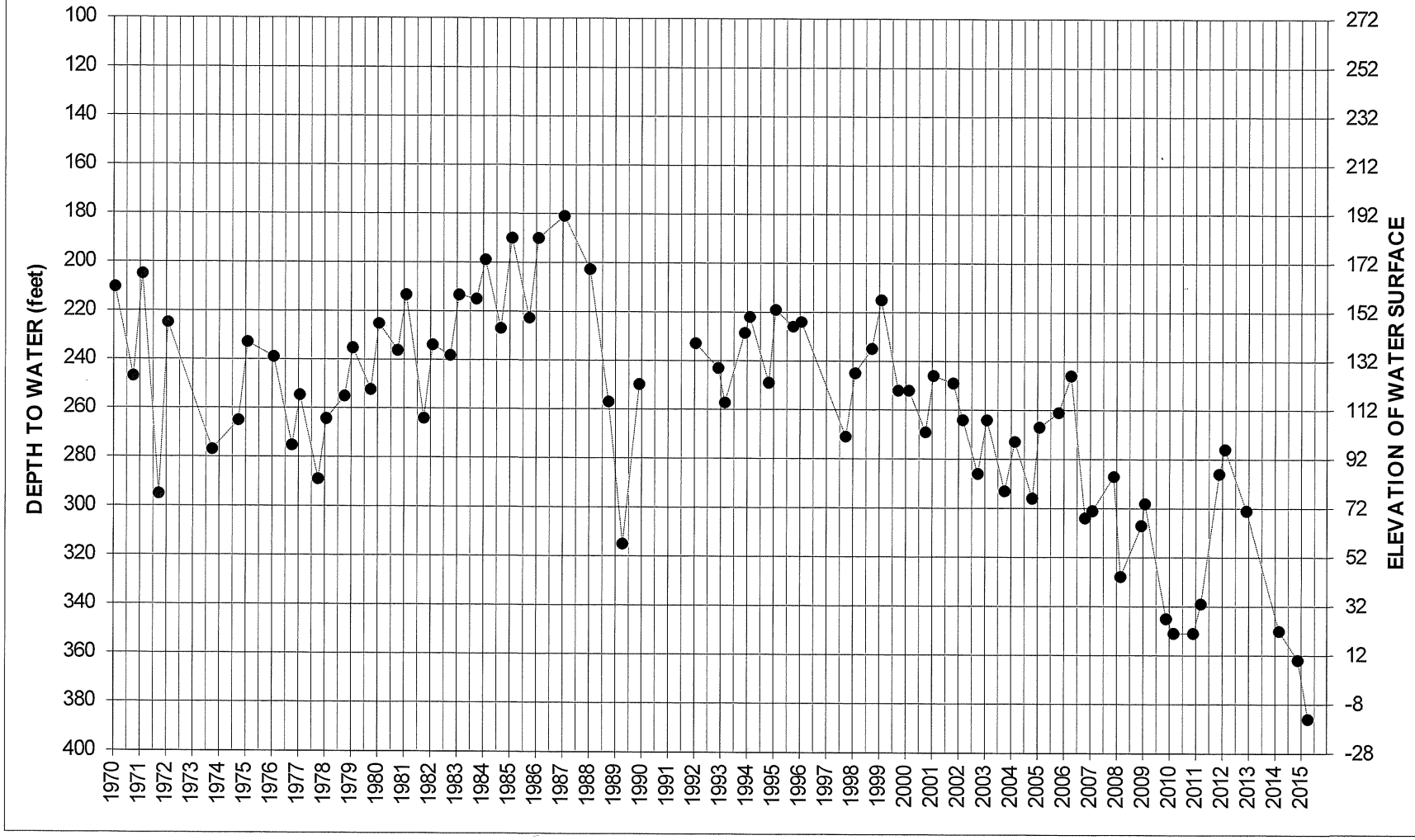
GEI Consultants
Boudman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-01N (336-800)



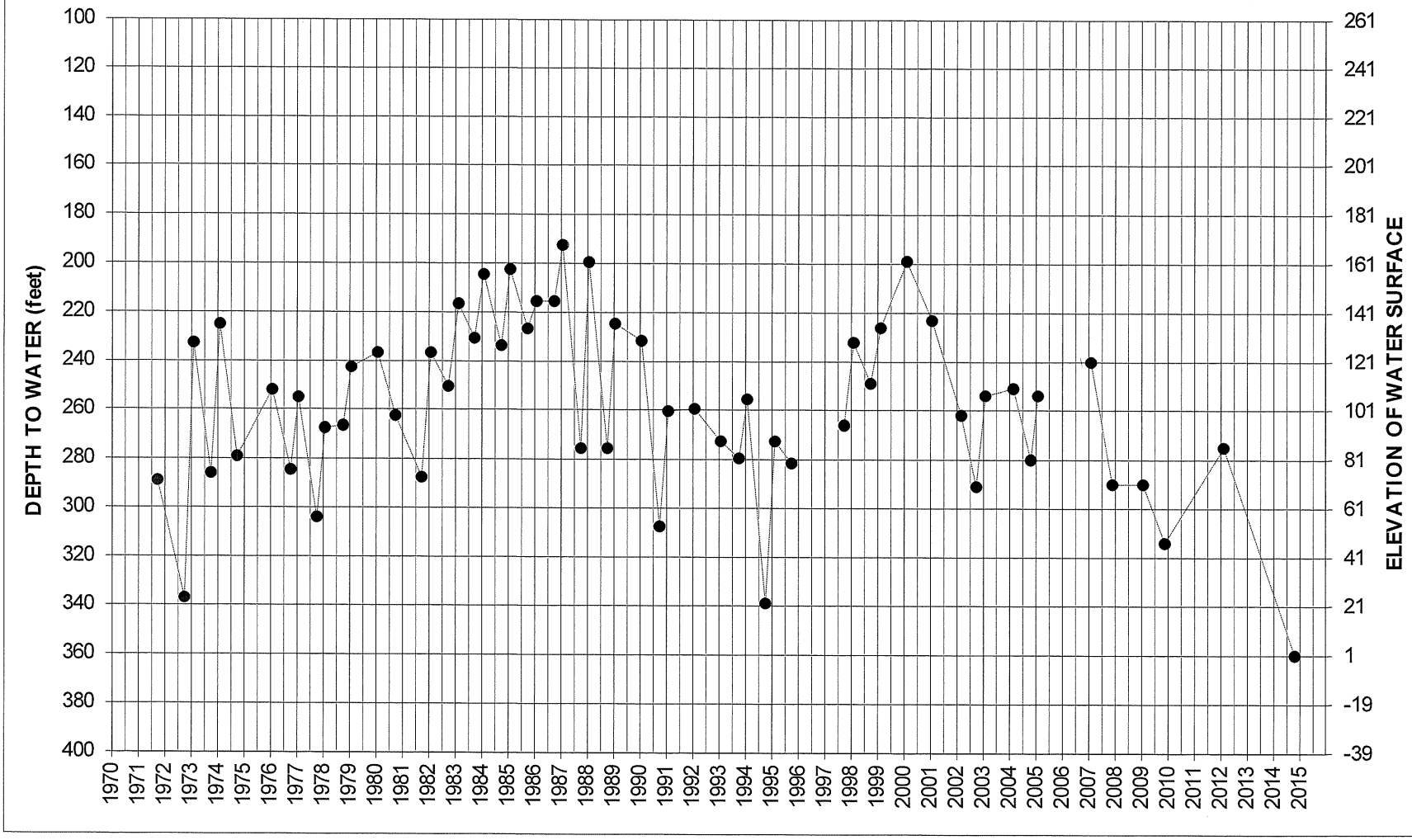
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-03H (340-800)



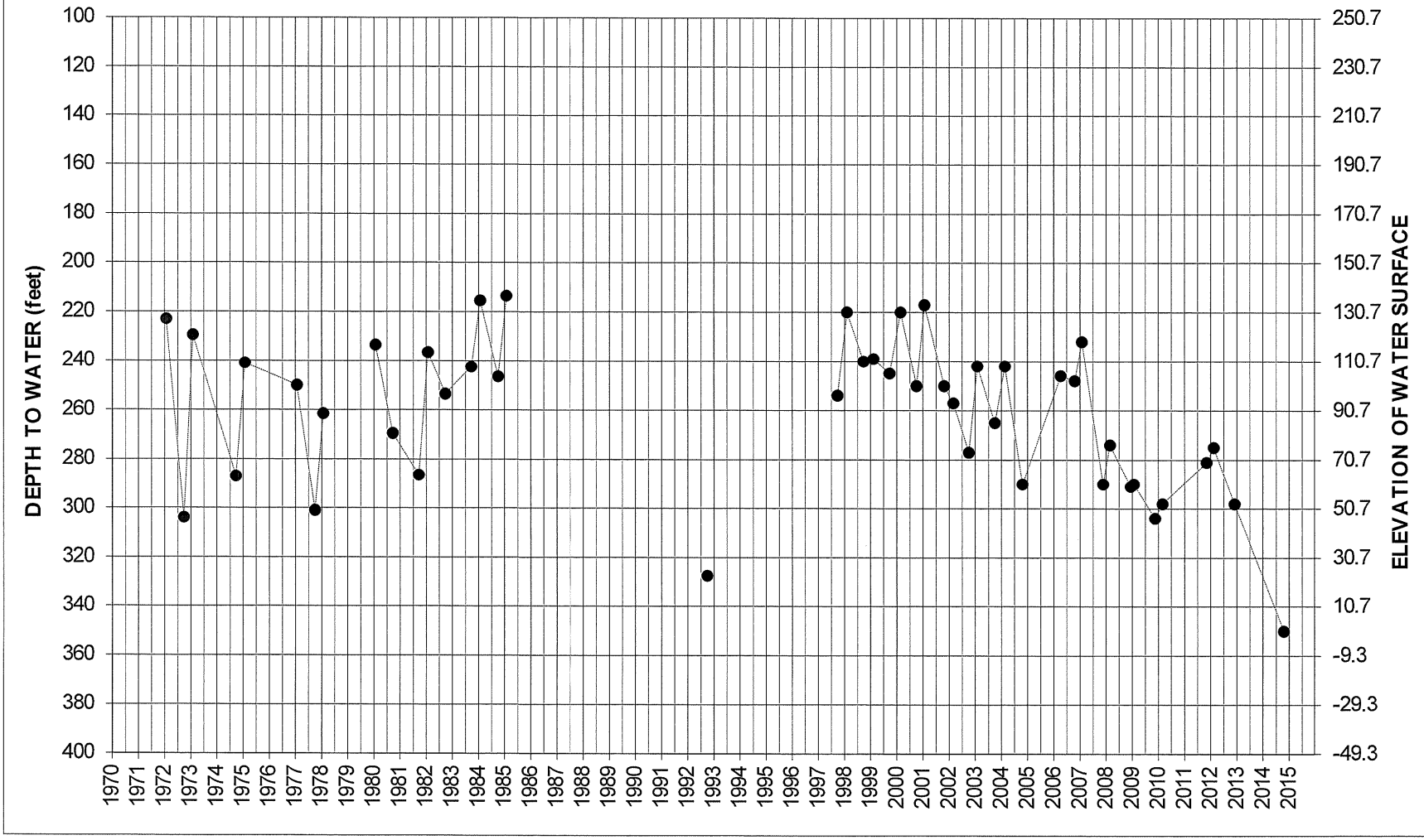
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-04H



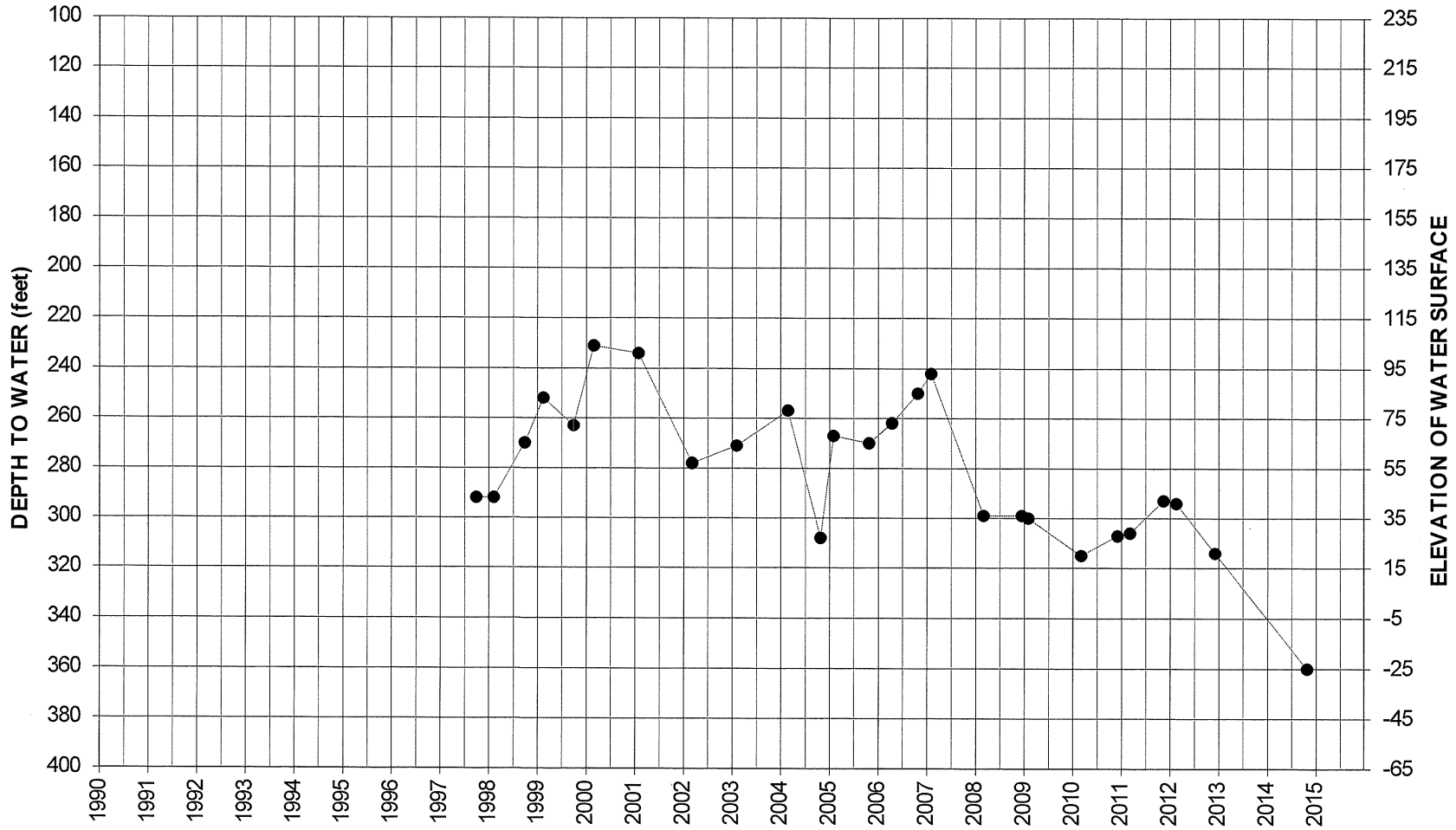
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-05H



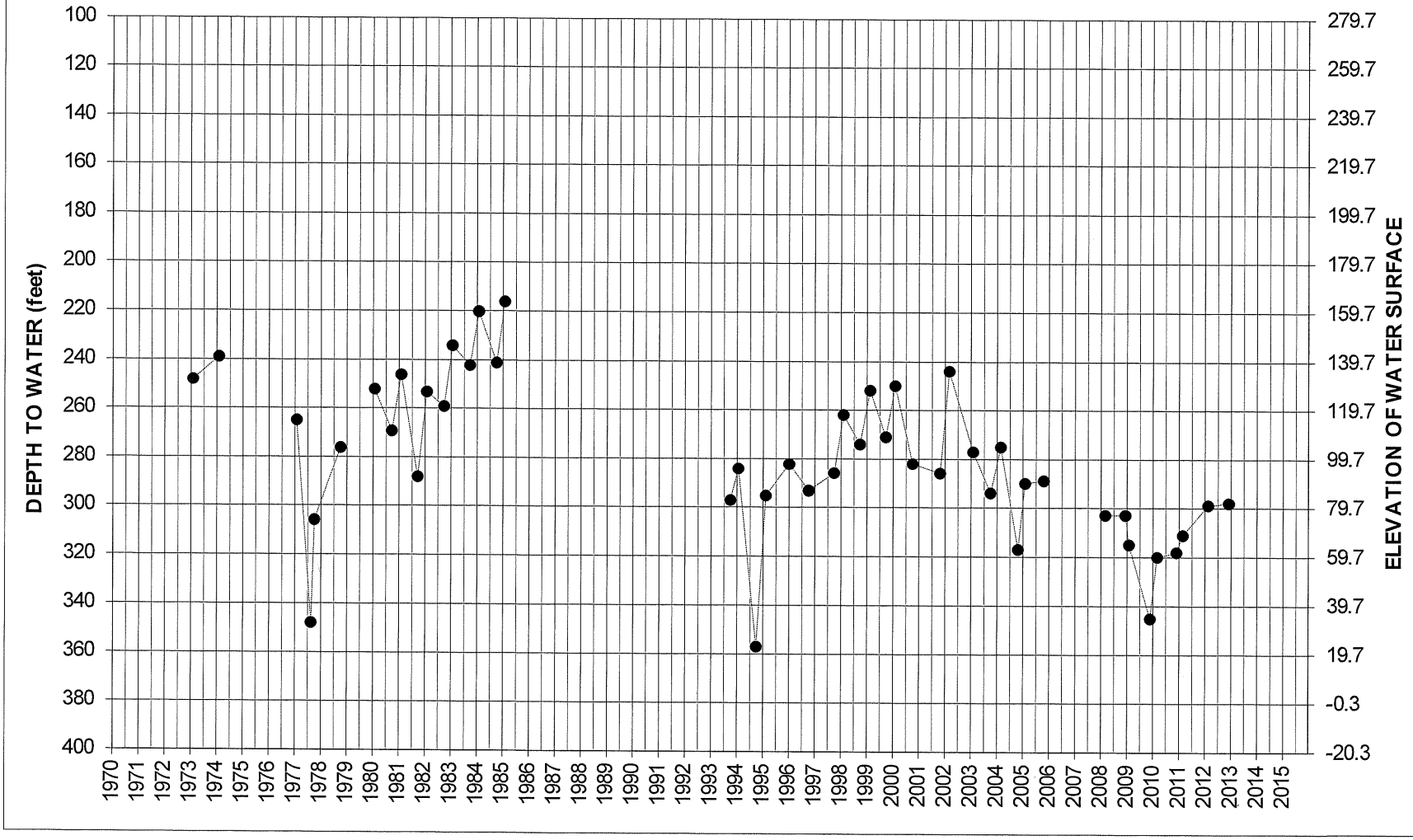
GEI Consultants
Boolkman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-06N



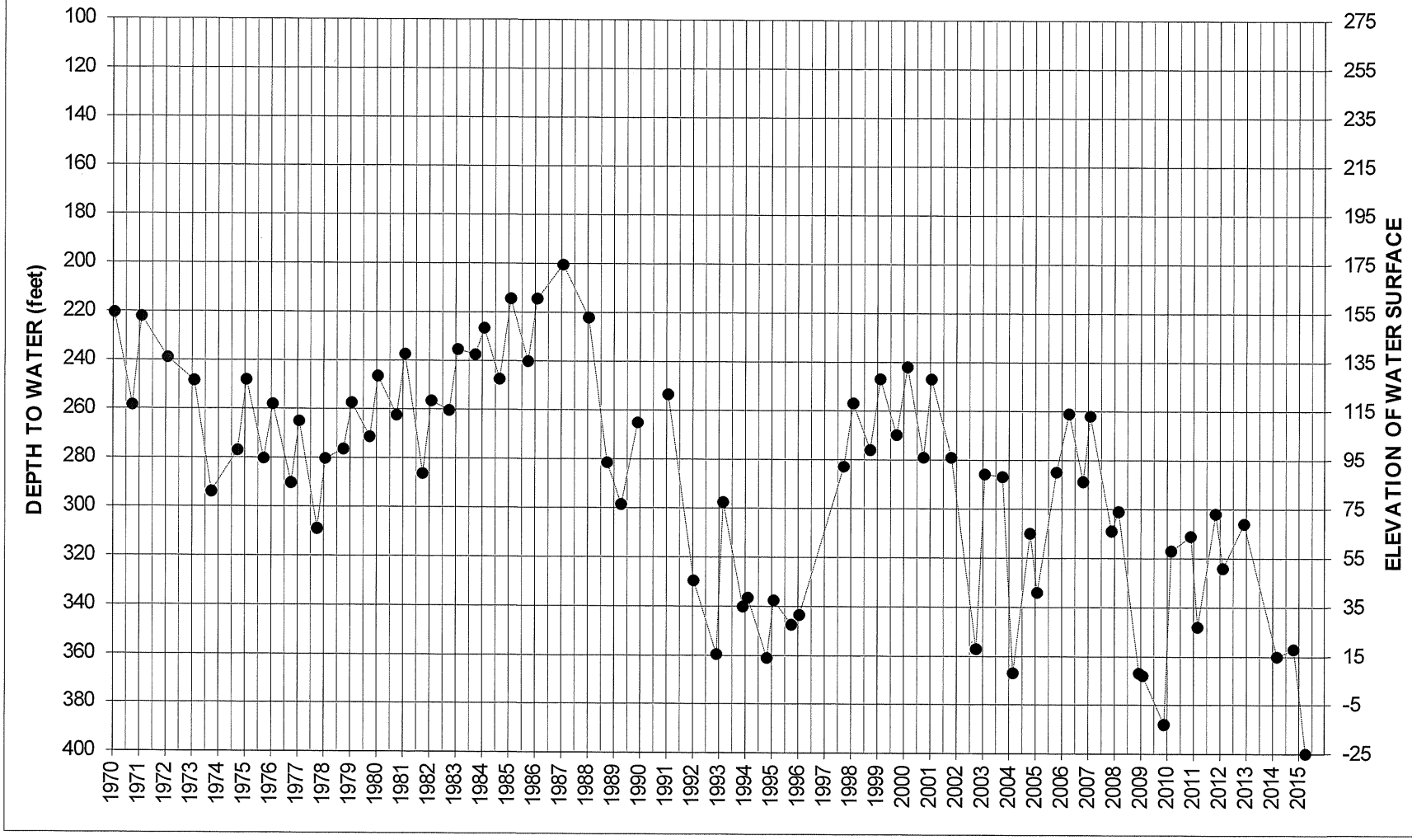
GEI Consultants
Boulmann-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-10J



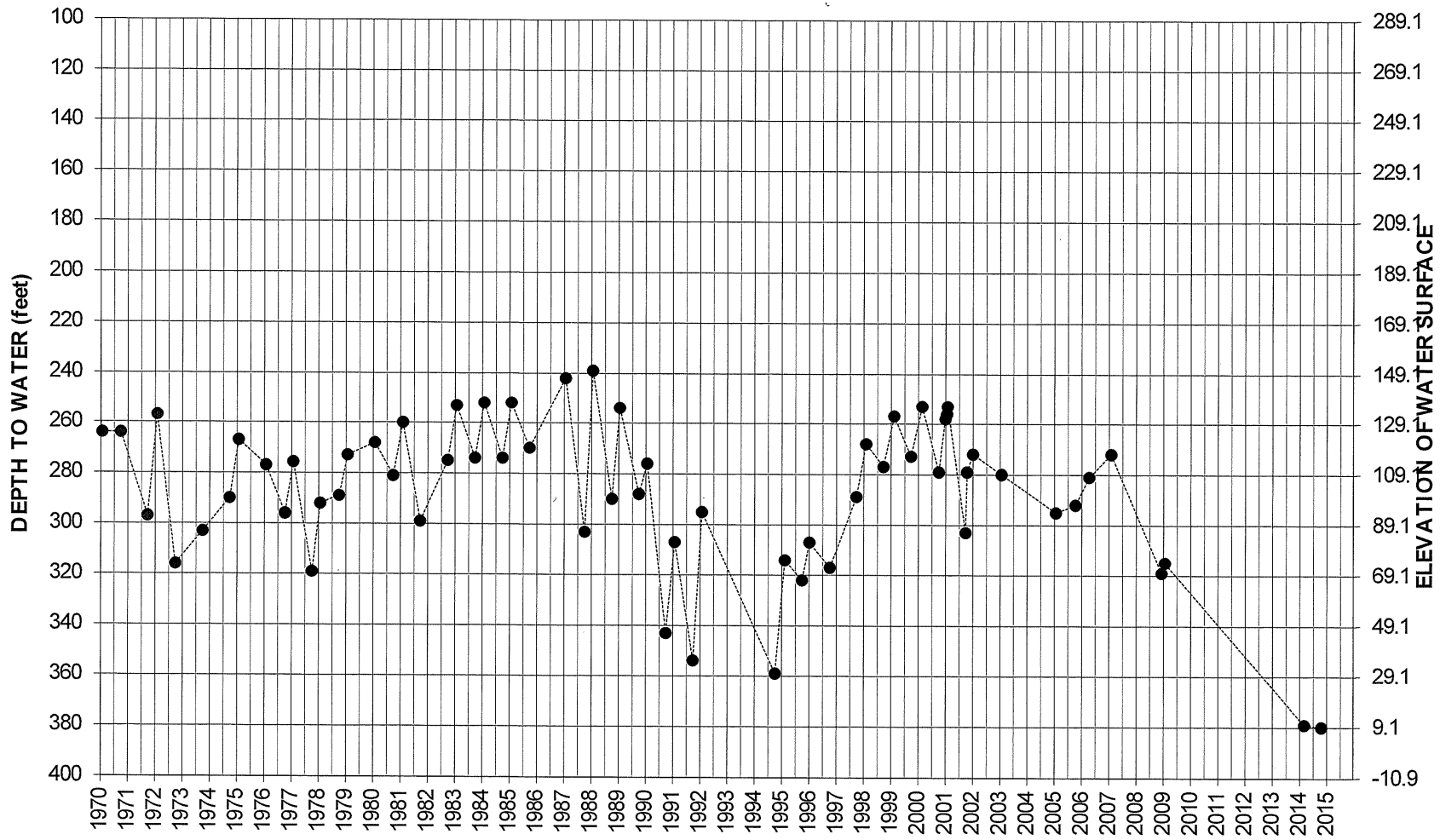
GEI Consultants
Boolman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-10L (342-800)



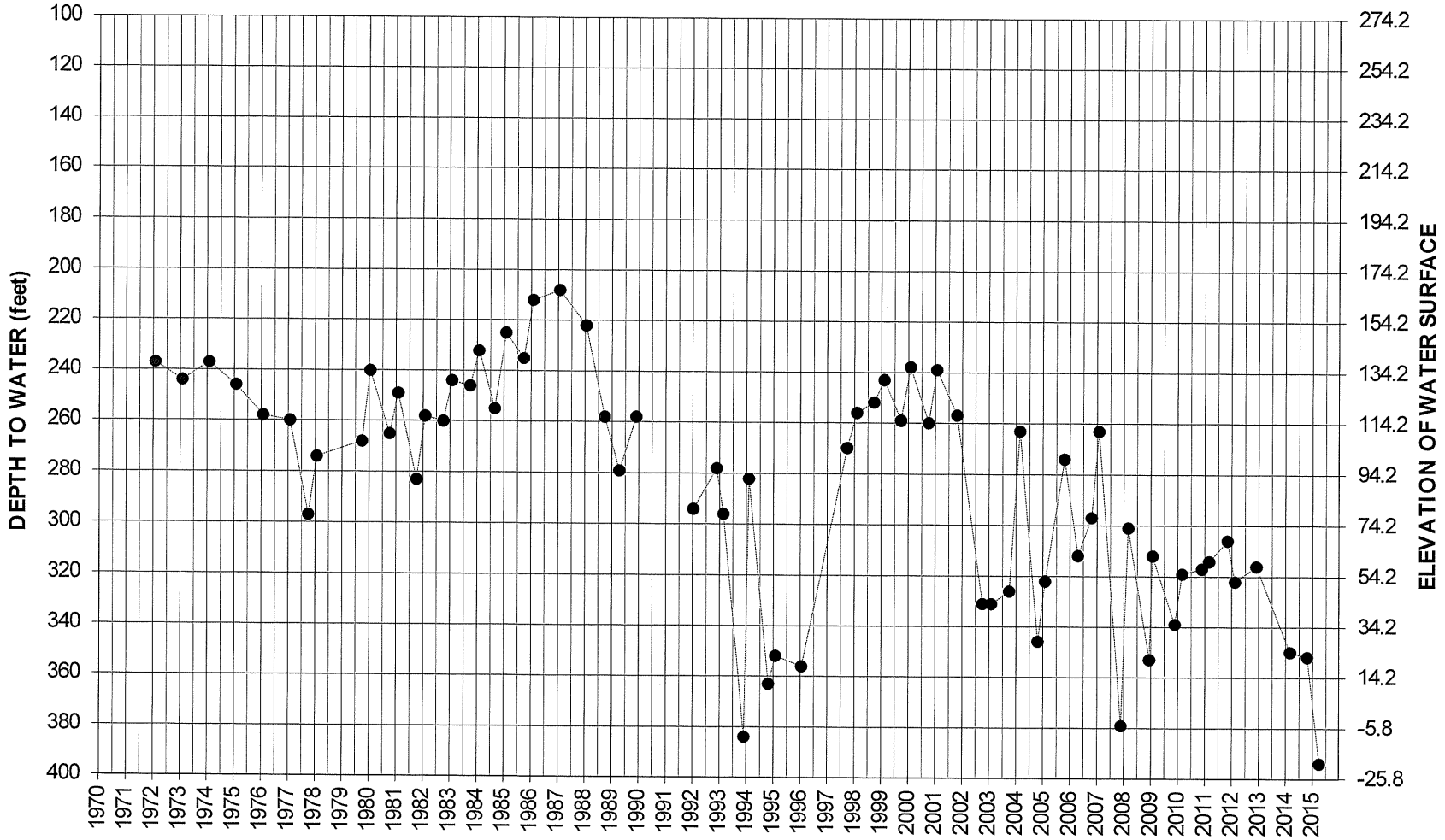
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-15J



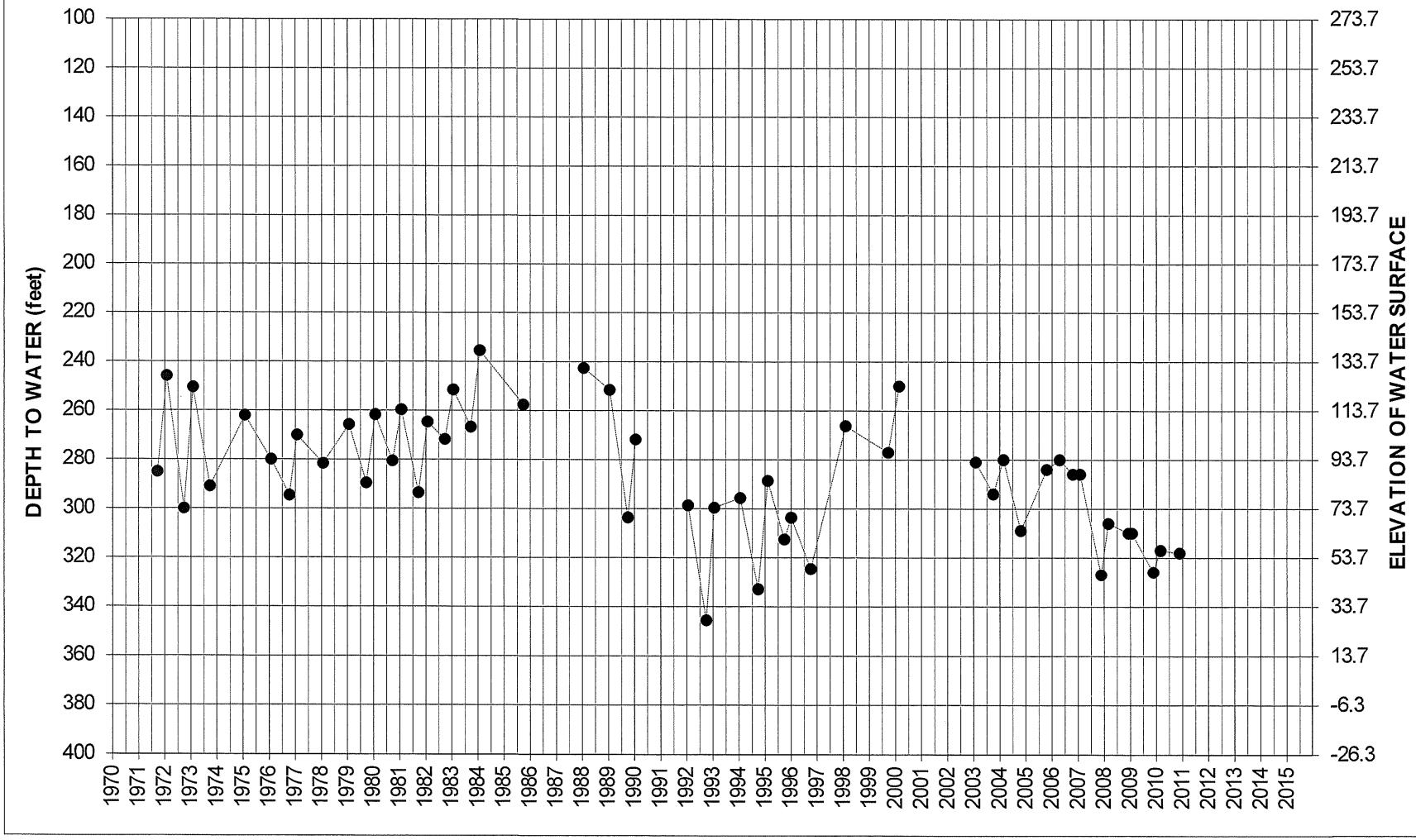
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-16H



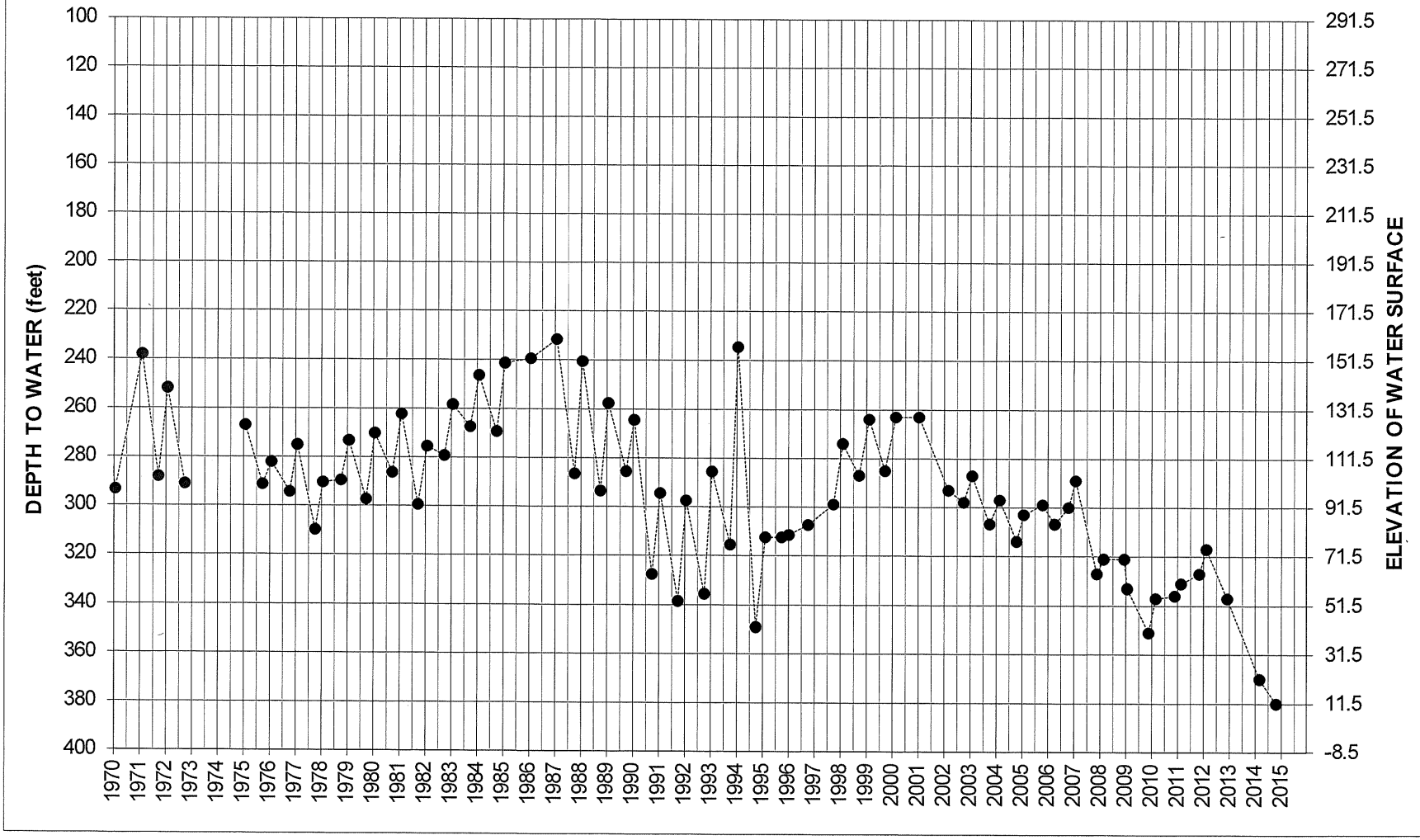
GEI Consultants
Boolman-Edmaniston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-21K



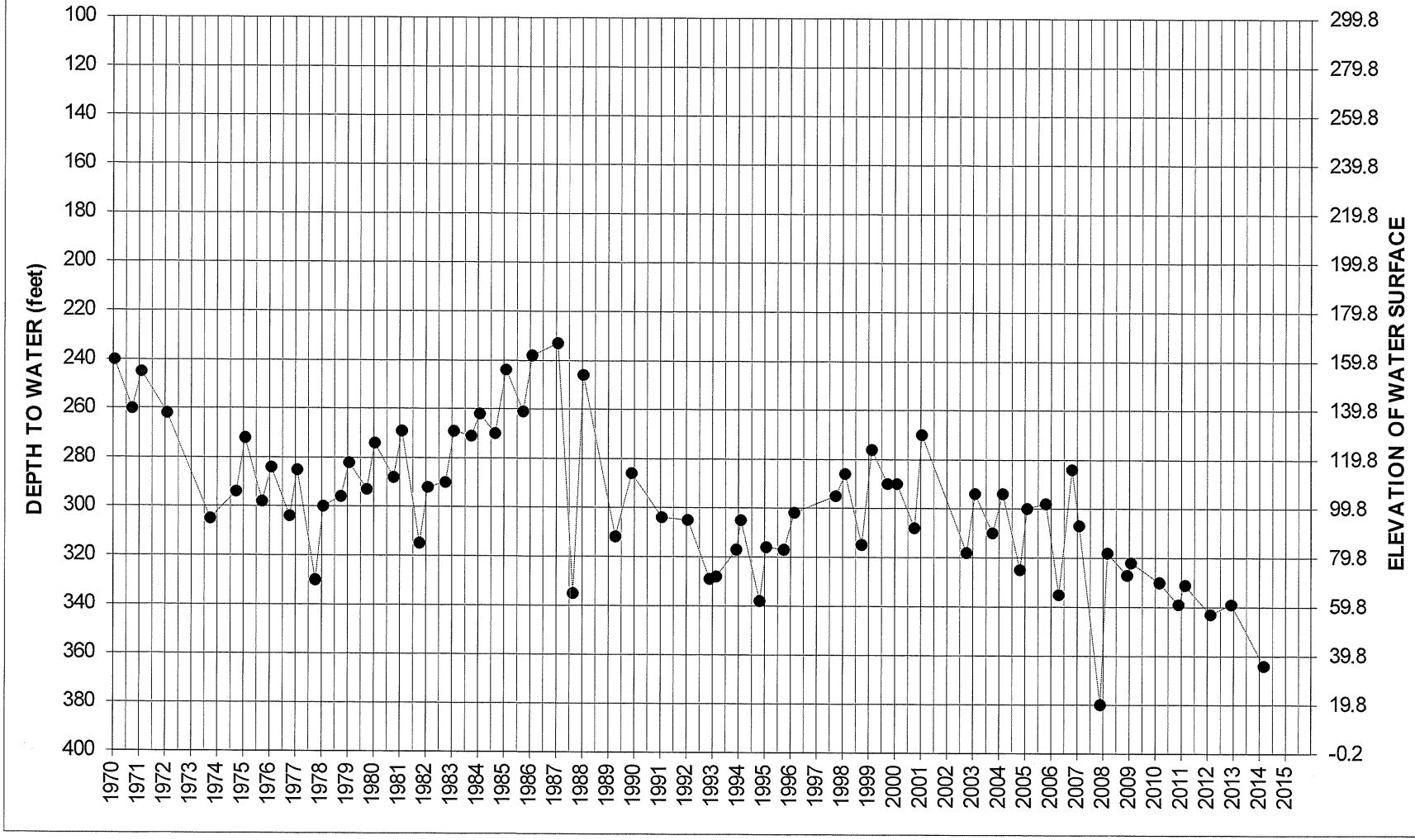
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Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-22J



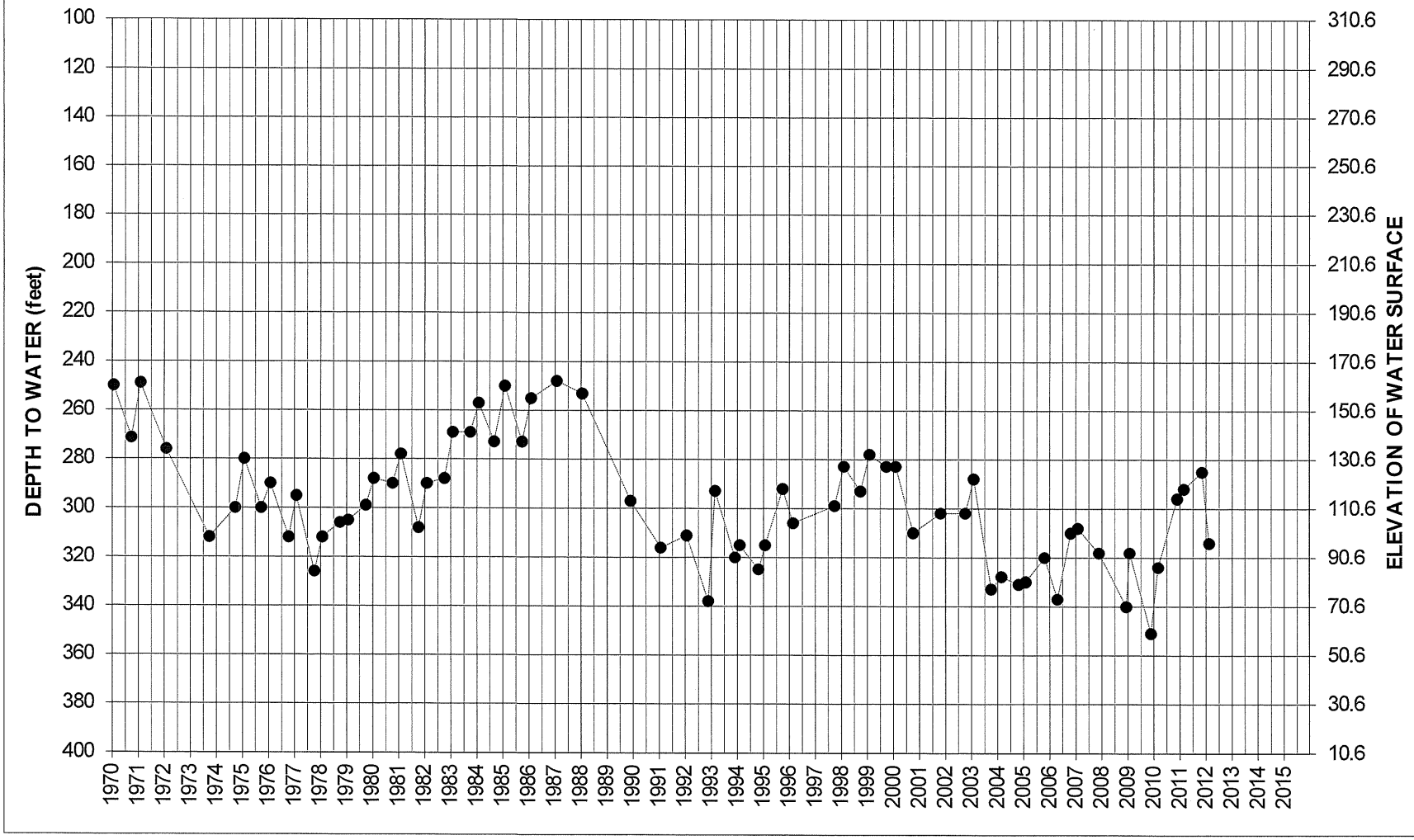
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Boulliman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-23C (341-803)



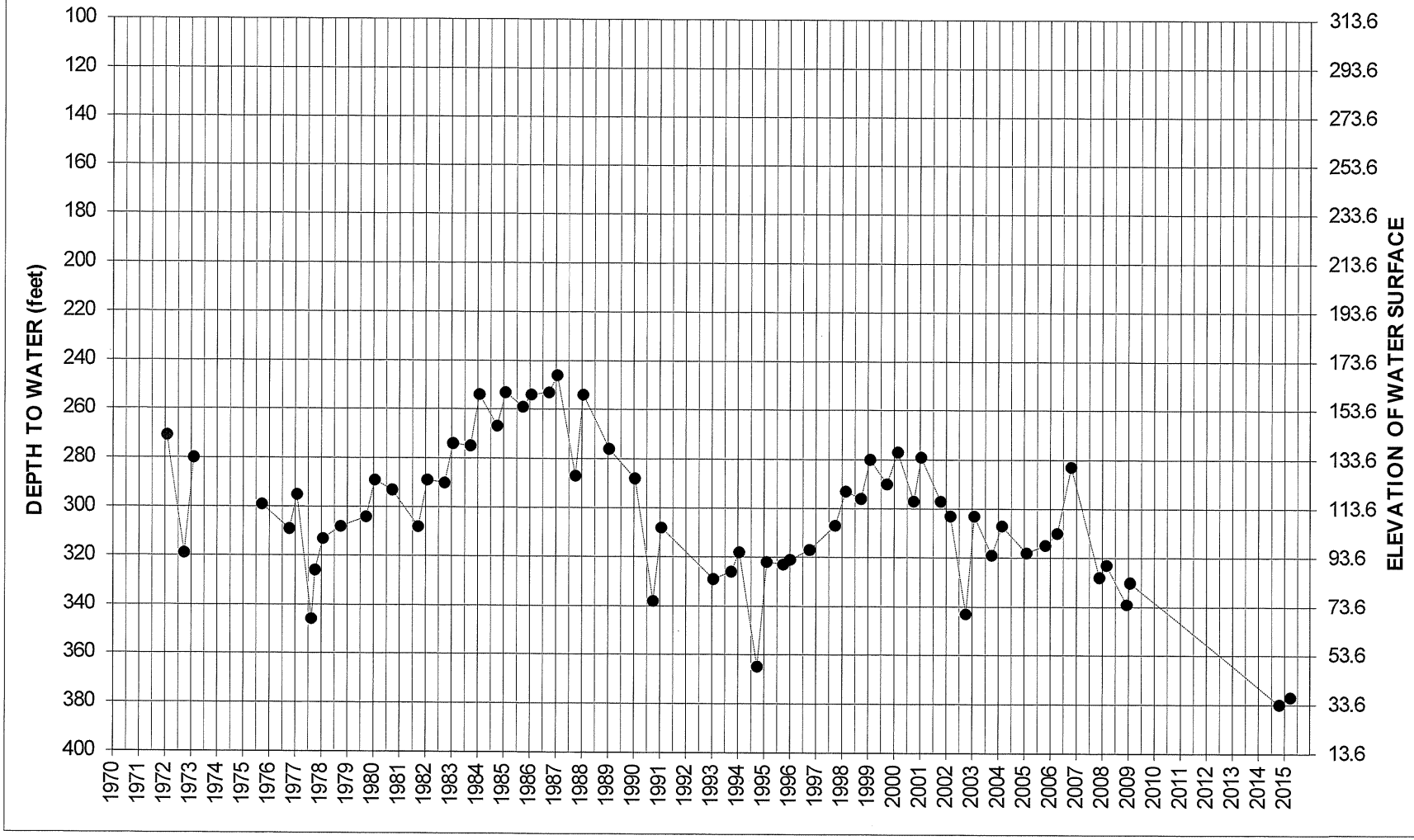
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-24C



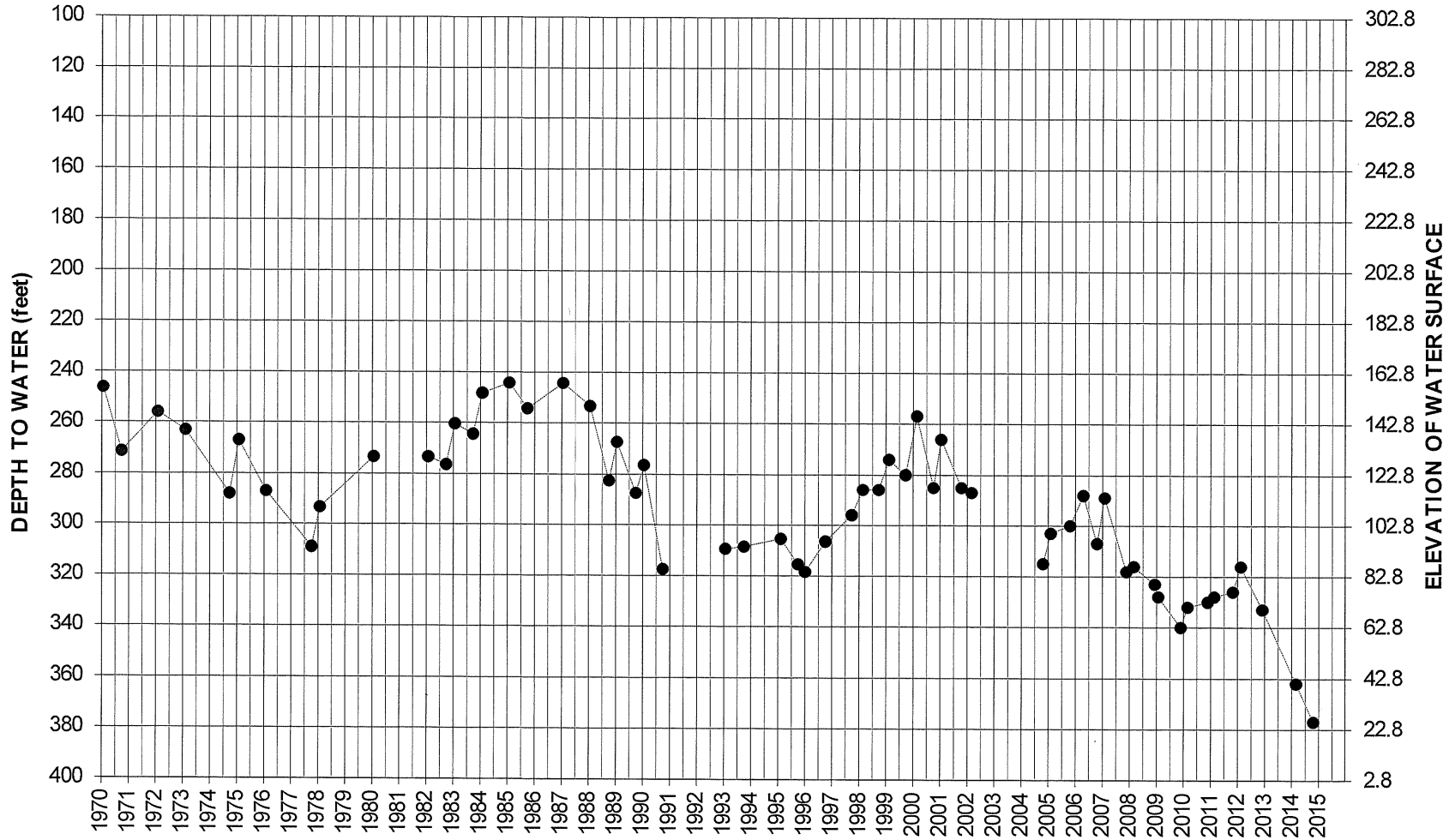
GEI Consultants
Boolman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-25J



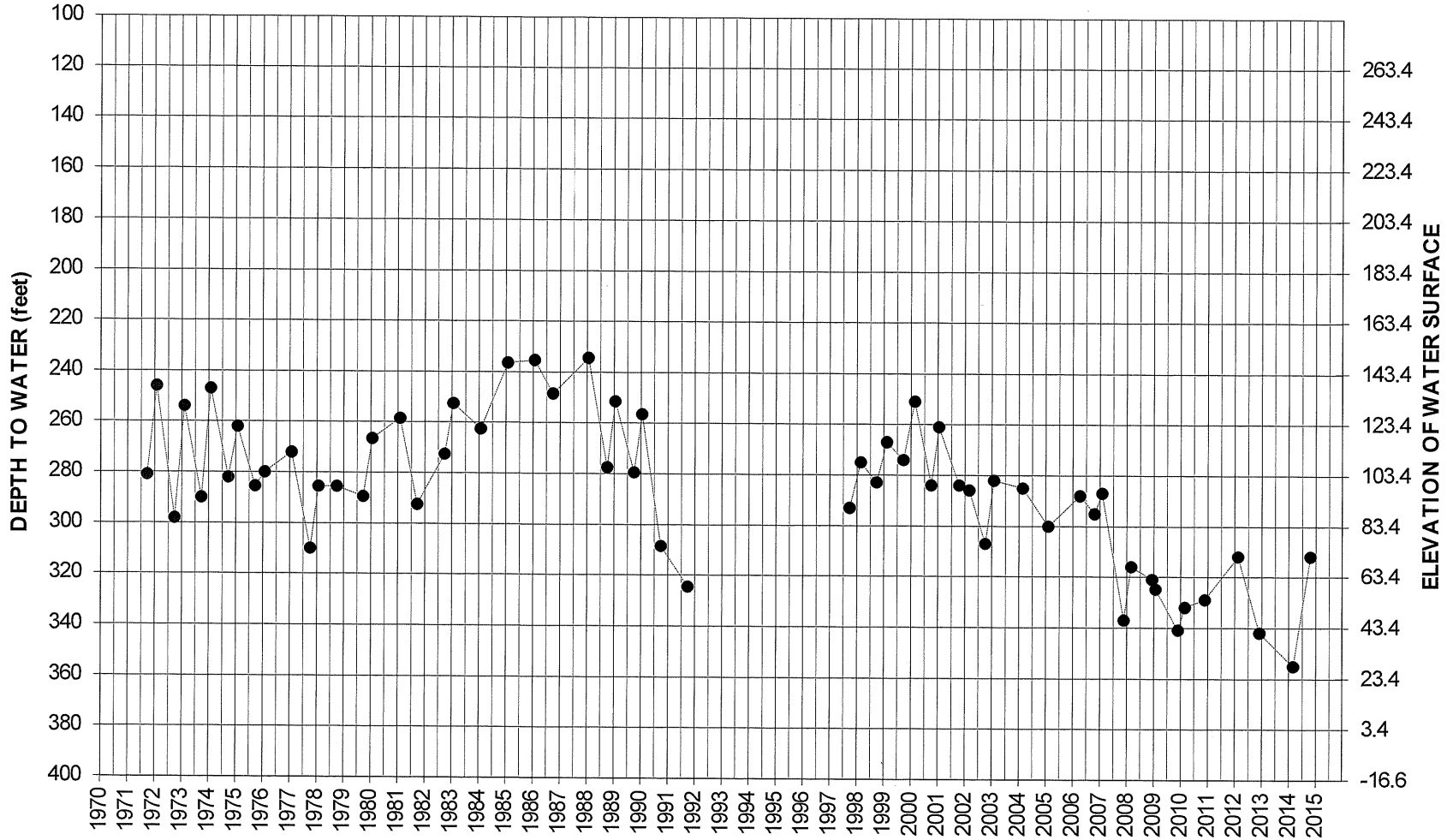
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-26K



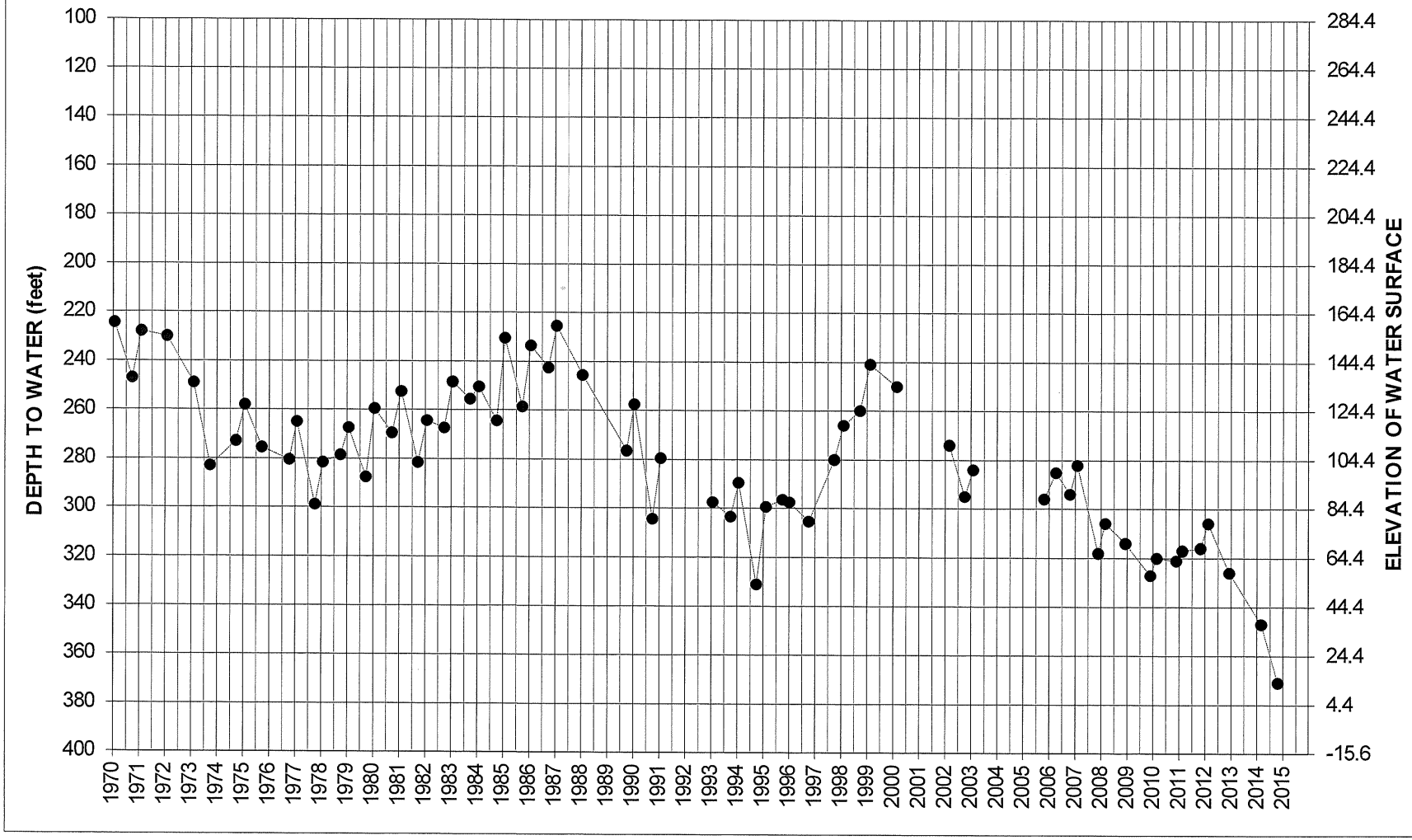
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-27C



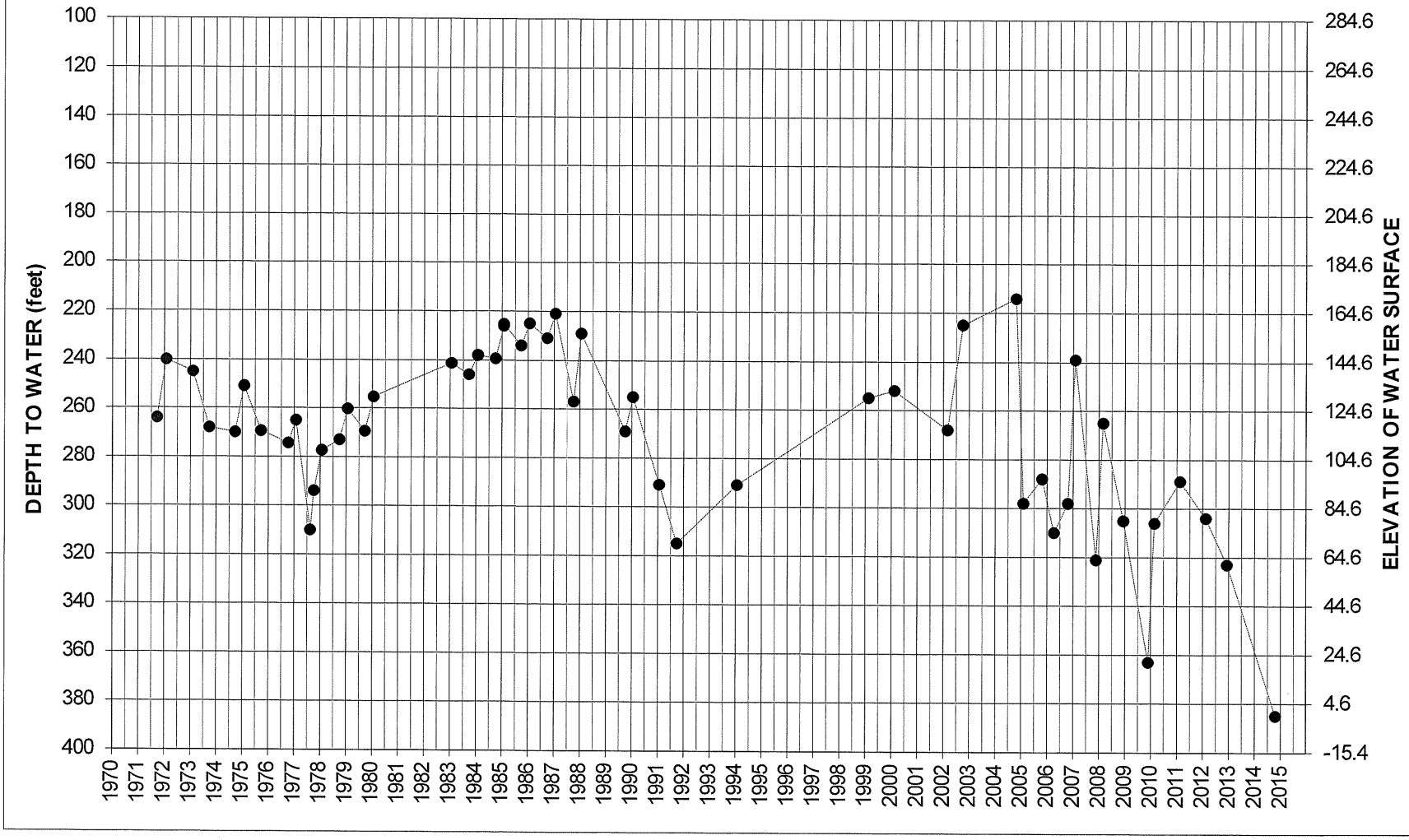
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-34A



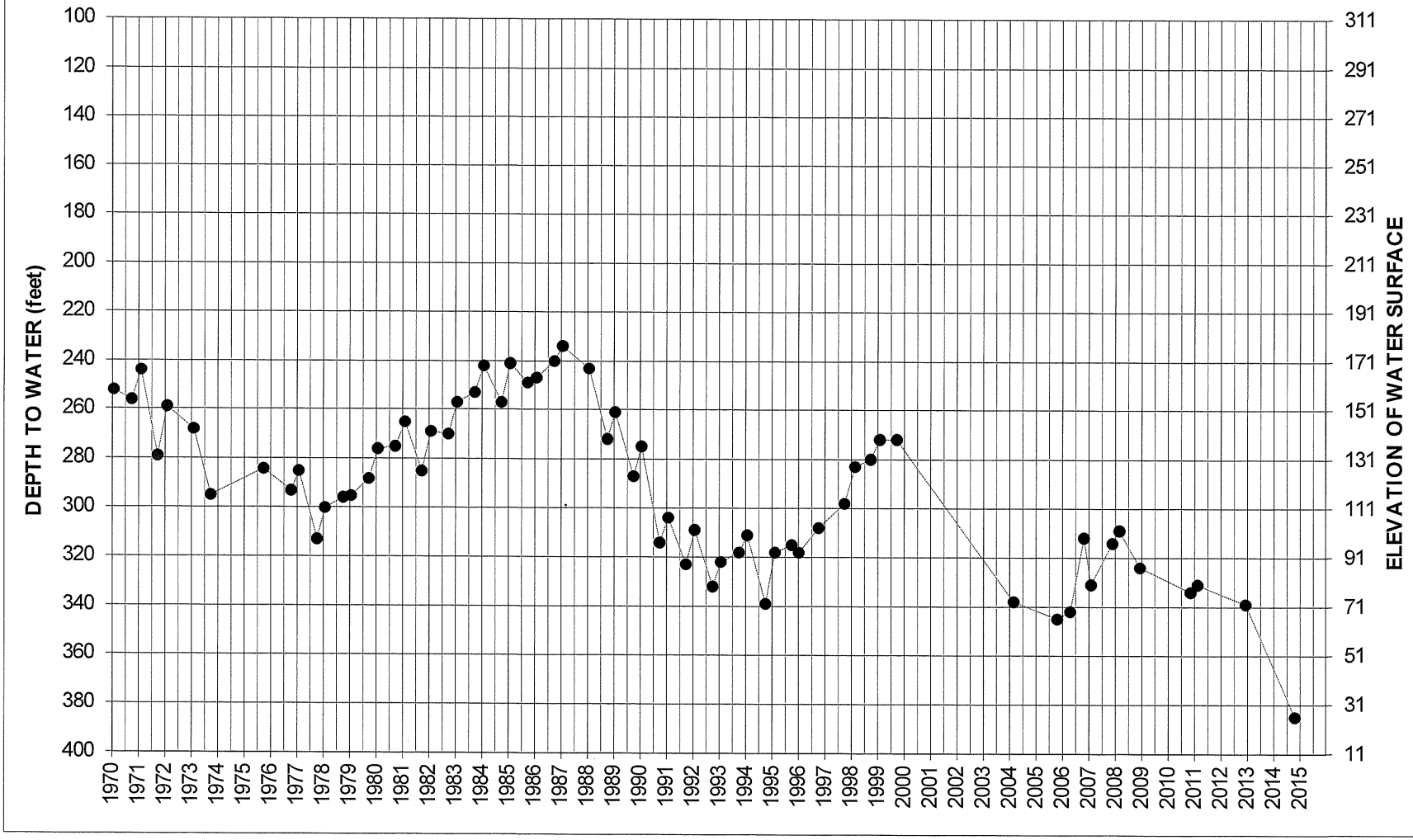
GEI Consultants
Boellman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-35L



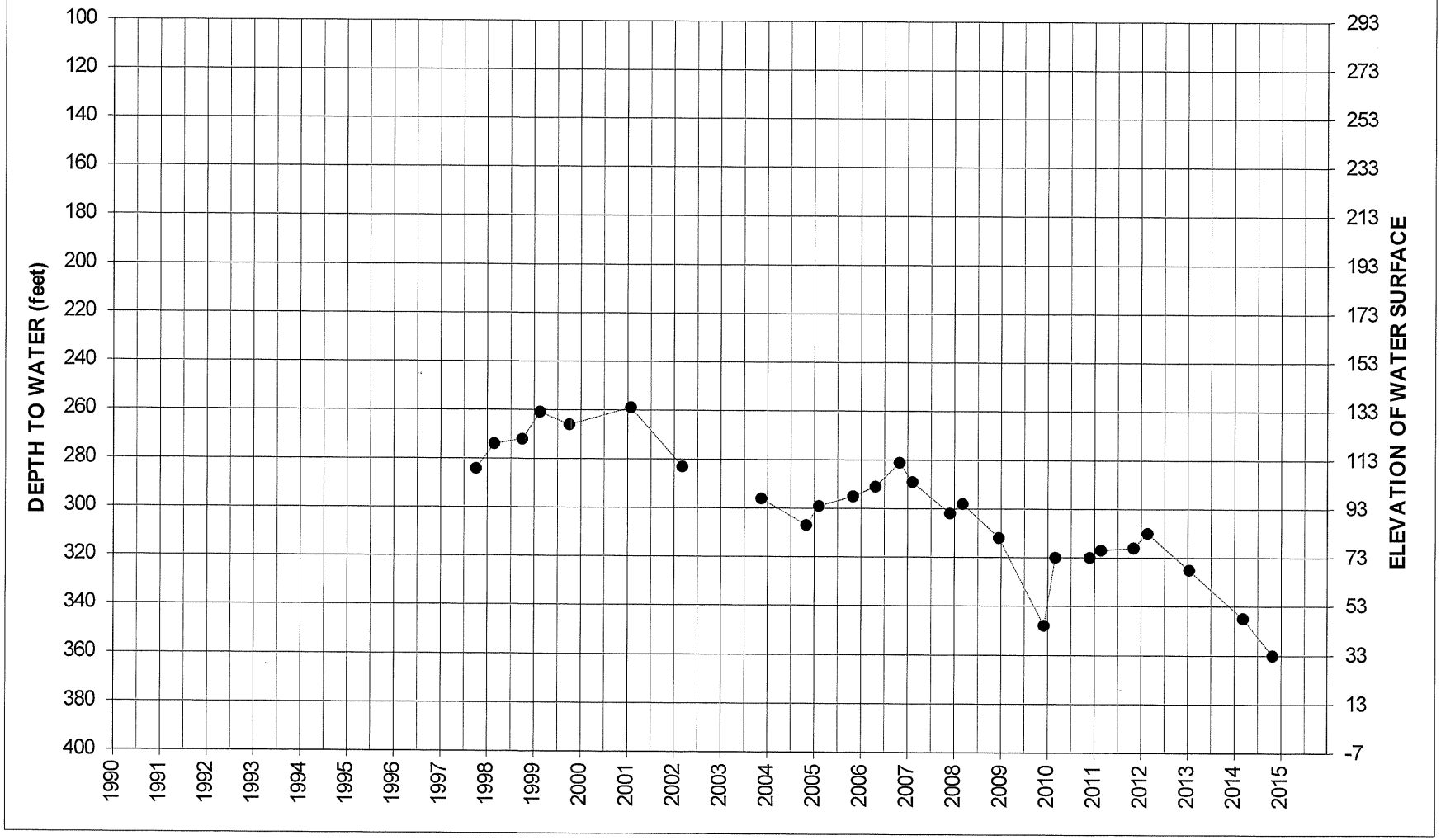
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-36J



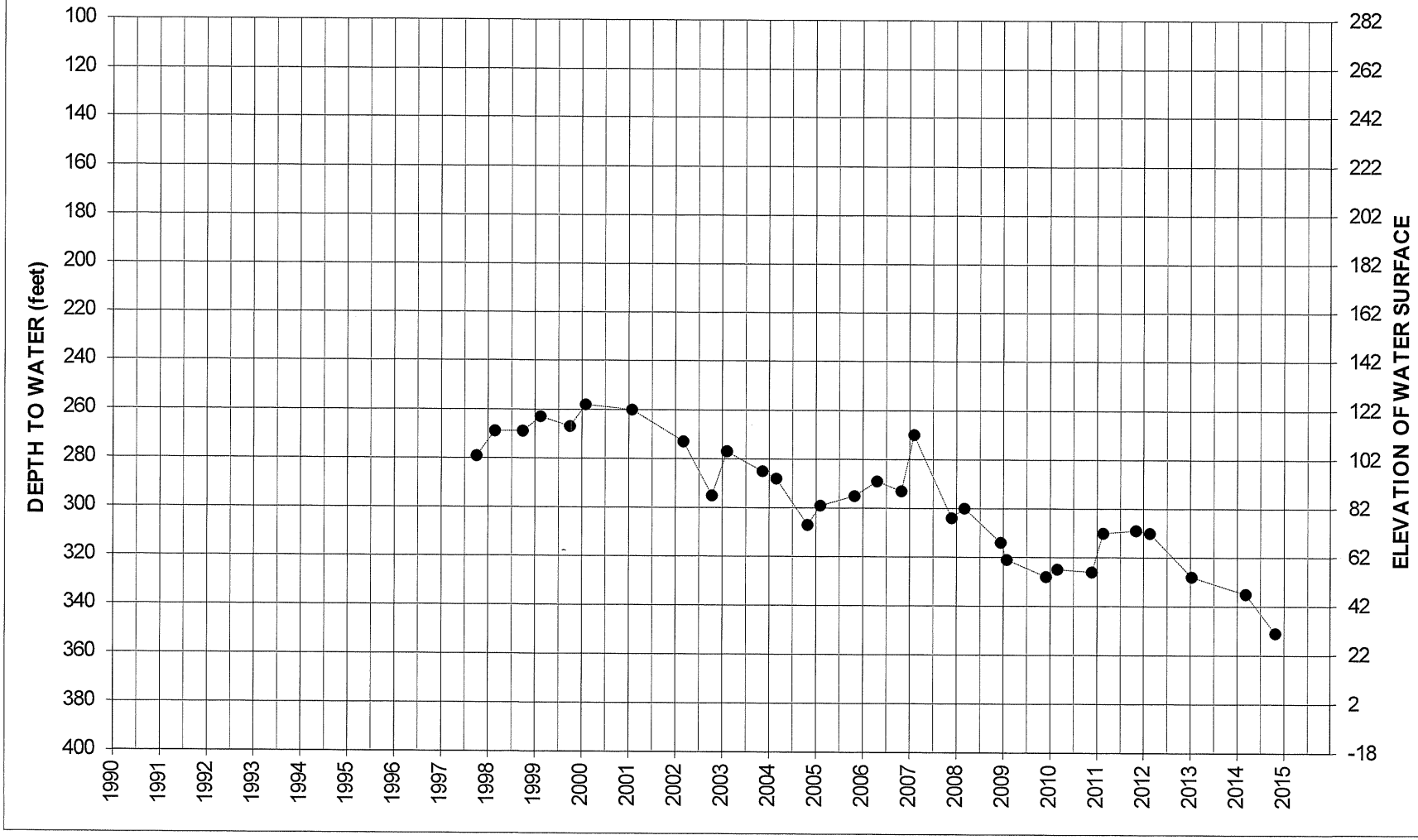
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/25-01C



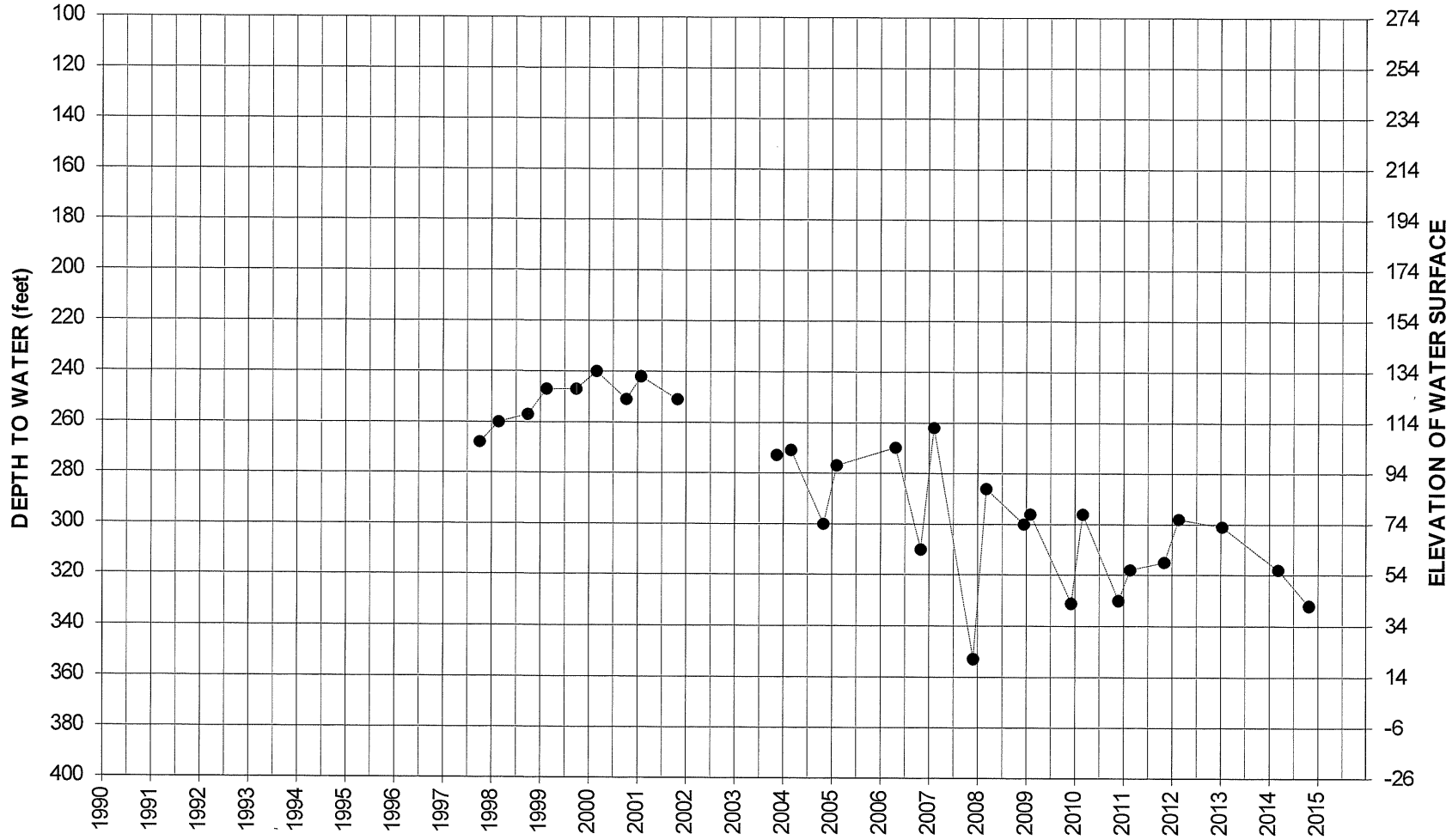
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/25-02A



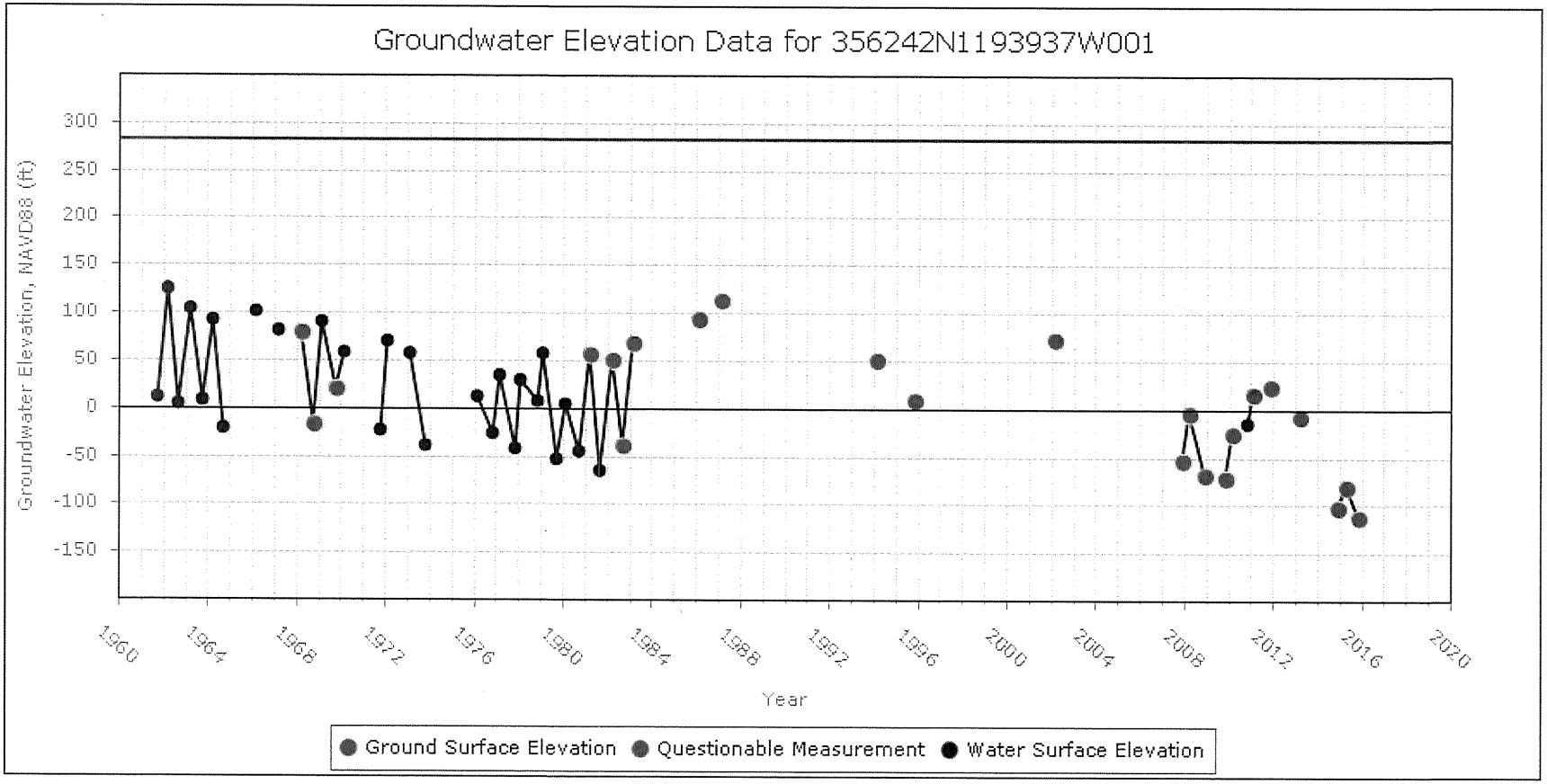
GEI Consultants
Boolman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/25-12Q

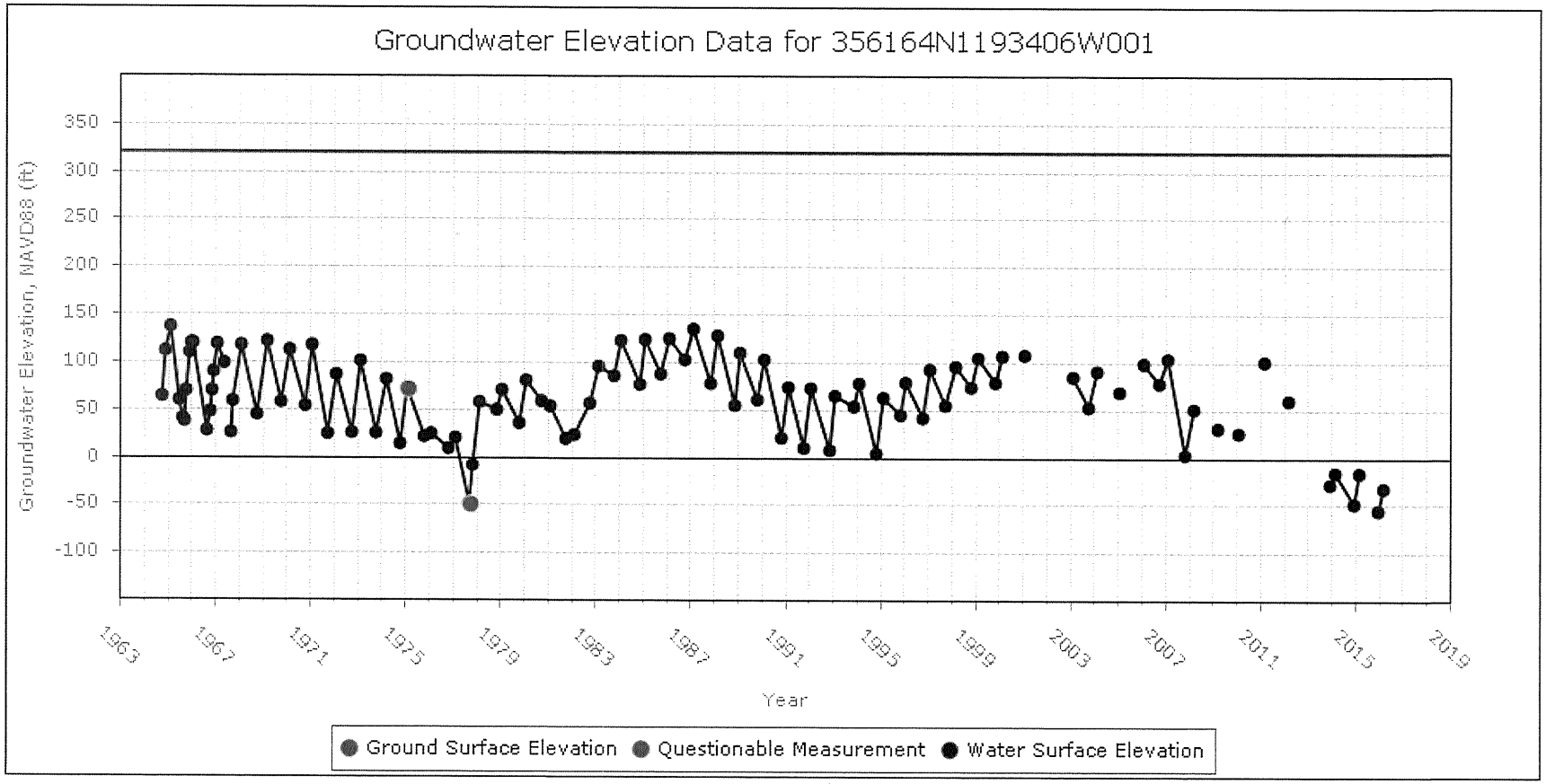


GEI Consultants
Bookman-Edmonston Division

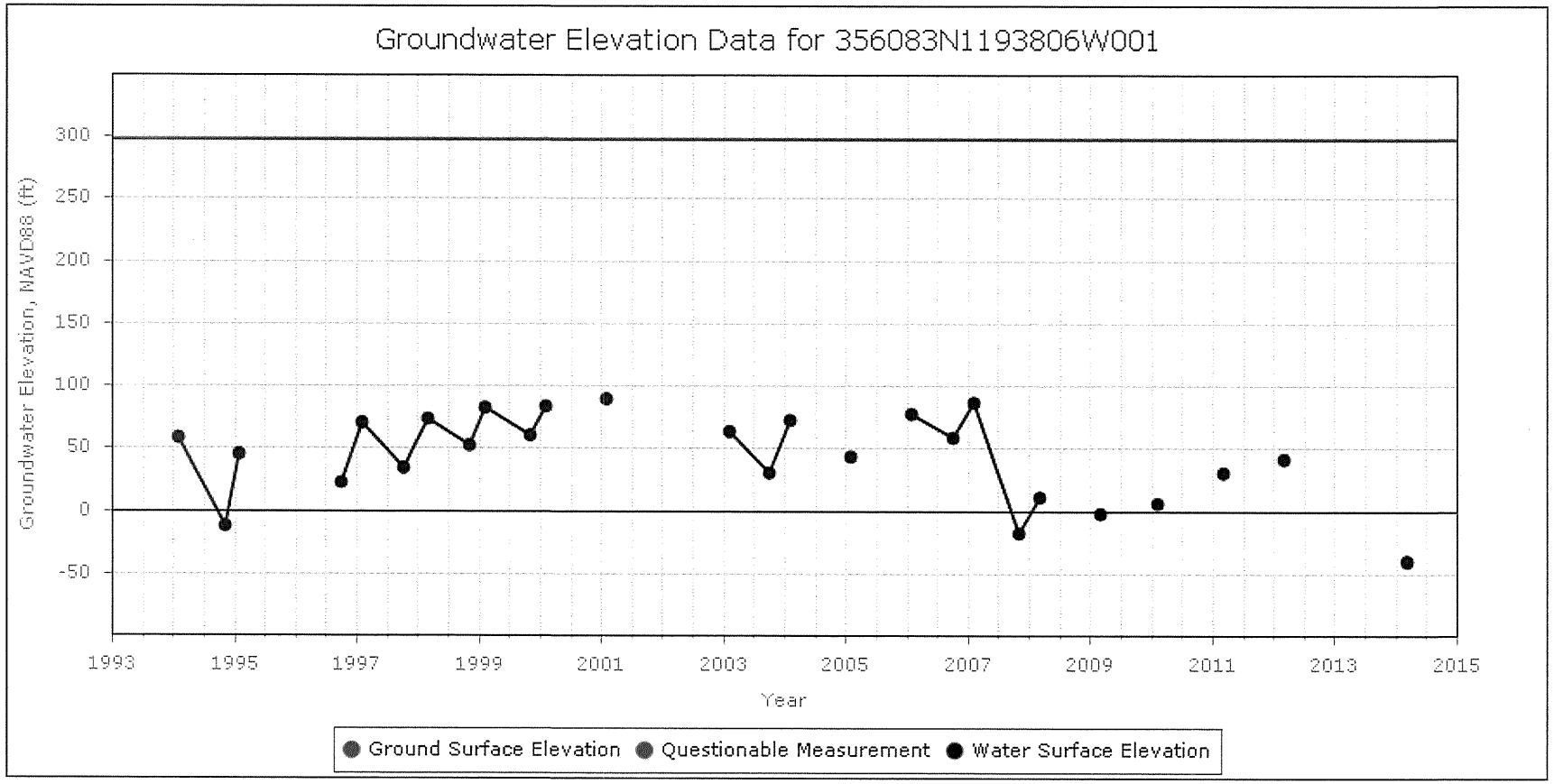
SHAFTER-WASCO IRRIGATION DISTRICT



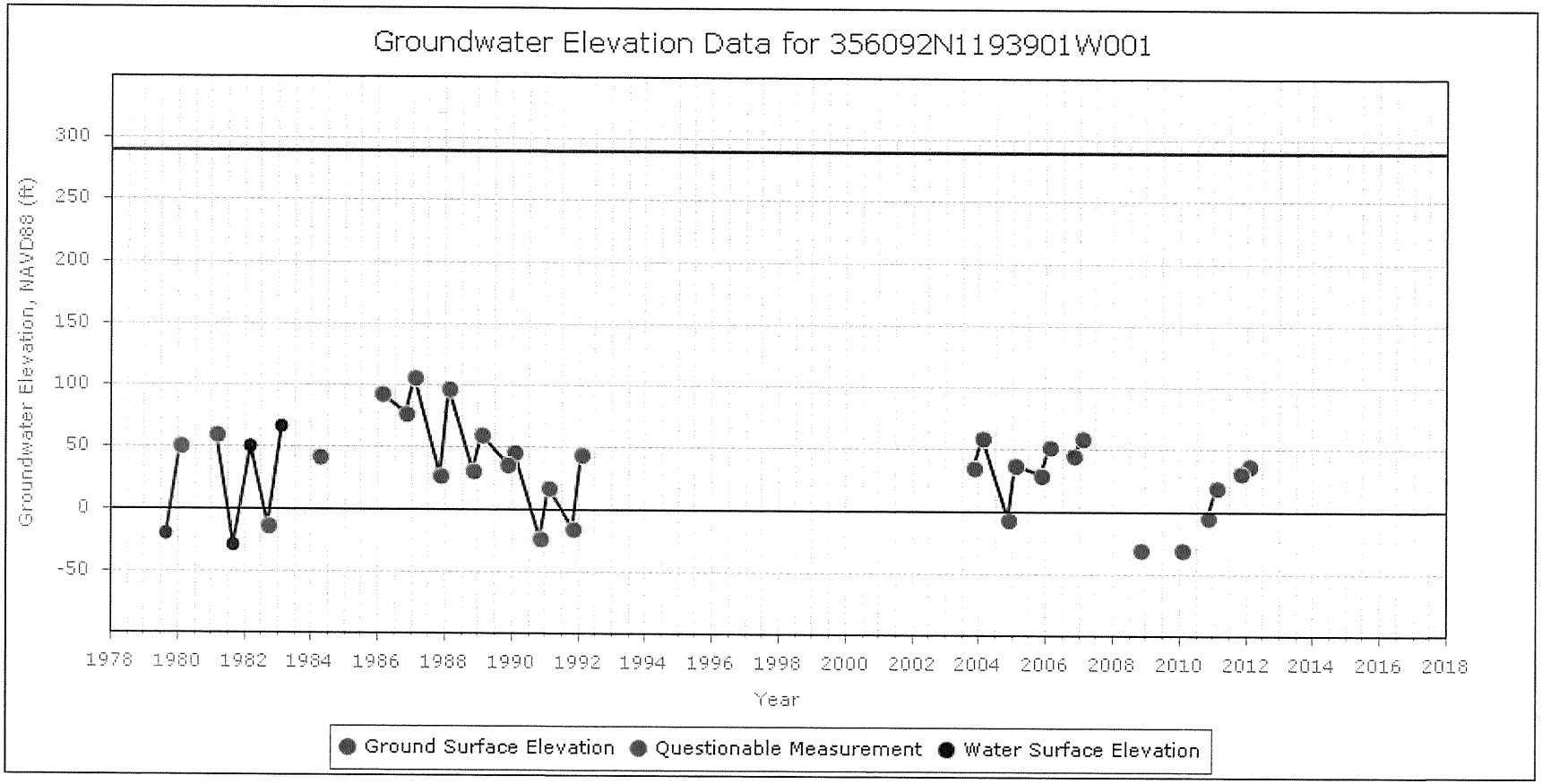
WATER-LEVEL HYDROGRAPH FOR WELL T26S/R24E-33F1



WATER-LEVEL HYDROGRAPH FOR WELL T26S/R24E-36P2

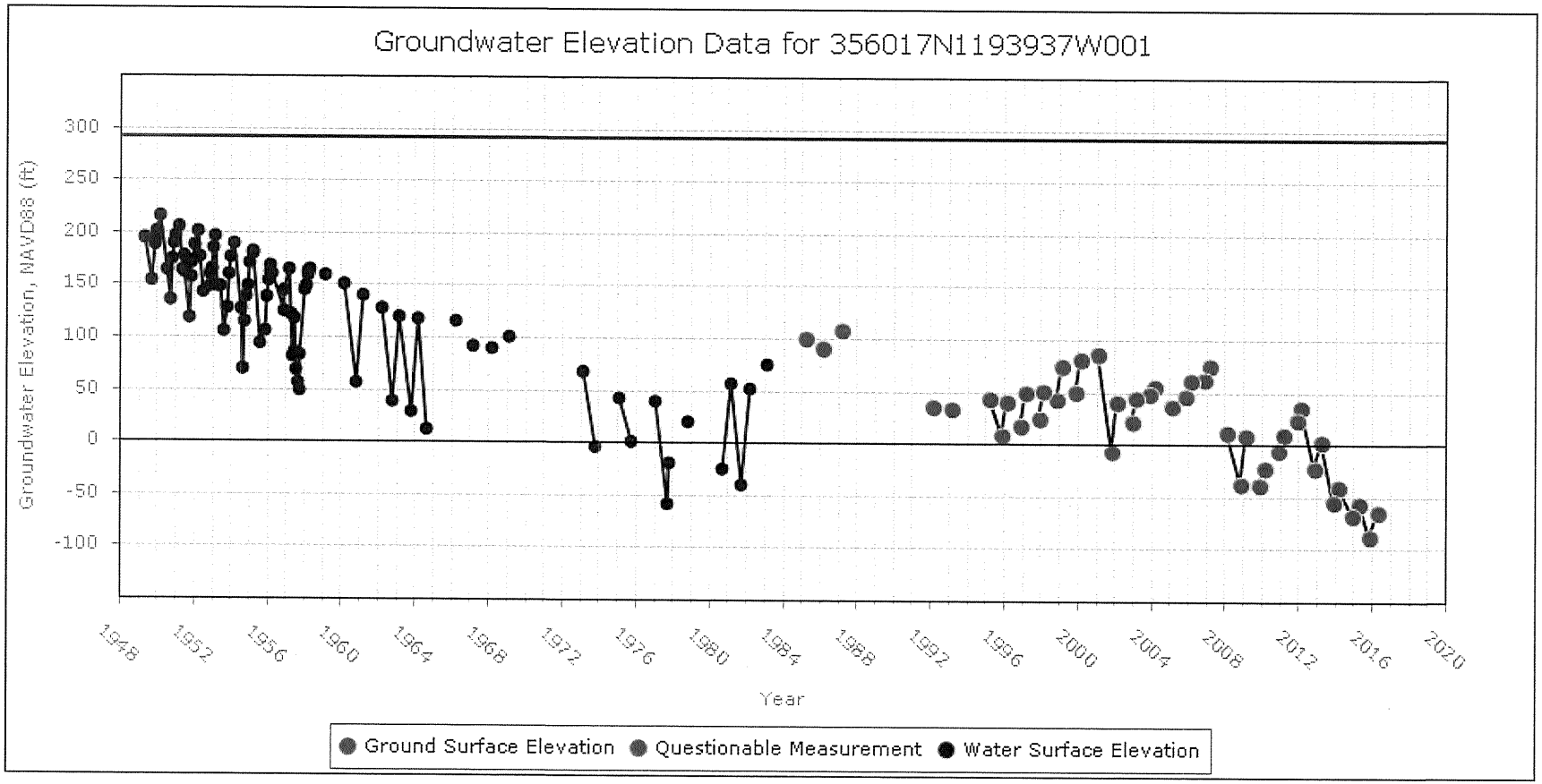


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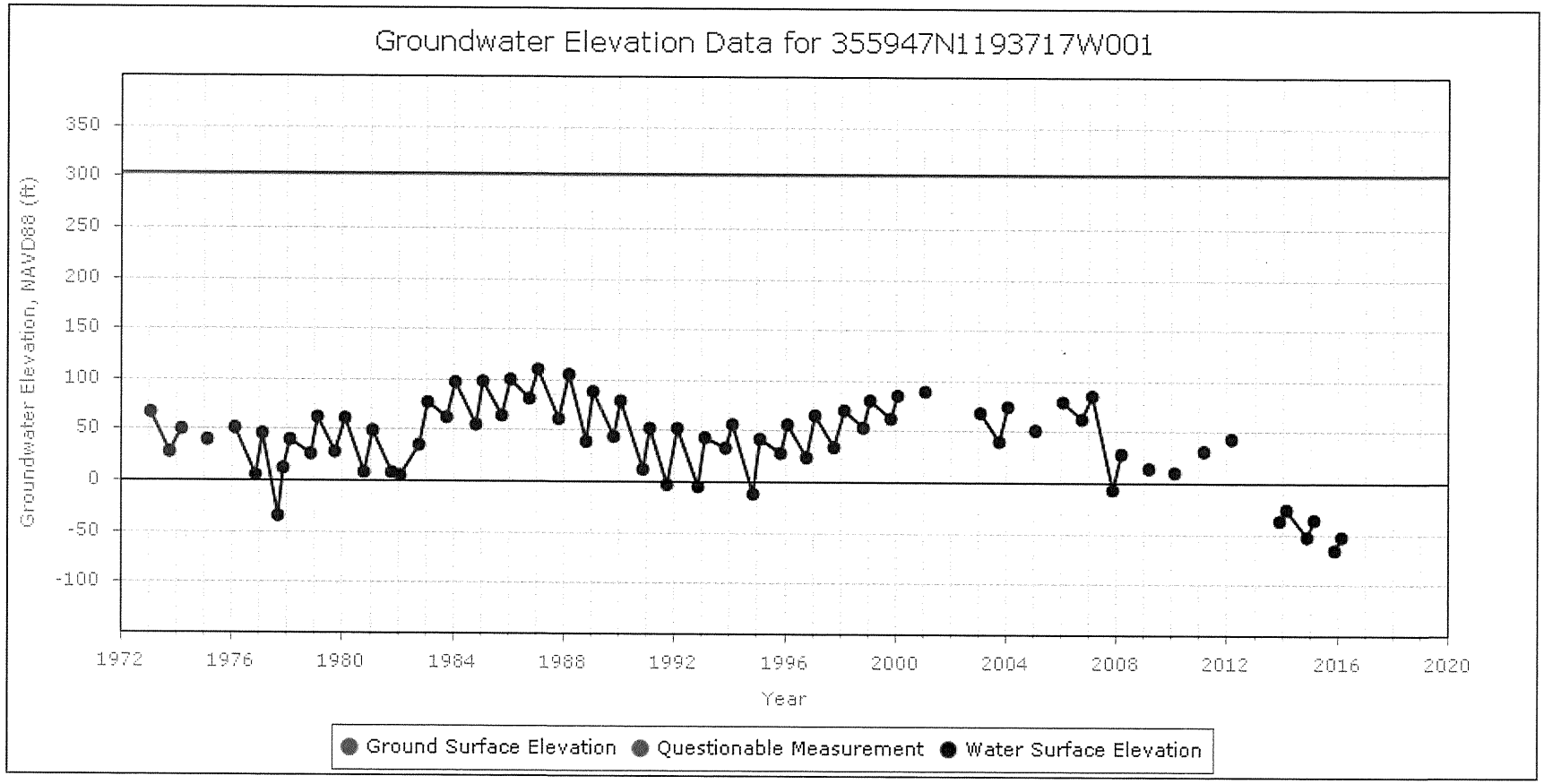


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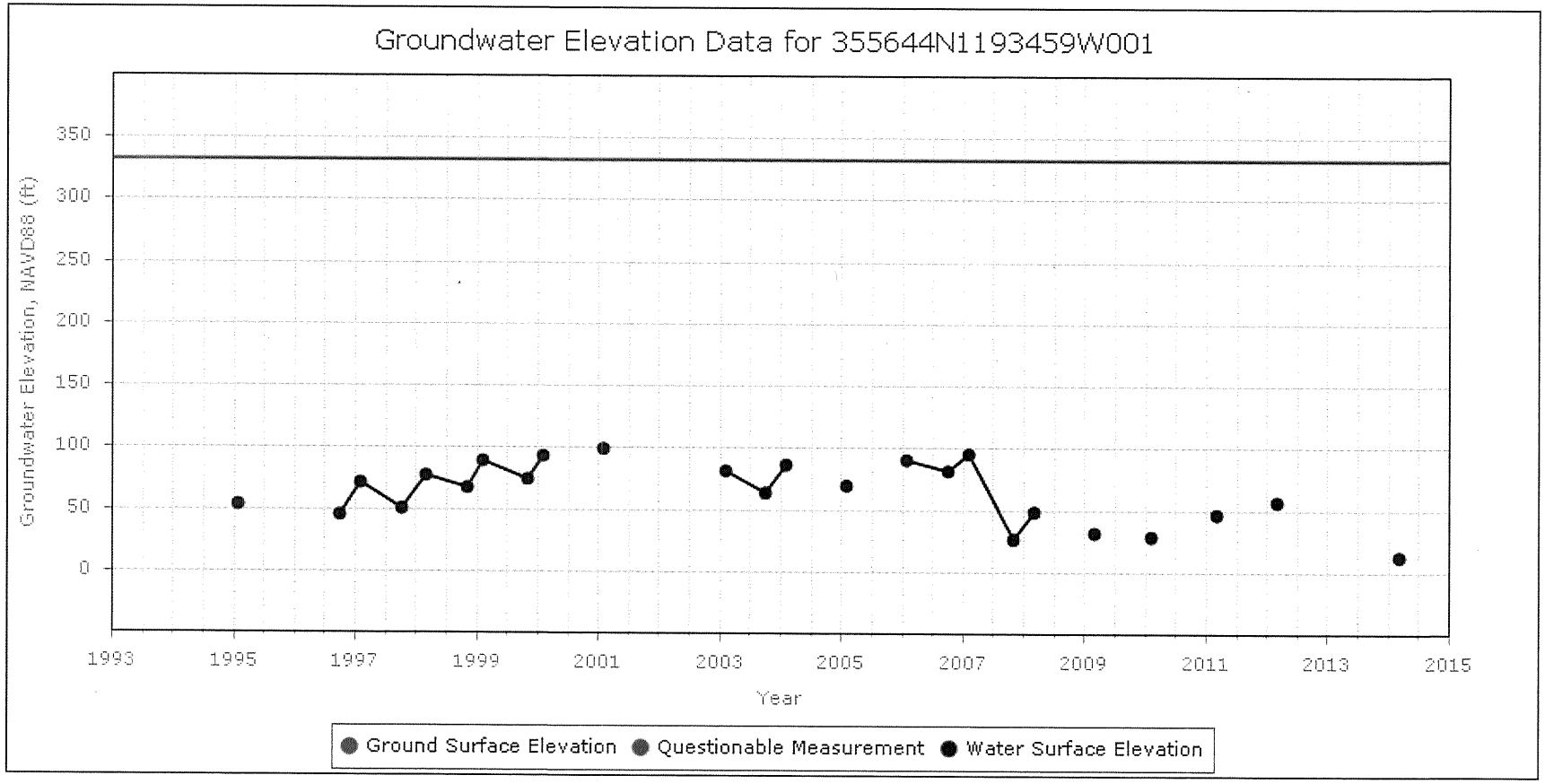
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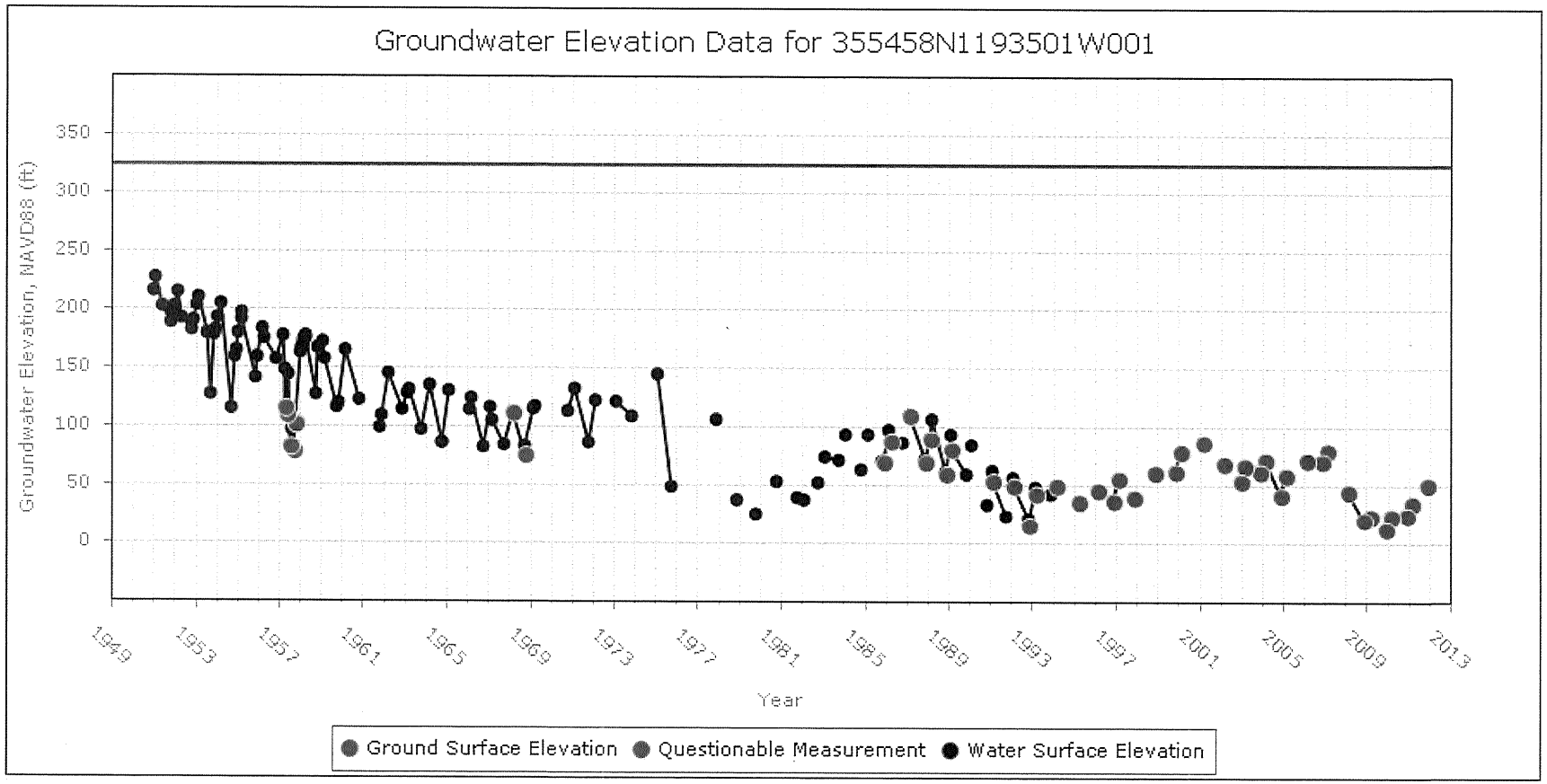
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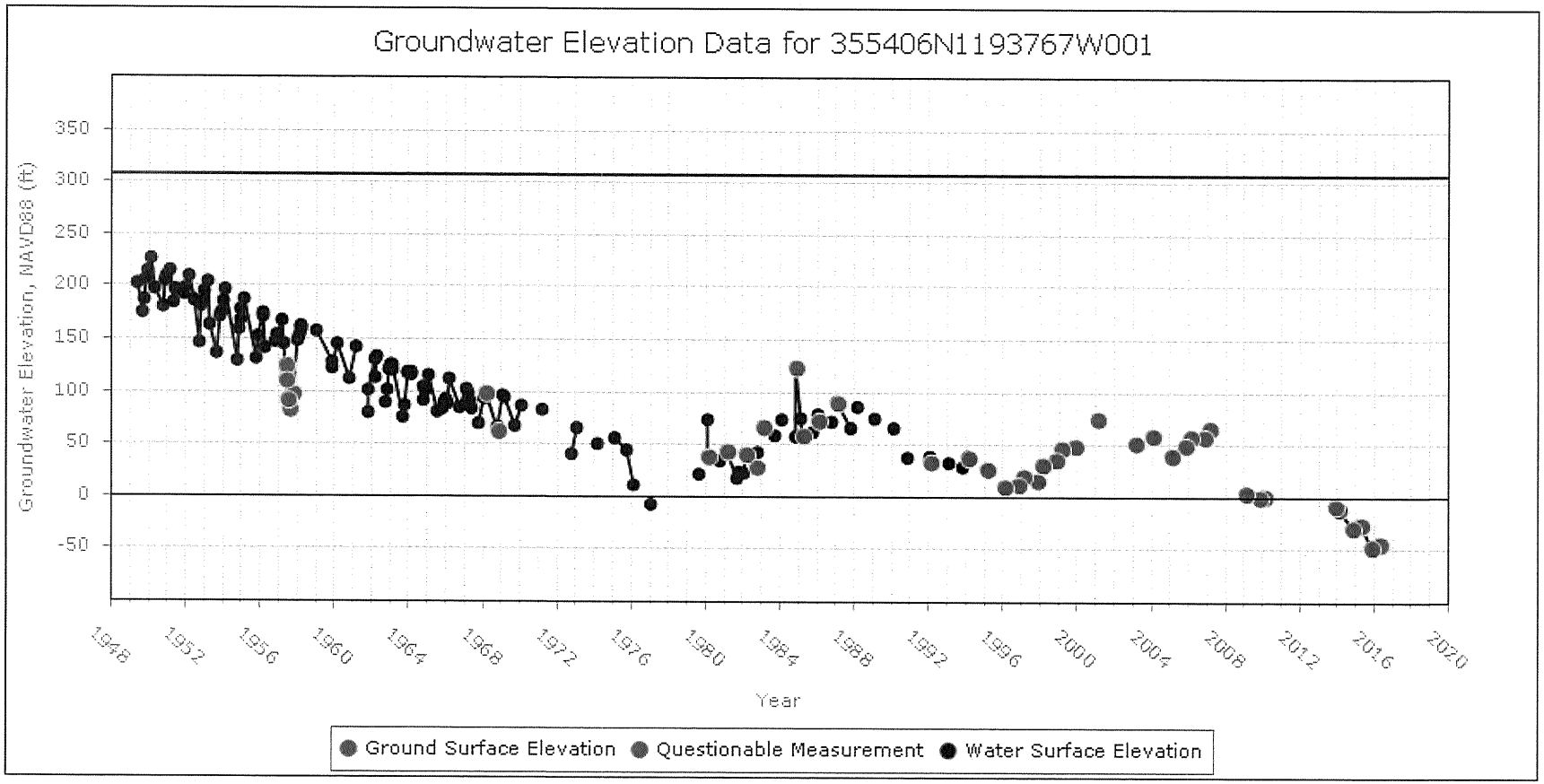
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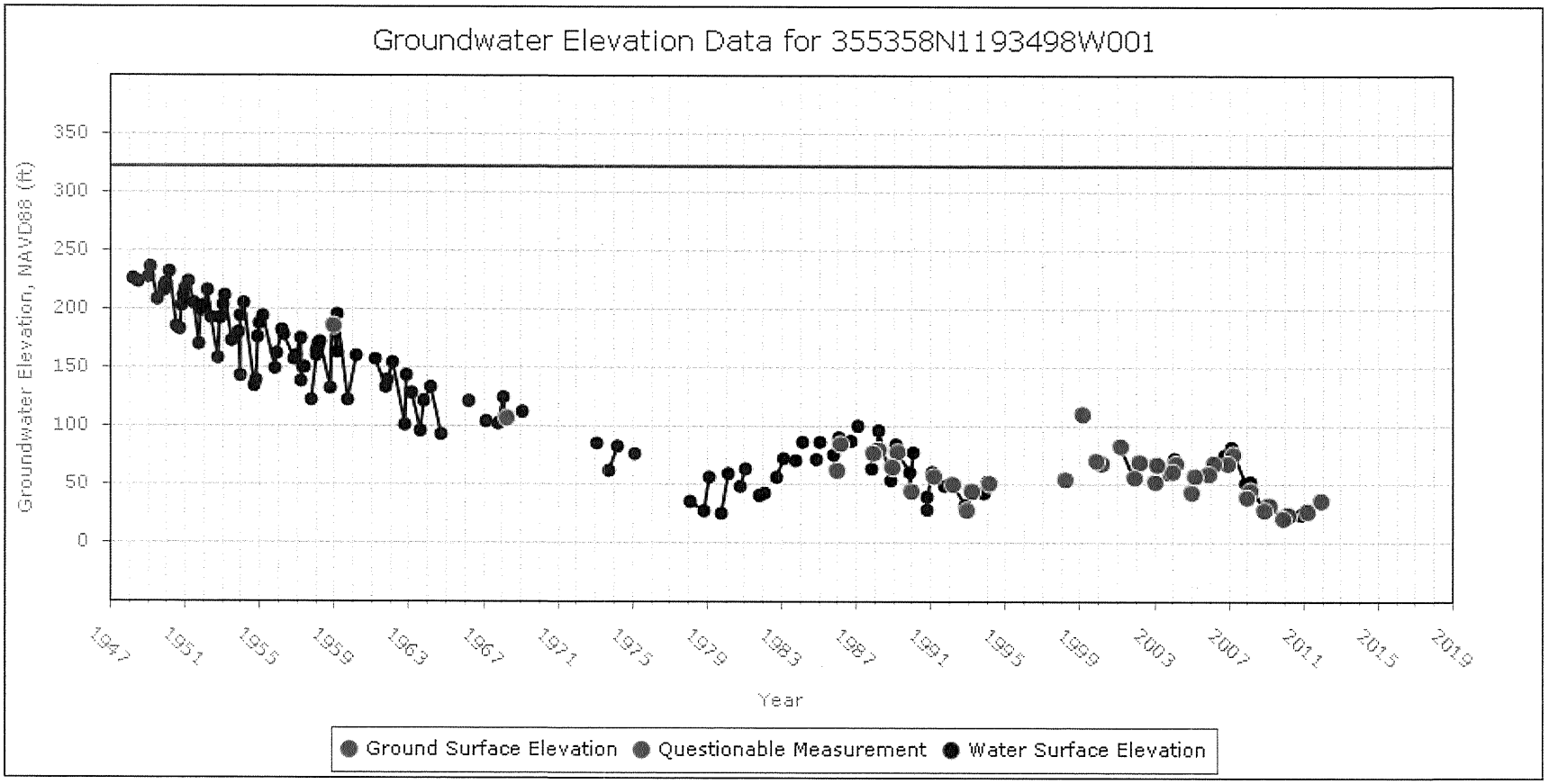
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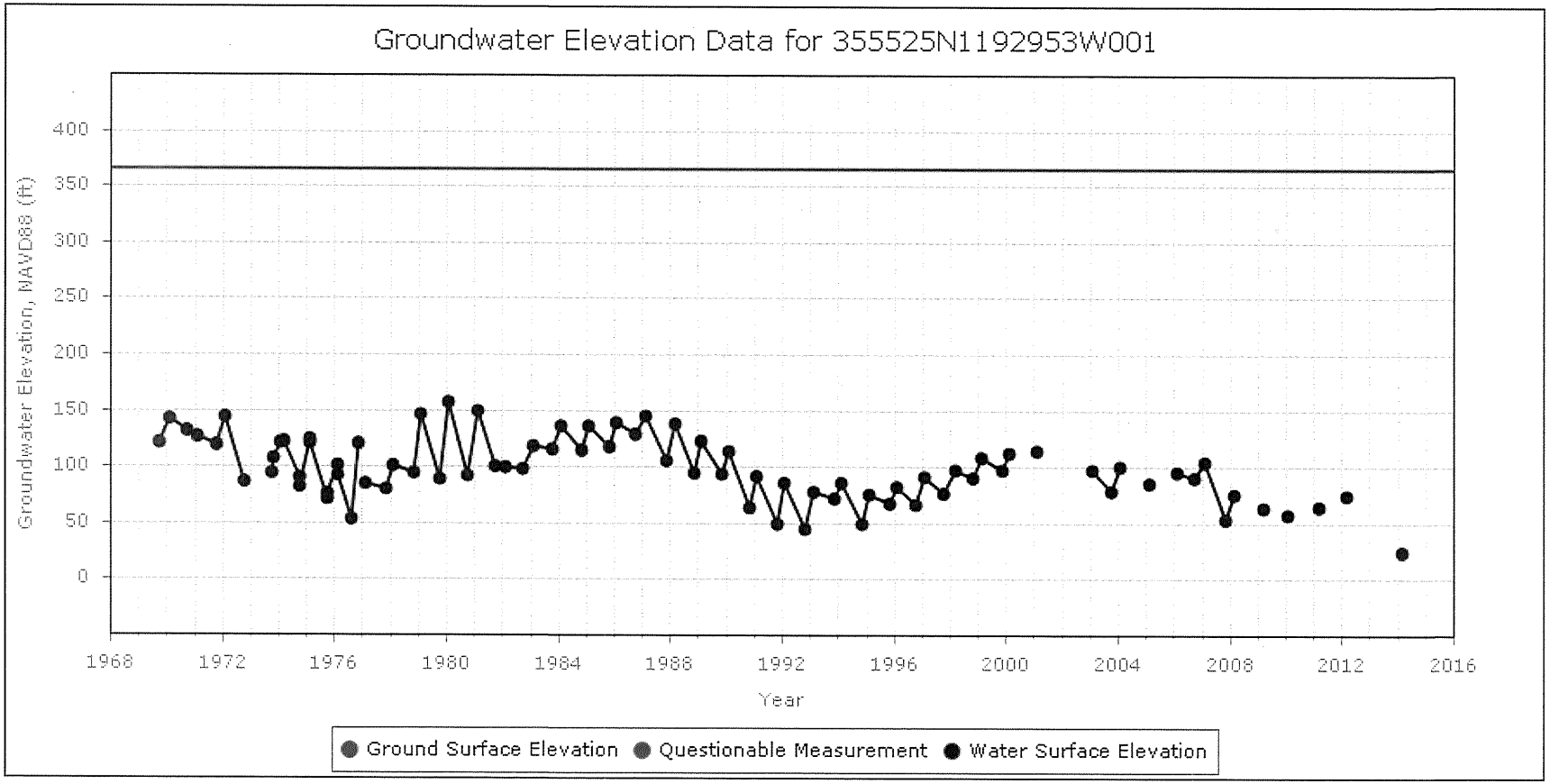
WATER-LEVEL HYDROGRAPH FOR WELL T27S/R24E-26R2



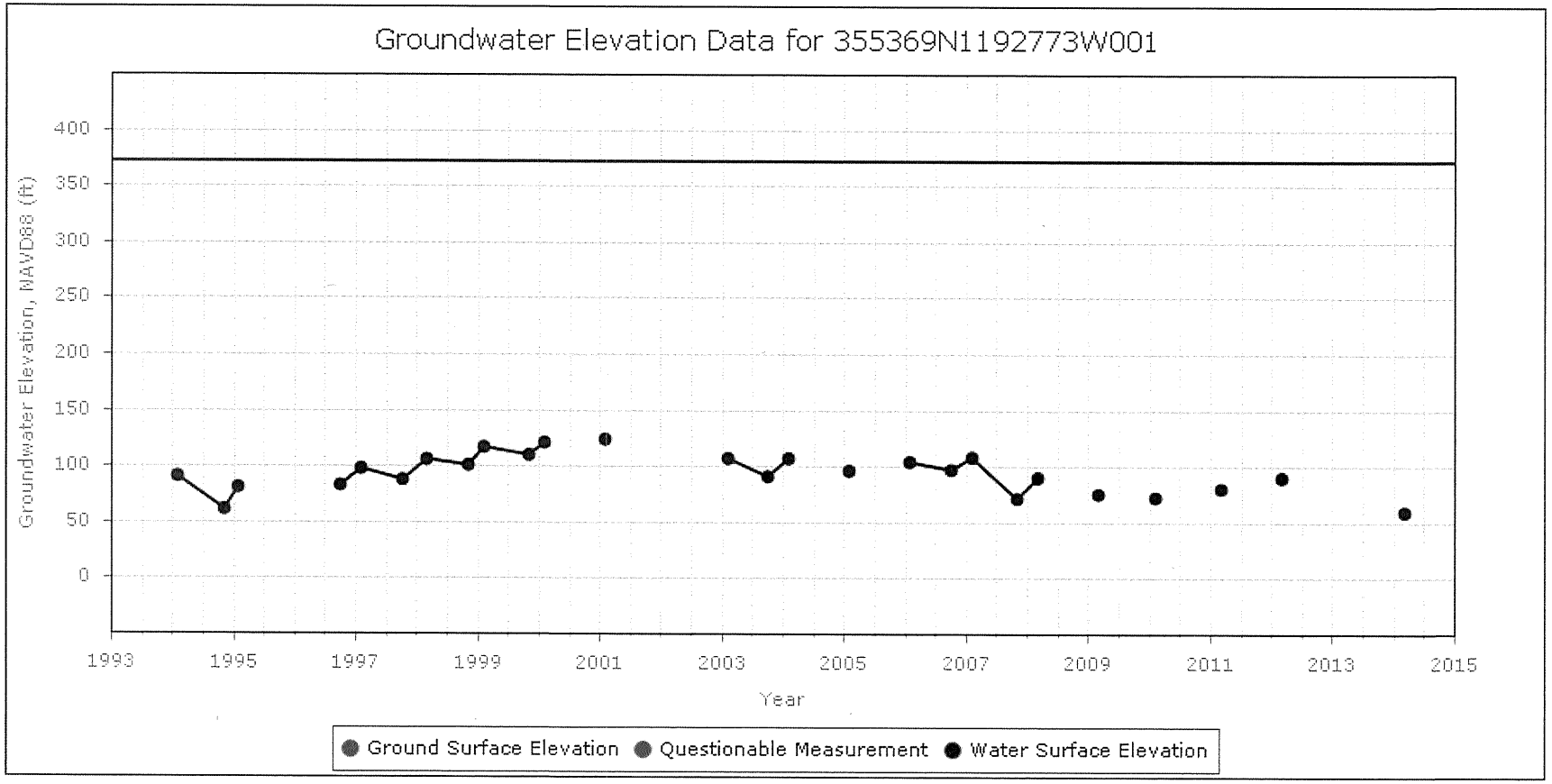
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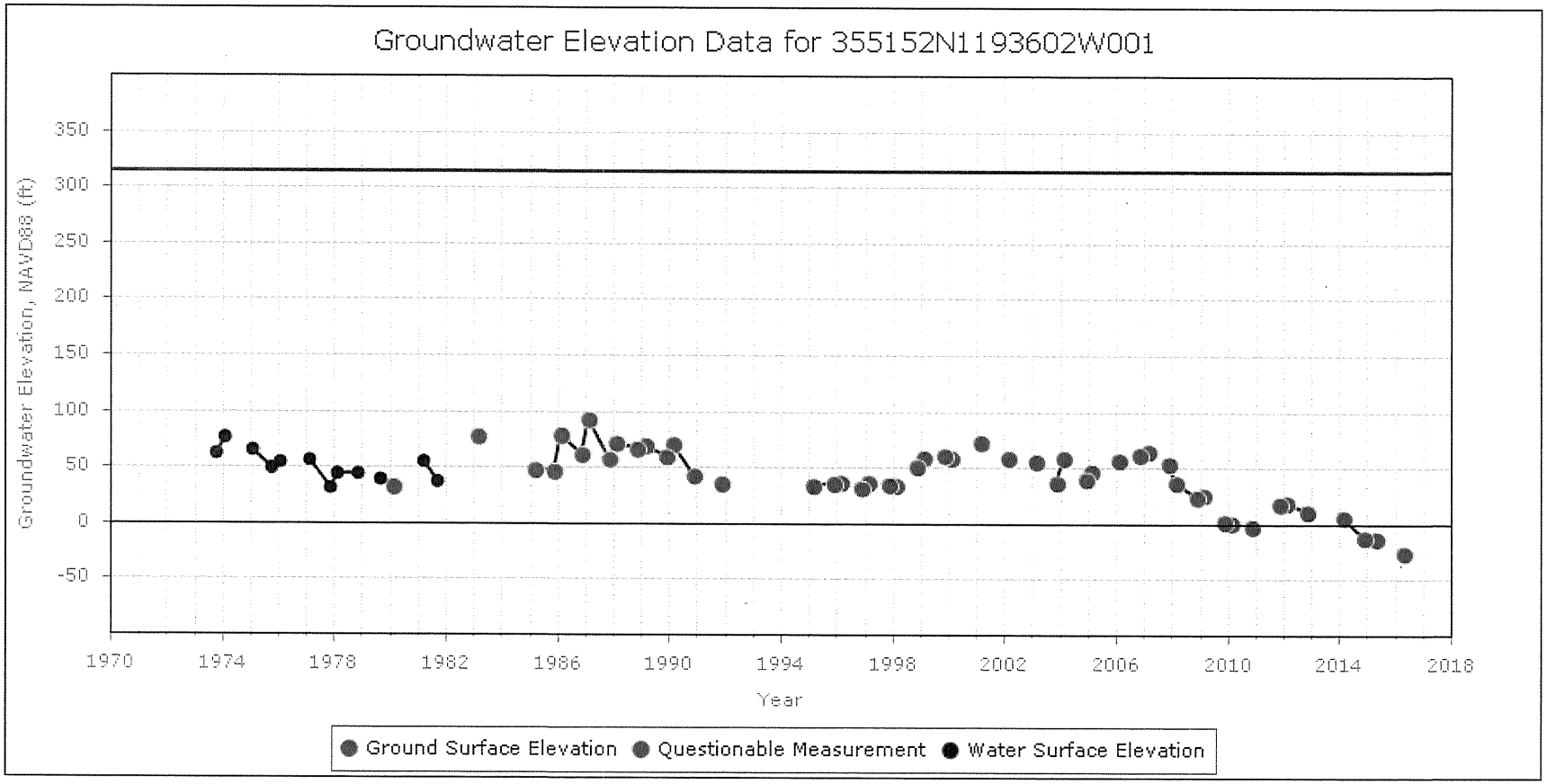
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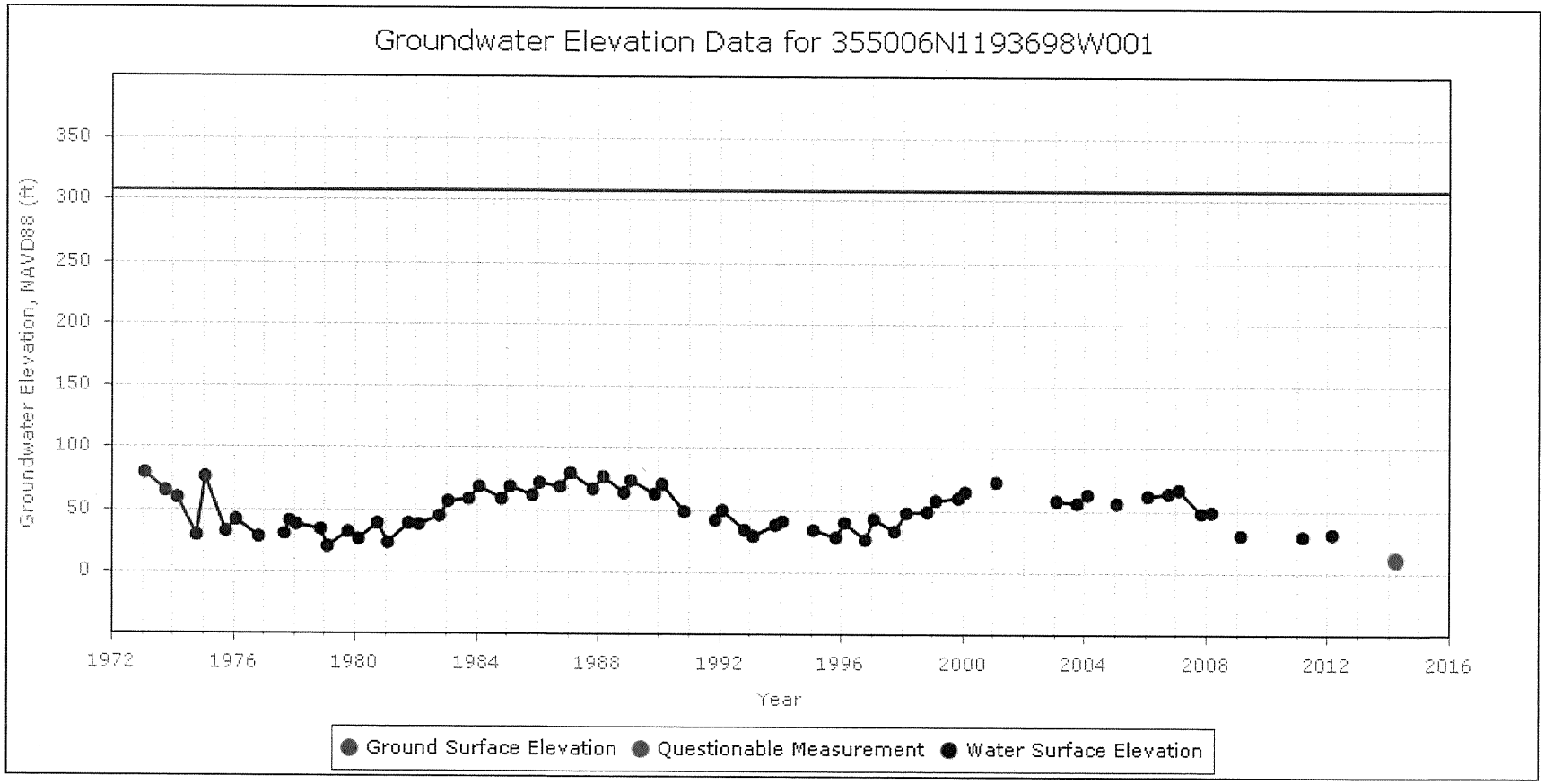
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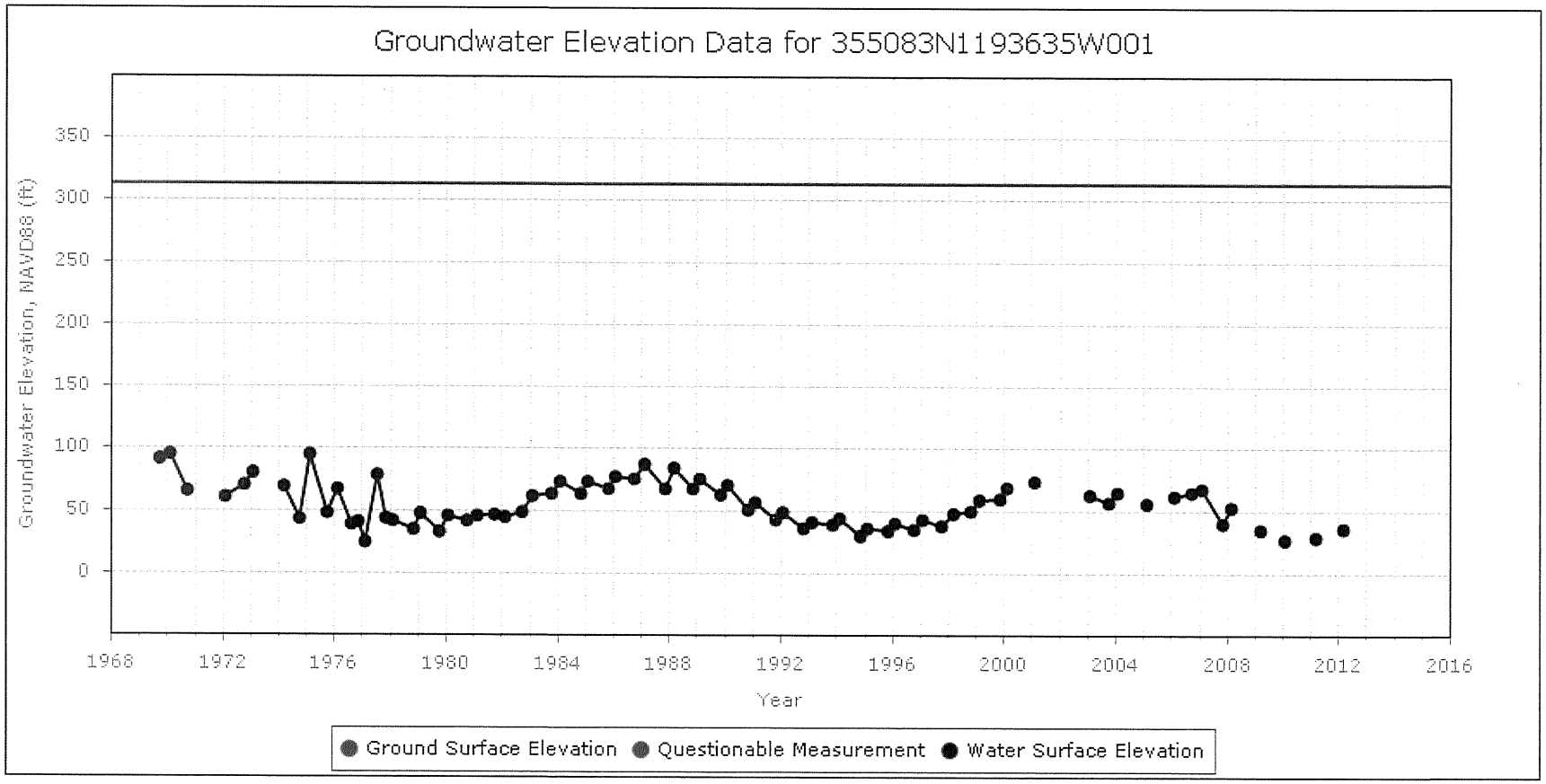
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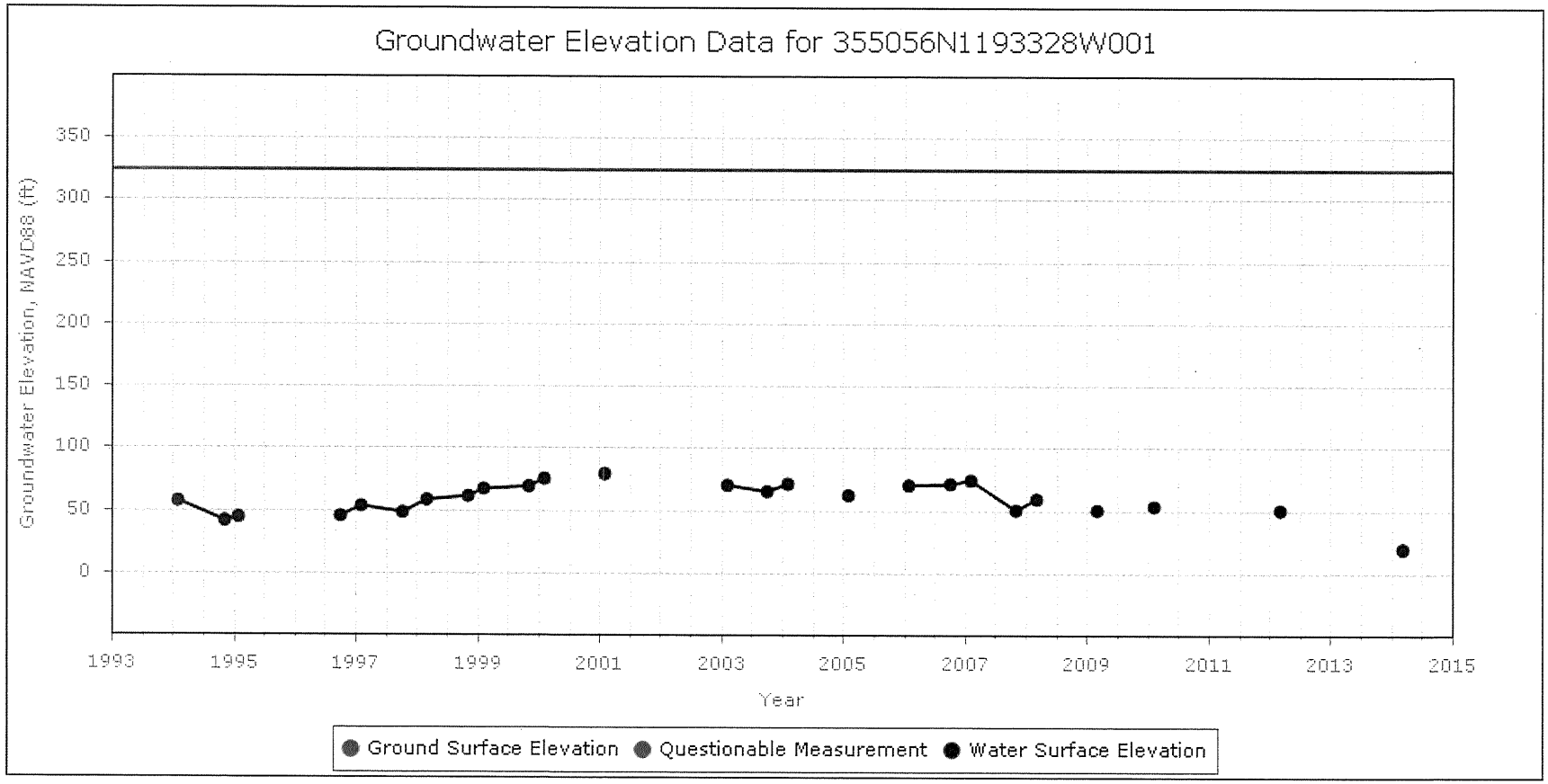
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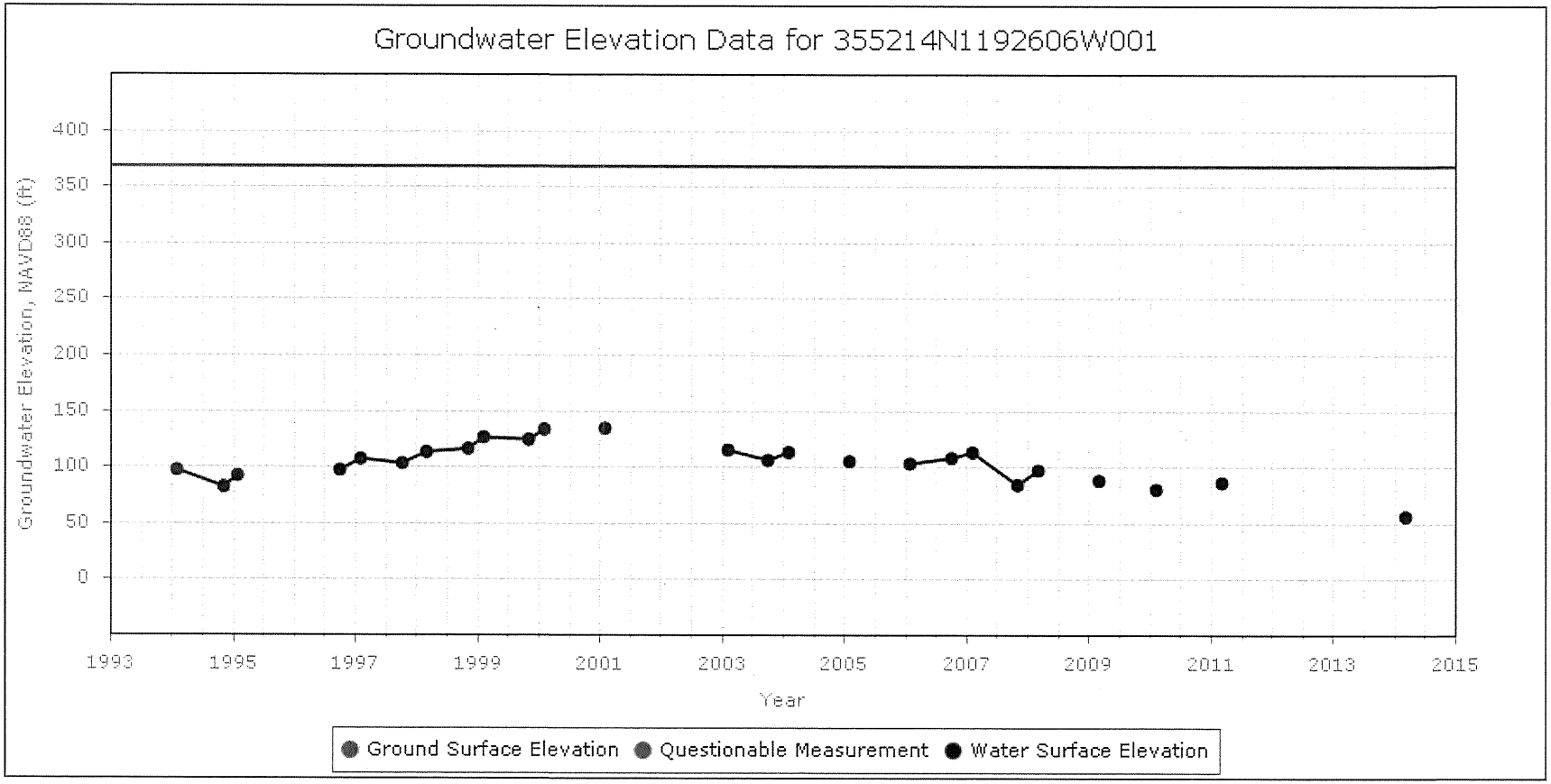
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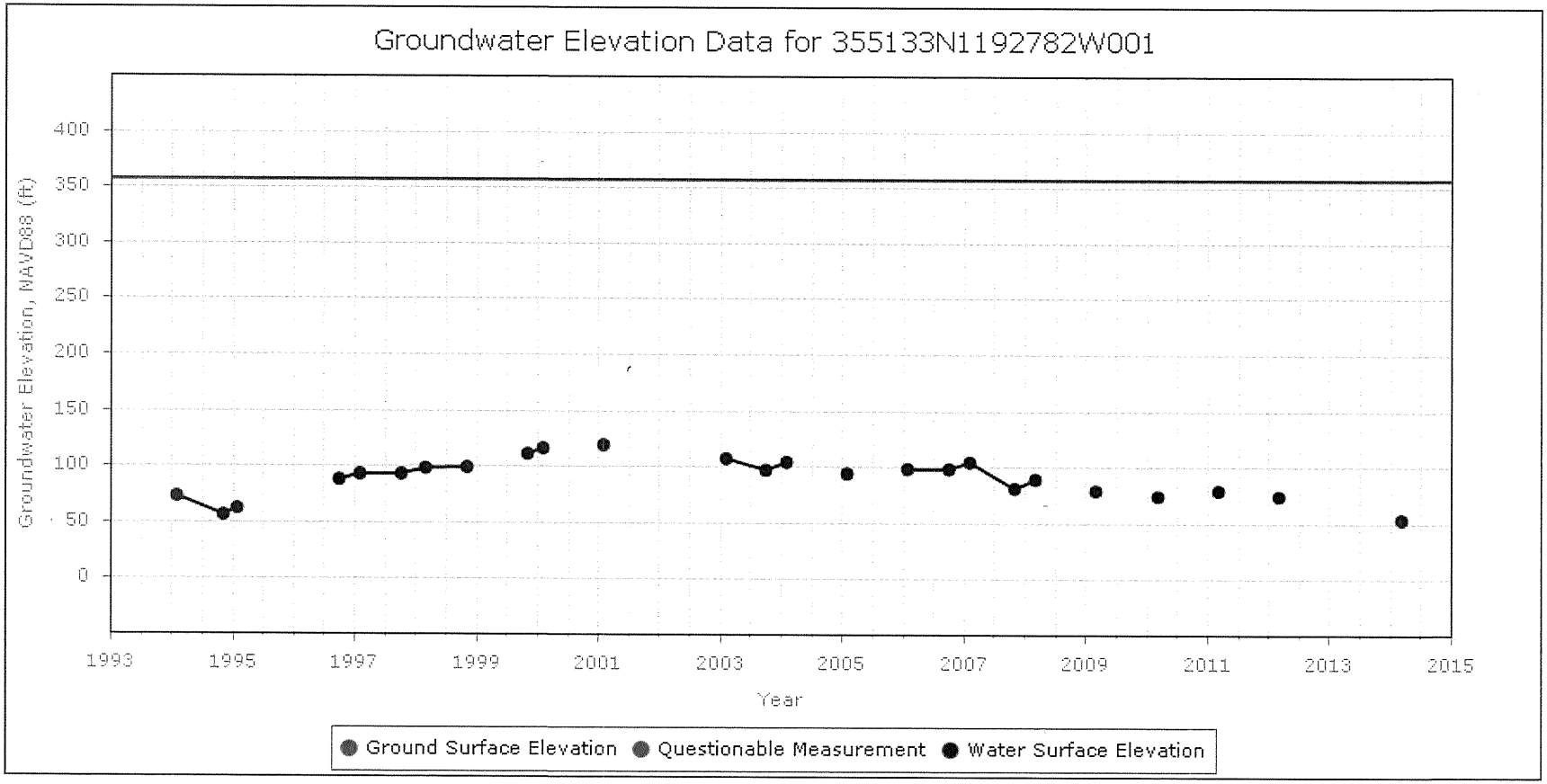
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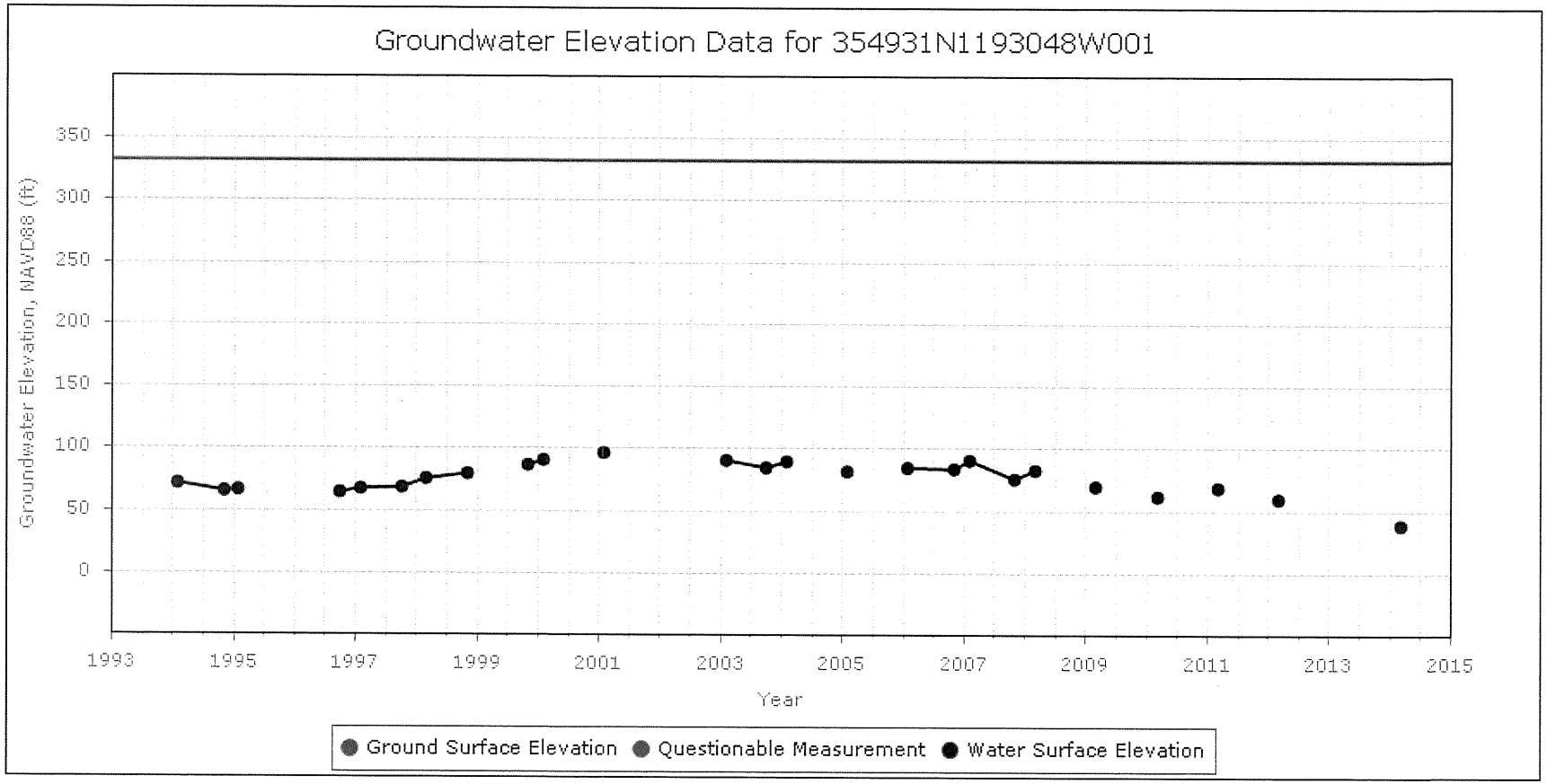
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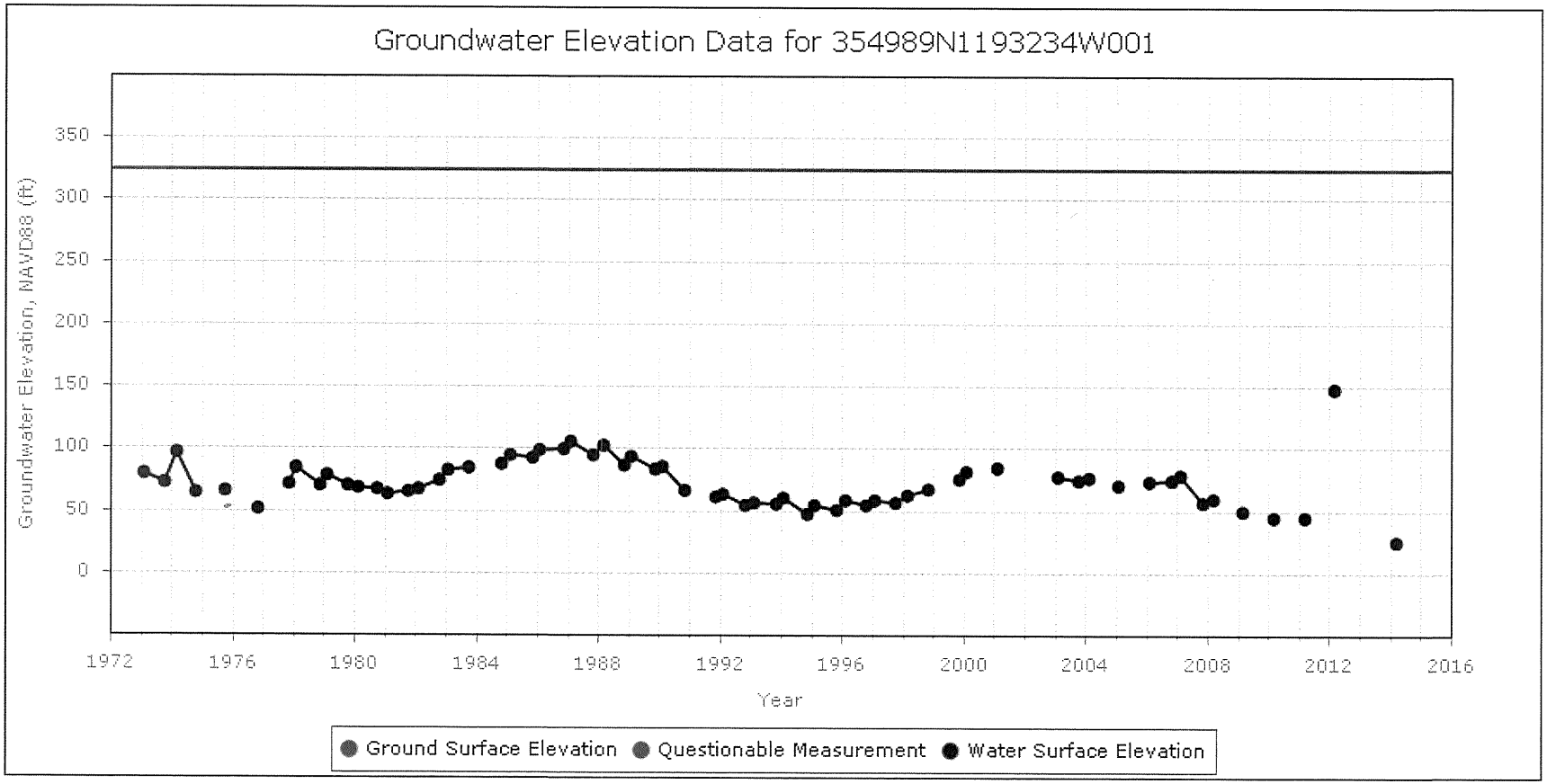
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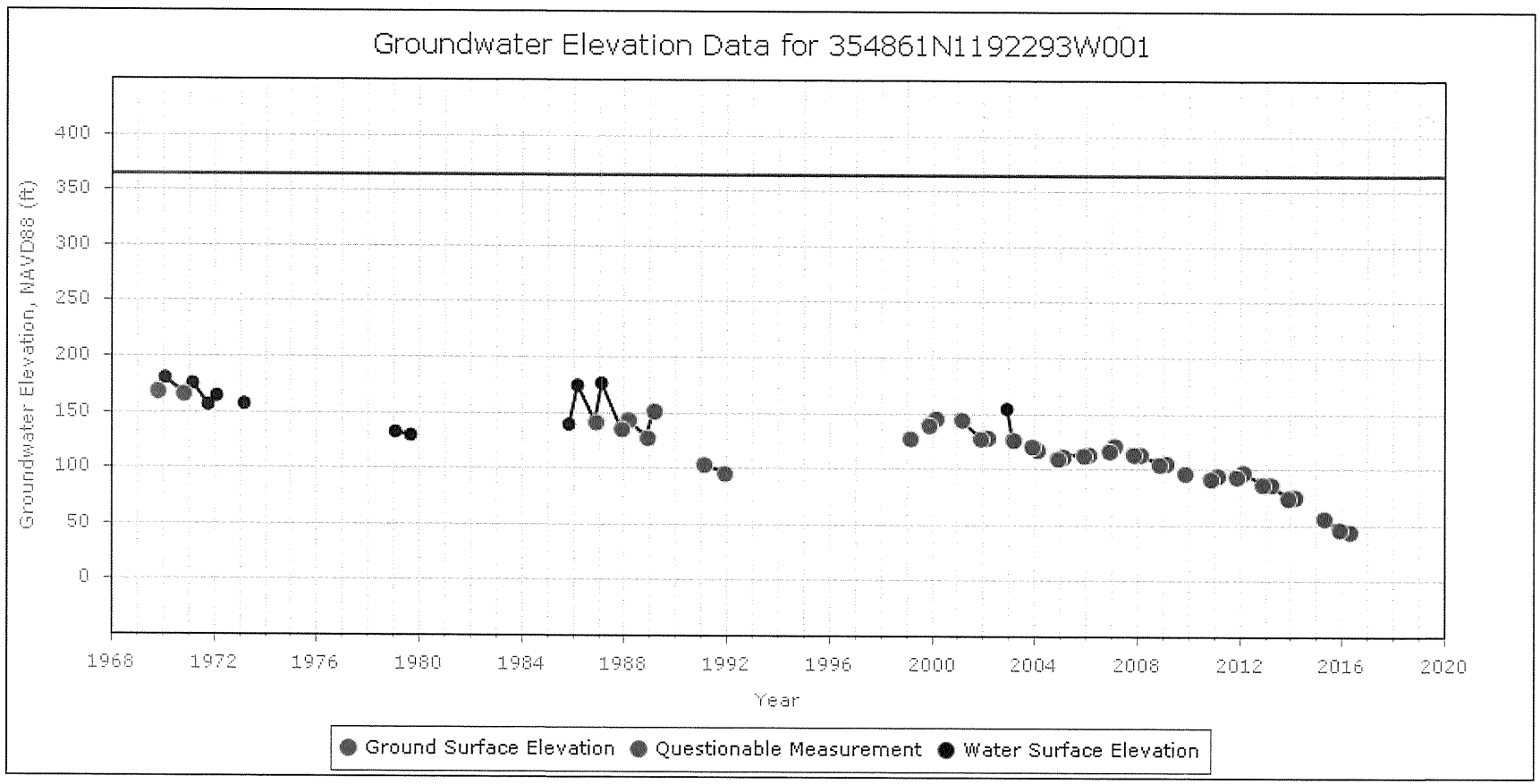
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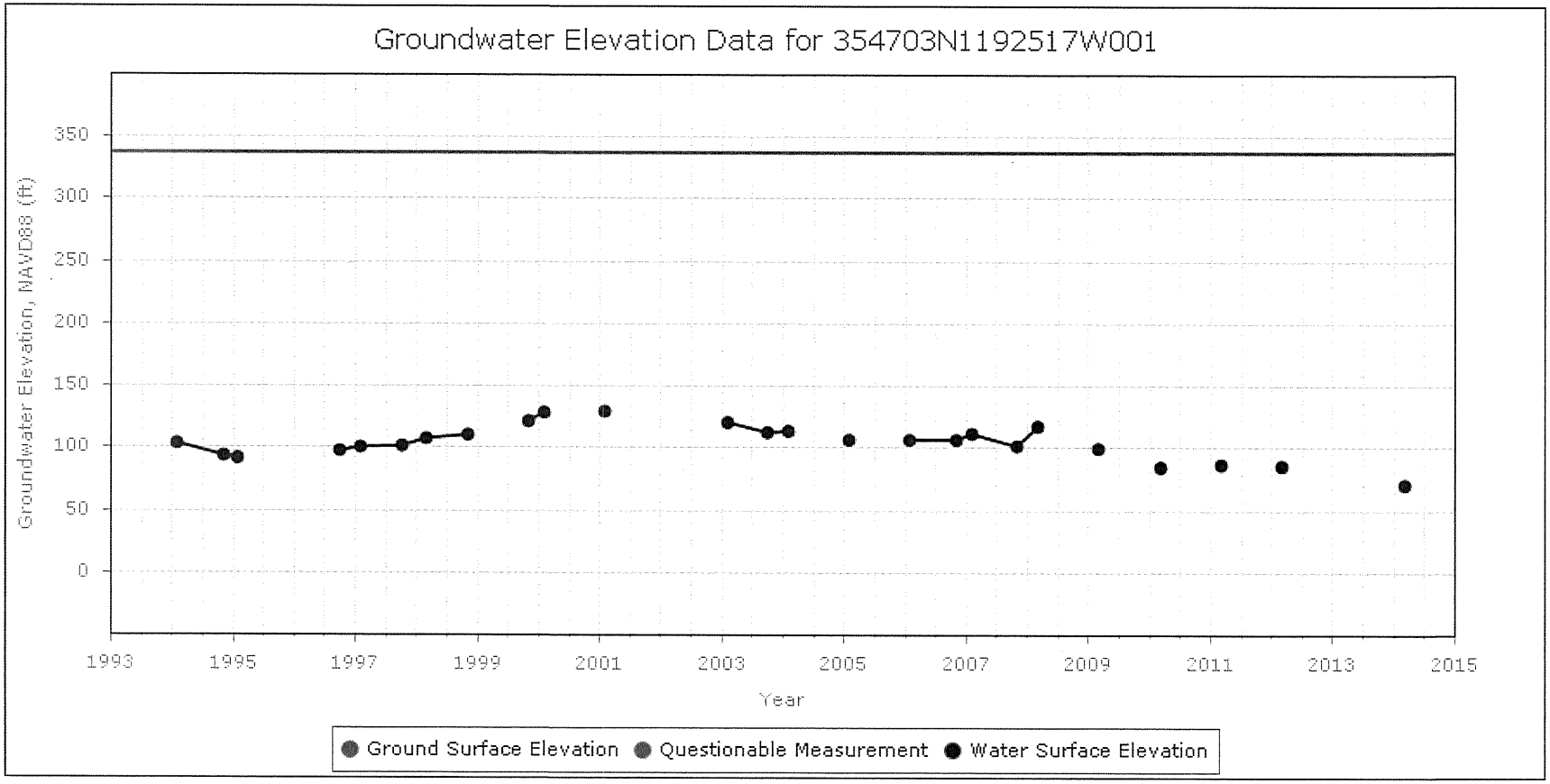
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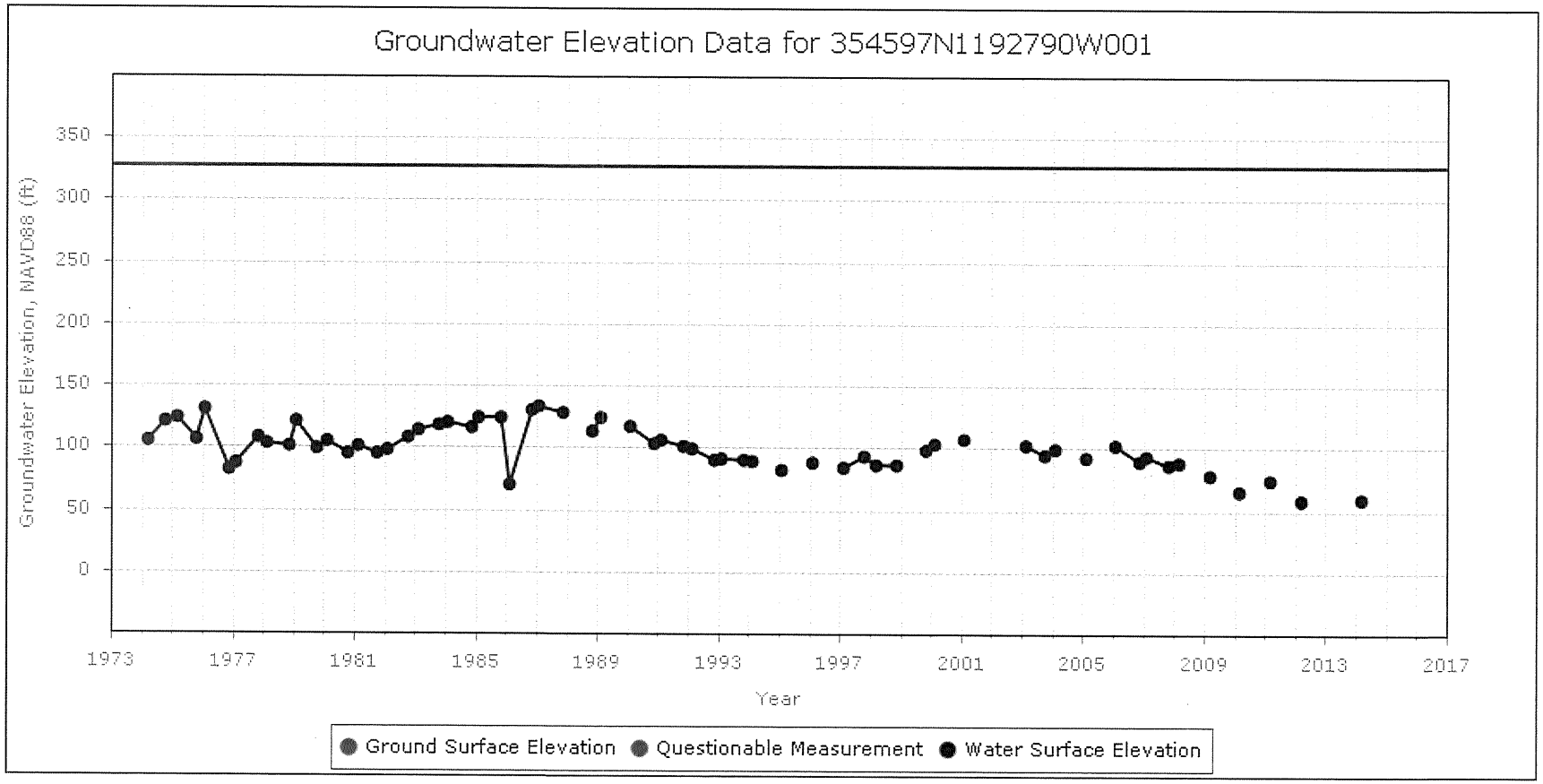
WATER-LEVEL HYDROGRAPH FOR WELL T28S/R25E-18C1



WATER-LEVEL HYDROGRAPH FOR WELL T28S/R25E-24A1



WATER-LEVEL HYDROGRAPH FOR WELL T28S/R25E-26C2

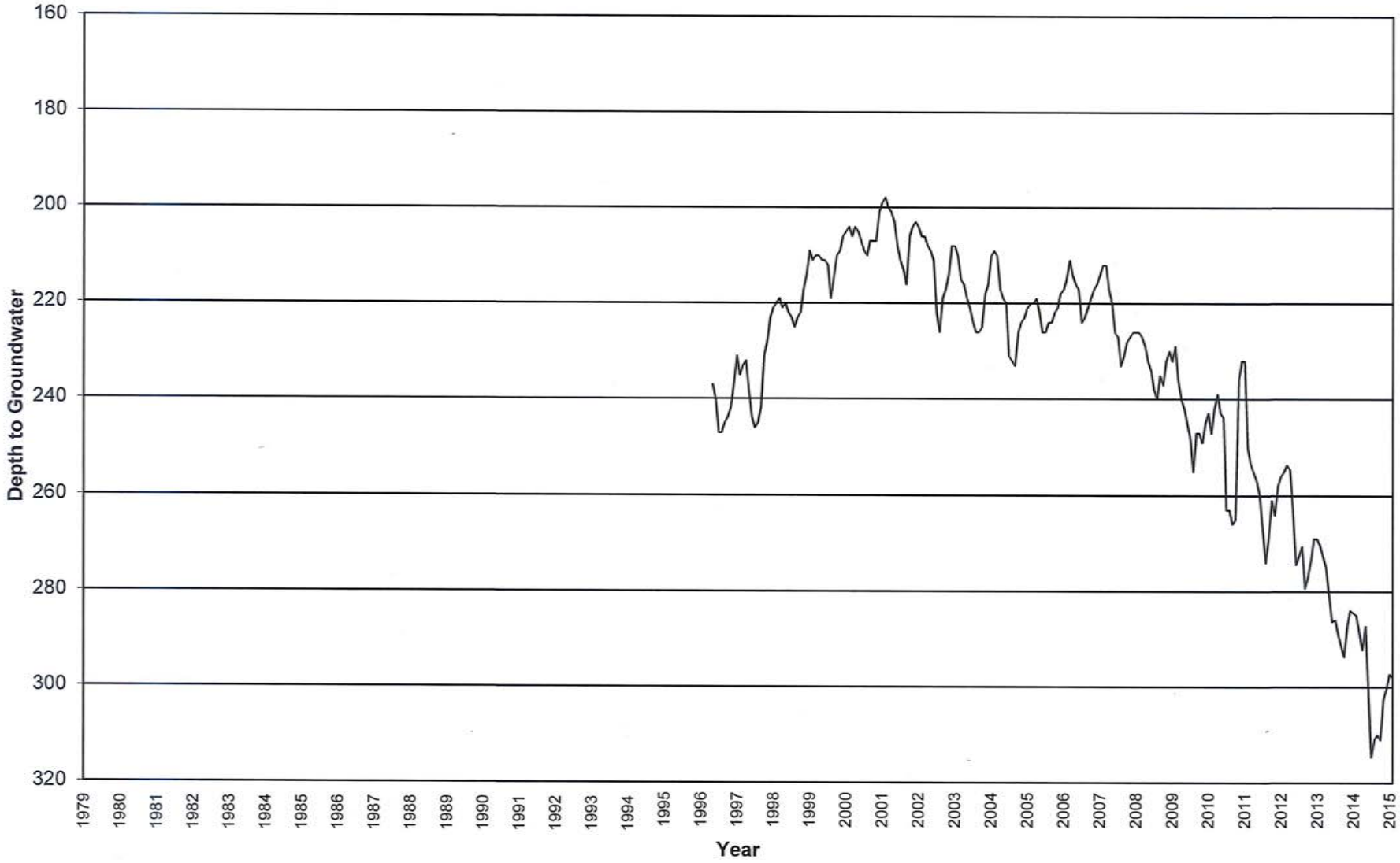


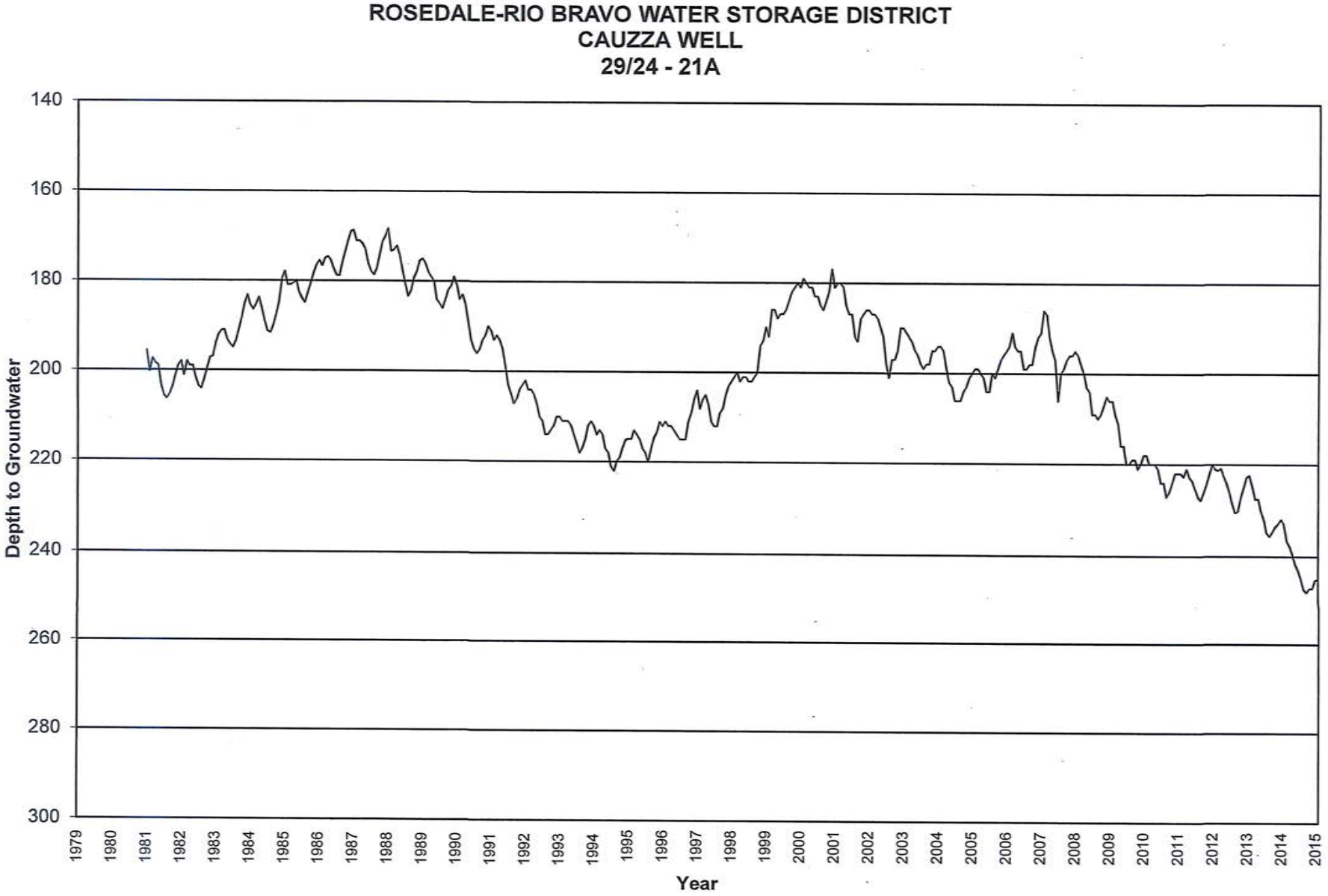
WATER-LEVEL HYDROGRAPH FOR WELL T28S/R25E-28R2

Close

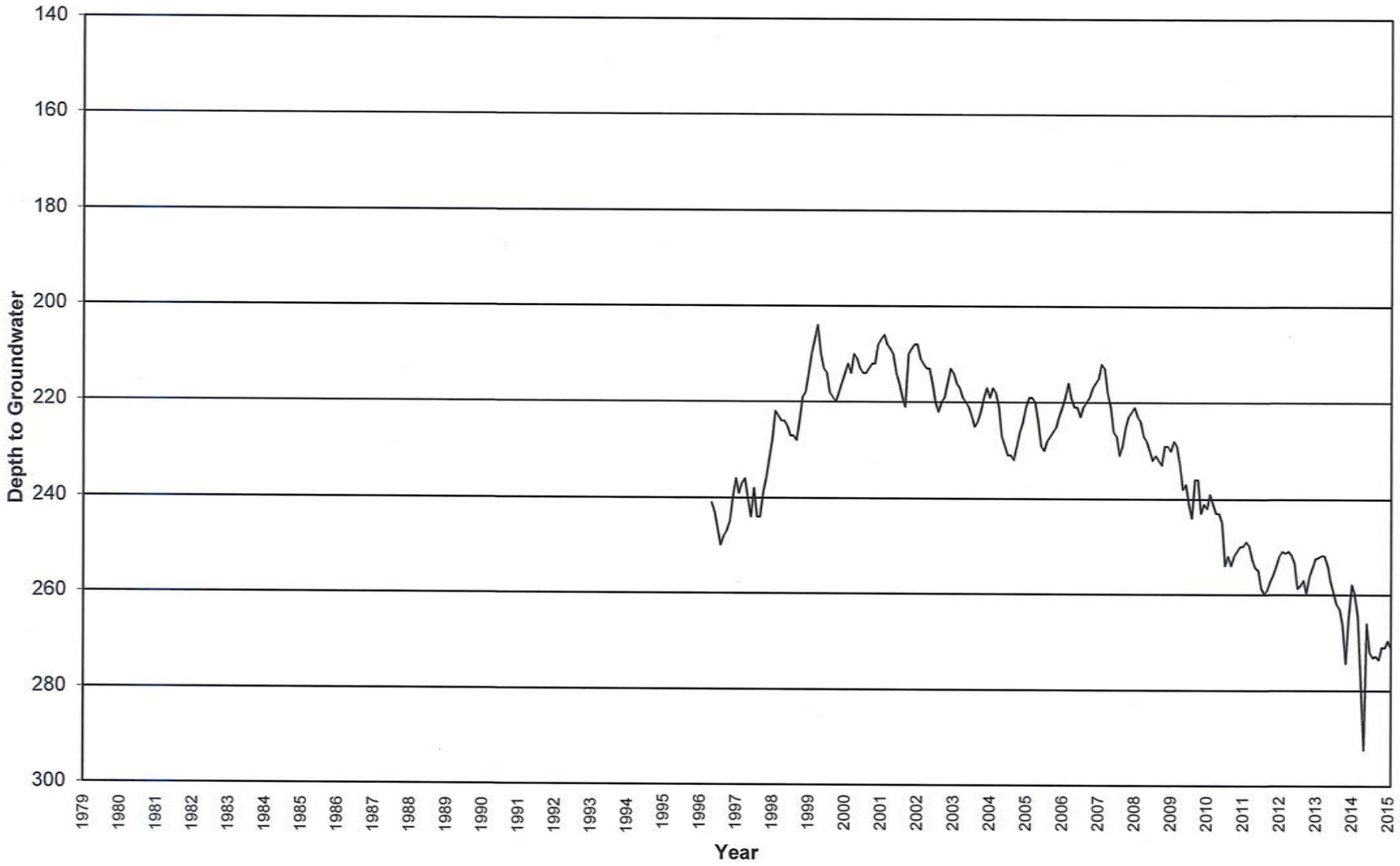
ROSEDALE-RIO BRAVO WATER
STORAGE DISTRICT

ROSEDALE-RIO BRAVO WATER STORAGE DISTRICT
BUSHNELL WELL
29/24 - 2J1

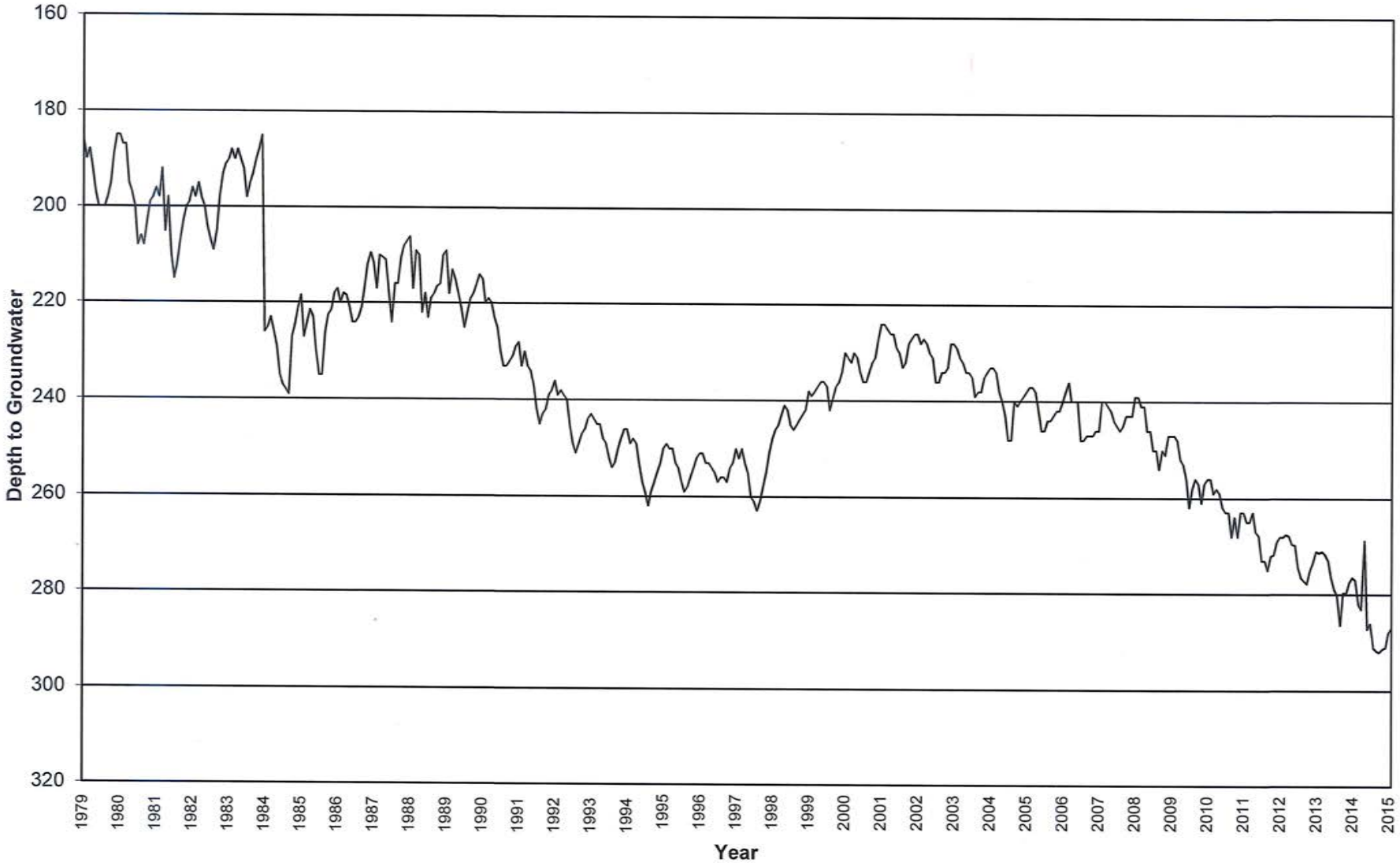



ROSEDALE-RIO BRAVO WATER STORAGE DISTRICT
CAUZZA WELL
29/24 - 21A
Depth to Groundwater
140
160
180
200
220
240
260
280
300
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
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2014
2015
Year

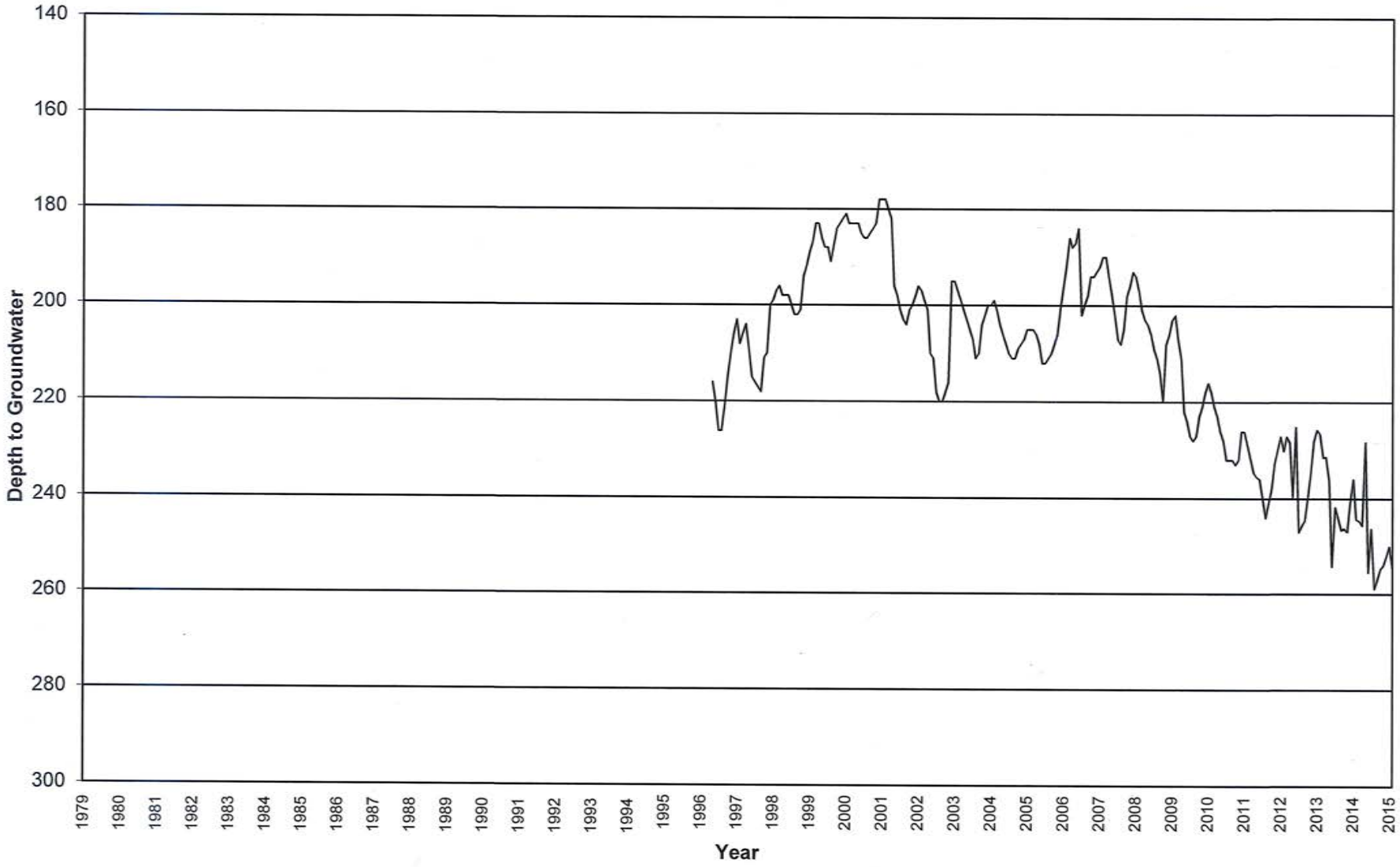
ROSEDALE-RIO BRAVO WATER STORAGE DISTRICT
L.R. STOUT WELL
29/25 - 3N1



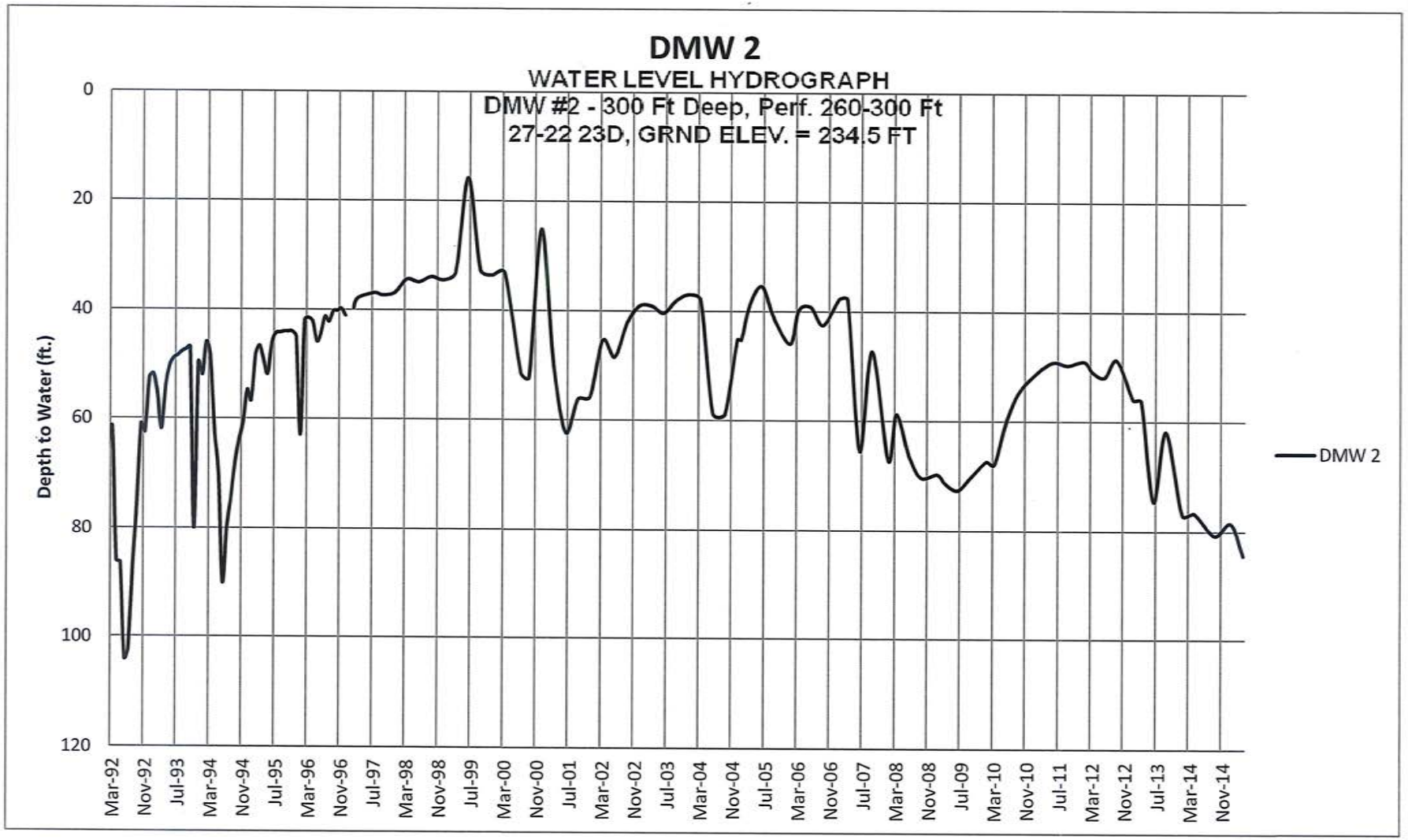
ROSEDALE-RIO BRAVO WATER STORAGE DISTRICT
HAAG WELL
29/25 - 5C (28/25 - 31)

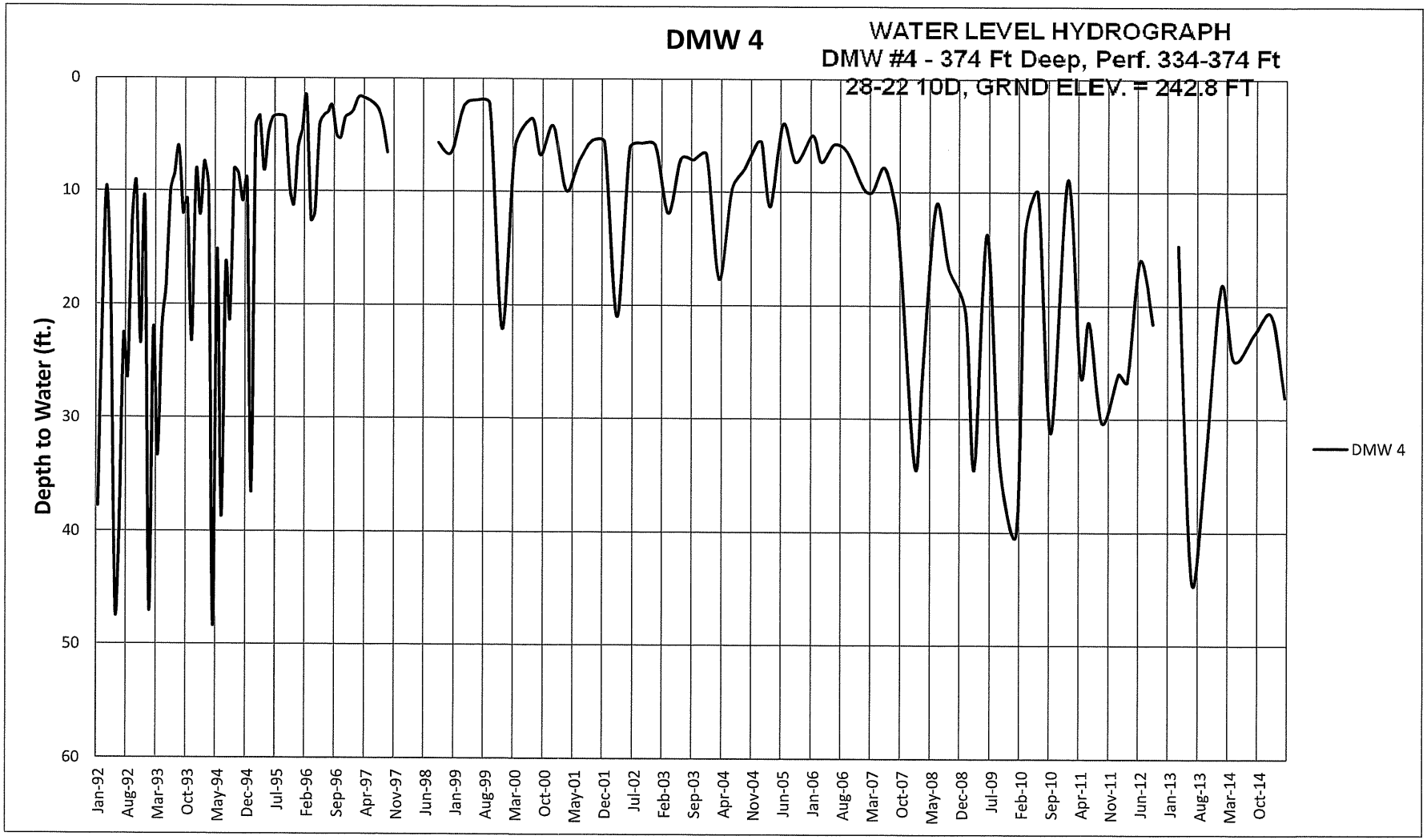


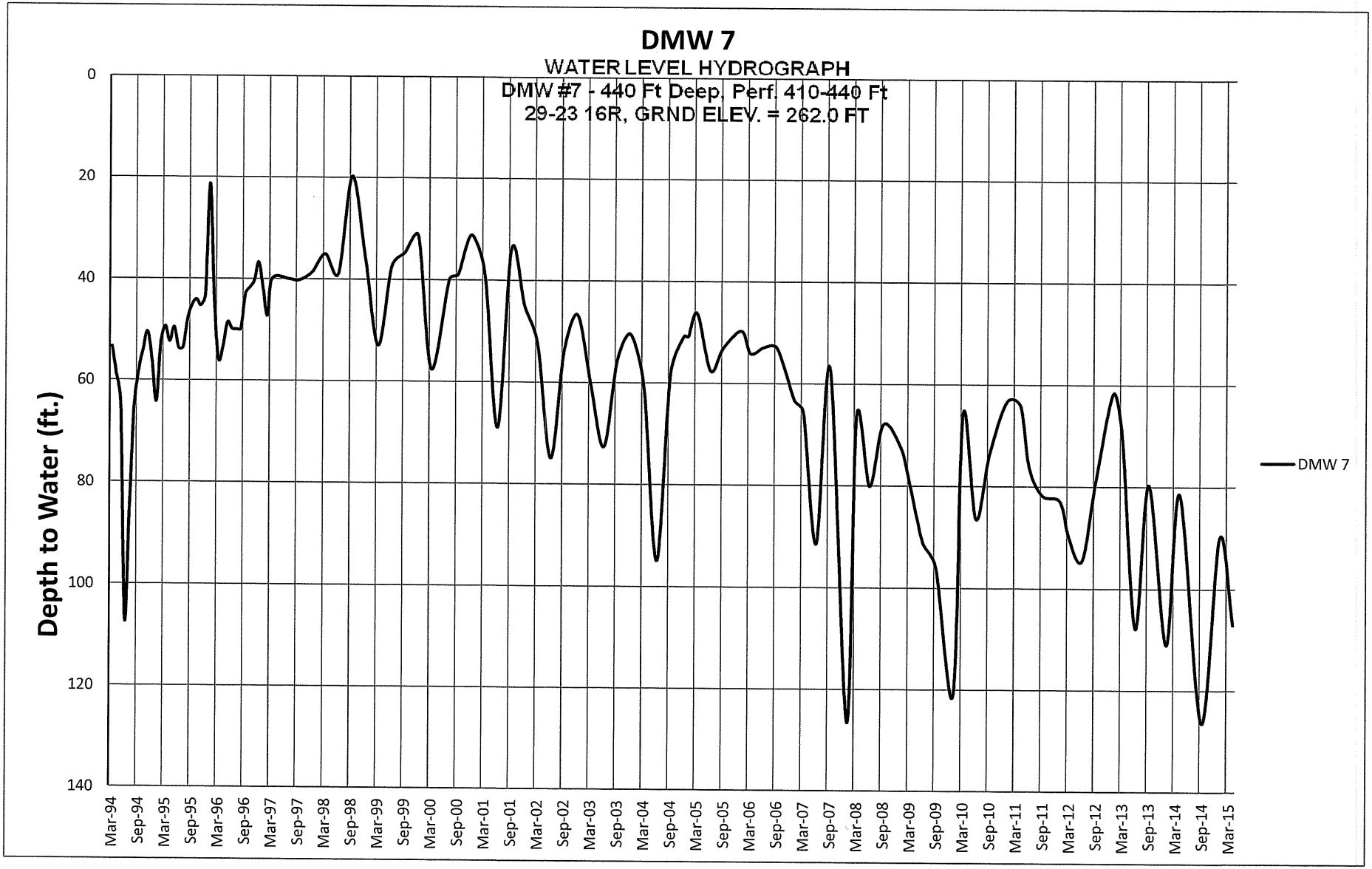
ROSEDALE-RIO BRAVO WATER STORAGE DISTRICT
SECTION 18 WELL
29/25 - 18A1

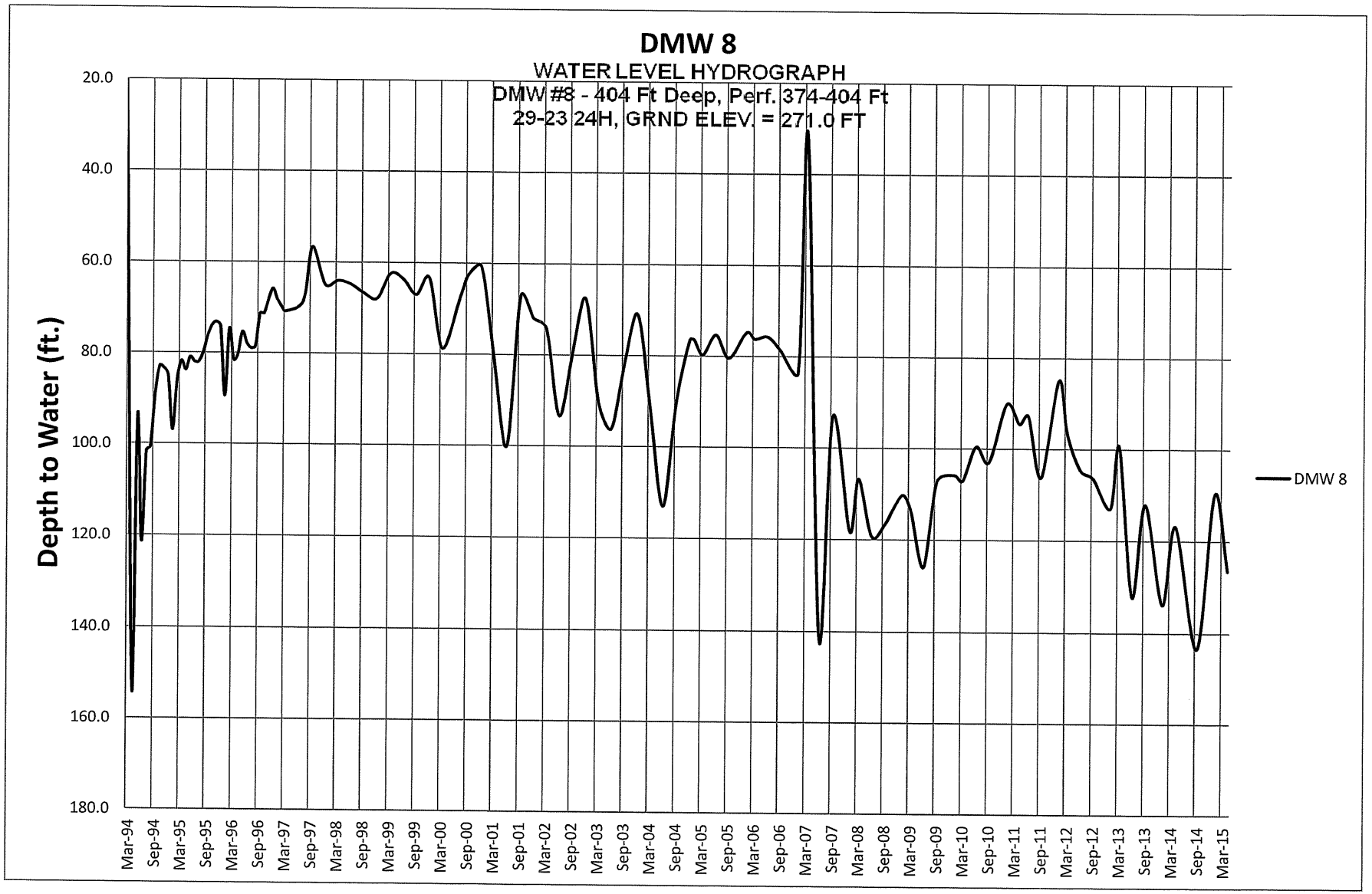


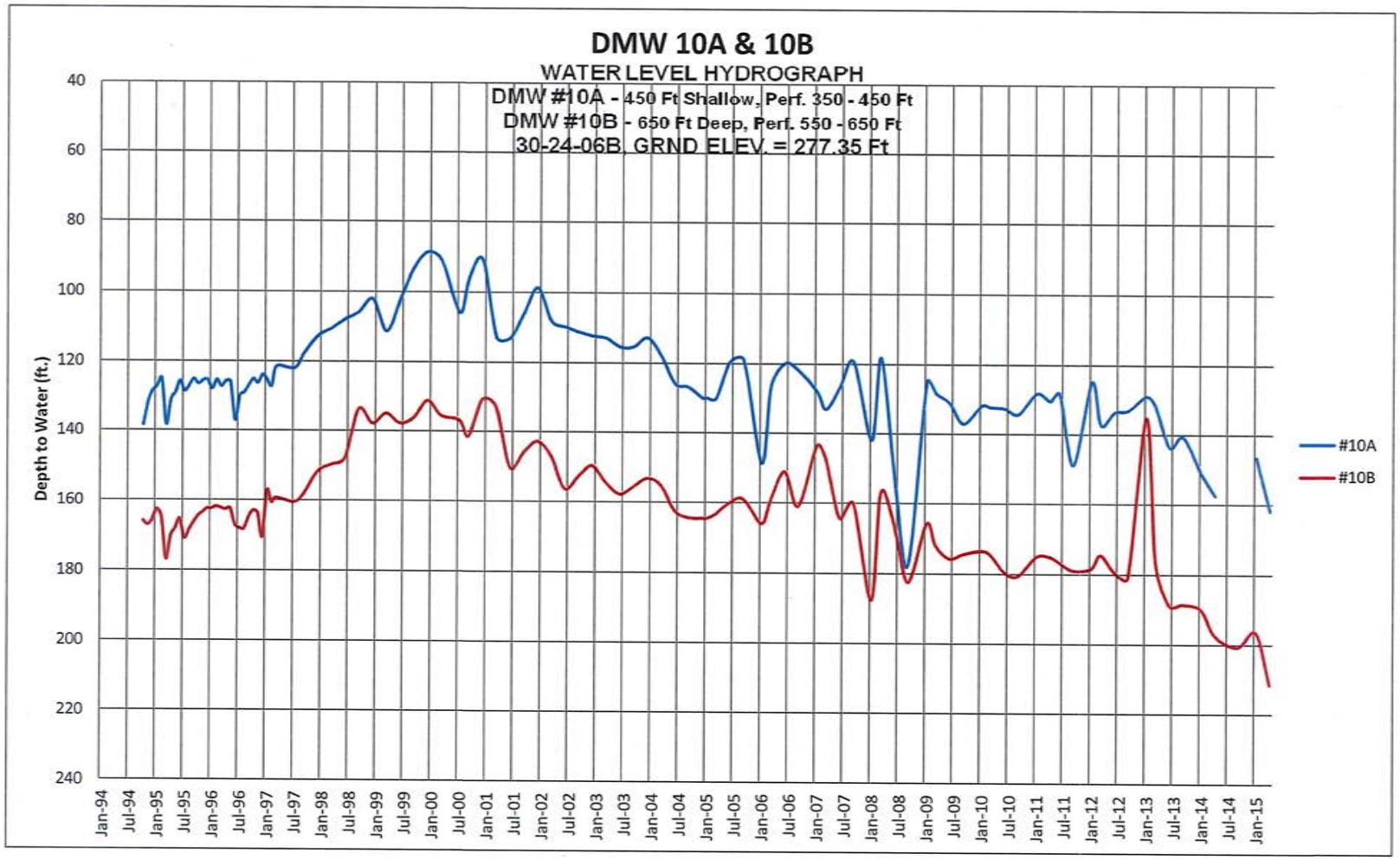
BUENA VISTA WATER STORAGE DISTRICT

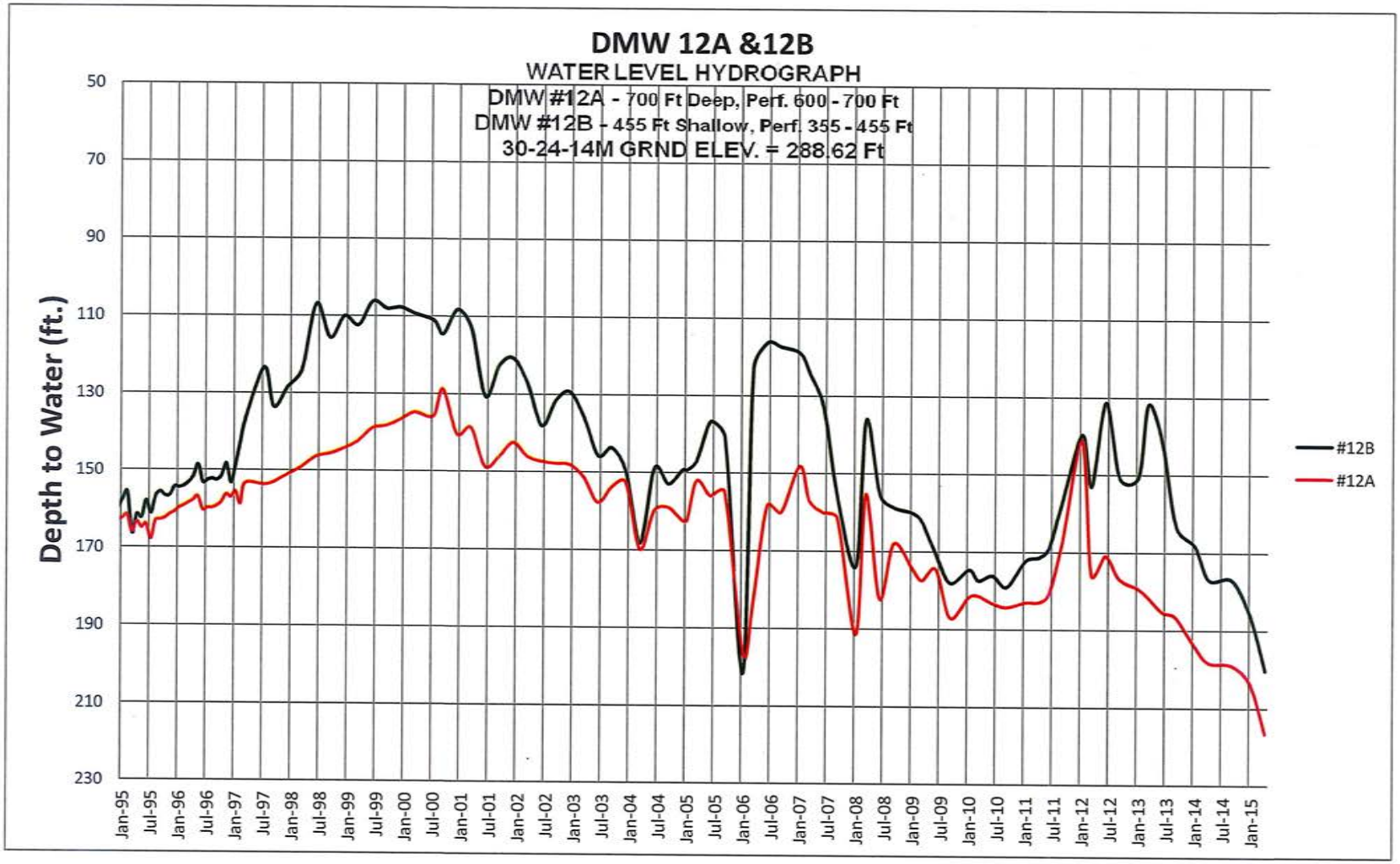

DMW 2
WATER LEVEL HYDROGRAPH
DMW #2 - 300 Ft Deep, Perf. 260-300 Ft
27-22 23D, GRND ELEV. = 234.5 FT
Depth to Water (ft.)
0
20
40
60
80
100
120
Mar-92
Nov-92
Jul-93
Mar-94
Nov-94
Jul-95
Mar-96
Nov-96
Jul-97
Mar-98
Nov-98
Jul-99
Mar-00
Nov-00
Jul-01
Mar-02
Nov-02
Jul-03
Mar-04
Nov-04
Jul-05
Mar-06
Nov-06
Jul-07
Mar-08
Nov-08
Jul-09
Mar-10
Nov-10
Jul-11
Mar-12
Nov-12
Jul-13
Mar-14
Nov-14
DMW 2


DMW 4
WATER LEVEL HYDROGRAPH
DMW #4 - 374 Ft Deep, Perf. 334-374 Ft
28-22 10D, GRND ELEV. = 242.8 FT
Depth to Water (ft.)
0
10
20
30
40
50
60
Jan-92
Aug-92
Mar-93
Oct-93
May-94
Dec-94
Jul-95
Feb-96
Sep-96
Apr-97
Nov-97
Jun-98
Jan-99
Aug-99
Mar-00
Oct-00
May-01
Dec-01
Jul-02
Feb-03
Sep-03
Apr-04
Nov-04
Jun-05
Jan-06
Aug-06
Mar-07
Oct-07
May-08
Dec-08
Jul-09
Feb-10
Sep-10
Apr-11
Nov-11
Jun-12
Jan-13
Aug-13
Mar-14
Oct-14
DMW 4


DMW 7
WATER LEVEL HYDROGRAPH
DMW #7 - 440 Ft Deep, Perf. 410-440 Ft
29-23 16R, GRND ELEV. = 262.0 FT
Depth to Water (ft.)
0
20
40
60
80
100
120
140
Mar-94
Sep-94
Mar-95
Sep-95
Mar-96
Sep-96
Mar-97
Sep-97
Mar-98
Sep-98
Mar-99
Sep-99
Mar-00
Sep-00
Mar-01
Sep-01
Mar-02
Sep-02
Mar-03
Sep-03
Mar-04
Sep-04
Mar-05
Sep-05
Mar-06
Sep-06
Mar-07
Sep-07
Mar-08
Sep-08
Mar-09
Sep-09
Mar-10
Sep-10
Mar-11
Sep-11
Mar-12
Sep-12
Mar-13
Sep-13
Mar-14
Sep-14
Mar-15
DMW 7


DMW 8
WATER LEVEL HYDROGRAPH
DMW #8 - 404 Ft Deep, Perf. 374-404 Ft
29-23 24H, GRND ELEV. = 271.0 FT
Depth to Water (ft.)
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
Mar-94
Sep-94
Mar-95
Sep-95
Mar-96
Sep-96
Mar-97
Sep-97
Mar-98
Sep-98
Mar-99
Sep-99
Mar-00
Sep-00
Mar-01
Sep-01
Mar-02
Sep-02
Mar-03
Sep-03
Mar-04
Sep-04
Mar-05
Sep-05
Mar-06
Sep-06
Mar-07
Sep-07
Mar-08
Sep-08
Mar-09
Sep-09
Mar-10
Sep-10
Mar-11
Sep-11
Mar-12
Sep-12
Mar-13
Sep-13
Mar-14
Sep-14
Mar-15
DMW 8


DMW 10A & 10B
WATER LEVEL HYDROGRAPH
DMW #10A - 450 Ft Shallow, Perf. 350 - 450 Ft
DMW #10B - 650 Ft Deep, Perf. 550 - 650 Ft
30-24-06B, GRND ELEV. = 277.35 Ft
Depth to Water (ft.)
40
60
80
100
120
140
160
180
200
220
240
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Jul-06
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
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Jul-13
Jan-14
Jul-14
Jan-15
#10A
#10B

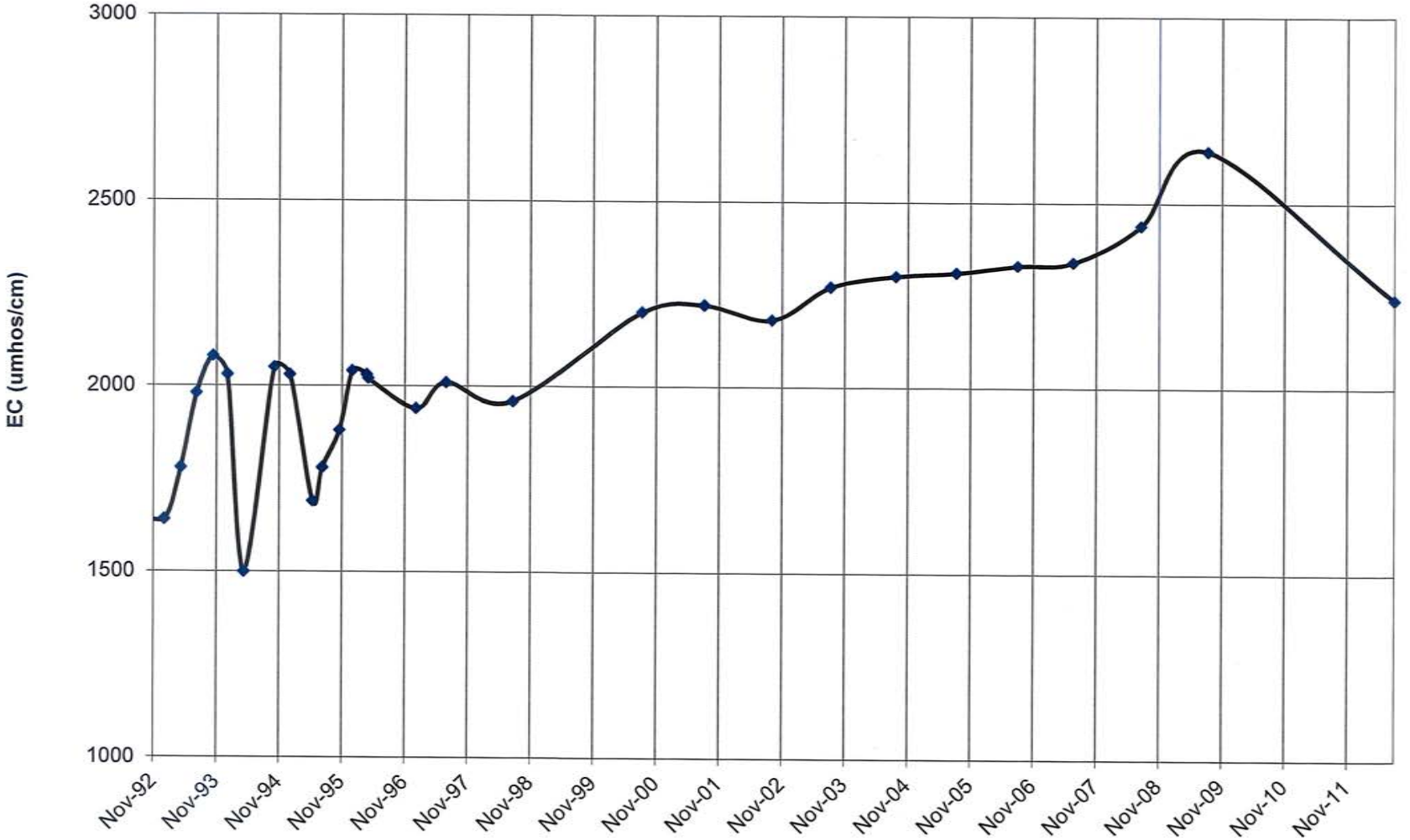

DMW 12A &12B
WATER LEVEL HYDROGRAPH
DMW #12A - 700 Ft Deep, Perf. 600 - 700 Ft
DMW #12B - 455 Ft Shallow, Perf. 355 - 455 Ft
30-24-14M GRND ELEV. = 288.62 Ft
Depth to Water (ft.)
50
70
90
110
130
150
170
190
210
230
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Jan-06
Jul-06
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
#12B
#12A

APPENDIX C

WATER QUALITY HYDROGRAPHS

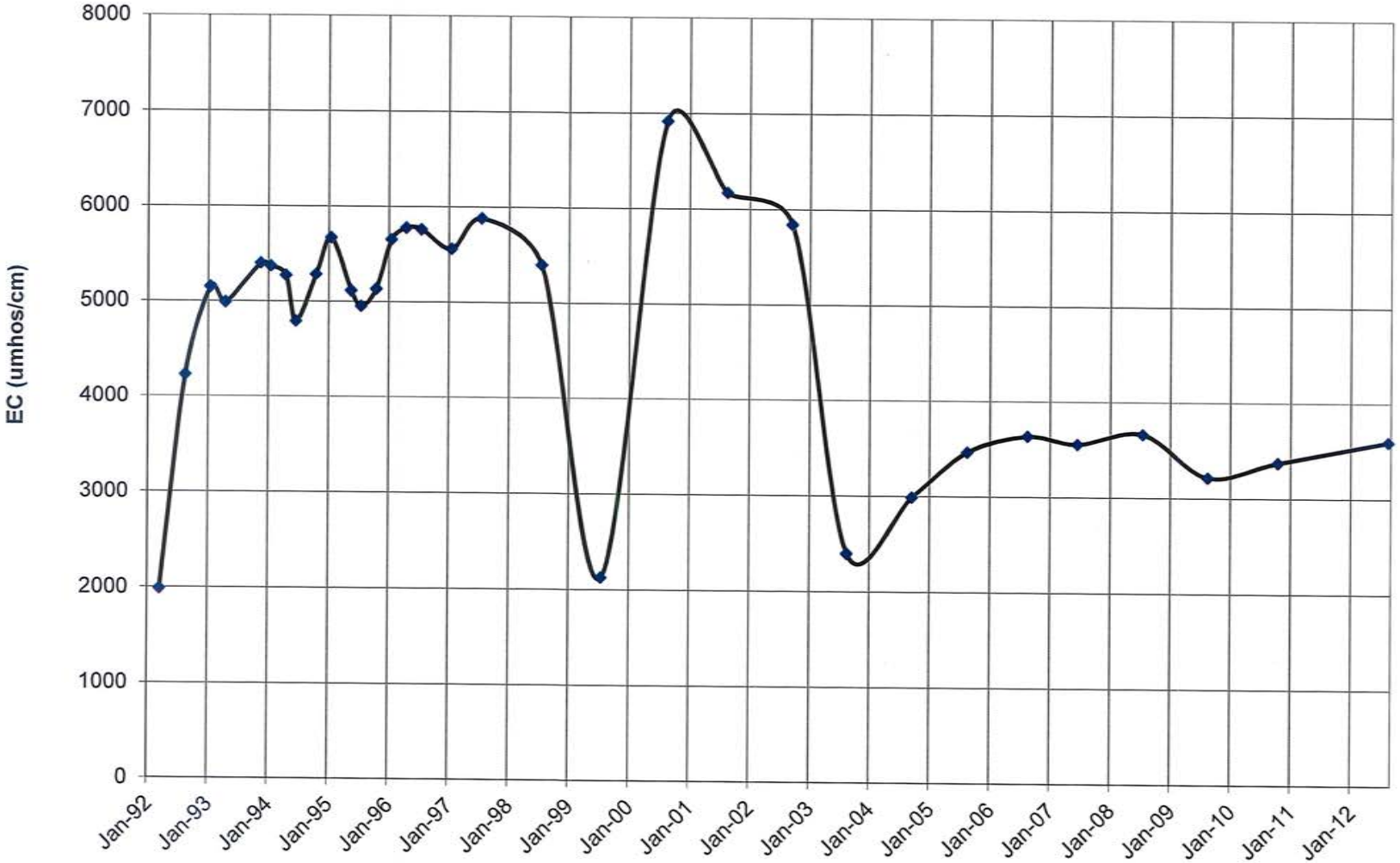
BUENA VISTA WATER STORAGE DISTRICT

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #1
Depth = 300 Ft, Perf. = 280-300 Ft
T27S R22E Sec. 8A



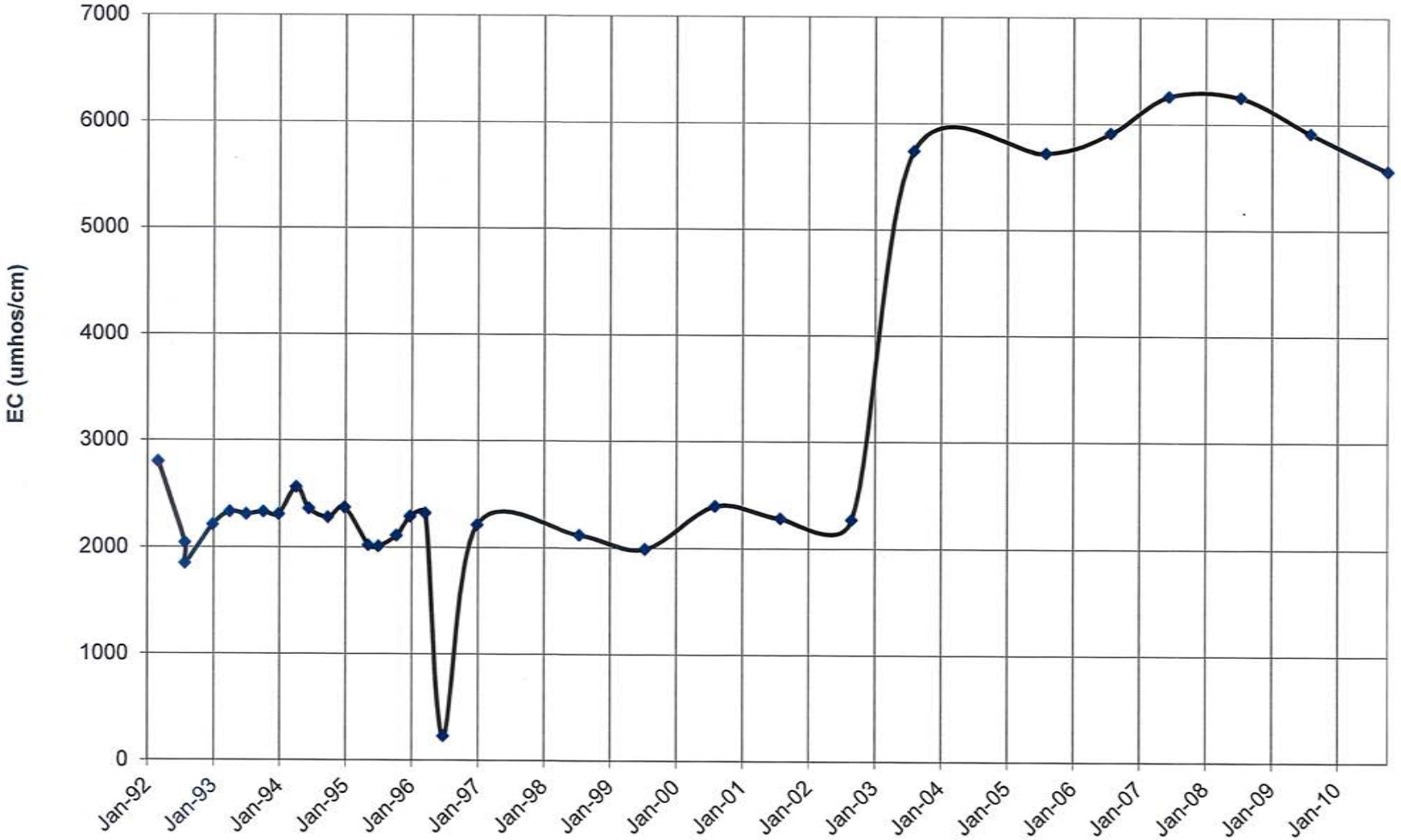
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #2
Depth = 300 Ft, Perf. = 260-300 Ft
T27S R22E Sec. 23D



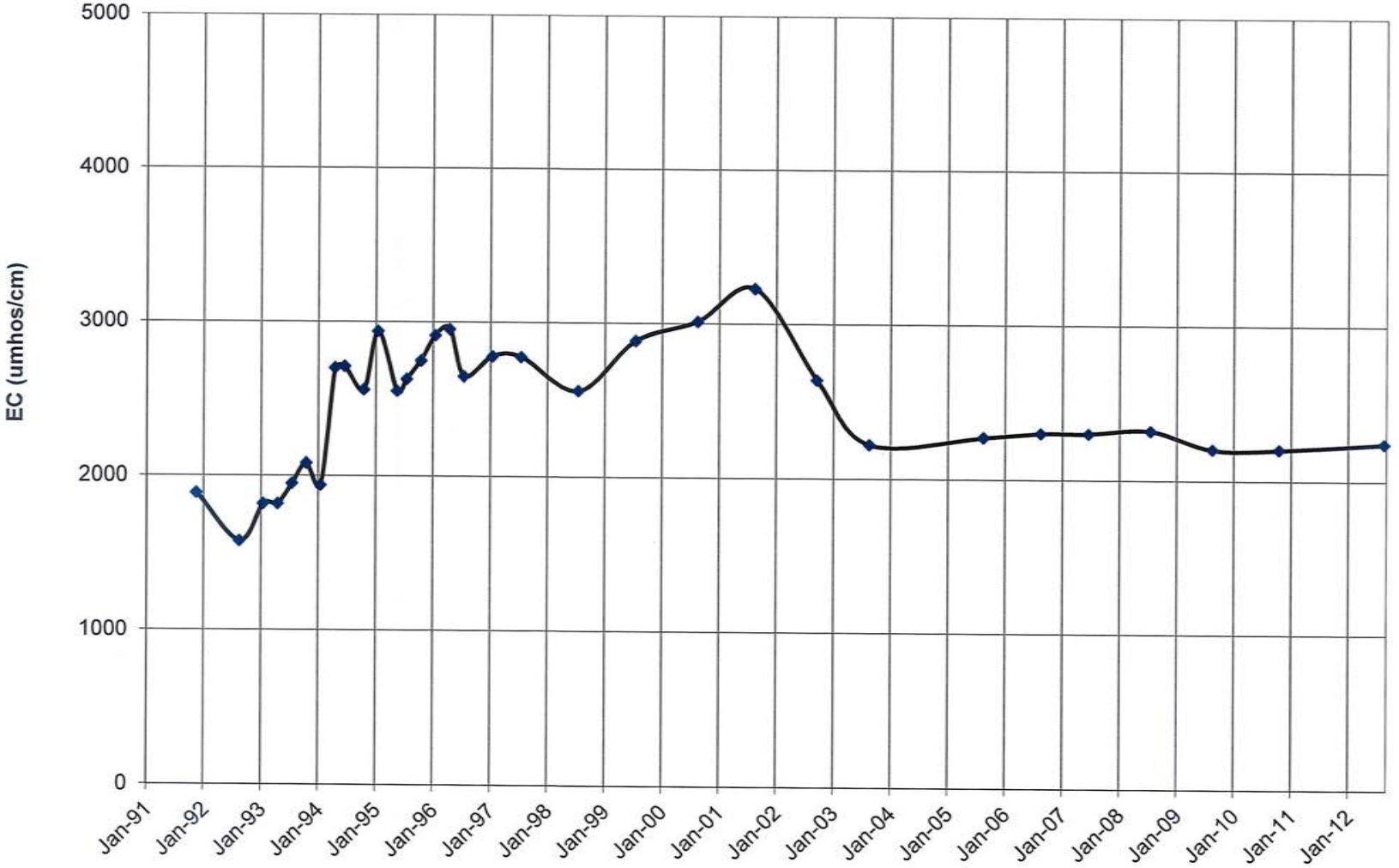
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #3
Depth = 220 Ft, Perf. = 200-220 Ft
T27S R22E Sec. 33A



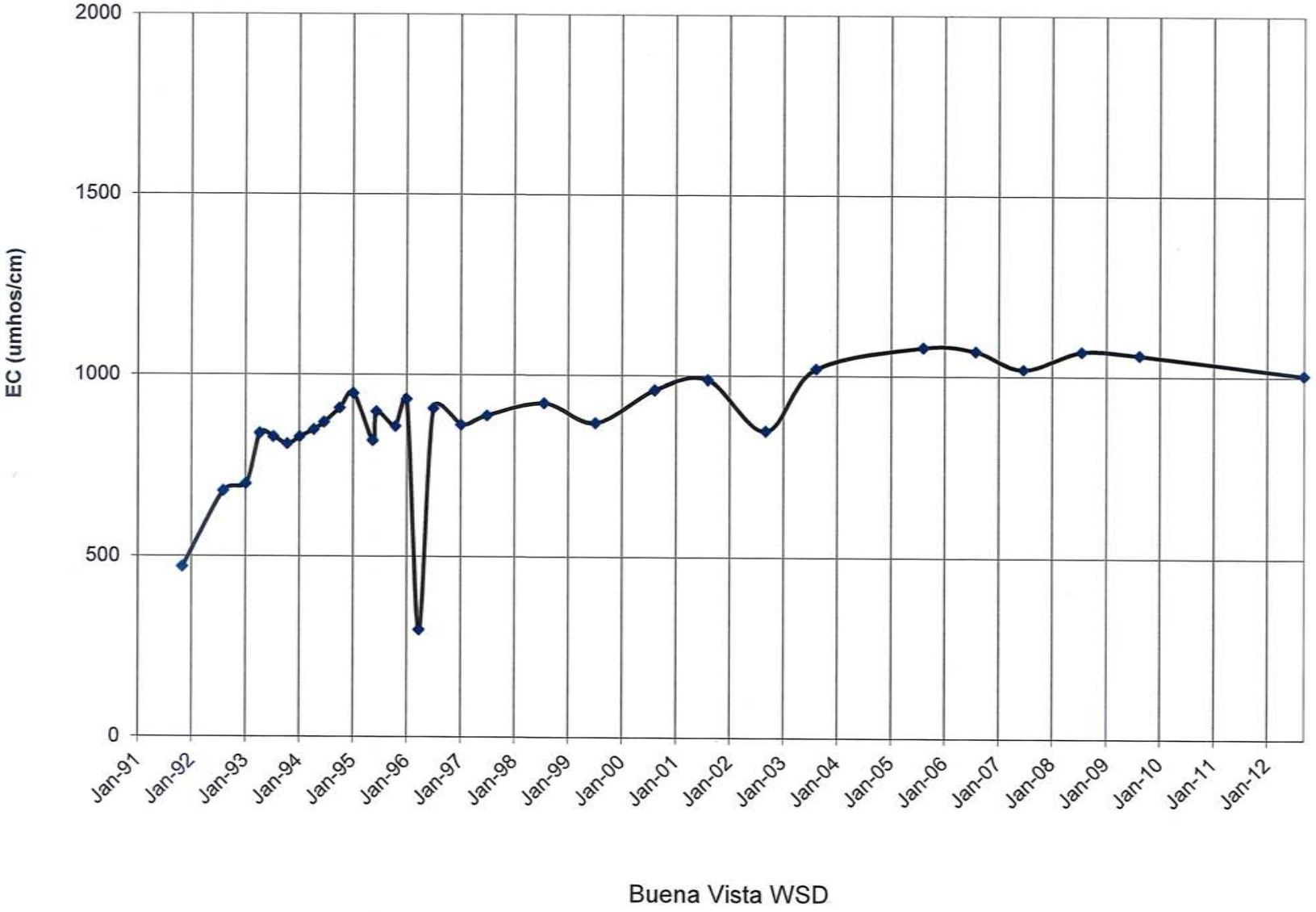
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #4
Depth = 374 Ft, Perf. = 334-374 Ft
T28S R22E Sec. 10D



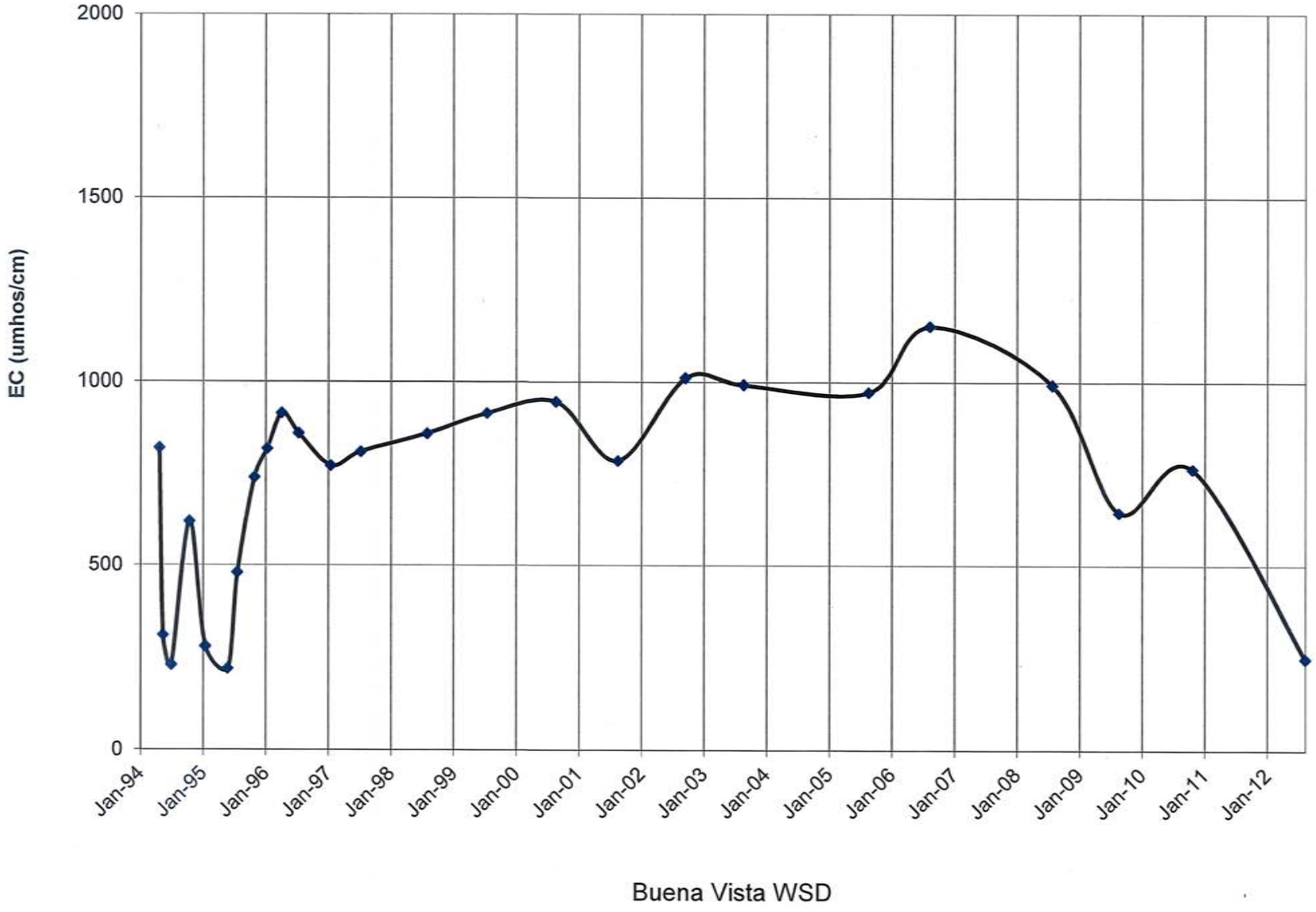
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #5
Depth = 310 Ft, Perf. = 240-310 Ft
T28S R22E Sec. 14R



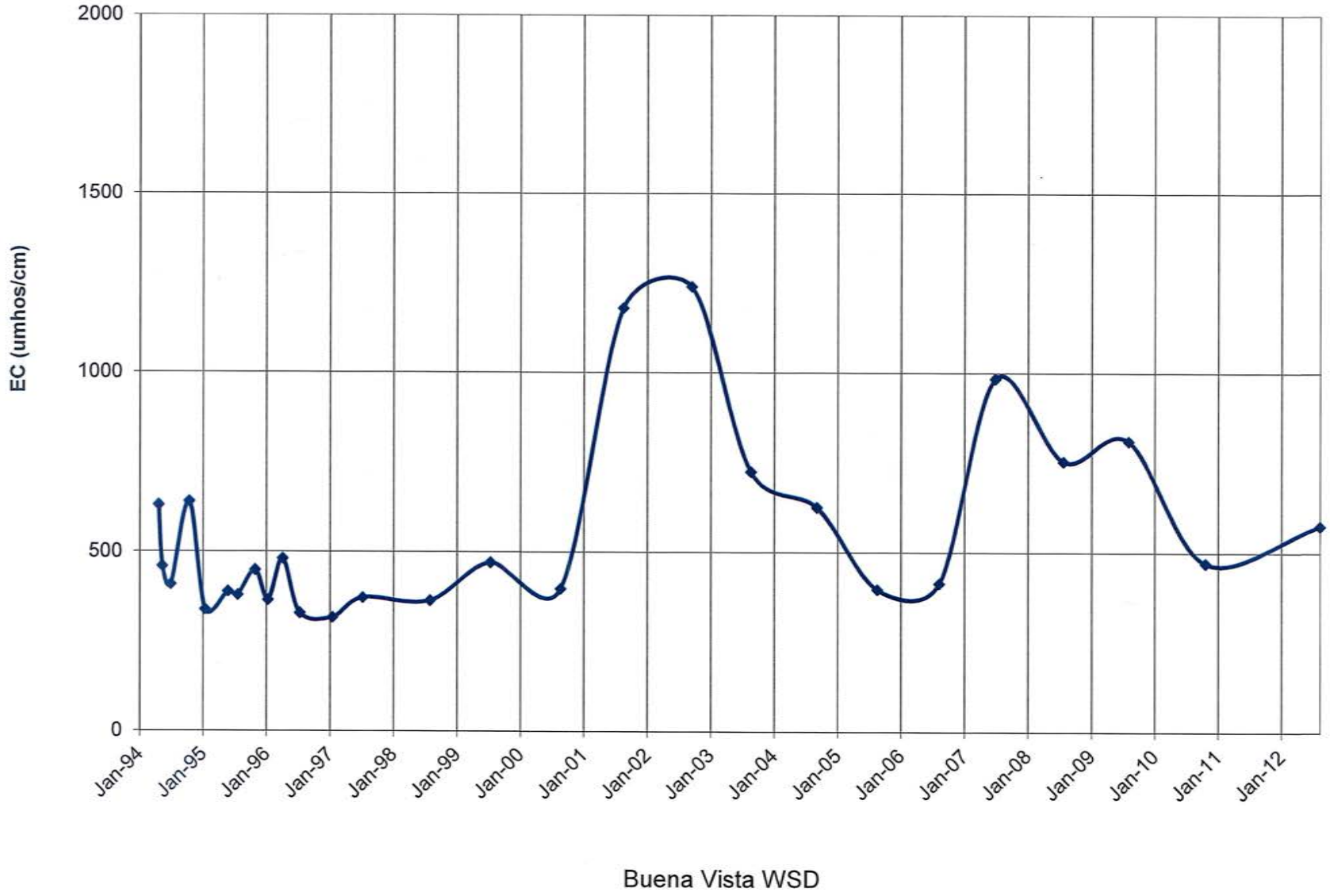
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #6
Depth = 440 Ft, Perf. = 410-440 Ft
T28S R23E Sec. 31B



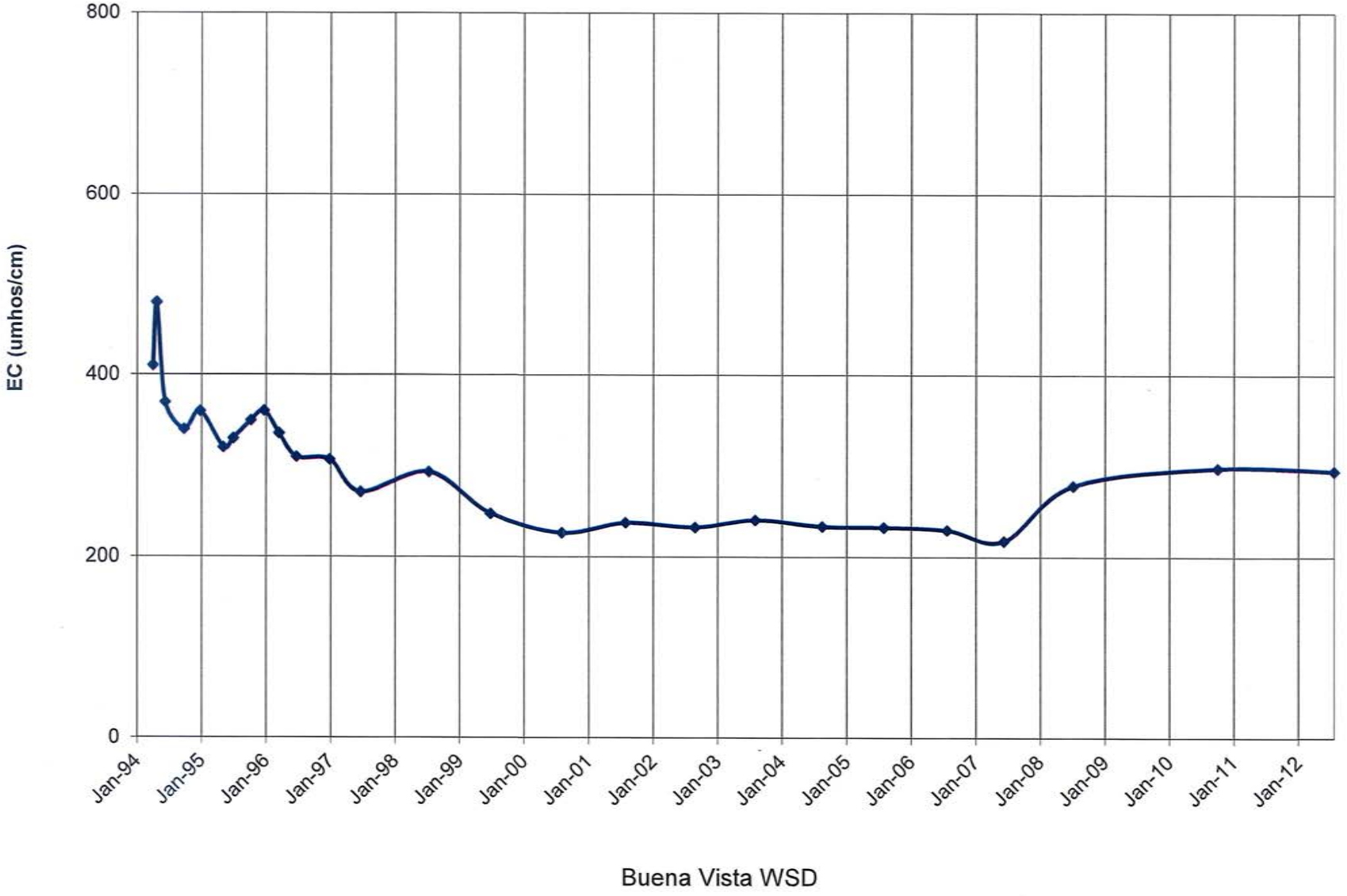
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #7
Depth = 440 Ft, Perf. = 410-440 Ft
T29S R23E Sec. 16R



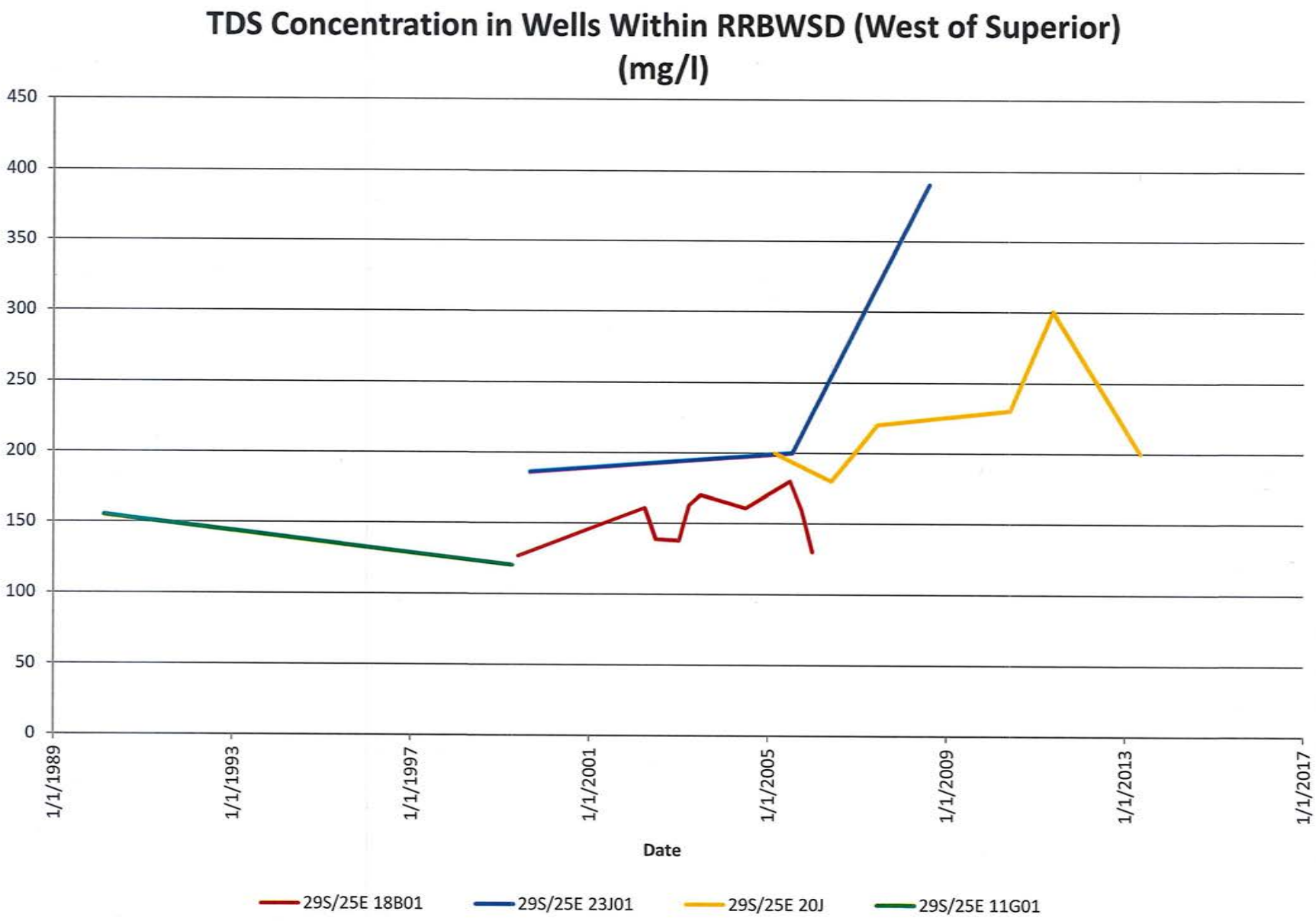
Buena Vista WSD

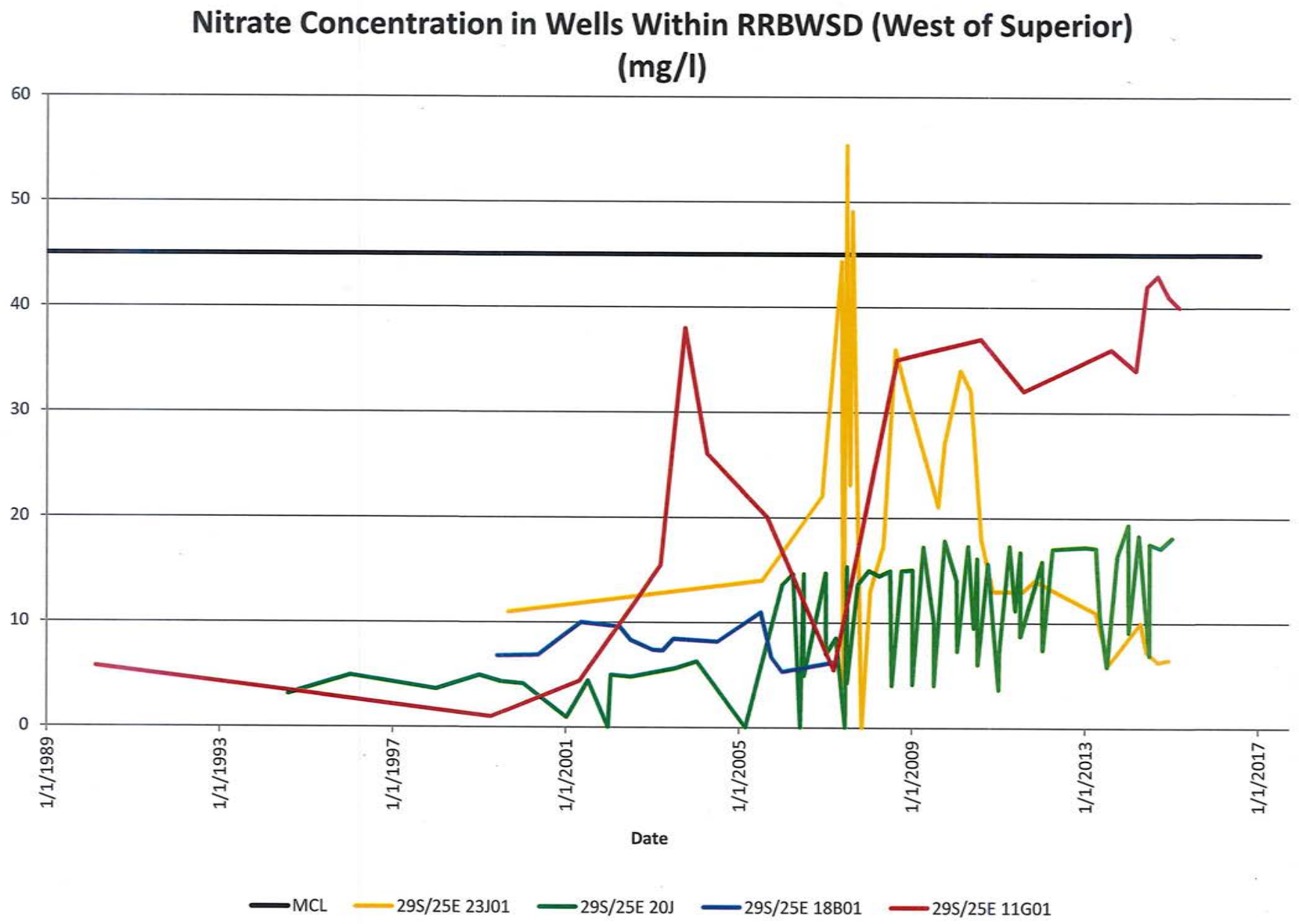
WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #8
Depth = 404 Ft, Perf. = 374-404 Ft
T29S R23E Sec. 24H

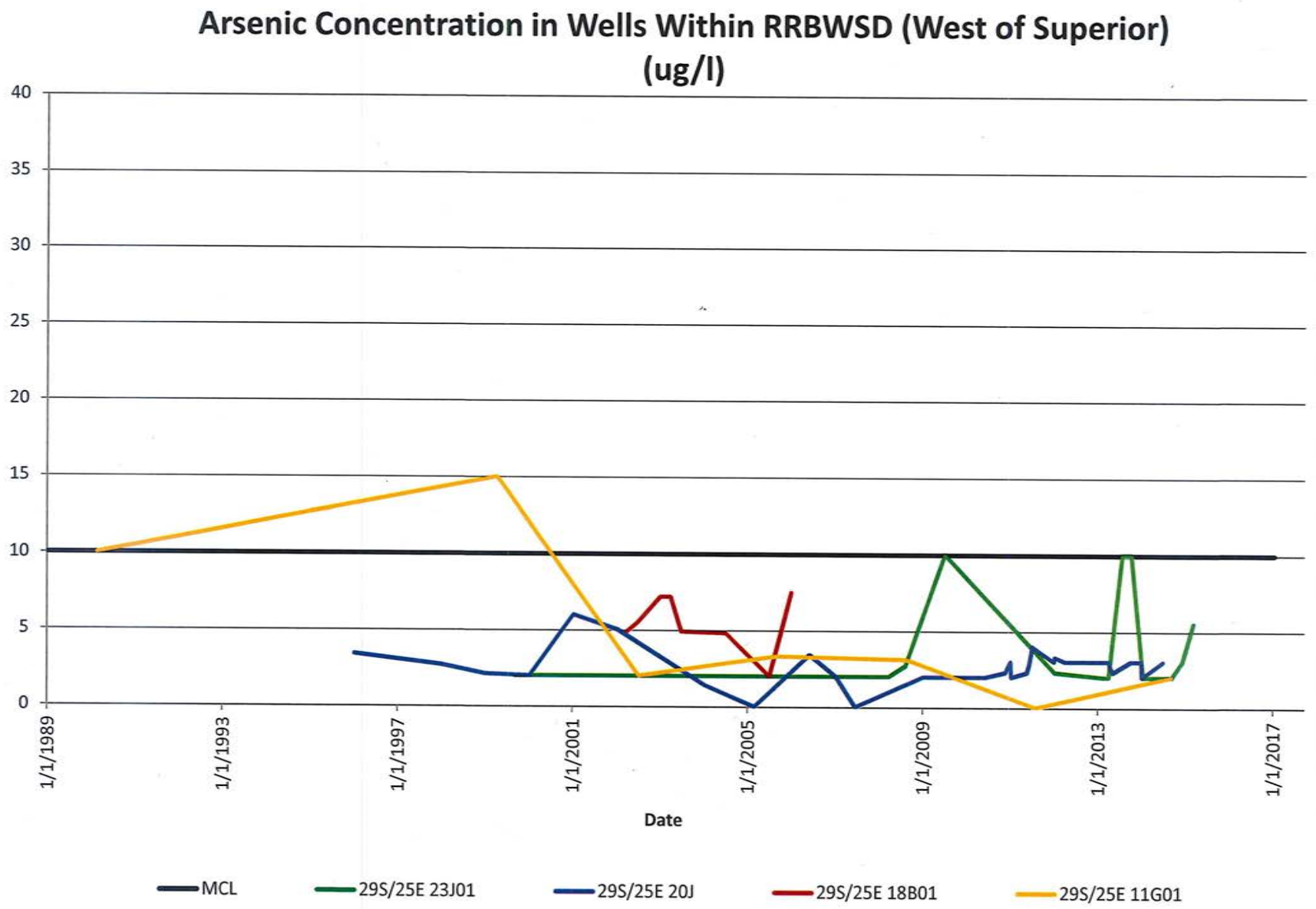


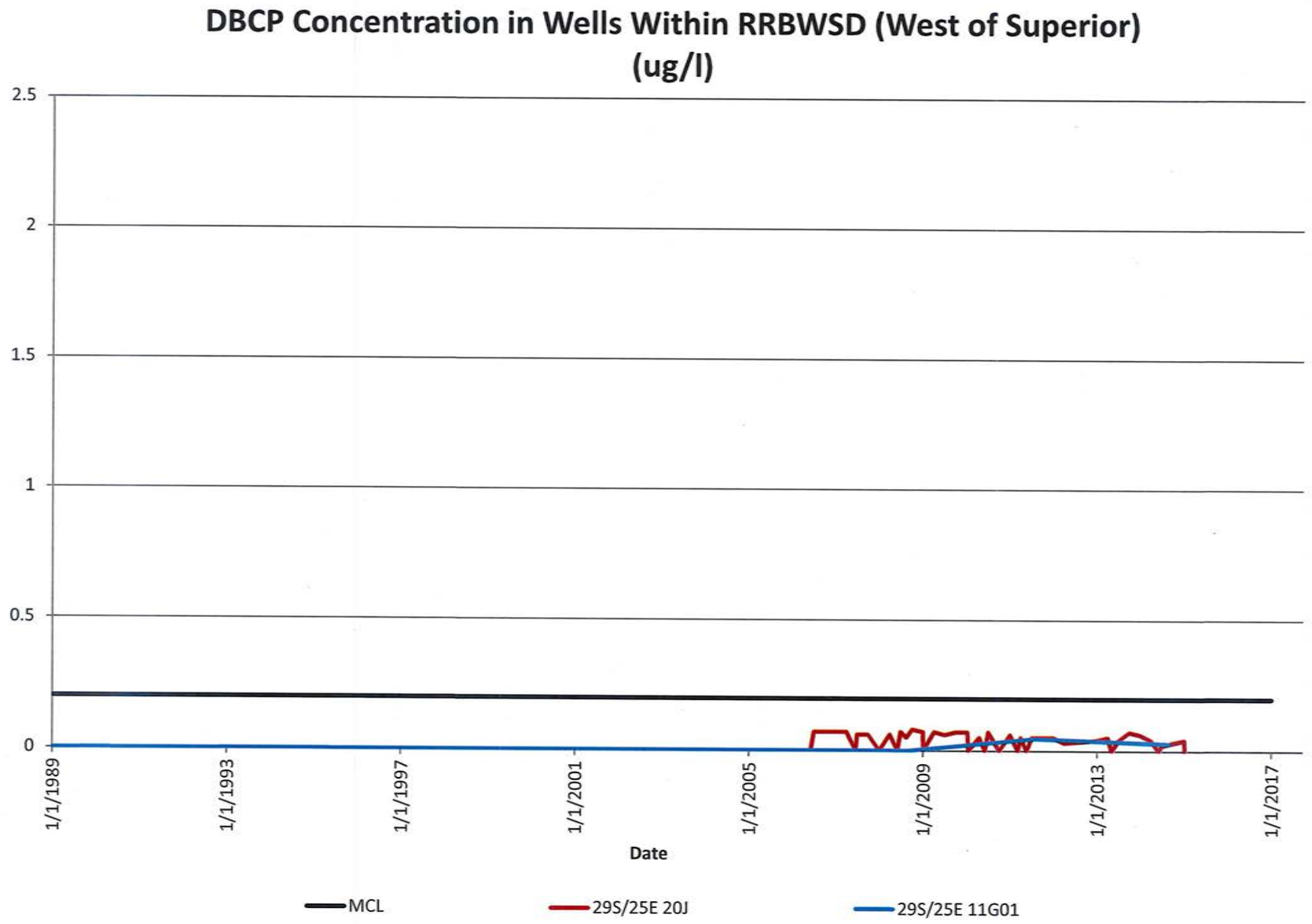
Buena Vista WSD

ROSEDALE-RIO BRAVO WATER
STORAGE DISTRICT


TDS Concentration in Wells Within RRBWSD (West of Superior)
(mg/l)
450
400
350
300
250
200
150
100
50
0
1/1/1989
1/1/1993
1/1/1997
1/1/2001
1/1/2005
1/1/2009
1/1/2013
1/1/2017
Date
29S/25E 18B01
29S/25E 23J01
29S/25E 20J
29S/25E 11G01


Nitrate Concentration in Wells Within RRBWSD (West of Superior)
(mg/l)
60
50
40
30
20
10
0
1/1/1989
1/1/1993
1/1/1997
1/1/2001
1/1/2005
1/1/2009
1/1/2013
1/1/2017
Date
MCL
29S/25E 23J01
29S/25E 20J
29S/25E 18B01
29S/25E 11G01


Arsenic Concentration in Wells Within RRBWSD (West of Superior)
(ug/l)
40
35
30
25
20
15
10
5
0
1/1/1989
1/1/1993
1/1/1997
1/1/2001
1/1/2005
1/1/2009
1/1/2013
1/1/2017
Date
MCL
29S/25E 23J01
29S/25E 20J
29S/25E 18B01
29S/25E 11G01


DBCP Concentration in Wells Within RRBWSD (West of Superior)
(ug/l)
2.5
2
1.5
1
0.5
0
1/1/1989
1/1/1993
1/1/1997
1/1/2001
1/1/2005
1/1/2009
1/1/2013
1/1/2017
Date
MCL
29S/25E 20J
29S/25E 11G01

APPENDIX D

WATER-BUDGET INFORMATION

SEMITROPIC WATER STORAGE DISTRICT

Original Bank

Existing Contracts	Contract Storage Capacity (AF)	Firm Recovery Capacity (AF/Year)	Entitlement Exchange (AF/Year) Min - Max		Effective Date of Agreement/ Amendment
Metropolitan Water District of Southern California	350,000	31,500	0 - 46,550	35%	December 12, 1994 May 6, 2003
Santa Clara Valley Water District	350,000	31,500	0 - 46,550	35%	June 1, 1997 April 24, 2003
Alameda County Water District	150,000	13,500	0 - 19,950	15%	July 1, 1997 Sept 28, 2001 April 24, 2003
Zone 7 Water Agency	65,000	5,850	0 - 8,645	7%	January 28, 1998 February 26, 2003
Newhall Land and Farming Co.	55,000	4,950	0 - 7,315	6%	May 21, 2001 February 26, 2003
San Diego County Water Authority	30,000	2,700	0 - 3,990	3%	October 8, 1998 May 21, 2001 Sept. 28, 2001 February 26, 2003 July 1, 2005
Total Subscription	**1,000,000**	**90,000**		**100%**	
Program Capacity	**1,000,000**	**90,000**	**0 - 133,000**		

Stored Water Recovery Unit, Area A

Existing Contracts	Contract Storage Capacity (AF)	Firm Recovery Capacity (AF/Year)		Effective Date of Agreement/ Amendment
Zone 7 Water Agency	9,750	3,250	7%	January 12, 2005
Poso Creek Water Company, LLC	60,000	20,000	40%	April 23, 2007
San Diego County Water Authority	4,500	1,500	3%	July 1, 2008
City of Tracy	10,500	3,500	7%	November 16, 2010
Homer, LLC	15,000	5,000	10%	October 1, 2012
Harris Farms, Inc	10,500	3,500	7%	November 15, 2013
Shows Family Farms, LP	300	100	0%	Sept. 10, 2014
Metropolitan Water District (Increased Recovery)		8,200	16%	Interim Recovery Agreement, December 18, 2014
Total Subscription	**110,550**	**45,050**	**90%**	
Program Capacity	**150,000**	**50,000**		
Remaning Capacity	**39,450**	**4,950**		

Stored Water Recovery Unit, Area B

Existing Contracts	Contract Storage Capacity (AF)	Firm Recovery Capacity (AF/Year)	Effective Date of Agreement/ Amendment
San Diego County Water Authority	15,000	5,000	August 20, 2008
Total Subscription	**15,000**	**5,000**	
Program Capacity	**450,000**	**150,000**	
Remaning Capacity	**435,000**	**145,000**	

SUMMARY OF INFLOWS, GROUNDWATER PUMPING, DELIVERIES, AND OUTFLOWS

(values in acre-feet unless noted otherwise)

	2007	2008	2009	2010	2011	2012	2013	2014
(+) Diverted from CA Aqueduct	99,892	18,670	19,967	202,455	337,139	200,366	46,285	5,748
Semitropic No. 1 (Parshall Flume)	33,347	12,403	19,716	67,071	157,174	87,612	34,437	4,884
Semitropic No. 2 (Penstock)	66,225	6,267	0	65,826	51,604	53,453	10,746	0
Semitropic No. 3	320	0	251	69,558	128,361	59,301	1,102	864
(+) Diverted from Main Drain	5,353	1,469	731	3,539	9,061	3,942	202	
(+) Inflow from P-565 Connection with North Kern		4,303	2,975		526			314
(+) Inflow from Diltz Intertie with Shafter-Wasco		2,162	3,061		539	601		1,443
(+) Poso Creek (Sec. 215 water)					5,785			
(=) Subtotal Inflow to District	**105,245**	**26,604**	**26,733**	**205,994**	**353,050**	**204,909**	**46,487**	**7,505**
(+) District Wells	46,467	56,240	66,532	10,614	0	16	44,141	82,221
(+) Pumping Agreement Wells	71,332	82,233	65,136	0	0	0	60,911	57,860
(=) Subtotal Groundwater Supplies (In-District)	**117,799**	**138,473**	**131,668**	**10,614**	**0**	**16**	**105,052**	**140,081**
Total Water Supplies	**223,044**	**165,077**	**158,401**	**216,608**	**353,050**	**204,925**	**151,539**	**147,586**
(+) Contract	78,334	65,831	57,984	80,849	109,268	89,706	53,778	20,387
(+) Non-Contract	64,268	786	2,427	103,376	205,451	94,147	10,620	4,483
(+) SAW	310	5,087	5,418	400	0	4,594	7,870	9,874
(+) Emergency (& Trans)	2,746	822	1,650	963	1,251	3,577	2,915	2,924
(=) Deliveries to Farm Turnouts	**145,658**	**72,526**	**67,479**	**185,587**	**315,970**	**192,024**	**75,183**	**37,667**
(+) Deliveries to Spreading (PPSG)	712	92	2	12,853	18,953	212	0	0
(+) Deliveries to Duck Clubs	150	0	0	952	1,394	119	0	0
(+) Deliveries to KNWR ("Refuge")	0	26	23	20	493	0	0	1,697
(=) Subtotal Deliveries inside Semitropic	**146,519**	**72,644**	**67,504**	**199,413**	**336,811**	**192,355**	**75,183**	**39,364**
(+) CA Aqueduct Pump-In	55,492	84,062	78,067	116	0	0	64,651	91,302
Semitropic No. 2 (Penstock)	31,546	41,094	36,103		0	0	32,140	46,308
Semitropic No. 3	23,946	42,968	41,964	116	0	0	32,511	44,994
(+) Outflow via P-565 Connection with North Kern								
(+) Outflow via Diltz Intertie with Shafter-Wasco				596				
(+) Outflow via Belridge 1A			728					
(=) Subtotal Outflow from District	**55,492**	**84,062**	**78,795**	**712**	**0**	**0**	**64,651**	**91,302**
Total Deliveries	**202,011**	**156,706**	**146,299**	**200,124**	**336,811**	**192,355**	**139,834**	**130,666**
Implied "Losses" (Supplies minus Deliveries)	**21,033**	**8,371**	**12,102**	**16,484**	**16,239**	**12,570**	**11,704**	**16,919**
	9%	5%	8%	8%	5%	6%	8%	11%

Source: Summary of flows into and out of SWSD from Dispatch program (Latis).

ACRES OF IRRIGATED CROPS AND OTHER LAND USES
SEMITROPIC WATER STORAGE DISTRICT
(values in acres)

CROP	2011	2012	2013	2014
Alfalfa	21,009	22,726	21,808	20,987
Cotton	9,530	6,860	4,811	4,516
Duck Pond	10,513	10,452	10,295	10,295
Fruits	2,001	2,089	2,048	1,397
Grain/Pasture	22,108	20,674	20,083	18,743
Grapes	4,743	5,344	5,639	5,915
Nursery	159	70	310	254
Nut Crops	62,086	64,254	66,994	69,355
Vegetables	4,420	4,028	4,558	3,817
Unidentified Crop	1,088	150	96	20
Waste & Miscellaneous Land	13,505	12,564	11,709	12,874
Exempt lands		9,934	11,146	11,146
Undeveloped Native Vegetation	71,124	62,275	61,921	62,101
TOTALS	**222,287**	**221,419**	**221,419**	**221,419**

Source: District land use survey.

NORTH KERN WATER STORAGE DISTRICT

North Kern Water Storage District

Annual Crop Surveys
(values in gross acres)

Crop Type	*2011*	*2012*	*2013*	*2014*
Alfalfa	1,701	2,146	3,688	3,653
Citrus	0	442	341	341
Corn	139	180	140	0
Cotton	2,037	3,815	1,546	612
Field Crops	0	0	0	0
Fruits	2,379	1,217	1,217	1,314
Grapes	6,783	6,274	6,453	6,569
Nursery	1,222	1,216	1,759	1,785
Nuts	36,721	37,836	38,818	38,994
Small Grains	858	629	450	751
Vegetables	1,561	1,778	1,182	1,224

Totals:				
All Crops	53,399	55,533	55,594	55,242
Perm. Crops	45,883	45,769	46,829	47,218

NORTH KERN WATER STORAGE DISTRICT

(values in acre-feet)

Calendar Year	Deliveries to Irrigation			District Well Production	Net Surface Supply	Deliveries to Spreading
	Class 1	Class 2	Total			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1995	76,904	47,969	124,873	0	367,136	202,581
1996	89,762	51,019	140,781	0	262,014	86,428
1997	78,857	56,800	135,657	0	272,997	106,187
1998	53,696	41,439	95,135	0	359,829	240,830
1999	75,250	34,873	110,123	0	171,869	30,645
2000	85,017	33,400	118,417	17,837	133,469	4,669
2001	84,346	22,164	106,510	60,582	75,408	0
2002	90,281	21,881	112,162	66,678	66,096	2,099
2003	83,433	24,432	107,865	20,647	110,236	897
2004	86,493	36,238	122,731	55,509	109,644	13,683
2005	84,018	54,735	138,753	0	288,879	104,884
2006	80,587	59,452	140,039	1,922	331,933	159,813
2007	83,103	50,850	133,953	99,760	87,325	30,151
2008	92,978	57,010	149,988	93,625	79,705	2,487
2009	91,711	55,948	147,659	100,029	85,962	13,083
2010	78,807	54,723	133,530	6,448	200,825	19,143
2011	75,723	61,809	137,532	0	387,207	203,179
2012	86,256	59,875	146,131	107,429	79,783	7,312
2013	84,521	47,712	132,233	140,551	229	1,029
2014	84,893	38,281	123,174	132,150	1,888	3,733
Avg (1995-2014)	**82,332**	**45,531**	**127,862**	**45,158**	**173,622**	**61,642**

Column Notes:

(2), (3), and (4) Includes surface water and District-pumped groundwater.

(5) Includes use of District wells to return previously banked water.

(6) Total surface supply less losses and deliveries outside District (deliveries outside District include pumped groundwater).

(7) Does not include incidental recharge from operation of the District's distribution system. Included in net surface supply.

NORTH KERN WATER STORAGE DISTRICT

Quantities in acre-feet

Year: 2011

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
NKWSD River Entitlement	+	24,459	14,943	20,586	41,194	44,297	47,824	24,544	8,887	6,855	7,161	4,610	1,020	246,380
Release	+ or -	8,341	7,517	12,795	2,806	2,503	18	0	0	10,427	12,913	17,288	19,519	94,127
ENTITLEMENT + OR - RELEASE	=	**32,800**	**22,460**	**33,381**	**44,000**	**46,800**	**47,842**	**24,544**	**8,887**	**17,282**	**20,074**	**21,898**	**20,539**	**340,507**
From KRC & Irr. Company	+	782	2	845	2,494	2,864	2,786	1,132	258	0	0	0	0	11,163
From City of Bakersfield	+	0	0	0	0	0	5,000	5,000	10,000	0	0	0	0	20,000
From Isabella Reservoir Storage	+	8,148	5,197	2,231	8,442	7,050	6,307	27,879	15,392	10,126	16,879	0	0	107,651
From Improvement District No. 4	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Buena Vista WSD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Kern Delta WD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
To City of Bakersfield	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Improvement District #4	-	0	1,886	0	0	0	0	0	0	0	0	0	0	1,886
To Cawelo WD	-	1,319	996	0	0	1,666	1,152	5,324	2,747	0	0	0	1,073	14,277
To Kern Delta WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Into Isabella Reservoir Storage	-	11,623	4,266	17,431	19,955	5,371	6,791	4,056	9,862	2,646	0	11,519	10,750	104,270
Other	+ or -	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DIVERTED FROM RIVER	=	**28,788**	**20,511**	**19,026**	**34,981**	**49,677**	**53,992**	**49,175**	**21,928**	**24,762**	**36,953**	**10,379**	**8,716**	**358,888**
Loss to Seventh Standard Line	-	61	56	61	60	61	60	61	61	60	61	60	61	723
NKWSD Deep Well Production	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-District Deep Well Production	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Poso Creek Natural Flow	+	0	1,014	4,699	5,524	903	83	0	0	0	0	0	0	12,223
Friant-Kern Inflow to Poso Creek	+	0	0	66	0	1,609	2,504	0	0	0	0	1,095	0	5,274
Friant-Kern Inflow to 8-1-0 Lateral	+	0	0	2,707	0	1,949	163	1,507	3,294	600	588	11,442	6,373	28,623
Rosedale Ranch Improvement District	-	926	589	579	119	238	222	222	222	67	762	571	369	4,886
Semitropic WSD via Poso Creek	-	0	0	0	16	1,609	2,504	0	0	0	0	0	0	4,129
CVC Conduit "A" Inflow	+	0	0	0	0	0	165	0	0	0	0	0	0	165
TOTAL DISTRICT SUPPLY	=	**27,801**	**20,880**	**25,858**	**40,310**	**52,230**	**54,121**	**50,399**	**24,939**	**25,235**	**36,718**	**22,285**	**14,659**	**395,435**
Class 1 Irrigation Deliveries	+	149	1,972	2,523	5,280	11,532	13,658	15,102	12,298	6,561	3,112	2,707	829	75,723
Class 2 Irrigation Deliveries	+	87	1,793	1,571	4,681	9,590	11,072	12,248	9,975	6,351	1,866	1,984	591	61,809
Semitropic WSD Irrigation Deliveries	+	0	0	0	0	0	0	0	82	0	0	42	0	124
Shafter-Wasco ID Irrigation Deliveries	+	0	0	48	119	0	0	0	222	0	0	18	0	407
To KRC & Irr. Company	-	0	0	0	0	0	0	0	0	0	0	105	0	105
Friant-Kern Canal Pump-In Deliveries	+	0	0	0	0	1,949 ?	0	0	0	0	0	0	5,643 ?	7,592 ?
TOTAL IRRIGATION USE	=	**236**	**3,765**	**4,142**	**10,080**	**23,071**	**24,730**	**27,350**	**22,577**	**12,912**	**4,978**	**4,856**	**7,063**	**145,760**
District Spreading Ponds (Kern)	+	22,177	12,629	11,427	19,392	19,216	19,779	16,770	0	7,146	23,859	5,756	6,218	164,369
District Spreading Ponds (Other)	+	0	0	2,235	0	0	0	0	0	0	588	9,917	5,643	18,383
Poso Creek Spreading (Kern)	+	66	323	1,426	591	1,049 ?	1,371	2,315	0	494	2,460	1,103	557	11,755
Poso Creek Spreading (Other)	+	0	0	66	3,679	3,679	0	0	0	0	0	1,248	0	8,672
TOTAL DISTRICT SPREADING	=	**22,243**	**12,952**	**15,154**	**23,662**	**23,944**	**21,150**	**19,085**	**0**	**7,640**	**26,907**	**18,024**	**12,418**	**203,179**
TOTAL DISTRICT USE		**22,479**	**16,717**	**19,296**	**33,742**	**47,015**	**45,880**	**46,435**	**22,577**	**20,552**	**31,885**	**22,880**	**19,481**	**348,939**
Total NKWSD Canal Loss		5,322	4,163	6,562	6,568	5,215	8,241	3,964	2,362	4,683	4,833	5,523	1,653	59,089 ? ?
												-595	-4821	
Into Reservoir Storage		11,623	4,266	17,431	19,955	5,371	6,791	4,056	9,862	2,646	0	11,519	10,750	104,270
Reservoir Evaporation Loss		538	492	647	1,122	1,308	1,726	1,747	1,640	1,295	802	802	480	12,599
From Reservoir Storage		8,148	5,197	2,231	8,442	7,050	6,307	27,879	15,392	10,126	16,879	0	200	107,651
END OF MONTH RESERVOIR STORAGE		**78,863**	**77,440**	**91,993**	**102,384**	**99,397**	**98,155**	**72,585**	**65,415**	**56,640**	**38,959**	**67,357**	**60,061**	
												49,676 ?	59,746 ?	

NORTH KER. .ATER STORAGE DISTRICT

Quantities in acre-feet

Year: 2012

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
NKWSD River Entitlement	+	3,633	2,439	111	7,854	8,408	146	0	0	0	0	0	0	22,591
Release	+ or -	11,455	4,513	3,426	3,976	496	0	0	0	177	548	5,257	13,020	42,868
ENTITLEMENT + OR - RELEASE	=	**15,088**	**6,952**	**3,537**	**11,830**	**8,904**	**146**	**0**	**0**	**177**	**548**	**5,257**	**13,020**	**65,459**
From KRC & Irr. Company	+	36	0	0	342	289	0	0	0	0	0	0	0	667
From City of Bakersfield	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Isabella Reservoir Storage	+	1,497	2,214	1,537	155	3,007	13,242	19,687	11,652	1,052	1,429	397	825	56,694
From Improvement District No. 4	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Buena Vista WSD	+	0	0	0	0	0	0	0	0	0	0	0	4	4
From Kern Delta WD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
To City of Bakersfield	-	1,003	571	0	0	0	0	0	0	0	0	0	0	1,574
To Improvement District #4	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Cawelo WD	-	522	0	0	0	0	0	2,317	2,509	232	0	0	0	5,580
To Kern Delta WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Into Isabella Reservoir Storage	-	4,832	612	67	7,921	3,831	0	0	0	0	18	1,832	2,387	21,500
Other	+ or -	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DIVERTED FROM RIVER	=	**10,264**	**7,983**	**5,007**	**4,406**	**8,369**	**13,388**	**17,370**	**9,143**	**997**	**1,959**	**3,822**	**11,462**	**94,170**
Loss to Seventh Standard Line	-	36	58	61	60	61	60	61	61	60	44	48	61	671
NKWSD Deep Well Production	+	0	1,121	6,054	9,717	13,388	15,139	15,554	15,251	14,229	13,170	3,806	0	107,429
Non-District Deep Well Production	+	61	0	107	1,670	2,628	3,654	3,876	2,142	286	0	0	0	14,424
Poso Creek Natural Flow	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Friant-Kern Inflow to Poso Creek	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Friant-Kern Inflow to 8-1-0 Lateral	+	0	1,524	0	0	0	0	0	0	0	0	0	0	1,524
Rosedale Ranch Improvement District	-	48	0	0	0	0	0	0	0	0	0	0	0	48
Semitropic WSD via Poso Creek	-	0	0	0	0	0	0	0	0	0	0	0	0	0
CVC Conduit "A" Inflow	+	0	0	0	0	0	0	0	250	2,509	2,061	0	0	4,820
TOTAL DISTRICT SUPPLY	=	**10,241**	**10,570**	**11,107**	**15,733**	**24,324**	**32,121**	**36,739**	**26,725**	**17,961**	**17,146**	**7,580**	**11,401**	**221,648**
Class 1 Irrigation Deliveries	+	1,622	3,765	5,076	6,150	10,368	14,565	14,690	11,486	7,014	7,617	2,977	926	86,256
Class 2 Irrigation Deliveries	+	1,192	3,662	3,489	4,708	7,456	9,344	10,078	7,236	5,292	4,092	2,059	1,267	59,875
NKWSD to K-T via FK Irrigation Deliveries	+	0	0	508	1,288	1,061	1,209	1,182	1,113	0	0	0	0	6,361
NKWSD to DEID via FK Irrigation Deliveries										442	0	0	0	442
Shafter-Wasco ID Irrigation Deliveries	+	0	159	292	663	968	2,454	4,405	2,753	1,027	456	0	0	13,177
To KRC & Irr. Company	-	0	32	0	0	0	0	0	0	0	0	0	0	32
Friant-Kern Canal Pump-In Deliveries	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL IRRIGATION USE	=	**2,814**	**7,618**	**9,365**	**12,809**	**19,853**	**27,572**	**30,355**	**22,588**	**13,775**	**12,165**	**5,036**	**2,193**	**166,143**
District Spreading Ponds (Kern)	+	2,955	270	0	0	0	0	0	0	0	0	234	2,867	6,326
District Spreading Ponds (Other)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Poso Creek Spreading (Kern)	+	40	0	0	0	0	0	0	0	0	0	317	629	986
Poso Creek Spreading (Other)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DISTRICT SPREADING	=	**2,995**	**270**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**551**	**3,496**	**7,312**
TOTAL DISTRICT USE		**5,809**	**7,888**	**9,365**	**12,809**	**19,853**	**27,572**	**30,355**	**22,588**	**13,775**	**12,165**	**5,587**	**5,689**	**173,455**
Total NKWSD Canal Loss		4,432	2,682	1,742	2,924	4,471	4,549	6,384	4,137	4,186	4,981	1,993	5,712	48,193
Into Reservoir Storage		4,832	612	67	7,921	3,831	0	0	0	0	18	1,832	2,387	21,500
Reservoir Evaporation Loss		464	541	704	875	1,420	1,555	1,427	936	615	420	244	173	9,374
From Reservoir Storage		1,497	2,214	1,537	155	3,007	13,242	19,687	11,652	1,052	1,429	397	825	56,694
END OF MONTH RESERVOIR STORAGE		**62,932**	**60,789**	**58,615**	**65,506**	**64,910**	**50,113**	**28,999**	**16,411**	**14,744**	**12,913**	**14,104**	**15,493**	

NORTH KERN \ :R STORAGE DISTRICT

Quantities in acre-feet

Year: 2013

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
NKWSD River Entitlement	+	395	0	0	125	610	60	4	0	0	0	0	0	1,194
Release	+ or -	6,751	65	99	110	0	0	0	140	0	0	3,256	6,237	16,658
ENTITLEMENT + OR - RELEASE	=	**7,146**	**65**	**99**	**235**	**- 610**	**60**	**4**	**140**	**0**	**0**	**3,256**	**6,237**	**17,852**
From KRC & Irr. Company	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From City of Bakersfield	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Isabella Reservoir Storage	+	2,505	4,244	0	906	0	2,507	1,830	0	0	0	37	0	12,029
From Improvement District No. 4	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Buena Vista WSD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Kern Delta WD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
To City of Bakersfield	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Improvement District #4	-	6,774	4,039	0	0	0	0	0	0	0	0	0	0	10,813
To Cawelo WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Kern Delta WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Into Isabella Reservoir Storage	-	448	0	0	34	610	60	4	90	0	0	3,172	5,781	10,199
Other	+ or -	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DIVERTED FROM RIVER	=	**2,429**	**270**	**99**	**1,107**	**0**	**2,507**	**1,830**	**50**	**0**	**0**	**121**	**456**	**8,869**
Loss to Seventh Standard Line	-	36	10	1	11	61	60	58	18	0	0	10	44	309
NKWSD Deep Well Production	+	0	8,218	11,446	17,865	18,613	19,250	19,148	15,786	12,593	10,983	6,022	627	140,551
Non-District Deep Well Production	+	0	0	292	2,083	4,834	5,282	5,695	5,068	3,606	2,475	0	0	29,335
Poso Creek Natural Flow	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Friant-Kern Inflow to Poso Creek	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Semitropic WSD to NKWSD via FK/8-1	+	0	0	0	0	0	0	2,266	707	0	0	0	0	2,973
Rosedale Ranch Improvement District	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Semitropic WSD via Poso Creek	-	0	0	0	0	0	0	0	0	0	0	0	0	0
CVC Conduit "A" Inflow	+	0	0	0	46	4,098	1,910	1,853	565	0	0	0	0	8,472
TOTAL DISTRICT SUPPLY	=	**2,393**	**8,478**	**11,836**	**21,090**	**27,484**	**28,889**	**30,734**	**22,158**	**16,199**	**13,458**	**6,133**	**1,039**	**189,891**
Class 1 Irrigation Deliveries	+	440	1,940	3,714	9,072	12,163	13,652	15,485	10,820	6,847	6,498	3,263	627	84,521
Class 2 Irrigation Deliveries	+	365	1,989	3,191	5,225	7,652	7,803	7,438	5,516	3,985	2,944	1,412	192	47,712
NKWSD to K-T via FK Irrigation Deliveries	+	0	0	0	0	1,061	994	480	359	1,080	635	0	0	4,609
NKWSD to DEID via FK Irrigation Deliveries	+	0	977	1,338	1,182	0	0	0	0	0	607	0	0	4,104
Shafter-Wasco ID Irrigation Deliveries	+	0	760	181	900	1,403	306	988	1,577	1,352	1,027	409	0	8,903
NKWSD to Cawelo	-		0	0	0	0	0	1,216	270	0	674	0	0	2,160
To KRC & Irr. Company	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Friant-Kern Canal Pump-In Deliveries	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL IRRIGATION USE	=	**805**	**5,666**	**8,424**	**16,379**	**22,279**	**22,755**	**- 23,175**	**18,002**	**13,264**	**11,037**	**5,084**	**819**	**147,689**
District Spreading Ponds (Kern)	+	914	0	0	0	0	0	0	0	0	0	0	0	914
District Spreading Ponds (Other)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Poso Creek Spreading (Kern)	+	115	0	0	0	0	0	0	0	0	0	0	0	115
Poso Creek Spreading (Other)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DISTRICT SPREADING	=	**1,029**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1,029**
TOTAL DISTRICT USE		**1,834**	**5,666**	**8,424**	**16,379**	**22,279**	**22,755**	**23,175**	**18,002**	**13,264**	**11,037**	**5,084**	**819**	**148,718**
Total NKWSD Canal Loss		559	2,812	3,412	4,711	5,205	6,134	7,559	4,156	2,935	2,421	1,049	220	41,173
Into Reservoir Storage		448	0	0	34	610	60	4	90	0	0	3,172	5,781	10,199
Reservoir Evaporation Loss		187	153	198	224	252	307	206	194	177	149	126	176	2,349
From Reservoir Storage		2,505	4,244	0	906	0	2,507	1,830	0	0	0	37	0	12,029
END OF MONTH RESERVOIR STORAGE		**13,249**	**8,852**	**8,654**	**7,558**	**7,916**	**5,162**	**3,130**	**3,026**	**2,849**	**2,700**	**5,709**	**11,314**	

NORTH KERN WATER STORAGE DISTRICT

Quantities in acre-feet

Year: 2014

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
NKWSD River Entitlement	+	0	252	0	0	388	79	0	8	0	0	0	0	727
Release	+ or -	369	26	1,070	2,687	793	0	0	0	0	0	1,900	7,258	14,103
ENTITLEMENT + OR - RELEASE	=	**369**	**278**	**1,070**	**2,687**	**1,181**	**79**	**0**	**8**	**0**	**0**	**1,900**	**7,258**	**14,830**
From KRC & Irr. Company	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From City of Bakersfield	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Isabella Reservoir Storage	+	22	97	0	510	817	2,731	6,590 2,872	66	0	0	0	533	11,366 1,640
From Improvement District No. 4	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Buena Vista WSD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Kern Delta WD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
To City of Bakersfield	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Improvement District #4	-	0	0	0	0	0	166	0	0	0	0	0	0	166
To Cawelo WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Kern Delta WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Into Isabella Reservoir Storage	-	369	234	320	324	215	18	0	8	0	0	1,685	843	4,016
Other	+ or -	0	0	0	0	0	0	2,872	0	0	0	0	4	4
TOTAL DIVERTED FROM RIVER	=	**22**	**141**	**750**	**2,873**	**1,783**	**2,626**	**6,590**	**66**	**0**	**0**	**215**	**6,952**	**22,018** 15,300
Loss to Seventh Standard Line	-	2	6	18	59	42	60	49	2	0	0	0	0	238
NKWSD Deep Well Production	+	4,033	9,404	8,472	12,720	16,459	17,823	17,213	13,020	13,020	13,196	5,072	1,718	132,150
Non-District Deep Well Production	+	0	0	0	1,787	6,015	5,679	6,633	5,207	4,374	1,700	30	0	31,425
Poso Creek Natural Flow	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Friant-Kern Inflow to Poso Creek	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Cawelo to NKWSD	+	821	0	1,561	26	0	0	0	0	0	0	0	0	2,408
Semitropic WSD to NKWSD via FK/8-1	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Rosedale Ranch Improvement District	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Semitropic WSD via Poso Creek	-	0	0	0	0	0	0	0	0	0	0	0	0	0
CVC Conduit "A" Inflow	+	0	0	0	0	0	613	85	26,754 0	0	0	0	0	698
TOTAL DISTRICT SUPPLY	=	**4,874**	**9,539**	**10,765**	**17,347**	**24,215**	**26,681**	**30,472**	**18,291**	**17,394**	**14,896**	**5,317**	**8,670**	**188,461** 184,743

Class 1 Irrigation Deliveries	+	1,162	3,229	4,354	8,539	12,286	14,628	15,295	9,320	8,045	6,274	1,539	222	84,893
Class 2 Irrigation Deliveries	+	526	2,105	2,634	4,225	5,113	5,530	6,589	3,890	3,830	2,910	760	169	38,281
NKWSD to K-T via FK Irrigation Deliveries	+	0	573	773	1,229	1,527	998	910	1,209	381	492	381	0	8,473
NKWSD to DEID via FK Irrigation Deliveries	+	1,089	1,155	0	0	0	0	0	0	985	1,159	726	0	5,114
Shafter-Wasco ID Irrigation Deliveries	+	21	897	373	653	954	202	151	262	303	234	143	0	4,193
OMW to K-Tulare	-	0	0	0	0	85	81	127	111	119	123	87	0	733
OMW to Cawelo	-	0	0	0	0	85	157	119	123	119	123	20	0	746
Nickel LLC to Cawelo	-	0	0	0	0	0	135	36	0	0	0	0	0	171
NKWSD to Cawelo	-	0	0	0	0	0	0	0	460	0	910	952	0	2,322
Shafter-Wasco ID to NKWSD	+	0	0	0	0	0	0	0	0	46	40	38	0	124
Friant-Kern Canal Pump-In Deliveries	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL IRRIGATION USE	=	**2,798**	**7,959**	**8,134**	**14,646**	**19,710**	**20,985**	**22,663**	**13,987**	**13,352**	**9,953**	**2,528**	**391**	**137,106**
District Spreading Ponds (Kern)	+	0	0	0	0	0	0	0	0	0	0	0	3,733	3,733
District Spreading Ponds (Other)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Poso Creek Spreading (Kern)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Poso Creek Spreading (Other)	+	0	0	0	0	0	0	0	4,091 0	0	0	0	0	0
TOTAL DISTRICT SPREADING	=	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3,733**	**3,733**
TOTAL DISTRICT USE		**2,798**	**7,959**	**8,134**	**14,646**	**19,710**	**20,985**	**22,663**	**13,987**	**13,352**	**9,953**	**2,528**	**4,124**	**140,839**
Total NKWSD Canal Loss		2,076	1,580	2,631	2,701	4,505	5,696	7,809	4,304	4,042	4,943	2,789	4,546	47,622 43,904

Into Reservoir Storage		369	234	320	324	215	18	0	8	0	0	1,685	843	4,016
Reservoir Evaporation Loss		238	208	319	402	434	426	276	232	198	163	119	97	3,112
From Reservoir Storage		22	97	0	510	817	2,731	2,872	66	0	0	0	533	11,366 7,648
END OF MONTH RESERVOIR STORAGE		**11,423**	**11,352**	**11,353**	**10,765**	**9,729**	**6,590**	**3,442**	**3,152**	**2,954**	**2,791**	**4,357**	**4,570**	

ROSEDALE-RIO BRAVO WATER
STORAGE DISTRICT

RRBWSD Groundwater Program Operations Report 1993-2014

Table 1 - Water Supplies For Rosedale-Rio Bravo Water Storage District

	Water Supply (Inflows)																			
	1. District Contractual Water Rights				2. District Water Purchases						3. District Programs (see Table 3 for details)					4. District Natural Inflows				
	a	b	c	d	a	b	c	d	e	f	a	b	c	d	e	a	b	c	d	
Year	Kern River Regulated Supply	SWP Table A Supply	Kern River Credited yet Undelivered Supplies	Subtotal (a + b + c)	SWP Article 21	SWP Pools	CVP Section 215	Purchased Groundwater	Short-term Purchases & Exchanges	Subtotal (a+b+c+d+e)	Gross Deliveries for Programs	Total to Program Accounts	Total Returned from Program Accounts	Total Program Account Balances	Gross Program Share for RRBWSD	Gross Useable Rainfall[1]	Unregulated Flood Flows[2]	Safe Yield[3]	Subtotal (a + b + c)	Total Supplies[4]
1993	26,890	29,810	-	56,700	-	25,826	5,859	-	1,000	32,685	23,000	15,333	-	15,333	7,667	23,680	-	12,683	36,363	133,415
1994	-	15,816	-	15,816	378	-	-	-	-	378	-	-	7,293	8,040	-	19,588	-	12,683	32,271	48,465
1995	87,383	29,900	-	117,283	7,858	-	693	-	(4,908)	3,643	29,515	19,677	-	27,717	9,838	27,522	2,992	12,683	43,198	173,962
1996	56,305	29,900	-	86,205	-	-	-	-	(6,690)	(6,690)	51,796	34,531	-	62,248	17,265	22,146	-	12,683	34,829	131,610
1997	59,226	29,900	-	89,126	-	-	-	-	(8,894)	(8,894)	39,054	29,861	11,476	80,633	9,193	16,316	20,793	12,607	49,716	139,141
1998	74,383	29,900	-	104,283	-	-	2,361	-	12,368	14,729	690	460	5,590	75,503	230	38,380	39,065	12,607	90,052	209,294
1999	14,787	29,900	-	44,687	3,790	30,000	-	-	219	34,009	3,187	3,187	29,753	48,937	-	16,948	-	12,607	29,555	108,251
2000	10,758	7,874	-	18,632	3,254	16,872	-	-	(8,071)	12,055	48,279	32,186	5,000	76,123	16,093	13,979	-	12,604	26,583	73,363
2001	3,972	2,943	-	6,915	691	122	-	9,130	8,718	18,661	4,037	2,146	3,733	74,536	1,808	20,785	-	12,601	33,385	60,770
2002	5,135	20,648	-	25,783	968	631	-	-	148	1,747	-	-	21,523	53,013	-	12,374	-	12,552	24,926	52,456
2003	7,576	27,077	-	34,653	838	255	-	-	-	1,093	25,143	21,810	23,030	51,792	3,333	14,736	-	12,552	27,287	66,367
2004	3,342	19,550	16,682	39,574	3,034	157	-	100,000	223	103,414	313	280	17,938	34,134	-	17,105	-	12,550	29,655	172,643
2005	56,017	26,475	-	82,492	3,807	587	-	-	4,134	8,528	215,077	136,490	3,943	166,680	67,897	24,599	-	12,529	37,128	196,045
2006	27,643	30,335	113	58,091	1,868	-	3,949	-	676	6,493	73,816	59,693	417	225,957	5,000	18,920	21,809	12,518	53,247	122,831
2007	7,783	17,122	85	24,990	552	145	-	10,000	(9,472)	1,225	8,200	29,323	44,103	211,176	-	9,051	-	12,518	21,569	47,784
2008	-	10,695	6,650	17,345	-	28	-	2,223	-	2,251	-	-	17,421	193,755	-	9,658	-	12,518	22,176	41,772
2009	-	12,044	3,505	15,549	-	48	-	5,792	(842)	4,998	4,633	4,170	14,818	183,107	-	15,385	-	12,506	27,891	48,438
2010	14,965	13,906	19,322	48,193	-	100	-	-	6,221	6,321	116,925	81,876	8,250	256,732	37,850	38,338	-	12,555	50,893	143,256
2011	35,776	6,144	966	42,886	4,355	527	11,954	-	34,874	51,710	181,287	127,412	11,000	373,144	51,753	13,617	-	12,555	26,172	172,521
2012	7,328	19,418	2,053	28,799	-	67	-	-	(571)	(504)	40,475	29,138	30,999	371,284	19,295	13,400	-	12,555	25,955	73,545
2013	-	23,852	10,000	33,852	-	1,607	-	25,000	-	26,607	-	-	44,194	327,090	-	10,311	-	12,728	23,039	81,683
2014	-	6,451	10,000	16,451	-	191	-	7,902	-	8,093	-	-	49,681	277,409	-	12,182	-	12,728	24,910	48,914
Total	499,269	439,670	69,376	1,008,315	31,393	77,163	24,816	160,047	29,133	322,552	865,427	627,571	350,162	3,194,342	247,222	409,022	84,659	277,121	770,803	2,346,526
Average	29,369	19,985	6,938	45,833	2,616	4,823	4,963	22,864	2,913	16,976	50,907	36,916	18,430	145,197	19,017	18,592	21,165	12,596	35,036	106,660
Median	9,271	20,099	-	37,114	465	134	-	-	-	6,407	15,600	17,505	11,238	78,378	2,571	16,632	-	12,578	29,605	94,967

Notes: 1. Effective precipitation calculated per method developed as a part of groundwater mediation process.
2. Unregulated flood flows include deliveries of floodwater from the Kern River and the Friant system.
3. Safe yield calculated based on 0.3 acre-feet/acre for total District gross (assessed) acres less non-farmed District owned lands.
4. Total supplies = 1d + 2f + 3e + 4d. Supplies do not include water banked for 3rd parties.

Table 2 - Water Demands & Balance For Rosedale-Rio Bravo Water Storage District

	Water Demands (Outflows)									Supplies (Inflows)	Balance			
	1. District Consumption			2. Other								Cumulative Groundwater Balance (End of Year)		
	a	b	c	a	b	c	d	e						
Year	Crop Use[1]	Urban Use[2]	Subtotal	Transfers	District ODC Losses[3]	Kern Fan Project Losses[4]	District Project Losses[4]	Subtotal	Total Demands [Col 1a+2d]	Total Water Supplies (Table 1)	Annual Balance (Change In Storage)	ODC Balance	Exportable Balance	Total Balance
1993	86,027	6,263	**92,290**	-	2,682	-	920	**3,602**	**95,892**	133,415	37,523	37,523		**37,523**
1994	83,373	6,452	**89,825**	-	267	-	-	**267**	**90,092**	48,465	(41,627)	(4,104)		**(4,104)**
1995	84,252	6,497	**90,749**	-	3,838	474	1,181	**5,493**	**96,242**	173,962	77,720	73,617		**73,617**
1996	83,861	6,542	**90,403**	-	2,564	931	2,072	**5,567**	**95,970**	131,610	35,639	109,256		**109,256**
1997	87,179	6,587	**93,766**	-	2,481	413	1,103	**3,997**	**97,763**	139,141	41,378	150,634		**150,634**
1998	88,808	6,631	**95,439**	-	4,187	776	28	**4,990**	**100,430**	209,294	108,865	259,499		**259,499**
1999	89,842	6,874	**96,716**	-	1,468	-	-	**1,468**	**98,184**	108,251	10,067	269,565		**269,565**
2000	86,634	7,117	**93,751**	-	771	1,400	1,931	**4,102**	**97,853**	73,363	(24,490)	245,075		**245,075**
2001	83,575	7,360	**90,935**	-	96	123	50	**270**	**91,204**	60,770	(30,435)	214,640		**214,640**
2002	81,138	7,603	**88,741**	-	122	117	-	**239**	**88,979**	52,456	(36,524)	178,117		**178,117**
2003	81,916	7,725	**89,641**	-	376	556	400	**1,332**	**90,973**	66,367	(24,606)	153,510		**153,510**
2004	81,707	7,877	**89,584**	-	251	-	-	**251**	**89,835**	172,643	82,808	136,318	100,000	**236,318**
2005	82,486	8,308	**90,794**	-	2,382	2,180	7,171	**11,732**	**102,527**	196,045	93,518	229,837	100,000	**329,837**
2006	83,284	8,454	**91,738**	-	2,223	638	338	**3,199**	**94,937**	122,831	27,893	235,921	121,809	**357,730**
2007	76,112	8,797	**84,909**	-	271	-	-	**271**	**85,180**	47,784	(37,396)	198,525	121,809	**320,334**
2008	79,624	8,703	**88,327**	3,000	-	-	330	**3,330**	**91,657**	41,772	(49,885)	151,640	118,809	**270,449**
2009	84,177	8,809	**92,986**	3,000	-	-	330	**3,330**	**96,316**	48,438	(47,877)	106,763	115,809	**222,572**
2010	86,748	8,825	**95,573**	-	828	231	2,322	**3,381**	**98,954**	143,256	44,302	151,065	115,809	**266,874**
2011	83,478	8,518	**91,996**	-	2,021	1,537	5,555	**9,113**	**101,109**	172,521	71,412	204,124	134,162	**338,286**
2012	84,621	8,518	**93,139**	4,000	284	67	2,392	**6,743**	**99,882**	73,545	(26,338)	181,786	130,162	**311,948**
2013	85,964	8,539	**94,503**	16,500	-	-	1,815	**18,315**	**112,818**	81,683	(31,134)	167,152	113,662	**280,814**
2014	87,465	8,539	**96,004**	5,000	-	-	550	**5,550**	**101,554**	48,914	(52,639)	119,511	108,664	**228,175**
Total	1,852,271	169,539	2,021,810	31,500	27,111	9,443	28,488	96,542	2,118,352	2,346,526				
Average	84,194	7,706	91,584	6,300	1,506	726	1,676	4,388	96,289	106,660				
Median	84,019	7,801	91,867	-	574	120	475	3,491	96,279	94,967				

Notes:
1. Crop use calculated per method developed as a part of groundwater mediation process (Cal Poly method).
2. Urban consumptive use estimated based on 1.2 acre-feet/net acre.
3. Losses are assessed at 3% per MOU on surface water deliveries for District recharge not a part of other programs.
4. Losses for banked water and for surface diversions for District use associated with banking programs are assessed per MOU. See Tables 3 and 4.

SUMMARY OF 2011 RRBWSD OPERATIONS

Quantities in Acre-feet

Est. Consumptive Use (2011 crop survey) =	72,400
Estimated Applied Water (75% Effic.) =	96,500
Estimated Diversions =	-16,700
Estimated Groundwater Pumping =	**79,800**
Total Deliveries to District =	276,700
Direct Recharge =	260,000
Applied Water - Consumptive Use =	24,100
Total Replenishment =	**284,100**
Replenishment Less Pumping =	**204,300**

(Subsurface inflow/outflow not considered)

SUMMARY OF 2012 RRBWSD OPERATIONS

Quantities in Acre-feet

Est. Consumptive Use (2012 crop survey) =	73,600
Estimated Applied Water (75% Effic.) =	98,100
Estimated Diversions =	0
Estimated Groundwater Pumping =	**98,100**
Total Deliveries to District =	37,600
Direct Recharge =	37,600
Applied Water - Consumptive Use =	24,500
Total Replenishment =	**62,100**
Replenishment Less Pumping =	**-36,000**

(Subsurface inflow/outflow not considered)

SUMMARY OF 2013 RRBWSD OPERATIONS

Quantities in Acre-feet

Est. Consumptive Use (2013 crop survey) =	74,600
Estimated Applied Water (75% Effic.) =	99,500
Estimated Diversions =	0
Banked Water Recovery =	35,200
Estimated Groundwater Pumping =	**134,700**
Total Deliveries to District =	0
Direct Recharge =	0
Applied Water - Consumptive Use =	24,900
Total Replenishment =	**24,900**
Replenishment Less Pumping =	**-109,800**

(Subsurface inflow/outflow not considered)

SUMMARY OF 2014 RRBWSD OPERATIONS

Quantities in Acre-feet

Est. Consumptive Use (2014 crop survey) =	76,300
Estimated Applied Water (75% Effic.) =	101,700
Estimated Diversions =	0
Banked Water Recovery =	47,900
Estimated Groundwater Pumping =	**149,600**
Total Deliveries to District =	0
Direct Recharge =	0
Applied Water - Consumptive Use =	25,400
Total Replenishment =	**25,400**
Replenishment Less Pumping =	**-124,200**

(Subsurface inflow/outflow not considered)

SOUTHERN SAN JOAQUIN MUNICIPAL
UTILITY DISTRICT

Summary Report by Crop

Date: Monday, February 28, 2011

Crop	Acreage
Alfalfa	2373.000 ac
Almonds	14169.500 ac
Berries,except Straw	61.000 ac
Cherries	393.000 ac
Corn	39.000 ac
Cotton	135.000 ac
Fallow	694.000 ac
Grapes	5155.500 ac
Hay - Other	653.000 ac
Kiwi	73.000 ac
Lemons and Limes	10.000 ac
Mandarins	99.000 ac
Naval Oranges	4077.500 ac
Nothing	836.000 ac
Oats	261.000 ac
Other fruits	8.000 ac
Pasture	25.000 ac
Pecans	394.000 ac
Pistachios	4519.000 ac
Raisin Grapes	212.000 ac
Roses	312.000 ac
Silage	135.000 ac
Sudan	97.000 ac
Table Grapes	10662.000 ac
Tomatoes	156.000 ac
Valencia Oranges	721.500 ac
Vegetables,other	176.000 ac
Walnuts	398.000 ac
Wheat	692.000 ac
Wine Grapes	128.000 ac
Grand Total:	**47665.000 ac**

Summary Report by Crop

Date: Wednesday, February 29, 2012

Crop	Acreage
Alfalfa	2429.000 ac
Almonds	14094.500 ac
Berries,except Straw	61.000 ac
Cherries	273.000 ac
Corn	39.000 ac
Cotton	135.000 ac
Fallow	657.400 ac
Grapes	5155.500 ac
Hay - Other	574.000 ac
Kiwi	73.000 ac
Lemons and Limes	10.000 ac
Mandarins	99.000 ac
Naval Oranges	4002.500 ac
Nothing	807.000 ac
Oats	261.000 ac
Other fruits	8.000 ac
Pasture	45.000 ac
Pecans	394.000 ac
Pistachios	4854.000 ac
Raisin Grapes	212.000 ac
Roses	312.000 ac
Silage	80.000 ac
Sudan	97.000 ac
Table Grapes	10702.000 ac
Tomatoes	156.000 ac
Valencia Oranges	721.500 ac
Vegetables,other	176.000 ac
Walnuts	398.000 ac
Wheat	865.000 ac
Wine Grapes	128.000 ac
Grand Total:	**47819.400 ac**

Summary Report by Crop

Date: Thursday, February 28, 2013

Crop	Acreage
Alfalfa	2747.000 ac
Almonds	14362.500 ac
Berries,except Straw	61.000 ac
Cherries	273.000 ac
Cotton	135.000 ac
Fallow	657.400 ac
Grapefruit	10.000 ac
Grapes	5326.500 ac
Hay - Other	132.000 ac
Kiwi	48.000 ac
Lemons and Limes	10.000 ac
Mandarins	99.000 ac
Naval Oranges	4002.500 ac
Nothing	832.000 ac
Oats	261.000 ac
Other fruits	8.000 ac
Pasture	45.000 ac
Pecans	394.000 ac
Pistachios	4854.000 ac
Raisin Grapes	212.000 ac
Roses	312.000 ac
Sudan	97.000 ac
Table Grapes	10852.000 ac
Tomatoes	156.000 ac
Valencia Oranges	721.500 ac
Vegetables,other	176.000 ac
Walnuts	361.000 ac
Wheat	1101.000 ac
Wine Grapes	128.000 ac
Grand Total:	**48374.400 ac**

Summary Report by Crop

Date: Friday, February 28, 2014

Crop	Acreage
Alfalfa	2966.000 ac
Almonds	14325.500 ac
Berries,except Straw	61.000 ac
Cherries	273.000 ac
Cotton	135.000 ac
Fallow	657.400 ac
Grapefruit	10.000 ac
Grapes	5385.500 ac
Hay - Other	95.000 ac
Kiwi	48.000 ac
Lemons and Limes	10.000 ac
Mandarins	99.000 ac
Naval Oranges	3954.500 ac
Nothing	727.000 ac
Oats	182.000 ac
Other fruits	8.000 ac
Pasture	45.000 ac
Pecans	394.000 ac
Pistachios	4854.000 ac
Raisin Grapes	212.000 ac
Roses	391.000 ac
Sudan	97.000 ac
Table Grapes	11103.000 ac
Tomatoes	156.000 ac
Valencia Oranges	721.500 ac
Vegetables,other	176.000 ac
Walnuts	361.000 ac
Wheat	835.000 ac
Wine Grapes	128.000 ac
Grand Total:	**48410.400 ac**

SSJMUD WATER YEAR

WATER YEAR	WATER TYPE	AF
1965 - 1966	100% CL 2	147,000
1966 - 1967	23% CL 2	108,500
1967 - 1968	100% CL 2	147,000
1968 - 1969	92% CL 1	89,240
1969 - 1970	100% CL 2	147,000
1970 - 1971	29% CL 2	111,500
1971 - 1972	35% CL 2	114,500
1972 - 1973	4% CL 2	99,000
1973 - 1974	77% CL 2	135,500
1974 - 1975	82% CL 2	138,000
1975 - 1976	60% CL 2	127,000
1976 - 1977	75% CL 1	72,750
1977 - 1978	25% CL 1	24,250
1978 - 1979	100% CL 2	147,000
1979 - 1980	63% CL 2	128,500
1980 - 1981	100% CL 2	147,000
1981 - 1982	6% CL 2	100,000
1982 - 1983	100% CL 2	147,000
1983 - 1984	100% CL 2	147,000
1984 - 1985	50% CL 2	122,000
1985 - 1986	10% CL 2	102,000
1986 - 1987	100% CL 2	147,000
1987 - 1988	91% CL 1	88,270
1988 - 1989	78% CL 1	75,660
1989 - 1990	98% CL 1	95,060
1990 - 1991	68% CL 1	65,960
1991 - 1992	100% CL 1	97,000
1992 - 1993	83% CL 1	80,510
1993 - 1994	90% CL 2	142,000
1994 - 1995	80% CL 1	77,600
1995 - 1996	100% CL 2	147,000
1996 - 1997	58% CL 2	126,000
1997 - 1998	60% CL 2	127,000
1998 - 1999	100% CL2	147,000
1999 - 2000	10% CL2	102,000
2000 - 2001	17% CL2	105,500
2001 - 2002	100% CL1	100,573
2002 - 2003	8% CL2	105,368
2003 - 2004	50% CL2	122,000
2004-2005	18% CL2	106,000
2005-2006	100% C1 + 215	141,115
2006-2007	10% C2 + 215	131,565
2007-2008	65% CL1	63,050
2008-2009	5% CL2	102,041
2009-2010	10% CL2	118,698
2010-2011	10% CL2	132,472
2011-2012	100% CL 1&2	142,000
2012-2013	60% CL 1	58,200
2013-2014	62% CL 1	60,140

SHAFTER-WASCO IRRIGATION DISTRICT

Shafter-Wasco Irrigation District

The average farm delivery of surface water by the District from **1988 to 2014** was about **52,990.0 acre-feet.**

Surface water deliveries were:

about **74,085.0 acre-feet** in **2011,**

about **33,852.0 acre-feet** in **2012,**

about **24,081.8 acre-feet** in **2013,**

and about **5,872.3 acre-feet** in **2014.**

Groundwater pumpage in the district was not measured or estimated for this period. Crop surveys were performed, but consumptive use of crops for the four years was not determined.

Note: Total Surface water delivery from 1988 to 2014 = 1,430,724.0 AF
/ 27 Years
= 52,990 AF AVERAGE

WATER YEAR		2011 Contract	2012 Contract	2013 Contract	2014 Contract	
January	SWID	0.0	4119.6	0.0	1137.9	52.9
	Bureau	0.0	4006.0	0.0	1085.0	
February	SWID	4437.5	6822.4	1765.8	3878.6	-215.4
	Bureau	4520.0	6787.0	1769.0	4094.0	
March	SWID	4498.2	1230.8	1656.4	12.8	-34.2
	Bureau	4483.0	1233.0	1761.0	47.0	
April	SWID	7376.6	1520.0	1905.6	34.3	4.3
	Bureau	7493.0	1451.0	1859.0	30.0	
May	SWID	9132.3	3756.2	2440.1	101.0	-79.0
	Bureau	9334.0	3838.0	2501.0	180.0	
June	SWID	11572.4	3841.6	4687.8	271.2	33.2
	Bureau	12076.0	3973.0	4775.0	238.0	
July	SWID	14041.9	2856.2	5022.0	316.0	52.0
	Bureau	14270.0	2881.0	5095.0	264.0	
August	SWID	10401.3	2293.3	2273.9	99.6	11.6
	Bureau	10371.0	2358.0	2073.0	88.0	
September	SWID	5908.0	2321.0	1545.1	6.6	6.6
	Bureau	6029.0	2377.0	1241.0	0.0	
October	SWID	4289.4	3326.6	1753.2	3.6	3.6
	Bureau	4498.0	3436.0	1352.0	0.0	
November	SWID	1882.5	1764.3	907.4	10.7	10.7
	Bureau	1825.0	1800.0	857.0	0.0	
December	SWID	544.9	0.0	124.5	0.0	0.0
	Bureau	627.0	0.0	68.0	0.0	
* Total		74085.0	33852.0	24081.8	5872.3	
Bureau		75526.0	34140.0	23351.0	6026.0	
Diff.		-1441.0	-288.0	730.8	-153.7	
Percent		-1.91%	-0.84%	3.13%	-2.55%	
			To NKWSD	2973.0		

Shafter-Wasco Irrigation District
2011 Crop Acreage Summary

Crop	Code	Total Acres
Pasture	1	**213**
Alfalfa/Hay	2	**2,768**
Corn	6 B	**849**
Sugar Beets	6 C	**36**
Wheat	6 E	**1,371**
Blackeye Bean	6 T	**74**
Tomatoes	10 AA	**263**
Garlic	10 AE	**37**
Carrots	10 H	**1,176**
Onions	10 T	**17**
Potatoes	10 V	**392**
Cherries	11 D	**572**
Plums	11 I	**139**
Persimmons	11 J	**28**
Oranges	12 B	**33**
Grapes	14	**1,156**
Cotton	18	**1,472**
Almonds	27 A	**17,414**
Walnuts	27 C	**199**
Pistachios	27 D	**799**
Nursery Stock	28	**825**
Broccoli	10 E	**15**
Cabbage	10 K	**7**
Plumcot	11 I	**27**
Dry Beans	6 H	**209**
Apricots	11B	**25**
Garden	10 AD	**3**
Strawberries	10C	**2**
Peas-green	10X	**6**
	Grand Total:	**30,127**

Double Crop Acreage Summary		
Corn	6 B	**72**
Wheat	6 E	**111**
Blackeye Bean	6 T	**190**
Tomatoes	10 AA	**136**
Carrots	10 H	**79**
Cotton	18	**85**
Broccoli	10 E	**37**
Total Double Crop :		**710**

Shafter-Wasco Irrigation District
2012 Crop Acreage Summary

Crop	Code	Total Acres
Pasture	1	**209**
Alfalfa/Hay	2	**2,888**
Corn	6 B	**1,119**
Wheat	6 E	**1,236**
Blackeye Bean	6 T	**367**
Tomatoes	10 AA	**187**
Garlic	10 AE	**37**
Carrots	10 H	**821**
Onions	10 T	**17**
Potatoes	10 V	**492**
Cherries	11 D	**572**
Plums	11 I	**139**
Persimmons	11 J	**32**
Oranges	12 B	**33**
Grapes	14	**1,173**
Cotton	18	**1,058**
Almonds	27 A	**17,504**
Walnuts	27 C	**274**
Pistachios	27 D	**740**
Nursery Stock	28	**979**
Broccoli	10 E	**15**
Plumcot	11 I	**27**
Dry Beans	6 H	**271**
Apricots	11B	**25**
Garden	10 AD	**3**
Strawberries	10C	**2**
Peas-green	10X	**6**
	Grand Total:	**30,226**

Double Crop Acreage Summary		
Alfalfa/Hay	2	**140**
Corn	6 B	**119**
Carrots	10 H	**114**
Broccoli	10 E	**117**
Total Double Crop :		**490**

Shafter-Wasco Irrigation District
2013 Crop Acreage Summary

Crop	Code	Total Acres
Pasture	1	**178**
Alfalfa/Hay	2	**2,940**
Corn	6 B	**959**
Wheat	6 E	**1,459**
Blackeye Bean	6 T	**487**
Tomatoes	10 AA	**187**
Garlic	10 AE	**143**
Carrots	10 H	**323**
Onions	10 T	**78**
Potatoes	10 V	**270**
Cherries	11 D	**633**
Plums	11 I	**139**
Persimmons	11 J	**59**
Grapes	14	**1,292**
Cotton	18	**858**
Almonds	27 A	**18,334**
Walnuts	27 C	**311**
Pistachios	27 D	**740**
Nursery Stock	28	**905**
Dry Beans	6 H	**76**
Apricots	11B	**25**
Garden	10 AD	**3**
Strawberries	10C	**2**
	Grand Total:	**30,401**

Double Crop Acreage Summary

Corn	6 B	**164**
Carrots	10 H	**376**
	Total Double Crop :	**540**

Shafter-Wasco Irrigation District

2014 Crop Year District Acreage Summary

CROP	CODE	TOTAL ACRES
Pasture	1	171
Tomatoes	10 AA	189
Garden	10 AD	5
Carrots	10 H	58
Cabbage	10 K	1
Onions	10 T	57
Potatoes	10 V	441
Strawberries	10C	2
Cherries	11 D	624
Plums	11 I	139
Persimmons	11 J	59
Apricots	11B	25
Grapes Table	14A	361
Grapes Raisin	14B	252
Grapes Wine	14C	527
Cotton Lint (American Pima	18	829
Alfalfa/Hay	2	2,242
Almonds	27 A	19,108
Walnuts	27 C	256
Pistachios	27 D	900
Nursery Stock	28	1,231
Wheat	6 E	962
Blackeye Bean	6 T	543
Corn Silage	6BS	580
TOTAL HARVESTED LAND:		**29,562**
No Crop	21 D	1,540
Commercial	31 C	1,766
Farmsteads	31 F	2,437
Waste-Misc	31 M	90
TOTAL NON HARVESTED LAND :		**5,833**
TOTAL CROP LAND:		**35,395**
Residential	31 R	3,371
Total Residential :		**3,371**
TOTAL DISTRICT LAND :		**38,766**

Sierra Scientific Services

The Geology and Groundwater Hydrology of the Buena Vista Water Storage District, Buttonwillow, Ca, including Descriptions of Relevant Facilities and Operations.

20 May, 2013

prepared for:

Buena Vista Water Storage District

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The Geology and Groundwater Hydrology of the Buena Vista Water Storage District, Buttonwillow, Ca, including Descriptions of Relevant Facilities and Operations.

INTRODUCTION.

The behaviors of the groundwater aquifers underlying the Buena Vista Water Storage District are dominated by three sets of factors , i.e., 1. the geology and physical properties of the subsurface, 2. the interactions between the groundwater hydrology and the surface hydrology associated with district farming and district water- conveyance operations, and 3. the interactions and responses to conditions along the district boundaries. We will discuss these factors in order to present a complete picture of the properties and behavior of the groundwater basin according to the currently available knowledge of the basin.

The information in this report was excerpted from other documents which have been prepared or are currently in preparation for the Buena Vista Water Storage District by Dr. Robert A. Crewdson, of Sierra Scientific Services, Bakersfield, Ca. This report presents descriptions of 1. the district, 2. conveyance facilities, 3. water supplies, 4. geology, 5 groundwater hydrology, and 6. selected references.

DISCUSSION.

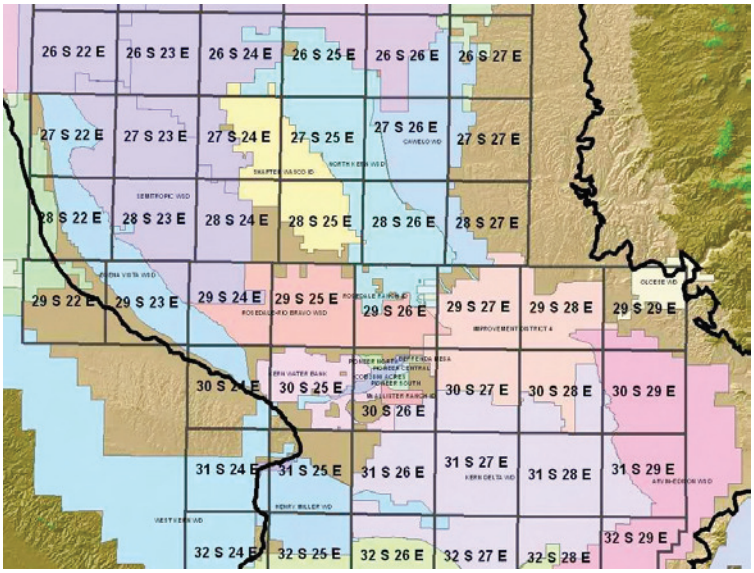
1. Description of the Buena Vista Water Storage District.

Regional Setting.

The lands of the Buena Vista Water Storage District (BVWSD or District) lie within the Southern San Joaquin Valley (SSJV) groundwater basin which lies entirely within the geographic boundaries of Kern County, CA. The SSJV groundwater basin covers about 1500 sq.mi. and is bounded on the east, south, and west by the topographic slope break between the flat-lying valley fill and the surrounding dissected foothills on three sides. The basin boundary on the north is the Kern County Line between Kern, Kings, and Tulare Counties, which is a political boundary but not a flow boundary. The longitudinal axis of the valley and groundwater basin is about 80 miles long, trending about N45°W from T10n/R19w-Sec01 SBBM to T25s/R22e-Sec01 MDBM. The transverse width of the valley and groundwater basin, perpendicular to the long axis, is 20 -40 miles depending on where it's measured.

The Buena Vista Water Storage District consists of two service areas, about ten miles apart, referred to as the Buttonwillow Service Area (BSA) and the Maples Service Area (MSA), covering a total of about 76 square miles west of Bakersfield, CA. About 91% of the cropped acreage and crop water consumption are in the Buttonwillow Service Area and the balance of the acreage and water

consumption are in the Maples Service Area. Both service areas overlie a belt of low, very flat, overflow lands and lake bottoms which forms the topographic axis of the valley and separates the alluvial fans of the opposite sides of the valley.



The MSA is about 7 miles long, 1 mile wide, and occupies the overflow lands between the Kern Lake Bed and the Buena Vista Lake bed along the southern toe of the Kern River alluvial fan. The Maples Service Area (MSA) is entirely surrounded by lands of the Kern Delta Water District which overlies the central main groundwater basin south of the Kern River.

The BSA is a 24-mile long, 3- mile wide, thin strip of land along the western basin margin and occupies the overflow lands within the Buttonwillow Syncline, lying between the Elk Hills and Buttonwillow Ridge (Dale, et al, 1966) west of the Kern River alluvial fan. The BSA shares parts of its northern, eastern, and southern boundaries with the Semitropic- and Rosedale -Rio Bravo- Water Storage Districts and the Kern Water Bank. The BSA shares its western boundary with undistricted lands which separate the district from the Belridge Water Storage District and oilfield properties farther to the west.

Local Setting.

The district lands are essentially reclaimed swamp lands located in and along the pre-development course of the lower Kern River which, after exiting the Southern Sierra Nevada mountains near Bakersfield and flowing south and then southwesterly across the southern San Joaquin Valley (SJV), ran down the topographic axis of the valley northwesterly toward its ultimate terminus at a shallow interior drainage basin which was once Tulare Lake. The water conveyance systems in and around the district consist of a network of levees and diversions to control the high flows of the Kern River, as well as an elaborate conveyance system of canals and drains to deliver surface water to- and collect runoff from- the serviceable lands within the District.

The northern half of the Buttonwillow Service Area is different in several respects from the rest of the district. The shallow soils are dense, heavy, and poorly- drained. The soils are underlain by a very shallow, perched water table containing groundwater with a salinity in excess of 2,000 mg/l. These conditions result in poor infiltration, water in the root zone, and shallow salt buildup so that crop selections which are limited to salt- tolerant crops. Crops in this area have lower overall crop yields compared to the same crops in better growing environments in other parts of the district.

The District recognizes from experience that the district water supply, natural drainage system, groundwater aquifer, and soils are all natural resources which must be actively managed in order to preserve a reliable, affordable, and productive agricultural environment. The District is currently in the process of implementing and updating their ground water management plan and other programs to meet this primary objective.

History.

The Buena Vista Water Storage District (referred to herein as District or BVWSD) was formed in 1924 for the purpose of managing the Kern River water rights of the member landowners and to provide for the surface delivery and aquifer recharge of Kern River water and other sources of water on behalf of the landowners and agricultural water users located within the District. The following historical account of the early district history has been excerpted from the 2002 Groundwater Status and Management Plan.

> The area which the District now serves was originally developed by two former meat supply merchants from San Francisco, namely Henry Miller and Charles Lux. In the early 1870s, these two men joined forces and set to build a cattle and sheep empire in the San Joaquin Valley. Extensive land holdings were acquired via the "Swamp and Overflow Act", the most productive Kern County portions of which are now within the Buena Vista Water Storage District. Miller and Lux's vast agricultural activities required farm help by way of tenant families many of whom imigrated from Italy. Surface water supplies diverted from the adjoining Kern River and from surface storage within Buena Vista Lake were used to develop lands north of and surrounding the lake, depending on its water levels.
>
> Irrigation activities from the Kern River, in and around the Bakersfield area, were first undertaken in the late 1850s, when small private ditches diverted water for the irrigation of grains. As the upstream diversions increased, controversies over the water arose, which resulted in lengthy litigation between upper and lower river users. Much of today's California appropriative and riparian water rights law resulted from the Supreme Court's decision in the Lux vs. Haggin case. The ruling created what is now known as the "California Doctrine" which recognizes both riparian and appropriative water rights. Despite the court's decision, the dispute continued and was finally settled via the historic Miller-Haggin Agreement of July 28, 1888. This agreement, where both appropriative and riparian rights were recognized, continues to be the basis by which the flow of the Kern River is divided among "First and Second Point" interests. The "Second Point" interests, namely Miller and Lux, received about one-third of the river flows from March through August. A subsequent amendment also apportioned the Second Point some of the high runoff winter flows. The Second Point right equates to an average entitlement of about 158,000 acre-feet per year, delivered by First Point interests to

Second Point of Measurement undiminished by delivery losses.

After the death of Henry Miller in 1916, Miller and Lux Land Company began selling much of their lands to the tenant farmers. Miller and Lux and the new landowners soon realized that a facilitator would be needed to represent the many vested interests of the water right. The Buena Vista Water Storage District was organized in July, 1924 and began operations following its 1927 Project Report. The Buena Vista project provided for the distribution of Second Point water rights that were tied to lands. The project also provided for added facilities to improve the distribution of the surface water supply. With completion of the District's 1927 project, the lands within the district were further developed for intensive agricultural use. Presently [2002], the principal crops being produced are cotton, grain, sugar beets, and alfalfa. Cotton is by far the dominate [sic] crop, making up about 85% of the annual cropping pattern.

Historically, the district has physically stored more water in the groundwater basin than it has removed for irrigation so that the District is said to be in overall positive water balance with respect to the basin, meaning that the cumulative volume of water brought into the district aquifers from historical annual surface water supplies exceeds the cumulative total volume of in-District groundwater extraction. Most of the stored water physically resides in the basin aquifers underlying the district. Some stored water resides in nearby groundwater banking projects and a small amount may temporarily reside in surface reservoirs. The records of the annual operations have been entered into the district's water accounting system as part of its district water balance.

District operations.

The District represents approximately 130 landowners[1] within two separate service areas, referred to as the Buttonwillow Service Area and the Maples Service Area, covering a total of about 78 square miles west of Bakersfield, CA. About 91% of the acreage is in the Buttonwillow Service Area (45,777 ac) and the balance of the total district acreage is in the Maples Service Area (4,350 ac). The total annual volume of applied water is similarly split between the two areas at approximately 135,000 af/y and 13,000 af/y, in the BSA and MSA respectively[2]

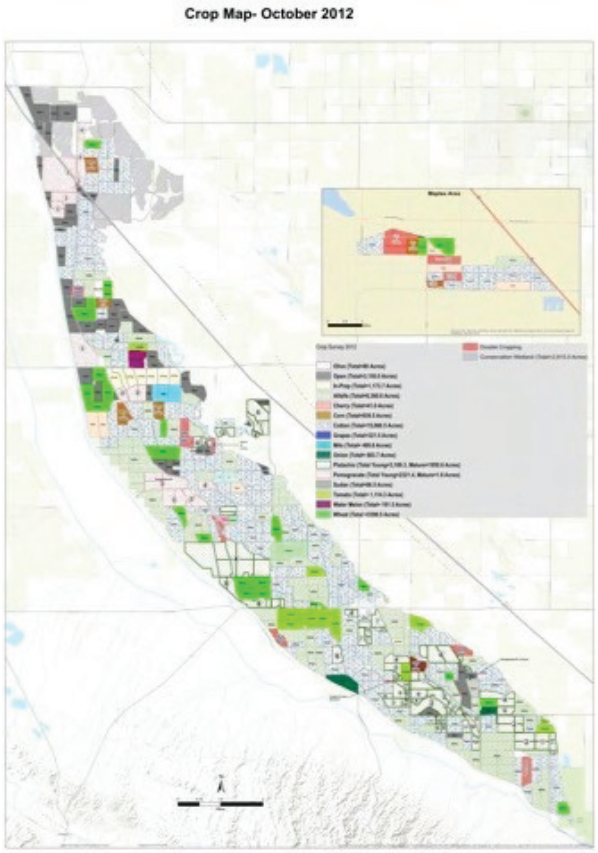
The principal crops grown in the district have changed over time from predominantly cotton and minor other row crops to a more recent preference for less cotton and a switch from row crops to trees. The historical consumptive water use since about 1960 ranged from 90,000 af/yr up to almost 120,000 af/yr and then back down to about 100,000 af/yr. In 2011, the total crop consumptive use in the Buttonwillow Service Area was 106,365 af of water on a total cropped acreage of 40,584 acres, including

[1] There are 130 different entities/landowners. Many of those entities have common owners but are technically different landowners. (Source: BVWSD, 2012).

[2] Based on district 2011 crop and consumptive use survey.

2,240 acres of wetlands, yielding an average annual consumptive use of 2 .62 af/ac.

The primary water demand within the District is for agriculture, all of which operates on irrigation. The semi-arid climate provides little precipitation, most of which falls during non- growing periods of the year, and there is no longer any stream or river flow in or near the district because of the upstream diversions of Kern River water created over the previous 130 years. The District owns and administers the water rights and state and federal water contracts, as well as manages the groundwater aquifer on behalf of the landowners. The majority of crop water demand is met by delivery of surface water from seasonally regulated flows of Kern River water, schedulable deliveries of State Water Project (SWP) water through the California Aqueduct, which began operation around 1969, and occasional purchases or exchanges for water from the Federal Central Valley Project, delivered to the Kern River Channel via the Friant- Kern Canal from westward- flowing Sierran drainages north of Kern County.



Irrigation demand that cannot be met by surface water deliveries must be satisfied by groundwater pumping. The BVWSD operates a conjunctive- use program in which surface water is deliberately recharged to and stored in the aquifer in "wet" years of excess surface water supply, for later recovery by pumping for use in "dry" years when the surface water delivery is insufficient to meet the entire crop demand. Over the last thirty years, the district created a net positive water balance relative to the aquifer, i.e., the district recharged an average net 44,000 af/y more surface water into the underlying aquifers than was removed by pumping over that period. A significant volume of that recharged water reaches the underlying aquifer through seepage losses from the district surface- water conveyance system. The average annual seepage losses (from the conveyance system to the groundwater aquifer) in the Buttonwillow- and Maples- Service Areas are 30,300 af/y and 1,100 af/y respectively, for an average total in- district seepage loss of 31,400 acre-feet per year.

<u>District water balance.</u>

A water balance is a written record of the inflows and outflows of water to and from the district, similar to a bank statement which records the credits and debits to someone's savings account. Depending on the purpose, the water balance may show just the physical water which flows in or out of the district's boundaries; alternately, the water balance might show the increases and decreases of

water to or from the district's water account, whether the district has actually taken delivery of such water or not. The written record of all such water transactions is referred to as the district water balance[3]. The physical flow of surface water through the district starts with new water supply flowing into the district (Inflow) and ends with tailwater flowing out of the district (Outflow). The annual inflow of water constitutes the annual new water supply and is augmented with both district and farm well water to constitute the total annual surface water supply. The flow of surface water enters and traverses the conveyance system and enters the fields to irrigate the crops. Excess surface water runs off the fields and is re-collected into the drain system (tailwater). Most of the tailwater is re-circulated and the remainder is delivered to users outside the district (Outflow). Along each segment of the conveyance channels or drains, water is lost from surface containment in the form of evaporation or percolation (seepage).

The water that leaves the district as annual outflow must be arithmetically equal to the annual Inflow minus the annual in-district consumptive uses and losses. This arithmetic statement is a simplified form of the district water balance. The District measures or estimates the gains, consumptive uses, and losses along every physical pathway in order to define the movement of all water in the district. All of that information is consolidated into a master dataset which can be used to track water usage within a single service area, within a single reach of a canal, or for the overall district. The consolidated data are summarized into an annual water balance which shows the water supplies, consumptive uses, losses, and the change in storage for the year. The water balance for a portion of the Buttonwillow Service Area was recently evaluated by Sierra Scientific Services in order to evaluate the groundwater impacts from canal seepage[4]. The data for that study and for the entire district are based on District records and databases.

For the period 1970 - 2011, the average annual district water supply was +182,574 af/y and the average annual water consumption was -134,911 af/y, including -109,770 af/y crop use and -12,766 af/y outflows. The long term average annual district balance was +46,409 af/y, meaning that the district had received more water supplies than it had consumed over the years. The water district has banked its excess water supply through seepage and deliberate recharge and this water is presently stored in the groundwater basin under the Buttonwillow Service Area and in several of the banking projects along the Kern River channel.

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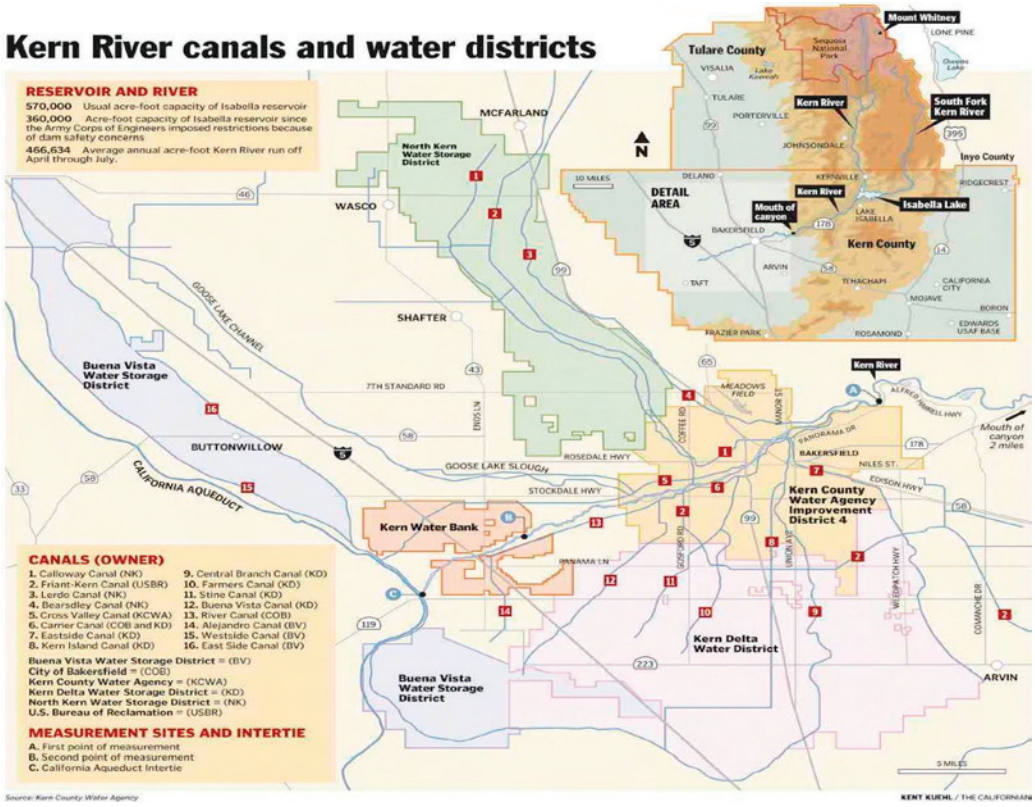
[3] BVWSD Water Balance 1970 - 2007, BV Water Management Plan, FEIR, 2009.

[4] Crewdson, Robert, A., October, 2012, A Preliminary Groundwater Impact Analysis of a Proposed Change in the Surface Water Conveyance System in the Northern Buttonwillow Service Area of the Buena Vista Water Storage District, Buttonwillow, California, Sierra Scientific Services, Bakersfield, Ca.

2. Description of the District Conveyance Facilities.

The district water conveyance and farming operations create a complex interaction between the surface water hydrology and the groundwater hydrology. To understand the groundwater hydrology, it is essential to also understand the surface water hydrology, i.e., the flow of water through the district's water conveyance facilities.

To better understand the District's facilities, it is useful to first understand the District's relationship to the regional water distribution facilities. More than a dozen major canal systems deliver water to the various Kern County water districts from three principal water sources inside and outside the county, i.e., the Kern River, the California State Water Project, and the Federal Central Valley Project. The Buena Vista Water Storage District is favorably located to receive waters by gravity flow from all three of these water sources, as described below.



Regional conveyance facilities- California Aqueduct.

In the mid-1960's, the State Water Project (SWP) completed the installation of canals, reservoirs, and pumping plants to re-distribute excess natural runoff in Northern California to urban and agricultural areas in central and southern California. The SWP has a contractual obligation to supply 2.557 million acre-feet per year (Maf/y) of Northern California water to Southern California, including 2.011 Maf/y to the Los Angeles Metropolitan Water District[5]. The SWP currently has a contractual obligation to supply 0.983 Maf/y firm and 94 kaf/y surplus water supply to the Kern County Water Agency and its member units, including the Buena Vista Water Storage District which holds a long-

[5] Source: California Dept Water Resources Bulletin 132-03, Table 1-6.

term contract for 21,300 af/y firm- and 3,750 af/y surplus water supply[6]. All of this water is conveyed through the California Aqueduct which runs down the west side of the San Joaquin Valley, with a channel capacity of about 5,000 cfs, depending on the reach. The Aqueduct runs down the edge of the topographic slope break along the west side of the San Joaquin Valley, and past the west side of the district for more than 30 miles. The district has four turnouts which provide more than 790 cfs capacity for water delivery from the district's state water supply by gravity flow into the district directly from the Aqueduct.

Regional conveyance facilities- Friant- Kern Canal.

In 1951, the federal Central Valley Project (CVP) completed the construction of the Friant- Kern (FK) canal which connects Sierran water supplies near Fresno to federal- project participants along the eastern side of the San Joaquin Valley through Bakersfield and as far south as the Arvin, Ca area. Depending on the reach, the FK Canal has a channel capacity of 2 ,000 – 4,000 cfs. North of Bakersfield, the FK canal runs parallel to the eastern basin margin near the slope break between the upper alluvial fans and the Sierran foothills on the east side of the SJV at much higher elevations than any of the valley lands to the west. Although the District is not a long- term CVP contractor and has no direct connection with this system, Buena Vista can receive temporary FK water supplies obtained by purchase or exchange through the local Cross Valley Canal, Kern River Channel, and the Kern River Canal, which connect the canal systems on the east side of the southern San Joaquin Valley to those on the west side in the immediate area of the District.

Regional conveyance facilities- Cross Valley Canal.

The Kern County Water Agency was chartered in 1961 by a special act of the California State Legislature and serves as the local contracting entity for obtaining, brokering, and distributing water to thirteen member entities for the State Water Project. The Agency brokers water from the SWP and both receives and delivers SWP waters to all local users. The two main arteries for this delivery system are the California Aqueduct and the 21.5 mile- long Cross Valley Canal (CVC) which was constructed with 900 cfs capacity in 1975 and increased to 1422 cfs capacity in 2012.

The bi- directional- flow CVC connects the conveyance systems of the Bakersfield area on the higher, east side of the San Joaquin Valley to the California aqueduct on the lower west side of the San Joaquin Valley. Westerly flow in the CVC is entirely by gravity, whereas easterly flow from the Aqueduct to Bakersfield is assisted by pumping- lifts on seven successive reaches.

BVWSD is one of the Kern County entities which entered into a long term contract for SWP water in 1967 which currently yields a long term average of approximately 60% of the SWP Table A

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[6] Source: GEI Consultants, 28 November, 2012.

contract amount of 21,300 af/y and access to 'interruptible' supplies[7]. Since the District has four of its own turnouts on the Aqueduct, as previously described, the District does not actually need the KCWA to wheel any of the District's entitlement water through the Agency's conveyance system. However, when the District purchases FK water, delivers water to banking projects on the Kern River, or fulfills a water transaction with another district, then some or all of these waters may be conveyed in part through the CVC.

Regional conveyance facilities- Kern River Channel.

The Kern River drains a 2,310- square mile (mi^2) watershed in the Southern Sierra Nevada Mountain Range, 2,074 mi^2 of which is above Lake Isabella. The headwaters drain small lakes west of Mt Whitney in the eastern half of Sequoia National Park. The North and South forks of the river pass through Inyo and Sequoia National Forests and the Golden Trout Wilderness before joining at Lake Isabella (created by dam construction in 1954) and then flowing west-southwest through the deeply-incised Kern River Canyon to Bakersfield.

The river meanders about twelve miles from the mouth of the Kern River Canyon (T29s/R30e-06) through the dissected uplands of ancestral alluvial deposits before emerging in the Bakersfield area at the apex of its modern depositional area known as the Kern Fan. The Kern Fan spreads radially outward through a 110° angle from its apex near the Chester Avenue Bridge (T29s/R28e-18). The Kern Fan extends about 19 miles west and 16 miles south from apex to toe with a constant topographic slope of about 7 ft per mile. Over time, the river channel has occupied different locations on the fan and many of the currently- existing irrigation canals that divert water to lands south of the river actually occupy the runs of former river channels. The current river channel runs about 18 miles on a fairly straight course at a bearing of S60W from the fan apex to the California Aqueduct Intertie (T30s/R25e-32) at the west edge of the basin just south of the small town of Tupman. The entire 18-mile length of the river is underlain by a persistent, elongated recharge mound which is the main source- and main location- of basin recharge.

The average annual natural flow of the Kern River is about 742,000 af/y (1894 - 2000). Since the completion of the Lake Isabella Dam in 1954, the United States Army Corps of Engineers (USACE) has controlled the daily flow of the Kern River below the dam for flood control. The USACE also provides releases as determined by the Kern River Watermaster, who represents downstream water rights holders and has the authority to request irrigation releases from the USACE[8]. The lower-river flow

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[7] Source: GEI Consultants, 28 November, 2012.

[8] The Watermaster represents the North Kern Water Storage District, the Buena Vista Water Storage District, the Kern Delta Water District, the Kern County Water Agency, and the City of Bakersfield, California (Kern Water Users), which collectively hold virtually all of the consumptive water rights on the Kern River. The rights are used primarily for irrigation of crops, as well as groundwater recharge benefitting agricultural, municipal and domestic

varies seasonally and daily because of the timing of snowmelt in the watershed and because of the regulated releases from the lake, which are ordered to meet downstream demands and power flow requirements. In most years, essentially all of the water flowing in the Kern River is diverted for irrigation purposes along a 10-mile stretch of the river channel through Bakersfield, from just above the Gordon's Ferry river crossing (T29s/R28e-02) to the Bellevue Weir at River Walk Park (T30s/R26e-01). Downstream from the Bellevue Weir, the Kern River channel is usually dry except in very wet years when the unregulated river flow released by the USACE exceeds the diversion capacity of all of the upstream takeouts. This condition is often referred to as "high- flow" or "flood- flow" by members of the water community.

Because of the riparian use of lower- river water by landowners prior to the formation of the District and because of the terms of an out-of-court settlement of the Lux- Haggin water lawsuits of the 1880s, the Buena Vista Water Storage District now holds a water right to approximately one- third of the 6-month Spring and Summer river flow during the months of March through August less the Kern Island 300 cfs (as measured at the First-point gauging station T28s/R28e-36). The First-point water rights holders must deliver this water undiminished by seepage losses to Buena Vista's point of delivery near the Enos Lane (Hwy 43) crossing of the Kern River channel which is known as "Second-point" (T30s/R25e-24). This water is delivered to Second-point through lined canals including the Carrier Canal and the Kern River Canal owned and operated by the City of Bakersfield. Historically, the District has received an average 158,000 af/y of Kern River water at Second point reduced by the amount of Isabella Reservoir hydrologic losses which average approximately 12,000 af/y.

The BVWSD and North Kern Water Storage District[9] contracted for 535,000 af of conservation storage space in the Lake Isabella Reservoir from the USACE, which they use to store and regulate their deliveries of river water for irrigation use. The capacity of the reservoir is 568,000 af which has been restricted by the USACE since 2006 to a maximum 360,000 af because of concerns over the physical integrity of the Lake Isabella Dam.

In- district conveyance facilities.

The District lands are contained in two individually- contiguous service areas, referred to as the Buttonwillow Service Area and the Maples Service Area, covering a total of about 76 square miles west of Bakersfield, CA. About 91% of the cropped acreage and crop water consumption are in the Buttonwillow Service Area (about 45,800 ac) and the balance of the acreage and water consumption are in the Maples Service Area (about 4,350 ac).

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uses. The Watermaster acts as agent for the Kern Water Users for purposes of controlling the storage and delivery of water to the respective public water users. Source: http://www.ferc.gov/whats-new/comm-meet/2010/031810/H-2.pdf

[9] Source: GEI Consultants, 28 November, 2012, based on BVWSD data.

Maples Service Area conveyance system.

The Maples Service Area (MSA) includes parts of about 12 sections of land in the southern part of township T31s/R26e and the northern part of township T32s/R26e. The MSA receives most of its irrigation water via the fully- lined Alejandro Canal which flows by gravity from a turnout on the Kern River Canal to the Buena Vista Aquatic Lakes, from which the Maples Canal carries water into the MSA. Diversions from the Maples Canal deliver water to the irrigated lands in the MSA. The MSA can also receive SWP deliveries from Aqueduct turnouts that deliver water directly into the western edge of the Buena Vista Aquatic Lakes.

Buttonwillow Service Area conveyance system.

The Buttonwillow Service Area (BSA) includes parts of 73 sections of land in 8 townships from T27s/R22e at the north end to T30s/R24e at the south end. The BSA can receive gravity inflow from turnouts on the California Aqueduct, from Second point via the Main Canal, or from the Buena Vista Aquatic Lakes Recreation Area via the Outlet Canal. The District can also receive high flow Kern River water directly from the lower Kern River channel although this stretch of river is dry most of the time due to prevailing climatic conditions and complete upstream diversion during most years.

The design and operation of the conveyance system within the BSA is controlled by the unique topography of the area. The southern San Joaquin Valley (SJV) is about 20 miles wide, depending on how you define it, in the vicinity of Bakersfield, CA. The BSA occupies a 26- mile long, 3- to 5- mile wide strip of fertile bottom lands along the far- west side of the Valley, where the pre-development course of the lower Kern River ran from the Buena Vista Lake bed northward toward the Tulare Lake bed through the topographic (low) axis of the southern SJV. Because of the great asymmetry of the Valley topography in this area, the axial trough (and therefore the BV District) is much closer to the western geographic edge of the Valley than to the east.

Water is being delivered by gravity flow to essentially all of the farm acreage in the BSA by surface water conveyance systems. Within the long, thin, southeast - northwest trending Buttonwillow Service Area, the topography is slightly lower down the middle than on the east or west sides. This natural feature has been cleverly exploited to develop a very efficient irrigation system in which a system of canals deliver surface water by gravity flow along- and inward from- the long edges of the District. The East Side Canal and West Side Canal run almost the entire length of the District. Water flows by gravity from south to north through the district via the West Side Canal and East Side Canal on opposite sides of the Buttonwillow Service Area. Water from these two peripheral canals is diverted to the interior of the district for irrigation. Water leaves the Side Canals via a distributary system of smaller lateral canals and private ditches which are interconnected by manually- operated weirs and turnouts operated by the District staff which deliver water directly to the fields. Runoff from the fields, sometimes referred to as tailwater, is collected in a tributary system of collection

ditches which flow to a Main Drain running northward down the center of the District at a gradient of about 2 ft per mile. Most of the drain water is reclaimed and re-used by District landowners; the remainder of the drain water is either delivered by natural flow to non-District landowners to the north or pumped to Semitropic lands to the east.

Altogether, there are approximately 125 linear miles of unlined canals and ditches within the two service areas of the District[10]. The District operates all of the weirs, turnouts, and control structures and maintains flow records for every stretch of District canal (excluding private ditches). Based on the district records[11], the average annual canal seepage loss is about 36,964 af/yr and 1,652 af/y in the BSA and MSA respectively, and is fairly uniformly distributed across the 78 sq.mi. of the District. This represents a district- wide groundwater recharge via infiltration (mostly canal seepage losses) of an average 0.63 ft/yr for every acre of District land, ranging from 0.4 - 1.5 af/ac/yr depending on the location within the District. This large- area seepage represents what is referred to as a "distributed-source" of recharge (rather than a "point- source") which spreads the recharge impacts over a very large area and creates only small impacts in any small localized areas.

3. Description of the District Water Supply.

The use of groundwater within the district is governed by the year- to- year variations in the district water supply. An overview of the district water supply can benefit from an overview of the water supply for the San Joaquin Valley portion of Kern County.

Kern County Water Supply.

The Buena Vista Water Storage District lies entirely within Kern County, California, which arguably has developed the best inter-connected surface- water conveyance system in the San Joaquin Valley. As a result, several Kern County water districts are strategically located to obtain significant water supplies from three different watersheds, i.e., the Southern Sierra Nevada watershed of the Kern River, the Central Western Sierra Nevada watershed of the federal Central Valley Project supplying the Friant- Kern Canal, and the Northern California watersheds near Mt Shasta and the Modoc Plateau of the California State Water Project.

According to the Kern County Water Agency, the average annual water supply for the San Joaquin Valley portion of Kern County is 2.3 million acre-feet per year, based on a basin-wide water balance for the period 1970 - 1998, as presented in Table 1, below. Besides providing more total water than the local sources alone provide, this mix of local, State, and Federal water sources is actually a

[10] Source: GEI Consultants, 28 November, 2012, based on BVWSD data.

[11] BVWSD, December, 2009, Buena Vista Water Storage District Final Environmental Impact Report for the Buena Vista Water Management Program, Appendix A., BVWSD Water Balance for Years 1970-2007.

great benefit because it significantly improves the water supply reliability for the County. Having a distributed water supply makes the County less vulnerable to a drought or a catastrophe on one system than would be the case if the County (or a single district) depended on a single supply[12].

Nevertheless, not all Kern County water districts share in these imported waters, which means that the Kern River is indeed the dominant or entire water supply for some districts. These districts, which are dependent on the Kern River alone for most or all of their water supply, have much lower water supply reliabilities per unit volume than those districts which also share in the imported water resources. The low water supply reliability of the Kern River is due to the extreme natural variability in the river flow, which makes it difficult to predict with sufficient accuracy the expected river flow over periods less than 30 - 40 years.

Table 1. 1970 - 1998 Kern County Water Supply.
(KCWA, August 27, 2001, Initial Water Management Plan, Public Review Draft, p. ES-13.)

Source		Avg flow (af/yr)	Share (%)		
Kern River	(local)	772,800	33.6%		
ep & mls*	(local)	324,000	14.1%	47.7%	local
SWP	(imported)	807,500	35.1%		
CVP	(imported)	395,100	17.2%	52.3%	imported
Total		2,299,400	100.0%	100.0%	total

* = effective precipitation & minor local streams

Due to increases in overall consumptive water use combined with water supply shortages during the seven drought years since 2000, the central San Joaquin Valley portion of Kern County has consumed an estimated 116,000 af/y more water than has been supplied from all sources over the last decade within a 454 sq.mi. central study area for which a water balance is available[13]. The water which has been used to meet the demand in excess of the available water supply, has come from the aquifers of the underlying groundwater basin, evidenced by an average 26.6 ft water level decline throughout the study area. Since the study area receives almost all of the groundwater recharge for the basin but

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[12] For a full analysis see: Crewdson, Robert, A., 2004, An Evaluation of Representative Hydrologic Periods for Basin and District Water Balances, Sierra Scientific Services. (prepared for & at the request of the Kern County Water Agency Ad Hoc Groundwater Mediation Technical Committee; authorized and funded by the Buena Vista & Rosedale - Rio Bravo Water Storage Districts.) *and* Crewdson, Robert, A., 20 November, 2003, An Evaluation of the Long-Term Water Supply of the Rosedale - Rio Bravo Water Storage District, Bakersfield, California, Sierra Scientific Services.)

[13] Todd Engineers, 18 Sep, 2012, Technical Memorandum No. 1: Site Conceptual Model, "With and Without Banking" Evaluation, Kern Fan Area, prepared for the Kern Fan Monitoring Committee, Kern County, California, p. 34 & Figure 3-32, Todd Engineers, Alameda, Ca.

represents only 30% of the total basin area, the total basin overdraft for the period is extrapolated to be in the range of 380,000 – 700,000 af/y for the last decade. The diversity of County water supplies has not prevented this overdraft water crisis because the total water demand simply exceeds total water supply. Nevertheless, the presence of over one million acre- feet per year of imported water supplies has made the magnitude of basin overdraft significantly less than if the county were dependent on only on its local water supplies.

By one definition[14], the removal of water from the basin in excess of the safe yield results in declining water levels and constitutes overdraft of the basin. If this overdraft were spread uniformly across the groundwater basin, it would have resulted in a basinwide decline in unconfined water levels of -26 to -48 ft. Since the extraction of groundwater has been concentrated in certain areas, groundwater levels have declined in some places by as much as 200 ft[15] and much less than average in others. These water levels will re-equilibrate but the overall basin average water level will not recover unless or until water is put back into the basin to replenish the aquifers.

Groundwater overdraft is also defined[16] as the state of a basin when groundwater extraction exceeds groundwater recharge over a period of years with approximately average conditions. Since the extreme drought conditions of the last decade are not considered to be "approximately normal conditions", the temporary decline of the basin water levels are expected to be balanced out by future gains in wetter- than- average periods and the basin for the last decade on that basis is not necessarily considered to have been in overdraft.

Buena Vista Water Storage District Water Supply.

Table 2. 1970 - 1998 BVWSD Water Supply. (From BV water balance spreadsheet 62-Date.xlsx)

Source		Avg flow (af/yr)	Share (%)		
Kern River	(local)	129,418	82.0%		
ep & mls*	(local)	00	00.0%	82.0%	local
SWP	(imported)	21,416	13.4%		
CVP	(imported)	7,211	4.6%	18.0%	imported
Total		157,775	100.0%	100.0%	total

[14] GRAC, 2005, California Groundwater Management, 2nd ed, p. 268.

[15] Data from KFMC Change in Potentiometric Surface elevation Maps, middle zone, Spring 07– Spring 08, Spring 08 – Spring 09, Spring 09 – Spring 10; Draft Groundwater Elevation Profiles AA' and BB' of 16 October, 2010; all prepared by Ken Schmidt and Kern County Water Agency.

[16] DWR, 2003, Bulletin 118- update, p.216.

Table 2 shows the district water supply for the same period as the Kern County data presented in Table 1 (1970 - 1998). The average district surface water supply for the period was 157,775 afy, about 10% greater than the district water consumption for the period. The result is that the majority of the 380,000 af of surplus water for the period was stored in the groundwater basin for future use.

In some years, water- delivery scheduling conflicts may prevent the district from meeting its entire water demand with surface- water deliveries, even if the total annual water supply is otherwise sufficient to meet the total annual demand for the year. In this case, groundwater will be pumped from the underlying basin during growing season and surface water will be recharged to the basin at other times and/or at other places. In drought years when the surface water supply needs to be augmented to meet demand, groundwater will be pumped from the underlying basin and this water will be accounted for as district water which has been previously stored in the basin. As long as the district water balance remains positive relative to the basin, then the water levels beneath the district will not decline unless water is lost from the aquifers due to other causes (see also discussion of groundwater hydrology in Section 5).

The way for the district to meet its water demand and avoid overdrafting the underlying basin is to create and sustain a long-term water supply which exceeds the district's long- term water demand by continuing to store water in the underlying aquifers in advance of pumping it out. The way for the district to lessen the amount of groundwater pumping in any given year is to increase its schedulable water supply from non-local sources so as to lessen the impact of the extreme variability of the district's Kern River water supply.

Surface water chemistry.

The district receives their surface water supplies from the Kern River, the State Water Project, and occasionally the federal Central Valley Project. The average reported general mineral chemistry for each of these water sources, based on data from the Kern County Water Agency are as follows: Average SWP surface water TDS = 350 - 450 mg/l; Average Kern River surface water TDS = 90 - 120 mg/l; Average Fraint-Kern surface water TDS = 50 mg/l. Based on BVWSD records, the average tailwater TDS = 200 - 400 mg/l.



4. Geology of the Buena Vista Water Storage District.

California's Great Valley and San Joaquin Valley.

The continuous, 440-mile long, Great Valley of central California runs from Redding in the north to the townsite of Grapevine 30 miles south of Bakersfield. The west-flowing Sacramento River, which connects the central Sierra Nevada watershed to the Pacific Ocean, splits the Great Valley into two parts and we refer to that portion south of the Sacramento River as the San Joaquin Valley.

Geologic history of the San Joaquin Valley.

The structure and history of the San Joaquin Valley as a northwest-trending structural trough between the Sierra Nevada and the Coast Ranges is described by Bartow, 1991. The division of the San Joaquin Valley into three physiographic regions including the western alluvial fans, the eastern alluvial fans, and the intra- basin deposits, is described by Burow and others, 1998. Within the San Joaquin Valley, the geology of overlapping terrace and alluvial fan systems reported by Marchand and Allwardt, 1981, for study areas outside of- but relevant to- Kern County, indicate that the more recent geologic history of the SJV includes cycles of alluviation, soil formation, and channel incision that were influenced by climatic fluctuations and resultant glacial stages in the Sierra Nevada (Bartow, 1991).

Through the 140+ million years of the Late Jurassic, Cretaceous, and Tertiary Periods of geologic time, the greater San Joaquin Valley was a large marine basin which was being filled with a tremendous volume of marine sediments[17]. These sediments have lithified into a sequence of sedimentary rocks, mostly sandstones, siltstones, and shales, which is more than 20,000 ft thick within Kern County. Tertiary crustal pressures during the last ten million years raised the Sierra Nevada, Temblor, and Coast Ranges causing sea level to regress out of the valley to its current position. These crustal deformations created the oil-rich anticlines in the Kern County area and the intervening structural sub-basins. The episodic Pleistocene glaciation and continental erosion on the mountainous margins of the San Joaquin Valley depression was the sediment source for non-marine deposition by alluvial, fluvial, and lacustrine processes in the interior of the Great Valley over the last million years. These more- recent non-marine sediments include the uppermost 700 - 1,000 ft thickness of unconsolidated sediments which comprise the groundwater aquifer and the sediments underlying the present topographic ground surface of the San Joaquin Valley groundwater basin.

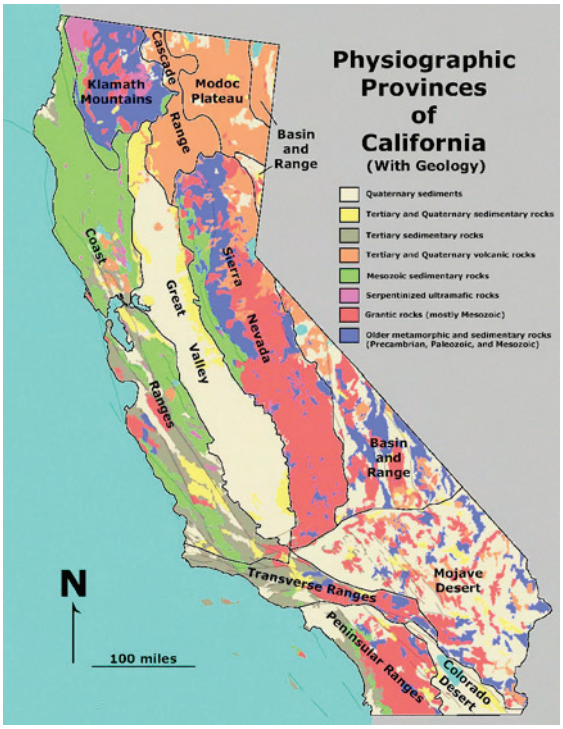
Geology of the Southern San Joaquin Valley (SSJV) Groundwater Basin.

The Kern County portion of the southern San Joaquin Valley is a subbasin of the larger San Joaquin Valley basin and this Kern County subbasin is bounded by both physical and jurisdictional boundaries. The north basin boundary is defined as the vertical plane coinciding with the northern boundary of Kern County. This boundary is a jurisdictional boundary and neither a geological nor a hydrological boundary. The basin perimeter on the east, south, and west sides has been defined by

[17] Bailey, Edgar, H., 1966, Geology of Northern California, CDMG Bulletin 190, see Chapter V. Great Valley Province.

others using the line along the topographic slope break between the flat-lying valley fill and the base of the adjacent dissected foothills or alluvial fans of the surrounding mountains, and also by others as the line of geologic contact between the surficial Holocene- age sediments of the valley fill and the Tertiary and older rocks of the adjacent landforms. It appears that the DWR has used a combination of both of these approaches to define the perimeter of the San Joaquin Valley groundwater basin in the Kern County portion of the Tulare Lake Hydrologic Region[18] (Figure 37, p. 176, DWR Bull. 118-2003). However, geologists are well-aware that the slope break is only rarely the true edge of the basin and that the very youngest quaternary sediments tend to cover up the deeper geological contacts which form the true basin boundary. Furthermore, these bounding sides are rarely vertical at depth and may be as complex as the undulating topography of the adjacent hilly terrain or a mountain flank.

In geological terms, the southern end of the San Joaquin Valley in Kern county is a deep geological trough which is bounded on the east by the Sierra Nevada mountain range, on the south by the Tehachapi Range, and on the west by the Temblor Range. The Sierra Nevada Range comprises primarily pre-Tertiary granitic rocks, and is separated from the Central Valley by a belt of dissected foothills comprised of locally oil-bearing Tertiary marine rocks. The Temblor Range runs along on the western side of the valley and consists of marine and continental sediments of Tertiary to Quaternary age (Gronberg and others, 1998). Prolific oil fields occur along the western basin margin within fold structures which are sub-parallel to the northwest- trending San Andreas Fault, a few miles to the west.

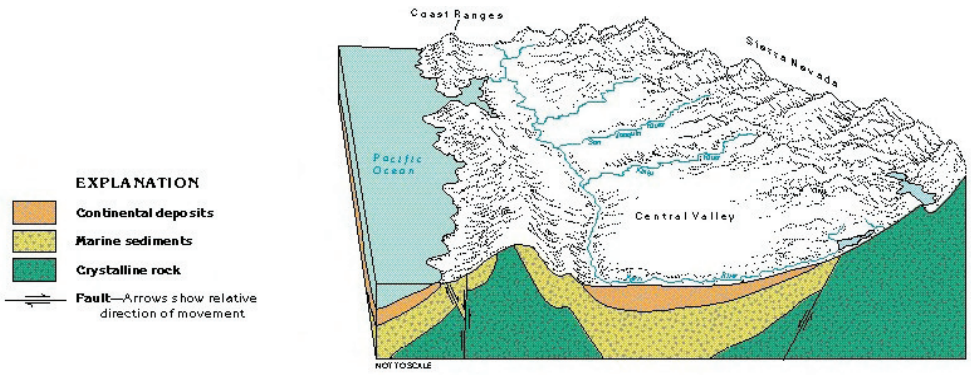


The valley trough has been filled with late Tertiary and Quaternary sediments which are geologically younger than- and derived from- the older rocks of the surrounding ranges. The sediments derived from the granitic terrain to the east consist mostly of unconsolidated, quartzo-feldspathic, detrital sands and silts with little clay, which includes the Kern River Formation and younger sediments. The sediments derived from the terrain to the west consist mostly of reworked marine shales and siltstones which yield unconsolidated clays and silts with some sands, which includes the Tulare Formation and younger sediments.

The trough contains a much larger volume of sediments derived from the east than from the west which is interpreted to be caused by a much greater source area to the east than to the west, and a

[18] DWR, 2003, California's Groundwater, Bulletin 118 - 2003, Figure 37, p. 176, Oct. 2003.

much greater orographic precipitation and runoff effect on the east than on the west throughout at least the Late Pliocene - Pleistocene Epochs. The vastly different volumes of sediment derived from opposite sides of the basin have created an asymmetry to the topography and the stratigraphy of the basin. The three large, conical, low- relief, fluvial/alluvial fans created by Poso Creek, the Kern River, and Caliente Creek, which exit the Sierras from north to south along the eastern basin margin, dominate the eastern boundary and the basin interior from Arvin to Delano. There are no alluvial fans anywhere along the southern and western basin boundaries that compare in size, shape, or importance to these three depo- systems. Rather, the southern and western basin boundaries are flanked by rather uniform, visibly-steeper, broad slopes formed from small, coalescing fans created by intermittant, braided stream or sheet flow deposits from higher elevations. The alluvial fan deposits on both sides of the valley are composed predominantly of coarser-grained sediments near the head of each fan and become finer grained toward the valley trough. The sediments in the eastern alluvial fans are more permeable than sediments in the western alluvial fan region because sediment-source rocks and watershed characteristics are different between the two areas.



The topographic axis of the basin, along which all surface water ultimately drains, is a narrow belt of low elevation separating the toes of the alluvial fans which spread out from opposite sides of the basin. Except for the southernmost part of the basin, the axis lies west of Interstate 5, within 1 - 3 miles of the topographic slope break which defines the western basin boundary, and more than 20 miles west of the eastern basin boundary. Both service areas of the water district straddle the basin axis.

We are interested in the low-salinity, water-bearing strata which fill the shallow, upper portion of the trough. These shallow, mostly Holocene, alluvial and fluvial strata are separated from deeper, high-salinity, Pleistocene, water-bearing strata by impermeable strata. The top of this impermeable boundary is approximately 600 - 3,000 ft deep in the central part of the basin and constitutes the bottom of the groundwater basin for our purposes. The boundary is generally taken to be the contact between the overlying unconsolidated sediments and the underlying sedimentary rocks.

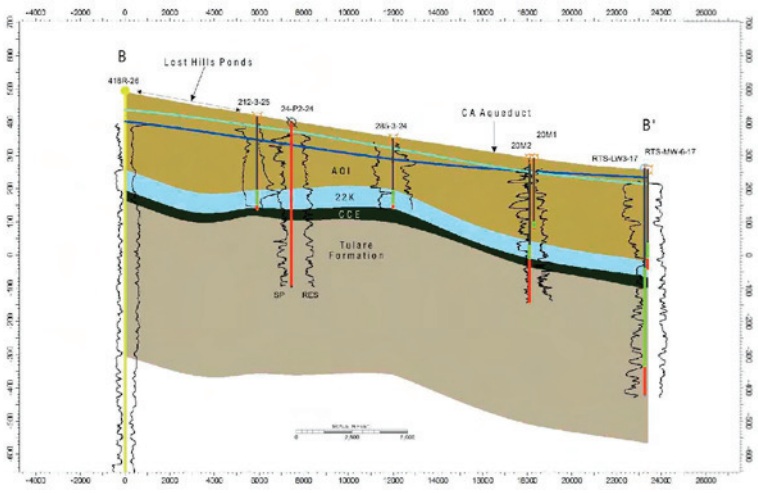
Corcoran Clay

Within the fresh water, upper- portion of the basin, the Corcoran Clay, is a glacial-outwash, lake deposit that is an important subsurface feature in the San Joaquin Valley because it is a laterally extensive confining unit which splits the deeper parts of the SSJV groundwater basin into a

shallow unconfined aquifer and a deeper confined aquifer, as described further below. The Corcoran Clay is a member of the Tulare Formation (Croft, 1972) and has been correlated with the E-clay (Page, 1986), the diatomaceous clay (Davis and others, 1959), and the lacustrine clay within the Turlock Lake Formation to the north of Kern County (Marchand and Allwardt, 1981). Page (1986) used results of previous work and a limited number of well logs and geophysical logs to map the areal extent of this regional confining unit. Burow and others, 2004, have recently used additional lithologic data to modify the mapped extent of this prominent unit in the region.

In the central parts of the main SSJV groundwater basin to the north- northwest and south-southeast of the Kern Fan, the 50-ft thick Corcoran Clay separates an unconfined aquifer shallower than about 300 ft depth from a confined aquifer deeper than about 350 ft. The Corcoran Clay does not exist under the Kern Fan where the shallow unconfined layers are separated from deeper, more confined layers by an intermediate zone of interbedded sands and silts which retard vertical groundwater flow and create an increase in semi- confinement with depth. In the Maples Service Area, the district has three wells which appear to show water level behavior indicative of confined conditions, but we do not have deep- well geophysical logs in the area to confirm whether or not the Corcoran Clay exists under the area.

Based on the work of others, the Corcoran Clay or another, stratigraphically- equivalent clay has been mapped or inferred to exist under the Buttonwillow Service Area. Some of the deeper wells in the southern BSA are completed down to a clay at a depth of about 550 - 600 ft. No wells appear to have been completed deeper because the producing interval above that clay has good water and sufficient productivity to make good irrigation wells.



Based on the work by Aera Energy geologists[19], there is a ±30 ft thick clay, which they identify as the CCE, or Corcoran Clay Equivalent, which is 220 - 320 ft deep and separates the unsaturated zone and the water- bearing 22K sand, from the underlying Tulare Formation, within the western basin for at least five miles to the west of the BSA, north of 7th Standard Rd.

In 1991, Pacific Geotechnical Associates mapped the "E" Equivalent Clay along the western

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[19] RWQCB, 15 November, 2011, Review- Phase II Groundwater Investigation Report, Row4/Lost Hills Wastewater Disposal Facility, South Belridge Oilfield, Kern County, Memorandum to Aera Energy LLC.

basin margin, including the Buttonwillow Syncline, Buttonwillow Anticline, and in parts of the main basin to the east of the water district. PGA reported[20] that:

> *"The "E" Equivalent Clay as identified in well 23s/24e-16B can be mapped as far south as T.30S.-R.24E., MDB&M, within the Buttonwillow trough. The clay can be correlated with confidence from the deepest part of the basin eastward to a line that extends roughly from Delano through McFarland and west of Shafter. The clay reaches depths of -900 feet subsea (1,100± feet subsurface) in T.25S.-R.20E., MDB&M, at the Kern County line."*

The PGA report states that the stratigraphic correlations based on E-logs were difficult or impossible where the clay was less than 50 ft thick, and the correlations probably could not have been completed without the extensive amount of proprietary seismic data that were available to them courtesy of ARCO Oil and Gas Co. The structural contour map on the clay which is presented as Plate IX in the PGA Report is currently the definitive map of the Corcoran Clay (aka CCE or E-Clay) in the vicinity of the water district. Because of the double plunge of the syncline, the clay is 450 - 600 ft deep under much of the BSA, rises southward to only about 100 ft deep under the south end of the BSA, and rises northward to about 250 ft deep under the north end of the BSA.

Geology of the Maples Service Area.

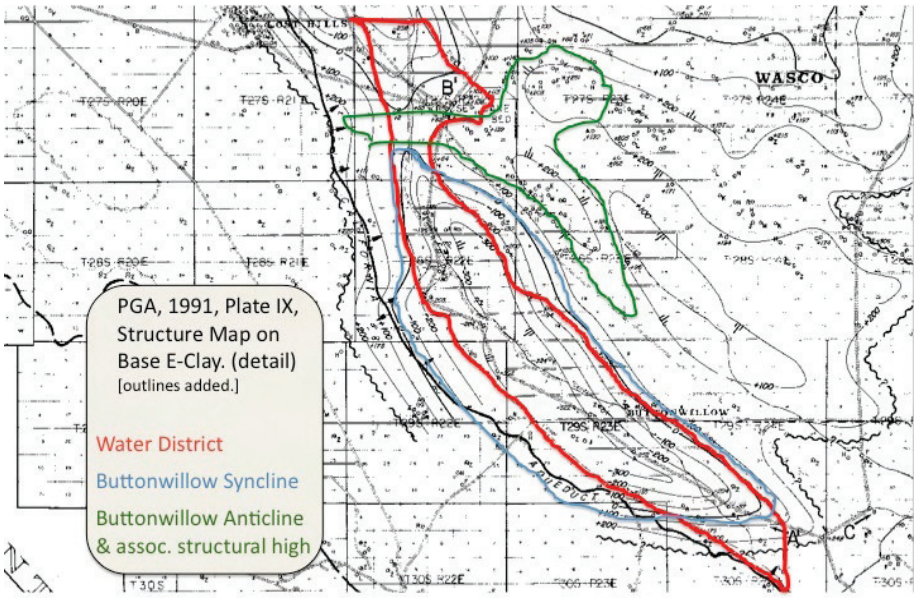
The MSA is about 7 miles long, 1 mile wide, and occupies the overflow lands between the Kern Lake Bed and the Buena Vista Lake bed along the southern toe of the Kern River alluvial fan. The MSA overlies the southern flank of the Bakersfield Arch where the basin structure dips steeply southward into the deep part of the southwestern basin. The MSA is underlain by Kern Fan type non- marine sediments, i.e., mostly unconsolidated sands and silts, with the Corcoran Clay equivalent at a depth of about 500ft and the Paloma clay at a depth of about 1,500 ft, according to PGA, 1991.

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[20] Pacific Geotechnical Associates, 20 September, 1991, Study of the Regional Structure Related to Ground Water Aquifers in the Southern San Joaquin Valley Ground Water Basin, Kern County, California, p. 1.

Geology of the Buttonwillow Service Area.

The BSA is a 24-mile long, 3- mile wide, thin strip of land along the western basin margin and occupies the overflow lands within the Buttonwillow Syncline, lying between Elk Hills and Buttonwillow Ridge (Dale, et al, 1966) west of the Kern River alluvial fan. The BSA overlies a part of the SSJV groundwater basin which is contained within the flanks of the doubly-plunging Buttonwillow Syncline (Figure 8. PGA, 1991, Plate IX detail, Structure Map on Base E-Clay.) and is geologically separated from the main basin to the east by the doubly- plunging Buttonwillow Anticline (PGA, 1991). There is no surface expression to the Buttonwillow Syncline, but the en echelon, axial ridge of the Buttonwillow Anticline forms the Buttonwillow Ridge which is about 30 ft topographically higher than the flat lands overlying the syncline. The Buttonwillow Anticline is approximately three (3) miles wide. Immediately to the east of the Buttonwillow Anticline is the Jerry Slough Syncline which is another en echelon structural trough which is considered to be part of the main basin north of the Kern River channel.



The BSA overlies an area where the underlying Pleistocene sediments (<1 my) are composed of inter-bedded, non-marine sediments which came from separate sediment sources to the east and to the west. These sediments, which inter-finger under the district are the thin, distal terminations of thicker deposits of differing textures and compositions which are characteristic of their separate, respective sources to the east and west. The Pleistocene alluvial, fluvial and lacustrine sediments from the east are part of the Kern River Formation which are characteristic of sediments derived from the igneous granitic bedrock of the Sierra Nevada range. The Pleistocene alluvial sediments from the west are part of the Tulare Formation and are characteristic of reworked marine sediments derived from the ranges to the west. A veneer of Recent alluvium, swamp-, river-, and lake- deposits covers the Pleistocene deposits over most of the southern San Joaquin Valley.

These facies changes under the district lands influence both the complexity of groundwater flow and the mineral chemistry of the waters under the district. The available well data from the

district are sufficient to establish the depositionally complex and laterally- discontinuous style of the local stratigraphy but are not sufficient to actually map the lateral extents of these units in the unmapped areas between wells. Various other workers have observed that some of the Pleistocene and Holocene alluvial sediments are so similar to the underlying Tulare and Kern River sediments that it is virtually impossible to differentiate them in the field.

The groundwater aquifer under the BSA consists of a sequence of interbedded, laterally-discontinuous, Quaternary sandy and silty sediments of non- marine origin. Down to a depth of about 200 ft, silty sediments tend to predominate, but from 200 - 600 ft sandy and silty sediments occur in approximately equal proportion. The sandy strata in this depth interval constitute the groundwater aquifer which is currently being exploited in the area. In the Buttonwillow Service Area, the majority of irrigation wells are completed in the depth interval from 200 - 500 ft deep mainly for reasons of better water quality and better sand productivity at depth. The local irrigation wells have 200 - 300 ft long completion intervals within this depth range and are capable of delivering 3.9 - 5.3 cfs sustained flow at discharge/drawdown ratios in the range of 0.04 - 0.09 cfs/ft.

In the northern half of the Buttonwillow Service Area, the near- surface sediments have significant clay content and create a separate, shallow perched water table only 2 - 12 ft deep, above the underlying aquifer. Other petrophysical data, including geological classification, sieve analyses, consolidation tests, grain and bulk densities, and moisture contents from a hollow stem auger sampling program which will be completed in 2013, will be reported and made available by the District after the project completion.

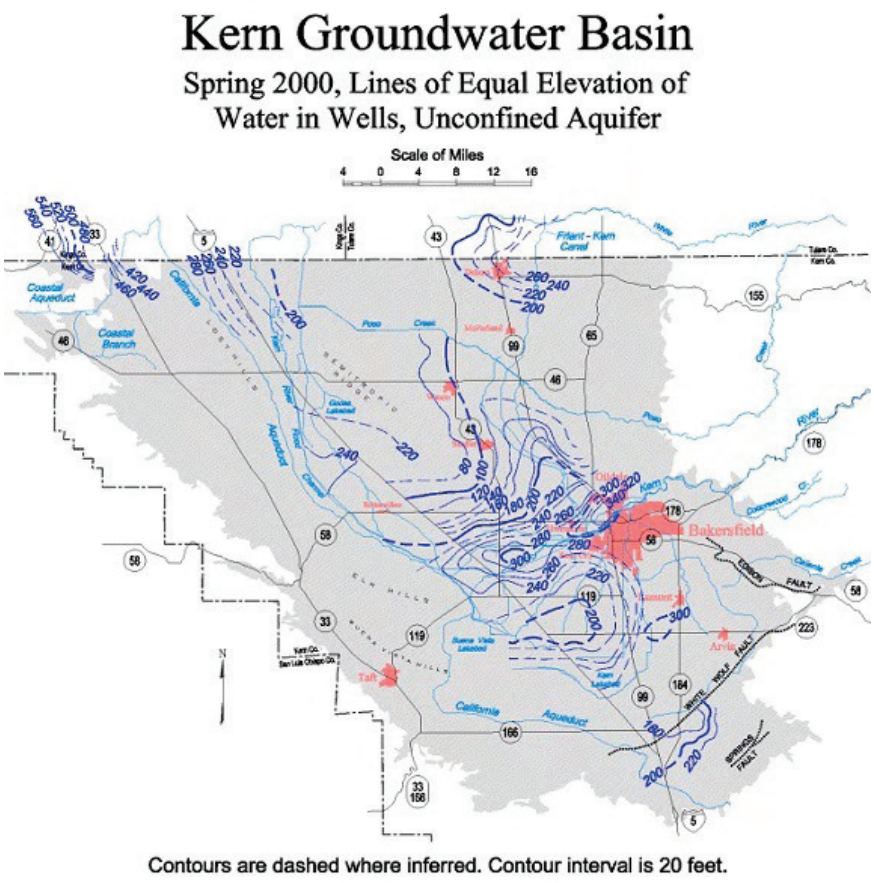
5. Groundwater Hydrology of the Buena Vista Water Storage District.

The Maples and Buttonwillow Service areas are about ten miles apart and overlie different parts of the basin, with different groundwater hydrologies and water chemistries. This discussion includes an introduction to the overall basin hydrology and summaries of the hydrologies of both service areas, with an emphasis on the Buttonwillow Service Area since it comprises the great majority of the district lands.

Hydrology of the overall basin.

The SSJV groundwater basin is often considered to be a single, large bathtub- like basin but, in detail, there are several small subbasins caused by local geological complexities along the east, south, and west basin boundaries. Each of these small subbasins has some degree of isolation from the main basin as manifested by some form of isolated water level behavior, distinct water chemistry, and delayed and/or attenuated pressure response to main- basin events, or vice versa.

A large and persistent groundwater recharge mound exists under the present Kern River channel traversing the Kern Fan which has separated the SSJV groundwater basin into two isolated flow regimes, one subbasin to the northwest and one subbasin to the southeast. These two subbasins[21] remain fully hydrologically connected and, together with the Kern Fan area, are considered to constitute the main basin. Historically, the average water levels in the southeast subbasin have been about 100 ft higher than the average water levels in the northwest subbasin, and the difference has been maintained by the intervening recharge mound. Hypothetically, if some or all of the Kern River recharge mound ceased to exist, then groundwater wold flow from the southeast basin into the northwest basin driven by the existing head difference.



The overall SSJV groundwater basin boundaries on the west, south, and east sides are considered to be no- flow boundaries so that the basin neither gains nor loses groundwater by lateral groundwater flow on these three sides. The basin boundary on the north is the Kern County Line which is a jurisdictional boundary but not a hydrological boundary and merely separates the Kern County portion of the basin from its physical continuation to the north/northwest. Hydrologically speaking, the groundwater basin inside Kern County is connected to- and mirrored by- its continuation in Kings and Tulare counties to the north. Groundwater is completely free to flow north out of Kern County or to flow south into Kern County depending on the prevailing hydrological gradient across the boundary at any time. Based on a review of water level maps over the last 80 years, the basin dynamics on opposite sides of the county line have mirrored each other, resulting in no persistent groundwater gradients and, therefore, no significant groundwater flow across the boundary either into or out of the basin. Virtually all of the gains and losses of groundwater from the basin occur across the

[21] Subbasins, as defined by the isolation of their respective flow regimes.

ground surface. The basin gains essentially all of its groundwater by either natural or manmade percolation of surface water. The basin loses groundwater by water wells for domestic and municipal water supplies or agricultural irrigation. These gains and losses are reflected in the rise and fall of the unconfined water table and by the rise and fall of pressure in the confined aquifer.

The base of the groundwater basin is sometimes defined as the boundary between fresh groundwater and underlying saline groundwater, which reportedly varies in the depth range from 700 to 2,000 ft. The separation of the two regimes based on chemistry is often taken to be a basal no- flow boundary underlying much of the main basin. The majority of deep irrigation wells are completed no deeper than 600 - 700 ft deep and have encountered no reported saltwater invasion from greater depth, so this shallower zone is the interval for which the most information is available, and has traditionally been the portion of the basin which is accessible to- and used by- the overlying farm and urban groundwater users. According to the Kern County Water Agency[22]:

> *The main groundwater basin in the San Joaquin Valley portion of Kern County covers about 963,000 acres. The estimated storage capacity of the top 600 ft is about 50 million acre-feet. Total groundwater in storage* [as of 2001] *is estimated at 40 million acre-feet, with 10 million acre-feet of dewatered storage capacity.*

Hydrology of the Maples Service Area. The groundwater hydrology under the MSA (mostly in the southern sections of T31s/R26e) is characteristic of the hydrology of the interior portion of the main basin which is south of the Kern River. The aquifers under the MSA are fully interconnected to the aquifers under the adjacent lands. From 1929 to the early- 1960s, groundwater flowed under the MSA from the northeast. The groundwater gradient under the MSA was consistently about -10 ft/mi, more or less, as groundwater flowed toward the southwest away from the Kern River recharge mound. During that 30-year period, the average groundwater elevation declined from about 280 ft to 260 ft.

Starting in the mid- 1960s, the groundwater gradients reversed, causing groundwater to flow under the MSA from the southwest, at gradients of -4 to -15 ft/mi, under the influence of a growing pumping depression to the northeast centered in the west half of township T31s/R27e. From the 1960s to the mid- 1980s, the average groundwater elevation remained at about 260 ft.

Basin water levels began to decline in 1988 and by the Spring, 1989, average water levels in the MSA had dropped from 260 ft to about 200 ft elevation, and the deep portion of the pumping depression had spread to include the Maples Service Area, so that the MSA received inward flow from all directions. As the drought continued into 1995, the Kern River recharge mound declined and the

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[22] KCWA, 2001, Initial Water Management Plan, Public Review Draft, 27 August, 2001, p. ES-10.

southwest end of the mound receded upriver until, for the first time, groundwater began to flow out of the southeast basin, under the MSA, under the southwestern-most stretch of the Kern River, and into the northwest basin. Water levels declined in the MSA and fluctuated between 180 - 200 ft elevation for the period.

During the wet period from 1995 to 1998, recharge along the Kern River reformed the groundwater mound which re-isolated the two main subbasins and raised the overall water levels. The MSA was still underlain by the pumping depression and water flowed into the MSA generally from the south. Water levels remained steady at about 200 ft elevation for the period.

The wet period was followed by another multi- year drought from 1999 into 2005, in which the recharge mound again declined almost to the point of re-opening a flowpath between the two subbasins. Water levels under the MSA declined from about 200 ft to 160 - 180 ft elevation and flow into the area was from the south. After the two wet years of 2006 - 2007, in which the water levels in the MSA recovered somewhat, water levels declined to new historic lows of 150 and 120 ft elevation in 2009 and 2010 as the MSA began to be drained by two pumping depressions, one to the northeast and one to the southwest.

Hydrology of the Buttonwillow Service Area. The Buttonwillow Service Area of the Buena Vista Water Storage District occupies a partially- isolated subbasin on the western basin margin northwest of the Kern River. For purposes of description, we divide the BSA into two parts, the northern and southern BSA based on the presence of a perched aquifer in the northern area, and somewhat different hydrology along the district margins of the two areas. Based on district groundwater elevation contour maps, the divide[23] between the northern and southern half of the BSA is located approximately at 7th Standard Rd. The water table under the northern half of the BSA is shallow, 2 - 12 ft deep, flat, featureless, and largely unchanged from year to year. The volume of canal seepage losses during the seasonal surface water irrigation run (average 111-days long from May - Aug) exerts a significant influence on both the depth and the salinity of the shallow groundwater. The water table under the southern half of the BSA is 200 - 250 ft deep and exhibits some water table fluctuations which mimic the hydrology of the climatic wet/dry cycle similar to that seen in the main basin to the east and southeast.

The vertical relationship between the perched aquifer and underlying aquifer is not clear based on available data except that the perching layers appear to terminate to the south near 7th Standard Road (near the boundary between townships T28s & T29s). To the north of this boundary, perched water exists and to the south of this boundary, the shallow section remains unsaturated down to the deeper aquifer water table. There is southward flow of perched water across this boundary which

[23] The location of the dividing line between the northern and southern BSA, as described, runs from the West Side Canal to the East Side Canal through the intersection of Imperial St and Main Drain Rd on a bearing of N45°E.

serves to percolate and recharge the aquifer to the south via a sloping water table.

According to district water level data, the groundwater gradients across the district boundaries north of 7th standard Rd have been essentially zero over time, so that very little groundwater has flowed laterally into or out of the northern BSA across the west, north, or east district boundaries. Heading to the southeast from the north- south divide, the groundwater elevation deepens at a rate of 5 - 6 ft per mile for 10 - 12 miles, i.e., almost all the way to the southeast end of the district. The volumetric flow rate out of the perched zone, and the corresponding impacts on the salinity and chemistry of the deeper zone, have not been determined to date.

In the Buttonwillow Service Area, the majority of irrigation wells are completed in the depth interval from 200 - 500 ft deep mainly for reasons of better water quality and better sand productivity at depth. The local irrigation wells have 200 - 300 ft long completion intervals within this depth range and are capable of delivering 3.9 - 5.3 cfs sustained flow at discharge/drawdown ratios in the range of 0.04 - 0.09 cfs/ft.

Lateral flow across the west BSA boundary.

The main basin boundary is located several miles to the west of the California Aqueduct, which is approximately 1.5 – 2.5 miles west of- and parallel to- the west-side District boundary, north of State Highway 58. Based on data from Aera Energy, the stratigraphy under the Belridge Water Storage District, west of the aqueduct and north of State Highway 58 is similar to that in the BSA, except that the Corcoran Clay equivalent is much shallower than under the BSA. The RWQCB reports that:

> *"Aera's groundwater investigation identified three aquifer zones. discontinuous water- bearing sand layers, separated by clay layers within the Holocene alluvium are designated as the unconfined Aquifer I (AQI). Underlying the AQI is a discontinuous clay aquitard which is underlain by the 22K Sand. Where water-bearing, the 22K Sand is designated as the semi-confined 22K Aquifer (22K). Underlying the 22K is a regionally continuous aquiclude, the Corcoran Clay Equivalent (CCE). The CCE correlates with the Corcoran Clay six miles to the east. Below the CCE is the Pleistocene Upper Tulare Formation, a thick sequence of relatively continuous, permeable, water-bearing sands and alternating clay layers, designated as the confined Aquifer II (AQII)."*

A few miles to the west-northwest of the water district, all three zones contain natural groundwaters with elevated TDS, and the top two aquifers have been locally impacted by oilfield wastewater brine plumes. The groundwater gradient in this area is northeasterly, i.e., with a component of easterly groundwater flow toward the BSA from the west. To date, however, the district has not observed the encroachment of the wastewater plume into the groundwater under the district.

The groundwater gradient data from the few available wells on the west BSA boundary suggest

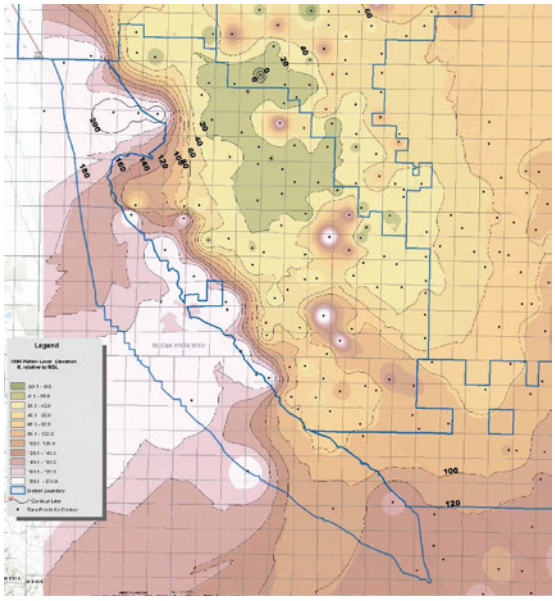
that there is very little or no groundwater gradient at all across the district boundary. This fact alone would seem to argue that the BSA cannot receive a significant amount of lateral inflow recharge from the west, and this basin boundary must therefore essentially be a no- flow boundary. On the contrary, there are water chemistry anomalies along the western edge of the groundwater basin within BVWSD and elsewhere that argue for the presence of inflow from the west. BVWSD is currently undertaking studies, including discussions with oilfield operators to the west who have detailed geological information, to try to improve the understanding of the basin boundary, but that study is in its early stages as of Spring, 2013.

Detailed shallow groundwater maps, along the western district boundary north of Seventh Standard Rd and south of State Highway 46, reveal that groundwater pumping by a line of irrigation wells located outside the district along the west side of the West Side Canal creates a linear pumping depression which appears to cause groundwater to flow westerly from the district interior toward the wells where the groundwater is, at least seasonally, 6 - 10 ft deeper than in the district interior. Because of the placement of these wells, this represents a true flux of shallow groundwater which leaves the district. However, this clearly cannot represent the natural groundwater flow and whether or not this should be included in a groundwater balance or groundwater analysis would depend on exactly what the boundary flow, however small, was intended to represent.

Lateral flow across the eastern BSA boundary, north of 7th Standard Rd.

The water level elevations (200+ ft msl) within the northern portion of the BSA are significantly shallower than the water level elevations (± 0 ft msl) in the large pumping depression a few miles to the east- northeast, centered in township T27s/R23e. The -200 ft step- like drop in groundwater elevation occurs across a 2 - 3 mile- wide zone which parallels the eastern district boundary.

Regional ground- water elevation maps clearly show that the water level contours which define the T27s/R23e pumping depression are asymmetric in the E-W direction with an inward gradient on the east of -10 ft/mi and an inward gradient on the west of -70 to -80 ft/mi. The pumping depression is east of this steep, step-like groundwater gradient while the BSA is west of the gradient.



Within the local water community, this narrow zone of steep gradients between BVWSD and the pumping depression has been interpreted to be a no-flow boundary caused by geologic structures running close to- and parallel

to- Interstate 5. The 1991 "Clay Study[24]" by Pacific Geotechnical Associates indicates that the geological axis of the Buttonwillow Anticline runs along this area, and is clearly visible in the local topography as an elongated hill. The district does not have well data which can be used to confirm whether or not the anticline or related geologic structures have affected the hydrology of the top 600 ft of strata in that area. But if this zone is a no-flow boundary, then the groundwater lateral flow across this zone would be zero.

The narrow zone of steep groundwater gradient might also be interpreted to be the result of substantial thinning of the aquifer due to geologic structures in the area between the BSA and the pumping depression to the east. A thinner aquifer would have a significantly reduced transmissivity (T), with or without an associated change in hydraulic conductivity, resulting in the groundwater elevations to the west remaining high, while a relatively small flux of water "spills" eastward through the linear zone of reduced transmissivity. The gradient across the area would be similar to that which is actually observed, given the limits of the existing data, and the groundwater flux across the zone would depend on the value of T, i.e., the thickness-conductivity product of the permeable strata within this zone. There may be other geological structures or conceptual models which might explain the presence of the zone of steep gradients, but we currently have no data from which can select a preferred model or estimate the lateral flow of groundwater through this zone.

The groundwater gradients across the actual eastern district boundary which lies 1 - 2 miles west of this linear feature are approximately zero at least along the eastern boundary of the northern half of the BSA. As was the case for the western boundary, the component of the groundwater gradient which crosses the east district boundary is so close to zero at almost every point that the aggregate inflows and outflows, if any, must be nearly zero, or too small to estimate given the uncertainties in the data at this time.

The tentative conclusion, given the amount of available data as of Spring, 2013, is that the lateral groundwater flow across the western, northern, and eastern district boundaries in the northern BSA must be very small, at least within the unconfined aquifer, since the groundwater gradients across both lateral boundaries are very small. The persistence of a very shallow water table over time appears to be consistent with a lack of significant lateral outflow of groundwater from under the district.

Lateral flow across the eastern BSA boundary, south of 7th Standard Rd.

Based on the groundwater elevation maps, a portion of the eastern boundary south of 7th Standard Rd is hydrologically interconnected with the main basin to the east. There is a four- mile stretch of district boundary from a point in T29s//R23e-11P to a point in T29s/R24e-28Q that exhibits an

[24] Pacific Geotechnical Associates, September 20, 1991, Study of the Regional Geologic Structure Related to Ground Water Aquifers in the Southern San Joaquin Valley Ground Water Basin, Kern County, California.

average outward directed groundwater gradient of about 35 ft/mile. If we assume a basic water balance on the district, we can estimate the flow parameters along this portion of the eastern BSA boundary.

The water balance representing the change in the volume of groundwater in aquifer storage over a specified time period for the Buttonwillow Service Area can be represented mathematically as follows: *Change in groundwater storage = Water in - Water out.* A positive water balance means that the groundwater aquifer under the BSA physically gained water while a negative balance means that the groundwater aquifer under the BSA physically lost water for the period. If we can quantify two of these terms, we can calculate the third.

The change in groundwater storage under the BSA over time has been determined by the California Energy Commission. In January, 2013, the California Energy Commission released a report[25] in which they evaluated the long term change in water levels under the BSA. Based on 19 water level hydrographs spread throughout BSA, the CEC concluded that the BSA- wide average water level rose +6.8 ft/decade since 1974. Using an estimated specific yield of 0.15, the CEC concluded that this represented a long- term average rate of increase in groundwater storage under the BSA of +4,600 af/y. This number represents the (annualized) average increase in groundwater storage.

The long term volume of water placed into groundwater storage has been determined by the water district staff. Based on the 1970 - 2007 district water balance, the district consumed less water than its water supply provided, and placed a net average annual +36,964 af/y into groundwater storage under the BSA. Since there is no significant inflow across the service area boundaries, the percolation of surplus district water supply constitutes the entire inflow to the basin. This number represents the (annualized) volume of water which flowed into basin storage. According to these two numbers, the basin water level is rising far less than it should be for the long term average volume of water that the water district is putting into the basin each year.

Therefore, we calculate using the water balance formula that the net average annual outflow of groundwater from the BSA is -32,364 af/y. This number represents the annual amount of groundwater that must flow out of the basin in order to reconcile the volume of inflow with the smaller observed increase in the volume of water in storage. This rate of outflow, equal to only 89 af/d, is equivalent to 9 water wells, each pumping all year at a constant rate of 5 cfs. This annual outflow volume is also equivalent to the total groundwater extraction of about 18 irrigation wells, each pumping at a constant rate of 5 cfs for about half a year, which is a reasonable scenario for the subbasin areas outside the BSA for which no surface water delivery system exists. In other words, it is possible that ±32,000 af/y of

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[25] Conway, Mike, Fio, John, and Deverel, Steve, January, 2013, Preliminary Water Supply Analysis, California Energy, Commission.

BV's surplus water is being extracted by non- district water wells which are located outside the district boundary but inside the Buttonwillow subbasin. The district currently has not determined to what extent this may be true. This annual outflow may also be due to natural outflows.

The loss of ±32,000 af/y from the basin may also be due to natural groundwater lateral outflow from the southern BSA along a 4-mile stretch of the eastern district boundary from about T29s/R23e-11P to T29s/R24e-28Q. An outward flux of 89 af/d, across a 4-mile stretch of district boundary, through a net 400 ft of aquifer thickness, under a gradient of 35 ft/mi, and a hydraulic conductivity of 70 ft/d will completely explain the loss of ±32,000 af/y from storage under the BSA. The water district currently has insufficient data to determine whether the parameters or the existence of such lateral flow are correct, but all of the combined physical properties which are required to account for such an outflow are consistent with the expected groundwater flow behaviors in the area. The actual outflow of groundwater from under the BSA is probably a combination of natural outflow and groundwater extraction by non- district water wells.

Aquifer properties.

The aquifer materials under the district are all unconsolidated sediments which are classified by grain size as sands, silts, or clays. The physical properties of interest include the in situ porosity, permeability, density, compressibility, moisture content, and grain size distribution. These properties help us to quantify the flow and storage properties of the aquifer strata. The district has recently begun to acquire aquifer data through core sampling and well testing. Based on the results of a Phase- 1 aquifer study which was performed by URS in 2009 - 2010, we have numerical values for the deep-aquifer storage and transport properties in the area near Seventh Standard Rd and Main Drain Rd. Based on the preliminary results of a Phase-2 aquifer study of which is currently being analyzed by Sierra Scientific Services[26], we have some numerical values for the perched- aquifer storage and transport properties in the area where Seventh Standard Rd intersects the East Side- and West Side-Canals. The district has not yet obtained aquifer property data for the rest of the district.

Deep aquifer data.

In late 2009 - early 2010 URS conducted aquifer tests in seven farm irrigation wells located in the central Buttonwillow Service Area of the Buena Vista Water Storage District, Kern County, California. All seven locations are within about 1.2- mile of the intersection of Seventh Standard Rd and Main Drain Rd (T29s/R23e- 04). At the District's request, URS selected these wells- of- opportunity

[26]Sierra Scientific Services has completed eight of ten proposed hollow-stem auger boreholes located throughout the district for the purpose of collecting sediment core samples to depths of 100 ft. The samples from all eight holes have been analyzed for physical properties by a Soils Engineering, Inc., of Bakersfield, Ca. See SEI Report of 02 Sep, 2011. The remaining two borings are scheduled for completion in Summer, 2013, after which, Sierra Scientific Services will present a final report of findings and interpretations. The protracted program duration is due to scheduling decisions associated with one of the district's projects.

for testing because of their appropriate spacing and proximity to the proposed BVWSD Brackish Groundwater Remediation Project well field. URS designed the well- testing program to obtain T & S values in order to validate the assumptions of their 2009 computer model of the potential drawdown impacts of the proposed well field. URS also designed the program to obtain water chemistry data on the distribution of higher- and lower- TDS waters known to exist within the aquifer.

URS presented their findings in a March, 2010 report titled: *Hydrogeologic Data Acquisition Report, Groundwater Monitoring and Process- Water Well- Field Development Project; prepared by URS for Hydrogen Energy California, Kern County, California, March, 2010.* Sierra Scientific Services provided a critical review of the report and an independent analysis of the test data and presented their findings in a June, 2010 report titled: *A Review of the Draft Report: Hydrogeologic Data Acquisition Report, Groundwater Monitoring and Process- Water Well- Field Development Project; prepared by URS for Hydrogen Energy California, Kern County, California, March, 2010; including an independent interpretation of the URS 2009 Well Test Data and an editorial review of the URS draft Report, 17 June, 2010, Sierra Scientific Services, Bakersfield, Ca.*

To summarize the URS findings, the deep aquifer is defined as extending from 200 - 600 ft depth below ground surface. The local irrigation wells have 100 - 300 ft long completion intervals within this depth range and are capable of delivering up to 3.9 - 5.3 cfs sustained flow at discharge/ drawdown ratios in the range of 0.04 - 0.09 cfs/ft (equivalent to: 25853 - 58169 gpd/ft or 0.08 - 0.18 af/d/ft). On the basis of these tests, the aquifer transmissivity ranges from 15,000 - 25,000 ft^2/d, and the average transmissivity in the central BSA is 18,200 ± 4400 ft^2/d. Using the aquifer net sand thickness from E-logs of the tested wells, the analysis of the BSA well test data gives hydraulic conductivities in the range of 30 - 80 ft/d, with an average K-value of 77±± 31 ft/day. The groundwater TDS is variable, depending on the depth zone, but ranges from 1,000 - 2,700 mg/l in the area of the well tests.

Shallow aquifer data.

In April - May, 2011 SSS conducted down- borehole petrophysical sampling and analyses as part of the Phase-2 study for the proposed BVWSD Brackish Groundwater Remediation Project well field. Soils Engineering, Inc. performed the requested lab analyses and presented the results in a data report of 02 September, 2011.

The preliminary results indicate that the hydraulic conductivities of the sands in the top 100 ft depth are 3 - 20 ft/d, quite permeable but much lower than the conductivities in the deep zone. However, the macro vertical permeability is quite low because of the presence of interbedded silt and clay layers. The TDS of the shallow, perched zone ranges from 850 - 5,500 mg/l based on district data from shallow piezometers. Other petrophysical data, including geological classification, sieve analyses, consolidation tests, grain and bulk densities, and moisture contents will be reported in SSSs final report after the completion of the analyses of the samples from the final two auger borings which are

scheduled for Summer, 2013.

Groundwater chemistry.

Most of the groundwater in the SSJV groundwater basin is one of three types: high- very high TDS, Na-Cl water, moderate- high TDS, Na/Ca-SO4 water, or low- moderate TDS, Ca-HCO3 water. The areas and zones where these distinct types of groundwater come into contact with each other are characterized by waters of intermediate TDS and mixed chemistry.

The chemistry of the low TDS, Ca-HCO3 type groundwater is similar to the chemistry of Kern River water, which is the main source of recharge for most of the basin. This type of water is referred to as east-side water because it is characteristic of the surface waters which drain from the granitic Sierra Nevada Range to the east of the basin. This type of water recharges the basin along the Kern River recharge mound and along Poso Creek and is widespread across the interior of main basin down to about 600 - 700 ft depth.

The chemistry of the moderate- high TDS, Na/Ca-SO4 type groundwater is similar to the chemistry of surface water runoff that drains from outcrops of Miocene- Pliocene marine sediments, and is primarily found in a strip along the west basin margin for more than 60 miles. This type of water is referred to as west-side water because it is characteristic of the surface waters which drain from the hills of the Temblor Range to the west side of the basin. There is far less runoff from the west side than from the east side, so there is far less SO4 groundwater than HCO3 groundwater in the basin.

The high-TDS, Na-Cl type groundwater is generally found in the deeper parts of the basin, regardless of what type of groundwater it underlies. No unique geological association has been established for this water type.

In the Maples Service Area, water wells have encountered east- side- type Na- HCO3 groundwater which dominates the basin to the north and east of the MSA, as well as mixed HCO3/ SO4 groundwater which dominates the areas of the Buena Vista Lake Bed and basin margin to the west and south, respectively. The east- side HCO3 groundwater has a TDS in the range of 200 - 500 mg/l, while the mixed- chemistry groundwater has a TDS in the range of 800 - 1,600 mg/l.

In the Buttonwillow Service Area, water wells have encountered groundwater of all three of the main water types plus mixed waters with associated TDS values which range from 500 to 5,000 mg/l. Dale, et al, 1966, (p. 66) reports:

"Ground water found in the axial trough[27] is a mixture of east-side and west-side ground water as well as

[27] The axial trough refers to the subbasin which underlies the Buttonwillow Service Area.

surface water which finds its way to the trough area before percolating downward to the ground-water body. The water is of the sodium type, but has many different sources. It varies widely both in concentration and chemical character of the anions. Generally, axial water nearer to west-side ground water exhibits more erratic quality change than does the axial water nearer to east-side ground water.

The contact between the east-side and axial ground water was placed at 1 equivalent per million (epm) of either sulfate or chloride. The fresh water east of the boundary, with the exception of the two saline areas, contains less than 1 epm, and the water west of the line contains more than 1 epm of sulfate or chloride."

Saline groundwater intrusion in the BSA.

The theory that the Miocene and younger marine sediments of the Coast Ranges are the source of saline groundwaters which are observed along the western margin of the southern SJV groundwater basin appears to have been originally proposed in the early 1960s by workers from the U.S. Geological Survey, although Dale, et al, 1996, report that Mendenhall (1916) attributed the high mineral content of certain waters to the Miocene - Pliocene marine sediments with which they were associated. Of the five related papers listed below, the paper by Dale, et al, 1966 covers the two service areas of the Buena Vista Water Storage District, but especially the BSA.

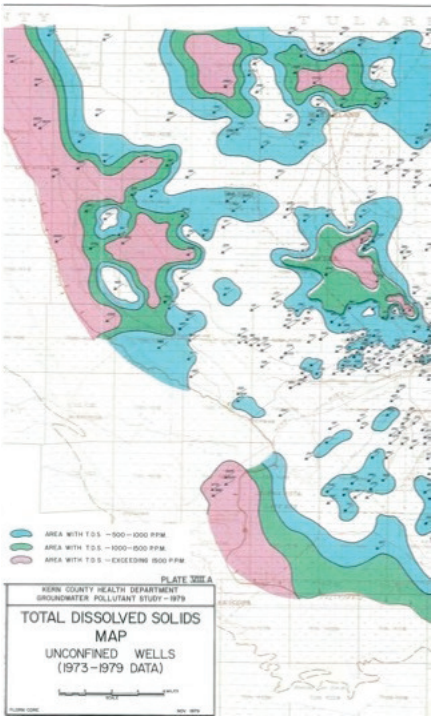
Croft, M.G., 1972. Subsurface geology of the Late Tertiary and Quaternary water-bearing deposits of the southern part of the San Joaquin Valley, California, U.S. Geol. Surv. Water-Supply Paper 1999H, 29 p.

Dale R.H., J.J. French, G.V. Gordon, 1966, Ground-water geology and hydrology of the Kern River alluvial fan area, California, U.S. Geol. Surv. Water Res. Div. Open-File Report.

Page, R.W., 1986. Geology of the fresh ground-water basin of the central valley, California, with texture maps and sections, U.S. Geol. Surv. Prof. Paper 1401C, 54 p.

Wood, P.R., and Dale, R.H., 1964, Geology and Ground-Water Features of the Edison- Maricopa Area Kern County, California, USGS WSP 1656.

Wood, P.R., and Davis, G. H., 1959, Ground-Water Conditions in the Avenal-McKittrick Area, Kings and Kern Counties, California, USGA WSP 1457.



In the early 1980s, a coalition of Kern County workers and consultants prepared a water quality study of the Kern County portion of the southern SJV groundwater basin in cooperation with the RWQCB and with Federal funding under the provisions of Section 208 Groundwater Pollutant Study (GPS) of Public Law 95-500. Two reports resulted from this effort, as listed below.

Kern Co. Health Dept, DEH, March, 1980, Groundwater Pollutant Study, San Joaquin Valley, Kern County, California.

Kern Co. Health Dept, DEH, and Kern County Water Agency, March, 1982, Groundwater quality Report, San Joaquin Valley, Kern County, California.

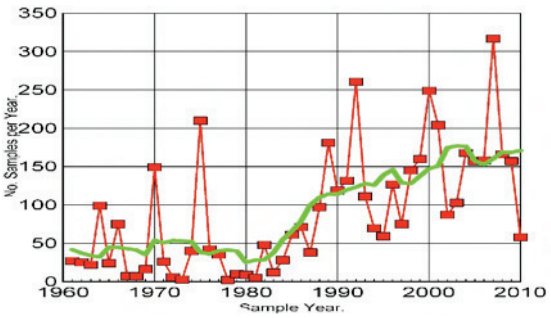
The same set of constituent concentration maps was provided with both reports, and the distributions of TDS in the unconfined and confined aquifers are displayed on maps VIII-A and VIII-B, respectively in the 1982 GPS Report (a copy of Maps VIII- A&B are included in the data package). As displayed on the maps, (Figure 2. 1982 GPS Map VIII-A, Unconfined Aquifer TDS Map.) the band of highest TDS concentrations is along the western basin margin, and concentrations decrease toward the basin interior.

The distribution of TDS concentrations is consistent with the theory that the saline waters are derived from sources to the west and get progressively diluted and ion- exchanged as they progressively mix with Sierra- Nevada derived waters in the basin interior to the east. This band of high- salinity and its associated basinward decrease in salinity can be followed for more than 60 miles along the western basin margin and is significantly more widespread than just the western edge of the water district.

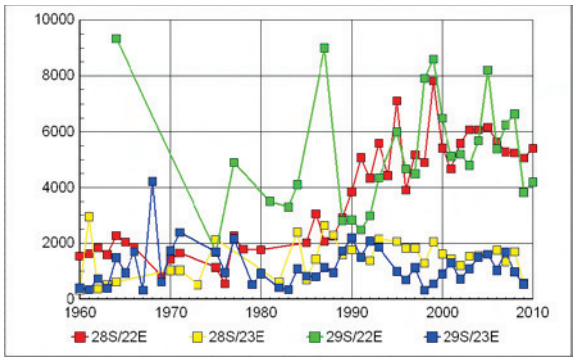
The water district staff accepts the USGS theory that the naturally- occurring saline groundwater flows into the district from sources to the west, as does the DWR as reported in Bulletin 118-03, page 178. The district also accepts the findings of the referenced 1980 & 1982 Groundwater Pollutant Study Reports that there is an easterly gradient of decreasing groundwater TDS content under the general area of Buttonwillow Service Area. The district is not trying to advocate or to prove the theory, but the district groundwater chemistry data support both sets of findings.

The water quality (EC) data from the BVWSD database are consistent with both the USGS theory of origin and the TDS constituent distributions mapped in the 1980s reports. Water chemistry data from water wells in the BSA corroborates the water quality trends which had previously been described by other workers. We analyzed water quality data from a four- township area centered on the BSA straddling 7th Standard Rd. (28s/22-23e, 29s/22-23e). The dataset includes 4,476 records, including 4,119 records of EC-only, 342 records of both EC and TDS, and 15 records of TDS- only, from 1,296 wells within the 144 sq.mi. area. Prior to the late- 1980s, there are insufficient data to illustrate the

temporal groundwater trends in individual wells. So we have calculated the average annual EC value for each year from 1960 to 2010 for a four township area, i.e., T28s/R22e, T28s/R23e, T29s/R22e, and T29s/R23e (Figure 3. EC in 4 Project- Area Townships, 1960 - 2010).

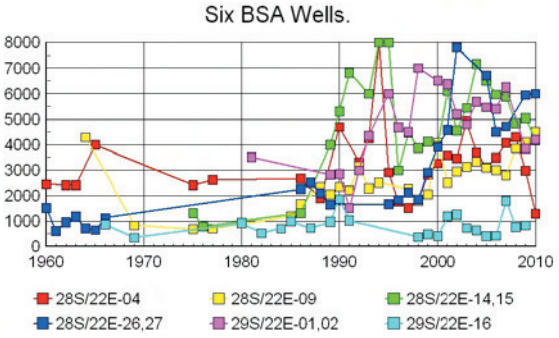


The 4- township dataset contains a total of about 40 EC records per year for the period from 1960 - 1980. The number of EC measurements per year increased throughout the 1980s and for the period from 1990 to 2010 the dataset contains an average of almost 150 EC measurements per year (Figure 1).



The average groundwater ECs in the two easterly townships (T28s/R23e and T29s/R23e) are approximately constant for the 50-year period from 1960 to 2010 at 1,450 uS/cm and 1,170 uS/cm, respectively, equivalent to an average TDS of 928 mg/l and 748 mg/l, respectively.

The average groundwater ECs in the two westerly townships (T28s/R22e and T29s/R22e) are significantly higher and show increases in EC over time. In township T28s/R22e, the average EC from 1960 to 1989 is 1,820 uS/cm (1,164 mg/l TDS) and the average EC from 1990 to 2010 is an average 5,373 uS/cm (3,439 mg/l TDS). In this township, most of the increase in EC occurs during the last half of the 1980s. In township T29s/R22e, the average EC from 1960 to 1989 is 4,829 uS/cm (3,091 mg/l TDS) and the average EC from 1990 to 2010 is 5,308 uS/cm (3,397 mg/l TDS). In this township, most of the increase in EC appears to occur from the early 1980s to the early 1990s. Based on these data, we conclude that the EC and TDS data demonstrate that the area between the West Side Canal and the Main Drain Canal near- and to the north of- the latitude of 7th Standard Rd is underlain by saline groundwater which interfaces with fresher groundwater to the east. Based on the existing data, the groundwater salinity between the canals is estimated to be in the range of 2,560 to 6,400 mg/l TDS content



The composite, average groundwater EC in both westerly townships exhibits considerable fluctuation over time. For the 30-year period from 1960 to 1989, the two westerly townships (T28s/R22e and T29s/R22e) had no recorded EC analyses anywhere in each township in 10 and 22 different years, respectively. The temporal sparseness makes it difficult to determine the significance or presence of trends in the data (Figure 4. EC v. Time Plots for 6 Wells, 1960 - 2010.)

The low spatial data density makes it difficult to map the lateral boundary (i.e., the interface) between the fresh and brackish waters under the district. Regardless of whether we define the boundary between fresh and brackish water as 1,000 or 1,500 mg/l, we have insufficient data to identify the exact location of the interface between the fresh and brackish waters under the district more precisely than somewhat east of the main drain. The groundwater chemistry data are insufficient to determine whether or not the interface is migrating over time.

The available water quality data are also insufficient at this time to prove that saline groundwater is flowing into the district from sources to the west. However, historical trends in irrigation practices suggest that the water quality west of the main drain has, in fact, degraded over time. It is reported that:

> *The local pumpers have documented, by progressive replacement of their wells from west to the east, the degradation [sic] water quality over time on the west side of the BSA.*[28]"

To the farmers in the water district, the abandonment and replacement of water wells due to the degradation of water quality over time is an expensive hardship which lessens the value of their land, increases their cost of water, and may require fallowing the land. Twenty years ago, more or less, when this was happening, no one in the water district felt that it was necessary to document, by way of water sampling, what was happening in the groundwater that was causing the farmers to relocate or abandon their irrigation wells, and/or fallowing their ground. Therefore, what the water district claims is not that we have the data which proves what was going on in the aquifer, but that whatever it was, the quality of the groundwater degraded to the point that the farmers in the western part of the district no longer used their wells and/or fallowed their ground. Today, one of the primary reasons that the water district has so little groundwater data along the west side of the district north of 7th Standard Rd is that so few wells exist in the area.

The theory that the saline groundwater under the BSA flows in from the west appears to contradict the observation that there is no observable groundwater gradient across the western BSA boundary. Both can't be true but the district does not currently have enough data to test the theories or resolve the issues, because the limited amount of available data just do not cover the entire boundary or all aquifer depths. The lack of observable saline groundwater migration within the district suggests that inflow may not occur continuously but only in short, infrequent, inflows, and perhaps only during the very wettest episodes of the climatic wet/dry cycle. During the rest of the time, the observable groundwater gradient may, in fact, be essentially zero. The district recognizes the source of saline water and the nature of the boundary flow on the west side as issues, among several others, for further study.

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[28] Quote from Dan Bartel (GEI) Memorandum to Maurice Etchechury (BVWSD), dated 15 March, 2013.

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FINAL

GROUNDWATER IMPACTS ASSESSMENT REPORT

KERN RIVER WATER ALLOCATION PLAN

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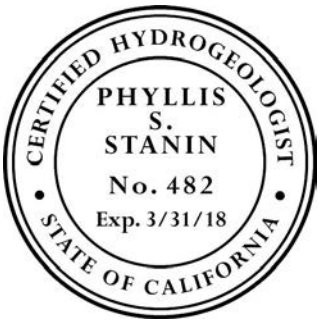
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List of Acronyms

AEWSD	Arvin-Edison Water Storage District
AFY	Acre-feet per year
BVWSD	Buena Vista Water Storage District
Cal Water	California Water Service Company, Bakersfield District
CEQA	California Environmental Quality Act
cfs	cubic feet per second
City or COB	City of Bakersfield
COB 2800	City of Bakersfield 2800 Acre Recharge Facility
CVHM	Central Valley Hydrologic Model
CV2Sim	California Central Valley Groundwater-Surface Water Simulation
CVP	Central Valley Project
CWD	Cawelo Water District
DBCP	1,2-Dibromo 3-chloropropane (also Dibromochloropropane)
DWR	California Department of Water Resources
EDB	Ethylene dibromide
GCWD	Greenfield County Water District
ID	Irrigation District or Improvement District
ID-4	Improvement District No. 4 of the Kern County Water Agency
KCWA	Kern County Water Agency
KDWD	Kern Delta Water District

KWB	Kern Water Bank
LPUD	Lamont Public Utilities District
MCL	maximum contaminant level
mg/L	milligrams per liter or parts per million (ppm)
msl	mean sea level
MODFLOW	three-dimensional (3D) finite-difference groundwater flow model code developed by USGS. Considered an international standard for simulating and predicting groundwater conditions and groundwater/surface-water interactions.
NKWSD	North Kern Water Storage District
NORMWD	North of the River Municipal Water District
OMWC	Oildale Mutual Water Company
RRBWSD	Rosedale-Rio Bravo Water Storage District
RRID	Rosedale Ranch Improvement District
SEIR	Supplemental Environmental Impact Report
SSJMUD	Southern San Joaquin Municipal Utilities District
SWID	Shafter-Wasco Irrigation District
SWP	State Water Project
SWSD	Semitropic Water Storage District
TDS	Total Dissolved Solids
USGS	U.S. Geological Survey
µg/L	micrograms per liter or parts per billion (ppb)
VWC	Vaughn Water Company
WAP	Draft Kern River Water Allocation Plan, Kern Delta Water District, 2011 (also called Proposed Project)
WD	Water District
WSD	Water Storage District
WSA	Water Service Area (also called (City) Domestic Water System service area)

Key Definitions and References used in this Report

2011 Impacts Assessment Potential Groundwater Impacts Assessment, Kern River Water Allocation Plan, Kern Delta Water District, prepared by Todd Engineers, November 1, 2011, included as Appendix E in the 2011 DEIR.

2011 DEIR Kern River Water Allocation Plan, Draft Environmental Impact Report, SCH# 2011041082, Prepared for Kern Delta Water District, Prepared by ESA, November 2011.

2012 FEIR Kern River Water Allocation Plan, Final Environmental Impact Report, SCH# 2011041082, Prepared for Kern Delta Water District, Prepared by ESA, September 2012.

2014 Order Order on Petition for Writ of Mandate filed June 5, 2014 by Ventura County Superior Court Judge Glen M. Reiser in consolidated cases challenging the adequacy of the 2012 FEIR under the California Environmental Quality Act (CEQA) (*North Kern Water Storage District et al. v. Kern Delta Water District*, Case No 56-2012-00425941-CU-WM-VTA; and *City of Bakersfield v. Kern Delta Water District*, Case No. 56-2012-00428753-CU-WM-VTA).

Caps Monthly maximum diversion limits imposed on KDWD's Kern River water rights by the Reed Decision.

Entitlement The quantity of Kern River water available by law or contract to a given diverter at any particular point in time.

Hydraulic Conductivity An aquifer property or parameter that describes the rate at which water can move through a permeable medium.

KDWD Superposition Model The model developed to conduct the quantitative groundwater impacts analysis in this report. The model is a MODFLOW model based on the USGS CVHM and the principle of superposition.

Preserved Entitlement The Reed Decision placed Caps on KDWD's Kern River water rights for those months where partial forfeiture had occurred. These Caps represent the Preserved Entitlement for each month and each right remaining after application of the partial forfeiture.

Release Water Kern River water accruing to a given water right that is not diverted by the water right holder; rather, the water is *released* and thereby becomes available for diversion by others.

Reed Decision 2005 decision by Judge Reed of the Superior Court of Tulare County (No. 96-172919), as modified by North Kern Water Storage District v. Kern Delta Water District, et al., No. F047706 (5th Dist. Feb.5, 2007) (Certified for Publication) (2007) 147 Cal.App.4th 555, finding a partial forfeiture of KDWD's Kern River water rights during certain months.

Vartabedian Opinion Opinion by Justice Vartabedian in North Kern Water Storage District v. Kern Delta Water District, et al., No. F047706 (5th Dist. Feb.5, 2007) (Certified for Publication) (2007) 147 Cal.App.4th 555.

EXECUTIVE SUMMARY

Introduction

This Draft Groundwater Impacts Assessment Report provides technical analyses to assist with preparation of a focused Draft Supplemental Environmental Impact Report (SEIR). The SEIR is being prepared by Kern Delta Water District (KDWD or District) for its Kern River Water Allocation Plan (WAP or Proposed Project) (Todd Engineers, 2011a). Impacts to groundwater as a result of the Proposed Project were analyzed in the Kern River Water Allocation Plan Final EIR (2012 FEIR) prepared by the District in 2012. As required by a recent court judgment, an SEIR is needed to provide additional information regarding the environmental setting and potential impacts of the Proposed Project on groundwater generally and, more particularly, on affected areas north of the Kern River and beneath the City of Bakersfield (City). This report focuses on requirements of the court judgment that are related to groundwater and provides a more quantitative impacts assessment than had been conducted previously.

Proposed WAP

Implementation of the WAP will maximize the District's use of its entitlement of Kern River water. In the WAP, the District prioritizes management actions for beneficial use of its full entitlement as recently modified by court decisions (Preserved Entitlement). The WAP management actions provide KDWD with more flexibility to move water among the various canal service areas within the District and to store water in the groundwater basin for future use. These actions allow KDWD to maximize use of its Preserved entitlement, including water that had previously been released to other entities (referred to herein as release water) including North Kern Water Storage District (NKWSD) and the City of Bakersfield (City or Bakersfield). The Proposed Project would end or reduce these historical releases.

Because KDWD, NKWSD and the City all use groundwater and surface water conjunctively, the use of release water by KDWD as part of the Proposed Project may result in a higher reliance on groundwater by NKWSD and the City. Conversely, the increased surface water diverted by KDWD may result in a decrease in the amount of groundwater used within the KDWD boundary. These potential impacts are used to guide the impacts assessment in this report.

Study Area and Study Period

A large, regional area has been delineated as the Project Study Area, covering more than 1,500 square miles as shown on **Figure 1-1**. This area has been identified to evaluate the environmental setting and Project-related impacts in all areas that could be potentially adversely affected by the Proposed Project, with a focus on areas north of the Kern River and beneath the City. The Study Area includes KDWD, the City, and water agencies north of the river; the area also extends about three miles north of the Kern County line in

recognition of the hydraulic connectivity of the Kern County Subbasin with adjacent groundwater basins to the north. The Study Period incorporates the period analyzed in the 2011 assessment (1997-2007) to represent average hydrologic conditions. That Study Period has also been extended to 2014 to include recent drought conditions. These two time periods (1997-2007 and 1997-2014) were used to assess impacts.

Projected Changes in Use and Location of KDWD Release Water

In order to quantify the amounts of release water that will no longer be available to other users, historical monthly Kern River entitlements, use, and historical releases by KDWD were evaluated from 1997 to 2014. This evaluation considers actual diversion records and past use of release water by NKWSD and the City – the two entities that account for almost all of the release water used in the basin. The amount of KDWD release water that will be used under the Proposed Project and the entity (or location) associated with historical use of that water are summarized in **Table 4**.

The historical records were also examined to estimate how the release water might have been used by NKWSD and the City. The type of use provided a method of determining when and where the reduction in release water and local impacts would occur. For NKWSD, release water was allocated on a monthly basis to one of the following uses:

- Spreading (Recharge) basins
- Canal losses from spreading
- Class 2 Service Area irrigation
- Canal losses from Class 2 Service Area irrigation
- Other use.

For the City, release water was allocated on a monthly basis to one of the following uses:

- KDWD (water applied to the COB 2800 for KDWD)
- Kern Water Bank spreading
- Other spreading (COB 2800)
- Other use.

The historical uses of KDWD release water by NKWSD and the City are summarized in **Tables 5** and **6**, respectively. Amounts of release water used historically by NKWSD and the City are shown graphically on **Figures 3-3** and **3-4**, respectively. The impacts assessment focused on how the reduction in release water would have impacted groundwater resources beneath NKWSD and the City.

To analyze impacts of the Proposed Project on KDWD, monthly amounts of previously-released Kern River water were redistributed according to management priorities in the WAP. The priorities, along with the corresponding average amounts of release water for each priority, are summarized in **Table 7**. WAP priorities are listed below:

Priority 1: Irrigation within Service Area Rights
Priority 2: Irrigation for Unmet Irrigation Demand in all Service Areas

Priority 3: Municipal and Industrial Demand within KDWD Boundaries
Priority 4: In-District Recharge
Priority 5: Pioneer Project Recharge
Priority 6: Other Uses.

Groundwater Conditions in the Northern Study Area

To provide context for the impacts analysis in adversely affected areas north of the river, groundwater conditions in the Northern Study Area are characterized in **Section 4** of this report. The characterization describes the physical setting including climate, hydrology, land use, groundwater use, and geology (see **Figures 4-1** through **4-5** and **Tables 9**, **10**, **11**, and **12**). The hydrogeologic setting provides information on subbasin aquifers (**Figures 4-6** through **4-9**), groundwater occurrence and flow, as well as trends and fluctuations in water levels (**Figures 4-10** through **4-14**). Groundwater budgets and overdraft conditions are documented in **Section 4.6** (see **Table 13** and **Figure 4-15**). **Section 4.7** presents historical and recent land subsidence throughout the subbasin (see **Figures 4-16** through **4-19**). Local groundwater quality is summarized in **Section 4.8** (**Figures 4-20** through **4-23**).

Groundwater Modeling of Proposed Project Impacts

A numerical model has been developed to quantify the groundwater impacts associated with the Proposed Project over space and time. A superposition modeling approach was selected as the most suitable method to support the groundwater impacts analysis. This superposition approach enables the Project-related changes to be calculated throughout the basin, and superimposed on the groundwater system so that the accumulated effects of the Project over time can be determined.

The development of the superposition model was based on modification of an existing, calibrated Central Valley Hydrologic Model (CVHM). The CVHM is a three-dimensional computer model developed by the USGS to simulate surface water and groundwater flow across the entire Central Valley. Use of the CVHM allows the superposition model to incorporate the aquifer basin structure, hydrostratigraphy and parameter values determined through calibration of the pre-existing model.

The model was used to evaluate groundwater impacts during the two study periods. A series of scenarios were set up and run to assess changes in groundwater conditions under both the Average Hydrologic Conditions (1997-2007) and Combined Study Period (1997-2014). A brief summary of the scenarios developed using the KDWD Superposition Model include:

- *The Baseline Scenario* simulates change in groundwater levels by applying the Proposed Project over the Combined Study Period of 1997 through 2014. The results of the Baseline Scenario were evaluated by superimposing the model results onto historical groundwater elevation data across the Study Area. This estimates what groundwater elevations would have been if the Proposed Project had been initiated in 1997.

- *Scenario A* projects the Combined Study Period (1997-2014) over 50 years to evaluate the accumulated changes in groundwater conditions resulting from the Proposed Project calculated after 10, 25, and 50 years. The updated period (2008-2014) incorporates the recent drought and water use on the Kern River.
- *Scenario B* projects the Average Hydrologic Conditions (1997-2007) over 50 years to evaluate the accumulated changes in groundwater conditions resulting from the Proposed Project calculated after 10, 25, and 50 years. This assessment uses the same time period analyzed in the 2011 Impacts Assessment (1997-2007) and represents average hydrologic conditions.

The release water reductions and additions were applied to the KDWD Superposition Model on a monthly basis. The modeling results provide the change in groundwater levels associated with the Proposed Project (Project-related impacts).

Impacts Conclusions

The impacts to the groundwater system as a result of the implementation of the KDWD WAP involve less recharge and more groundwater pumping north of the river and immediately south of the river accompanied by an equivalent amount of more recharge and less groundwater pumping south of the river. Conclusions from the impacts analysis are summarized below.

- Long-term operation of the Proposed Project over a 50-year period lowers water levels beneath NKWSD and SWID – approximately -2 to -3 feet lower, spatially averaged over their service areas. Project-related water levels are lower than non-Project levels by an average of about -1 foot beneath SWSD (**Table 17**). Long-term Project-related water levels rise beneath the City of Bakersfield about 3 to 4 feet, on average.
- Spatially averaged maximum water level declines in any given month throughout the Study Periods (Scenarios A and B) are -13 feet lower beneath NKWSD (see Scenario A, **Table 17**) and -8 feet lower beneath the City of Bakersfield WSA (see Scenarios A and B on **Table 17**).
- Project-related impacts on water levels are within the magnitude of seasonal fluctuations (compare project-related changes to fluctuations on hydrographs in **Appendix C**). An examination of several hundred hydrographs indicates that the magnitude of the impacts is small compared to the variability in the observed water level data over the Combined Study Period (1997-2014) (e.g., **Figures 6-12a** through **6-12k**; see also **Appendix C**).
- Project-related impacts are larger during wet periods when more water has been released and regional water levels are rising. Impacts during dry periods are much less due to limited availability of Project-related release water.

- The larger Project-related impacts to water levels (localized declines of more than about -15 feet) occur over small areas around spreading basins and canals (Model Layer 1) or at pumping centers during wet periods when large amounts of release water are assumed to be replaced with groundwater (Model Layer 3). Declines around spreading basins can reduce local mounding by more than about -15 feet. Declines from pumping can spike to about -15 feet in some areas. These declines typically last a few months, followed by a recovery to the long-term average Project-related impact of -2 to -3 feet under NKSWD (where the greatest impacts occur).
- Regional groundwater flow will not change significantly due to the Project-related redistribution of water (**Figures 6-3** and **6-6**). Because the Proposed Project creates higher water levels south of the river, changing hydraulic gradients allows more water to flow from beneath the river to the north, partially mitigating Project-related impacts in that area.
- The overall water budget for the groundwater system is not impacted substantially; impacts result from a redistribution of groundwater in storage from north to south (see **Table 18**) with no significant net change in groundwater volume in the subbasin. Impacts are minor compared to the overall groundwater in storage. Project-related changes to groundwater in storage indicate a minor net benefit associated with the capacity to capture additional subsurface inflow in the subbasin.
- Even though the overall groundwater in storage in the subbasin is not adversely impacted by the Proposed Project, groundwater in storage is reduced locally beneath NKWSD (see **Tables B-5** and **B-7**, **Appendix B**).
- The rate of decline of groundwater in storage in the Northern Study Area gradually decreases over time as subsurface flows into the area increase. After 50 years, the modeling results indicate that the long-term rate of change to groundwater in storage shifts from a decreasing to a slight increasing trend; however, the cumulative loss of groundwater in storage from the earlier time periods would remain (see summaries at bottom of Annual Storage Change column in **Tables B-5** and **B-7** in **Appendix B** for total storage change at 10, 25 and 50 years).
- KDWD's use of the release water under the Proposed Project raises water levels locally (by replacing groundwater pumping) and adds to groundwater in storage south of the river. This allows for partial alleviation of local overdraft conditions beneath KDWD (see **Table 13** for estimated overdraft in Subregion 21 shown on **Figure 4-15**).
- A theoretical analysis of Project-related impacts to groundwater resources was conducted in compliance with the 2014 Order, assuming no subsurface inflows or outflows beneath impacted areas (no equilibration of the groundwater system). That analysis concludes that water levels beneath NKWSD would be lowered by about -77 feet and water levels beneath the City of Bakersfield would be lowered by about -52 feet after 50 years of Proposed Project operation. Consistent with the theoretical nature of the analysis, impacts occur in a small area beneath NKWSD; because the concept of lateral groundwater flow is excluded under the assumption

of non-equilibration, impacts do not extend beyond the NKWSD or City of Bakersfield boundaries.

- Project-related impacts relating to potential land subsidence were calculated using a one-dimensional mathematical model of vertical compaction, which has been used by the USGS and other investigators in the Central Valley. The analysis calculated Project-related subsidence impacts when water levels would be representative of historic low levels (September 2014) during the modeled time period. The 18-year Combined Study Period (1997-2014) was repeated three times (Scenario A) resulting in a cumulative change in Project-related subsidence impacts after 54 years. The conservative one-dimensional analysis suggested a potential Project-related impact of up to 2.2 inches of land subsidence in NKWSD. This impact is considered small; larger magnitudes of land subsidence were not reported to have resulted in local infrastructure problems in NKWSD.
- Using a conservative mixing model approach, water quality impacts as a result of the Proposed Project are small. The NKWSD mixing model indicates a slight rise in TDS concentrations of about 4.7 mg/L after 10 years and about 6.4 mg/L after 25 years of Proposed Project operation. At the end of the 50- year analysis, TDS concentrations are about 4.4 mg/L higher. The annual maximum increase of 6.88 mg/L occurs in Year 27 (see **Table F-2**, **Appendix F**). This increase of up to 6.88 mg/L beneath NKWSD is small compared to typical TDS concentrations of 250 mg/L or higher. The City of Bakersfield mixing model also indicates a slight rise in groundwater TDS concentrations of 1 mg/L and 2.5 mg/L after 10 and 25 years, respectively and a rise of 4.8 mg/L at the end of 50 years (**Table 23**; see also **Appendix F**).

1 INTRODUCTION

Kern Delta Water District (KDWD or District) is preparing a focused Draft Supplemental Environmental Impact Report (SEIR) on its Kern River Water Allocation Plan (WAP or Proposed Project) (Todd, 2011a). Impacts to groundwater as a result of the Proposed Project were analyzed in the Kern River Water Allocation Plan Final EIR (2012 FEIR) prepared by the District in 2012. As required by a recent court judgment, an SEIR is being prepared to provide additional information and calculations regarding potential impacts of the Proposed Project generally and, more particularly, on areas north of the Kern River and beneath the City of Bakersfield. This report focuses on these additional requirements and provides a more detailed assessment as specifically directed by the court. The locations of KDWD south of the Kern River and the impacts assessment Study Area are shown on **Figure 1-1**[1]. Also included on **Figure 1-1** are the political boundaries of local water agencies as well as the boundary of the Kern County Subbasin of the larger San Joaquin Valley Groundwater Basin.

1.1 BACKGROUND

Implementation of the WAP will maximize the District's use of its entitlement of Kern River water. In the WAP, the District prioritizes management actions for beneficial use of its full entitlement as recently modified by court decisions (Preserved Entitlement). After a series of court trials, appeals and decisions spanning 1998 to 2007, the ultimate finding (referred to as the Reed Decision[2]) required partial forfeiture of certain water rights. Specifically, the Reed Decision established monthly maximum diversions (herein referred to as *Caps*) in certain months on four of the KDWD diversion rights. Historically, KDWD often diverted less than its full entitlement, releasing water to other entities including North Kern Water Storage District (NKWSD) and the City of Bakersfield (City or Bakersfield). The Proposed Project would end or reduce releases as KDWD maximizes use of its Preserved Entitlement. **Figure 1-1** shows the location of the NKWSD, the City WSA, and the Kern River.

The WAP management actions provide KDWD with more flexibility to move water among the various canal service areas within the District and to store water for future use. Accordingly, these actions allow KDWD to use its full entitlement; however, more water used by KDWD will cause less water to be released to NKWSD and the City (referred to herein as *release water*). Since all three entities use groundwater and surface water conjunctively, the absence of release water may result in higher reliance

[1] Due to overlapping areas, not all water purveyors are shown.

[2] In the original trial, the Honorable Kenneth E. Conn found that Kern Delta had forfeited a portion of its Kern River entitlements based on non-use. The matter was appealed and the Court of Appeal reversed the determination of forfeiture and directed a retrial of the question "whether Kern Delta forfeited by nonuse any part of its paper entitlements …" (See, North Kern Water Storage District v. Kern Delta Water District, et al., No. F033370 (5th Dist. Jan.31, 2003, as modified March 3, 2003) (unpublished opinion). The matter was remanded and re-tried before the Honorable Melinda M. Reed and Judgment was entered on February 9, 2005 finding that Kern Delta had forfeited a portion of its Kern Island right during the months October through January and a portion of its Farmers right during the month of August. (Tulare County Superior Court Case No. 96-172919). The matter was again appealed and the Court of Appeal modified the Judgment finding additional forfeiture as to certain of Kern Delta's junior appropriative Kern River rights (See, North Kern Water Storage District v. Kern Delta Water District, et al., No. F047706 (5th Dist. Feb.5, 2007) (Certified for Publication) (2007) 147 Cal.App.4th 555. The Reed Judgment and the Appellate Court's Opinion After Rehearing modifying the Reed Judgment are collectively referred to herein as the "Reed Decision". See, North Kern Water Storage District v. Kern Delta Water District (2007) 147 Cal.App.4th 555.

on groundwater by NKWSD and the City. Conversely, the increased surface water diverted by KDWD may result in a decrease in the amount of groundwater used within the KDWD boundary.

A previous assessment[3] of these potential impacts to groundwater (Todd Engineers, 2011b) provided a detailed accounting of monthly release water over an 11-year Study Period (1997 – 2007) and estimated how that water would be re-directed under the Proposed Project. The impacts of changing the availability of surface water – along with the associated reliance on groundwater – were analyzed for the entities that had previously used the release water. However, the methodology used for the 2011 assessment was relatively static in time and could not quantify how the accumulated impacts would be distributed throughout the groundwater system over time as a result of changes to groundwater flow. It was recognized that impacts would alter local hydraulic gradients, resulting in groundwater levels equilibrating at different levels than seen today over large areas of the groundwater basin. However, the method used for the 2011 assessment was essentially static in time and did not quantify how cumulative impacts would be distributed throughout the groundwater system over time - such as in areas north of the Kern River - as a result of the Proposed Project.

Ventura County Superior Court Judge Glen M. Reiser issued an Order[4] on June 5, 2014 and subsequent Judgment[5] on July 11, 2014 requiring KDWD to set aside its certification of the 2012 FEIR and related actions. The 2014 Judgment found that the 2012 FEIR's project description and impact discussions regarding air quality, greenhouse gases, energy consumption, biological resources and aesthetics were adequate. Further, according to the court, the 2012 FEIR and WAP did a commendable job describing the project setting for KDWD.

However, the court found other aspects of the 2012 FEIR to be noncompliant with CEQA. Specifically, the court concluded that the 2012 FEIR failed to adequately consider and evaluate the environmental setting within areas outside KDWD, specifically those areas north of the Kern River and beneath the City that could be adversely affected by the Project. The 2014 Order noted that potential environmental impacts should have been quantified in those areas, specifically as to groundwater levels, aquifer overdraft conditions, groundwater quality, land subsidence, water supply, and agriculture. The 2014 Order also *requires recognition and discussion of neighboring areas of adverse impacts* with an emphasis on areas north of the Kern River and beneath the City.

1.2 GOAL AND OBJECTIVES

The goal of this assessment is to provide supplemental information and data along with a more quantitative impacts analysis to comply with technical requirements of the 2014 Order. In order to meet this goal, a hydrogeological characterization has been conducted for the potential impact areas of the

[3] Documented in the *Potential Groundwater Impacts Assessment*, Todd Engineers, November 1, 2011. Included as **Appendix E** in the 2011 Draft EIR. Referred to herein as the *2011 impacts assessment*, or the *2011 assessment*.
[4] Order on Petition for Writ of Mandate filed June 5, 2014 by Ventura County Superior Court Judge Glen M. Reiser in consolidated cases challenging the adequacy of the 2012 FEIR under the California Environmental Quality Act (CEQA) (*North Kern Water Storage District et al. v. Kern Delta Water District*, Case No 56-2012-00425941-CU-WM-VTA; and *City of Bakersfield v. Kern Delta Water District*, Case No. 56-2012-00428753-CU-WM-VTA) (2014 Order).
[5] Judgment Granting Peremptory Writ of Mandate and Injunction entered on July 11, 2014 by Ventura County Superior Court Judge Glen M. Reiser in consolidated cases challenging the adequacy of the 2012 FEIR under the California Environmental Quality Act (CEQA) (*North Kern Water Storage District et al. v. Kern Delta Water District*, Case No 56-2012-00425941-CU-WM-VTA; and *City of Bakersfield v. Kern Delta Water District*, Case No. 56-2012-00428753-CU-WM-VTA) (2014 Judgment).

Proposed Project with an emphasis on areas north of the Kern River and beneath the City. The characterization analyzes water levels, groundwater use, overdraft conditions, subsidence, and groundwater quality. This characterization builds on and expands upon the information provided in the 2011 assessment.

The assessment also incorporates numerical modeling capable of quantifying impacts from the Proposed Project in all affected areas over space and time. The 2011 assessment, which involved average hydrologic conditions using 1997 – 2007 data, has been updated and expanded through 2014 to account for recent drought conditions and recent use of Kern River water with the Caps in place. Methods, assumptions, analyses and results are described in this report.

1.3 STUDY AREA

A large, regional area has been delineated as the Study Area, covering more than 1,500 square miles as shown on **Figure 1-1**. This area has been identified to comply with the 2014 Order to assess and evaluate the environmental setting and Project-related impacts in all areas that could be potentially adversely affected by the Proposed Project, with a focus on areas north of the Kern River and beneath the City. The Study Area includes KDWD, the City, and water agencies north of the river; the area also extends about three miles north of the Kern County line in recognition of the hydraulic connectivity of the Kern County Subbasin with adjacent groundwater basins to the north. As required by the 2014 Order, the northern portion of the Study Area shown on **Figure 1-2**, including lands within the City WSA, is the focus of detailed information on the hydrogeologic setting and groundwater conditions.

The Study Area shown on **Figure 1-1** was used to identify water agencies for public record requests in order to consider agency-specific data in the groundwater evaluation. The groundwater model used in this impacts assessment is not limited by the Study Area boundary: it covers an area larger than the Study Area and extends approximately 20 miles north of the Kern County line (discussed in more detail in **Section 5** and **Appendix B**), so that Project-related impacts are simulated throughout the groundwater basin, independent of Study Area, county, or district.

1.4 STUDY PERIOD

The Study Period for the analysis incorporates the period analyzed in the 2011 assessment (1997-2007) to represent average hydrologic conditions. That Study Period has also been expanded from 2008 through 2014 to include recent conditions. The use of these two time periods and the combined period in this impacts assessment is discussed below.

1.4.1 Average Hydrologic Conditions (1997–2007)

For the 2011 assessment, actual hydrologic conditions and Kern River diversions from 1997 through 2007 were used as a model for water availability and use. That study period corresponded to the one used in the WAP and represented average hydrologic conditions in terms of precipitation and river flows. The period was sufficiently long to include wet and dry conditions, allowing evaluation of a wide range of flow conditions in the river. At the time of the 2011 assessment, the period also represented a recent time period reflective of then-current water use conditions.

During the 11-year period of 1997 – 2007, average precipitation (6.33 inches per year) was within about five percent of the long-term (1889-2014) average annual precipitation at Bakersfield (5.98 inches per

year) (NOAA, 2015). That time period was also representative of average hydrologic conditions for the Kern River as reflected by the Annual River Index (100 percent of average) as reported in the annual Kern River Hydrographic Reports. When evaluating impacts associated with the Proposed Project, actual historical diversions for the 1997-2007 study period were modified to reflect the restrictions later imposed by the Reed Decision.

1.4.2 Updated Hydrologic Conditions (2008–2014)

To assess recent and future impacts, data from a more recent study period (2008 – 2014) have been added to the impacts analysis. This time period represents recent conditions of water availability and use. Priorities from the WAP were used to estimate how release water would be reapportioned under the Proposed Project using actual diversions and releases for this time period.

This more recent time period is relevant to the analysis because it: 1) more accurately reflects recent water use and availability conditions, 2) encompasses a time period when Caps were in place pursuant to the Reed Decision, and 3) ends with several years of severe drought conditions. Average precipitation during the 2008-2014 period (5.3 inches per year) was about 89 percent of the updated long-term (1889-2014) average (5.98 inches per year) (NOAA, 2015). The Kern River Annual River Index for the 2008-2014 time period was 80 percent of average as reported in the annual Kern River Hydrographic Reports, indicating drier than average flow conditions.

1.4.3 Combined Study Period (1997–2014)

The combined time period of 1997-2014 provides a good representation of long-term average hydrologic conditions but also incorporates recent actual water availability information, along with a recent multi-year severe drought. The Combined Study Period contains significant wet and dry hydrologic periods allowing for an analysis of project impacts over a variety of hydrologic conditions. During this period, average precipitation was 5.93 inches per year, within one percent of the long-term (1889-2014) average annual precipitation at Bakersfield (5.98 inches per year) (NOAA, 2015). The Kern River Annual River Index for the entire 1997-2014 study period was 92 percent of the long-term average, which is represented by an index of 100 percent.

1.4.4 Selected Study Periods (1997–2014 and 1997 – 2007)

An updated, Combined Study Period of 1997 – 2014 is used in the impacts analysis to represent both long-term average and recent conditions. The 18-year period allows for impacts to be analyzed over a wide range of hydrologic conditions on the Kern River including one of the wettest years (1998) and one of the driest years (2014) in the historical record. This Study Period also incorporates Kern River water use under a variety of operations.

In addition, a separate, parallel impacts analysis is also conducted for the 11-year Study Period 1997 – 2007, which was used for the 2011 impacts assessment. This 1997-2007 Study Period is maintained in the updated impacts analysis to allow direct comparison of modeling results with the results from the 2011 assessment. The average amount of release water associated with this Study Period (33,048 acre-feet per year (AFY)) has been specifically referenced in the 2014 Order and is the basis for several specific requirements in the Order. Accordingly, this Study Period has been analyzed separately using more quantitative methods including numerical modeling.

Although the methodology for the impacts analysis is identical for both time periods, results are presented separately for the two Study Periods to allow comparison of a range of impacts.

1.5 ANALYSIS APPROACH

The purpose of this assessment is to evaluate the impacts resulting from a change in location and use of surface water that had been historically released but will now be used by KDWD as part of the Proposed Project. Data from the 2011 assessment (1997 – 2007) have been maintained in the analysis and updated through 2014. Importantly, a numerical model has been developed and applied for this analysis to provide a quantitative assessment of cumulative impacts over a wider geographic area that was not provided in the 2012 FEIR. The model directly simulates the changes to groundwater levels and flow from the redistribution of the Kern River water and estimates the accumulated change over time as the groundwater system equilibrates to Project-related changes in flow. The modeled area specifically includes areas north of the Kern River and beneath the City that could be adversely affected by the elimination of release water under the Proposed Project. Impacts are assessed separately for the 1997-2014 and 1997-2007 Study Periods and extend 10, 25, and 50 years into the future for each time period.

Most modeling analyses presented herein assume that groundwater conditions can equilibrate over time – which in this context, refers to principal of groundwater flow patterns stabilizing sometime after impacts extend increasingly outward geographically. However, the Order also requires an additional analysis with an "*alternative assumption that there will be no short-term and mid-term groundwater 'equilibration' in the adversely affected area over the next 10, 25 and 50 years*". An analysis without equilibration assumes that the impacted area is not connected to the remainder of the groundwater basin hence that no subsurface inflow or outflow can occur that would enable stable conditions to be achieved. An analysis without the assumption of equilibration is detailed in **Section 6.3**.

1.6 DATA

For more than 50 years, the U.S. Geological Survey (USGS), the California Department of Water Resources (DWR), Kern County Water Agency (KCWA), and others have been investigating and reporting on groundwater conditions in the subbasin. In addition to the publicly-available documents and data, KDWD submitted a Public Records Act Request to 18 local water agencies and municipalities in order to incorporate agency-specific groundwater data in the analysis. Data were received from the 17 local agencies listed in **Table 1**.

Table 1. Entities Providing Data to Support the Project Impacts Assessment

Arvin Edison Water Storage District (AEWSD)	North of the River Municipal Water District (NORMWD)
City of Bakersfield (City or COB)	Oildale Mutual Water Company (OMWC)
Buena Vista Water Storage District (BVWSD)	Rosedale-Rio Bravo Water Storage District (RRBWSD)
California Water Service Company (Cal Water)	Semitropic Water Storage District (SWSD)
Cawelo Water District (CWD)	City of Shafter (Shafter)
Greenfield County Water District (GCWD)	Shafter Wasco Irrigation District (SWID)
Kern County Water Agency (KCWA)	Southern San Joaquin Municipal Utilities District (SSJMUD)
Lamont Public Utilities District (LPUD)	City of Wasco (Wasco)
North Kern Water Storage District (NKWSD)	

Each entity was sent an individualized letter requesting specific data over a specific time period (primarily 1997-2014 or 2008-2014 if earlier data were already compiled). Requested data included, where appropriate:

- Groundwater levels/elevations and contour maps
- Groundwater pumping and use (agency, municipal, agricultural)
- Groundwater recovery well pumping and use (banking or recharge project)
- Agency, municipal, and agricultural well coordinates, geologic logs, electric logs, and construction data
- Imported water deliveries and use
- Surface water deliveries and use
- Groundwater, surface water, and imported water quality
- Aquifer characterization information
- Groundwater recharge (volumes and location)
- Canal water losses
- Numerical groundwater flow modeling executable files, records, and reports
- Irrigation efficiencies, return flows, or other measures of consumptive use
- Groundwater or agricultural management plans or similar information on management of water use
- Land subsidence monitoring and reports
- Future water supply and demand projections
- Agreements and other documentation relating to past or future water supplies or deliveries
- Agreements or other documentation pertaining to the construction of recharge basins or water conveyance systems.

Follow-up correspondence and discussions with the water supply entities occurred to facilitate and assist with data gathering. In some cases, site visits were conducted to assist with data gathering. Public agency data were supplemented with other data and documents available through DWR, USGS, and other data sources. Relevant documents and data are cited throughout the text of this report and included in the reference list in **Section 8**.

1.7 REPORT ORGANIZATION

The following sections of this report provide the framework and methodology to identify and quantify potential groundwater and other related potential impacts of the Proposed Project. **Section 2** of this report provides background information on water supply and the historical use of Kern River water by KDWD, NKWSD, and the City. NKWSD and the City are the two entities that historically used almost all of the KDWD release water and therefore, are the two entities most directly impacted by the Proposed Project. **Section 3** describes how the Proposed Project will affect the availability of Kern River water among First Point diverters on the river.

Section 4 describes the environmental setting and groundwater conditions in the Study Area with a focus on potentially-affected areas beneath the City and north of the Kern River. This section provides the hydrogeologic context for the impacts assessment. **Section 5** describes the groundwater impacts assessment including the methodology and assumptions. **Section 6** presents the results of the impacts assessment, including impacts to groundwater levels, groundwater in storage, land subsidence, and groundwater quality. Also included in **Section 6** is the analysis "without equilibration," as required by

the 2014 Order. **Section 7** summarizes the conclusions of the impacts analysis and provides a proposed monitoring plan. A list of references cited in this report is provided in **Section 8**.

Finally, a series of appendices contains detailed tables of KDWD Monthly Releases (**Appendix A**), documentation of the groundwater model used for the impacts analysis (**Appendix B**), additional results from the impacts analysis modeling (**Appendices C**, **D**, and **E**), and documentation of the water quality mixing model (**Appendix F**).

2 KERN RIVER ALLOCATION AND WATER USE

In order to develop a clear understanding of how the release water may have been used in the Study Area, historic diversion and use of Kern River water was reviewed. The review focused on river water use by the three primary First Point diverters on the Kern River: KDWD, the City, and NKWSD. These three entities divert Kern River water based on entitlement and flow at a key stream gage referred to as First Point (**Figure 1-1**). As First Point diverters, the City and NKWSD have historically used almost all of the water released by KDWD (release water).

This section summarizes background information on the allocation of the Kern River and water use by KDWD, NKWSD and the City. **Section 3** provides more detailed data and analysis of the actual amounts of release water available and the amounts used by KDWD, NKWSD and the City.

2.1 KERN RIVER WATER ALLOCATION

Flow in the Kern River was adjudicated by the 1900 Shaw Decree. Over the years, it has been apportioned among many users based on entitlements determined through canal company consolidations, water rights acquisitions, court decisions, and agreements (KDWD, 2009). The assigned water right entitlements are considered "paper entitlements or theoretical entitlements" meaning that they can be reduced based on the daily flow in the river (Vartabedian Opinion, 2007). These theoretical entitlements are reported in the annual Kern River Hydrographic Reports along with adjusted entitlements and use. Since its 1976 purchase of the canal company that was the former record keeper for these rights, the City has taken over Kern River operations and record keeping and still uses the same single-page spreadsheet that was used historically to record diversions by each separate water right holder (Bogart, 2009).

In 1888, two permanent stream gage stations were established to measure flow in the Kern River on a real-time basis. The first station is referred to as First Point of measurement (**Figure 1-1**). The record of daily discharge here is used to allocate water among the various Kern River interests, referred to as First Point diverters, Second Point diverters, and Lower River diverters. The Second Point of measurement is approximately 20 miles downstream and is used to check upgradient water use (and entitlements) with diversion rights downgradient of Second Point (Boyle, 1975).

A third downstream gage is located at an intertie between the river and the California Aqueduct that was constructed in 1977 to convey Kern River flood waters into the aqueduct to prevent flooding of downstream lands (Intertie). The Intertie is near Tupman, downstream of Second Point (**Figure 1-1**). Since construction of Isabella Reservoir in 1953, water allocation is based on a calculated number to account for both diversions and storage in the reservoir (Kern County Parks and Recreation website, 2010; Boyle, 1975). The three Kern River measuring stations - First Point, Second Point, and the Intertie – are shown on **Figure 1-1**.

KDWD and City of Bakersfield are successors-in-interest to all First Point water rights holders. Buena Vista Water Storage District (BVWSD) is successor-in-interest to all Second Point water right holders. The KCWA is successor-in-interest to all Lower River water right holders (downstream of Second Point). Water allocated to a First Point diverter, but not used, can be released to another First Point diverter (release water). Allocated water not used by any First Point diverter can be used by the Second Point diverter (BVWSD), and allocated water not used by the Second Point diverter can be used by the Lower River diverter (KCWA) (BVWSD, 2007).

The recordation of river water distribution occurs on a daily basis through a cooperative effort that is summarized on a monthly basis in the annual Kern River Hydrographic Reports (COB, Kern River Hydrographic Reports, 1997-2014). Each day the quantity of water flowing in the river is determined and corrected to account for storage in Lake Isabella. The entitlements are then allocated to individual diverters according to their legal and contractual rights and priorities. Water users can place requests for delivery of water each day. Any allocated water that is not needed or requested is subsequently "released" to other users. A City representative then offers this release water to the next junior right holder with demand that day up to its full Shaw Decree amount or paper right. Each day starts anew where the flow in the river is determined, the entitlement is calculated, and water is delivered to conveyance canals based on demand and the canal's entitlement (Bogart, 2009).

In extremely wet years, when flow exceeds the 3,162 cubic feet per second (cfs), all rights are fulfilled and additional water is considered surplus. Historically, First Point users did not take all surplus water and it became available to Second Point and Lower River users. Surplus water can also be diverted to the California Aqueduct through the Intertie (Bogart, 2009).

2.2 KERN DELTA WATER DISTRICT WATER USE

For more than 130 years, canal systems located within the KDWD boundary have delivered a cost-effective, high quality water supply to support the agricultural economy on District lands south of the Kern River. These systems were first developed as separate canal companies, each with its own Kern River water right and defined service area, and were later consolidated. KDWD was formed in 1965 to provide a public entity that secures and manages a diverse portfolio of water supplies conjunctively to benefit water users and to preserve the service areas' existing water rights to the Kern River. Facilities and Kern River water rights were subsequently acquired by the District. The KDWD boundary covers approximately 129,000 acres, about 90,000 of which are irrigated agriculture. **Figure 2-1** shows the historical utility service areas and main canals within the KDWD boundary.

As part of recent court decisions, KDWD has been forced to forfeit a portion of its water rights, decreasing its entitlement on the Kern River. This forfeiture coincides with increasing uncertainty of the reliability of imported supplies and declining groundwater levels beneath the District. As such, KDWD intends to use its full remaining entitlement as determined by court decisions (Preserved Entitlement), preserving current water rights and increasing overall supply during certain times.

KDWD developed the Proposed Project to implement prioritized management actions to utilize full use of its Preserved Entitlement. Project objectives include:

- Meet existing underserved water demand within KDWD's boundary;
- Maintain sustainable groundwater resources and a sustainable water balance;
- Provide equitable distribution of water among the historical utility service areas;
- Serve the growing demand for water and emerging needs of customers in KDWD; and
- Maintain KDWD water right assets.

Kern River water rights quantified in the Reed Decision as KDWD Preserved Entitlements average about 201,943 acre feet per year (AFY) based on average river conditions between 1997 and 2007. KDWD actually used an average 178,863 AFY during this time frame. If the caps imposed by the Reed Decision had been in place, KDWD would only have been allowed to use an average of 168,895 AFY during this

time frame thus releasing an average of 33,048[6] AFY of its Preserved Entitlement while existing District demands remain unmet.

The WAP demonstrates beneficial uses for the full amount of KDWD's Preserved Entitlements needed to meet existing unmet demands. KDWD's diversion and use of former release water will result in a change in location and timing of Kern River water use and also will likely result in an associated change in location and timing of groundwater use. These Project-related changes in water use for NKWSD and the City are discussed below.

2.3 NORTH KERN WATER STORAGE DISTRICT WATER USE

The NKWSD was organized in 1935 and encompasses about 60,000 acres north of the Kern River and generally west of Highway 99 (NKWSD, 2016a) (**Figures 1-1** and **1-2**). The NKWSD provides irrigation water for primarily orchards and vineyards – mainly almonds, pistachios and grapes (NKWSD, 2016b). Facilities and classification of lands within NKWSD is shown on **Figure 2-2**.

NKWSD water supply includes groundwater, Kern River water, Poso Creek water, State Water Project (SWP) and Central Valley Project (CVP) water (either directly or through exchange), and treated oil field produced water. Historically, most of NKWSD's supplies are from the Kern River or from Kern River water recharged to the groundwater basin (NKWSD, 2016b).

The Rosedale Ranch area, south of Seventh Standard Road (**Figure 2-2**), was annexed to NKWSD without surface water supplies. In 1980 an improvement district was organized to acquire water for distribution to Rosedale Ranch lands for irrigation or recharge (Bookman-Edmonston, 1993). The Rosedale Ranch Improvement District (RRID) encompasses about 10,000 acres of mostly developed agriculture with increasing areas of urbanized land (NKWSD, 2016a). Groundwater is the main water supply; surface water (primarily Kern River water) is purchased when available in wet years. RRID and NKWSD share management and personnel but have separate sources of water and are financially independent (NKWSD, 2016a; Bookman-Edmonston, 1993).

NKWSD adopted a Project Plan in 1950 to provide for access to Kern River water, land to be used for groundwater recharge, and other water transmission facilities such as canals, gates, weirs, and pipelines (NKWSD, 2016a). There are two main classes of lands identified in the 1950 Project Plan: Class 1 Service Area and Class 2 Service Area (NKWSD, 2003) (**Figure 2-2**). The Class 1 Service Area (also called Canal Served Lands) is served primarily Kern River water through the NKWSD canal system and supplemented in shortage years by groundwater pumped from NKWSD wells. Class 2 Service Area (also called Private Pump Served Lands) is served primarily by private wells. NKWSD can provide surface water to Class 2 Service Area but is under no obligation to do so. NKWSD water supplied to Class 2 Service Area can be categorized into three types:

- **Regular Class 2 Service Area Water** is available when the water needs of Class 1 Service Area have been satisfied and/or NKWSD spreading is occurring.

[6] The average of 33,048 AFY for 1997 through 2007 time period was developed using a strict accounting of the water released to parties other than any of the KDWD service area canals. This average has been adjusted upward slightly to 33,099 AFY for this updated analysis to exclude water released by one KDWD canal and subsequently used by a downstream KDWD canal. This adjustment is more conservative and removes negative numbers from the release water totals to avoid confusion. Applying these same restrictions over the updated Combined Study Period of 1997 to 2014, the KDWD average release was calculated to be 27,342 AFY (see **Table 3**).

- **Special Class 2 Service Area Water** is available when NKWSD is able to purchase water from others for the benefit and use by Class 2 Service Area.
- **Emergency Class 2 Service Area Water** is available on a temporary, interruptible basis while private pumping facilities are inoperative.

NKWSD receives about 150,000 AFY of Kern River water through a 1952 Agreement. This supply has historically been supplemented by purchases of approximately 20,000 AFY from the City of Bakersfield pursuant to a 1976 contract (Bakersfield.com News, 2010a, 2010b and NKWSD, 2016a). The basic term of the 1976 contract with the City expired at the end of 2011 but the contract continues pursuant to extension term provisions (NKWSD, 2016a).

NKWSD also uses treated water from nearby oilfield production where large amounts of water are produced as a byproduct of oil and gas recovery operations. NKWSD receives about 12,000 AFY of produced water from local oil producers and has the ability to receive up to 21,000 AFY (NKWSD, 2016b). The produced water is treated and blended with other water supplies for crop irrigation (NKWSD, 2016b).

Groundwater recharge of surface water supplies occurs in constructed spreading basins, natural channels, and unlined canals (Bookman-Edmonston, 1993). Locations of the NKWSD spreading basins (recharge facilities) are included on **Figure 2-2**. NKWSD also pumps groundwater into canals from about 80 District-operated wells to supplement surface water during dry periods (Schmidt, 2007).

NKWSD can also store water upstream in Lake Isabella (with certain restrictions) if available Kern River water is not needed at that time. Stored water can be released from the reservoir when demand rises, typically during the irrigation season. In addition, NKWSD has been or is involved in exchanges with numerous local water agencies including CWD, KCWA Improvement District #4 (ID-4), BVWSD, KDWD, COB, Kern-Tulare Water District (KTWD), SWSD, RRID, Rag Gulch Water District, and SWID, among others (COB, 2010 Kern River Hydrographic Report).

NKWSD has also implemented water banking and exchange programs to optimize management of water supplies, increase the total volume of water brought into the District, and develop facilities to improve future water management (NKWSD, 2016d). NKWSD, along with SWSD and CWD, operate banking programs where surface water from banking partners is received in wet years and delivered to landowners for irrigation in lieu of groundwater pumping. Groundwater that would have been pumped remains in storage and is credited to the banking partner account. In times of water supply deficiencies, the water may be recovered and returned to the banking partner either directly through physical deliveries (e.g., via the California Aqueduct) or indirectly via an exchange of surface water (Poso Creek RWMG, 2014).

2.4 CITY OF BAKERSFIELD WATER USE

Water supply for Metropolitan Bakersfield is provided by several water districts and private water companies. The City of Bakersfield Water Resources Department and the California Water Service Company provide most of the supply, as discussed in more detail in the following sections. These and other suppliers of water are listed in **Table 2** and shown on **Figure 2-3**.

Table 2. Water Suppliers to Metropolitan Bakersfield

Water Supplier to Metropolitan Bakersfield	Water Supply Sources
California Water Service Company, Bakersfield District (Cal Water)	Groundwater, Kern River, and SWP water
City of Bakersfield Water Resources Department, Water System (City Water System)	Groundwater, Kern River, SWP, and Recycled water
Vaughn Water Company (VWC)	Groundwater
Oildale Mutual Water Company (OMWC)	Groundwater, SWP water
North of the River Municipal Water District (NORMWD)	Groundwater, SWP water (Merged into OMWC in 2014)
East Niles Community Services District (East Niles CSD)	Groundwater, SWP water
Improvement District No. 4 Kern County Water Agency (ID-4)	Groundwater, Kern River, and SWP water

Water supply consists of groundwater, surface water, and imported water sources. Groundwater provides most of the City's supply, which is replenished locally from natural recharge, canal seepage, spreading basins, and recycled water. The City also has a Kern River entitlement that averaged about 130,000 AFY between 1997 and 2014. The use of treated imported SWP water has increased in recent years with the expansion of local water treatment plants.

2.4.1 California Water Service Company (Cal Water)

Cal Water is the largest municipal water supplier in Bakersfield. Its system serves a large portion of the City and segments of unincorporated lands adjacent to the City (**Figure 2-3**). Cal Water's Bakersfield District was formed with the purchase of Bakersfield Water Works in 1926 (Cal Water, 2016b).

Between 2011 and 2015, Cal Water provided water supply from the following sources (Cal Water, 2016a):

- Groundwater – 58 percent
- Untreated Kern River water purchased from the City – 21 percent
- Treated SWP and Kern River water purchased from wholesaler KCWA ID-4 – 21 percent

Groundwater: Groundwater has historically supplied up to 80 percent of demands in the Cal Water service area (Cal Water, 2016a). Cal Water currently operates about 77 active wells to supply Bakersfield customer needs (Cal Water, 2016b). In recent years, Cal Water has replaced a portion of its groundwater supply with treated Kern River water as treatment plant capacity has increased. From 2007 to 2015, Cal Water reduced groundwater pumping from 53,889 AFY to 33,388 AFY (Cal Water, 2011 and 2016a).

Kern River Water from the City: Cal Water has a long-term supply agreement with the City of Bakersfield for 67,200 AFY of Kern River water. Cal Water owns and operates the Northeast Bakersfield Water Treatment Plant, which can treat 22,400 AFY. Future expansions of the plant will increase its capacity to 67,200 AFY. The North Garden Water Treatment Plant has a capacity to treat 8,960 AFY of Kern River water. Half of this amount (4,480 AFY) is supplied to the City under contract. Additional water treatment plants (Southwest Bakersfield WTP and Rosedale Ranch and Seventh Standard Corridor WTP) are

proposed to provide additional capacity in staged phases, with some portion of the water committed to the City. Source water for these WTPs will be Kern River water from long-term contracts with the City (Cal Water, 2016b).

SWP and Kern River Water from KCWA ID-4: KCWA ID-4 provides wholesale water to Cal Water from SWP entitlements and from Kern River flows. Water is recharged to groundwater or treated in the Henry Garnett WTP and conveyed to three retail suppliers including Cal Water (Cal Water, 2016b). Cal Water's contract for SWP from ID-4 is for 20,500 AFY of treated water from the treatment plant during normal hydrologic years with greater deliveries during peak summer periods (Cal Water, 2016b).

2.4.2 City of Bakersfield Water System (City Water System)

The City Domestic Water System service area (City WSA) covers about 35 percent of the western portion of Bakersfield (about 38 square miles) (**Figure 2-3**). Similar to Cal Water, the City relies on a variety of water sources including groundwater, Kern River water, imported SWP water, and recycled water. The City contracts with Cal Water to operate its water distribution system.

In 2010, the City Water System supplied water from the following sources (Stetson, 2014):

- Groundwater – 88 percent
- Treated water from Cal Water's North Garden Treatment Plant – 4 percent
- Treated SWP and Kern River water purchased from wholesaler KCWA ID-4 – 8 percent

Groundwater: Groundwater supply is pumped from approximately 53 active groundwater wells within City boundaries with a spacing of about four wells per square mile. Between 2006 and 2010, wells provided an average of 42,700 AFY for municipal water supply (Stetson, 2014). The City also owns the 2800 acre recharge ponds along the Kern River.

Kern River Water: The City holds pre-1914 appropriative Kern River water rights that typically yield an average of about 135,000[7] AFY (Stetson, 2014). This average does not include past use of release water (Stetson, 2014). The Kern River water is treated for domestic use, provided for agricultural use in accordance with the City's agricultural contracts, or used for groundwater recharge via several pathways including the COB 2800 acre recharge ponds, the Kern River channel, and the Carrier Canal.

Recycled Water: The City uses tertiary treated wastewater to irrigate parkland within City boundaries that would have otherwise used potable water. In 2010, this amounted to 1,120 AFY. An additional 6,645 AF of secondary treated water was recharged via effluent storage ponds and 12,000 AF was exported outside City boundaries for local irrigation in 2010 (Stetson, 2014). Recycled water use within City boundaries is expected to double by 2020 (Stetson, 2014).

[7] The City's Kern River entitlement averaged 148,718 AFY between 1997 and 2007 and averaged 129,282 AFY between 1997 and 2014. During the 1997 to 2014 time period, annual entitlements ranged from 23,492 AFY (2014) to 371,761 AFY (1998) (see Table 6).

3 PROJECTED CHANGES IN USE OF KDWD RELEASE WATER

KDWD plans to use its Preserved Entitlement, including previously released water as described in the WAP. To analyze groundwater impacts of this use, the amount of release water is quantified over time, and the change in location and use of the water is evaluated as described in the sections below.

3.1 KDWD RELEASE WATER

In order to quantify the amounts of release water that will no longer be available to other users, historical monthly entitlements, use, and releases by KDWD were evaluated. These amounts are listed in **Table 3** from 1997 through 2014 and discussed in more detail below.

Table 3 values are from annual Kern River Hydrographic Reports (COB, 1997-2014). The Annual River Index represents the percentage of flow on the river that year compared to the historic average. River Indexes above 100 indicate years that were wetter than average while River Indexes below 100 indicate dryer than average years. Entitlements represent the quantity of Kern River water available to KDWD. The Use column is the amount of entitlement water KDWD diverted and used and the Release column is the amount of entitlement water KDWD did not divert (which water was made available to other diverters).

In order to quantify the amount of release water that would be used for the Proposed Project, historical releases over the 1997 through 2007 period required adjustment to account for the Caps (i.e., Preserved Entitlement from the Reed Decision, discussed previously in **Section 2.2**). These releases average 33,099[8] AFY (1997-2007) as shown in **Table 3**. Updated amounts of release water were also calculated for 2008-2014 and the Combined Study Period of 1997-2014. As shown in **Table 3**, average releases for those additional time periods are 18,296 AFY and 27,342 AFY, respectively. After 2007, the Reed Decision was in place so adjustments for the Caps were not needed.

The KDWD annual release water volumes for the 1997 to 2014 period listed in **Table 3** are shown graphically on **Figure 3-1**. **Appendix A** lists the release amounts by month. **Figure 3-2** shows the same amounts of release water as **Figure 3-1**, but on a monthly basis. The 1997 to 2007 values, shown on the top graph of **Figure 3-2**, are based on actual monthly amounts of release water that have been adjusted to account for the Reed Decision restrictions. Monthly releases from 2008 to 2014, shown on the lower half of **Figure 3-2**, did not require adjustment because those restrictions were in place after 2007. Additional details of this analysis are provided in the WAP.

Collectively, the data on **Figure 3-2** represent the projected amount of release water that KDWD now plans to use. **Figure 3-2** also illustrates the monthly variability of release water based on differing hydrologic conditions, as discussed in more detail below.

[8] The 2012 FEIR used an average of 33,048 AFY for 1997 through 2007. This average becomes 33,099 AFY when instances when KDWD lesser water rights canals use of release water are not included in totals.

Table 3. KDWD Kern River Entitlements and Releases

Calendar Year	Annual River Index	Entitlements[1] (AFY)	Releases[1, 2] (AFY)
1997	162	249,665	37,778
1998	236	262,140	100,790
1999	60	190,689	28,141
2000	66	189,079	21,556
2001	54	163,853	21,543
2002	58	165,234	19,871
2003	71	193,838	21,016
2004	56	174,696	16,463
2005	159	256,745	48,038
2006	147	231,918	33,526
2007	35	143,517	15,367
2008	71	194,057	2,134
2009	65	185,470	11,372
2010	126	224,603	19,651
2011	201	272,426	71,700
2012	45	159,397	14,638
2013	28	131,783	1,072
2014	24	118,006	7,504
1997-2007			
Average	100	201,943	33,099[3]
Minimum	35	143,517	15,367
Maximum	236	262,140	100,790
2008-2014			
Average	80	183,677	18,296
Minimum	24	118,006	1,072
Maximum	201	272,426	71,700
1997-2014			
Average	92	194,840	27,342
Minimum	24	118,006	1,072
Maximum	236	272,426	100,790

1. 1997 through 2007 entitlements and releases are calculated, i.e., actual releases were adjusted to reflect restrictions imposed by the Reed Decision.
2. Release totals do not include instances when release water exceeds KDWD entitlements on a monthly basis. See Appendix A for further details.
3. The 1997-2007 average of 33,099 AFY is derived from 33,048 AFY as described in Appendix A.

1997-2007 Releases. As shown in **Table 3** the adjusted release water amounts average 33,099 AFY for the 1997 to 2007 period and range between 15,367 AFY (2007) and 100,790 AFY (1998)[9]. Four years (1997, 1998, 2005 and 2006) had average or above average release water while release water volumes in the remaining seven years were below average. The very wet year of 1998 resulted in the largest amount of release water (three times greater than the average) that skewed the average upward.

Most of the releases (about two-thirds of the total amount) occurred in the winter/spring months of January through April – during times of large river flows and rainfall (**Figure 3-2**). The largest monthly release (21,147 AF) occurred in January 1997. Releases in 1998 occurred in every month (except December), indicative of the large amount of precipitation that year (13.23 inches/year in Bakersfield, more than twice the long-term average). Much smaller releases occurred in the summer months with the exception of a very wet year such as 1998.

1997-2014 Releases. Release water amounts for the entire 1997 to 2014 time period average 27,342 AFY and range from 1,072 (2013) to 100,790 AFY (1998) (**Table 3**). The average release decreased (33,099 AFY to 27,342 AFY) when the 2008 to 2014 data were added to the 1997 to 2007 data due to the recent dry period (when less river water was available) and increased use of available river water within KDWD.

The steps for incorporating these volumes of release water into the impacts analysis are summarized below and described in the sections that follow.

1. Adjusted monthly KDWD releases for 1997-2007 to match restrictions from the Reed Decision to determine the amount of water that would have been released if the Caps were in place between 1997 and 2007. This step is documented in the WAP.
2. Tabulated monthly KDWD releases for 2008-2014 (**Appendix A**). After 2007, the Caps were in place and no further adjustments are needed.
3. Compared the 1997 to 2014 monthly release amounts to actual diversions and use of release water by NKWSD and the City to establish monthly amounts of release water that would no longer be available to NKWSD and the City under the Proposed Project. A review of annual Kern River Hydrographic Reports determined that these two parties were consistently the recipients of most of the release water. Residual release water was assigned to other entities (see Step 5 below).
4. Examined Kern River Hydrographic Reports to determine the potential types of use for the release water by both parties (e.g., irrigation or groundwater recharge). If release water was not available, NKWSD and the City would replace that supply with groundwater as evidenced by their increased pumping in times of drought. Increased pumping (or decreased spreading) was assigned to specific locations within NKWSD and the City for each month in the 1997 to 2014 period.
5. Allocated any remaining release water amounts that were not used by NKWSD and the City to other users in the basin, provided they used release water as documented in the Hydrographic Reports. While it was impossible to determine exactly where this water could have been used, for analysis purposes, it was assigned to be recharged in the Kern Water Bank or the Pioneer Project, used by BVWSD, or recharged in the Kern River channel, similar to what has occurred historically with surplus Kern River water.

[9] In this document, the term *release water* is used for both the adjusted 1997-2007 release water and for the 2008 to 2014 release water.

6. Assigned the previously-released Kern River water to specific locations within KDWD on a monthly basis during the 1997-2014 period based on the priorities identified in the WAP.
7. Developed a numerical groundwater flow model to analyze groundwater impacts from these changes in location and use of potential release water associated with the Proposed Project (**Section 5**).

3.2 HISTORICAL USE OF KDWD RELEASE WATER

In order to evaluate potential impacts to groundwater, actual diversions and potential use of release water by NKWSD and the City during the 1997 to 2014 period were examined. Hydrographic Reports were used to identify potential types of water use that occurred in each month when release water was available, such as groundwater recharge, agricultural irrigation, reservoir storage, and/or exchange. The KDWD release water and an estimate of the entity or location associated with historical use of the release water is shown on **Table 4** and discussed in more detail below.

Table 4. Historical Use of KDWD Release Water

Calendar Year	Total Project Release Water[1] (AFY)	Release Water Lost to Intertie (AFY)	NKWSD Release Water Use (AFY)	City Release Water Use (AFY)	Release Water Not Used by NKWSD or City[2] (AFY)
1997	37,778	0	14,439	19,673	3,666
1998	100,790	34,008	46,360	18,796	1,626
1999	28,141	0	20,164	7,550	427
2000	21,556	0	17,673	3,659	224
2001	21,543	0	17,948	3,577	18
2002	19,871	0	16,018	3,786	67
2003	21,016	0	16,551	3,988	477
2004	16,463	0	15,278	1,155	30
2005	48,038	0	30,649	13,499	3,890
2006	33,526	1,347	21,044	10,744	391
2007	15,367	0	13,248	2,119	0
2008	2,134	0	52	1,437	645
2009	11,372	0	10,476	896	0
2010	19,651	0	13,590	4,516	1,545
2011	71,700	0	38,070	30,711	2,919
2012	14,638	0	12,130	2,447	61
2013	1,072	0	414	443	215
2014	7,504	0	4,576	2,691	237
1997-2007					
Average	33,099	3,214	20,852	8,050	983
Minimum	15,367	0	13,248	1,155	0
Maximum	100,790	34,008	46,360	19,673	3,890
1997-2014					
Average	27,342	1,964	17,149	7,316	913
Minimum	1,072	0	52	443	0
Maximum	100,790	34,008	46,360	30,711	3,890

1. Represents previously released water. Does not include net negative release values when KDWD used more water than entitlement
2. Assumed used at Kern Water Bank, Pioneer Project, BVWSD and River recharge

As shown on **Table 4**, there were some extremely wet years when surplus river water was not used by any party and was instead released to the California Aqueduct through the Kern River Intertie to prevent downstream flooding (**Figures 1-1** and **1-2**). Between 1997 and 2014, Intertie flow occurred in three years: 1997 (1,793 AF), 1998 (130,226 AFY) and 2006 (73,411 AF). During these periods, so much water was flowing in the Kern River that those entities entitled to do so either could not or did not want to divert the water. The annual Intertie flow volumes are even higher than annual release water volumes in 1998 and 2006. In 2006, flow was diverted into the Intertie because of storage restrictions imposed on Isabella Reservoir (Core, 2009). Water that flowed through the Intertie was lost from the basin.

Table 4 summarizes the historical use of KDWD release water. Release water impact amounts appear in the column on the left side of the table next to the dates. These release water amounts represent the amount of previously released water (see far-right column in **Table 3**) that KDWD now plans to use. The next four columns document estimated use of release water. As mentioned previously, some release water left the basin through the Intertie. Presumably that water could have replaced the KDWD release water if NKWSD or the City had needed it. Although this adjustment only occurred for a few months, the volumes were large as shown in **Table 4**. Intertie flow did not occur during the 2008 to 2014 period. The next two columns on **Table 4** show the amount of release water used by NKWSD and the City. How and where the release water was used within NKWSD and the City is evaluated in more detail in the following sections.

For some months, total amounts of release water used by NKWSD and the City did not equal the total KDWD release water estimates. Records were insufficient to always determine which part of the total of release water used by either party was from KDWD. This was particularly applicable to the 1997-2007 time period when releases had been adjusted to reflect the Reed decision limitations. To provide a consistent methodology of allocating KDWD release water to each party in any given month, a percentage was assigned to NKWSD and the City based on the total release water used by both entities for that month. Using this methodology, NKWSD had used approximately 70 percent of all available release water and the City had used approximately 27 percent over the 1997 to 2007 period. Over the 1997 to 2014 period, these percentages were adjusted to 68 percent for NKWSD and 29 percent for the City. Data developed from the application of these percentages are provided in **Table 4**.

There were also some months in which the volume of release water actually taken by either NKWSD or the City was less than the available amount of the post Reed Decision KDWD release water. In those months the release water was adjusted to match what was actually taken. This adjustment amounted to an average of approximately 3 percent of the release water.

The annual Kern River Hydrographic Reports documented that NKWSD and the City did not use all of the release water available, even when the totals were corrected for outflows at the Intertie. The remaining amounts are documented in the *Release Water Not Used by NKWSD or City* column of **Table 4** and averaged 983 AFY for the 1997 to 2007 period and 913 AFY for the 1997 to 2014 period. This leftover release water not taken by NKWSD or the City indicates that the water was available for downstream water rights holders on the river. Hydrographic Reports were examined to determine how the remaining water would likely have been used; the results of this examination were used to ensure that all release water was included in the impacts assessment. The incorporation of this release water used by others in the impacts analysis is described in **Section 5**.

3.3 NKWSD KERN RIVER WATER USE REDUCTIONS

A summary of annual NKWSD Kern River water entitlements and release water adjustments is presented in **Table 5** and shown graphically on **Figure 3-3**. Data include the volume of Kern River water to which NKWSD was entitled and estimated release water to be reallocated for each year during the 1997 to 2014 period. NKWSD's Kern River entitlement varies from year to year, ranging from a low of 727 AFY in 2014 to a high of 246,380 AF in 2011 (**Table 5**). Its average entitlement for 1997 to 2007 was 97,146 AFY. During the 1997 to 2014 period, its average entitlement was 92,808 AFY.

Table 5. NKWSD Release Water Reductions

Calendar Year	NKWSD Kern River Entitlement (AFY)	NKWSD Release Water Used (AFY)	Total NKWSD River Water Used (Entitlement + Release Water) (AFY)	Estimated Portion of Release Water to be Used by the Project (AFY)	Estimated NKWSD Use of Project Water (AFY)				
					Spreading	Canal Losses from Spreading	Irrigation	Canal Losses from Irrigation	Other[1]
1997	188,170	66,837	255,007	14,439	6,341	114	5,275	942	1,767
1998	215,878	109,778	325,656	46,360	46,360	0	0	0	0
1999	42,903	36,599	79,502	20,164	9,951	113	8,471	645	984
2000	62,355	34,881	97,236	17,673	1,192	330	5,124	699	10,328
2001	41,657	35,487	77,144	17,948	0	0	4,300	1,193	12,455
2002	49,430	51,699	101,129	16,018	0	0	9,114	2,201	4,703
2003	69,701	43,352	113,053	16,551	0	0	8,507	2,196	5,848
2004	32,446	45,686	78,132	15,278	5,407	1,822	3,271	1,052	3,726
2005	203,559	75,855	279,414	30,649	24,681	800	5,168	0	0
2006	158,698	49,628	208,326	21,044	7,031	337	9,852	1,402	2,422
2007	3,813	35,079	38,892	13,248	5,273	0	7,975	0	0
2008	69,816	30,975	100,791	52	0	0	52	0	0
2009	53,896	51,759	105,655	10,476	4,574	953	2,827	226	1,896
2010	207,324	15,511	222,835	13,590	493	103	2,107	352	10,535
2011	246,380	94,127	340,507	38,070	36,116	1,741	213	0	0
2012	22,591	42,868	65,459	12,130	270	92	11,668	100	0
2013	1,194	16,658	17,852	414	0	0	414	0	0
2014	727	14,103	14,830	4,576	0	0	4,576	0	0
1997-2007									
Average	97,146	53,171	150,317	20,852	9,658	320	6,096	939	3,839
Minimum	3,813	34,881	38,892	13,248	0	0	0	0	0
Maximum	215,878	109,778	325,656	46,360	46,360	1,822	9,852	2,201	12,455
1997-2014									
Average	92,808	47,271	140,079	17,149	8,205	356	4,940	611	3,037
Minimum	727	14,103	14,830	52	0	0	0	0	0
Maximum	246,380	109,778	340,507	46,360	46,360	1,822	11,668	2,201	12,455

1. See text for discussion and locations of "Other" uses of release water

The numbers in the first three columns following the calendar year are from annual Kern River Hydrographic Reports (COB, 1997-2014). These reports were used to determine how much of the KDWD release water was used by either NKWSD or the City during each month of the Study Period. Data were reviewed first to confirm that the full amount of the adjusted KDWD release water could be accounted for. Because the monthly volumes of release water actually used by NKWSD and the City were not the same as the adjusted KDWD amounts (due to forfeiture by the courts), a percentage was applied to NKWSD and the City based on the total release water used for each month. There were some months in which the volume of release water actually taken by either NKWSD or the City was less than their calculated percentage of the Post-Reed decision KDWD release water. In those months the release water was adjusted to match what was actually taken. As mentioned previously, these amounts were further adjusted by removing the volumes of water that had left the basin through the Intertie. Although this adjustment only occurred for a few months, the volumes were large (**Table 4**).

Because of the reductions of the Intertie and the adjustments for the Caps on KDWD, the estimated amounts of former release water to be used by KDWD as part of the Project (Project release water) are often much less than the amount of release water used by NKWSD historically (compare columns 3 and 5 on **Table 5**). The amounts of the Project-related release water used by NKWSD (**Table 5**, column 5) are shown graphically on **Figure 3-3** and represent what would have been available in 1997 to 2014 with the Caps. These are the amounts that KDWD proposes to put to beneficial use as part of the Project (as estimated for hydrologic conditions similar to the 1997 to 2007 and the 1997 to 2014 time periods). The volumes of release water range from 52 AF in 2008 to 46,360 AF in 1998. The 1997 to 2007 average is 20,852 AFY and the 1997 to 2014 average is 17,149 AFY.

It was not possible to determine exactly how NKWSD would have used the post Reed Decision KDWD release water in comparison to its Kern River entitlement. However, during almost all of the months that KDWD release water was used by NKWSD, there was at least an equal amount of water used for either Class 2 Service Area irrigation or recharge in spreading basins. For the few months when these two uses were less than the total amount claimed, it was observed that water could have been part of an exchange or, under limited circumstances, added to reservoir storage at Lake Isabella. These amounts could potentially be used later for irrigation. Based on these analyses, the unavailability of release water to NKWSD in the future would result in a need to increase groundwater pumping for Class 2 Service Area irrigation and a reduction in water available for recharge in NKWSD spreading basins.

To assess impacts on NKWSD, release water reductions were assumed to occur in the following order, based on the amount of release water that could have contributed to each water use in each month of the analysis:

1. Spreading (Recharge) basins
2. Canal losses from spreading
3. Class 2 Service Area irrigation
4. Canal losses from Class 2 Service Area irrigation
5. Other use.

For example, if the total monthly release water could be accounted for in the volumes diverted to spreading basins, it was assumed that the KDWD water was used there. If spreading did not occur during that month, canal losses were considered. Each use in order was evaluated for each month until the total monthly amount of KDWD release water had been accounted for. The *Other use* category represents use of release water that could not be assigned to the first four priority uses based on the data in the Kern River Hydrographic Reports. These reductions were estimated to be available at some

unidentified location within the NKWSD service area and were removed evenly from the entire area in the impacts analysis.

3.4 CITY OF BAKERSFIELD KERN RIVER WATER USE REDUCTIONS

A methodology similar to the allocation of release water to NKWSD was used to allocate the City's use of KDWD release water on a monthly basis over the 1997 to 2014 Study Period. An annual summary of the City's entitlements and release water adjustments is shown on **Figure 3-4** and in **Table 6.** As shown in **Table 6**, the City's entitlement ranged from 23,492 AFY in 2014 to 371,761 AFY in 1998 with an average value of 148,718 AFY for the 1997 to 2007 period and 129,282 AFY for the 1997 to 2014 period. The City has also historically used additional Kern River water from KDWD releases, and the adjusted values of the utilized releases are shown on **Figure 3-4** and in **Table 6**. Between 1997 and 2007, an average of 8,050 AFY release water was used by the City with use varying between 1,155 AF in 2004 and 19,673 in 1997. Between 1997 and 2014, the average is slightly smaller at 7,316 AFY.

Table 6. City of Bakersfield Release Water Reductions

Calendar Year	City Kern River Entitlement (AFY)	City Release Water Used (AFY)	Total City River Water Used (Entitlement + Release Water) (AFY)	Estimated Portion of Release Water to be Used by the Project (AFY)	Estimated City Use of Project Water (AFY)			
					KDWD	Kern Water Bank	Other Spreading	Other[1]
1997	273,956	56,781	330,737	19,673	585	4,250	8,772	6,066
1998	371,761	69,913	441,674	18,796	4	9,457	1,009	8,327
1999	85,847	16,774	102,621	7,550	180	0	0	7,370
2000	92,239	6,998	99,237	3,659	137	0	0	3,522
2001	74,077	6,517	80,594	3,577	168	0	0	3,409
2002	74,373	10,794	85,167	3,786	0	0	0	3,786
2003	102,111	8,048	110,159	3,988	0	0	0	3,988
2004	80,932	3,815	84,747	1,155	0	0	0	1,155
2005	219,961	20,535	240,496	13,499	2	0	4,613	8,884
2006	215,501	19,960	235,461	10,744	0	6,421	2,227	2,096
2007	45,145	4,891	50,036	2,119	0	0	0	2,119
2008	101,289	5,177	106,466	1,437	0	0	0	1,437
2009	91,369	3,394	94,763	896	0	0	0	896
2010	153,812	68,400	222,212	4,516	0	0	2,558	1,958
2011	234,744	45,950	280,694	30,711	0	0	28,968	1,743
2012	57,907	6,184	64,091	2,447	0	0	0	2,447
2013	28,564	3,525	32,089	443	0	0	0	443
2014	23,492	5,061	28,553	2,691	0	0	0	2,691
1997-2007								
Average	148,718	20,457	169,175	8,050	98	1,830	1,511	4,611
Minimum	45,145	3,815	50,036	1,155	0	0	0	1,155
Maximum	371,761	69,913	441,674	19,673	585	9,457	8,772	8,884
1997-2014								
Average	129,282	20,151	149,433	7,316	60	1,118	2,675	3,463
Minimum	23,492	3,394	28,553	443	0	0	0	443
Maximum	371,761	69,913	441,674	30,711	585	9,457	28,968	8,884

1. See text for discussion and locations of "Other" uses of release water

Data in the Kern River Hydrographic Reports were not sufficiently detailed to determine how the City would have used the KDWD release water in comparison to its Kern River entitlement. The City has numerous contracts and agreements for selling, exchanging, or otherwise delivering Kern River water to numerous parties including the County of Kern, various agricultural water districts, recreational features, replacement of evaporative loss at certain lakes, other water purveyors, construction sites, and individuals. In addition, for several months when large amounts of release water were used, large volumes of water were recharged in the City's spreading basins at the COB 2800, indicating that release water may have been stored in the groundwater bank. Over the 1997 to 2014 period, annual Kern River Hydrographic Reports show that water transfers and banking by the City involved more than 35 various parties/features/projects in the Kern County Subbasin.

Because of this complex situation, it cannot be determined what options the City might select for replacement, if any, of the release water that would be used by KDWD under the Project. As a result it is assumed that the lack of available KDWD release water would result in an increase in groundwater pumping and/or a decrease in groundwater recharge.

To assess impacts on the City, release water reductions were assigned to occur in the following order:

1. KDWD (water applied to the COB 2800 for KDWD)
2. Kern Water Bank spreading
3. Other spreading (COB 2800)
4. Other use.

Allocations to specific City uses of the release water are presented on an annual basis in **Table 6**. For item No. 1 above, small amounts of Kern River water were designated as being released by KDWD, diverted by the City, and reported back to KDWD. This appears to have resulted from a collaborative distribution of Kern River water to the COB 2800. The *Other use* category represents use of release water that could not be assigned to the other City uses from the Kern River Hydrographic Reports. These reductions were assigned evenly over the City WSA.

3.5 KDWD PROJECTED USE OF RELEASE WATER

The WAP accounts for use of KDWD's Preserved Entitlements, including the potential release water needed to meet existing unmet demands. WAP analyses have been updated from the 2011 assessment to include the 18-year Study Period (1997-2014) to determine amounts of water allocated to each of the following six priorities:

Priority 1: Irrigation within Service Area Rights

Priority 2: Irrigation for Unmet Irrigation Demand in all Service Areas

Priority 3: Municipal and Industrial Demand within KDWD Boundaries

Priority 4: In-District Recharge

Priority 5: Pioneer Project Recharge

Priority 6: Other Uses.

These are described in more detail in the WAP and summarized in **Table 7**. Monthly amounts of release water to be reallocated have been documented over an 18-year Study Period (1997 – 2014). How and where these monthly amounts may be used by KDWD are allocated according to the priority of

management actions as described in the WAP. To model impacts of the Proposed Project on KDWD, monthly amounts of previously-released Kern River water were redistributed according to these same WAP management priorities. These priorities are discussed below along with the strategy for analyzing Project-related impacts.

Table 7. Allocation of KDWD Release Water

Priority	Management Action	1997-2007 Average (AFY)	1997-2014 Average (AFY)
1	Irrigation within Service Area Rights	168,895	167,498
2	Irrigation for Unmet Irrigation Demand within KDWD boundaries	10,488	8,595
3	Municipal and Industrial Demand within KDWD Boundaries	6,281	6,281
4	In-District Recharge	15,281	11,856
5	Pioneer Project Recharge	226	138
6	Other Uses	772	472
Average Annual Entitlement[1]		**201,943**	**194,840**
Use of Release Water (Priorities 2-6)[2]		**33,048**	**27,342**

1. 1997-2007 adjusted for court restrictions
2. The modeled release water average after adjustments was 33,099 AFY for 1997-2007 (see Appendix A)

PRIORITY 1: DELIVER IRRIGATION WATER ACCORDING TO SERVICE AREA RIGHTS

Priority 1 involves the continued delivery of irrigation water to each of the KDWD service areas with strict adherence to each service area's original water right. This priority describes the ongoing operations of KDWD and does not involve changes as a result of the Proposed Project. This priority is included in the WAP to assure continuation of a minimum level of deliveries within each service area. Priority 1 is estimated to represent an average of about 168,895 AFY in the WAP (1997-2007 time period). For the updated Study Period, the average amount is 167,498 (1997-2014).

PRIORITY 2: DELIVER IRRIGATION WATER FOR UNMET IRRIGATION DEMAND

Priority 2 allows unmet agricultural demand to receive available Kern River water that may have been previously released by other service areas. The District would move available Kern River water throughout the District as a whole, to provide water to underserved areas. This optimization allows underserved areas of the District to decrease pumping of groundwater and/or free up additional water sources for other underserved areas in the District. As documented in its Groundwater Management Plan, total irrigation demand within KDWD exceeds the amount of Kern River water available. It is not currently possible to identify specific parcels on which the increase in surface water may be apportioned. Depending on cropping patterns, changing water use, and other factors, the underserved areas could occur anywhere throughout the entire District at any given time. Examples of potential release water use in the WAP also identify unserved lands within KDWD boundaries between the Eastside Service Area and Kern Island Service Area – referred to as State Lands – where either groundwater pumping or available water from the State Water Project may be replaced. In addition, areas with smaller amounts of surface water (e.g., Buena Vista Service Area) have a relatively high irrigation demand currently unmet by surface water.

Priority 2 was estimated to average about 10,488 AFY in the WAP (1997 – 2007). For the updated baseline, the average amount is estimated at 8,595 AFY (1997 – 2014).

PRIORITY 3: MEET IN-DISTRICT M&I DEMANDS

As described in the WAP, Priority 3 satisfies demand for municipal and industrial (M&I) water on urbanized land within KDWD that is currently served by others including Greenfield County Water District (GCWD), Lamont Public Utilities District (LPUD), and the City of Bakersfield. For the City of Bakersfield, KDWD is under obligation for provision of M&I water associated with urbanized lands in KDWD service areas (Buena Vista, Stine, Famers, and Kern Island) that overlap the City of Bakersfield.

Priority 3 was estimated to average about 6,281 AFY in the WAP (1997 – 2007). M&I demands presented in the recently-updated KDWD Groundwater Management Plan (GWMP) indicate that the actual average total demand is higher than this estimated average. Nonetheless, we recommend simulating the estimated amounts documented in the WAP for the impacts analysis.

The average amount from the WAP of 6,281 AFY is also maintained for the updated baseline (1997 – 2014). Monthly amounts of water assigned to the M&I priority ranged from zero (when no water was available) to 3,895 AF/month.

PRIORITY 4: PERFORM IN-DISTRICT GROUNDWATER RECHARGE

In order to conserve available Kern River water during non-irrigation periods or to increase local water levels, the District plans to recharge available Kern River water within the District. This recharge would occur after all surface irrigation and M&I demands have been met for that time period. To support this activity, the District will use current capacity in its seven recharge basins covering approximately 814 acres, representing an average monthly capacity of about 8,700 AF/month, and an additional 4,000 AF/month along the unlined canals. The canal recharge represents an average along all of the KDWD canals.

Priority 4 was estimated to represent an average of about 15,281 AFY (1997 – 2007). For the updated baseline, the average amount is estimated at 11,856 AFY (1997 – 2014).

PRIORITY 5: RECHARGE WATER IN PIONEER PROJECT FOR OVERDRAFT MITIGATION

KDWD is a participant in the Pioneer Project, a local groundwater bank operated by Kern County Water Agency. The Pioneer Project consists of more than 1,700 acres of recharge basins, the closest of which is about one mile northwest of KDWD on the Kern River. KDWD can recharge and recover water under the rules governing project operation. Some water is banked for overdraft correction and is not recoverable.

Priority 5 was estimated to represent an average of about 226 AFY (1997 – 2007). For the updated baseline, the average amount is 138 AFY (1997 – 2014).

PRIORITY 6: OTHER USES

This priority allows operational flexibility for use of short-term – but relatively large – volumes of water that occur in a few wet months during times when Priorities 1 through 5 have been met. Potential beneficial uses of this water allow for soil flushing, increased cropping on fallowed land, or recharge on District lands outside of the canal and recharge basin system. The water could also be stored using excess recharge capacity in nearby groundwater banking projects along the Kern River. The WAP also notes that if agencies outside of the District could use additional water during these atypical months, KDWD could also arrange for a transfer or sale of the entitlement water after all other priorities have been met.

Priority 6 was estimated to represent an average of about 772 AFY. For the updated baseline, the average amount is 472 AFY (1997 – 2014).

The priority management action items associated with the WAP (discussed above) provide guidance for how the release water may be distributed across KDWD for the Project. **Table 8** shows how the Project release water is allocated in KDWD for the impacts analysis. More information about the incorporation of data from **Tables 5**, **6**, and **8** in the impacts analysis is included in **Section 5**.

Table 8. KDWD Release Water Retained for Project

Calendar Year	Total Project Release Water[1] (AFY)	Distribution of Retained Release Water (AFY)					
		Irrigation Reduction	City of Bakersfield Pumping Reduction[2]	Recharge Basins[3]	Canal Recharge[4]	Pioneer Basin	Other[5]
Table 7 Priority		Priority 2	Priorities 3 & 6	Priorities 3 & 4	Priorities 3 & 4	Priority 5	Priority 6
1997	37,778	9,385	4,579	13,741	6,318	750	3,004
1998	100,790	23,966	11,921	41,917	19,275	1,500	2,210
1999	28,141	10,150	4,143	9,486	4,362	0	0
2000	21,556	7,526	2,194	8,108	3,728	0	0
2001	21,543	7,354	3,885	7,059	3,246	0	0
2002	19,871	10,282	4,130	3,739	1,720	0	0
2003	21,016	9,143	3,141	5,981	2,751	0	0
2004	16,463	5,362	2,993	5,554	2,554	0	0
2005	48,038	12,657	6,150	19,526	8,978	242	485
2006	33,526	11,883	4,508	11,738	5,398	0	0
2007	15,367	8,217	2,685	3,058	1,406	0	0
2008	2,134	2,134	0	0	0	0	0
2009	11,372	4,007	2,623	3,248	1,494	0	0
2010	19,651	7,541	3,879	5,638	2,593	0	0
2011	71,700	12,938	15,452	28,876	13,278	0	1,156
2012	14,638	5,960	5,788	1,979	910	0	0
2013	1,072	1,072	0	0	0	0	0
2014	7,504	5,138	1,578	540	248	0	0
1997-2007							
Average	33,099	10,539	4,575	11,810	5,431	227	518
Minimum	15,367	5,362	2,194	3,058	1,406	0	0
Maximum	100,790	23,966	11,921	41,917	19,275	1,500	3,004
1997-2014							
Average	27,342	8,595	4,425	9,455	4,348	138	381
Minimum	1,072	1,072	0	0	0	0	0
Maximum	100,790	23,966	15,452	41,917	19,275	1,500	3,004

1. Represents previously released water. Does not include net negative release values when KDWD used more water than entitlement.
2. City of Bakersfield Pumping Reduction is 67% Priority 3 and 50% Priority 6 water
3. Recharge Basins is 68.5% of the total of Priority 4 plus 33.3% of Prioirity 3 up to 8,700 AF/month
4. Canal Recharge is 31.5% of the total of Priority 4 plus 33.3% of Prioirity 3 up to 4,000 AF/month
5. Other irrigation reduction is 50% of Priority 6 plus any excess of Priority 4 (Basins and Canal recharge) that exceeds 12,700 AF/month

4 GROUNDWATER CONDITIONS

In order to provide context for the assessment of Project-related impacts on groundwater resources, past and present groundwater conditions are reviewed, including groundwater occurrence and flow, water levels, overdraft conditions, land subsidence, and groundwater quality. As required by the 2014 Order, this evaluation focuses on potential adversely-affected locations north of the Kern River and beneath the City. This area is referred to as the Northern Study Area and covers about 1,100 square miles of the larger Study Area; the Northern Study Area, along with service areas of the primary water purveyors and irrigation districts, is shown on **Figure 1-2**.

Information and data on local groundwater conditions and water supply in the Northern Study Area were provided by the following water agencies in response to a Public Records Data Request in support of this study:

- Buena Vista Water Storage District (BVWSD)
- Semitropic Water Storage District (SWSD)
- Southern San Joaquin Municipal Utilities District (SSJMUD)
- Shafter-Wasco Irrigation District (SWID)
- North Kern Water Storage District (NKWSD)
- Cawelo Water District (CWD)
- Rosedale-Rio Bravo Water Storage District (RRBWSD)
- Cities of Wasco, Shafter, and Bakersfield

Agency-specific data were supplemented with other published information and data to provide a comprehensive assessment of the Northern Study Area.[10] Collectively, these data were reviewed and incorporated into the analysis of groundwater conditions provided in this section. A description of the Kern County Subbasin and the regional hydrogeologic setting, including the entire Study Area, is also provided as context for the analysis.

4.1 KERN COUNTY SUBBASIN

The Study Area is primarily located in the Kern County Subbasin of the San Joaquin Valley Groundwater Basin as defined by DWR (Subbasin 5-22.14, DWR, 2006) (**Figure 1-1**). The subbasin is one of the largest in the state, covering approximately 2,800 square miles (1,792,000 acres) and containing more than 40,000,000 AF of groundwater in storage (DWR, 2006; 2016c). The subbasin is defined generally by the Kern County line on the north (northern boundary recently modified as discussed below), by the Sierra Nevada and Tehachapi Mountains to the east and south, and by the San Emigdio Mountains and consolidated units of the Coast Ranges on the south and west.

The northern and southern subbasin boundaries shown on **Figure 1-1** (and subsequent figures in this report) include recent modifications by DWR (as of July 1, 2016). The northern subbasin boundary was slightly realigned along jurisdictional boundaries for certain agencies in Kings and Tulare counties (DWR, 2016c). The southern subbasin boundary was revised along a geologic fault that separates the southern portions of both Wheeler Ridge-Maricopa WSD and Arvin Edison WSD from the remaining Kern County Subbasin (DWR, 2016c). These modifications had not yet been made during the preparation of the 2011 DEIR; therefore, the subbasin boundary on **Figure 1-1** differs slightly from the one shown on the figures

[10] Data was also provided by Arvin-Edison Water Storage District in the southern Study Area.

in the 2011 DEIR and the 2011 Impacts Assessment report. However, the modified boundary does not affect the impacts assessment presented in this report.

DWR has recently conducted a basin prioritization study, identifying and ranking California groundwater basins/subbasin as having a high, medium, low, or very low priority (DWR, 2015). The prioritization was based on local reliance of groundwater resources and existing adverse impacts to these resources, among other factors. Kern County Subbasin is in the top 25 high-priority basins and has been identified as an important agricultural subbasin with existing adverse conditions of overdraft, land subsidence, and water quality degradation. In January 2016, DWR added the subbasin to its list of 21 critically-overdrafted basins in the state (DWR, 2016a).

Since the early 1900s, groundwater conditions in the subbasin have been studied by DWR, USGS, and others. Key studies providing historical groundwater information are incorporated into the description of groundwater conditions in the following sections. As mentioned previously, additional information has been provided to KDWD by individual water agencies and municipalities through a data request process in support of this impacts assessment. Relevant documents and data from the published studies and individual parties are cited in the information below and included in the reference list (**Section 8**).

4.2 PHYSICAL SETTING

The Study Area is located on a relatively flat valley floor surrounded by uplands (**Figure 1-1**). Interstate 5 and Highway 99 traverse the western and eastern portions of the Study Area, respectively, with Highway 46 crossing the Northern Study Area from east to west. The valley floor is asymmetrical with lower elevations along the western side. Ground surface elevations along the western floor of the Study Area range from about 330 feet above mean sea level (msl) in the south to about 200 feet in the north (near the Kings, Tulare, and Kern county lines).

On the east, the Study Area extends up onto the western edge of consolidated sedimentary units that rise above the valley floor. The highest surface elevations in the eastern portion of the Study Area are above 1,000 feet msl east and southeast of Bakersfield (**Figure 1-1**). The elevation of the Kern River is about 430 feet msl at the eastern edge of the Study Area and about 310 feet msl on the western edge of the Study Area.

The consolidated sedimentary units also occur on the western side of the valley. West of the Study Area, geologic units of the Coast Ranges crop out and form hills in the western subbasin (for example, see the Elk Hills southwest of the Study Area on **Figure 1-2**). In addition, two sandstone ridges, Semitropic Ridge and Buttonwillow Ridge, occur within the western portion of the Study Area causing surface elevations to rise about 40 feet above the valley floor (**Figure 1-2**).

4.2.1 Climate

The Study Area is located in an arid to semi-arid climate with a long-term (1889 – 2014) average annual precipitation of 5.98 inches per year, as measured at the Bakersfield Airport climate station (NOAA, 2015). Annual precipitation is highly variable and ranges from less than two inches per year (e.g., 1959) to more than 13 inches per year (e.g., 1998). About two-thirds of the precipitation occurs in December through March. **Figure 4-1** shows the annual precipitation for the 18-year Study Period 1997 – 2014. The annual average for this period is 5.93 inches per year, within one percent of the long-term average of 5.98 inches per year.

4.2.2 Hydrology

The Kern River is the primary drainage in the basin and crosses the Study Area from east to west. The river originates at high elevations near Mt. Whitney (elevation 14,494 feet, msl) in the Sierra Nevada and has a large watershed above the Study Area of about 2,407 square miles (City of Bakersfield, 2012b). For more than 150 years, the river has provided most of the natural surface water supply in the subbasin, including drinking water, agricultural irrigation, and other uses. Although the river appears to end at the California Aqueduct (Intertie stream gage on **Figure 1-2**), the river historically turned north near this area and flowed out of the County to its terminus at the Tulare Lake Bed.

In order to address downstream flooding, the U.S. Army Corp of Engineers completed Lake Isabella in 1953, approximately 40 miles upstream from the First Point stream gage (**Figure 1-2)**. Since that time, Isabella Dam has been operated for flood control, hydroelectric power, and conservation storage. Since 1976, the City has taken responsibility for water supply operations on the Kern River, including monitoring and recording of river flows and water use. The City presents these data in annual Hydrographic Reports that also provide information on entitlements and amounts of water diverted or released. Details on the allocation of Kern River entitlements and release water were described previously in **Section 2.1**.

Flows in the Kern River are highly variable, subject to both flooding and drought. Since 1893, flows have ranged from 175,409 AFY (2014) to 2,520,149 AFY (1916), with a long-term average of 719,250 AFY (Bakersfield, 2014). Kern River flows for the Study Period 1997-2014 are shown graphically on **Figure 4-1** and range from 175,409 AFY (2014) to 1,717,967 AFY (1998). To provide a means of comparison between recent flows and long-term average flow conditions, an annual river index is calculated in the Kern River Hydrographic Reports. An index of 100 percent is representative of the long-term average flow in the river. Kern River indices are calculated for flows between April and July as well as for the calendar year. The indices for the 18 calendar years in the 1997-2014 Study Period are provided on the lower graph of **Figure 4-1**. As shown on the graph, the annual Kern River Index ranged from 24 percent (2014) to 236 percent (1998) over the Study Period, with an average of 93 percent.

Imported surface water is also an important source of supply in the subbasin. The Central Valley Project (CVP), operated by the U.S. Bureau of Reclamation, has provided water supply to local CVP contractors since 1951 with the completion of the Friant Kern Canal. Water is also available from the State Water Project (SWP), distributing flows from northern California through a series of aqueducts, reservoirs, and pump stations, including the California Aqueduct shown on **Figure 1-2**. SWP water has been available to the subbasin through KCWA, a state-water contractor since 1968.

4.2.3 Land Use and Groundwater Use

The Study Area was settled for mining and farming in the mid-1800s with initial sparse development on the valley floor, in part due to the presence of swamps and lakes. By the late 1800s, an extensive canal network had been constructed to drain the land and divert surface water to agricultural areas. Groundwater use dates back to around 1880 (Bertoldi, et al., 1991). Population in the subbasin grew in the early 1900s after the discovery of oil in the Kern River Oilfield in 1899 and also as a result of the California Home Extension Association in 1907, which sold large blocks of land in California to out-of-state home-seekers at wholesale prices (Los Angeles Herald, 1906; SWID, 2016). From the 1940s through the 1960s, agricultural development expanded throughout the valley. The Kern County

Subbbasin currently supports more than 900,000 acres of irrigated agriculture and more than 700,000 residents (DWR, 2015).

Land use in the Northern Study Area is illustrated by the aerial photograph of the Northern Study Area shown on **Figure 4-2**. The photograph shows the agricultural development, most of which represents irrigated acreage. There are pockets of undeveloped land throughout the Northern Study Area, with some large areas in the northwest, including the Kern Wildlife Refuge (**Figure 4-2**). The uplands to the east and southwest of the Northern Study Area contain large oil fields, additional agricultural development and undeveloped lands.

Although the Northern Study Area has been highly developed for agriculture, it also includes a large urban center, the City of Bakersfield (lower southeastern portion of **Figure 4-2**). Smaller urban developments in the Study Area include the cities of Shafter and Wasco, and other small communities such as Buttonwillow, McFarland, and Delano (**Figure 4-2**). These urban centers are continuing to expand in the subbasin. From 2000 to 2010, Bakersfield was one of the fastest growing cities in the nation with a population increase of 40.6 percent (KEDC, 2015).

Most of the Northern Study Area is covered by various districts (**Figure 4-4**) that were formed primarily to provide local or imported surface water for agriculture and for groundwater replenishment (through local recharge or banking projects). Service areas and estimated irrigated acreage for the primary agencies in the Northern Study Area are summarized in **Table 9** below, generally listed from west to east across the subbasin.

Table 9. Irrigated Acreage in Northern Study Area

Agricultural Water District	Service Area (acres)	Irrigated Acres[1] (acres)
Lost Hills Water District	74,357	32,000
Semitropic Water Storage District	221,000	125,000
Buena Vista Water Storage District	50,000	45,000
Shafter-Wasco Irrigation District	38,766	30,300
Rosedale-Rio Bravo Water Storage District	44,000	27,500
North Kern Water Storage District (with Rosedale Ranch ID)	69,200	62,400
Cawelo Water District	45,000	33,071
South San Joaquin Municipal Utilities District	67,000	51,000
TOTALS	609,323	406,271

[1] The amount of irrigated lands vary from year to year within each District; acreage above was taken from the most recent information in each District's GWMP, AWMP, or from the District website.

As shown in the table, approximately two-thirds of the district lands are developed for irrigated agriculture. Primary crops grown in the Northern Study Area include almonds, pistachios, grapes, cotton, alfalfa, and other field, grain, and vegetable crops (SWSD, 2012; NKWSD, 2012; P&P, 2014; and P&P, 2012).

The cropping pattern in the subbasin and throughout Kern County has changed significantly over the last two decades. In particular, there has been a well-documented trend toward conversion to permanent crops including fruit and nut orchards. Data from the Kern County Agricultural Commission illustrate this trend over the 18-year Study Period, as shown in **Table 10**.

Table 10. Total Irrigated Acres and Permanent Crop Acres in Kern County

Year	Total Harvested Crops (acres)	Total Permanent Crops (acres)	Permanent Crops (%)
1997	846,279	272,743	32%
1998	862,671	279,869	32%
1999	875,390	306,313	35%
2000	868,628	301,318	35%
2001	888,589	302,192	34%
2002	851,968	293,593	34%
2003	866,201	288,867	33%
2004	891,576	295,400	33%
2005	873,005	312,292	36%
2006	902,160	332,077	37%
2007	923,022	343,294	37%
2008	878,538	349,307	40%
2009	832,535	352,850	42%
2010	803,769	362,932	45%
2011	897,458	410,231	46%
2012	878,631	417,053	47%
2013	839,079	420,515	50%
2014	880,457	516,030	59%

Source: Kern County Department of Agriculture, Annual Crop Reports, 1997 – 2014.

As illustrated in **Table 10**, permanent crops represented about one-third of the total irrigated acreage from 1997 to 2004. Beginning in about 2005, the percentage of permanent crops increased over time and covered more than one-half of the total harvested acreage by 2014.

This trend toward permanent crops is also mirrored in the data from the Northern Study Area. The conversion from cotton (and other crops) to permanent crops is exemplified by data from SWSD shown on **Figure 4-3**. As shown on the graph, cotton covered about 55,000 acres in SWSD from 1988 to 1997, but declined to less than 10,000 acres by 2008. Acreage planted with permanent crops shows the opposite trend, representing about 10,000 acres in 1988, and increasing to more than 70,000 acres in 2012. Using a recent average amount of irrigated acres for SWSD from **Table 9** (125,000 acres), permanent crops represent more than one-half of the total irrigated acres in SWSD – a percentage consistent with the percent of permanent crops throughout all of Kern County (**Table 10**).

For more than 120 years, both groundwater and local surface water have been used for agricultural water supply in the Study Area. Imported surface water has provided an important supplemental supply, especially in areas of groundwater level declines and limited local surface water. Currently, most agricultural water districts and municipalities in the Study Area rely on a wide variety of sources for water supply, as summarized in **Table 11**.

Table 11. Water Supply Portfolio for Primary Water Agencies in Study Area

Agencies	Groundwater	Surface Water					Recycled	Oil Field
		Kern River	SWP	CVP	Section 215[2]	Poso Creek		
Northern Study Area								
City of Bakersfield[1]	X	X	X				X	
Buena Vista Water Storage District	X	X	X		X^{EX}			
California Water Service Company[1]	X	X	X				X	
Cawelo Water District	X	X	X		X	X		X
Kern County Water Agency - ID4[1]	X	X	X		X			
Lost Hills WD	X (limited)		X					
North Kern Water Storage District	X	X	X^{EX}	X^{EX}	X	X		X
North of the River Municipal Water District	X		X					
Oildale Mutual Water Company	X		X					
Rosedale Rio Bravo Water Storage District	X	X	X					
Semitropic Water Storage District	X	X	X			X		
City of Shafter	X							
Shafter-Wasco Irrigation District	X			X				
Southern San Joaquin Municipal Utilities District	X			X				
Vaughn Water Company, Inc.	X							
City of Wasco	X						X	
Southern Study Area								
Arvin Edison Water Storage District	X	X^{EX}	X^{EX}	X	X			
Greenfield County Water District	X							
Kern Delta Water District	X	X	X		X		X	
Lamont Public Utility District	X						X	
Wheeler Ridge Maricopa Water Storage District	X		X					

X^{EX} = through exchanges and transfers

1. Service area extends both north and south of river

2. Section 215 water is a temporary (not to exceed one year) supply of CVP water made possible as a result of an annually large water supply not otherwise storable for project purposes, or infrequent and otherwise unmanaged flood flows of short duration.

Information based on Agency's recent Agricultural Water Management Plan, Groundwater Management Plan, Urban Water Management Plan, or other Water Management Plan.

Although there are numerous sources of supply in the Study Area, all of the primary local agencies listed in **Table 11** rely on groundwater for some portion of their water supply. More than 15,000 wells have been drilled in the subbasin for a variety of uses. DWR reports approximately 577 current public water supply wells that, along with additional domestic wells, provide drinking water for subbasin residents (DWR, 2015). Combined groundwater use for municipal and agricultural supply was estimated by DWR

at about 1,040,000 AFY for the recent basin prioritization process (DWR, 2015). This groundwater pumping total appears low compared to other recent estimates from DWR (i.e., from published water budgets discussed in subsequent sections), and may not include all pumping in the basin such as industrial pumping (e.g., by the local oil and gas industry) or recovery pumping for groundwater banking projects. Recent estimated groundwater use in the Northern Study Area is summarized by water agency in **Table 12**.

Table 12. Estimated Groundwater Use, Northern Study Area

Local Agency in Northern Study Area	Estimated Groundwater Use (AFY)	Percent of Total Water Supply
Lost Hills Water District	0	0
Semitropic Water Storage District (SWSD)	289,439	73%
Buena Vista Water Storage District (BVWSD)	57,877	36%
Shafter-Wasco Irrigation District (SWID)	91,694	89%
City of Wasco	4,618	100%
City of Shafter	1,388	100%
North Kern Water Storage District (NKWSD)	235,292	90%
Southern San Joaquin Municipal Utilities District (SSJMUD)	34,482	28%
Cawelo Water District (CWD)	72,150	58%
Rosedale Rio Bravo Water Storage District	39,300	41%
City of Bakersfield Water Service Area	37,976	88%
California Water Service Company (Cal Water)	33,388	63%
North of the River Municipal Water District (NORMWD)	387	NA
Oildale Mutual Water Company (OMWC)	151	2%
Kern County Water Agency, Improvement District 4 (ID-4)	GW recovery only	0%
Vaughn Mutual Water Company	11,104	100%
TOTAL	**619,807**	

Use of water sources vary from year to year. Data estimated from recent Agricultural Water Management Plans and Urban Water Management Plans 2010 - 2015.

Data indicate that groundwater use varies significantly from agency to agency depending on overall demand and availability of other water sources. Groundwater use also varies over time. Recent severe drought conditions have resulted in a shortage of both local and imported surface water supplies, increasing the reliance on groundwater. Conjunctive management of surface water and groundwater has occurred for more than a century in the subbasin, and numerous local groundwater recharge and groundwater banking projects have been developed as discussed in more detail below.

4.2.4 Groundwater Banking and Recharge Projects

The permeable deposits of the Kern River Fan combined with unlined river channels and canals and local banking projects allow significant amounts of managed and un-managed groundwater recharge. Many agencies in the area, including KDWD, NKWSD, and the City (among others), have developed recharge projects or formal banking programs specifically for the storage of surface water and the replenishment of groundwater.

Since the late 1980s, large-scale groundwater recharge/banking operations have been constructed along the Kern River. The first major banking project, the City's 2800-acre spreading area (referred to herein as the COB 2800), is located on the western edge of Bakersfield with ponds both north and south of the river (see the general location on **Figure 4-4**). The City's COB 2800 extends about 6 miles and includes old river channels, overflow lands and constructed spreading basins and totals about 1,470 acres of land available for recharge. Recharge has averaged approximately 5,900 AFY (Stetson, 2014).

Other major recharge facilities on the Kern River Fan are also shown by the blue polygons on **Figure 4-4**. In addition to the COB 2800, several major banking projects include the Pioneer Project (2,233-acres operated by KCWA), Berrenda Mesa Project (jointly operated by Berrenda Mesa WD and KCWA), and the large Kern Water Bank, which covers about 20,000 acres (operated by the Kern Water Bank Authority).

Given the permeable nature of the Kern River Fan sediments, almost all of the enhanced recharge projects both along the river and away from the river involve surface spreading through ponds, low-lying fields, or basins. Some projects involve the recharge of water for the sole purpose of replenishment of the groundwater basin, while other projects involve storing water to be subsequently extracted on behalf of the banker or a third party; some banking projects do both. For example, participants in the Pioneer Project can recharge water for overdraft correction or for storage and recovery. Numerous sources of water are recharged at the projects including local surface water (Kern River and other drainages) and imported water (SWP and CVP).

KDWD owns and operates approximately 814 acres of spreading basins throughout the District to allow for groundwater replenishment of surplus district water and for banking water with one of its banking partners (Metropolitan Water District of Southern California and San Bernardino Valley Municipal Water District) (**Figure 2-1**). The basins have a theoretical recharge capacity of 121,000 AFY assuming basins are full and recharge continuously at average infiltration rates. This illustrates that large volumes of water can be recharged when water is available. Intentional and measured groundwater recharge occurs in the form of canal seepage as water deliveries are conveyed along the KDWD canal system during the irrigation season. Significant amounts of additional groundwater recharge can also be achieved through release of water into the unlined canals for the purpose of groundwater recharge, especially during winter months when both recharge water and canal capacity are available (Todd, 2013).

Additional groundwater recharge and banking projects occur in the Northern Study Area (**Figure 4-4**). SWSD delivers surplus SWP and CVP water from its banking partners (generally in wet years) to landowners for irrigation in lieu of groundwater pumping (allowing the groundwater resources to be conserved). In times of water shortages, banking partners can request their in-lieu banked water whereby SWSD returns the banked water to the California Aqueduct either from its SWP supply or from groundwater pumped from district or landowner wells. SWSD can also conduct direct recharge through its 525-acre spreading grounds along Poso Creek and is a participant in the Kern Water Bank and the

Pioneer Project (**Figure 4-4**). At the end of 2015, SWSD had banked more than 600,000 AF of groundwater in storage for its banking partners (Semitropic, 2015).

NKWSD is close to major Kern River, SWP and CVP water conveyances and service areas and has entered into water transfer and exchange agreements with numerous agencies including CWD, SWID and SWSD, among others. Surplus water can be recharged via its 1,500 acres of spreading ponds, Poso Creek channel, and unlined canals (**Figure 4-4**). Recharge facilities have a capacity up to 300,000 AFY (25,000 AF/month). Due to drought conditions and water shortages, only about 3,733 AF were recharged in the spreading ponds in 2014. This amount was supplemented by about 47,622 AF of canal seepage-related recharge (NKWSD, 2015). In contrast, more than 200,000 AFY were spread during the relatively wet years of 1995, 1998, and 2011.

Groundwater banking and recovery occurs in BVWSD via in-lieu banking where West Kern Water District stores surplus water in BVWSD for later recovery. It also participates in recharge and recovery at the Pioneer Recharge Project (BVWSD, 2016). Current plans for additional recharge facilities in BVWSD are underway (BVWSD, 2015)

Shafter-Wasco Irrigation District (SWID) has entered into groundwater banking and water exchange agreements with both NKWSD and SWSD including interconnected pipelines between the districts. SWID provides excess surface water for recharge into the adjacent districts to be recovered based on SWID demand.

Cawelo WD also conducts in-lieu banking for its banking partners to store surplus water and recover it when needed. It has over 400 acres of spreading ponds to use for direct recharge (**Figure 4-4**). In 2015, 4,006 AF were recharged (CWD, 2015).

RRBWSD recharges and banks Kern River water along with SWP and CVP water in its 1,300 acres of groundwater recharge basins and channels north of the Kern Water Bank (**Figure 4-4**). Recovery wells and a network of pipelines are used to return water to its groundwater banking partners. RRBWSD also uses groundwater recharge and recovery facilities outside its boundaries through agreements with the City, Kern Water Bank Authority, KCWA, and the Irvine Ranch Water District (IRWD). In 2014, RRBWSD had a banking balance of more than 277,000 AF in groundwater in storage for its banking partners (AECOM, 2016b).

4.2.5 Geology

The Study Area is located in the southern-most portion of the Central Valley, a structural trough underlain by pre-Eocene-age rocks of the Coast Ranges to the west and the crystalline basement rocks of the Sierra Nevada to the east. The trough terminates against a complex structural zone south of the Study Area, which forms the Tehachapi Mountains and the southern extent of the Coast Ranges. The trough has been infilled with sediments extending to depths of 20,000 feet locally.

In general, the deepest sediments were deposited in marine environments prior to the uplift of the Coast Ranges. Following this tectonic activity and down-warping of the valley, deposits of marine origin – transitioning to continental deposits – filled in the trough. The continental deposits have been eroded from the uplands to the east, west and south of the subbasin and include both unconsolidated alluvial deposits and the older consolidated sedimentary units (e.g., sandstone) beneath the alluvium. These geologic units range in age from Miocene (older) to Holocene (younger, representing Neogene- and

Quaternary-Period sediments). Collectively, the continental deposits contain most of the fresh water in the groundwater subbasin.

Surface geologic units for the Northern Study Area are shown on **Figure 4-5**. This geologic map has been modified slightly[11] from GIS data of the *Geologic Map of California* developed by the California Division of Mines and Geology (CDMG, 2000). As shown by the yellow shading on **Figure 4-5**, most of the Northern Study Area is covered by alluvial deposits of Holocene and Pleistocene age (Quaternary Period, labeled Qal). Although alluvial sediments extend west of the Northern Study Area, sediments are thinner there with generally lower quality groundwater.

Older, consolidated to semi-consolidated units of predominantly sandstone (mostly Pleistocene and Pliocene age) underlie the alluvium and crop out on the edges of the Study Area (labeled QPc on **Figure 4-5**). These units include the Tulare Formation (Pliocene- to Pleistocene-age) in the western subbasin and the Kern River Formation (Miocene- to Pleistocene-age) in the eastern subbasin. Additional older units also provide groundwater supply in local areas around the subbasin perimeter (e.g., the Olcese and the Santa Margarita formations east of the Northern Study Area) (DWR, 2006). Tectonic folding of these units has produced several anticlinal sandstone ridges that crop out on the valley floor (see Buttonwillow Ridge and Semitropic Ridge on **Figure 4-5**).

In the Northern Study Area, the eastern and western boundary of the Kern County Subbasin is generally defined by the occurrence of older, finer-grained sediments generally of pre-Pliocene age that represents the transition from continental deposits to marine sedimentary units (labeled M on **Figure 4-5**). These units terminate against the crystalline basement rocks of the Sierra Nevada (grMz) on the east and against pre-Eocene age sedimentary rocks and, at depth, against crystalline basement rocks of the Coast Ranges.

4.3 HYDROGEOLOGIC SETTING

The primary aquifers in the Study Area are composed of unconsolidated Quaternary-age alluvial fan and older continental deposits that extend to depths below 2,000 feet locally. However, in many areas, groundwater quality becomes more saline below this depth and most Study Area wells pump from zones above 2,000 feet. Depositional environments of the sediments in the aquifer systems and confining layers include coalescing alluvial fans, fluvial, floodplain, and lake bed deposits. Because of the asymmetrical nature of the valley and timing of orogenic events, deposits eroded from the uplands on the east have migrated further across the valley than deposits sourced from the west.

A major alluvial fan was deposited by the ancestral and present-day Kern River, referred to locally as the Kern River Fan. Coarse-grain sands and gravels within the fan support high-yielding wells and large-scale groundwater banking projects. The fan covers approximately 1,000 square miles of the subbasin; a regional geologic map and an estimate of the extent of the Kern River Fan is shown on **Figure 4-6** (Page, 1986; Boockoff, 2005). The Kern River Fan extends about 30 miles across the valley floor and covers most of the Southern Study Area and a portion of the Northern Study Area (**Figure 4-6**). The southern rim of the Kern River Fan consists of fine-grained flood-basin deposits and paleo-lake beds that were the

[11] Some older units outside of the groundwater subbasin have been combined on Figure 4-5 for simplicity, but most geologic unit labels have been preserved from the source.

terminus of local streams and flood water from the river (see Buena Vista Lake Bed, Kern Lake Bed, and brown-shaded flood-basin deposits – labeled Qb – on **Figure 4-6**).

Prior to development, the Kern River turned north near the uplands of the Elk Hills and flowed about 40 miles to its terminus at the Tulare Lake Bed, near the Kern County line (**Figure 4-6**). Since the regulation of river flows and the construction of Isabella Dam in the early 1950s, the Tulare, Buena Vista, and Kern lake beds no longer receive regular surface water flood flows and have been converted to agriculture.

Fluvial deposits associated with the ancestral Kern River system consist of coarse-grained sands and gravels along the primary river channel through Bakersfield. However, the fluvial and flood-basin deposits on the western side of the Study Area are relatively fine-grained (shaded in brown and labeled Qb on **Figure 4-6**). Clay deposits up to several thousand feet thick have been observed beneath the Tulare Lake Bed and thick clay zones are also observed beneath the Kern and Buena Vista Lake Beds. These fine-grained sediments locally impede surface recharge and vertical flow, and result in perching or confining layers in the groundwater system. Some of these clay layers have been mapped regionally and have been designated as clay layers A through F with increasing depth (Page, 1986). The widespread E-clay has been mapped beneath the southern and eastern portions of KDWD, the western side of the Study Area and portions of the northwestern Study Area (Croft, 1972; Page, 1986).

Subsurface conditions beneath the Kern River Fan and the Northern Study Area are illustrated by the conceptual block diagram on the top of **Figure 4-7**. The primary aquifers of the groundwater basin are generally represented by the light yellow shading. Although local aquifers represent a variety of continental depositional environments, the shallow basin deposits are labeled *Alluvial Fan Deposits* to be consistent with the original source of the diagram (Page, 1986) and to represent the overall basin setting. The deepest basin sediments, shown in purple, represent consolidated sedimentary units deposited in predominantly marine environments, containing more saline groundwater. The intervening layer (darker yellow) represents transitional units that have both continental and marine equivalents and variable groundwater quality throughout the subbasin.

The subsurface geology beneath the Northern Study Area is depicted in the regional cross section A-A' shown on the bottom of **Figure 4-7**. The location of this regional cross section across the Northern Study Area is shown on **Figure 4-8**. The regional cross section was taken from the upper portion of a regional section presented in the SWSD 2012 Groundwater Management Plan (SWSD, 2012) and has been modified slightly for illustration purposes. Geologic units on the cross section have been assigned similar colors as shown on the block diagram to reflect the continental alluvial fan deposits, transitional deposits, and marine sedimentary units[12].

As shown on the cross section, the continental deposits that contain most of the fresh water in the groundwater basin vary in thickness across the Northern Study Area. In the eastern subbasin, the primary fresh-water aquifers are up to 2,000 feet thick (see light yellow shading on regional cross section A-A', **Figure 4-7**). Groundwater becomes more saline to the west and the fresh-water portions of the subbasin thin significantly, especially beneath Lost Hills (northwestern edge of the Study Area) and areas west of the Lost Hills anticline.

These conditions have led SWSD to delineate an "effective groundwater basin" for management purposes. The general extents of the Kern County Subbasin and this "effective groundwater basin" are

[12] Only the upper-most marine sedimentary units are included in the section in order to emphasize the primary aquifers of the groundwater basin; marine sedimentary units extend deeper than shown.

shown on the regional cross section on **Figure 4-7**. This area – defined by a dashed orange line – is also shown on a map of the Northern Study Area (**Figure 4-8**). The area generally coincides with the delineation of the Northern Study Area on the east and west sides of the valley. The delineation of this "effective groundwater basin" generally delineates the primary portion of the groundwater basin from fringe areas in the Kern County Subbasin on the west and east that have either relatively poor groundwater quality or some geologic impedance that limits subsurface inflow and outflow with the central portion of the subbasin.

Also included on **Figure 4-8** are the extents of confining layers designated the A-Clay (shallow) and the E-Clay (deeper) as mapped across the Northern Study Area (see dashed green and red lines on **Figure 4-8**) (SWSD, 2012). These local extents mapped by SWSD are slightly different from the regional extents presented by USGS investigators (Croft, 1972; Page 1986), but these differences do not affect this analysis. As explained in more detail in subsequent sections of this report, the impacts analysis used a modeling tool based on a detailed analysis of textures and local clay layers and does not rely solely on any previous mapping or specific designations of clay layers.

As indicated by the SWSD dashed lines, the A-Clay is present in the northwestern corner of SWSD. The A-clay and other shallow fine-grained units impede downward migration of recharge and result in shallow and perched groundwater conditions in the area (SWSD, 2012). This zone of shallow groundwater is shaded in blue on **Figure 4-8** and extends beneath the northern portion of BVWSD along the western edge of the Northern Study Area. Groundwater in this zone is only about five to 20 feet deep (SWSD, 2012). The E-Clay extends further to the southeast than the A-clay and also creates a confining layer, separating an upper aquifer from lower aquifers (SWSD, 2012).

Although the E-clay does not appear to extend beneath most of NKWSD (**Figure 4-8**), additional clay layers in this area have been identified by NKWSD at depths of about 300 feet and 700 feet. These two clay zones have been interpreted as confining layers for aquifers beneath the northern portion of NKWSD (NKWSD, 2012). The confining layers and intervening aquifers beneath NKWSD are shown on two cross sections, A-A' and C-C,' reproduced on **Figure 4-9** from the NKWSD GWMP (NKWSD, 2012). The locations of the cross sections are provided on **Figure 4-8**. As shown, the 300-foot confining layer is thin in some wells and absent in the southern portion of the cross section.

As illustrated on **Figure 4-9**, most of the NKWSD irrigation wells are drilled to a depth of about 1,050 feet with several hundred feet of perforations (represented by the black shading along wells on **Figure 4-9**). The top of perforations are typically at depths from about 300 feet to 500 feet and extend down to about 700 feet to 1,000 feet (NKWSD, 2012). As shown, these wells are typically screened below the 300-foot clay layer.

4.4 GROUNDWATER OCCURRENCE AND FLOW

As illustrated by the hydrogeologic information above, groundwater occurs under both unconfined and confined conditions beneath the Northern Study Area. In general, groundwater is more confined with depth and with distance from the axis of the Kern River Fan (along the Kern River), where textures are relatively coarse-grained and confining layers are thin or absent. Aquifers beneath the river are unconfined at greater depths than beneath areas away from the central portion of the Kern River Fan.

These aquifers appear to be well connected hydraulically north and south of the river. A groundwater mound forms beneath the river during wet periods as a result of surface recharge along the river

channel and unlined canals. This condition results in divergent flow directions to the north and south of the river. However, local gradients are dynamic and result in varying amounts of water flowing north, south, and along the river channel at various times. When the channel is dry, the mound dissipates and groundwater can flow beneath the river from one side to the other, as controlled by local groundwater gradients.

From a subbasin perspective, groundwater flows from the surrounding uplands west, south, and east into the subbasin and migrates toward discharge points at pumping wells or toward the northwestern portion of the Study Area where most of the subsurface outflow from the Kern County Subbasin occurs. These general groundwater flow patterns are evident on most groundwater elevation maps that have been prepared over the past few decades (Page, 1986; KCWA, 2016). Annual groundwater elevation contour maps based on spring water level measurements for the Study Periods were provided by KCWA in support of this study (KCWA, 2016). Maps are prepared with spring data to illustrate groundwater flow prior to the irrigation season when numerous cones of depression complicate local groundwater flow patterns. The KCWA map for recent conditions in Spring 2014, the end of the Study Period, is shown on **Figure 4-10**.

As shown on **Figure 4-10**, groundwater flow is highly influenced by recharge along the Kern River, including water in the river channel and numerous groundwater banking projects (see also **Figure 4-4**). Water levels beneath the eastern portion of the river are above 300 feet msl, representing some of the highest water levels in the Study Area. Arrows indicate general groundwater flow directions to the north and south away from the river. Groundwater north of the river generally flows northwest to the subbasin outflow along the Kern County line.

Also as indicated on **Figure 4-10**, groundwater levels have declined to more than 100 feet below sea level (see negative contour label "-100" beneath SWSD). Due to severe drought conditions over the past several years, water levels have declined to record lows.

For comparison, an additional KCWA groundwater elevation contour map is shown on **Figure 4-11**. This map was based on water levels measured in Spring 1998, a year when precipitation was 223 percent of the long-term average. As shown on the map, 1998 water levels in the central portion of the Study Area are generally 50 feet or more higher than 2014 water levels. Water levels in the northern portion of the Study Area are above sea level and indicate more subsurface outflow across the northern subbasin boundary (Kern County line). Although water levels on the 1998 map are significantly higher over almost all of the Study Area compared to recent levels, the general groundwater flow patterns are similar in that water flows north and south away from the river and can move beneath the river from north to south or south to north, controlled by local groundwater gradients (see arrows that cross the river on both **Figure 4-10** and **Figure 4-11**). Although flow occurs beneath the river during many time periods and is highly dynamic, much of the groundwater that flows from south to north beneath the river occurs during dry periods when the mound beneath the river has dissipated. Nonetheless, arrows crossing the river (indicating gradients controlling groundwater flow) illustrate the hydraulic connectivity of the two portions of the Study Area (i.e., Northern and Southern).

4.5 WATER LEVEL TRENDS AND FLUCTUATIONS

Water levels have been recorded in the subbasin since at least the 1920s, but data before the 1950s and 1960s are sparse. Several long-term records (dating back to the 1930s) are available for wells on the east and west sides of the valley, relatively close to the Kern River. According to these records, water levels

were relatively flat in the late 1930s and 1940s, but began a long and sustained decline of about 150 feet from 1945 through the drought of 1977. Declines during this period were larger away from the river; a long-term record between Shafter and Wasco indicate a decline of almost 250 feet, more than seven feet per year. Information from SWSD confirms this rate of decline, indicating declines of about eight feet per year in its service area during this time period (SWSD, 2012). This steep decline was arrested, in part, by the wide-spread availability of imported surface water in the late 1970s. Wet hydrologic conditions between 1978 and 1983 allowed water levels to recover somewhat across the basin.

The availability of water level data increased significantly in the 1960s, providing a more complete record of water level trends and fluctuations in the Study Area over the last 50 years. Available data have been compiled into large data sets by KCWA and DWR. These data were used to construct hydrographs showing water level changes over the last 50 years (1965 – 2015) across the Study Area. The analysis focused on potential areas of Project-related impacts including areas beneath the City and in the Northern Study Area.

Representative hydrographs from 32 wells were selected for illustration purposes. Hydrograph locations are shown on **Figure 4-12**; hydrographs are presented on **Figures 4-13** and **4-14**. A smaller version of the location map is included on **Figures 4-13** and **4-14** to assist with spatial distribution. Although all but a few hydrographs are in the Northern Study Area, hydrographs on **Figure 4-13** are the more northern wells and hydrographs on **Figure 4-14** are the more southern wells. Hydrographs are numbered 1 through 15 on **Figure 4-13** and 16 through 30 on **Figure 4-14** to facilitate the discussion; note that data from two hydrographs (Hydrographs 1 and 2 on **Figure 4-13**) combine data from two wells, resulting in a total of 30 hydrographs from 32 wells. The Study Period (1997-2014) is highlighted on the hydrographs for reference. The vertical scale covers 300 feet on all hydrographs, but is adjusted locally, when needed, to accommodate the data. The horizontal scale (1965-2015) is identical for all hydrographs.

Hydrographs 1 and 2 illustrate the occurrence of shallow groundwater levels (represented by the orange lines on Hydrographs 1 and 2, **Figure 4-13**) near wells with much deeper water levels in pumping zones (blue lines). This area of shallow groundwater in the northwest portion of the Study Area was discussed previously in **Section 4.3** and generally delineated by the blue shading on **Figure 4-8**.

In general, water level declines from 1965 through the late 1970s are evident on most hydrographs with sufficient data. Declines vary from about 50 to 60 feet (e.g., Hydrographs 9 and 26) to more than 100 feet (e.g., Hydrograph 12) (**Figure 4-13**). This time period coincides with significant increases in groundwater production in the area when imported water was not yet available and groundwater banking projects had not been constructed.

Since the late 1970s, there are generally two wet cycles and two dry cycles evident from most hydrographs (e.g., Hydrographs 14 and 15 on **Figure 4-13** and Hydrographs 16-19 on **Figure 4-14**). Water levels rose in response to wet hydrologic conditions in the early 1980s and declined with the drought of the early 1990s. Water levels rose again in 1998 in response to wet conditions, fluctuated into the early-2000s, but remained relatively high through the wet year of 2005. However, after that wet period and especially around 2011, water levels in most wells began to decline at a faster rate due to the severe drought conditions that continued through the end of the 1997 - 2014 Study Period. Almost all of the hydrographs with sufficient data end the period of record at or near historic low levels (**Figures 4-13** and **4-14**).

Hydrographs along the western reaches of the Kern River indicate more cyclic fluctuations than those in the north as a result of groundwater banking projects (e.g., Hydrographs 23 and 26-30, **Figure 4-14**). These wells are more locally influenced by recharge and recovery operations in the banking projects than wells away from the river. Although banking operations are often coincident with hydrologic cycles (i.e., more water available for recharge during wet periods and more recovery during dry periods), the hydrographs near banking generally have higher peaks during recharge and, in some cases, lower troughs during recovery (e.g., Hydrograph 27 on **Figure 4-14**). Banking began in the 1980s (COB 2800 project) and expanded in the 1990s (Kern Water Bank and others).

Other short-term fluctuations can also be seen on the hydrographs. Hydrographs with more serrated patterns and large short-term fluctuations (e.g., Hydrographs 3 and 7, **Figure 4-13**) are influenced by pumping water levels either in the well actually being measured or in an adjacent well. These pumping fluctuations are often more than 50 feet. Both SWSD and NKWSD report "at-well" pumping drawdowns up to about 100 feet during the irrigation season (NKWSD, 2012; SWSD, 2012). NKWSD indicates typical drawdowns of 50 to 75 feet (NKWSD, 2012). Seasonal fluctuations of about ten feet are typical for many of the wells with sufficient seasonal data on **Figure 4-14** (e.g., Hydrograph 21).

The Study Period of 1997-2014 is highlighted on the hydrographs and illustrates the final wet cycle and the recent severe drought. For most wells, the overall water level decline from the beginning of the Study Period to the end of the Study Period is about 50 feet or less (e.g., Hydrographs 1, 8, 9, 12, and 13-15 on **Figure 4-13** and Hydrographs 16, 17, 19, and 21 on **Figure 4-14**). Several hydrographs indicate larger declines, and may be exacerbated due to large seasonal fluctuations (e.g., Hydrographs 2-5, 7, and 11 on **Figure 4-13**). In addition, hydrographs near banking projects have more variable fluctuations as indicated above (e.g., Hydrographs 27-29 on **Figure 4-14**). Notwithstanding the relatively small changes over the Study Period, the water level data from these and other Study Area wells indicate an overall long-term decline across the subbasin over time.

Further, as mentioned previously, most water levels at the end of the Study Period indicate historic low levels (as indicated by the long-term hydrographs dating back to 1965). These low water levels have been projected onto the NKWSD cross sections on **Figure 4-9**. Groundwater elevations for Spring 2014 are estimated from the region al water elevation contour map on **Figure 4-10** and groundwater elevations for November 2014 were estimated from the NKWSD water level database provided in support of this project. Water levels are labeled approximate because some of the NKWSD reported water levels could not be substantiated with reference points and depth to water data in the same water level database for the same well. Nonetheless, the lowest groundwater elevations reported by NKWSD for November 2012 (approximately -100 feet below sea level) were used for illustration purposes. At these historic low levels, groundwater elevations are generally below the 300-foot confining layer.

4.6 GROUNDWATER BUDGETS AND OVERDRAFT CONDITIONS

As described above, record declines in water levels indicate that groundwater is being withdrawn beyond the level of replenishment within the subbasin, a concept generally referred to as overdraft. Conditions of overdraft are evaluated using groundwater budgets – an accounting of the multiple inflows and outflows (including subsurface flows) associated with a groundwater system over a certain time interval. When outflows (e.g., groundwater pumping) are higher than inflows, groundwater is being removed from storage. In general, the system can be considered in overdraft if there is a net depletion of groundwater in storage over average hydrologic conditions.

In 1980, DWR added the Kern County Subbasin to a list of 11 groundwater basins in the state that were subject to conditions of critical overdraft (DWR, 1980). According to DWR, a basin is determined to be in critical overdraft if "continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts" (DWR, 1980). At that time, DWR estimated the overdraft in the Kern County Subbasin at 600,000 AFY. DWR determined that the most adverse impact from the overdraft was the increase in pumping costs associated with water level declines. DWR also noted that deep subsidence was continuing at the northern Kern County line near Delano and to the south near the intersection of Highway 166 and Interstate 5. Importation of surface water had slowed the impacts of overdraft in some areas; DWR noted that if the full entitlement of imported water from the State Water Project were available and if no new agricultural lands went into production after 1980, then overdraft conditions would be mitigated. However, since 1980, full entitlement of imported water has not been available for the basin and groundwater pumping has been used to make up the surface water deficit. In 2016, DWR reevaluated its list of critically overdrafted basins and retained the Kern County Subbasin as one of 21 basins on the list (DWR, 2016a).

Since the 1980 estimation of 600,000 AFY of overdraft, several additional water budget evaluations have been made. DWR estimated no overdraft for a short-term analysis using a normalized year with 1990 hydrologic conditions (indicating a positive change of groundwater in storage of about 133,700 AF). An additional water budget prepared by KCWA from 1970 to 1998 indicated a loss of about 325,000 AFY of groundwater in storage.

The 2014 Order requires the identification and quantification of "past and present aquifer overdraft locations within the adversely affected locations north of the Kern River and beneath the City." Because the entire subbasin is in hydraulic communication, groundwater is in constant flux across the Study Area. Local groundwater movement is dynamic and complex, and changes with varying stress on the aquifer such as pumping wells and recharge conditions. To comply with the 2014 Order requirement for determining the amount of overdraft in certain locations within the basin, existing zone budgets from an independently-developed regional numerical model have been used to objectively assess past and present overdraft conditions. These model zone budgets provide groundwater budgets on a subregion basis within the Kern County Subbasin as described below.

The regional model was developed by DWR using the Integrated Water Flow Model (IWFM) code. The model, referred to as C2VSim, simulates groundwater flow throughout the entire Central Valley and has been used as a tool by DWR to develop groundwater budgets in various subregions of the Central Valley. Three such subregions have been analyzed in the Kern County Subbasin. A key feature of IWFM is DWR's agricultural and urban water supply and demand management module that dynamically simulates both surface water and groundwater supplies based on demand estimates, as affected by usage and climatic conditions. The model contains monthly historical data from 1921 through 2009 and provides a platform for simulating future demand.

It is recognized that the C2VSim model is a regional model covering the entire Central Valley and, as such, likely contains incomplete information on managed aquifer recharge and other local water budget components. DWR is currently revising and updating this model; the updated C2VSim is scheduled for release in late 2017. The current model represents the best regional tool available to estimate overdraft conditions throughout the subbasin. The estimation of overdraft conditions north of the Kern River is generally corroborated by declining water levels, which have reached historic lows in many wells as described in **Section 4.5** above (see also, **Figures 4-13** and **4-14**). The overall estimate of subbasin overdraft from the C2VSim model is close to independent estimates made by DWR in 1980.

As shown on **Figure 4-15**, three subregions in the Kern County Subbasin (designated Subregions 19, 20, and 21) have been used to divide the subbasin, generally grouping water agency service area boundaries as described below:

- Subregion 19: Western and northwestern subbasin including SWSD and Buena Vista WSD (northern area), and Lost Hills WD, along with the three westside water districts (West Kern WD, Belridge WSD, and Berrenda Mesa WD)
- Subregion 20: Northeastern subbasin including Shafter Wasco Irrigation District (SWID), NKWSD, Cawelo WD, SSJMUD, KTWD, and the cities of Shafter and Wasco.
- Subregion 21: Kern River and the southern subbasin including KDWD, City of Bakersfield, Kern Water Bank, RRBWSD, Arvin-Edison WSD, Buena Vista WSD (southern area), and Wheeler-Ridge Maricopa WSD.

Subregions 19 and 20 contain most of the lands north of the Kern River and almost all of the areas likely affected by the Proposed Project. Subregion 21 contains KDWD and areas most likely to benefit from the Proposed Project.

The inflows and outflows from the groundwater system are included in the model. The primary components of inflows (water added to groundwater in storage) consist of the following:

- Surface recharge including precipitation, irrigation return flows, banking and managed recharge, and net recharge from surface water-groundwater interactions
- Subsurface inflow from adjacent subregions or consolidated units from the valley perimeter (reported component is the net result of subsurface inflows minus subsurface outflows)
- Water released from storage due to subsidence (see **Section 4.7** for more information on subsidence).

The primary components of outflow for each subregion are also represented in the model and include subsurface outflow and groundwater pumping. However, because the estimation of subsurface inflow (in the bullet list above) is the net result of inflow minus subsurface outflow, subsurface outflow is embedded in that inflow component. Therefore, groundwater pumping is the only component of outflow reported separately in the model groundwater budget for these three subregions.

Groundwater budgets have been estimated in each of these subregions for the Study Period of 1997 – 2007. Data are not available for the updated Study Period that extends to 2014 (see **Section 1.4.4**). Groundwater budgets from this time period have been extracted from the model, averaged over the 11-year period, and are summarized in **Table 13**.

As shown by the negative change in storage in the table, all three subregions are considered to be in overdraft for this time period. The largest depletion of groundwater in storage (-283,883 AFY) occurred in Subregion 21, which includes KDWD. The two regions north of the Kern River, Subregion 19 and 20, also exhibited overdraft conditions, although the change of groundwater in storage was somewhat smaller (-231,710 AFY and -194,061 AFY, respectively). Collectively, the average overdraft in the subbasin is estimated at -709,654 AFY, similar in magnitude but higher than the overdraft estimate of 600,000 AFY for the subbasin made by DWR in 1980.

Table 13. Average Groundwater Budget 1997 – 2007, C2VSim Model Subregions

Subregion	INFLOW			OUTFLOW	
	Net Surface Recharge (AFY)	Net Subsurface Inflow (AFY)	Subsidence Storage (AFY)	Pumpage (AFY)	Change in GW Storage (AFY)
19	324,198	108,732	71,177	735,817	-231,710
20	301,164	-80,335	42,305	457,195	-194,061
21	650,988	64,846	23,266	1,022,983	-283,883

4.7 LAND SUBSIDENCE

The overdraft conditions described above, exacerbated by the recent drought, have resulted in lowered groundwater levels – a condition which can contribute to subsidence of the ground surface. As water levels decline in the subsurface, dewatering and compaction of aquifer materials, predominantly fine-grained materials such as clay, can cause the overlying ground surface to subside.

This process is illustrated by two conceptual diagrams shown on **Figure 4-16**. The upper diagram depicts an alluvial groundwater basin with a regional clay layer and numerous smaller discontinuous clay layers. Water level declines associated with pumping causes a decrease in water pressure within the pore space (pore pressure) in the aquifer system (Galloway, et al., 1999). Because the water pressure in the pores helps support the weight of the overlying aquifer (including the sediments, water, vegetation, and structures on the land surface), the decrease of pore pressure causes more of the weight of the overlying aquifer to be transferred to the sediments grains forming the structure of the sediment layer. The difference between the water pressure in the pores and the weight of the overlying aquifer is termed the effective stress. If the effective stress borne by the sediment grains exceeds the structural strength of the sediment layer, then the aquifer system begins to deform. This deformation consists of re-arrangement and compaction of fine-grained units[13], as illustrated on the lower diagram on **Figure 4-16**. The tabular nature of the fine-grained sediments allows for preferred alignment and compaction. As the sediments compact, the ground surface can sink (shown by the 2nd column on the lower diagram of **Figure 4-16**.

Land subsidence due to groundwater withdrawals can be temporary (elastic) or permanent (inelastic). Elastic deformation occurs when sediments compress as pore pressures decrease, but expand by an equal amount as pore pressures increase. With respect to groundwater pumping, a decrease in water levels causes a small elastic compaction in both coarse- and fine-grained sediments; however, this compaction recovers as the effective stress returns to its initial value. Since elastic deformation is relatively minor and fully recoverable, it is not considered an impact.

During inelastic deformation, or compaction, the sediment grains rearrange into a tighter configuration that reduces the pore space and thereby effectively decreasing the volume of the subsurface sediment layer. Inelastic deformation does not recover as pore pressures increase, thus this compaction is

[13] Although extraction of groundwater by pumping wells causes a more complex deformation of the aquifer system than discussed herein, the simplistic concept of vertical compaction is often used to illustrate the land subsidence process (Galloway, et al., 1999; LSCE et al., 2014).

permanent. Compressible clay particles are often tabular in form and more subject to permanent realignment (and inelastic subsidence). Generally, coarse-grained deposits (e.g. sand and gravels) generally have sufficient intergranular strength and do not undergo inelastic deformation within the range of pore pressure changes generally encountered from groundwater pumping.

Inelastic compaction is initiated when the magnitude of the greatest pressure that has acted on the clay layer since its deposition, or preconsolidation stress, is exceeded. With respect to the effects of groundwater pumping, the preconsolidation stress is exceeded when groundwater levels in the aquifer reach a new historically low water level. The volumetric compaction of the clay layers in the subsurface is transmitted to the land surface where it is manifested as land subsidence.

During the compaction process, the water in these pore spaces is forced out of the clay layers as the sediments are forced into a tighter configuration. The volume of compaction is equal to the volume of groundwater that is expelled from the clay layers and can represent a substantial volume of water. However, once the water is expelled and the structure rearranged, this represents a permanent loss of the water storage volume in the clay layers. Although space within the aquifer is reduced by an amount equivalent to subsidence of the land surface, this storage reduction does not substantially decrease usable storage for groundwater. This is because the compressed clay layers do not typically store significant amounts of *usable* groundwater (LSCE, 2014). However, inelastic compression may decrease the vertical permeability of the clay layer resulting in minor changes in vertical flow.

The following potential impacts can be associated with land subsidence due to groundwater withdrawals (modified from LSCE, et al., 2014):

- Damage to infrastructure including foundations, roads, bridges, or pipelines
- Loss of conveyance in canals, streams, or channels
- Diminished effectiveness of levees
- Collapsed or damaged well casings
- Land fissures.

Damage to CVP infrastructure related to historical land subsidence has been documented just north of the Study Area. In 1976, subsidence along the Tulare-Wasco reach of the Friant-Kern Canal was determined to have interfered with operations (Prokopovich, 1984). A 17-mile segment of the canal required rehabilitation and raising of three pumping plants. As of 1984, post-construction land subsidence along the damaged reach was reported to be more than about five feet. The Friant-Kern Canal extends across the Northern Study Area, through NKWSD to the Kern River. The U.S. Bureau of Reclamation monitors two multi-port monitoring wells in NKWSD (and other monitoring points outside of the Study Area) to track the ongoing potential for subsidence-related problems.

Land subsidence in the San Joaquin Valley has been documented for more than 60 years and recent investigations using satellite imagery and other local methods indicate continuing problems in some areas. Although the areas with the most documented subsidence are generally north of the Study Area, both historical and recent subsidence have been documented in various parts of Kern County. From 1967 to 1980 a series of key studies on land subsidence in the San Joaquin Valley were published by the U.S. Geological Survey in cooperation with DWR (Ireland, et al., 1984; Lofgren, 1975; Lofgren and Klausing, 1969). Collectively, these studies document areas of historical land subsidence in the Study Area as shown on **Figure 4-17**.

4.7.1 Land Subsidence 1926 - 1970

The areas of land subsidence on **Figure 4-17** illustrate subsidence that occurred in the Study Area from 1926 to 1970 (Ireland, et al., 1984). Although data represent the accumulated subsidence over a 44-year period, USGS estimates that about 75 percent of the subsidence occurred in the 1950s and 1960s, corresponding to extensive groundwater development (Galloway, et al., 1999). As shown on **Figure 4-17**, there are two primary areas of historical land subsidence in the Kern County Subbasin where the ground surface has subsided more than one foot. The southern area covers about 500 square miles and includes almost all of the KDWD service area. Subsidence values range from 1 foot to more than 9 feet along the KDWD southern boundary. Much of this subsidence is related to the fine-grained materials associated with the flood basin deposits and paleo-lake beds discussed previously and shown on **Figure 4-6**.

The northern area covers more than 650 square miles of the Northern Study Area and extends to the north into Kings and Tulare counties. This area includes most of NKWSD, as well as CWD, SWID, and more than two-thirds of SWSD. Subsidence values range from 1 foot in southern NKWSD to more than 10 feet on the northern boundary of SSJMUD. As indicated by the contours, the northern area of subsidence extends north of the Kern County line, increasing to more than 12 feet just east of Highway 99. Although subsurface conditions vary, the areas with the most land subsidence can be generally correlated to areas where depositional environments suggest a predominance of fine-grained sediments.

A portion of the time period associated with this initial subsidence evaluation includes a period of significant water level declines (1945-1977 – see **Section 4.6**). Importantly, water levels during this time period were continuing to fall to then-historic lows each year, changing pore pressures in sediments for the first time, which would be associated with larger amounts of subsidence. Water level declines associated with the exact time period of the Ireland, et al. (1984) evaluation are difficult to estimate, given the sparse water level records in the 1920s. However, as indicated by several long-term records discussed in **Section 4.6** above, water level declines were insignificant until about 1945. From the mid-1940s through 1977, water levels declined approximately 150 feet (along the Kern River) to about 250 feet in the central and northern portions of the Northern Study Area, a rate of about 5 to 8 feet per year. This rate of water level decline resulted in land subsidence of about 0.04 feet/year (1 foot over 25 years) to about 0.4 feet/year (9 feet over 25 years).

4.7.2 Land Subsidence 1961 - 2009

There are insufficient regional subsidence maps across the Study Area to bridge the time gap between the end of the USGS studies (1970) and more recent subsidence evaluations (2014-2015). To provide an estimation of land subsidence for the time period between the historical and recent data, USGS conducted model simulations of land subsidence. Investigators used the historical subsidence data, information from individual extensometers, geologic texture analyses, and a groundwater model to estimate the accumulated amount of land subsidence associated with the period 1961 through 2009. This analysis was presented in a public presentation on land subsidence in the Central Valley (Faunt and Phillips, 2014); the model simulation of subsidence from 1961-2009 is shown on **Figure 4-18**.

In general, the analysis suggests that subsidence has exceeded 5 feet over larger portions of the Study Area than the 1926 – 1970 analysis, especially in the Southern Study Area (see yellow shading on **Figure 4-18**). In the Northern Study Area, the area exceeding 5 feet (yellow shading) extends around NKWSD (mostly green shading) and continues to areas north of the Study Area where land subsidence has been

documented to be some of the worst in the Central Valley. The map also indicates that the northern portions of NKWSD have subsidence exceeding 5 feet, similar to the 1-foot to 5-feet range indicated by the USGS study (**Figure 4-17**). In its GWMP, NKWSD reports land subsidence of about one foot in its northeastern service area (near Highways 46 and 99) for the time period 1962 – 1988 (NKWSD, 2012). This subsidence was apparently limited in extent; during that same time period, there was no observed subsidence in Wasco, just west of NKWSD.

It is recognized that the accuracy of the USGS map on **Figure 4-17** is less certain because it represents simulations from a computer model rather than contours of measured data. Nonetheless, it provides the best available estimation of continued subsidence beyond the 1984 USGS study (Ireland et al., 1984).

4.7.3 Land Subsidence 2007 - 2011

More recently, the California Water Foundation commissioned a summary report on subsidence in California that contained a map of total subsidence from 2007 to 2011 (**Figure 4-19**). The figure shows subsidence derived from Interferometric Synthetic Aperture Radar (InSAR) data by the Jet Propulsion Laboratory (JPL) as part of an ongoing study funded by National Aeronautics and Space Administration (NASA) and DWR. Also included on **Figure 4-19** are select contours from the historical subsidence study by USGS discussed previously on **Figure 4-17**. As shown on **Figure 4-19**, most of the Study Area is estimated to have experienced total land subsidence generally less than one-half foot from 2007 through 2011. The southern portion of NKWSD and other areas in the eastern subbasin did not appear to experience land subsidence during this time period (**Figure 4-19**).

4.8 GROUNDWATER QUALITY

Groundwater quality within the Study Area has been designated for both agricultural and municipal beneficial uses (among others). In general, groundwater chemistry varies across the valley. In the western subbasin, groundwater is typically a sodium chloride or calcium sulfate type (Bertoldi, et al., 1991). Water chemistry is more variable in the eastern subbasin but is typically a sodium/calcium bicarbonate water type, especially in the Northern Study Area (Bertoldi, et al., 1991). Groundwater typically has a lower salinity on the eastern side of the valley (reflecting more river and mountain front recharge) and is more highly mineralized in the western areas (reflecting marine sediments).

Using total dissolved solids (TDS) as a water quality indicator, TDS concentrations in the Kern County Subbasin average between 400 and 450 mg/L, but can be up to 5,000 mg/L (DWR, 2006). For drinking water purposes, water with a TDS concentration of 500 milligrams per liter (mg/L) or less is recommended, but can be usable up to 1,000 mg/L. TDS concentrations should be below 450 mg/L for irrigation of salt sensitive crops. The secondary maximum contaminant level (MCL) for TDS is 500 mg/L.

Additional groundwater quality data in the Study Area is provided in the following sections. TDS is presented to indicate variability in overall water quality across the Study Area. Two primary constituents of concern, nitrate and pesticides, are also evaluated. Data are taken from a larger groundwater quality study conducted in 2015 for the Kern River Watershed Coalition Authority (P&P, 2015). This database included over 100,000 records for TDS, nitrate, and pesticides over the 1909 through 2014 period. Well construction information was not generally available for the wells and, as a result, the analyses presented on the three supporting figures does not incorporate evaluation of depth or aquifer material associated with water quality results. Accordingly, these figures present a general representation of areas with groundwater quality concerns.

4.8.1 Total Dissolved Solids

TDS concentrations in the primary production zones of the Northern Study Area typically range between 250 to 350 mg/L (Poso Creek RWMP, 2014). TDS concentrations are more variable in the west and can range up to 3,000 mg/L in some areas (AECOM, 2016a). Shallow water quality can have elevated salinity resulting from natural conditions (such as old marine and lakebed deposits) and/or irrigation practices.

On a local level, groundwater quality can be affected by the quality and quantity of recharge water. Recharge is primarily from Kern River water and artificial recharge at groundwater banking facilities. Additional recharge sources include agricultural and municipal irrigation return flows and infiltration of intermittent streamflow along the edge of the Kern County subbasin.

Kern River water is of high quality, with low TDS concentrations generally on the order of 100 mg/L (Poso Creek RWMP, 2014). Poso Creek water has higher TDS concentrations but less than SWP TDS concentrations, which range between 250 and 350 mg/L. CVP water is also of high quality with TDS concentrations on the order of 50 mg/L (Poso Creek RWMP, 2014). Other sources of recharge include oil-field produced water. This water can have TDS concentrations on the order of 700 mg/L but the water is blended to reduce concentrations to typically no more than 450 mg/L, which is satisfactory for most agricultural uses (Poso Creek RWMP, 2014).

Figure 4-20 shows maximum TDS concentrations in groundwater for the 1997-2014 Study Period. Yellow circles indicate TDS detections below 1,000 mg/L. Green circles indicate TDS concentrations between 1,000 and 1,500 mg/L and the blue circles represent the wells where maximum concentrations were above 1,500 mg/L. The highest concentrations of TDS occur along the western portion of the Study Area and sporadically in the north.

4.8.2 Nitrate

Nitrate concentrations during the 1997-2014 Study Period are shown on **Figure 4-21**. Yellow circles indicate where nitrate (as NO_3) concentrations are below 45 mg/L. Orange circles indicate detections between 45 and 90 mg/L and the dark red circles represent locations where concentrations were greater than 90 mg/L. As shown by the map, elevated nitrate concentrations are more prevalent on the eastern portions of the Study Area and sporadically in the center of the Northern Study Area. The primary MCL for nitrate as NO_3 is 45 mg/L; the MCL for nitrate as N is 10 mg/L.

4.8.3 Pesticides

Pesticide detections during the 1997-2014 Study Period are shown on **Figure 4-22**. The data represents sampling of any pesticide with non-detections shown as yellow circles, detections shown as orange circles and MCL exceedances shown as purple circles. There does not appear to be a spatial trend for detections and exceedances. Pesticides detections are more recurrent in the central and northeast portions of the Northern Study Area but the number of samples collected in these areas is also greater.

4.8.4 Localized Areas with Constituents of Concern

The Kern Fan Monitoring Committee (KFMC) evaluates groundwater quality in and around the Kern Water Bank and other Kern Fan banking projects. A summary water quality map prepared by KFMC is provided on **Figure 4-23** and shows localized areas of groundwater quality concerns north of the Kern River. Areas are based on data from 1998 – 2006 (AECOM, 2016a), a time period similar to the early

Study Period used for this Project impacts assessment (1997 – 2007, see **Section 1.4.4**). As shown on **Figure 4-23**, areas are delineated where three constituents of concern have been detected at elevated concentrations in groundwater: nitrate and two fumigants, dibromochloropropane (DBCP) and ethylene dibromide (EDB). The map shows two general areas where nitrate concentrations are higher than 40 mg/L. The map also shows three localized areas of DBCP at concentrations higher than its MCL of 0.2 micrograms per liter (ug/L) and two areas with EDB concentrations higher than 0.02 ug/L (**Figure 4-23**). The primary MCL for EDB is 0.05 ug/L.

5 GROUNDWATER MODEL

To quantify the groundwater impacts associated with the Proposed Project over space and time as required by the 2014 Order, a numerical model was developed. A numerical groundwater model is a quantitative tool capable of evaluating the impact of potential future changes in pumping or recharge operations on groundwater levels, flows and water budgets throughout the groundwater basin. The model represents a mathematical description of the hydrogeological conceptual model, combining data on basin geometry, aquifer properties, recharge, and discharge to simulate changes in groundwater levels and calculate the water balance over time (Bear and Verruijt, 1987). This section describes the approach, development and validation of the numerical groundwater model used to support the groundwater impacts analysis.

5.1 SUPERPOSITION MODELING APPROACH

A superposition modeling approach was selected as the most suitable method to support the groundwater impacts analysis. As detailed in the following section, this superposition approach enables the Project-related changes to be calculated throughout the basin, and superimposed upon the groundwater system so that the accumulated effects of the Project over time can be determined.

5.1.1 Conceptual Understanding

The purpose of the groundwater impacts analysis is to evaluate the change in groundwater levels as a result of the Proposed Project. Groundwater levels will change as a result of reduced recharge and increased pumping in areas primarily north of the Kern River and increased recharge and decreased pumping in areas primarily south of the Kern River. **Figure 5-1** provides a conceptual example of the anticipated effects of the Proposed Project that require analysis. When surface water is diverted to a recharge basin, a groundwater mound typically forms under the facility during operations. If less water is diverted into the basin, the height of the mound would be less, resulting in lower groundwater levels (see top diagram, **Figure 5-1**). The volume of groundwater in the aquifer represented by the relative change in groundwater levels is referred to as the change of groundwater in storage.

Similarly, an increase in pumping would result in greater drawdown (i.e., lowering) of groundwater levels in a pattern that is greatest near the pumped well and diminishes with increasing distance. For increased recharge or decreased pumping, the changes would be a rise in groundwater levels.

The fundamentals of groundwater hydraulics, including Darcy's Law and the Law of Conservation of Mass (Todd and Mays, 2004; Bear and Verruijt, 1987; Freeze and Cherry, 1979; Bouwer, 1978), can be used to calculate the changes in groundwater levels resulting from the Project-related changes in recharge or pumping as discussed below.

5.1.2 Principle of Superposition

The Principle of Superposition within groundwater systems is derived from the equation of groundwater flow based on Darcy's Law (Todd and Mays, 2004; Bear and Verruijt, 1987; Freeze and Cherry, 1979; Bouwer, 1978), which is provided below:

$$\frac{d}{dx}\left(Tx\frac{dh}{dx}\right)+\frac{d}{dy}\left(Ty\frac{dh}{dy}\right)+W=S\frac{dh}{dt} \quad (1)$$

where h = groundwater level or head
T = transmissivity
W = water sink or source term representing the water balance
S = Storage Coefficient

This differential equation is linear in terms of the groundwater head (h) – that is, anywhere that h appears in this equation, it is only to a single power; for example, it is not squared or cubed. Because the equation is linear in h, any number of equations – representing, for example, multiple different stresses on the groundwater system - can be summed to provide the total change to the system resulting from all of the individual stresses. Furthermore, the right hand side of the equation shows that the change in head (dh) is a function of time (dt). This indicates that equation 1 can be used to superimpose the effect of the changes in multiple, transient (i.e., time-varying) stresses to determine the accumulated impact of these stresses on groundwater levels over time. This means that calculated changes in groundwater levels associated with an action (such as the Proposed Project) can be added to other groundwater level distributions to determine the combined effects on the groundwater system (Reilly et al., 1987, Bennett, 1976). The superposition approach allows for the accumulated effects of the Proposed Project to be analyzed separately from the effects of other pumping and recharge occurring in the basin.

Figure 5-2 provides an example of the application of the Principle of Superposition. The example shows the effects of pumping from two different wells on groundwater levels measured at a single monitoring location. The pumping rates are different and the timing of the pumping varies. The drawdown associated with each well can be calculated independently and then added together. The bottom panel depicts the total, accumulated effect of the pumping at both wells on the water levels measured at the single monitoring location when the two independent calculations are superimposed to provide the combined drawdown.

5.1.3 Application of Superposition Models

The Principle of Superposition is routinely applied in the solution of both analytical and numerical groundwater flow problems (Reilly et al., 1987). In contrast to a model that attempts to describe and predict each and every basin-wide stress – many of which may not be readily quantifiable – the superposition technique has the benefit that it focuses on calculating the water level changes that result from the specific stresses of interest and superimposing those upon the basin-wide system. Major advantages of the superposition technique are summarized by Reilly et al. (1987) as follows.

- The effects of a specified stress (i.e., groundwater pumping, managed recharge) on the system can be evaluated even if other stresses are unknown.
- The effects of a change in stress on the system can be evaluated even if the initial conditions are unknown.
- The effect of one stress on the system can be isolated from the effects of all other stresses on the system.

When the Principle of Superposition is used in groundwater modeling, the model results are presented in terms of change in groundwater levels rather than in absolute values of groundwater elevations. Therefore, the model results provide the relative change in groundwater levels due to the Proposed Project; in other words, a superposition model directly calculates the groundwater level impacts from the Proposed Project. By applying the Principle of Superposition, the relative change in groundwater

levels can be added (superimposed) to measured or simulated groundwater elevations to determine a predicted groundwater elevation associated with Project impacts.

The water balance derived from a superposition model represents the change in the groundwater flux as a result of the simulated changes. Therefore, a positive flux may represent an increase in inflow or a decrease in outflow as a result of the Proposed Project. Likewise, a negative flux may represent an increase in outflow or a decrease in inflow as a result of the Proposed Project.

As a result, the superposition modeling approach as implemented for the Proposed Project incorporates detailed information about the hydrostratigraphy and distributions of stresses throughout the basin-wide groundwater system, yet it is relatively simple to use. The use of a superposition modeling approach thus enables the groundwater impacts analysis to assess the effects of the Project on the groundwater system in isolation from other acting stresses (e.g., pumping, recharge, etc.) without having to obtain data of non-project related stresses to simulate the Project. Using a superposition model, calculation of groundwater impacts is inherently precise because flow quantities other than Project-related components are set to zero (Leake, 2011). Thus, use of the superposition modeling technique allows for the formulation of the Proposed Project scenarios, and simulation of Proposed Project-related changes directly, in a manner that incorporates all of the details of the Proposed Project while mitigating the need to collect non-project related data that may not be obtainable.

The superposition model approach has been applied for other comparable projects. **Table 14** provides a representative list of reports documenting the use of a superposition models that are publically available using an internet search. The superposition approach is a standard, well-established method that has been accepted for evaluating groundwater impacts, supporting groundwater management, and providing regulatory compliance. The use of superposition models has been increasing in recent years with several applications for complex projects, especially in New Mexico, Idaho, California and Arizona.

Table 14. Representative List of Published References on the Use of Superposition Models for Similar Applications

Citation	Location	Purpose of Model	Review Agency
Leake, Owen-Joyce and Heilman, 2013	Parker-Palo Verde-Cibola area, Arizona and California	Effects of groundwater withdrawals on Adjudicated Colorado River flow depletion	USGS, US Bureau of Reclamation
Barroll, 2006, 2012	Taos Valley, New Mexico	Taos Adjudication Settlement for use in water rights administration under the 2006 Draft Taos Settlement	New Mexico Office of the State Engineer
Sukow, 2012	Eastern Snake Plain, Idaho	Support development of a Comprehensive Aquifer Management Plan	Idaho Department of Water Resources
Leonard Rice Engineers, 2012	Denver-Julesburg Basin, Colorado	Regulatory compliance with Colorado Produced Non-tributary Ground Water Rules of discharge to streams	Colorado Division of Water Resources
Leake, Hoffman and Dickinson, 2008	Lower Colorado River Valley, California and Arizona	Effects of groundwater withdrawals on Adjudicated Colorado River flow depletion (US Supreme Court, 2006)	USGS, US Bureau of Reclamation
Wylie, 2005	Eastern Snake Plain, Idaho	Resolution of conflicts among water users and in future water administration	Idaho Department of Water Resources
Larson, et al., 2005	Roswell Underground Water Basin, New Mexico	Evaluate impacts associated with proposed changes in pumping patterns	New Mexico Office of the State Engineer
Bergeron and Freeman, 2005	Hanford Site, Washington	Estimate concentrations in groundwater for a specific constituent inventory	US EPA
Leake et al., 2005	Little Colorado River Area, Northeastern Arizona	Effects of groundwater withdrawals on stream flow depletion	USGS
Roark, 2001	Santa Fe Group Aquifer System, New Mexico	Investigate surface water/groundwater interactions with Rio Grande and Santa Fe Group aquifer system	City of Albuquerque
McAda, 2001	Rio Grande Valley, Albuquerque, New Mexico	Amount and timing of induced infiltration from the Rio Grande surface-water system from pumping	City of Albuquerque
Hubbell et al., 1997	Eastern Snake Plain, Idaho	Demonstration of superposition technique to increase efficiency of groundwater flow modeling	Idaho Dept. of Water Resources
Bradner, 1996	Upper Floridan Aquifer, Orange County, Florida	Evaluate the impacts from redistribution of recharge from drainage wells on groundwater levels	USGS, Orange County Stormwater Dept.
Takahashi and Peralta, 1995	East Shore Area of the Great Salt Lake, Utah	Optimization of perennial groundwater yield planning	Utah State University
Focazio and Speiran, 1993	Coastal Plain Aquifer, southeastern Virginia	Estimate groundwater-level declines from episodic pumping from six well fields	Hampton Roads Planning Commission
Prince and Schneider, 1989	Glacial aquifers, New York	Refine aquifer properties by simulating the aquifer geometry and field conditions of pumping tests	USGS

5.2 GROUNDWATER MODEL METHODOLOGY

The modeling used to support the groundwater impacts analysis for the Proposed Project is based on the Principle of Superposition and, thus, is referred to as the KDWD Superposition Model. The methodology and model development of the KDWD Superposition Model are summarized below. Additional documentation on the model development is provided in **Appendix B**.

5.2.1 General Methodology

The development of a superposition model is typically based on modification of an existing, calibrated, historical groundwater model. The advantage of this approach is that the superposition model incorporates the aquifer basin structure, hydrostratigraphy and parameter values determined through calibration of the pre-existing model. The general methodology requires that the initial simulated groundwater level for the aquifer and all model boundaries be set equal to zero, making all initial fluxes in the model also equal to zero. A detailed discussion of the application of superposition to groundwater hydraulics is provided by Reilly et al. (1987). The conversion of an existing groundwater model to a superposition model requires some modification. The general process for setting up a superposition model includes:

- The model layer top and bottom elevations are recalculated relative to the initial groundwater elevations to provide a saturated thickness that preserves the hydrogeology of the aquifer system.
- All boundary conditions not associated with the Project are removed.
- All head-dependent boundary conditions representing subsurface flow, such as constant head boundaries, are set to an elevation of zero.
- Elevations of natural features included in the model, such as streambed elevations, are also recalculated relative to the initial groundwater elevations.
- All aquifer properties, including hydraulic conductivities, transmissivities and aquifer storage from the existing groundwater model are maintained and remain fixed for the analysis.

As detailed above, the Principle of Superposition is derived for systems in which the change in groundwater is a linear function of the change in stresses. In natural settings, however, changes in a groundwater system may occur in a nonlinear manner. Nonlinearities are not uncommon in practice: indeed Reilly et al. (1987) noted that superposition models are commonly applied without significant modifications to simulate mildly nonlinear systems as long as the effects of the nonlinearity are small relative to the dimensions of the aquifer system. Methods for handling more complex nonlinearities have been advanced by Reilly and Harbaugh (2004), Durbin et al. (2008), Leake (2011), Takahashi and Peralta (1995), among others, who summarize practices to address complex nonlinearities in superposition models. Nonetheless, it is always best-practice to evaluate the likely degree and significance of any nonlinearities on a project-specific basis (Reilly et al., 1987; Reilly and Harbaugh, 2004). For the KDWD Superposition Model an assessment was made of the likely effect on model results of the following potential sources of nonlinearity:

- Groundwater-surface water interactions – This relationship becomes nonlinear if groundwater levels cross the river bed elevation (point of discontinuity) during the simulation periods causing the calculation of the rate of seepage to change from a continuous equation to a constant value.

If groundwater levels remain consistently above or below the riverbed elevation, the relationship remains linear. In the KDWD Superposition Model, the Kern River and other simulated streams are consistently disconnected from the aquifer; as a result, this condition does not constitute a source of nonlinearity for the KDWD Superposition Model.

- Aquifer parameters – Where the aquifer is unconfined, aquifer transmissivity changes over time as groundwater levels change. If groundwater level changes are small relative to the total aquifer thickness (typically less than 10 to 20 percent), the error associated due to this nonlinearity is acceptably small (Reilly et al., 1987; Morrison, 2006). In the KDWD Superposition Model, the groundwater level changes resulting from the Proposed Project are small relative to the total aquifer thickness; therefore, the effects of unconfined aquifer conditions as a source of nonlinearity are minor for the KDWD Superposition Model.

Following standard practice (Reilly et al., 1987; Reilly and Harbaugh, 2004; Durbin et al., 2008; Leake, 2011), the effects of nonlinearity are within an acceptable range that allow for use of the KDWD Superposition Model as a quantitative tool to support the groundwater impacts analysis.

5.3 BASE MODEL SELECTION

Consistent with best-practice, the KDWD Superposition Model is developed on the basis of an existing, previously calibrated, groundwater model, referred to here as the Base Model. The following summarizes the process to select the Base Model.

5.3.1 Assessment of Available Models

In selecting a Base Model, several general criteria were evaluated. These include:

1. Model covers the entire Study Area and sufficient areas beyond.
2. Emphasis on characterization of aquifer properties.
3. Model development is well documented and model files are publically available.
4. Model uses an industry-standard modeling code for public acceptance and ease of use.

Two existing regional models cover the entire Study Area and sufficient areas beyond. These are the USGS Central Valley Hydrologic Model (CVHM) (Faunt, 2009) and the DWR California Central Valley Groundwater-Surface Water Simulation (C2VSim) Model (Brush, Dogrul and Kadir, 2013). CVHM is based on the USGS MODFLOW code; C2VSim is based on the Integrated Water Flow Model (IWFM) code.

There are several local models developed for specific purposes by the various water agencies in the Study Area. These models may include more detailed data for local areas; however, they do not cover the entire Study Area whereas the regional aquifer data required for the KDWD Superposition Model already exists in CVHM and C2VSim.

Both of the regional models (CVHM and C2VSim) are calibrated to data obtained throughout the entire Central Valley, and as such the accuracy of their data on the local scale has been subject to critical review. For example, the CVHM has a recognized deficiency in accurately representing the recharge volumes from the numerous groundwater banking operations in Kern County in the model (Faunt, 2009); this deficiency - rather than model structure and parameterization - is considered to be the

primary factor impacting the CVHM calibration in Kern County. Since these water budget terms are not used in the KDWD Superposition Model, this deficiency is not considered to appreciably affect the use of the CVHM as the Base Model. Therefore, CVHM is considered the best model available to serve as the base model for the Superposition Model. In summary, the CVHM was selected for use as the Base Model for developing the KDWD Superposition Model for the following main reasons, listed in descending order of priority:

- The comprehensive regional geologic characterization included in CVHM is of great value to the KDWD Superposition Model. The aquifer properties in the CVHM are based on a sound regional geologic characterization derived from thousands of geologic logs and texture analyses. This is not included in the current C2VSIM.
- The KDWD Superposition Model does not directly simulate non-Project related water balance components, so these positive aspects of the C2VSIM, which are a deficiency of the CVHM, are not of benefit to the Project.
- CVHM was developed using the USGS MODFLOW code, which is in wider use than the IWFM code, and is an established industry-standard computer code with commercially-available model data processors. Thus, the use of MODFLOW provides more tools to setup the model, evaluate the model results, and provide easier review by any third-party reviewer.
- Although under development, the IWFM code used for C2VSim has limited model data processing capability at this time, which makes working with the C2VSim model more time consuming for purposes of this study and those of any third-party reviewer.

In summary, the use of any of the pre-existing local models as a basis for the KDWD Superposition Model was considered less suitable for purposes of the impact analysis than the use of CVHM or C2VSim. Of the two regional models, CVHM provides a more comprehensive aquifer characterization data set for the KDWD Superposition Model.

5.3.2 Central Valley Hydrologic Model (CVHM) Overview

The CVHM is a three-dimensional (3D) computer model developed by the USGS to simulate surface water and groundwater flow across the entire Central Valley (Faunt, 2009). The geologic framework and aquifer properties of CVHM were developed based on a comprehensive geologic analysis including the USGS Sediment Texture Analysis (Faunt, Hanson and Belitz, 2009). CVHM also simultaneously accounts for changing water supply and demand across the landscape, and simulates surface water and groundwater flow across the entire Central Valley (Faunt, Hanson and Belitz, 2009). CVHM is designed to simulate water usage in the Central Valley on a regional scale.

CVHM uses a uniform grid spacing of one square mile that is oriented parallel to the valley axis, about 34 degrees west of north. In order to adequately represent the growing season, the annual hydrologic cycle in CVHM is divided into 12 monthly stress periods.

CVHM simulates the Central Valley Aquifer by subdividing the subsurface into 10 layers (**Figure 5-3**). The top layer (Layer 1) represents the land surface. Model Layers 2 and 3 represent the shallow aquifer. Model Layers 4 and 5 represent the Corcoran Clay Member of the Tulare Formation, or its equivalent, where present. Model Layers 6 through 10 represent the deeper aquifers.

For the CVHM, the bottom of the model was specified on the basis of well-completion records to incorporate the vertical intervals of the aquifer system being stressed by pumpage. The model bottom extends to 1,800 feet below land surface, and where the Corcoran Clay is present, to 1,500 feet below the Corcoran Clay (**Figure 5-3**). For the most part, saline water is deeper than the model bottom (Faunt, Hanson and Belitz, 2009).

5.3.3 USGS Sediment Texture Analysis Overview

The USGS Sediment Texture Analysis was used to develop aquifer properties for the CVHM and subsequently used to develop the KDWD Superposition Model. The USGS conducted the Sediment Texture Analysis by compiling and describing lithology for approximately 8,500 drillers' logs to better define aquifer properties for the heterogeneous valley-fill deposits of the Central Valley aquifer system (Faunt, Hanson and Belitz, 2009). The geologic descriptions on each log were classified using a discrete binary texture classification of either "coarse-grained" or "fine-grained" similar to those originally defined by Page (1986). The coarse-grained sediment texture is defined as consisting of sand, gravel, pebbles, boulders, cobbles, or conglomerate. Fine-grained sediment texture is defined as consisting principally of clay, lime, loam, mud, or silt. The basis for calculating aquifer properties from texture data is based on the spatial correlation between saturated hydraulic conductivity[14] and pore-size distributions in geologic media (Faunt, Hanson and Belitz, 2009).

The spatial distribution of the sediment texture, both horizontally and vertically, was developed by applying a geostatistical analysis. For this analysis, the percentage of coarse-grained sediment texture was computed for each 50-foot depth interval. The utilization of the percentage of coarse-grained deposits, or texture, was based on a methodology developed in earlier works by Page (1986) and Burow et al. (2004). The geostatistical analysis applied a three-dimensional kriging technique to map the percentage of coarse-grained deposits onto a one-mile spatial grid at 50-foot depth intervals from land surface down to 3,000 feet below land surface across the Central Valley (Faunt, Hanson and Belitz, 2009).

The results of the USGS Sediment Texture Analysis show substantial heterogeneity and systematic variation in the texture of the sediments in the Central Valley that reflect the observed regional, spatial, and vertical heterogeneity in the aquifer system. These characteristics were correlated to known sediment source areas, independently mapped geomorphic provinces, and factors affecting the development of alluvial fans (Faunt, Hanson and Belitz, 2009). In the San Joaquin Valley, especially on the eastern side, the areas of coarse-grained texture are more widespread than the areas of fine-grained texture and occur along the major rivers. In the southern part of the San Joaquin Valley, the alluvial fans derived from the Sierra Nevada are much coarser grained than the alluvial fans to the north. In contrast to the eastern San Joaquin Valley, the western San Joaquin Valley generally is finer-grained and is underlain by the Corcoran Clay Member of the Tulare Formation. These finer textures reflect the source material consisting of shales and marine deposits from the Coast Range. These rocks generally yield finer-grained sediments than the granitic parent rocks that make up the alluvial fans on the eastern side of the valley (Faunt, Hanson and Belitz, 2009).

[14] Hydraulic conductivity (K) is a coefficient of proportionality that describes the rate at which water can move through a permeable medium.

USGS used the Sediment Texture Analysis as the geologic basis for determining aquifer properties for the 10-layer CVHM (**Figure 5-3**). The layering for CVHM matches that used for the USGS Sediment Texture Analysis; therefore, the aquifer properties derived from USGS Sediment Texture Analysis were incorporated into CVHM (Faunt, Hanson and Belitz, 2009; Faunt et al., 2009). The aquifer properties were updated during calibration, and the final parameters used are documented in USGS publications (Faunt et al., 2009). The method for developing the aquifer properties from the USGS Sediment Texture Analysis is described more fully in the CVHM model documentation (Faunt et al., 2009). In summary, the assumptions used to develop the aquifer properties for CVHM include:

- The horizontal hydraulic conductivity is calculated as the weighted arithmetic mean of the percentage of coarse- and fine-grained sediments defined by the sediment texture analysis multiplied by the assigned hydraulic conductivities for each texture. For the San Joaquin Valley, the coarse-grained hydraulic conductivity is 2.4×10^{-1} feet per day, and fine-grained hydraulic conductivity is $3.3\times10^{+3}$ feet per day.
- Vertical hydraulic conductivity between layers is calculated as a weighted power mean of the percentage of coarse- and fine-grained sediment textures between the midpoints of adjacent 50-foot layers multiplied by the assigned hydraulic conductivities for each texture.
- Specific yield was calculated using a linear relation based on the percentage of coarse-grained deposits. Where there were no coarse-grained deposits, the specific yield was 0.09. Where the deposits are all coarse-grained, the specific yield was 0.40. The median and average values are 0.23 and 0.24, respectively, well within previously estimated values of specific yield (Faunt et al., 2009).
- The specific storage is calculated by calculating the weighted arithmetic mean of the percentage of coarse- and fine-grained sediments multiplied by the assigned porosity for each texture. This value is then multiplied by the compressibility of water (1.4×10^{-6} per foot) to determine the specific storage.

This method for estimating aquifer properties using the USGS Sediment Texture Analysis approach has been applied successfully in previous groundwater-flow models in the San Joaquin Valley (Phillips and Belitz, 1991; Belitz and Phillips, 1995; Burow et al., 2004; Phillips et al., 2007). The value of using the CVHM aquifer properties derived from the USGS Sediment Texture Analysis in the KDWD Superposition Model is that the aquifer properties are derived from a comprehensive regional analysis based on a consistent set of geologic data and developed by technically-credible methods.

5.4 KDWD SUPERPOSITION MODEL DEVELOPMENT

The following discussion describes the development of the KDWD Superposition Model from the CVHM (Faunt, 2009). Additional information about model development is provided in **Appendix B**.

5.4.1 Model Setup

The KDWD Superposition Model covers all of the Study Area as well as areas outside the Study Area. The eastern, southern and western boundaries are extended to natural basin boundaries where the alluvial sediments terminate against bedrock units. The northern boundary extends into portions of Kings and Tulare counties (**Figure 5-4**) along a line from a point near the intersection of Highway 33 and the Kern County line to the Town of Exeter along the Sierra Foothills in Tulare County (**Figure 5-4**). The final selection of the northern boundary was determined through an iterative process of evaluating initial

model results so that the boundary was sufficiently far from Project-related actions to have minimal effect on the analysis of groundwater impacts.

The KDWD Superposition Model was setup to run in MODFLOW 2005 using the model data processor Groundwater Vistas version 6 MODFLOW interface (ESI, 2011). Model grid dimensions, aquifer properties, and boundaries for the KDWD Superposition Model were derived directly from the CVHM (Faunt et al., 2009). For the conversion of the CVHM to the KDWD Superposition Model, the following changes were made:

- Length units used in the model were converted from meters used in the CVHM to feet for convenience for analysis, including all model dimensions and aquifer properties.
- The model grid spacing was refined by a factor of four (4), from 5,280 feet to 1,320 feet, to improve the spatial resolution of the simulated groundwater level changes related to the Proposed Project. This results in a 16-fold increase in grid spacing compared to CVHM, with each new model cell 40 acres in size. This grid spacing increases the resolution for assessing drawdown and mounding during the model simulations.

5.4.2 Boundary Conditions and Initial Conditions

The superposition methodology requires that most of the existing CVHM boundary conditions be either removed from the simulation, set to an initial value of "zero" (representing no change at the beginning of the calculations) or otherwise modified such that the Proposed Project changes that are to be superimposed on the system are the only deterministic stresses that are placed upon the model. The exceptions are natural boundaries that may influence Project conditions. The non-Project boundary conditions used in the KDWD Superposition Model include the following:

- The constant head boundary placed along the northern model boundary represents the interaction with the Central Valley aquifer to the north (**Figure 5-4**). The constant head boundary was set to an elevation of zero, consistent with the superposition methodology.
- Streams, including the Kern, White and Tule rivers (**Figure 5-4**), were converted from the Streamflow Routing Package to the Drain Package. The Drain Package allows groundwater to exit to the surface if groundwater levels rise to the level of the streambed, but does not allow for induced recharge from the streams to the aquifer. Since changes to stream recharge from the Proposed Project are simulated using the MODFLOW Recharge Package, the use of a passive drain provides a means to allow groundwater discharge to the simulated rivers. The streambed elevations were modified to represent the relative height of the streambed above the top of the initial groundwater surface following the superposition methodology (Reilly et al., 1987).
- Geologic faults in the CVHM were remapped onto the finer grid of the KDWD Superposition Model, and the same aquifer properties were applied to the faults as in the original model. Initial conditions were taken directly from the CVHM simulation results for December 1996 to accommodate the initial month of the Study Period (January 1997).

Boundary conditions for remaining boundaries included in the CVHM (e.g., recharge, evapotranspiration, pumping wells, and farm processes) were removed from the KDWD Superposition Model. The assumption is that these conditions will remain the same during the Proposed Project;

therefore, following the Principle of Superposition (Reilly et al., 1987), the KDWD Superposition Model does not include them in the simulation.

5.4.3 Definition of Model Layers

The CVHM characterizes the Central Valley aquifers with ten model layers (**Figure 5-3**). Given the prevailing hydrostratigraphy within the Project Area and the objectives of the impact analysis, these ten layers were grouped together within the KDWD Superposition Model to form four model layers as follows, which also simplifies the analysis and presentation of model results:

- Model Layer 1 groups together CVHM model layers 1, 2 and 3 to simulate the Shallow Aquifer in the Kern County Subbasin.
- Model Layer 2 groups together CVHM model layers 4 and 5 to simulate an interval with increased clay layers, including the 300-foot clay that locally can form an aquitard limiting vertical flow (e.g., **Figure 4-8**).
- Model Layer 3 groups together CVHM model layers 6 and 7 to simulate the Main Production Aquifer in the Kern County Subbasin.
- Model Layer 4 groups together CVHM model layers 8, 9 and 10 to simulate the Deep Aquifer in the Kern County Subbasin.

The top of Model Layer 1 was defined as the top of the groundwater surface: its initial value was set to zero (0) so that calculations made with the model would directly represent the change from the initial condition, consistent with the use of superposition methods (Reilly et al., 1986). The thickness of the model layers represents the saturated thickness below the top of the groundwater surface. The average thickness for each model layer is listed in **Table 15** for the Northern and Southern Study Areas. The CVHM simulation results for December 1996 were used as the top of the groundwater surface. Therefore, the saturated thickness for each model layer was preserved to accurately represent the local hydraulic character.

5.4.4 Aquifer Properties

A key criterion of selecting CVHM as the Base Model was to take advantage of the comprehensive USGS Sediment Texture Analysis (Faunt, Hanson and Belitz, 2009) to develop the spatial distribution of aquifer properties. Accordingly, final aquifer properties were extracted from the CVHM and applied to the KDWD Superposition Model in a manner to preserve the hydraulic characteristics.

This step required that the aquifer properties from the 10-layer CVHM model be composited and mapped to the 4-layer KDWD Superposition Model using standard procedures for calculating the equivalent property values in a layered aquifer system (Todd and Mays, 2004; Bear and Verruijt, 1987; Freeze and Cherry, 1979; Bouwer, 1978). The application of these standard procedures is discussed in more detail in Appendix B. The key aquifer properties extracted from CVHM include:

- Horizontal Hydraulic Conductivity (K_H) assumes groundwater flow is generally parallel to the geologic layering; therefore, the equivalent K_H was calculated using a thickness-weighted average following the above referenced standard procedures. As a result, the equivalent K_H was determined mainly by the layers with the highest K_H values.
- Vertical Hydraulic Conductivity (K_Z) assumes groundwater flow is generally perpendicular to the geologic layering; therefore, the equivalent K_Z was calculated using a harmonic mean following

the above referenced standard procedures. As a result, the hydraulic resistances of the layers are additive, so that the equivalent K_Z was mainly determined by the layers with the lowest K_Z values.

- Specific Storage (S_S) assumes that the porosity remain nearly constant, therefore, the equivalent specific storage was calculated using a thickness-weighted average following the above referenced standard procedures.
- Specific Yield (S_Y) is not a function of thickness and can be used directly from the CVHM following the above referenced standard procedures.

The equivalent aquifer properties were calculated for each model layer following the referenced standard procedures (Todd and Mays, 2004; Bear and Verruijt, 1987; Freeze and Cherry, 1979; Bouwer, 1978). The calculation was performed for the center point of each CVHM grid. A natural neighbor interpolation method was applied to distribute the aquifer properties from CVHM to the refined KDWD Superposition Model grid to preserve the CVHM aquifer properties. The aquifer properties and thicknesses from the appropriate CVHM model layers were tabulated, and the calculation for each aquifer property was done on a cell-by-cell basis. The thicknesses were calculated relative to the December 1996 groundwater surface to represent the saturated thickness. Only those portions of the aquifer below the December 1996 groundwater surface were included in the calculation. The average value for each of the listed aquifer properties is provided in **Table 15** for each model layer for the Northern and Southern Study Areas (generally north and south of the Kern River).

Table 15. Spatial Average of Aquifer Properties Used in Superposition Model

Aquifer Property	Model Layer 1	Model Layer 2	Model Layer 3	Model Layer 4
Northern Study Area				
Saturated Thickness (ft)	225	28	440	1,050
Horizontal Hydraulic Conductivity (ft/d)	300	2	70	37
Vertical Hydraulic Conductivity (ft/d)	0.26	0.0016	0.07	0.01
Specific Storage (1/ft)	5.3E-04	4.7E-07	5.6E-07	5.7E-07
Specific Yield (%)	0.21	N/A	N/A	N/A
Southern Study Area				
Saturated Thickness (ft)	250	17	427	1,025
Horizontal Hydraulic Conductivity (ft/d)	335	2	67	22
Vertical Hydraulic Conductivity (ft/d)	0.28	0.0019	0.07	0.01
Specific Storage (1/ft)	7.0E-04	4.3E-07	5.4E-07	5.4E-07
Specific Yield (%)	0.21	N/A	N/A	N/A

5.5 GROUNDWATER IMPACTS ANALYSIS SETUP

In order to simulate the Proposed Project using the KDWD Superposition Model, boundary conditions were used to represent the locations and time-varying rates of the anticipated additions and reductions in release water resulting from the Proposed Project. This representation of the movement of Project-related surface water allows for a more realistic analysis of the groundwater impacts.

- *The MODFLOW Recharge Package* (Harbaugh, 2005) was used to simulate changes in recharge at spreading grounds, canals and other surface recharge-related changes. The Recharge Package is a specified flux boundary condition where the user applies a rate (units of feet per day) and the model integrates the flux over the specified area to preserve the mass balance. This flux was applied to Model Layer 1 to represent processes that occur at or near the surface and affect the Shallow Aquifer. At locations where the recharge is reduced, the MODFLOW Recharge Package can be used to reduce the net amount of recharge or, where necessary, specify negative values that represent the reduction in the water available for spreading activities. At locations where recharge is increased, the recharge is increased using the MODFLOW Recharge Package.

- *The MODFLOW Well Package* (Harbaugh, 2005) was used to simulated changes in pumping by irrigation and municipal wells. The Well Package is also a specified flux boundary condition where the user applies a volume (units of cubic feet per day). The Well Package can be applied to a specified model layer, to represent local well construction. Negative volumes represent increased pumping and positive volumes represent reduced pumping.

The release water reductions and additions were applied to the KDWD Superposition Model on a monthly basis, reflecting the CHVM stress periods and reproducing the seasonal patterns of groundwater levels that occur over a year. For each month, the model applies the amounts and locations of the Project-related changes with respect to recharge and pumping based on the detailed monthly analysis of historical diversions and use of release water as discussed in **Section 3** of this report. The following provides a description of how each of the release water reductions and allocations were applied in the KDWD Superposition Model.

5.5.1 Application of NKWSD Release Water Reductions

Reductions of release water available to NKWSD as a result of the Project are discussed in **Section 3.3** and summarized in **Table 5**. These reductions were directly applied in the KDWD Superposition Model as a removal of groundwater to evaluate how the reductions in release water would impact groundwater levels in NKWSD and the surrounding areas. The following describes how the allocation of release water reductions listed in **Table 5** for the NKWSD were applied:

- **Spreading** represents decreases in recharge water applied at the major spreading operations in NKWSD. The reductions were applied using the MODFLOW Recharge Package at the NKWSD spreading grounds (**Figure 5-5**).

- **Canal Losses from Spreading** represents decreases in water percolating to the groundwater along the unlined Calloway and Lerdo canals equivalent to what would have occurred if release water had been conveyed to the spreading grounds. The reductions were applied using the MODFLOW Recharge Package along primary canals in NKWSD (**Figure 5-5**).

- **Irrigation** represents increases in groundwater pumping to compensate for reductions in surface water deliveries to the Class 2 Service Area in NKWSD (Class 2 lands are shown on **Figure 2-2**). The increased pumping was applied using uniformly spaced wells across the NKWSD Class 2 lands with the MODFLOW Well Package. The increased pumping was applied to Model Layer 3 consistent with the primary pumping zones beneath impacted areas of NKWSD, based on local well construction data (NKWSD, 2012).

- **Canal Losses from Irrigation** represents a reduction in water percolating to the groundwater along the unlined Calloway and Lerdo canals equivalent to the amount that would have occurred during conveyance of the Project release water for irrigation use. The reductions were applied using the MODFLOW Recharge Package along primary canals in NKWSD that are used to supply water to the Class 2 Service Area lands (**Figure 5-5**).

- **Other** represents increases in groundwater pumping to compensate for reductions in surface water deliveries in NKWSD. This occurs during time periods when release water was apparently diverted by NKWSD (according to Kern River Hydrographic Reports), but no recharge or Class 2 Service Area irrigation was documented during the month of diversion. Because it was diverted, it was assumed to have been used in the District. Since the location of this pumping is unclear, this increased pumping volume was applied using uniformly spaced wells across the NKWSD Class 1 Service Area using the MODFLOW Well Package. The increased pumping was applied to Model Layer 3, consistent with local well construction information (NKWSD, 2012).

5.5.2 Application of City of Bakersfield Release Water Reductions

The City of Bakersfield reductions in release water associated with the Proposed Project as discussed in **Section 3.4** and summarized in **Table 6**. These reductions were directly applied in the KDWD Superposition Model as a removal of groundwater to evaluate impacts on local groundwater levels in the City and the surrounding areas over time. The following describes how the release water reductions listed in **Table 6** were applied:

- **KDWD** is a category in some of the annual Kern River Hydrographic Reports that lists KDWD as a recipient of City water. This water represents collaborations between KDWD and the City for the recharge of Kern River water. The specific location for the application of this water is not specified in the Hydrographic Reports; therefore, the reduction in recharge under the Proposed Project was simulated as a decrease in recharge at the COB 2800. The reductions were applied using the MODFLOW Recharge Package (**Figures 4-4** and **5-5**).

- **Kern Water Bank** is a category from the Kern River Hydrographic Reports that is considered to represent decreases in the amount of Kern River water applied at the Kern Water Bank by the City. The reductions were applied using the MODFLOW Recharge Package at the Kern Water Bank (**Figures 4-4** and **5-5**).

- **Other Spreading** was assumed to represent decreases in the amount of Kern River water applied at the COB 2800 by the City. The reductions were applied using the MODFLOW Recharge Package at the COB 2800 (**Figures 4-4** and **5-5**).

- **Other** represents increases in groundwater pumping to compensate for reductions in surface water deliveries to the City of Bakersfield for municipal or industrial use. The increased pumping was applied using uniformly spaced wells across the City of Bakersfield WSA using the MODFLOW Well Package. The increased pumping is applied to Model Layer 3 because the City pumping wells are typically completed in this aquifer.

5.5.3 Application of Release Water Reductions Not Used by NKWSD or City

During some months of the analysis, the volume of water released by KDWD was not used by either the NKWSD or the City as discussed in **Section 3.2**. The volume of water is listed as *Release Water Not Used by NKWSD or City* in **Table 4**. During months when this water was available, the water was allocated to the other likely users of release water along the Kern River based on information from the Hydrographic Reports. These reductions were directly applied in the Superposition Model as a removal of groundwater to evaluate local impacts to groundwater levels. The following describes where and how these release water reductions were applied:

- **Kern Water Bank** represents additional decreases in the amount of Kern River Water recharged at the Kern Water Bank. The reductions were applied using the MODFLOW Recharge Package at the Kern Water Bank (**Figures 4-4** and **5-5**).
- **Pioneer Spreading Grounds** represents decreases in the amount of Kern River Water applied at the Pioneer Spreading Grounds. The reductions were applied using the MODFLOW Recharge Package at the Pioneer Spreading Grounds (**Figures 4-4** and **5-5**).
- **Buena Vista Water Storage District Diversions** represents increases in groundwater pumping to compensate for reductions in surface water deliveries to BVWSD. The increased pumping was applied using uniformly spaced wells over the entire BVWSD service area using the MODFLOW Well Package. The increased pumping was applied to Model Layer 1 because pumping in this area is primarily from the shallow aquifer.
- **Kern River** represents decreases in water percolating to the groundwater along the Kern River channel. The reductions are applied using the MODFLOW Recharge Package along the Kern River between First Point and Second Point (**Figure 5-5**).

As shown on **Table 4**, there were some extremely wet years when surplus river water was not used by any party and was released to the California Aqueduct through the Kern River Intertie to prevent flooding. Although Intertie flows of release water only occurred during a few months, the volumes were large (**Table 4)**. The *Release Water Lost to the Intertie* is 34,008 AF in 1998 and 1,347 AF in 2006. Because this water is assumed to have exited the basin, this release water is not assumed to be associated with an impact to local groundwater resources. As such, it is not represented as a reduction in recharge or an increase in pumping in the KDWD Superposition Model. However, under the Proposed Project, the *Release Water Lost to the Intertie* is assumed to be captured by KDWD and is applied as an increase in recharge as described in the following section. This simulates the benefit of capturing additional floodwater that otherwise would have been lost to the basin as described in the WAP and summarized in **Section 3.2**.

5.5.4 Application of KDWD Release Water Use

The use of the release water by KDWD under the Proposed Project as discussed in **Section 3.5** and summarized in **Table 8**. Monthly amounts of available water were directly applied in the KDWD Superposition Model as additional recharge or a reduction of groundwater pumping to evaluate impacts on groundwater levels in KDWD and surrounding areas. The following describes where and how the increase of Project water in KDWD was applied:

- **Irrigation Pumping Reduction** represents increased use of release water in lieu of groundwater pumping in KDWD. The reduced pumping was applied using uniformly spaced wells across all KDWD service areas using the MODFLOW Well Package. The decreased pumping is applied to Model Layers 1 and 3 to represent pumping from both the shallow and deep aquifers in this area.
- **City of Bakersfield Pumping Reduction** represents decreases in groundwater pumping to compensate for increased Kern River water deliveries to the City for municipal and industrial use due to the reallocation of the release water. The decreased pumping was applied using uniformly spaced wells across the City WSA using the MODFLOW Well Package. The decreased pumping was applied to Model Layer 3 because the City pumping wells are typically completed in the deeper aquifer.
- **Increase in Recharge Basin Recharge** represents increases in release water applied at the KDWD recharge basins. The increased recharge was applied using the MODFLOW Recharge Package at the KDWD recharge basins (**Figures 2-1** and **5-5**).
- **Increase in Canal Recharge** represents increases in release water percolating to groundwater along unlined canals in KDWD. The increased recharge to groundwater was applied using the MODFLOW Recharge Package along primary canals in KDWD (**Figures 2-1** and **5-5**).
- **Increase in Pioneer Spreading Grounds** Recharge represents increases in the amount of release water applied at the Pioneer Spreading Grounds by KDWD. The increased recharge was applied using the MODFLOW Recharge Package at the Pioneer Spreading Grounds (**Figures 4-4** and **5-5**).
- **Other** represents unspecified use of available release water by KDWD. Half of the water assigned to this category was applied to additional decreases in groundwater pumping to compensate for increased surface water deliveries to the City of Bakersfield following the procedures described above. The other half of water is attributed to unspecified uses within KDWD and is assumed to increase recharge. This portion of the release water is applied using the MODFLOW Recharge Package uniformly across KDWD.

5.6 KDWD SUPERPOSITION MODEL VALIDATION SCENARIO

Although the underlying CVHM Base Model was calibrated by the USGS to data obtained throughout the Central Valley – presumably using reasonable care in developing the geologic framework and determining aquifer properties – it is appropriate to demonstrate that the use of the KDWD Superposition Model built from the CVHM for the specific objectives of this impact analysis reasonably reproduces historical groundwater level changes. To achieve this, a Validation Scenario was developed to test the ability of the KDWD Superposition Model to evaluate regional groundwater impacts by simulating a historical period during which field data were obtained that measured changes that occurred under similar hydrologic conditions. The following section summarizes the Validation Scenario setup and results. Additional details on the Validation Scenario are presented in **Appendix B**.

5.6.1 Validation Scenario Setup

To test the ability of the KDWD Superposition Model to evaluate regional groundwater impacts, a Validation Scenario was constructed to evaluate groundwater level changes resulting from recharge operations at the Kern Water Bank from 1993 to 1998. This period represents the initial recharge operations at the Kern Water Bank and other nearby recharge facilities prior to significant recovery activities. The Validation Scenario is specifically setup to evaluate the ability of the KDWD Superposition Model to simulate the effects of major changes in groundwater levels as a result of managed aquifer recharge. This addresses the recognized deficiency that CVHM does not accurately represent the recharge volumes from the Kern County groundwater banking operations (Faunt, 2009). In so doing, the Validation Scenario tests whether the KDWD Superposition Model can simulate the relative change in groundwater levels when the reported recharge volumes for the groundwater banking projects are used.

Detailed records of the volume of groundwater recharged is available for the various groundwater banking operations in and around the Kern Water Bank (**Figure 5-6**). Unpublished groundwater banking data used for the Validation Scenario was provided directly by Kern County Water Agency, Kern Water Bank Authority and neighboring agencies for the following facilities:

- Kern Water Bank
- Pioneer Project
- COB 2800 project
- Rosedale-Rio Bravo recharge facilities
- Buena Vista Water Storage District recharge facilities
- Berrenda Mesa project
- Kern River channel recharge.

During the period from 1993 to 1998, nearly 3.1 million AF of water was recharged in the Kern Water Bank and other nearby recharge facilities. In response to these large recharge events groundwater levels increased from 50 to 200 feet across the banking areas as documented by numerous local monitoring wells. Therefore, a clear quantification of the volume of recharge over this period is available. These volumes were applied monthly in the KDWD Superposition Model at the appropriate facility using the MODFLOW Recharge Package to Model Layer 1 in a manner analogous to that which is also being used to simulate the Proposed Project.

By comparison, the maximum 6-year change in release water for the Proposed Project is 0.2 million AF, which is about 6 percent of the Kern Water Bank volume of 3.1 million AF. Therefore, the Validation Scenario actually incorporates more extreme changes than would be imposed by the Proposed Project: the use of an “extreme case” Validation Scenario is an appropriate and standard procedure for validation in scientific and engineering investigations (Reilly et al., 1987), because if the model is shown to perform well under the more extreme Kern Water Bank recharge scenario, it can be confidently concluded that the KDWD Superposition Model will perform well simulating the more moderate conditions for the Proposed Project.

5.6.2 Validation Scenario Results

The actual measured change in groundwater levels that occurred within the aquifer is observed from 1,495 groundwater level measurements collected from 26 monitoring wells located in and around the

Kern Water Bank between 1993 and 1998. The measured change in groundwater levels is calculated as the difference of the measured groundwater elevation during the simulation period minus the groundwater elevation from late 1992, prior to the early large recharge events. Monitoring wells with insufficient data (i.e., the last four months of 1992) were excluded from the data set.

For each of these 26 locations, the simulated groundwater level change was compared to the calculated groundwater level change based on the measured data for that well. **Figure 5-7** provides a representative set of hydrographs from four monitoring wells located in different areas of the Kern Water Bank. A comparison of simulated and measured groundwater level changes indicate a strong agreement with the overall timing and magnitude of the groundwater level changes associated with these recharge events.

In addition to visual comparisons such as presented in **Figure 5-7**, the difference between the measured and simulated change in groundwater levels at the monitoring locations (referred to as the residual) was evaluated using summary statistics similar to those commonly used to evaluate model calibration, as follows:

- The correlation coefficient ranges from 0 to 1 and is a measure of the closeness of fit of the data to a 1 to 1 correlation. A correlation of 1 is a perfect correlation. The correlation coefficient of 0.86 for the Validation Scenario indicates a strong correlation between simulated and observed groundwater level change.
- The residual mean is computed by dividing the sum of the residuals by the number of residual data values. The residual mean tests whether the model results are biased towards over- or underestimating groundwater levels. The closer this value is to zero, the better the validation. The residual mean for the Validation Scenario of -2.1 feet is considered minor. A negative value indicates this minor bias is towards overestimating the change in groundwater levels in the KDWD Superposition Model.
- The residual standard deviation evaluates the scatter of the data. A lower standard deviation indicates a closer fit between the simulated and observed data. The standard deviation for the Validation Scenario is 24.7 feet.
- The absolute residual mean is a measure of the overall error in the model. The absolute residual mean is computed by taking the square root of the square of the residuals and dividing that by the number of measurements. The absolute residual mean for the Validation Scenario is 18.9 feet.
- The ratio of the absolute residual mean divided by the range of observed groundwater elevations provides a means to assess the absolute residual mean in context with the scale of the simulation. The ratio for the Validation Scenario is 0.09 feet. Typically, a validation is considered good when this ratio is below 0.15 (ESI, 2011).

Considering these results in context with the overall range of measurements of 204 feet, the residual mean of -2.1 feet represents a relative percentage difference of about one percent. For the absolute residual mean of 18.9 feet, the relative percentage difference is about nine percent. Based on these results, the Validation Scenario demonstrates that the KDWD Superposition Model, using the CVHM aquifer properties, is able to simulate the relative change in groundwater levels when the reported recharge volumes for the groundwater banking projects are used.

Because the recharge volumes and groundwater level changes in the Validation Scenario are much greater than those produced by the Proposed Project, the simulation results of the Proposed Project scenarios should have a similar or better relative percentage difference as that determined for the Validation Scenario. For example, if simulation results for the Proposed Project scenarios produce a change in groundwater levels of 5 feet, then relative accuracy of the simulation would be approximately +/- 0.5 feet. Therefore, using the example of a simulated 5-foot change in groundwater levels, the range of groundwater level changes that would likely occur would be 4.5 to 5.5 feet, a reasonable accuracy range for Project-related impacts. The validation scenario demonstrates that the level of accuracy of the KDWD Superposition Model is suitable to simulate future groundwater level changes on the scale of the Proposed Project.

6 GROUNDWATER IMPACTS ANALYSIS

The goal of the impacts analysis is to quantify potential groundwater impacts from a shift of release water from NKWSD and the City to KDWD, using hydrologic and water use conditions during the Study Period. Based on the details provided in **Sections 2** and **3** of this report, the impacts involved increased groundwater pumping and reduced amounts for recharge by the City and NKWSD (**Tables 5** and **6**), as well as decreased pumping and increased spreading by KDWD (**Tables 7** and **8**). Additional Project-related actions were also incorporated into the analysis to provide a full accounting of the release water as described in **Section 5**. The timing and use of the release water by KDWD was taken from the WAP (**Table 4**).

6.1 APPLICATION OF THE KDWD SUPERPOSITION MODEL

The KDWD Superposition Model is the primary tool for the quantitative impacts analysis of groundwater levels. The methodology used for the modeling is discussed in **Section 5**. The model was used to evaluate groundwater impacts using conditions from different base periods as discussed in **Section 1.4**. In summary:

- *The Average Hydrologic Conditions (1997-2007)* was the Study Period used for the 2011 Impacts Assessment with an annual average release water of 33,099 AFY to be used by KDWD as part of the Proposed Project. During this period, the Annual River Index was 100 percent of the long-term average; therefore, this period is representative of average hydrologic conditions.
- *The Combined Study Period (1997-2014)* extends the analysis of the release water through 2014 to include recent hydrologic conditions of water availability and use on the Kern River. This period has an annual average release of 27,342 AFY to be used by KDWD as part of the Proposed Project. During this period, the Annual River Index was 92 percent of the long-term average, slightly drier than average conditions. Importantly, this period also includes the effects of the recent severe drought cycle on hydrologic and water use conditions.

A series of scenarios were setup and run to assess changes in groundwater conditions under both the Average Hydrologic Conditions (1997-2007) and Combined Study Period (1997-2014). A brief summary of the scenarios developed using the KDWD Superposition Model include:

- *The Baseline Scenario* simulates change in groundwater levels by applying the Proposed Project over the Combined Study Period of 1997 through 2014. The results of the Baseline Scenario were evaluated by superimposing the model results onto historical groundwater elevation data across the Study Area. This estimates what groundwater elevations would have been if the Proposed Project had been initiated in 1997. The analysis includes a separate assessment of the 1997-2007 period in compliance with the 2014 Order.
- *Scenario A* projects the Combined Study Period (1997-2014) over 50 years to evaluate the accumulated changes in groundwater conditions resulting from the Proposed Project calculated after 10, 25, and 50 years. The updated period (2008-2014) incorporates the recent drought and water use on the Kern River.

- *Scenario B* projects the Average Hydrologic Conditions (1997-2007) over 50 years to evaluate the accumulated changes in groundwater conditions resulting from the Proposed Project calculated after 10, 25, and 50 years. This assessment uses the same time period analyzed in the 2011 Impacts Assessment (1997-2007) and represents average hydrologic conditions.

The results of the KDWD Superposition Model provide the change in groundwater levels associated with the Proposed Project (also referred to as Project-related impacts). Model results are presented using a variety of maps and graphs to provide for a comprehensive analysis of Project-related impacts on groundwater resources. Techniques used to present the results of the groundwater impacts analysis are summarized briefly below:

- *Groundwater Level Change Maps* – contour maps that show the simulated change in groundwater levels over the Study Area as a result of the Proposed Project. This analysis provides a direct assessment of the spatial distribution of groundwater level impacts of the Proposed Project.

- *Superposition Groundwater Elevation Contour Maps* – simulated groundwater level changes are superimposed on historical groundwater elevation contour maps (based on measured groundwater elevation data) to provide estimated groundwater elevation contours associated with the Proposed Project. This analysis evaluates the impacts of the Proposed Project on actual elevations and hydraulic gradients in the Study Area. The superposition contour maps are compared to historical data for the Baseline Scenario.

- *Superposition Groundwater Elevation Transects* – simulated groundwater level changes are superimposed on historical measured groundwater elevations along a vertical profile (cross section) across the Study Area. This analysis helps to further illustrate the impacts of the Proposed Project on groundwater levels, gradients, and changes in groundwater flow in the Study Area. The superposition transects are provided for the Baseline Scenario.

- *Change Hydrographs* – hydrographs that show the change in groundwater levels over time for representative locations throughout the Study Area as a result of the Project. This analysis provides a direct assessment of the magnitude of impacts of the Proposed Project on groundwater levels over time in the Study Area.

- *Superposition Hydrographs* – simulated groundwater elevation changes are superimposed onto hydrographs (based on measured groundwater elevation data) to evaluate Project-related impacts relative to historical groundwater elevation data. This analysis evaluates the scale of the impacts of the Proposed Project compared to the historical variation in groundwater levels in the Study Area over time. The superposition hydrographs are compared to historical data for the Baseline Scenario.

- *Spatial Averaged Groundwater Level Change* – the change in groundwater levels across a select area is calculated by taking an arithmetic average of groundwater level changes across a specific water district or area for a specific time period to evaluate regional groundwater level changes over time and compare average Project-related changes from district to district.

- *Change in the Study Area Water Balance* – simulated groundwater inflows and outflows are tabulated in the KDWD Superposition Model to provide an assessment of groundwater movement as a result of the Proposed Project and to estimate changes in the volume of groundwater in storage.

Collectively, these maps and graphs, along with additional model results, illustrate how the Project will impact groundwater throughout the Study Area, over the Study Periods, and extending 50 years into the future. Water balance data generated from the KDWD Superposition Model is used to evaluate the change in the volume of groundwater in aquifer storage as a result of the Proposed Project. The results of the analysis were also used to inform the additional analysis of Project-related impacts on land subsidence and groundwater quality, which are discussed at the end of **Section 6**. The results of the groundwater impacts analysis using the KDWD Superposition Model is summarized below.

6.2 GROUNDWATER LEVEL IMPACTS ANALYSIS FOR BASELINE SCENARIO

Although the Baseline Scenario covers both the Average Hydrologic Conditions Study Period (1997-2007) and the Combined Study Period (1997-2014), results for both periods are presented separately. This allows a more direct comparison to the 2011 Impacts Assessment and ensures compliance with the 2014 Order.

The objective of the Baseline Scenario is to assess the impacts from the Proposed Project – assuming that the Project had occurred from 1997 through 2014 – by applying the Principle of Superposition (Reilly et al., 1987). The Proposed Project was simulated with the KDWD Superposition Model following the methodology described in **Section 5.5**. The Baseline Scenario results were then "superimposed" onto groundwater contour maps and hydrographs (based on measured data) by adding the simulated water-level change to actual measured groundwater elevations. The results of the superposition process provide estimated groundwater elevations in addition to the water level changes that are simulated directly by the model. The Baseline Scenario also illustrates the concepts of superposition and provides context for evaluating the magnitude of Project-related impacts on groundwater levels.

6.2.1 Project-related Impacts on Groundwater Elevations and Flow in the Study Area

For the Baseline Scenario, the following steps were used to evaluate the regional effects of the Proposed Project on groundwater levels and flow patterns in the Study Area:

1. Regional groundwater elevation maps for Spring 2007 and Spring 2014 (approximating the end of the two Study Periods), based on data compiled and contoured by the KCWA, were digitized to represent regional groundwater levels without the Proposed Project (**Figures 6-2** and **6-5**, respectively).

2. Simulated changes in groundwater levels were used to develop a groundwater level change map for Spring 2007 and Spring 2014 (**Figures 6-1** and **6-4**, respectively) for Model Layer 3, which represents the primary production aquifer represented by the KCWA regional groundwater elevation maps.

3. The simulated groundwater level change was superimposed onto the digitized groundwater elevation maps to develop a groundwater elevation contour map that reflects impacts of the

Proposed Project on regional groundwater levels and flow at the end of the two Study Periods, 2007 and 2014 (**Figures 6-3** and **6-6**, respectively).

Figure 6-1 presents results from the Baseline Scenario showing the simulated water level change due to the Proposed Project equivalent to April 2007 that assumes 11 years of implementation of the Proposed Project. The model results show that groundwater levels are generally 3 to 4 feet higher in KDWD and generally 4 to 6 feet lower in NKWSD after more than 10 years of Proposed Project operation. The largest water level change occurs in northwestern NKWSD, where groundwater levels are 6 to 10 feet lower than without the Project. This area is in the vicinity of NKWSD recharge facilities where the amount of water available for recharge is being reduced due to the Proposed Project. Lower water levels of -2 to -5 feet extend westward into SWID. Groundwater levels are also lower in eastern SWSD (-1 to -3 feet) and north of the Kern County Line (about -1 foot). In the east, water levels are lower in CWD (-3 to -6 feet) toward the eastern model boundary. The location of the zero contour, representing the transition from positive to negative change in groundwater levels, occurs just north of the Kern River. Model results indicate that the Proposed Project results in higher groundwater levels beneath most areas of the City.

Figure 6-2 presents a regional groundwater elevation map for Spring 2007 developed by KCWA (KCWA, 2016) which represents a "No-Project" evaluation. As shown on the map, the highest water levels occur along the Kern River with groundwater elevations of 250 to 300 feet msl. Across KDWD, groundwater elevations are generally 200 to 250 feet msl, and in NKWSD, groundwater elevations are generally 100 to 200 feet msl. The lowest groundwater elevations are in the SWSD where groundwater elevations are below 50 feet msl. In Spring 2007, recharge along the Kern River resulted in a mound of higher groundwater elevations with groundwater flowing to the north and south away from the mound.

Figure 6-3 presents the superimposed groundwater elevations (red contours) on the regional groundwater elevation map (blue contours). The superimposed contours were calculated by adding the simulated change in groundwater levels (**Figure 6-1**) to the measured groundwater contour map (**Figure 6-2**). As shown on **Figure 6-3**, implementation of the Proposed Project shifts the groundwater elevation contours slightly, but does not result in any substantial change in the direction or magnitude of groundwater flow. The groundwater elevation change resulting from the Proposed Project is small relative to the overall range in groundwater elevations measured in the Study Area.

Figure 6-4 presents the Baseline Scenario results equivalent to April 2014 that assumes 17 years of implementation of the Proposed Project. Model results show a similar pattern to those presented in **Figure 6-1**. Minor variations in the magnitude of the groundwater elevation change occur, but the overall distribution and pattern of Project-related change is very similar to April 2007 (compare **Figures 6-1** and **6-4**). During the first few years, the majority of the change is derived locally from groundwater in storage. Over time, the lower groundwater levels induce increasing inflows from upgradient and decreasing downgradient outflows. As a result, groundwater levels stabilize in the immediate vicinity of the Study Area with widespread minor groundwater level declines north of the river and groundwater level increases south of the river.

Figure 6-5 presents a regional groundwater elevation map for Spring 2014 developed by KCWA (KCWA, 2016). Spring 2014 occurs during a severe drought in the region with lower groundwater levels than in 2007. The most significant differences include the breakdown of the mound under the Kern River, especially in the area of the Kern Water Bank where groundwater levels are 100 to 200 feet lower

compared to the Spring of 2007. Groundwater levels are below sea level (negative contour values) in a large area covering portions of SWSD, NKWSD and SWID. Groundwater flow patterns are shifted by the lower levels, with more groundwater flowing toward the north than in previous years.

Figure 6-6 presents the superimposed groundwater elevations, which are calculated by adding the simulated change in groundwater levels (**Figure 6-4**) to the measured groundwater contours (**Figure 6-5**). The regional groundwater elevation contours for Spring 2014 are maintained on **Figure 6-6** for reference. Similar to the previous example, the Proposed Project shifts the groundwater elevation contours, but does not result in any substantial change in the direction or magnitude of groundwater flow. The groundwater elevation change resulting from the Proposed Project is small relative to the overall range in groundwater elevations measured in the Study Area.

6.2.2 Project-Related Impacts Illustrated with Groundwater Level Transects

As an additional illustration of the regional changes resulting from the Proposed Project, a series of hydrologic transects were developed for the Spring 2014 data. The transects are vertical profiles of the subsurface and show the elevation of measured groundwater levels along with the superimposed groundwater levels described on **Figure 6-6**. Transects illustrate the magnitude of the Project-related changes and the regional variability in groundwater elevations beneath the Study Area.

The locations of three transects are shown on **Figure 6-7**. Transect locations were selected to illustrate areas with the maximum amount of groundwater level change associated with the Project. Each transect shows a profile of the simulated and actual groundwater elevations (from **Figure 6-6**). The vertical scale is highly exaggerated to differentiate the small magnitude of change between the two groundwater elevation surfaces; however, this also exaggerates the regional groundwater gradients and causes the groundwater surface to look overly steep. Without the exaggeration, the water surface would appear flat and changes in the hydraulic gradients (steepness of the water surface) would not be readily visible on the graphic. Nonetheless, the exaggerated transect illustrates the relative hydraulic gradients and changes in gradients as a result of the Project. Where gradients are increased by the Project, groundwater flows into Project-impacted areas at a faster rate.

Transect A (**Figure 6-8**) runs from northwest to southeast across SWSD, NKWSD, the City, and KDWD. As shown, both measured and simulated groundwater levels are higher beneath KDWD and the river and decline to more than 300 feet below ground surface to the northwest. Depth to groundwater ranges from about 150 to 300 feet below ground surface. As indicated on **Figure 6-8**, the difference between simulated (Project-related) and measured groundwater elevations are highlighted by colors: where Project-related elevations are lower than measured elevations, the difference is highlighted in purple. A rise in groundwater elevations as a result of the Project is indicated by yellow highlighting.

On Transect A, Project-related elevations are lower than the measured data by about -5 to -10 feet beneath NKWSD, primarily as a result of increased pumping (**Figure 6-8**). Beneath the City, Project-related groundwater levels range from a -1-foot decline to a 2-foot rise. In KDWD, groundwater levels are generally 2 to 4 feet higher due to the Proposed Project. As indicated on Transect A, the change in groundwater levels does not affect the overall direction of groundwater flow. However, the change does increase groundwater gradients toward the north, resulting in more flow toward NKWSD (subsurface inflow) from beneath the river than would occur without the Project.

Transect B (**Figure 6-9**) is oriented southwest-northeast across BVWSD, SWSD, SWID, NKWSD, and SSJMUD. Transect B crosses NKWSD near the area of greatest Project-related impacts (compare **Figures 6-6** and **6-7**). In this area, the Project lowers water levels by about -5 to -10 feet (**Figure 6-9**). Project-related impacts are less to the east beneath SSJMUD and to the west beneath SWID and SWSD. The higher groundwater elevations (both simulated and measured) in the western SWSD and BVWSD reflect geologic and hydrogeologic variability across the basin; water level measurements on the KCWA regional contour map (used for **Figure 6-9**) may reflect water levels in a local shallow aquifer where many local wells are completed (see also the area of shallow groundwater on **Figure 4-8**).

Transect C (**Figure 6-9**) is oriented southwest-northeast from the KWB towards the City, generally along the Kern River. As shown, both simulated and measured groundwater levels are variable beneath the river, reflecting the severe drought and associated operations at the banking projects. Measured groundwater elevations beneath these banks are lower locally due to increased recovery operations (pumping) as well as reduced water available for banking recharge. Relatively high measured groundwater levels remain under the City and KCWA ID-4. Similar to the other transects, the Project-related change to groundwater elevations is very small and difficult to see, even at the highly exaggerated vertical scale used for the transect (**Figure 6-9**). Because of the proximity of this transect to the increased water use in KDWD, operation of the Proposed Project results in slightly higher water levels over much of the transect.

6.2.3 Hydrograph Analysis of Project-Related Impacts on Water Levels

To evaluate how the Proposed Project changes groundwater levels over time, hydrographs were constructed from the KCWA water level database (KCWA, 2016) and the simulated Project-related water level changes were superimposed onto these hydrographs. In order to comply with the directive in the 2014 Order to analyze a "sufficiently comprehensive and representative number of adversely affected locations north of the Kern River and beneath the City", hydrographs at 344 locations were constructed and evaluated. For each hydrograph, the Project-related changes were superimposed (added) to the measured water levels; both the measured levels and the superposition levels are shown on these hydrographs (referred to herein as Superposition Hydrographs). In addition to the Superposition Hydrographs, hydrographs with water levels changes only were constructed using direct output from Model Layers 1, 2, and 3 (referred to as Change Hydrographs). Change Hydrographs and Superposition Hydrographs are generated for each hydrograph location and are combined on one page or figure for comparison purposes.

For discussion purposes, 11 representative hydrographs were selected to examine more closely in this report; the locations of these representative hydrographs are shown on **Figure 6-10**. These include locations near major recharge facilities to assess the maximum groundwater level change, as well as locations proximal and distal to these facilities to assess the magnitude of groundwater level change with distance. Locations have also been chosen to represent the areas of maximum impact due to increased groundwater pumping. The locations of the remaining 333 hydrographs are shown on **Figure 6-11** and included with this report as **Appendix C**.

Change Hydrographs and Superposition Hydrographs for the 11 representative locations are presented in **Figures 6-12a** through **6-12k**. Each figure contains both types of hydrographs for each location. The upper hydrograph is the Change Hydrograph for the Baseline Scenario, representing the change in water levels due to the Proposed Project over the Study Period 1997 to 2014. Negative numbers on the Y-axis

of the Change Hydrograph indicates a lowering of the water level as a result of the Project. The lower hydrograph is the Superposition Hydrograph that superimposes the simulated groundwater level change for Model Layer 3 (the primary pumping zone) by adding model results to the measured groundwater elevation data from 1997 to 2014 for each measured data point. The lower Superposition Hydrograph shows both the measured (green) and superimposed (purple) groundwater elevations.

Figure 6-12a (28S/26E-27A) shows the model results for a location in southeastern NKWSD near the District's recharge facilities (**Figure 6-10**; see also the southern-most recharge basin on **Figure 2-2**). Reductions in water available for recharge in NKWSD causes less groundwater mounding beneath the basin, lowering the mound by about -18 feet in 1998 in Model Layer 1 (Change Hydrograph on the top of **Figure 6-12a**). Although the magnitude is relatively large, this change occurs over a small area beneath the recharge basin (see illustration of concept on **Figure 5-1**); as the mound dissipates, the Project-related change decreases in magnitude very quickly. After 1998, the Project-related change for Model Layer 1 is reduced to about -3 to -5 feet in a matter of months (**Figure 6-12a**). This cycle is repeated during other wet periods (2005 and 2011) when significant groundwater recharge operations occur with less water as a result of the Project.

These conditions cause the Change Hydrograph for Model Layer 1 to spike; the spiky nature of Model Layer 1 in response to changes in the recharge mound can be seen on many of the Change Hydrographs from the model. A spiky character for Model Layer 3, also seen on numerous Change Hydrographs, typically reflects an increase in pumping for certain months during the irrigation season.

Water level changes in Model Layer 3 (**Figure 6-12a**) show influences both from reduced recharge in Model Layer 1 and increased irrigation pumping in Model Layer 3 due to the Proposed Project. Project-related changes range from -3 to -10 feet over the simulation period. The Superposition Hydrograph (lower graph on **Figure 6-12a**) shows the results of the Baseline Scenario superimposed onto measured groundwater levels. As shown on the figure, Project-related changes are small relative to the variability observed in the measured data. The maximum Project-related changes generally occur when the groundwater levels are high because that is when the most release water is being removed from the impacted areas. During the drought period represented by 2012 to 2014 when groundwater levels are at record lows, the Project-related changes are relatively minor.

Figure 6-12b (28S/26E-31J01) shows the model results in southwestern NKWSD (**Figure 6-10**). The Change Hydrograph (upper graph) indicates that this location is not as influenced by recharge operations as the previous hydrograph on **Figure 6-12a**. For example, note the absence of downward spikes on **Figure 6-12b** for Model Layer 1 during wet periods. Rather, this location appears to be more influenced by the Project-related increase in irrigation pumping in NKWSD (**Table 5**), which is simulated in Model Layer 3. The impact of the increased irrigation pumping is shown on the Change Hydrograph as spikes of lower water levels ranging from -3 to -15 feet in Model Layer 3 that last from one to four months (top of **Figure 6-12b**). Following each spike, water levels recover as the drawdown from the increased pumping is dissipated. The Change Hydrograph in Model Layer 1 shows an undulating trend of Project-related changes that vary from -2 to -4 feet and correspond to periods of recharge at the District recharge facilities (**Figure 6-12a**). Similar to other hydrographs, the Superposition Hydrograph shows that the Project-related changes are small relative to the variability observed in the measured data.

Figures 6-12c and **6-12d** (29S/27E-17Q01 and 30S/27E-10P01) show model results for two locations beneath the City (**Figure 6-10**). Under the Proposed Project, the City receives both *less* release water

(**Table 6**), and *more* release water (**Table 8**) at various times throughout the Baseline Scenario because of the overlap in the City and KDWD service areas. In addition, the groundwater model tracks changes in groundwater flow due to increased groundwater levels in KDWD, which causes increased groundwater flow to the north toward the City (subsurface inflow). Collectively, these conditions result in very small changes, both adverse and beneficial, to groundwater levels beneath the City.

The small changes are reflected on the Change Hydrographs and the Superposition Hydrographs on **Figures 6-12c** and **6-12d. Figure 6-12c,** located in the northern part of the City near NKWSD, shows that the change in groundwater levels is near zero with monthly changes ranging from an increase of 2 feet to a decrease of -2 feet. **Figure 6-12d**, located in the southern part of the City near KDWD, shows that groundwater levels generally increase over time at this location. The variability seen in the Change Hydrograph of **Figure 6-12d** (upper graph) reflects the combined additions and reductions of release water to the City and influences from the additions of release water to KDWD.

Figure 6-12e (27S/26E-32E) shows model results in east-central NKWSD (**Figure 6-10**). The Change Hydrograph for Model Layer 1 corresponds to reductions in recharge and canal losses, whereas the spikes in Model Layer 3 reflect the periods of increased pumping in the NKWSD Class 2 Service Area (**Table 5**). As shown on the Superposition Hydrograph (bottom of **Figure 6-12e**), groundwater elevations from Model Layer 3 are lower than measured by -2 to -10 feet; however, the magnitude of change is small relative to the variability observed in the measured data.

Figure 6-12f (26S/25E-22H01) shows model results in northern NKWSD (**Figure 6-10**). The Change Hydrograph for Model Layer 1 shows overall lower water levels of about -3 to -4 feet over the Baseline Period, reflecting reductions in water deliveries to the recharge facilities during wet periods. The spikes in Model Layer 3 reflect the periods of increased pumping in the Class 2 Service Area (**Table 5**). The changes in water levels for Model Layer 3 range from -2 to -13 feet over the Baseline Period, with a long-term change of about -3 feet. These changes are reflected in the Superposition Hydrograph on the bottom of **Figure 6-12f**. As with previous hydrographs, the Project-related changes in groundwater elevations are small relative to the variability observed in the measured data.

Figures 6-12g and **6-12h** (28S/25E-14C03 and 27S/25E-07R01) show results for two locations in SWID (**Figure 6-10**). **Figure 6-12g,** located near Shafter, shows a similar pattern to that shown on the nearby hydrographs on **Figure 6-12e**, but the changes are smaller. This observation illustrates that Project-related impacts diminish with distance from the point of changed use. The Change Hydrograph on **Figure 6-12h,** located near Wasco, is closer to NKWSD, and displays the influences from the NKWSD increase in pumping (see Model Layers 2, 3 and 4). Water level changes in Model Layer 3 range from -5 to -15 feet, with a long-term change of about -2 to -3 feet. In Model Layer 1, water levels are lower by about -2 feet to -3 feet over the Baseline Scenario. Similar to the previous hydrographs, the Superposition Hydrographs on **Figures 6-12g** and **6-12h** indicate small Project-related changes in groundwater elevations relative to the variability observed in the measured data.

Figures 6-12i, **6-12j** and **6-12k** (27S/24E-27F02, 26S/24E-21R01 and 26S/23E-07P01) show model results for three locations in SWSD (**Figure 6-10**). SWSD is not impacted directly by reductions in release water, but is slightly affected by changes in the groundwater system beneath NKWSD. For the Change Hydrographs in **Figures 6-12i** and **6-12j** (located closer to NKWSD), Project-related changes occur primarily in Model Layer 3 with spikes of -3 to -5 feet with a long-term change of about -1 to -2 feet. Similarly, Model Layer 1 shows a long-term decrease of -1 to -2 feet. Hydrographs on **Figure 6-12k** are

located farther from NKWSD, and indicate long-term changes in water levels of about -1 foot. As noted previously, these hydrographs illustrate that Project-related changes are diminishing with distance from NKWSD. As shown on the Superposition Hydrographs (bottom graphs on **Figures 6-12i**, **6-12j**, and **6-12k**), the Project-related changes are so small as to be difficult to distinguish on the graphs. As with all previous hydrographs, Project-related changes to groundwater elevations are small relative to the variability observed in the measured data.

6.2.4 Spatial Average of Project-Related Changes to Groundwater Levels, Baseline Scenario

Groundwater level changes vary and are greatest near pumped wells or recharge mounds. These changes diminish quickly with increasing distance from wells or recharge facilities as illustrated schematically in **Figure 5-1**. In order to provide a quantitative assessment of the Project-related changes in groundwater levels on a water-district-wide-basis, spatial averages were calculated from the Baseline Scenario results. The spatial average provides another appropriate and reasonable method to assess the groundwater impacts over the broader areas of interest.

To calculate the spatial average, the accumulated changes in groundwater levels are averaged for all grid cells located within a water district service area at a specified time interval. Model Layer 3 is used in this process because this is the primary aquifer for groundwater pumping in the Northern Study Area and would represent maximum impacts to wells. The results of the spatial averaging of groundwater level change at the end of the Average Hydrologic Conditions (1997 to 2007) and the Combined Study Period (1997 to 2014) are presented in **Table 16**.

Table 16. Spatially Averaged Change in Groundwater Levels – Baseline Scenario

Water Agency	Average Hydrologic Conditions (1997 to 2007) (feet)		Combined Study Period (1997 to 2014) (feet)	
	End of Period	Maximum Month	End of Period	Maximum Month
North Kern Water Storage District (NKWSD)	-2.6	-9.5	-2.2	-12.5
Shafter-Wasco Irrigation District (SWID)	-2.1	-5.2	-1.9	-6.8
Semitropic Water Storage District (SWSD)	-0.6	-1.3	-0.8	-1.5
City of Bakersfield WSA	+0.8	-8.0	+0.7	-8.0
Kern Delta Water District (KDWD)	+2.7	+3.5	+2.6	+5.0

Note: End of Period is the accumulated groundwater level change at the end of the respective simulation period.
Maximum Month is the greatest accumulated change in groundwater level for any month within the simulation period.

As shown in **Table 16**, the long-term average water level change in NKWSD is -2.6 feet at the end of the 11-year Average Hydrologic Conditions and -2.2 feet at the end of the 18-year Combined Study Period. During those periods the maximum monthly groundwater level change, based on a spatial average over the entire NKWSD, was -9.5 and -12.5 feet, respectively. The groundwater level change at the end of the Combined Study Period in SWID are about -2 feet and diminish to less than -1 foot in SWSD. Maximum monthly groundwater level changes were -6.8 feet in SWID and -1.5 in SWSD. Beneath the City WSA, the

Project results in a small rise in groundwater levels of less than one foot at the end of the respective simulation periods; however, the maximum monthly changes were -8.0 feet. Finally, the Project produces an average water level rise beneath KDWD of between 2 and 3 feet and maximum monthly rises between 3 and 5 feet.

6.3 GROUNDWATER LEVEL IMPACTS ANALYSIS FOR SCENARIO A

Consistent with the intent of the 2014 Order that requires a long-term, multi-decade impact analysis, Scenario A simulates a 50-year time period using the Combined Study Period (1997-2014) by repeating the 18-year period three times to evaluate the long-term accumulated effects of the Proposed Project. Scenario A is setup according to the methodology described in **Section 5.5** and applying the Proposed Project as summarized in **Tables 5**, **6** and **8**. For this analysis, Project-related changes in the adversely affected areas were evaluated after 10, 25, and 50 years to compare various long-term changes. Results of the 50-Year groundwater level impact analysis for Scenario A are provided below.

6.3.1 Water Level Changes, Scenario A

Figures 6-13, **6-14**, and **6-15** presents the Project-related changes in groundwater levels after 10, 25 and 50 years of operation of the Proposed Project. Four maps are shown on each figure, one for each of the four model layers in the KDWD Superposition Model.

Figure 6-13 shows the groundwater level change for Simulation Year 10 of the Proposed Project (equivalent to 2006 conditions shown in **Table 4**). The change contours show the Project has the largest adverse impact on water levels in NKWSD, where water levels are lower by about -2 feet to -10 feet in various areas and model layers. The largest benefit to water levels is in KDWD, where water levels rise about 1 foot to 6 feet. Groundwater level changes in the City are generally plus or minus one foot. Groundwater level impacts generally diminish with distance from NKWSD as indicated by smaller changes to water levels beneath SWID and SWSD. A summary of the impacts to groundwater levels for Year 10 (**Figure 6-13**) in the affected areas for each model layer is provided below:

- In Model Layer 1, the impacts of -4 to -12 feet are primarily focused near the recharge facilities and canals in southern NKWSD; groundwater level changes range from -2 to -3 feet in northern NKWSD. Groundwater level declines range from -1 to -3 feet in SWID, and are generally less than -1 foot in SWSD.
- In Model Layer 2, the overall pattern generally mimics that of Model Layer 1 except in the northwestern portion of NKWSD where groundwater levels are affected by the increase in irrigation pumping in Model Layer 3. Contours in this area are also being influenced by the change in textures in Model Layer 2; as discussed previously, the E-clay pinches out in this area (see **Figure 4-8**).
- In Model Layer 3, the Project-related changes are primarily associated with the increase in irrigation pumping, but are also affected by reductions in recharge and canal losses throughout NKWSD. The largest changes occur in northwestern NKWSD, the City of Wasco and the northern portion of SWID, where water levels are lowered from -6 to -12 feet. Groundwater level changes in SWSD range from -2 feet to less than -1 foot.
- In Model Layer 4, the groundwater level changes are associated with effects for Model Layer 3. In NKWSD water levels are lowered by -1 foot to -3 feet.

Figure 6-14 shows the groundwater level change for Simulation Year 25 of the Scenario A. The general pattern is similar to that for Year 10 (**Figure 6-13**), but the overall magnitude of the groundwater level change is less. Given the cyclical nature of the repeating hydrology, Year 25 corresponds to a period when smaller amounts of release water were available and Project impacts were less (**Table 4**). The largest Project-related changes to water levels are associated with increased irrigation pumping and reductions in recharge from canal losses beneath NKWSD. The groundwater level changes generally range from -2 to -4 feet in SWID, and from -2 feet to less than -1 foot in SWSD. Across the City, Project-related changes in water levels range from declines of -1 foot to increases of 2 feet (**Figure 6-14**).

Figure 6-15 shows the groundwater level change for Simulation Year 50 of the Scenario A. The general pattern is similar to that for Years 10 and 25 (**Figure 6-13** and **6-14**). Collectively, **Figures 6-13** through **6-15** show that the rate of Project-related changes is greatest in the first 10 years of the Project and becomes more stable by Years 25 to 50.

6.3.2 Hydrograph Analysis for Scenario A

Similar to those prepared for the Baseline Scenario, 344 Change Hydrographs were constructed for Scenario A. Because this scenario analyzes future changes for which no measured data exist, Superposition Hydrographs such as those used for the Baseline Scenario are not included. Change Hydrographs are discussed below for the same 11 representative locations used for the Baseline Scenario (**Figure 6-10**). Change Hydrographs for the 333 remaining locations across the Study Area (**Figure 6-11**) are presented in **Appendix D**.

The 11 representative Change Hydrographs are presented on **Figures 6-16a** through **6-16f** (hydrographs from 2 locations are combined on each figure). The hydrographs allow Project-related changes to be examined over time at specific locations throughout the Study Area. Because Scenario A repeats the 18-year Combined Study Period (1997-2014) three times, the overall pattern for the first 18 years on the 11 Change Hydrographs are consistent with patterns observed for the Baseline Period (**Section 6.1**); that pattern is then generally repeated three times (e.g., compare the Change Hydrographs on **Figure 6-16a** with the Change Hydrographs on **Figures 6-12a** and **6-12b**). However, the Change Hydrographs also show lower groundwater levels of about -1 to -2 feet during the second and third 18-year cycles, compared to the first cycle.

In NKWSD and SWID, the rate of decline is greatest during the first 18-year cycle, but stabilizes through the rest of the simulation whereas groundwater levels in the City show a general increasing trend over the 50-Year period. This is because during the first few years, the majority of the change in NKWSD and SWID is derived locally from groundwater in storage. Over time, the lower groundwater levels induce groundwater inflow from upgradient areas and decrease outflows from downgradient areas. This effect compensates for the ongoing Project-related reductions in recharge and increases in pumping beneath NKWSD. This results in a stabilization of groundwater levels in NKWSD and SWID, and widespread low-level groundwater level declines over a broad area of the Northern Study Area. In the City, groundwater levels increase over time in response to increased recharge and decreased pumping by KDWD beneath the City as a result of the Proposed Project.

6.3.3 Spatial Analysis of Groundwater Level Change for Scenario A

The spatial analysis of groundwater level change discussed in **Section 6.1.4** was repeated for Scenario A; results are presented in **Table 17** and shown on **Figure 6-17**. More detailed data for the spatial analysis

are presented in **Appendix B**. Results show that Project-related declines in water levels beneath NKWSD and SWID average between -2 and -3 feet over the 50 year period. Short-term maximums occur during wet periods when more water is available on the Kern River. During these times, the maximum changes in groundwater levels in NKWSD and SWID range from -7 to -13 feet on average due to the reduction in release water. Further, Project-related declines remain in this range from Year 10 through Year 50. Beneath SWSD, the average project-related declines range from -0.6 feet in Year 10 to -1.2 feet in Year 50. Maximum groundwater level changes are -2.0 feet. The lower maximum in SWSD is due to the distance from NKWSD.

Beneath the City, groundwater levels continually rise throughout the 50-year period, averaging from 0.8 feet in Year 10 to 3.6 feet in Year 50. A short-term maximum decline occurs early in the period due to increased pumping. In KDWD, average Project-related water levels increase from 3.0 feet in Year 10 to 5.2 feet in Year 50. Results for Scenario B are also included in **Table 17** and discussed in the following sections.

Table 17. Spatially Averaged Change in Groundwater Levels for the Scenario A and Scenario B

Water Agency	10 Years	25 Years	50 Years	Max Month
Scenario A (feet)				
North Kern Water Storage District	-2.8	-3.0	-2.4	-13.0
Semitropic Water Storage District	-0.6	-1.1	-1.2	-2.0
Shafter-Wasco Irrigation District	-2.1	-2.6	-2.4	-7.3
City of Bakersfield WSA	+0.8	+1.4	+3.6	-8.0
Kern Delta Water District	+3.1	+3.9	+5.2	+7.0
Scenario B (feet)				
North Kern Water Storage District	-2.8	-3.9	-3.3	-11.6
Semitropic Water Storage District	-0.6	-1.2	-1.5	-1.8
Shafter-Wasco Irrigation District	-2.1	-3.3	-3.1	-7.0
City of Bakersfield WSA	+0.8	+2.1	+3.0	-8.0
Kern Delta Water District	+3.1	+5.4	+6.4	+8.8

Note: End of Period is the accumulated groundwater level change at the end of the respective simulation period.
Max Month is the greatest accumulated change in groundwater level for any month within the simulation period.

6.4 GROUNDWATER LEVEL IMPACTS ANALYSIS FOR SCENARIO B

Scenario B was setup following the same approach as that used for Scenario A (**Section 6.3**). The difference is that the Proposed Project is based on data from the 11-year Average Hydrologic Conditions Study Period (1997-2007), which is repeated five times to provide a 50-year analysis. The groundwater level changes in the adversely affected areas were evaluated at 10, 25 and 50 years. A summary of the results of this water level impact analysis is provided below.

6.4.1 Water Level Changes for Scenario B

Figures 6-18, **6-19** and **6-20** present the change in groundwater levels after 10, 25 and 50 years of the Proposed Project for each of the four model layers in the KDWD Superposition Model.

Figure 6-18 shows the groundwater level change after 10 years of the Proposed Project. Year 10 of the Study Period (1997-2007) used in Scenario B is the same year as Year 10 of the Combined Study Period (1997 to 2014) used in Scenario A; therefore, **Figure 6-18** is identical to **Figure 6-13**.

Figure 6-19 shows the groundwater level change after 25 years of the Proposed Project, which is equivalent to conditions in Year 1999 (**Table 4**). These groundwater impacts are much greater than for Year 25 in the Scenario A (compare **Figures 6-19** and **6-14**). This is due to arbitrary selection of Year 25 for two scenarios with different periods of varying hydrology. For the Scenario B, Year 25 follows the extreme impact year of 1998 in the 11-year cycle when large quantities of release water that were historically recharged in NKWSD were now unavailable under Project conditions. Model Layers 1 and 2 show groundwater level changes of -10 to -20 feet near district recharge facilities in southern NKWSD. In Model Layer 3, Project-related changes to groundwater levels are generally -5 to -10 feet across NKWSD. In SWID, groundwater levels are lowered by about -2 feet to -5 feet, and -1 to -3 feet in SWSD. Beneath the City, Project-related groundwater level changes generally range from -1 foot to a rise of 5 feet.

Figure 6-20 shows the groundwater level change after 50 years of the Proposed Project, with Year 50 simulating conditions equivalent to Year 2002 (**Table 4**). The general pattern is similar to that for Years 10 and 25 (**Figure 6-18** and **6-19**), but the overall magnitude of the groundwater level change is less. This is due to the year-to-year changes in the 11-year cycle being lower in Year 50 than in Years 10 or 25 (**Table 4**). The Project-related changes are associated with increased pumping in the NKWSD Class 2 Service Area and reductions in recharge from canals. The impacts beneath SWID generally range from -2 to -5 feet. Beneath SWSD, the impacts range from -3 feet to less than -1 foot. Groundwater levels generally rise beneath the City.

6.4.2 Hydrograph Analysis for Scenario B

To evaluate the overall groundwater level changes over the Scenario at specific locations, Change Hydrographs were prepared for Scenario B at the same 11 representative locations (**Figure 6-10**) used for the other scenarios. In addition, Change Hydrographs were prepared for the remaining 333 locations across the Study Area (**Figure 6-11**) for Scenario B; those hydrographs are presented in **Appendix E**.

Change Hydrographs for the 11 representative locations are presented in **Figures 6-21a** through **6-21f** (two hydrographs per figure). Hydrographs show the simulated change in groundwater levels due to 50 years of operation of the Proposed Project resulting from repeating the 11-year Average Hydrologic Conditions (1997 to 2007) five times. Because of this repetition of hydrologic conditions, the overall patterns for the first 11 years of the Change Hydrographs are consistent with the patterns for the Baseline Scenario (**Section 6.1**), but is repeated five times (e.g., compare **Figure 6-21a** with **Figure 6-16a**). The overall trend shows that the largest groundwater level changes are about -2 to -4 feet greater than observed in Scenario A after the first 11-year cycle. A pattern similar to Scenario A results is observed beneath NKWSD and SWID where the rate of decline is greatest during the first 11-year cycle but then stabilizes through the rest of the simulation. Similar to other scenarios, groundwater levels show a general increasing trend beneath the City.

Further comparison of **Figures 6-21a** with **6-16a** shows that the magnitude of the greatest groundwater level declines are comparable. These maximum events represent the repetition of 1998 in the hydrologic cycle for the scenario. During 1998, high flows in the Kern River resulted in maximum change in the use of release water for the Proposed Project (**Table 4**). Intervening periods with lower flows on

the Kern River result in lesser changes in the use of release water for the Proposed Project. During these periods, the change in groundwater levels is reduced because of increased upgradient inflows and decreased downgradient outflows in response to lower groundwater levels.

Scenario A (**Figure 6-16a**) includes the updated period from 2008 to 2014, so it includes an additional maximum groundwater level change event representing 2011 in the hydrologic cycle when high flows occurred on the Kern River. Drought periods in 2007 to 2009 and 2012 to 2014 result in minimum changes in the use of release water for the Proposed Project due to low flows on the Kern River. As a result, Scenario B has a higher average annual release water available for use by KDWD as part of the Proposed Project making groundwater level changes for Scenario B slightly greater than for Scenario A.

6.4.3 Spatial Analysis of Groundwater Level Change for Scenario B

The spatial analysis discussed in **Sections 6.2.4** and **6.3.3** was repeated for Scenario B, and results are presented in the lower half of **Table 17**. The results show that the magnitude of the average groundwater level change is generally greater after 50 years for Scenario B compared to Scenario A by about -0.3 to -1.2 feet. Beneath NKWSD and SWID, water levels change between -3 and -4 feet over the 50 year period. Beneath SWSD, the average groundwater level change ranges from -0.6 feet in Year 10 to -1.5 feet in Year 50. In the City, groundwater levels continually rise with the average increasing from 0.8 feet in Year 10 to 3.0 feet in Year 50. In KDWD, average groundwater levels rise from 3.0 feet in Year 10 to 6.5 feet in Year 50.

6.5 GROUNDWATER IN STORAGE IMPACT ANALYSIS

The KDWD Superposition Model calculates the change in groundwater in storage as a result of the Proposed Project for each monthly stress period over the simulation period; however, because the monthly stress periods include times when storage accrues and times when storage is depleted, the average over the simulation period is used to determine the long-term groundwater in storage change. Because a superposition model simulates change, a positive groundwater in storage change represents either an increase in subsurface inflow or a decrease in subsurface outflow, whereas, a negative groundwater in storage change represents an increase in outflow or a decrease in inflow as a result of the Proposed Project.

The average change in water balance components for the Baseline Scenario, including groundwater in storage changes, are summarized in **Table 18**. The results are presented for the Northern and Southern Study Areas (generally north and south of the Kern River) for the two Study Periods. The *Net Proposed Project Release Water Change* is model-derived output that summarizes the total additions and reductions in release water use. In the case of the City of Bakersfield, municipal pumping and the Pioneer Spreading Grounds were assigned both reductions and additions of release water so these numbers essentially canceled out in the averages presented in **Table 18**. To verify that the Proposed Project is accurately reflected in **Table 18**, the sum of the *Net Proposed Project Release Water Change* for the Northern and Southern Study Areas in **Table 18** is equal to the average *Release Water Lost to Intertie* shown in **Table 4**. Additional information is provided in **Appendix B** that documents the distribution of release water to the different areas and the annual summaries of the water balance data.

For the 1997 - 2007 Study Period, about 55 percent of the water balance changes in the Northern Study Area resulting from the Proposed Project are derived from groundwater in storage. Of the remaining

volume, about 35 percent is from increased groundwater flows from the Southern to the Northern Study Area and 10 percent are from increased groundwater flows from outside the Study Area. These changes in groundwater flows are the result of shifting groundwater flow patterns in response to changes in hydraulic gradients due to higher groundwater levels in the Southern Study Area and are not necessarily Project-related release water. For the 1997 to 2014 Study Period, about 41 percent of the water balance changes in the Northern Study Area are derived from groundwater in storage, about 44 percent is from groundwater flow from the Southern Study Area, and 15 percent is from groundwater inflow from outside the Study Area (**Table 18** and **Appendix B**).

Table 18. Change in Water Balance for the Baseline Scenario by Study Area

Year	Net Proposed Project Release Water Change (AFY)	Subsurface Flow from outside Study Area (AFY)	Subsurface Flow within Study Area (AFY)	Net Change of Groundwater in Storage (AFY)
Northern Study Area				
1997 – 2007 Average	-23,982	2,465	8,443	-13,074
1997 – 2014 Average	-19,587	2,954	8,656	-7,978
Southern Study Area				
1997 – 2007 Average	27,196	-5,288	-8,443	13,465
1997 – 2014 Average	21,552	-4,749	-8,656	8,147

[1]The higher net release water allocation in the Southern Study Area includes the *Release Water Lost to Intertie* that is applied to KDWD but not taken from NKWSD or City of Bakersfield as discussed in **Section 5.5.3**. See Appendix A for additional details and breakdowns of these values.

For the Scenario A, the average water balance components were calculated for time intervals over 10, 25 and 50 years (**Table 19** and **Appendix B**). The results show that over the long-term, the percentage taken from groundwater in storage decreases over time in the Northern Study Area, and the percentage due to changes in groundwater flow increases. The percentage of the Proposed Project derived from decreased groundwater in storage in the Northern Study Area decreases from 58 percent after 10 years to 18 percent after 50 years. The percentage of the Proposed Project derived from changes in groundwater flow (from outside and within the Study Area) in the Northern Study Area increases from 42 percent after 10 years to 82 percent after 50 years.

Table 19. Change in Water Balance for the Scenario A by Study Area

Year	Net Proposed Project Release Water Change (AFY)	Subsurface Flow from outside Study Area (AFY)	Subsurface Flow within Study Area (AFY)	Net Change of Groundwater in Storage (AFY)
Northern Study Area				
10-Year Average	-25,080	2,350	8,263	-14,467
25-Year Average	-20,972	3,540	9,944	-7,489
50-Year Average	-19,877	4,629	11,649	-3,599
Southern Study Area				
10-Year Average	28,615	-5,267	-8,263	15,085
25-Year Average	23,747	-5,101	-9,944	8,702
50-Year Average	21,999	-5,016	-11,649	5,334

[1]The higher net release water allocation in the Southern Study Area includes the *Release Water Lost to Intertie* that is applied to KDWD but not taken from NKWSD or City of Bakersfield as discussed in **Section 5.5.3**.

For Scenario B, a similar pattern is observed (**Table 20** and **Appendix B**). The percentage of the Proposed Project derived from changes of groundwater in storage decreases from 58 percent after 10 years to 18 percent after 50 years. The percentage of the Proposed Project derived from changes in groundwater flow (from outside and within the Study Area) increases from 42 percent after 10 years to 82 percent after 50 years. The 10-year averages shown on **Tables 19** and **20** are the same because the first 11 years of Scenarios A and B repeat the same hydrologic sequence.

Table 20. Change in Water Balance for the Scenario B by Study Area

Year	Net Proposed Project Release Water Change (AFY)	Subsurface Flow from outside Study Area (AFY)	Subsurface Flow within Study Area (AFY)	Net Change of Groundwater in Storage (AFY)
Northern Study Area				
10-Year Average	-25,080	2,350	8,263	-14,467
25-Year Average	-25,202	4,076	11,650	-9,476
50-Year Average	-24,198	5,508	14,219	-4,471
Southern Study Area				
10-Year Average	28,615	-5,267	-8,263	15,085
25-Year Average	29,391	-6,008	-11,650	11,733
50-Year Average	27,707	-6,224	-14,219	7,263

[1]The higher net release water allocation in the Southern Study Area includes the *Release Water Lost to Intertie* that is applied to KDWD but not taken from NKWSD or City of Bakersfield as discussed in **Section 5.5.3**.

Collectively, the analysis of the Project-related water balance indicates that there is no loss of groundwater in storage in the subbasin associated with the Project. Although there is a net loss in storage north of the river, the amount is small related to the overdraft conditions in the area. For example, the net loss of -13,074 AFY for the 1997-2007 Study Period (**Table 18**) compared to an overdraft in the Northern Study Area of -425,771 AFY for that same period (Subregions 19 and 20, see

Table 13), represents a change of about 3 percent. In contrast, the gain in net groundwater in storage of 13,465 AFY (**Table 18**) compared to an overdraft in the Southern Study Area of -283,883 AFY (Subregion 21, see **Table 13**), represents a difference of about 5 percent. Further, over the long-term, the loss of groundwater in storage in the Northern Study Area is compensated by increased subsurface inflows such that the net loss is less than 5,000 AFY after long-term operation of the Project (**Tables 19** and **20**).

To evaluate the long-term rate of change to groundwater in storage, a moving average analysis was used to filter out year-to-year effects. A more detailed discussion of the moving average analysis is presented in **Appendix B**. This analysis indicates that the long-term rate of decline to groundwater in storage in the Northern Study Area slowly decreases over the 50-year simulation period due to increased subsurface groundwater flows primarily from the Southern Study Area. The increased recharge and reduced pumping in the Southern Study Area from the Proposed Project leads to increases in groundwater flow to areas north of the Kern River including NKWSD and the City. After 50 years, the modeling results indicate that the long-term rate of change to groundwater in storage shifts from a decreasing to a slight increasing trend for both Scenarios A and B; however, the cumulative loss of groundwater in storage from the earlier time periods would still remain.

6.6 SENSITIVITY ANALYSIS FOR KDWD SUPERPOSITION MODEL

A sensitivity analysis is the evaluation of model input parameters to evaluate their effect on model outputs such as change in groundwater levels. The process consists of varying model input parameters over a reasonable range of uncertainty and evaluating the relative change in the simulation results. The purpose of the sensitivity analysis is to demonstrate how variability and/or uncertainty in model input data may affect the predicted Project-related impacts.

For the KDWD Superposition Model, aquifer properties retained from the CVHM model were determined to be the parameters providing the most uncertainty for the impacts analysis. Horizontal conductivity and storage parameters (both specific yield and specific storage) affect changes in water levels, groundwater flow, and groundwater in storage; accordingly, these parameters were selected for the sensitivity analysis.

Sensitivity analyses were run for the Validation Scenario and for Scenario A. For each sensitivity analysis, a separate model run was setup where one parameter was varied in Model Layers 1 and 3 by a set percentage over the entire model domain. Model Layers 1 and 3 were chosen since these are the model layers where the Proposed Project changes were applied. Simulation results were compared to evaluate the differences between the model sensitivity runs relative to either the Validation Scenario or Scenario A results. The following provides a summary of the results of the sensitivity analysis.

6.6.1 Sensitivity Analysis of Validation Scenario

For the Validation Scenario, the sensitivity analysis evaluates the effect of varying key aquifer properties by comparing measured to simulated groundwater level changes for the Kern Water Bank recharge simulation. A series of model sensitivity runs were setup whereby one of the key parameters (horizontal hydraulic conductivity or storage parameters) was varied by either plus-or-minus (+/-) 25 percent. A total of four model sensitivity runs were developed.

The Validation Scenario sensitivity analysis used a statistical analysis to correlate the difference between the measured to simulated groundwater levels for the six-year Kern Bank simulation. The primary measure for the statistical analysis is the difference, or residual, between the measured to simulated changes in groundwater levels. Discussion of the statistical parameters is provided in **Section 5.6.2**.

The results of the Validation Scenario sensitivity analysis are summarized in **Table 21**. The results show that some statistical measures improve whereas others are poorer; however, the unaltered Validation Scenario provides the better overall correlation. Increasing the hydraulic conductivity or decreasing the storage properties produce similar statistical measures to the Validation Scenario, whereas decreasing the hydraulic conductivity and increasing the storage properties produces the poorer results in terms of the scaled absolute residual mean relative to the Validation Scenario. In general, the percentage difference in the absolute residual mean and standard deviation relative to the Validation Scenario results ranges from 1 to 9 percent, which is less than the 25 percent variation applied to the parameter. This indicates that the model results are not overly sensitive to variations in the aquifer parameters, and that the aquifer parameters derived from the CVHM are generally robust. This further supports that the KDWD Superposition Model, as it is configured for this study, provides realistic, representative simulation results of groundwater level change in the Study Area.

Table 21. Sensitivity Analysis for Validation Scenario Comparing Differences in Statistical Analysis Comparing Measured to Simulated Groundwater Level Change

Statistical Parameter	Validation	K_x +25%	K_x -25%	S +25%	S -25%
Residual Mean	-2.1	0.8	-6.1	2.5	-8.9
Absolute Residual Mean	18.9	19.2	18.9	18.8	20.5
Standard Deviation	24.7	26.2	23.2	26.0	23.5
Scaled Absolute Residual Mean	0.092	0.094	0.092	0.092	0.100

Note: S = Storage parameters including specific storage (Ss) and specific yield (Sy)
Kx = horizontal hydraulic conductivity
+25% indicates that parameter was increased by 25 percent
-25% indicates that parameter was decreased by 25 percent

6.6.2 Sensitivity Analysis of Scenario A

For Scenario A, the sensitivity analysis evaluates the effect of varying the key aquifer properties on the magnitude of simulated groundwater level changes due to the Proposed Project. The same key parameters, hydraulic conductivity and storage properties, were varied; however a higher percentage was applied as a conservative measure in assessing the effect of varying the aquifer properties on the magnitude of the scenario results. A set of four model sensitivity runs were setup where one of the key parameters was varied by either plus-or-minus (+/-) 50 percent.

The Scenario A sensitivity analysis used hydrographs from representative well locations (**Section 6.3.2** and **Figure 6-10**) and the spatial analysis (**Section 6.3.3** and **Table 17**). The primary measure is the difference between the simulated changes in groundwater levels for the different model sensitivity runs compared to the Scenario A results. The hydrographs assess the variability in groundwater levels over time at three representative locations (**Figures 6-22a** to **6-22c**). The spatial analysis provides a regional assessment of the change in groundwater levels at a specific time (**Table 22**).

Table 22. Sensitivity Analysis for Scenario A Comparing Differences in Spatially-Averaged Simulated Groundwater Level Change for Simulation Year 25

Water Agency	Scenario A	K_x +50%	K_x -50%	S +50%	S -50%
Average Annual Accumulated Groundwater Level Change for Simulation Year 25					
North Kern Water Storage District	-4.3	-3.2	-6.3	-4.0	-4.1
Semitropic Water Storage District	-1.2	-1.1	-1.3	-1.0	-1.5
Shafter-Wasco Irrigation District	-3.4	-2.7	-4.6	-3.1	-3.5
City of Bakersfield WSA	1.3	1.2	1.6	0.9	2.4
Kern Delta Water District	4.2	3.4	5.7	3.5	5.6
Maximum Monthly Accumulated Groundwater Level Change for Simulation Year 25					
North Kern Water Storage District	-9.2	-7.7	-12.1	-8.9	-9.2
Semitropic Water Storage District	-1.6	-1.5	-1.6	-1.3	-1.9
Shafter-Wasco Irrigation District	-5.9	-5.3	-6.7	-5.5	-5.1
City of Bakersfield WSA	2.4	2.0	3.3	2.0	3.6
Kern Delta Water District	4.7	3.8	6.2	3.9	6.1

Note: S = Storage parameters including specific storage (Ss) and specific yield (Sy)
Kx = horizontal hydraulic conductivity
+50% indicates that parameter was increased by 50 percent
-50% indicates that parameter was decreased by 50 percent

The spatial analysis includes both the accumulated and maximum simulated groundwater level change for Simulation Year 25 based on an arithmetic average calculated over a specific water district following the same procedure discussed in **Sections 6.2.4** and **6.3.3**. Simulation Year 25 was selected to provide a consistent time period that is representative of the more significant groundwater level impacts that occur during Scenario A. The accumulated spatial average represents the total groundwater level changes from the beginning of the simulation to the end of Simulation Year 25. The maximum spatial average is the maximum change for any month during the simulation.

The spatial analysis results for the model sensitivity runs are presented in **Table 22**. The greatest magnitude of variability occurs in NKWSD. However, even varying aquifer properties by 50 percent results in average groundwater levels in NKWSD within one to two feet of those for Scenario A. Variations in SWID and SWSD are lower (0.1 to 1.0 feet) reflecting attenuation of the effects of the Proposed Project with distance from NKWSD. In the City, the variability was less than one foot. The results for the maximum monthly change in the spatial average at Simulation Year 25 show that although the magnitude of the groundwater level changes are greater than Scenario A, the changes are proportional to the difference relative to Scenario A as seen for the accumulated average. The maximum monthly changes range from 0.1 to 2.9 feet. The spatial average results indicate that the simulation results are more sensitive to reductions in either the hydraulic conductivity or the storage properties.

Figure 6-22a is for a location near the NKWSD spreading grounds that is representative of the maximum change in groundwater levels. A set of five curves are shown representing the simulated change in groundwater levels for Scenario A and the four sensitivity analysis runs. The hydrograph results show that groundwater level changes are most sensitive to reducing the hydraulic conductivity or the storage properties. The relative difference compared to Scenario A is greatest during the maximum events, and least during period of minor events. In general, the maximum changes are proportionally similar to the spatial averaged results relative to Scenario A. Reducing the hydraulic conductivity also increases the

recovery time from large release water reductions. This is due to the slower rate of groundwater inflow to help groundwater levels recover. At the end of the simulation, the change in groundwater levels for the model sensitivity runs at this location are within 2 to 4 feet of the Scenario A results.

Figure 6-22b is for a location along the boundary of NKWSD and SWID near the Class 2 Service Area. The results for Model Layer 1 show a much different pattern than is shown on **Figure 6-22a** due to increased distance from the NKWSD spreading grounds. In Model Layer 3, the spiky nature of the results reflects the periodic variations in pumping in the Class 2 Service Area due to the Proposed Project. This location is more sensitive to reductions in the hydraulic conductivity, whereas the results of the other model sensitivity runs tends to cluster near to the Scenario A results. At the end of the simulation, the change in groundwater levels for the model sensitivity runs at this location are within 1 to 3 feet of the Scenario A results.

Figure 6-22c is for a location within the City of Bakersfield. These results indicate that this location is much less sensitive to variations in aquifer properties than observed in NKWSD or SWID. This likely due to the smaller volumetric changes due to the Proposed Project in the City and higher groundwater inflows from the south due the proximity to increased recharge in KDWD. At the end of the simulation, the change in groundwater levels for the model sensitivity runs at this location are within 1 to 2 feet of the Scenario A results.

Overall, the sensitivity analysis indicates that varying the key aquifer parameters significantly (+/- 50 percent) results in variations in the simulated groundwater levels on the order of 1 to 4 feet. Locally, short-term maximums may increase up to 10 feet but these variations are not sustained over the entire simulation. The results of the sensitivity analysis further confirm that the KDWD Superposition Model, as it is configured for this study, provides an acceptable level of accuracy for evaluating long-term changes in groundwater levels.

6.7 SUBSIDENCE IMPACTS ANALYSIS

As described in **Section 4.7**, water level declines associated with groundwater extraction have contributed over 10 feet to land subsidence in the Kern County Subbasin in the past. Two large areas of concentrated subsidence have been identified. One area is centered in the Southern Study Area along the southern KDWD boundary; a second area occurs in the Northern Study Area, generally from northern NKWSD to beyond the Kern County line (see **Figures 4-17** and **4-18**). Although subsidence could potentially occur in any area where water levels are declining, these documented areas of historical subsidence are considered the most vulnerable due to the predominance of fine-grained sediments throughout the aquifer system.

For the subsidence impacts analysis, potential subsidence due to Project-related water level change is analyzed using methods and data from USGS field investigations of land subsidence in California (Poland and Ireland, 1988, Bull and Poland, 1975, Lofgren and Klausing, 1969), as well as USGS model simulations of subsidence (Leake and Prudic, 1991 and Hoffman et al., 2003). For the subsidence impacts analysis, the potential total subsidence is calculated based on simulated water level changes using the KDWD Superposition Model and historical subsidence rates measured in the Study Area.

6.7.1 Method to Calculate Potential Future Subsidence Impacts

As explained in **Section 4.7**, the weight of the overlying aquifer is borne by the sediment grains and the water pressure in the pores of the sediments (pore pressure). As water levels are lowered by groundwater pumping, the pore pressure decreases causing more of the weight of the overlying aquifer (effective stress) to be transferred to the sediment grains. If the effective stress exceeds the structural strength of the sediments, the individual grains begin to compact into a tighter configuration that is manifested at the land surface as subsidence.

Inelastic, or permanent, compaction is initiated when the magnitude of the greatest pressure that has acted on a clay layer since its deposition – referred to as pre-consolidation stress – is exceeded. With respect to the effects of groundwater pumping, the preconsolidation stress is exceeded when groundwater levels reach a new historically low water level in the aquifer. Therefore, the analysis focuses on potential Project-related impacts during the Study Period when water levels are at historic low levels.

The calculation of subsidence is based on a one-dimensional mathematical model of vertical compaction (Helm, 1977), which is based on a modification of Terzaghi's consolidation theory (Terzaghi and Peck, 1948). The model computes aquitard compaction due to specified changes in effective stress within an adjacent aquifer. For most sediments, inelastic compaction is approximately proportional to the logarithm of the effective stress (Jorgensen, 1980). However, for aquifer-system compaction, the incremental changes in effective stress are typically small. Poland (1969) concluded that a linear form of Helm's (1977) subsidence model would provide a reasonable approximation of the ultimate compaction for the range of changes in the effective stress resulting from the lowering of water levels due to groundwater pumping. This linear equation is equivalent to Equation 13.4 in the Terzagi and Peck (1948) section on "*Compressibility of Confined Layers of Soil*" to calculate the reduction in clay layer thickness. Using this approach, the following equation is used for the subsidence impacts analysis:

$$\Delta z = S_{sk} * m_f * \Delta h \qquad (2)$$

where Δz = the computed total, or ultimate, compaction (or subsidence)

S_{sk} = skeletal specific storage, or coefficient of volume compressibility, for inelastic compaction of the compacting, or fine-grained, beds

m_f = the aggregate thickness of the compacting, or fine-grained, beds

Δh = the change in groundwater levels (hydraulic head) during compaction

Equation 2 assumes that the stresses associated with groundwater level changes are propagated throughout the entire thickness of compressible interbeds instantaneously. In actual aquifer systems, there may be a time lag whereby the rate of compaction is slower in thicker clay layers due to the difficulty in expelling the water from the layer. Equation 2 represents the total magnitude of compaction that ultimately may be attributed to the specified change in groundwater levels (Δh) and the characteristics of the clay (m_f and S_{sk}), including any time lag.

Multiple reports by the USGS (Poland and Ireland, 1988, Bull and Poland, 1975, Lofgren and Klausing, 1969) evaluated land subsidence in the Santa Clara and Central Valleys that either use the Helm (1997) model, or the linearized form (Equation 2), as part of their analysis. The Helm (1977) model is incorporated into MODFLOW to calculate subsidence in both the Interbed Storage Package (Leake and

Prudic, 1991) and the Subsidence Package (Hoffman et al., 2003). Both Leake and Prudic (1991) and Hoffman et al. (2003) cite other examples of other studies that have utilized a similar approach for calculating subsidence.

6.7.2 Parameter Selection

The calculation of potential future land subsidence associated with the Project requires parameters for the change in groundwater levels (Δh) at historically low water levels and the characteristics of the compressible clay layers (m_f and S_{sk}). The parameters required for Equation 2 were developed based on the results of the KDWD Superposition Model, the USGS Textural Analysis and the CVHM subsidence parameters. For the analysis, subsidence is calculated for different depth intervals based on the model layers used in the KDWD Superposition Model Layers. Therefore, the parameters are developed separately for each model layer. The following summarizes the selection of parameters used for the subsidence impacts analysis.

6.7.2.1 Change in Water Levels

The specified change in groundwater levels (Δh) represents the Project-related water level declines during periods of historically low water levels. Historically low water levels typically occur during periods characterized by the following conditions:

- Period of extended severe drought
- Significant reduction in surface water deliveries for water supply
- Expanded groundwater pumping to compensate for reduced availability of surface water
- Increased pumping from groundwater banking projects

The Project-related water-level declines that occur when groundwater levels are below historic lows have the potential to contribute to inelastic land subsidence. However, a period with significant reductions in surface water supplies would correspond to periods with little to no availability of release water. Project-related water level declines are at their maximum during periods of high availability of release water, and are at their minimum during periods of little to no availability of release water. As a result, Project-related water-level declines that occur when groundwater levels are below historic lows will not be the maximum change, but tend towards the minimal change.

The KDWD Superposition Model was used to evaluate Project-level impacts over a 50-year period utilizing the 1997 – 2014 baseline period. During the 1997 to 2014, the late summer and fall of 2014 represents a period that meets the above listed conditions when historically low groundwater levels were observed in the Kern County Subbasin. Therefore, September 2014 represents the Project-related water level change during a period of historically low groundwater levels. To evaluate subsidence over a period of 50-years, the results for Scenario A, which repeats the 18-year period from 1997 to 2014 three times (**see Section 6.3**), is used. To extend the evaluation to at least 50 years, the simulated water levels for September 2014 during the third 18-year cycle of Scenario A, representing cumulative change in Project-related water levels after 54 years, are used for the subsidence impacts analysis.

For the analysis, the results from the KDWD Superposition Model were downloaded for every model grid cell for each of the four model layers. To illustrate the magnitude of Project-related water level changes used for the analysis, **Figure 6-23** provides a composite of the maximum groundwater level

change from all 4 model layers. The maximum water level decline that occurs during the period of historically low water levels ranges between 3 to 4 feet and is centered in northern NKWSD.

6.7.2.2 Thickness of Compacting Layers

For the subsidence impacts analysis, the aggregate thickness of the compacting layers (m*f*) is derived from the USGS Textural Analysis (Faunt et al., 2009) that was used in the development of the CVHM model (**see Section 5.3.3**). The USGS Textural Analysis uses a binary texture classification of either "coarse-grained" or "fine-grained" on the basis of the geologic log description. Coarse-grained sediments are defined as consisting of sand, gravel, pebbles, boulders, cobbles, or conglomerate, whereas fine-grained sediments are defined as consisting of clay, lime, loam, mud, or silt. Since not all fine-grained sediments tabulated for the textural analysis are highly compressible, the total fine-grained sediments from the USGS Textural Analysis is considered to overestimate the thickness of compressible fine-grained sediments.

The USGS Textural Analysis (Faunt et al., 2009) developed a total thickness of fine-grained deposits per square mile over the entire Study Area at 50-foot depth intervals. The aggregate thickness of fine-grained sediments (m*f*) was tabulated for each layer in the KDWD Superposition Model. The aggregate thickness for Model Layer 4 was limited to approximately the upper third (approximately 300 feet) of the layer, which is equivalent to CVHM Model Layer 8 (see **Appendix B** for definition of CVHM model layers). Since Project-related groundwater pumping is assigned to Model Layer 3 in the KDWD Superposition Model, water level change in Model Layer 4 is not considered to occur over the full thickness of the layer, and therefore, deeper clay layers would not experience a change in effective stress. This assumption is consistent with USGS analysis of extensometer data that shows that subsidence primarily occurs above the lowest level of pumping (Poland and Ireland, 1988, Bull and Poland, 1975, Lofgren and Klausing, 1969, and Ireland et al., 1984).

Figure 6-23 shows the spatial distribution of the total aggregate thickness of fine-grained sediments (m*f*) for all layers in the Northern Study Area. The distribution shows highest aggregate fine-grained sediment thicknesses along the Northern Study Area in Kings and Tulare Counties. In the southern NKWSD and COB area, the aggregate fine-grained sediment thicknesses are lower.

6.7.2.3 Skeletal Specific Storage

The skeletal specific storage (S_{sk}) characterizes the magnitude of compaction that will occur for each one-foot change in the effective stress per each foot of compressible sediment thickness. The S_{sk} can be variable for different sediment types depending on the grain size and depositional history of the layer. To be consistent with the USGS Textural Analysis data in CVHM, a single S_{sk} value of 1.37×10^{-4} ft^{-1} is used to represent the overall bulk character of the fine-grained sediments (Faunt et al., 2009). Lofgren and Klausing (1969) empirically derived a coefficient of volume compressibility (m_v) 1.1×10^{-4} ft^{-1} (m_v is equivalent to S_{sk}) from consolidation tests and other field data for a 760-foot borehole in Pixley for their evaluation of subsidence that covers parts of the Northern Study Area including the NKWSD area. The S_{sk} used for the CVHM (1.37×10^{-4} ft^{-1}) is consistent with the value Lofgren and Klausing (1969) derived empirically from field data; therefore, it provides the most reasonable and appropriate estimation of S_{sk} for use in the subsidence impacts analysis. .

6.7.3 Quantitative Analysis of Subsidence

For the quantitative analysis of subsidence, Equation 2 was calculated over the Study Area using a 500-foot grid spacing. The parameters for aggregate thickness of fine-grained sediments (m*f*) and the change in groundwater levels (*Δh*) at historically low water levels were interpolated from the input data sets to each grid node using the Golden Graphics Mapping Software Package *Surfer*™. The skeletal specific storage (S_{sk}) is a constant, applied uniformly for all grid nodes. Using *Surfer*™, the total compaction for each of the four model layers was calculated by multiplying the parameters (m*f*, S_{sk} and *Δh*) following Equation 2 at each grid node. The calculated total compaction for each model layer was summed at each grid cell using *Surfer*™ to calculate the total land subsidence.

Figure 6-24 shows the results of the quantitative analysis of subsidence as a contour map of the calculated total subsidence over the Northern Study Area. The results show an area with a total estimated subsidence of 0.1 feet (approximately 1.2 inches) over the northern and central areas of NKWSD and extending into adjacent areas. The highest total estimated subsidence of greater than 0.15 feet (1.8 inches) occurs over an area located in the northern NKWSD (**Figure 6-24**). The maximum calculated subsidence is 0.18 feet (2.2 inches).

In addition, **Figure 6-24** shows the total estimated subsidence contours along with the total aggregate thickness of fine-grained sediments to illustrate relative trends. The overall trends in total estimated land subsidence are consistent with the historical trends in subsidence in the region (see **Figures 4-17** and **4-18**). The northern extension of the -0.1-foot contour to the Kern County Line follows an area with a thicker aggregate fine-grained sediment thickness. The -0.1-foot contour does not extend as far to the south where the aggregate fine-grained sediment thickness is less.

The line of no change (zero contour line) for Project-related water levels is located about 3 miles north of the Kern River (**Figure 6-23**). South of the zero contour line, the simulated changes in water levels are positive indicating that the Project-related impacts result in higher water levels. Therefore, based on the results of the KDWD Superposition Model, areas south of the zero contour line would not experience additional land subsidence due to the Project-related impacts. Rather, in the Southern Study Area, the Project would reduce the overall magnitude of land subsidence that may occur during periods of historically low water levels by 1 to 4 inches.

6.7.4 Historical Analysis of Subsidence

As described in **Section 4.7**, groundwater extraction and associated water level declines historically have contributed to land subsidence throughout the Kern County Subbasin. Historical land subsidence of over 9 feet has occurred in the Southern Study Area, and over 10 feet of historical land subsidence has occurred along the Kern and Tulare county lines in the Northern Study Area (see **Figures 4-17** and **4-18**). Over the NKWSD, land subsidence varies from over 4 feet along the northern boundary to less than one foot in the southern portion. Historical land subsidence for the City of Bakersfield is generally less than one foot.

The potential ultimate subsidence associated with the Project (discussed above) is comparable to historical subsidence rates. Ireland et al. (1984) estimated subsidence of up to 5 feet along the northern boundary of the NKWSD Service Area prior to 1970 (see **Figures 4-17** and **4-18**). During the period 1945 - 1977, water level declines of about 10 feet per year in the Northern Study Area are associated with about 0.4 feet per year of subsidence. Actual local subsidence would depend on the occurrence of fine-

grained sediments and the relationship of the geology with the then-current water level. Lofgren and Klausing (1969) estimated subsidence along the Kern and Tulare County lines in the Northern Study Area as ranging from 0.15 to 0.4 feet per 10 feet of water level decline.

Applying these historical rates of subsidence in the Study Area to the Project-related water level declines during periods of historically low water levels (Δh) provides another means to estimate the potential total subsidence attributed to the Project. The maximum Δh from KDWD Superposition Model used for the subsidence impacts analysis (at historic low water levels) is 3.96 feet. Using the subsidence rate of 0.4 feet per 10 feet of water level decline, the maximum Δh produces a total subsidence of 0.16 feet (1.9 inches). This is consistent with the results of the quantitative analysis using Equation 2 and demonstrates that the results of Equation 2 are consistent with historical rates of subsidence measured in the Study Area.

6.7.5 Potential Infrastructure Impacts from Project-related Subsidence

Project-related water levels are expected to decline in areas north of the Kern River where release water will no longer be available. However, some of the largest short-term water level declines, which are primarily related to changes in surface recharge operations, would not contribute to land subsidence. Although the potential exists for up to 2.2 inches of land subsidence attributed to Project impacts in the Northern Study Area, adverse impacts from this magnitude of additional subsidence are unlikely. NKWSD has not reported infrastructure damage due to land subsidence even though recent subsidence greater than 2.2 inches has been documented in the district (NKWSD, 2012). The Project would raise water levels to minimize future land subsidence in the more-susceptible areas of the Southern Study Area.

6.8 GROUNDWATER QUALITY IMPACTS ANALYSIS

Groundwater quality within the Study Area has been designated for both agricultural and municipal beneficial uses (among others) and water quality degradation could lead to loss of some of these uses. Changes in water quality as a result of the Proposed Project may occur from two separate mechanisms:

- Changes to groundwater quality as a direct result of the Proposed Project, whereby less Kern River water is available for use in NKWSD and the City and is replaced by groundwater. The quality of these two waters differ, especially in total dissolved solids (TDS) or salts, resulting in changes in the loading of salts to the groundwater.
- Changes in the direction or rate of migration of existing water quality constituents already in the groundwater due to changes in the hydraulic gradient as a result of the Proposed Project.

The following provides a summary of the groundwater quality impacts analysis.

6.8.1 Salt Loading Analysis

Since the Proposed Project consists of reallocating water between different locations within the same groundwater subbasin, there is no overall effect to salt loading on a subbasin scale. However, water quality effects may occur on a more local scale. To assess the potential changes in salt loading associated with the Proposed Project for NKWSD and the City, a spreadsheet-based mass balance mixing model was developed.

The mixing model provides a representation of the natural system that assesses the effects of changes in the use of surface water and groundwater on water quality using a mass balance method. The mixing model represents the aquifer as a simplified system representing the volume of groundwater. Reasonable estimates for the primary inflows and outflows to groundwater including groundwater recharge, pumping, and return flows were made; however, as a conservative assumption, no subsurface inflows or outflows were incorporated into the models. The mass balance approach used in the mixing models estimates the change in salt loading due to the Proposed Project based on changes in water sources (with differing water quality) beneath the NKWSD and the City WSA. **Appendix F** provides additional documentation on the setup and application of the water quality mixing models.

For this analysis, a base case scenario without the Proposed Project, and a Proposed Project scenario were developed to assess the differences in salt loading and TDS concentrations due to the Proposed Project. The changes in the water balance due to the Proposed Project in NKWSD and the City include:

- Decreased surface water recharge at spreading basins and from canal losses leads to a reduction in the direct salt loading; however, loss of the relatively low TDS surface water recharge may lead to an overall increase in the TDS concentrations in groundwater.
- Increased groundwater pumping due to a decrease in the availability of surface water for irrigation use leads to higher direct removal of salts from groundwater thus increasing the salt removal from groundwater.
- Higher percentage of groundwater used for irrigation leads to an increase in groundwater return flows consisting of relatively high TDS concentrations that percolate back to groundwater thus increasing the salt loading. The percentage of return flows for agricultural irrigation in NKWSD was assumed to be 20 percent of applied irrigation water and 7.1 percent of urban water use for urban return flow in the City.
- In the City, the Proposed Project also includes increased surface water availability to the City that can be used in lieu of groundwater from wells for the City's water supply. Less pumping leads to more salt remaining in the aquifer.

The scenarios assess water quality changes over time by repeating the 1997 through 2014 Study Period conditions to evaluate water quality changes in groundwater for 10, 25 and 50 years. The results for the NKWSD and the City are presented in **Table 23**. Annual results of the mixing model analysis for the base case and Proposed Project scenarios for both NKWSD and the City are provided in **Appendix F**.

The mixing model results for NKWSD show that overall salt loading decreases over time by over 1,000 tons per year due to reduced loading from spreading basins and canal losses and increased removal by groundwater pumping. The TDS concentration does increase due to the loss of the dilution effects of adding low TDS concentration surface water at the spreading basins resulting in an average annual increase of 0.1 to 0.5 mg/L. The accumulated increase in TDS concentrations from 10 to 50 years vary between 4.4 to 6.4 mg/L.

Table 23. Summary of Results of Salt Loading Analysis from Mixing Model Analysis

Water Agency	10 Years	25 Years	50 Years
Salt Loading Analysis for North Kern WSD			
Average Annual Change in GW Pumping (AFY)	10,131	8,818	8,277
Average Annual Change in GW Return Flow (AFY)	2,026	1,764	1,655
Average Annual Change in SW Return Flow (AFY)	-2,026	-1,764	-1,655
Average Annual Change in Surface Spreading (AFY)	-11,481	-9,495	-9,140
Average Annual Change in Salt (TDS) Load (tons)	-1,366	-1,185	-1,065
Average Annual Change in TDS Concentration (mg/L)	0.47	0.26	0.09
Accumulated Change in TDS Concentration (mg/L)	4.7	6.4	4.4
Salt Loading Analysis for City of Bakersfield			
Average Annual Change in GW Pumping (AFY)	96	-593	-729
Average Annual Change in GW Return Flow (AFY)	7	-42	-52
Average Annual Change in SW Return Flow (AFY)	-7	42	52
Average Annual Change in Surface Spreading (AFY)	-1,770	-2,403	-2,374
Average Annual Change in TDS Load (tons)	-45	-31	-37
Average Annual Change in TDS Concentration (mg/L)	0.08	0.10	0.10
Accumulated Change in TDS Concentration (mg/L)	0.8	2.5	4.8

Note: GW = groundwater
SW = Surface water

The mixing model results for the City show a similar trend. There is an overall decrease in salt loading, but the change is smaller relative to the lower changes in the water balance due to the Proposed Project. The TDS concentration also shows a slight annual increase of about 0.1 mg/L due to the loss of the dilution effects of adding low TDS concentration surface water at the COB 2800 acre recharge facility. The accumulated change in TDS concentrations from 10 to 50 years shows an increasing trend from 0.8 to 4.8 mg/L.

6.8.2 Hydraulic Gradient Analysis for Migration of Constituents of Concern

Another potential water quality impact is changes in the direction or rate of migration of existing constituents of concern in groundwater due to changes in the hydraulic gradient as a result of the Proposed Project. **Section 4.8** provides information on several key water quality parameters (TDS, nitrates, and pesticides) and selected constituents of concern in the Study Area. **Figure 4-23** provides outlines of localized areas of constituents of concern in groundwater that occur in the northern portion of the City and the south portion of NKWSD.

The hydraulic gradient analysis relies on the modeling results with the KDWD Superposition Model. Results indicate that the Proposed Project would cause generally higher groundwater levels in the Southern Study Area and lower groundwater levels in the Northern Study Area. Therefore, the hydraulic gradients would increase from south to north. **Figures 6-1** through **6-4** illustrate changes in groundwater levels for 2007 and 2014. These results are superimposed onto the regional groundwater contour maps developed by KCWA (**Figures 6-2** and **6-5**) to provide groundwater contour maps for the Proposed Project (**Figures 6-3** and **6-6**). Inspection of these maps, and review of the hydrographs in **Appendices C**, **D** and **E**, indicate that the groundwater flow direction does not vary as a result of the Proposed Project.

Therefore, there is no predicted change in the direction of migration of the constituents of concern on **Figure 4-23** as a result of the Proposed Project.

The rate of migration of constituents of concern is affected by a variety of factors including chemical reactions, attenuation, dispersion, etc. However, the primary driving factor is the rate of groundwater flow or flow velocity. The rate of groundwater flow is derived from Darcy's Law and is typically expressed in the form of

$$v = \frac{K}{n}\frac{dh}{dx} \quad (3)$$

As shown in Equation 3, the rate of groundwater flow (*v*) is a function of the hydraulic conductivity (*K*), aquifer porosity (*n*) and the hydraulic gradient (*dh/dx*). Since K and n represent physical properties of the aquifer, these do not change as a result of the Project. As a result, the change in the rate of groundwater flow is directly proportional to the change in the hydraulic gradient. Furthermore, the hydraulic gradient (*dh/dx*) represents the change in groundwater level (*dh*) over a horizontal distance (*dx*). Therefore, if the change in groundwater levels is evaluated over the same distance, the change in the rate of groundwater flow is directly proportional to the change in groundwater levels.

The KDWD Superposition Model results (**Figures 6-1** and **6-4**) show that over the area of the constituents of concern on **Figure 4-23**, the change in groundwater levels ranges from 0 to 4 feet. Based on the regional groundwater contour maps developed by KCWA (**Figures 6-2** and **6-5**), the overall change in groundwater levels over this same area ranges from 100 to 150 feet. Based on this evaluation, the percentage change in the groundwater levels across the area of the constituents of concern (**Figure 4-23**) ranges from zero to four percent. Therefore, the rate of migration of the constituents of concern as a result of the Proposed Project may increase up to four percent. For example, if the rate of migration was 100 feet per year, under the Proposed Project, the rate of migration may increase to up to 104 feet per year.

6.9 GROUNDWATER IMPACTS ANALYSIS ASSUMING NO EQUILIBRATION

In compliance with the 2014 Order, an additional analytical assessment has been conducted to evaluate Project-related impacts on groundwater levels for the 1997-2007 Study Period. As required, the analysis assumes that groundwater levels cannot equilibrate in areas impacted by the Project. Specifically, the Order requires the impacts analysis to be:

> "*quantified and calculated on the alternative assumption that there will be no short-term and mid-term groundwater "equilibration" in the adversely affected area over the next 10, 25 and 50 years*".

In this context, *equilibration* refers to the foundational principle of Darcy's Law (Todd and Mays, 2004; Bear and Verruijt, 1987; Freeze and Cherry, 1979; Bouwer, 1978) that governs groundwater flow and the changing groundwater flow patterns associated with changes in stresses in the aquifer. An analysis without equilibration simply assumes that the impacted area is not connected to the remainder of the groundwater basin and that no subsurface inflow and outflow will be allowed to occur conceptually. The non-equilibration analysis provides an overall water balance consistent with the Law of Conservation of Mass, but does not consider groundwater flow governed by Darcy's Law. A non-

equilibration or water balance approach is a commonly-applied technique for groundwater assessments where the primary issue is volumetric analysis.

This non-equilibration approach limits the evaluation of Project-related impacts from affecting any location other than where the Project-related changes are applied (primarily in NKWSD, the City, and KDWD). For example, the assumption behind "non-equilibration" automatically precludes any of the impacts occurring in NKWSD or the City from affecting adjacent water districts such as SWID, CWD, or SWSD.

This analysis builds on the 2011 Impacts Assessment and extends that analysis into the future for 10, 25, and 50 years, while not allowing the groundwater system to equilibrate. Background on the 2011 assessment and the methodology, results, and limitations for this analysis are described below.

6.9.1 Background

The 2011 Impacts Assessment employed an analytical water-balance methodology for estimating Project-related impacts to local water levels on a monthly basis for the 1997-2007 Study Period. Although the analysis quantified impacts associated with specific actions for each month in the Study Period, the static nature of the analysis prevented a quantitative assessment of how the monthly impacts accumulated over time because the analysis made the conservative assumption to not include subsurface inflows and outflows from outside the localized impact area. In other words, the dynamic nature of subsurface inflow and outflow along the boundaries of locally impacted areas was not quantified in the analysis.

The analysis recognized that groundwater is almost always in constant motion, even though groundwater flow velocities are relatively small (generally, feet per day to feet per year). Further, it was recognized that changes in hydraulic gradients would induce more subsurface inflow into adversely impacted areas and "equilibrate" the Project-related lowering of groundwater levels over time. Because this process was known to occur, the monthly groundwater impacts were not strictly additive over time. Nonetheless, the analysis was not designed to quantify how much and how quickly lowered water levels would recover. That deficiency has now been remedied by the development and application of the KDWD Superposition Model, as documented in previous sections of this report. Even though Project opponents recognized that some equilibration would occur in the Kern County Subbasin over time (GEI, 2012), this impacts analysis without equilibration is conducted to comply with requirements in the 2014 Order.

6.9.2 Potential Project-Related Groundwater Level Impacts if No Equilibration

The analysis begins with the detailed monthly impacts to water levels that had been conducted for the 2011 Impacts Assessment (Todd, 2011b). Those impacts were presented on an annual basis in the 2011 Impacts Assessment (as Table 6 in that document) and are reproduced here as **Table 24** for reference. As shown on the **Table 24**, a quantitative assessment of Project-related changes to water levels (depth to groundwater) was conducted for each discrete area where impacts were estimated to occur. These impacted areas are almost identical to those established in the KDWD Superposition Model[15] (see **Section 5.5**). Impacted areas within KDWD (higher water levels), the City, and NKWSD are shown in

[15] Impact areas were discretized in more detail in the KDWD Superposition Model than in the 2011 Impacts Assessment due to the added flexibility associated with a numerical modeling tool.

columns on the left (column 1-6), center (columns 7-14), and right (columns 15-17) portions of the table, respectively (**Table 24**). Columns 10-14 combine the net effects of the Project on areas where KDWD and the City WSA overlap.

The non-equilibration assessment assumes that the local areas where impacts occur are not connected to surrounding groundwater and that the Project-related changes in depth to groundwater persist from year to year and are additive over time[16]. This approach ignores any inflow into the area of each impact component, as if each were surrounded by impermeable walls extending to the base of the aquifer and, conceptually creates a depression or "hole" in the groundwater surface beneath NKWSD (something that would not occur naturally in the groundwater system). Impacts are extended over a 50 year period by repeating the 1997-2007 conditions (representing average hydrologic conditions with wet and drought cycles) five times. The changes predicted for each year in this period were added to the changes from the previous years to present an estimate of the accumulated changes for each component 50 years into the future.

The accumulated non-equilibration change in water levels is shown for every year of the 50 year period in **Table 25**. In addition to the predicted groundwater elevation changes by component, **Table 25**[17] also includes estimates of total changes distributed over the entire areas of KDWD, the City, and NKWSD. These additional assessments assume that groundwater level changes are distributed across each service area, thus reducing the uncertainty of exactly where each "hole" would occur. Impacts are also presented as accumulated changes without any short or long term equilibration. Results for Years 10, 25 and 50 are highlighted on the table. As shown, the accumulated impacts for NKWSD are lowered water levels of -15.5 feet, -39.3 feet, and -77.3 feet for Years 10, 25, and 50, respectively. Accumulated impacts for the City are lowered water levels of -10.4 feet, -26.1 feet, and -52 feet for Years 10, 25, and 50, respectively. Finally, accumulated impacts for KDWD are higher water levels of 13 feet, 33.7 feet, and 65.1 feet for Years 10, 25, and 50, respectively (**Table 25**).

6.9.3 Potential Project-Related Subsidence Impacts if No Equilibration

As required by the 2014 Order, a theoretical condition (defined as non-equilibration in the previous section) is also considered for the land subsidence analysis. Based on the definition of non-equilibration, the analysis assumes that there is no subsurface inflow or outflow at the local area of groundwater impact beneath NKWSD and the City. As discussed in the analysis of water levels without allowing the groundwater to equilibrate (see **Section 6.5** above), water levels would be theoretically lowered about -52 feet and -77 feet beneath the City and NKWSD, respectively (**Table 25**).

Although the magnitude of water level impacts for the non-equilibration analysis are not as large as the historic long-term decline in the Northern Study Area (-150 feet to -250 feet, see **Section 4.7.1**), the application of the long-term rate of land subsidence during that time period (0.04 feet per year to 0.4 feet per year) would provide a potential conservative estimate. For a 50-year period, land subsidence for a theoretical non-equilibration estimation may range between 2 feet and 20 feet. Due to the coarse-grained nature of the sediments, historical subsidence of more than about 1 foot has not been documented beneath the City. Given the magnitude of previous water level declines (-150 feet) associated with historical subsidence compared to the estimate from the non-equilibration analysis (-52

[16] Project opponents acknowledge that the results were not strictly additive (see page 4 item 2) (GEI, 2012).

[17] The total area of impacts was estimated in GIS, includes areas around spreading basins, and is slightly larger than the area of irrigated acreage reported by NKWSD.

feet beneath the City and -77 feet beneath NKWSD), additional Project-related subsidence would not be expected to be larger than 1 foot. Consistent with the assumptions of the no-equilibration analysis, land subsidence could not occur outside of the areas of NKWSD and the City because such an analysis concentrates all of the impacts in NKWSD and the City and does not allow impacts to migrate away from these areas.

6.9.4 Potential Project-Related Water Quality Impacts if No Equilibration

The evaluation of groundwater quality impacts in **Section 6.8.1** does not consider groundwater inflow and outflows in the mixing model analysis; therefore, those results in **Section 6.8.1** are representative of groundwater quality impacts under the no-equilibration condition. Under the no-equilibration condition, the hydraulic gradient analysis does not apply since there is no consideration of the movement of groundwater.

6.9.5 Limitations of Non-Equilibration Analysis

The no equilibration analysis is academic and theoretical. The nature of the analysis results in impacts that are over-estimated in some areas (NKWSD and the City) while under-estimating impacts in other areas (other areas in the Northern Study Area). It must be emphasized that the analysis is theoretical and violates the principles of groundwater flow in the subbasin. Conceptually, such an analysis assumes that there are impenetrable walls surrounding the adversely-impacted zones in NKWSD and the City, and that these areas are not hydraulically connected to the surrounding groundwater basin. Although investigators have documented local impedances such as geologic faults and shallow perched water in some portions of the subbasin, no investigator has concluded that such occurrences prevent subsurface inflow or outflow across the surface boundaries of NKWSD or the City. To the contrary, as demonstrated by the KDWD Superposition Model (**Sections 5** and **6**), and by analyses from the USGS, DWR, KCWA, and local water agencies including NKWSD and the City, groundwater throughout the Study Area is hydraulically connected and in motion under hydraulic gradients – a concept that cannot be incorporated in a static analysis with “no equilibration.”

Nonetheless, such theoretical, conservative assumptions can be useful in applications to a groundwater impacts analysis. For example, the conservative nature of this analysis might be of assistance to the quantification of impacts if the accumulated impacts over the 50-year period were relatively minor. It could then be concluded that impacts analyzed with less conservative assumptions would be less than results from the more conservative one, making additional quantitative analysis unnecessary. Accordingly, such a conservative methodology is considered and modified slightly for the analysis of Project-related impacts on groundwater quality (**Section 6.8**). In addition, the concept of non-equilibration of the groundwater system is considered in the analysis of potential land subsidence as discussed in **Section 6.9.3**.

Table 24. Potential Groundwater Impacts from 2011 Impacts Assessment

Modified Water Year (June 1 through May 31)	Potential Groundwater Depth Change within KDWD, feet						Potential Groundwater Depth Change within City, feet			Potential Groundwater Depth Change where KDWD and City Overlap, feet					Potential Groundwater Depth Change within NKWSD, feet		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	KDWD Service Area	KDWD Canal Spreading Areas	KDWD Basin Spreading Areas	KDWD Service Area and Canal Spreading Areas Overlap	KDWD Service Area and Basin Spreading Areas Overlap	KDWD Service Area, Canal Spreading Areas, and Basin Spreading Areas Overlap	City Water Service Area	City 2800-acre Spreading Areas	City Water System Area and 2800-acre Spreading Area Overlap	KDWD and City Water System Areas Overlap	KDWD and City Water System Areas and KDWD Basin Spreading Areas Overlap	City Water Service Area and KDWD Canal Spreading Areas Overlap	KDWD and City Water System Areas and KDWD Canal Spreading Areas Overlap	KDWD and City Water System Areas and KDWD Basin and Canal Spreading Areas Overlap	NKWSD Basin Spreading Areas	NKWSD Class II Agricultural Areas	NKWSD Basin Spreading and Class II Agricultural Areas Overlap
1998	0.89	1.89	16.31	2.78	17.20	19.09	-0.13	-0.22	-0.34	0.77	17.07	1.77	2.66	18.97	-10.70	-1.36	-12.06
1999	1.49	0	11.74	0	13.23	0	-2.88	-0.13	-3.01	-1.39	10.35	0	0	0	-1.18	-1.60	-2.78
2000	0.38	0	4.12	0	4.50	0	-0.67	0	0	-0.29	3.83	0	0	0	-0.52	-2.57	-3.09
2001	0.63	0	3.14	0	3.77	0	-0.88	0	0	-0.25	2.89	0	0	0	0	-1.93	0
2002	0.54	0	1.27	0	1.81	0	-0.60	0	0	-0.06	1.21	0	0	0	0	-3.16	0
2003	0.53	0	2.94	0	3.46	0	-0.66	0	0	-0.13	2.80	0	0	0	0	-2.86	0
2004	0.31	0	2.51	0	2.81	0	-0.39	0	0	-0.08	2.42	0	0	0	-1.13	-2.34	-3.47
2005	0.69	1.86	6.21	2.55	6.91	8.77	-1.80	-1.31	-3.11	-1.11	5.11	0.06	0.75	6.96	-8.33	0	0
2006	0.81	0.59	7.82	1.40	8.63	9.22	-0.25	-1.02	-1.27	0.56	8.38	0.34	1.15	8.97	-3.32	-2.81	-6.13
2007	0.70	0	1.22	0	1.92	0	-0.60	0	0	0.10	1.33	0	0	0	-2.22	-1.76	-3.98
Average	**0.70**	**0.43**	**5.73**	**0.67**	**6.43**	**3.71**	**-0.89**	**-0.27**	**-0.77**	**-0.19**	**5.54**	**0.22**	**0.46**	**3.49**	**-2.74**	**-2.04**	**-3.15**

From Todd, 2011 Table 6

Table 25. Potential Accumulated Groundwater Level Impacts Assuming No Equilibration

Year	Potential Groundwater Depth Change within KDWD, feet							Potential Groundwater Depth Change within City, feet				Potential Groundwater Depth Change within KDWD and City Overlap, feet					Potential Groundwater Depth Change within NKWSD, feet			
	KDWD Service Area	KDWD Canal Spreading Areas	KDWD Basin Spreading Areas	KDWD Service Area and Canal Spreading Areas Overlap	KDWD Service Area and Basin Spreading Areas Overlap	KDWD Service Area, Canal Spreading Areas, and Basin Spreading Areas Overlap	Total KDWD Groundwater Change	City Water Service Area	City 2800-acre Spreading Areas	City Water System Area and 2800-acre Spreading Area Overlap	Total City Groundwater Change	KDWD and City Water System Areas Overlap	KDWD and City Water System Areas and KDWD Basin Spreading Areas Overlap	City Water Service Area and KDWD Canal Spreading Areas Overlap	KDWD and City Water System Areas and KDWD Canal Spreading Areas Overlap	KDWD and City Water System Areas and KDWD Basin and Canal Spreading Areas Overlap	NKWSD Basin Spreading Areas	NKWSD Class II Agricultural Areas	NKWSD Basin Spreading and Class II Agricultural Areas Overlap	Total NKWSD Groundwater Change
Average Area (acres)	**128,756**	**1,757**	**12,848**	**2,919**	**7,156**	**410**	**128,756**	**25,535**	**6,778**	**2,508**	**25,535**	**3,675**	**226**	**407**	**277**	**27**	**7,954**	**29,331**	**2,126**	**72,898**
1	0.9	1.9	16.3	2.8	17.2	19.1	2.7	-0.1	-0.2	-0.3	-0.3	0.8	17.1	1.8	2.7	19.0	-10.7	-1.4	-12.1	-2.8
2	2.4	1.9	28.0	2.8	30.4	19.1	5.3	-3.0	-0.3	-3.3	-3.2	-0.6	27.4	1.8	2.7	19.0	-11.9	-3.0	-14.8	-5.2
3	2.8	1.9	32.2	2.8	34.9	19.1	6.1	-3.7	-0.3	-3.3	-3.9	-0.9	31.3	1.8	2.7	19.0	-12.4	-5.5	-17.9	-6.4
4	3.4	1.9	35.3	2.8	38.7	19.1	7.1	-4.6	-0.3	-3.3	-4.8	-1.2	34.1	1.8	2.7	19.0	-12.4	-7.5	-17.9	-7.1
5	3.9	1.9	36.6	2.8	40.5	19.1	7.7	-5.2	-0.3	-3.3	-5.4	-1.2	35.4	1.8	2.7	19.0	-12.4	-10.6	-17.9	-8.4
6	4.5	1.9	39.5	2.8	44.0	19.1	8.5	-5.8	-0.3	-3.3	-6.0	-1.4	38.2	1.8	2.7	19.0	-12.4	-13.5	-17.9	-9.6
7	4.8	1.9	42.0	2.8	46.8	19.1	9.1	-6.2	-0.3	-3.3	-6.4	-1.4	40.6	1.8	2.7	19.0	-13.5	-15.8	-21.4	-10.8
8	5.5	3.8	48.2	5.3	53.7	27.9	10.6	-8.0	-1.7	-6.5	-9.0	-2.5	45.7	1.8	3.4	25.9	-21.9	-15.8	-21.4	-12.4
9	6.3	4.3	56.1	6.7	62.3	37.1	12.2	-8.3	-2.7	-7.7	-9.8	-2.0	54.1	2.2	4.6	34.9	-25.2	-18.6	-27.5	-14.3
10	**7.0**	**4.3**	**57.3**	**6.7**	**64.3**	**37.1**	**13.0**	**-8.9**	**-2.7**	**-7.7**	**-10.4**	**-1.9**	**55.4**	**2.2**	**4.6**	**34.9**	**-27.4**	**-20.4**	**-31.5**	**-15.5**
11	7.9	6.2	73.6	9.5	81.4	56.2	15.7	-9.0	-2.9	-8.1	-10.6	-1.1	72.5	3.9	7.2	53.9	-38.1	-21.8	-43.6	-18.2
12	9.4	6.2	85.3	9.5	94.7	56.2	18.3	-11.9	-3.0	-11.1	-13.6	-2.5	82.8	3.9	7.2	53.9	-39.3	-23.4	-46.4	-20.7
13	9.7	6.2	89.4	9.5	99.2	56.2	19.1	-12.5	-3.0	-11.1	-14.3	-2.8	86.6	3.9	7.2	53.9	-39.8	-25.9	-49.4	-21.8
14	10.4	6.2	92.6	9.5	103.0	56.2	20.1	-13.4	-3.0	-11.1	-15.1	-3.0	89.5	3.9	7.2	53.9	-39.8	-27.9	-49.4	-22.6
15	10.9	6.2	93.9	9.5	104.8	56.2	20.7	-14.0	-3.0	-11.1	-15.7	-3.1	90.7	3.9	7.2	53.9	-39.8	-31.0	-49.4	-23.9
16	11.4	6.2	96.8	9.5	108.2	56.2	21.5	-14.7	-3.0	-11.1	-16.4	-3.2	93.6	3.9	7.2	53.9	-39.8	-33.9	-49.4	-25.0
17	11.7	6.2	99.3	9.5	111.0	56.2	22.1	-15.1	-3.0	-11.1	-16.8	-3.3	96.0	3.9	7.2	53.9	-40.9	-36.2	-52.9	-26.2
18	12.4	8.1	105.5	12.1	117.9	64.9	23.6	-16.9	-4.3	-14.2	-19.4	-4.4	101.1	4.0	8.0	60.8	-49.3	-36.2	-52.9	-27.9
19	13.2	8.7	113.3	13.5	126.6	74.2	25.2	-17.1	-5.3	-15.5	-20.2	-3.9	109.5	4.3	9.1	69.8	-52.6	-39.0	-59.0	-29.7
20	14.0	8.7	114.5	13.5	128.5	74.2	26.0	-17.7	-5.3	-15.5	-20.8	-3.8	110.8	4.3	9.1	69.8	-54.8	-40.8	-63.0	-30.9
21	14.8	10.6	130.9	16.3	145.7	93.2	28.7	-17.8	-5.6	-15.8	-21.0	-3.0	127.9	6.1	11.8	88.8	-65.5	-42.1	-75.1	-33.7
22	16.3	10.6	142.6	16.3	158.9	93.2	31.3	-20.7	-5.7	-18.8	-24.0	-4.4	138.2	6.1	11.8	88.8	-66.7	-43.7	-77.9	-36.1
23	16.7	10.6	146.7	16.3	163.4	93.2	32.1	-21.4	-5.7	-18.8	-24.7	-4.7	142.0	6.1	11.8	88.8	-67.2	-46.3	-81.0	-37.3
24	17.3	10.6	149.9	16.3	167.2	93.2	33.1	-22.3	-5.7	-18.8	-25.5	-4.9	144.9	6.1	11.8	88.8	-67.2	-48.2	-81.0	-38.1
25	**17.9**	**10.6**	**151.1**	**16.3**	**169.0**	**93.2**	**33.7**	**-22.9**	**-5.7**	**-18.8**	**-26.1**	**-5.0**	**146.1**	**6.1**	**11.8**	**88.8**	**-67.2**	**-51.4**	**-81.0**	**-39.3**
26	18.4	10.6	154.1	16.3	172.5	93.2	34.6	-23.5	-5.7	-18.8	-26.8	-5.1	148.9	6.1	11.8	88.8	-67.2	-54.3	-81.0	-40.5
27	18.7	10.6	156.6	16.3	175.3	93.2	35.1	-23.9	-5.7	-18.8	-27.2	-5.2	151.4	6.1	11.8	88.8	-68.3	-56.6	-84.4	-41.7
28	19.4	12.4	162.8	18.8	182.2	102.0	36.6	-25.7	-7.0	-21.9	-29.8	-6.3	156.5	6.2	12.5	95.7	-76.7	-56.6	-84.4	-43.3
29	20.2	13.0	170.6	20.2	190.8	111.2	38.2	-26.0	-8.0	-23.2	-30.6	-5.7	164.9	6.5	13.7	104.7	-80.0	-59.4	-90.6	-45.2
30	20.9	13.0	171.8	20.2	192.8	111.2	39.0	-26.6	-8.0	-23.2	-31.2	-5.6	166.2	6.5	13.7	104.7	-82.2	-61.2	-94.5	-46.4
31	21.8	14.9	188.1	23.0	209.9	130.3	41.7	-26.7	-8.2	-23.5	-31.4	-4.9	183.3	8.3	16.3	123.7	-92.9	-62.5	-106.6	-49.1
32	23.3	14.9	199.9	23.0	223.2	130.3	44.3	-29.6	-8.4	-26.5	-34.4	-6.3	193.6	8.3	16.3	123.7	-94.1	-64.1	-109.4	-51.6
33	23.7	14.9	204.0	23.0	227.7	130.3	45.1	-30.2	-8.4	-26.5	-35.1	-6.6	197.4	8.3	16.3	123.7	-94.6	-66.7	-112.5	-52.7
34	24.3	14.9	207.1	23.0	231.5	130.3	46.1	-31.1	-8.4	-26.5	-35.9	-6.8	200.3	8.3	16.3	123.7	-94.6	-68.6	-112.5	-53.5
35	24.9	14.9	208.4	23.0	233.3	130.3	46.8	-31.7	-8.4	-26.5	-36.5	-6.9	201.5	8.3	16.3	123.7	-94.6	-71.8	-112.5	-54.8
36	25.4	14.9	211.3	23.0	236.7	130.3	47.6	-32.4	-8.4	-26.5	-37.2	-7.0	204.3	8.3	16.3	123.7	-94.6	-74.7	-112.5	-55.9
37	25.7	14.9	213.8	23.0	239.5	130.3	48.1	-32.8	-8.4	-26.5	-37.6	-7.1	206.8	8.3	16.3	123.7	-95.7	-77.0	-115.9	-57.1
38	26.4	16.8	220.1	25.6	246.4	139.1	49.6	-34.6	-9.7	-29.6	-40.2	-8.2	211.9	8.3	17.1	130.6	-104.1	-77.0	-115.9	-58.8
39	27.2	17.4	227.9	27.0	255.1	148.3	51.2	-34.8	-10.7	-30.9	-41.0	-7.6	220.2	8.7	18.2	139.6	-107.4	-79.8	-122.1	-60.6
40	27.9	17.4	229.1	27.0	257.0	148.3	52.0	-35.4	-10.7	-30.9	-41.6	-7.5	221.6	8.7	18.2	139.6	-109.6	-81.6	-126.0	-61.8
41	28.8	19.3	245.4	29.7	274.2	167.4	54.7	-35.6	-10.9	-31.3	-41.8	-6.8	238.6	10.4	20.9	158.6	-120.3	-82.9	-138.1	-64.6
42	30.3	19.3	257.1	29.7	287.4	167.4	57.3	-38.4	-11.0	-34.3	-44.8	-8.1	249.0	10.4	20.9	158.6	-121.5	-84.5	-140.9	-67.0
43	30.7	19.3	261.3	29.7	291.9	167.4	58.1	-39.1	-11.0	-34.3	-45.4	-8.4	252.8	10.4	20.9	158.6	-122.0	-87.1	-144.0	-68.2
44	31.3	19.3	264.4	29.7	295.7	167.4	59.1	-40.0	-11.0	-34.3	-46.3	-8.7	255.7	10.4	20.9	158.6	-122.0	-89.0	-144.0	-69.0
45	31.8	19.3	265.7	29.7	297.5	167.4	59.8	-40.6	-11.0	-34.3	-46.9	-8.7	256.9	10.4	20.9	158.6	-122.0	-92.2	-144.0	-70.2
46	32.4	19.3	268.6	29.7	301.0	167.4	60.6	-41.2	-11.0	-34.3	-47.6	-8.9	259.7	10.4	20.9	158.6	-122.0	-95.1	-144.0	-71.4
47	32.7	19.3	271.1	29.7	303.8	167.4	61.1	-41.6	-11.0	-34.3	-48.0	-9.0	262.2	10.4	20.9	158.6	-123.1	-97.4	-147.4	-72.6
48	33.4	21.1	277.3	32.3	310.7	176.2	62.6	-43.4	-12.3	-37.4	-50.6	-10.1	267.3	10.5	21.7	165.5	-131.5	-97.4	-147.4	-74.2
49	34.2	21.7	285.2	33.7	319.3	185.4	64.2	-43.7	-13.4	-38.6	-51.4	-9.5	275.6	10.8	22.8	174.5	-134.8	-100.2	-153.6	-76.1
50	**34.9**	**21.7**	**286.4**	**33.7**	**321.3**	**185.4**	**65.1**	**-44.3**	**-13.4**	**-38.6**	**-52.0**	**-9.4**	**277.0**	**10.8**	**22.8**	**174.5**	**-137.0**	**-102.0**	**-157.6**	**-77.3**

7 IMPACTS CONCLUSIONS AND GROUNDWATER MONITORING

The impacts to the groundwater system as a result of the implementation of the KDWD WAP involve less recharge and more groundwater pumping north of the river and immediately south of the river accompanied by an equivalent amount of more recharge and less groundwater pumping south of the river. Specific conclusions from the impacts analysis are summarized below. Groundwater monitoring programs that will continue to provide information on the local groundwater resources are also summarized.

7.1 IMPACTS CONCLUSIONS

Based on the analysis, the following conclusions are made regarding impacts from implementation of the KDWD WAP:

- Long-term operation of the Proposed Project over a 50-year period lowers water levels beneath NKWSD and SWID – approximately -2 to -3 feet lower, spatially averaged over their service areas. Project-related water levels are lower than non-Project levels by an average of about -1 foot beneath SWSD (**Table 17**). Long-term Project-related water levels rise beneath the City of Bakersfield about 3 to 4 feet, on average.

- Spatially averaged maximum water level declines in any given month throughout the Study Periods (Scenarios A and B) are -13 feet lower beneath NKWSD (see Scenario A, **Table 17**) and -8 feet lower beneath the City of Bakersfield WSA (see Scenarios A and B on **Table 17**).

- Project-related impacts on water levels are within the magnitude of seasonal fluctuations (compare project-related changes to fluctuations on hydrographs in **Appendix C**). An examination of several hundred hydrographs indicates that the magnitude of the impacts is small compared to the variability in the observed water level data over the Combined Study Period (1997-2014) (e.g., **Figures 6-12a** through **6-12k**; see also **Appendix C**).

- Project-related impacts are larger during wet periods when more water has been released and regional water levels are rising. Impacts during dry periods are much less due to limited availability of Project-related release water.

- The larger Project-related impacts to water levels (localized declines of more than about -15 feet) occur over small areas around spreading basins and canals (Model Layer 1) or at pumping centers during wet periods when large amounts of release water are assumed to be replaced with groundwater (Model Layer 3). Declines around spreading basins can reduce local mounding by more than about -15 feet. Declines from pumping can spike to about -15 feet in some areas. These declines typically last a few months, followed by a recovery to the long-term average Project-related impact of -2 to -3 feet under NKSWD (where the greatest impacts occur).

- Regional groundwater flow will not change significantly due to the Project-related redistribution of water (**Figures 6-3** and **6-6**). Because the Proposed Project creates higher water levels south

of the river, changing hydraulic gradients allows more water to flow from beneath the river to the north, partially mitigating Project-related impacts in that area.

- The overall water budget for the groundwater system is not impacted substantially; impacts result from a redistribution of groundwater in storage from north to south (see **Table 18**) with no significant net change in groundwater volume in the subbasin. Impacts are minor compared to the overall groundwater in storage. Project-related changes to groundwater in storage indicate a minor net benefit associated with the capacity to capture additional subsurface inflow in the subbasin.

- Even though the overall groundwater in storage in the subbasin is not adversely impacted by the Proposed Project, groundwater in storage is reduced locally beneath NKWSD (see **Tables B-5** and **B-7**, **Appendix B**).

- The rate of decline of groundwater in storage in the Northern Study Area gradually decreases over time as subsurface flows into the area increase. After 50 years, the modeling results indicate that the long-term rate of change to groundwater in storage shifts from a decreasing to a slight increasing trend; however, the cumulative loss of groundwater in storage from the earlier time periods would remain (see summaries at bottom of Annual Storage Change column in **Tables B-5** and **B-7** in **Appendix B** for total storage change at 10, 25 and 50 years).

- KDWD's use of the release water under the Proposed Project raises water levels locally (by replacing groundwater pumping) and adds to groundwater in storage south of the river. This allows for partial alleviation of local overdraft conditions beneath KDWD (see **Table 13** for estimated overdraft in Subregion 21 shown on **Figure 4-15**).

- A theoretical analysis of Project-related impacts to groundwater resources was conducted in compliance with the 2014 Order, assuming no subsurface inflows or outflows beneath impacted areas (no equilibration of the groundwater system). That analysis concludes that water levels beneath NKWSD would be lowered by about -77 feet and water levels beneath the City of Bakersfield would be lowered by about -52 feet after 50 years of Proposed Project operation. Consistent with the theoretical nature of the analysis, impacts occur in a small area beneath NKWSD; because the concept of lateral groundwater flow is excluded under the assumption of non-equilibration, impacts do not extend beyond the NKWSD or City of Bakersfield boundaries.

- Project-related impacts relating to potential land subsidence were calculated using a one-dimensional mathematical model of vertical compaction, which has been used by the USGS and other investigators in the Central Valley. The analysis calculated Project-related subsidence impacts when water levels would be representative of historic low levels (September 2014) during the modeled time period. The 18-year Combined Study Period (1997-2014) was repeated three times (Scenario A) resulting in a cumulative change in Project-related subsidence impacts after 54 years. The conservative one-dimensional analysis suggested a potential Project-related impact of up to 2.2 inches of land subsidence in NKWSD. This impact is considered small; larger magnitudes of land subsidence were not reported to have resulted in local infrastructure problems in NKWSD.

- Using a conservative mixing model approach, water quality impacts as a result of the Proposed Project are small. The NKWSD mixing model indicates a slight rise in TDS concentrations of about 4.7 mg/L after 10 years and about 6.4 mg/L after 25 years of Proposed Project operation. At the end of the 50- year analysis, TDS concentrations are about 4.4 mg/L higher. The annual maximum increase of 6.88 mg/L occurs in Year 27 (see **Table F-2**, **Appendix F**). This increase of up to 6.88 mg/L beneath NKWSD is small compared to typical TDS concentrations of 250 mg/L or higher. The City of Bakersfield mixing model also indicates a slight rise in groundwater TDS concentrations of 1 mg/L and 2.5 mg/L after 10 and 25 years, respectively and a rise of 4.8 mg/L at the end of 50 years (**Table 23**; see also **Appendix F**).

7.2 MONITORING PROGRAMS

Over the last decade, regional and local groundwater monitoring programs have been substantially expanded. Numerous agencies in the Northern Study Area have developed monitoring programs and have documented protocols in their groundwater management plans (KDWD, 2012; SWSD, 2012; P&P, 2012; P&P, 2014; CWD, 2007). In addition, KCWA and other governmental agencies are improving monitoring protocols and data management. In particular, DWR has developed new online tools and information websites for groundwater resources.

Much of this recent activity is in response to 2014 legislation referred to as the Sustainable Groundwater Management Act (SGMA). This legislation requires, among other things, development of Groundwater Sustainability Agencies (GSAs) and Groundwater Sustainability Plans (GSP). These requirements involve regional and state-wide coordination on numerous groundwater activities including evaluations of sustainability indicators. Many agencies are bolstering their groundwater data sets to provide sufficient monitoring information on these indicators, which include: groundwater levels and storage, groundwater quality, land subsidence, and surface water-groundwater interaction[18]. Monitoring programs that address these important components of groundwater resources are summarized below.

7.2.1 Monitoring Programs for Water Levels and Storage

As discussed previously, water levels have been recorded in the Kern County Subbasin since at least the 1920s and maintained in regional databases by KCWA and DWR. However, much of these historical data are associated with significant data gaps in how data were collected, where wells are located, and how wells are constructed/operated. In addition, previous monitoring programs were voluntary and data may not be available for public review and use.

Water level data provide the foundational data sets for monitoring changes in storage. Additional monitoring data useful in storage calculations are the groundwater elevation contour maps available from KCWA, DWR, and others. Key water level monitoring programs are summarized below.

7.2.1.1 CASGEM Program

In 2009, the State adopted legislation that establishes a California Statewide Groundwater Elevation Monitoring (CASGEM) program. As part of this program, local agencies are required to develop and implement a local water level monitoring program, approved by DWR, and submit data to an online

[18] The six Sustainability Indicators defined by SGMA are combined and shortened here for simplicity. The reader is referred to http://groundwater.ca.gov/ for more information on sustainability indicators and SGMA.

statewide data system. Local agencies with groundwater authority can elect to become an individual Monitoring Entity or cooperate with other local agencies to form an association to serve as a Monitoring Entity. According to the DWR website, the local agencies listed on **Table 26** are designated Monitoring Entities for the Kern County Subbasin and submit water level data to DWR (most recent submittal March, 2016) (DWR, 2016b).

Table 26. CASGEM Monitoring Entities in the Kern County Subbasin

Monitoring Entity	Associated Well Count	Authority
North Kern Water Storage District	9	Local Agency Pursuant to WC Part 2.75
Semitropic Water Storage District	46	Local Agency Pursuant to WC Part 2.75
Cawelo Water District	7	Groundwater Management Agency
Shafter-Wasco Irrigation District	8	Local Agency Pursuant to WC Part 2.75
Kern-Tulare Water District	18	Local Agency Pursuant to IRWM
Deer Creek & Tule River Authority	3	Local Agency Pursuant to WC Part 2.75
KCWA Improvement District No. 4	5	Local Agency Pursuant to WC Part 2.75
Kern River Fan Group[1]	34	Voluntary Cooperative Groundwater Monitoring Association
Kern Water Bank Authority[2]	15	Voluntary Cooperative Groundwater Monitoring Association
West Kern Water District	2	Local Agency Pursuant to WC Part 2.75
Arvin-Edison Water Storage District	41	Groundwater Management Agency

[1]-Includes Kern Delta Water District, Rosedale Rio-Bravo WSD, and Buena Vista WSD
[2]- Kern Water Bank Authority Project Participants

7.2.1.2 Project-related Groundwater Monitoring Committees

Two subregional groups have been formed to provide local groundwater monitoring data and evaluations for two large groundwater banking projects. The Kern Fan Monitoring Committee and the Semitropic Groundwater Monitoring Committee allow Project Participants and local entities that may be impacted to collect and review monitoring data to assist in guiding operations of the banking projects. Both committees coordinate data collection and management and produce biennial reports.

7.2.2 Groundwater Quality Monitoring Programs

Groundwater quality monitoring is conducted and/or compiled in the Kern County Subbasin by various entities for numerous purposes and include:

- State Water Resources Control Board Division of Drinking Water (SWRCB DDW)
- Central Valley Regional Water Quality Control Board (RWQCB)
- DWR

- USGS
- Kern County and KCWA
- Various water suppliers including water wholesalers and retailers, cities, and water districts
- Private groundwater users
- Cleanup sites.

Historical water quality data is limited but with the ongoing transition from hard copy to electronic data, water quality data are increasingly becoming more accessible. **Table 27** summarizes many of the groundwater quality monitoring programs conducted by water agencies in the Northern Study Area.

Table 27. Selected Groundwater Quality Monitoring Programs

Entity	Groundwater Quality Monitoring Program Description
North Kern Water Storage District	District supply wells and monitoring wells plus private wells which discharge into the District's distribution system are sampled in years used for District irrigation water delivery (about one out of two years on average). Sampled for standard agricultural-type analyses. Select wells are sampled for drinking water-type analyses every four years.
Rosedale Rio Bravo Water Storage District	Monitored by numerous entities within the district including industrial users, small mutual water companies, Vaughn Water Company, City of Bakersfield, and individual landowners. Kern Fan Monitoring Committee samples four double-completion monitoring wells located within RRBWSD on a semi-annual basis.
Semitropic Water Storage District	SWSD collects annual water samples from all wells connected to the District system on a three-year cycle, with one-third of the wells tested every year. Water quality testing includes standard agricultural-type and some drinking water (Title 22) testing.
Cawelo Water District	District's deep wells (and occasionally some private wells) are sampled in years of heavy use when surface water supplies are reduced.
Buena Vista Water Storage District	BVWSD's 14 dedicated monitoring wells are sampled annually.
Shafter-Wasco Irrigation District	Recommended a groundwater quality monitoring program in its 2012 GWMP
Cities of Bakersfield, Wasco and Shafter	Required by State to monitor drinking water quality in accordance with Title 22.
Cal Water, VMC, NORMWD/OMWC	Required by State to monitor drinking water quality in accordance with Title 22.
KCWA	Collects, interprets and distributes groundwater data for the San Joaquin Valley and Indian Wells Valley groundwater basins. Approximately 800 wells and piezometers are monitored on a semiannual basis, and 240 are monitored monthly within the Kern Fan area.
Arvin-Edison Water Storage District	District samples select private and District wells once per year.

Source: Data from entities' GWMPs and various websites.

The Groundwater Ambient Monitoring and Assessment (GAMA) Program is an interagency collaboration between the State and Regional Water Boards, DWR, Department of Pesticide Regulations, USGS, and Lawrence Livermore National Laboratory, and cooperation with local water agencies and well owners. It is a publicly accepted plan to monitor and assess groundwater quality in basins that account for 95 percent of the State's groundwater use. Plan components include priority basins, Geotracker on-line database, private wells, and special studies. In 2006, 50 wells were sampled in the Kern County Subbasin for a GAMA priority basin study (Shelton et al., 2008).

7.2.3 Land Subsidence Monitoring Programs

As discussed in **Section 4.7**, land subsidence in the San Joaquin Valley has been documented for more than 60 years and recent investigations indicate continuing problems in some areas. Although the areas with the most documented subsidence are generally north of the Study Area, both historical and recent subsidence have been documented in various parts of Kern County.

Since the 1950s, the DWR has monitored borehole extensometers in wells throughout the San Joaquin Valley. The monitoring network consisted of 31 extensometers at 21 sites by the end of the 1960s but reduced to 6 extensometers at 5 sites by 2010. A new regional monitoring network is currently being developed (AECOM, 2016a). Since 1994, 4 extensometers have been used for monitoring subsidence in the Kern Fan area (AECOM, 2016a).

Table 28 summarizes available information on subsidence monitoring conducted by water provider entities, mainly in the Northern Study Area.

Table 28. Subsidence Monitoring Programs

Entity	Subsidence Monitoring Program Description
North Kern Water Storage District	Monitoring monuments installed at 11 locations. 2012 GWMP indicated that monitoring would occur after each significant pumping season, estimated to be in about one out of two years. The U.S. Bureau of Reclamation monitors two multi-port monitoring wells in NKWSD (and other monitoring points outside of the Study Area) to track the ongoing potential for subsidence-related problems in relation to the Friant-Kern Canal.
Rosedale Rio Bravo Water Storage District	No historical subsidence documented within district. District conducts periodic review of land subsidence monitoring by others.
Semitropic Water Storage District	The District has not monitored subsidence directly, but a borehole extensometer was recently constructed in a new well field area (SWSD, 2012).
Cawelo Water District	Periodically reviews land subsidence through use of data and reports developed by others.
Buena Vista Water Storage District	Periodically looks for visual signs of land subsidence, such as collapsed wellheads. Reviews Kern Water Bank extensometer data and published studies.
Shafter-Wasco Irrigation District	Does not conduct subsidence monitoring (as of 2012 GWMP)
Kern Water Bank/Department of Water Resources	Subsidence on the Water Bank has been independently monitored by DWR since June of 1994.
KCWA	Periodic measurements of 28 benchmarks distributed throughout the Kern Fan area have been used to monitor elevations of the land surface (AECOM, 2016a).

Source: Data from entities' GWMPs and various websites.

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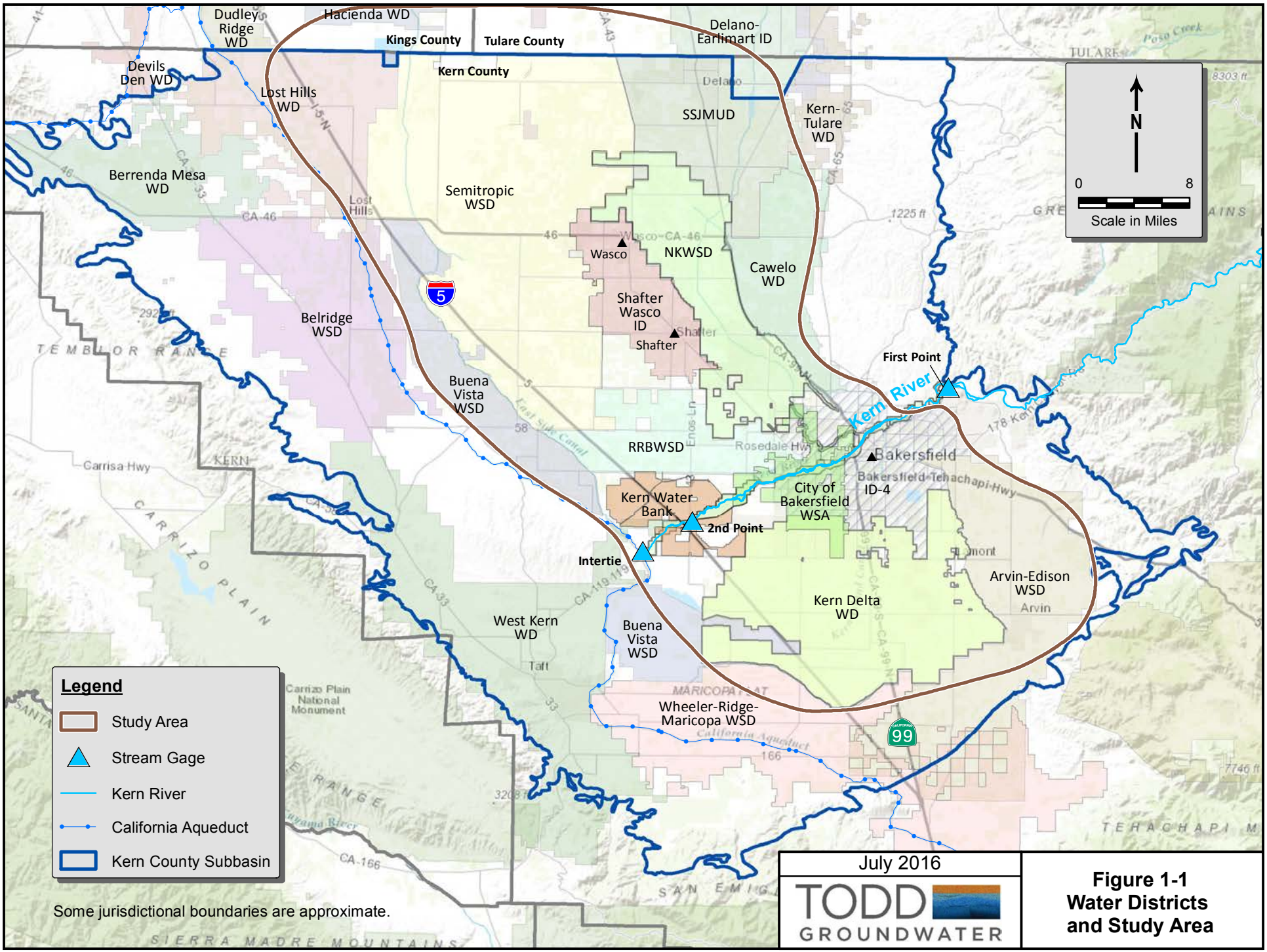
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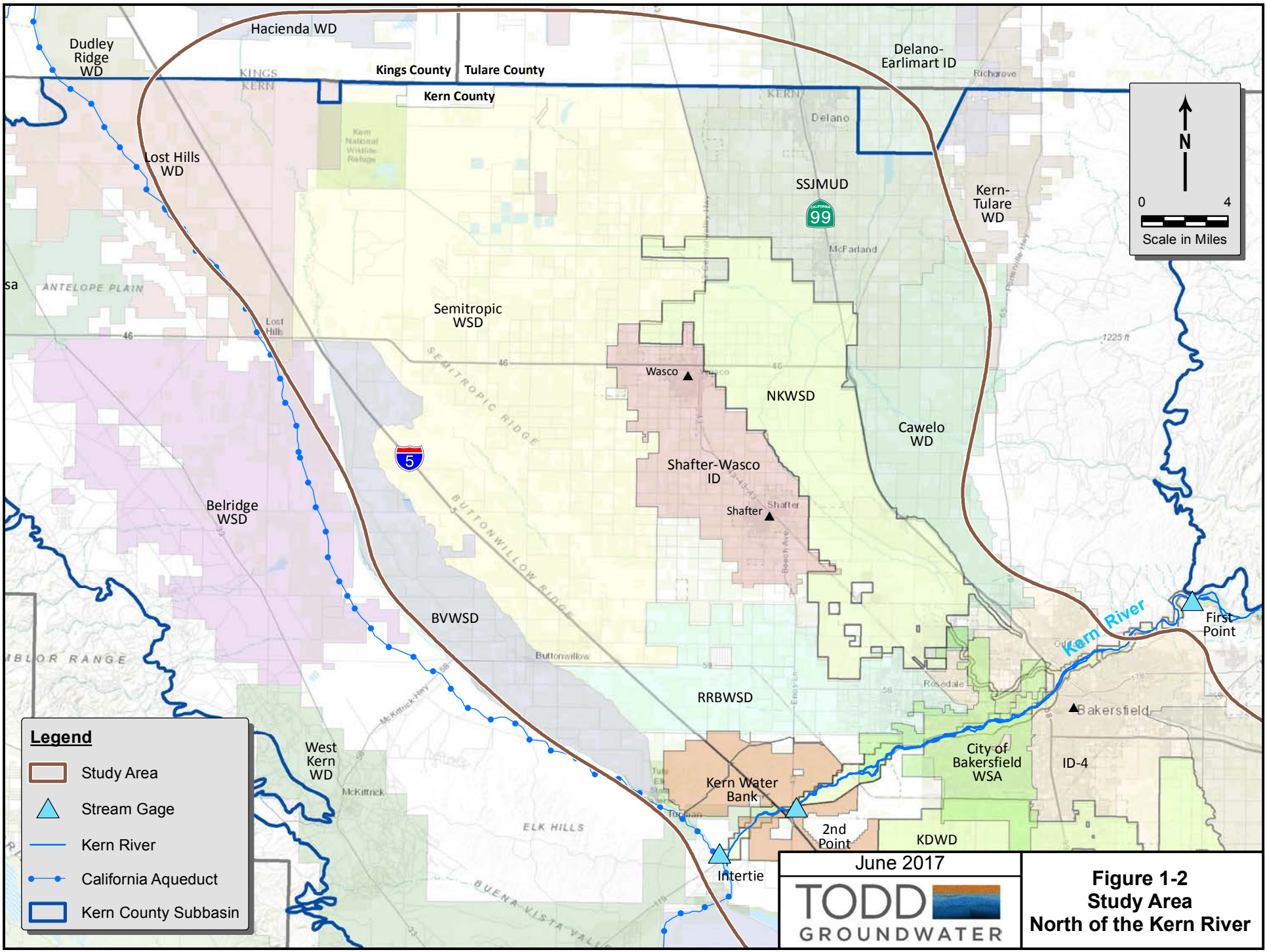
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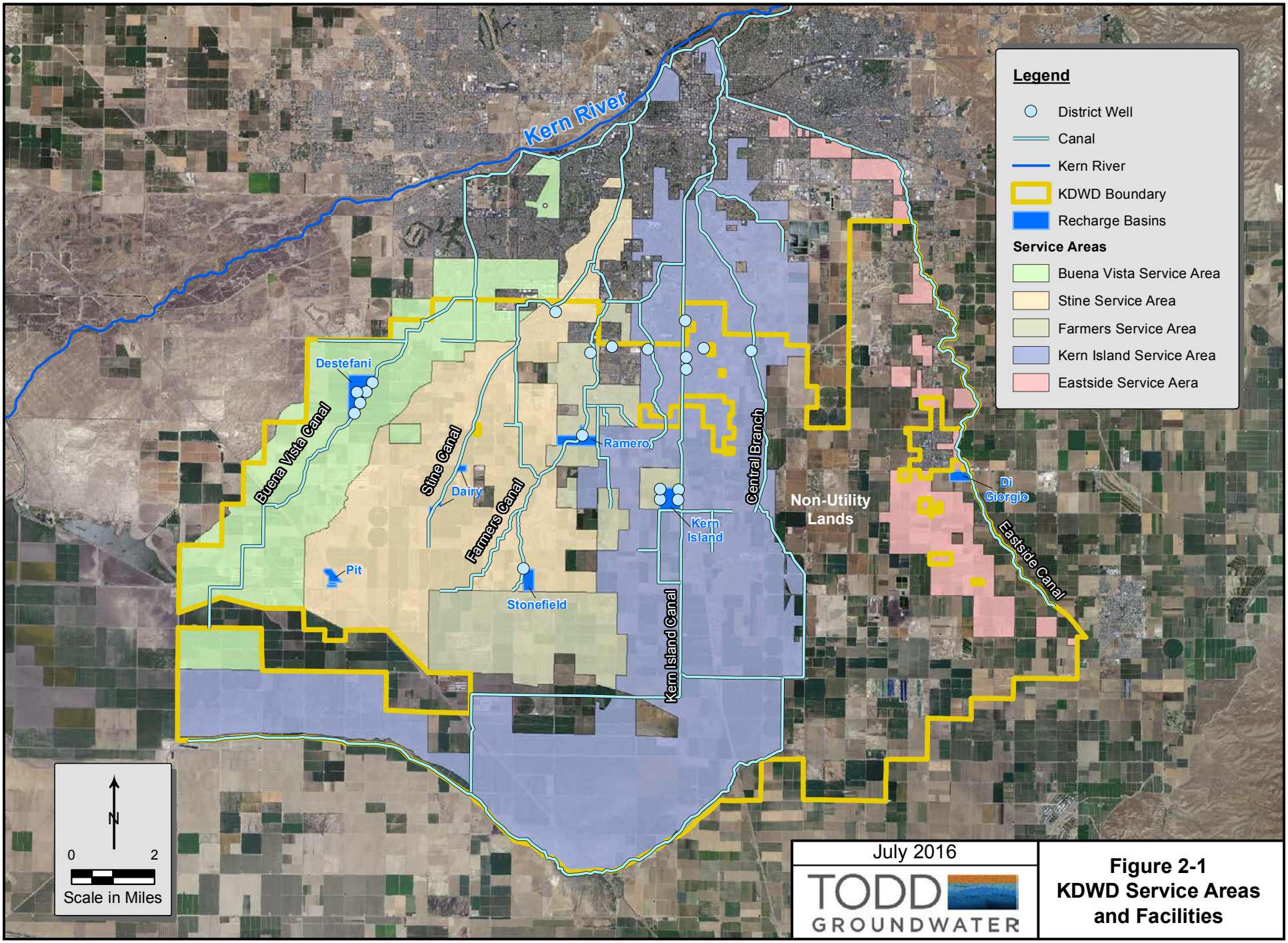
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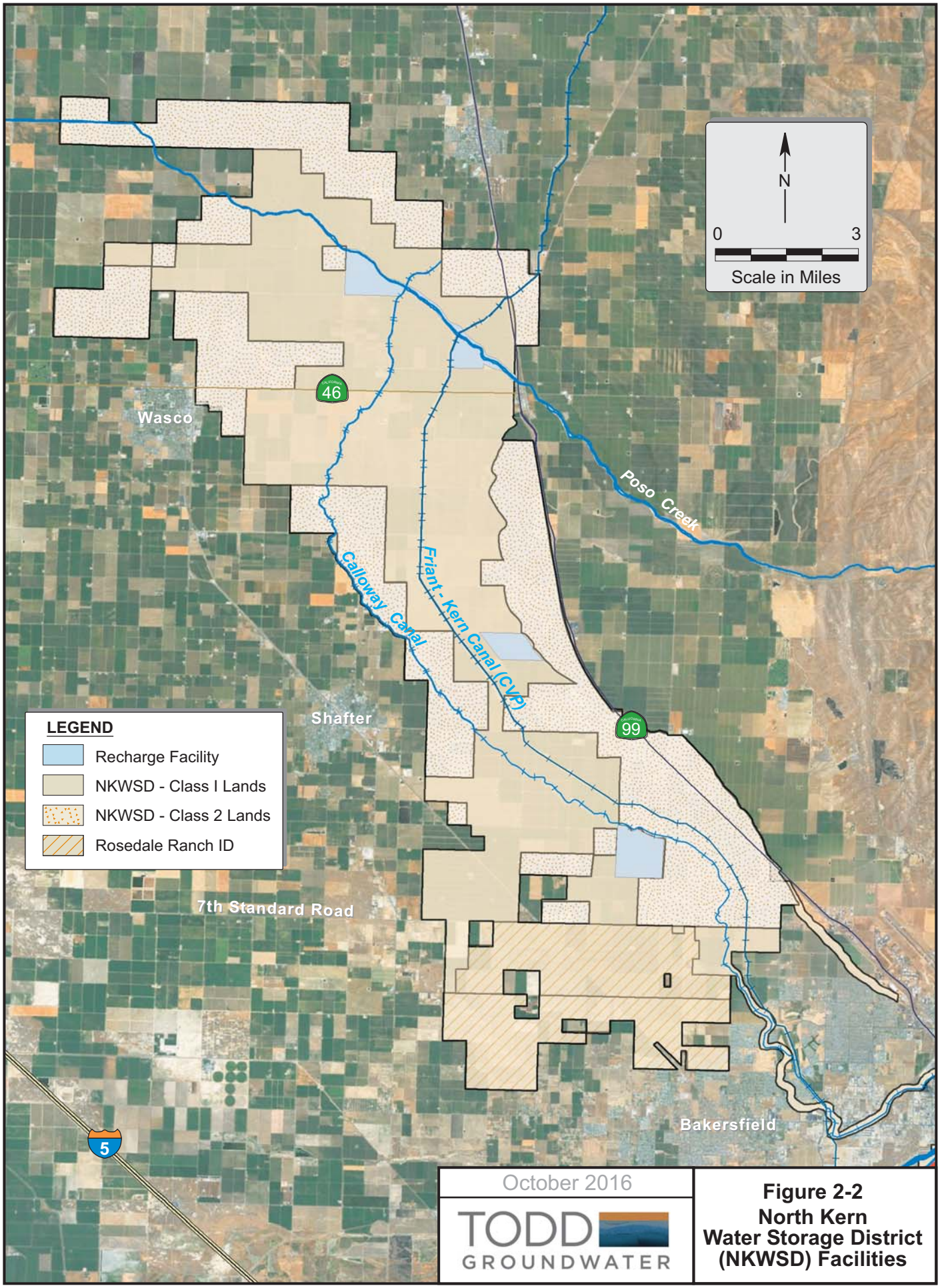
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FIGURES


Dudley Ridge WD
Hacienda WD
Kings County
Tulare County
Kern County
Delano-Earlimart ID
Devils Den WD
Lost Hills WD
SSJMUD
Kern-Tulare WD
Berrenda Mesa WD
Semitropic WSD
Wasco
NKWSD
Cawelo WD
Shafter Wasco ID
Shafter
Belridge WSD
First Point
Kern River
Buena Vista WSD
RRBWSD
Bakersfield
Bakersfield-Tehachapi-Hwy
City of Bakersfield WSA
ID-4
Kern Water Bank
2nd Point
Intertie
Arvin-Edison WSD
Arvin
Kern Delta WD
West Kern WD
Buena Vista WSD
Taft
Wheeler-Ridge-Maricopa WSD
Carrizo Plain National Monument
TEMBLOR RANGE
CARRIZO PLAIN
SIERRA MADRE MOUNTAINS
TEHACHAPI M
Carrisa Hwy
Rosedale Hwy
Enos Ln
N
0
8
Scale in Miles
Legend
Study Area
Stream Gage
Kern River
California Aqueduct
Kern County Subbasin
Some jurisdictional boundaries are approximate.
July 2016
TODD GROUNDWATER
Figure 1-1
Water Districts and Study Area


Hacienda WD
Dudley Ridge WD
Kings County
Tulare County
Kern County
Delano-Earlimart ID
Lost Hills WD
SSJMUD
Kern-Tulare WD
Semitropic WSD
Wasco
NKWSD
Cawelo WD
Shafter-Wasco ID
Shafter
Belridge WSD
BVWSD
RRBWSD
Kern River
First Point
Bakersfield
City of Bakersfield WSA
ID-4
Kern Water Bank
2nd Point
KDWD
Intertie
West Kern WD
McKittrick
ELK HILLS
Buttonwillow
Rosedale
Lost Hills
ANTELOPE PLAIN
SEMITROPIC RIDGE
BUTTONWILLOW RIDGE
BUENA VISTA VALLEY
Richgrove
Delano
McFarland
N
0
4
Scale in Miles
Legend
Study Area
Stream Gage
Kern River
California Aqueduct
Kern County Subbasin
June 2017
TODD GROUNDWATER
Figure 1-2
Study Area
North of the Kern River


Legend
District Well
Canal
Kern River
KDWD Boundary
Recharge Basins
Service Areas
Buena Vista Service Area
Stine Service Area
Farmers Service Area
Kern Island Service Area
Eastside Service Aera
Kern River
Destefani
Buena Vista Canal
Stine Canal
Dairy
Farmers Canal
Ramero
Central Branch
Non-Utility Lands
Kern Island
Di Giorgio
Eastside Canal
Pit
Stonefield
Kern Island Canal
N
0
2
Scale in Miles
July 2016
TODD GROUNDWATER
Figure 2-1
KDWD Service Areas and Facilities



October 2016

TODD GROUNDWATER

Figure 2-2
North Kern Water Storage District (NKWSD) Facilities

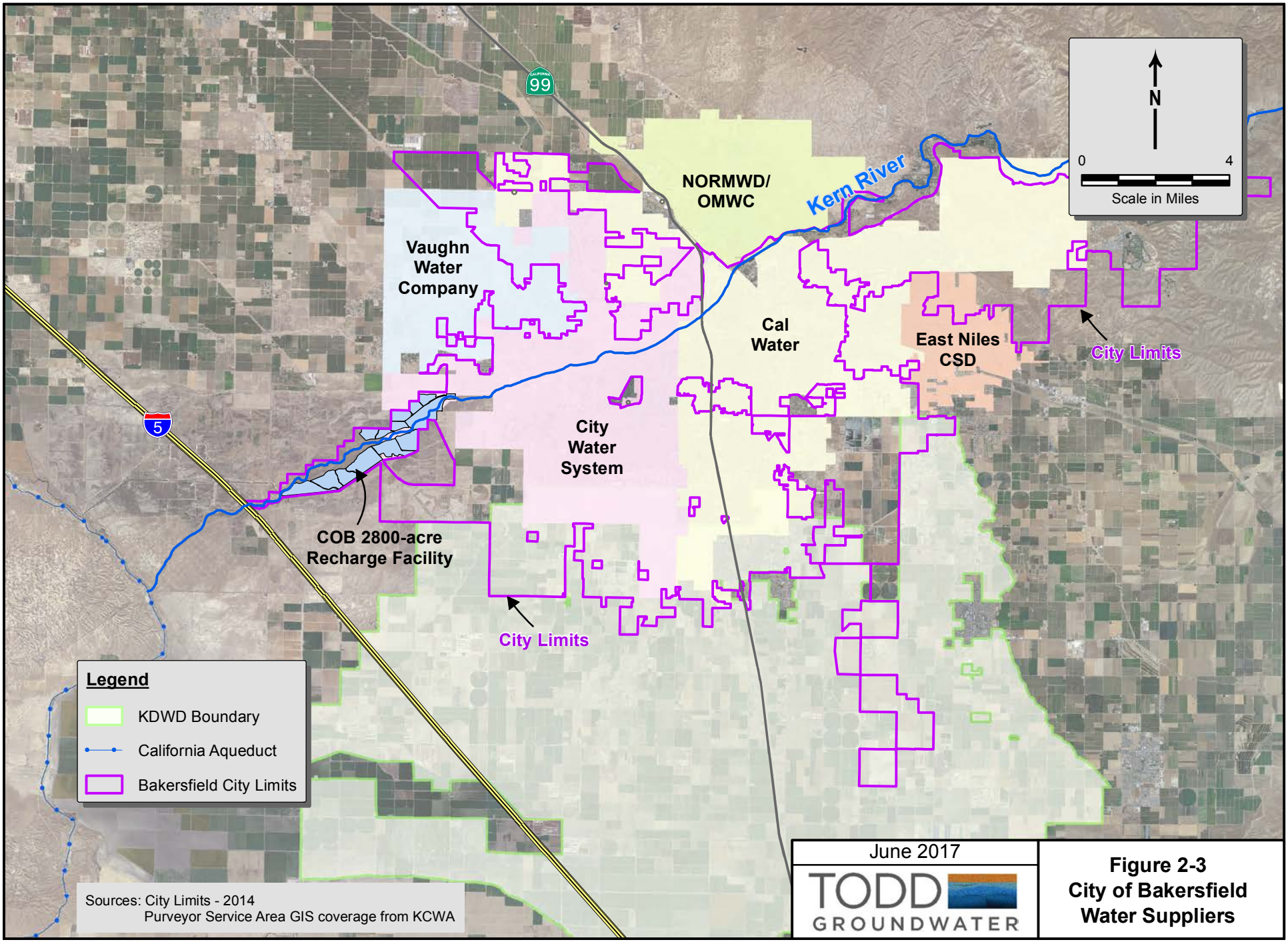
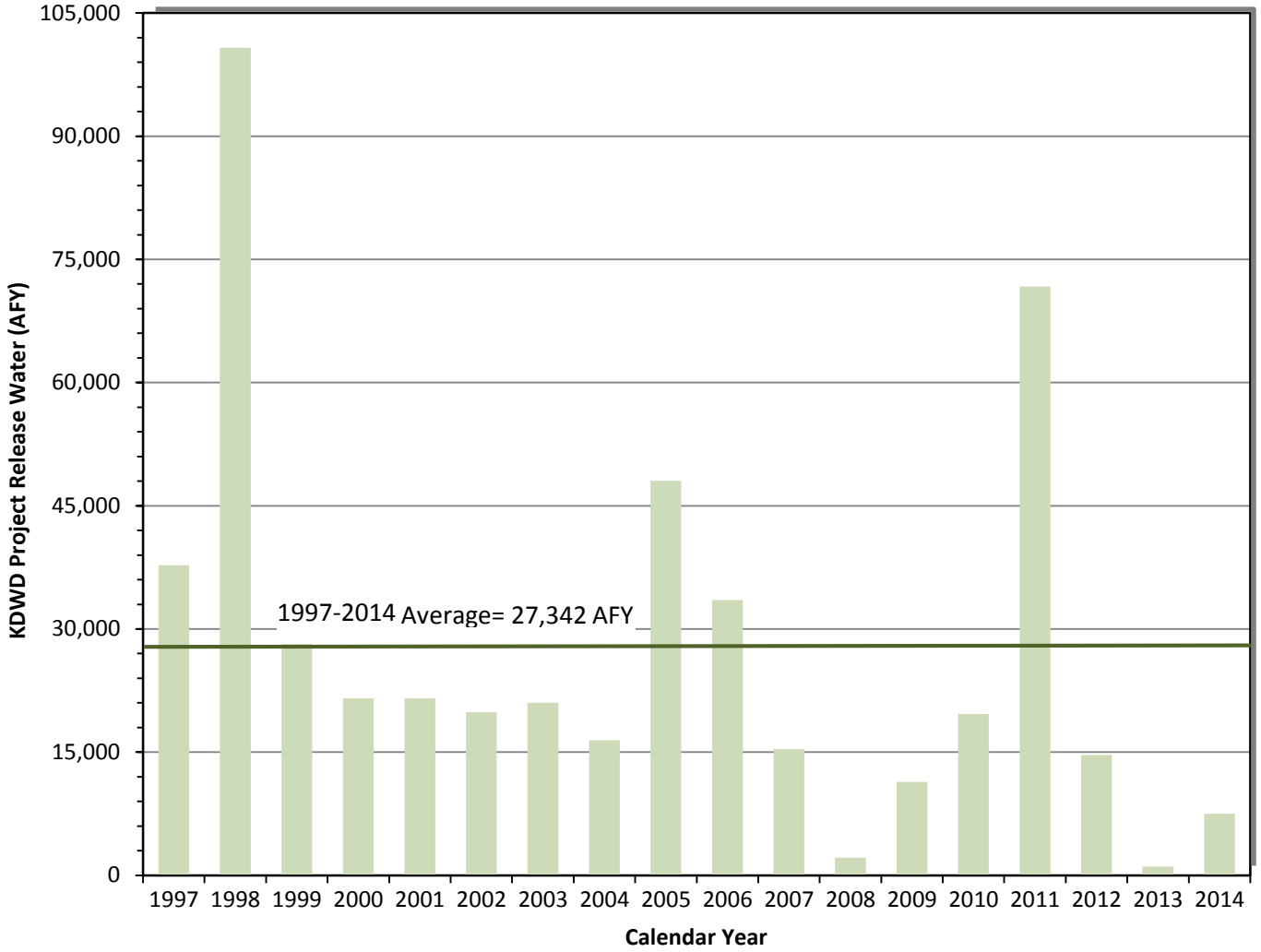


Figure 2-3
City of Bakersfield
Water Suppliers

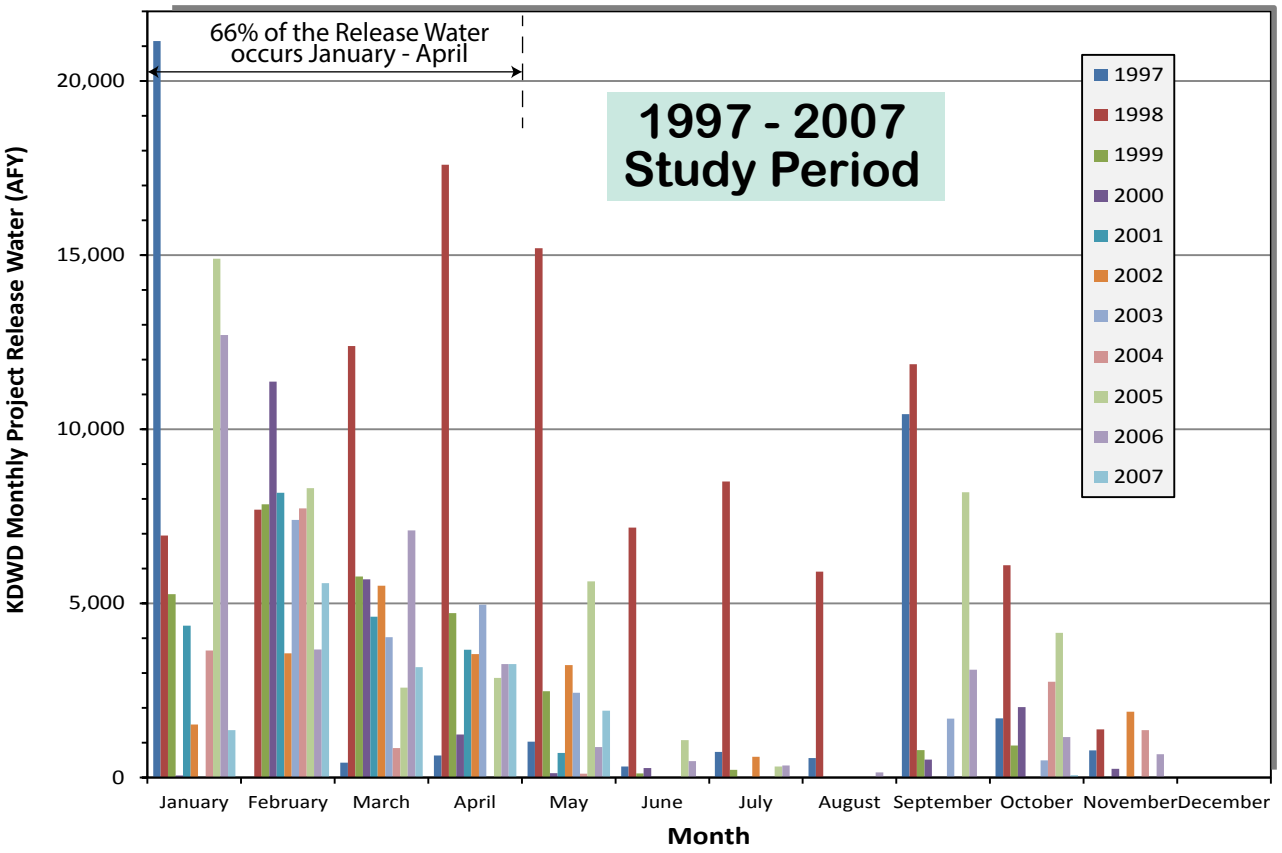


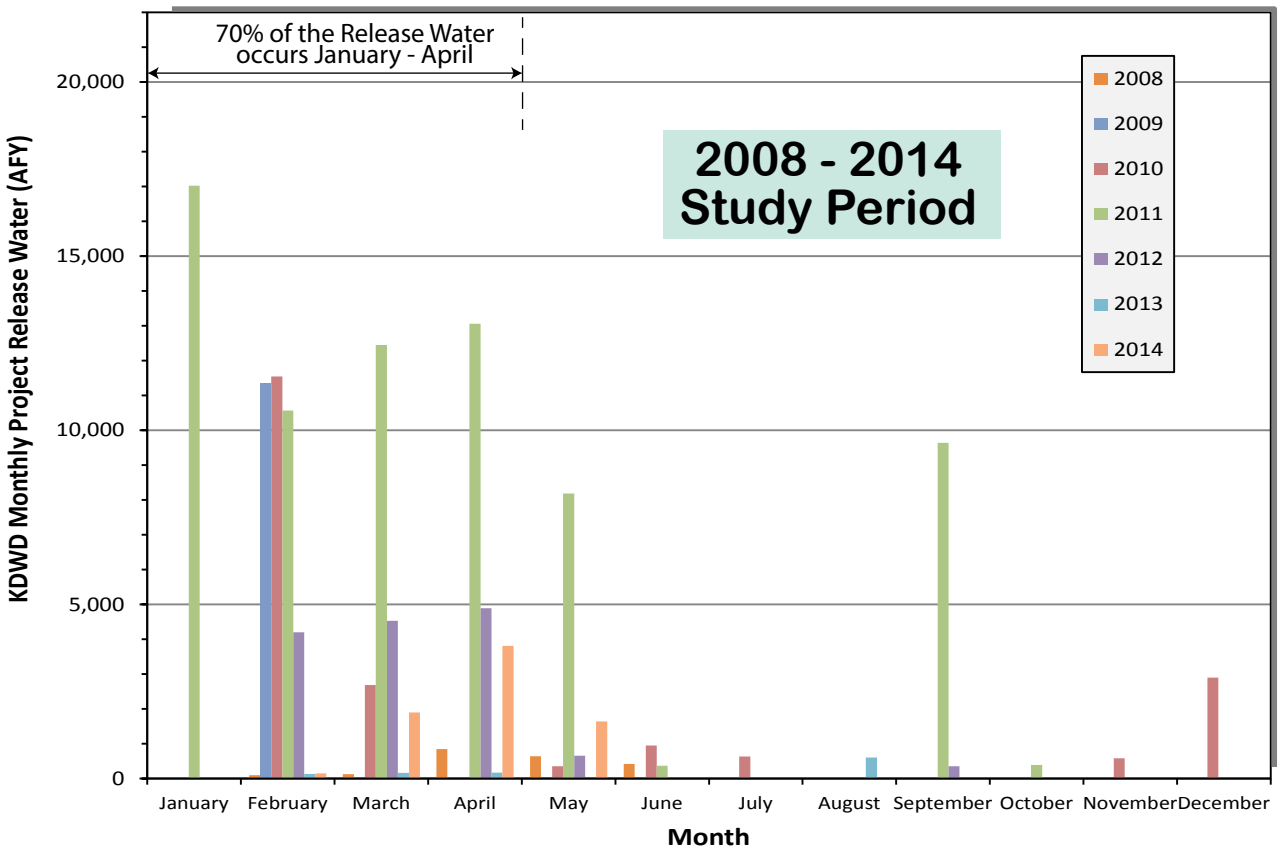
Notes: 1997 - 2007 KDWD Release Water Adjusted by the Reed Decision
2008 - 2014 Reed Decision in place
Does not include net negative release values

July 2016

TODD GROUNDWATER

Figure 3-1
Project Release Water



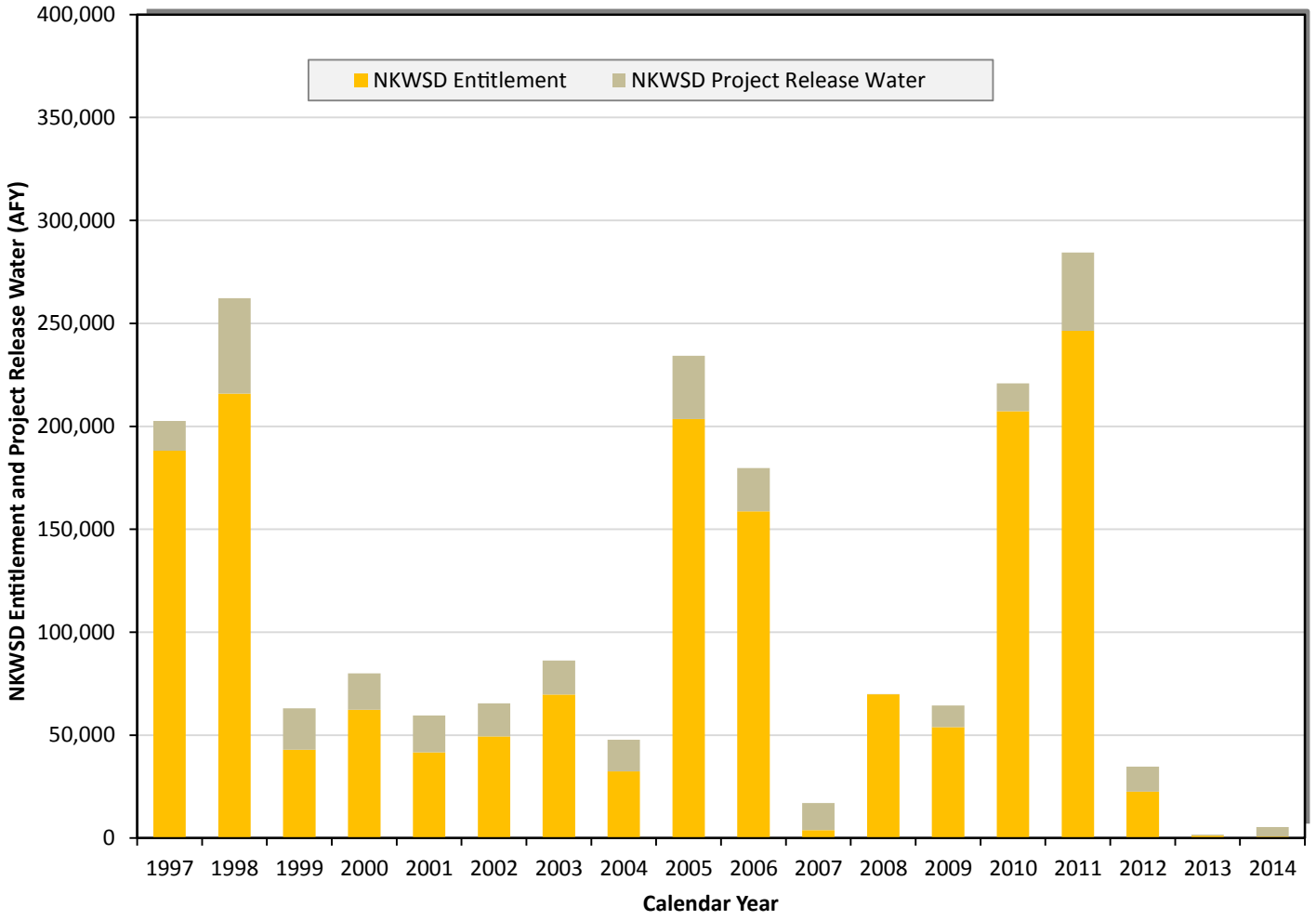


Notes: 1997 - 2007 KDWD Release Water Adjusted by the Reed Decision
2008 - 2014 Reed Decision in place
Does not include net negative release values

July 2016

TODD GROUNDWATER

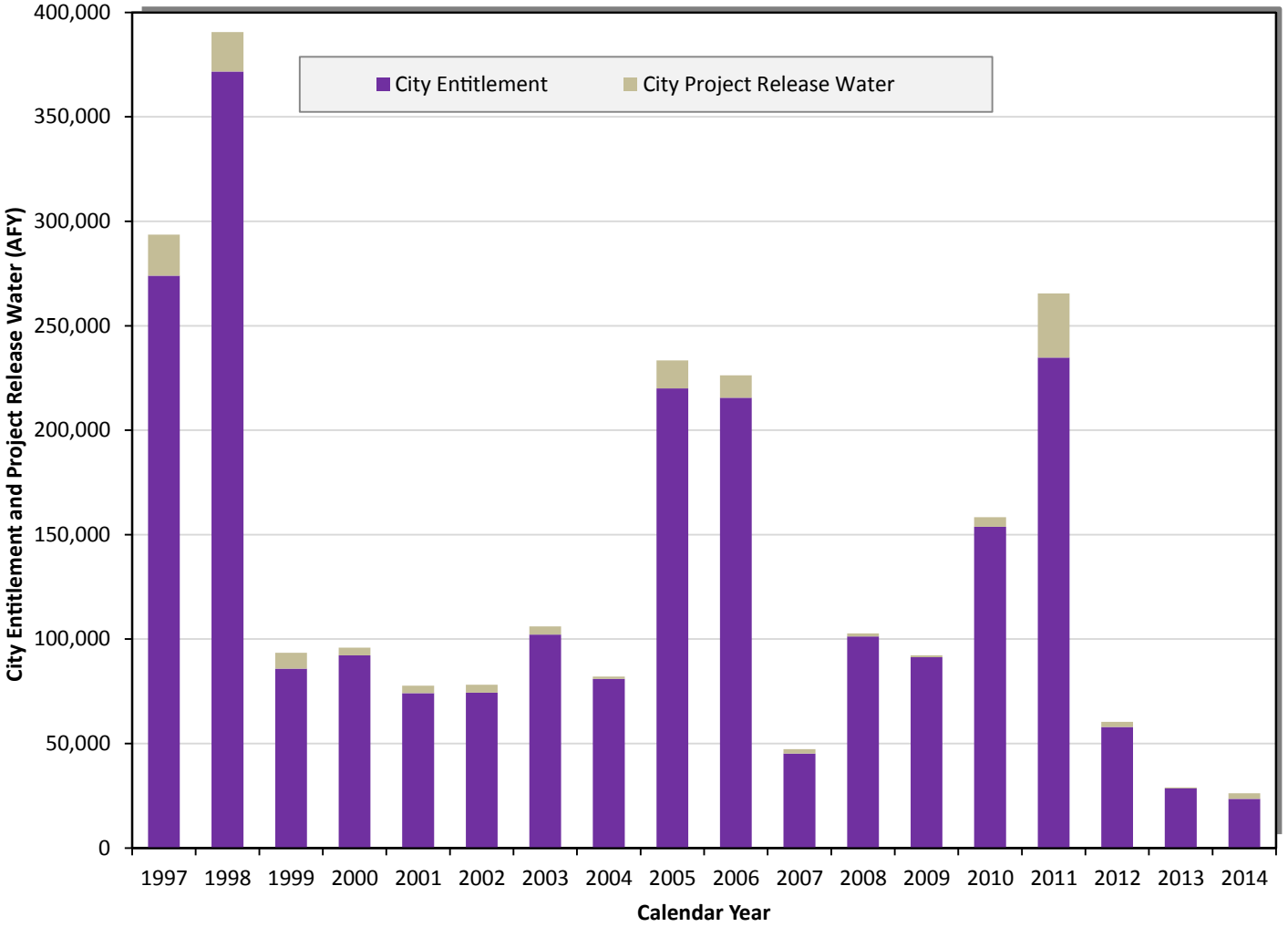
Figure 3-2
Monthly Project Release Water



July 2016

TODD GROUNDWATER

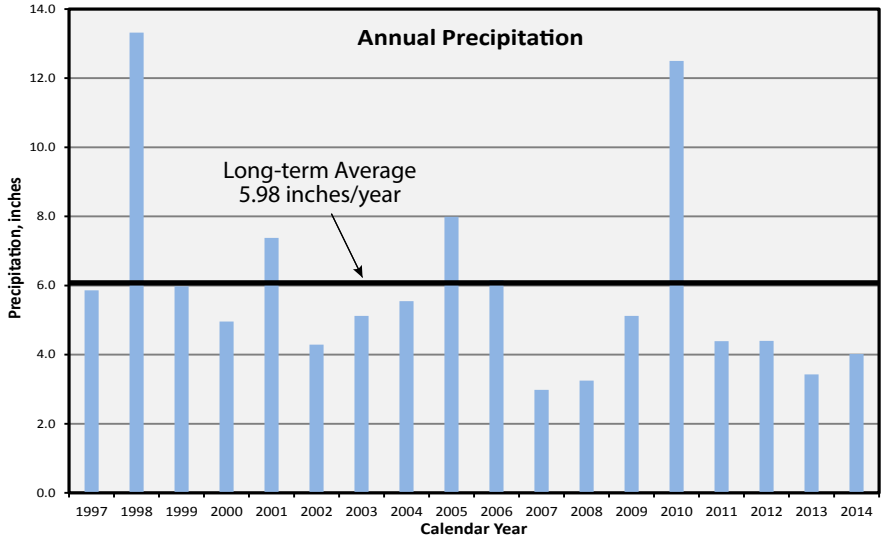
Figure 3-3
NKWSD Entitlement and Use of Project Release Water



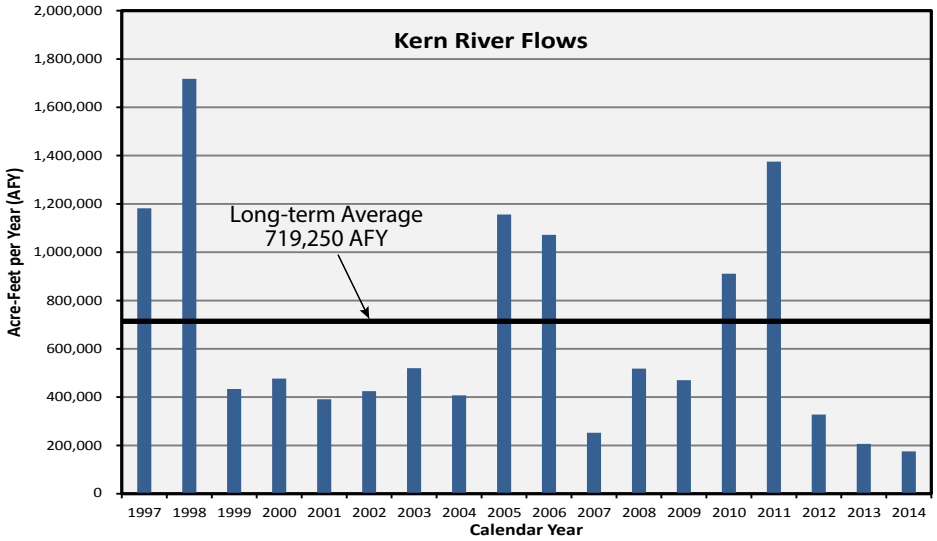
July 2016

TODD GROUNDWATER

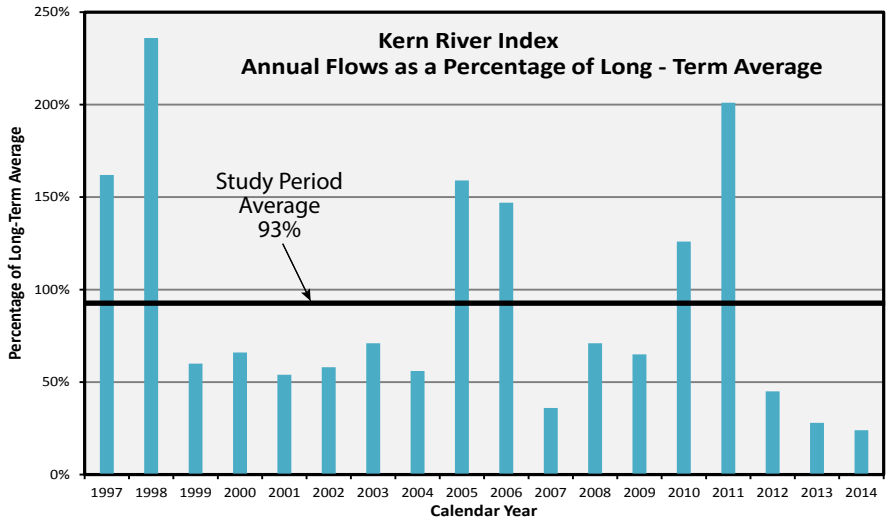
Figure 3-4
City Entitlement and Use of Project Release Water



Source: Bakersfield Meadows Field Airport Station, CA (NOAA, 2015)



Source: City of Bakersfield, Kern River Hydrographic Annual Reports, 1997 - 2014.

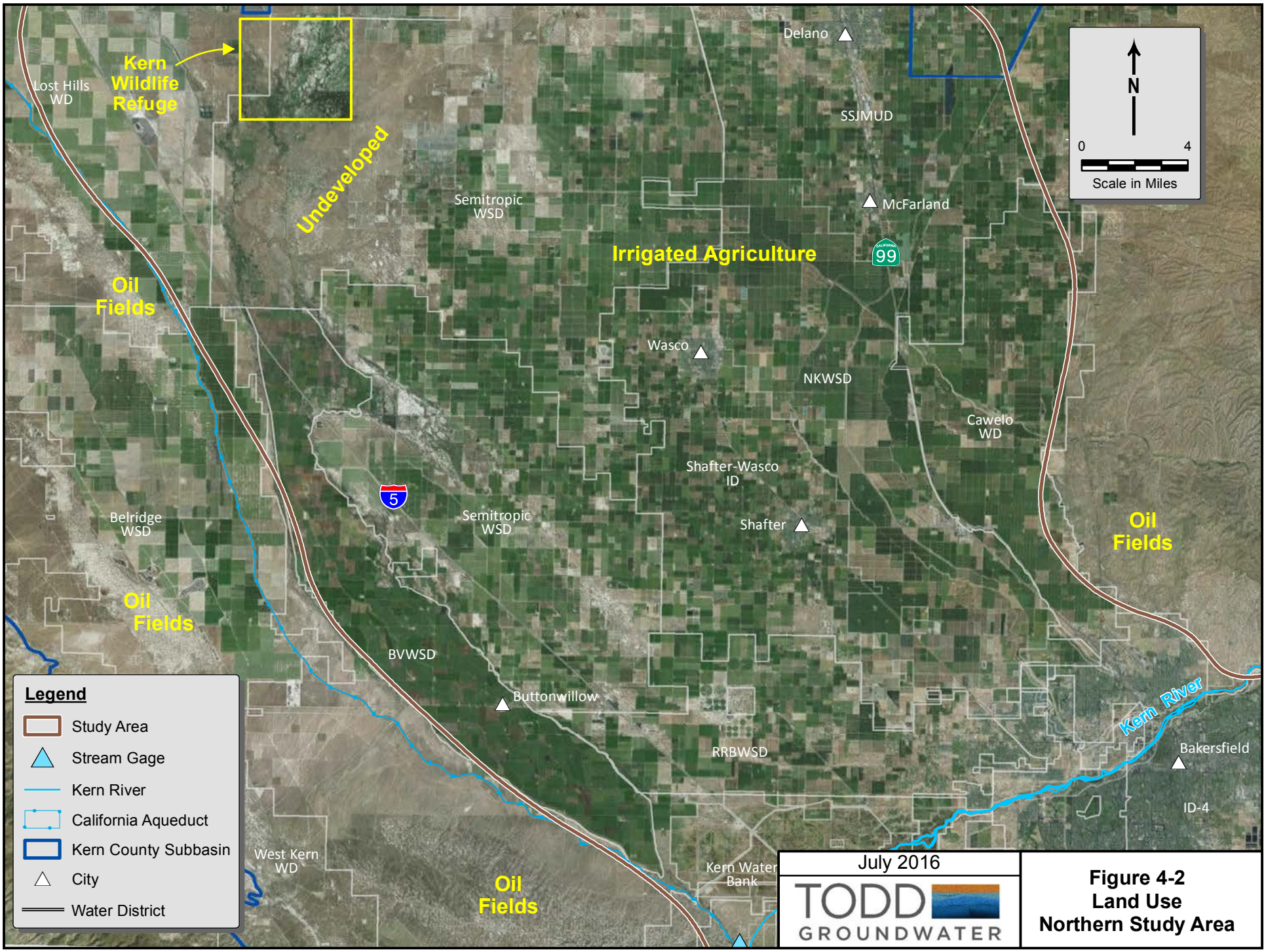


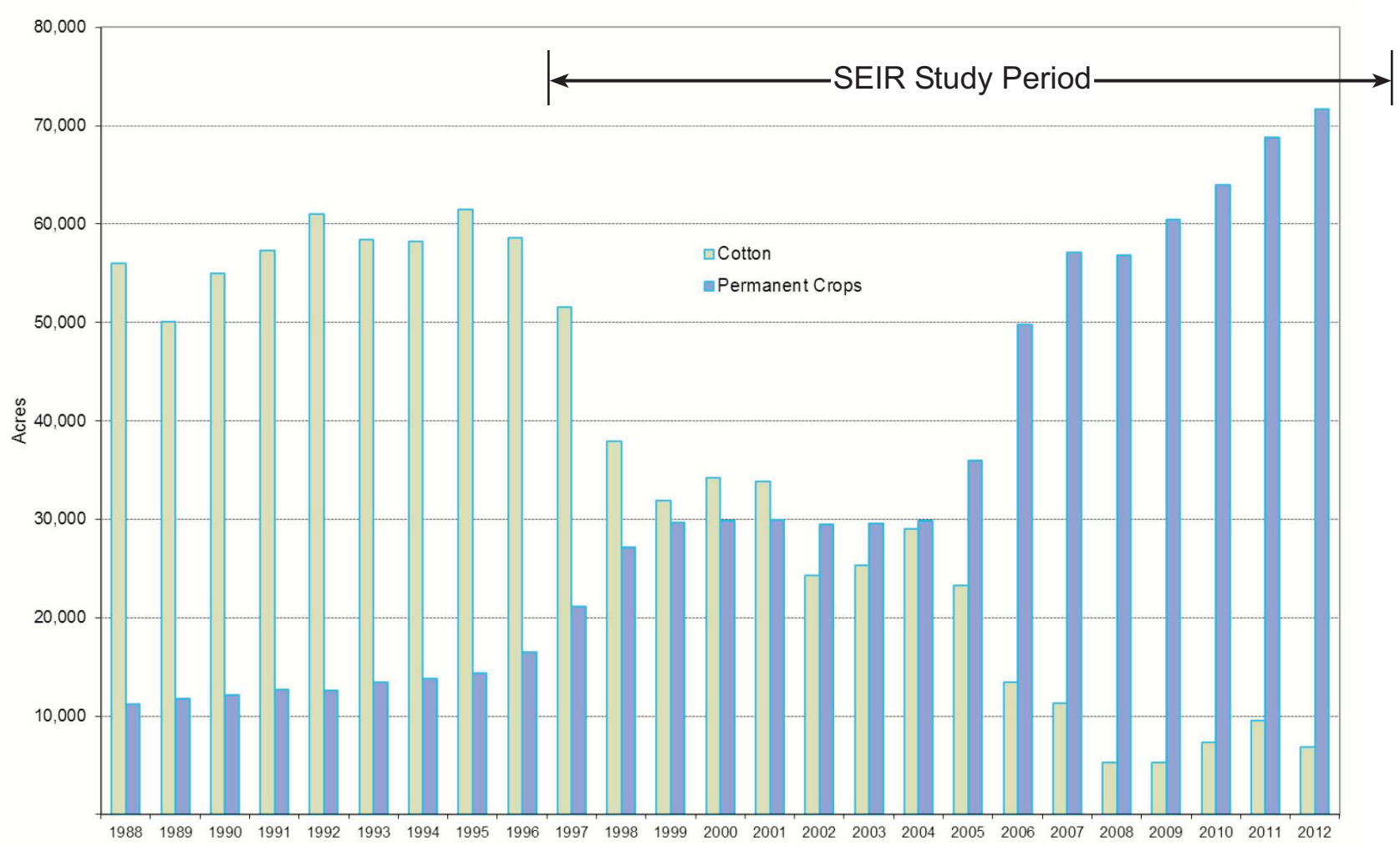
Source: City of Bakersfield, Kern River Hydrographic Annual Reports, 1997 - 2014.

July 2016

TODD GROUNDWATER

Figure 4-1
Annual Precipitation and Kern River Flows


Kern Wildlife Refuge
Lost Hills WD
Undeveloped
Delano
SSJMUD
McFarland
Semitropic WSD
Irrigated Agriculture
99
Oil Fields
Wasco
NKWSD
Cawelo WD
Shafter-Wasco ID
5
Belridge WSD
Semitropic WSD
Shafter
Oil Fields
Oil Fields
BVWSD
Buttonwillow
Kern River
RRBWSD
Bakersfield
ID-4
West Kern WD
Kern Water Bank
Oil Fields
N
0
4
Scale in Miles
Legend
Study Area
Stream Gage
Kern River
California Aqueduct
Kern County Subbasin
City
Water District
July 2016
TODD GROUNDWATER
Figure 4-2
Land Use
Northern Study Area

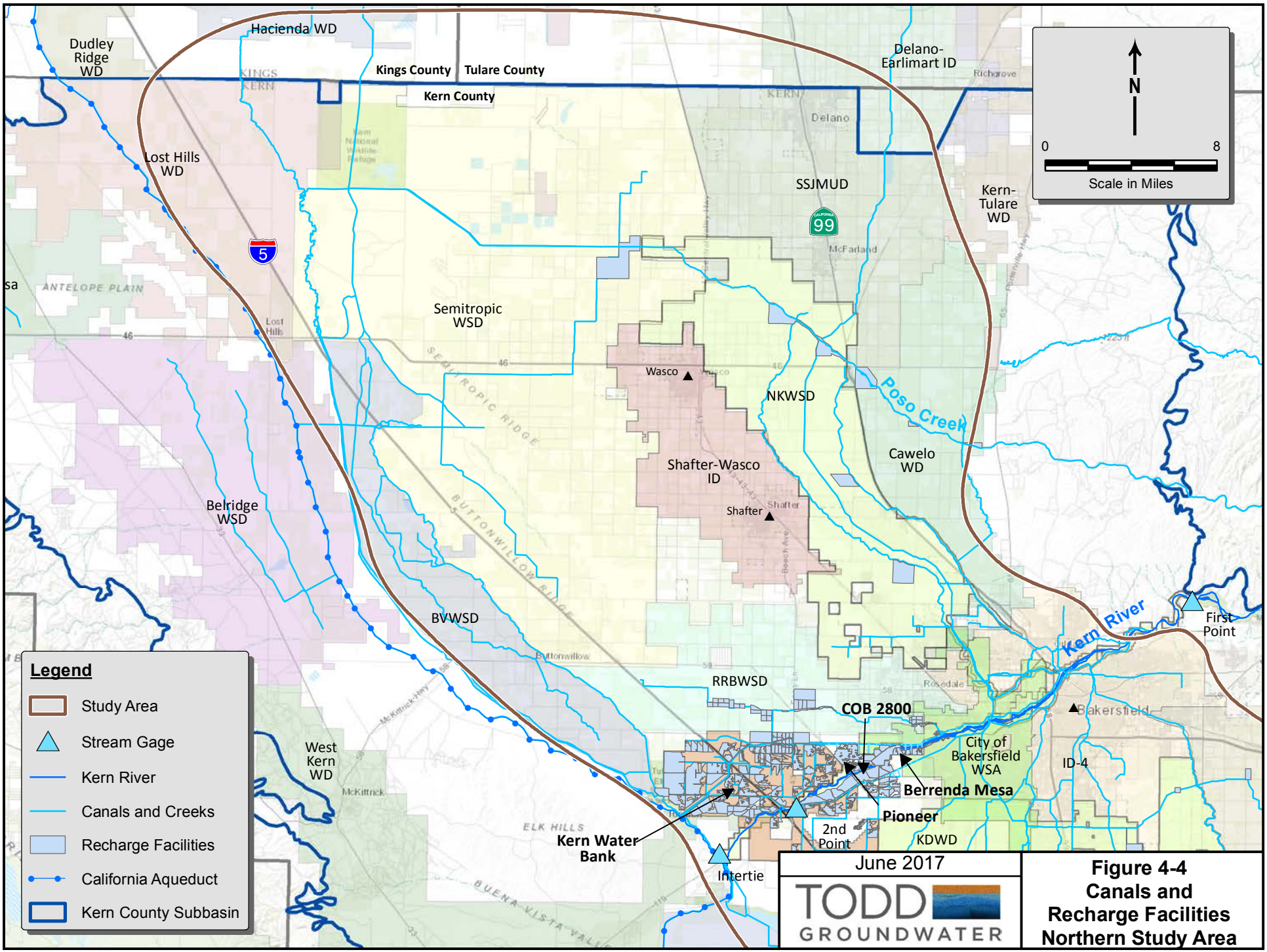


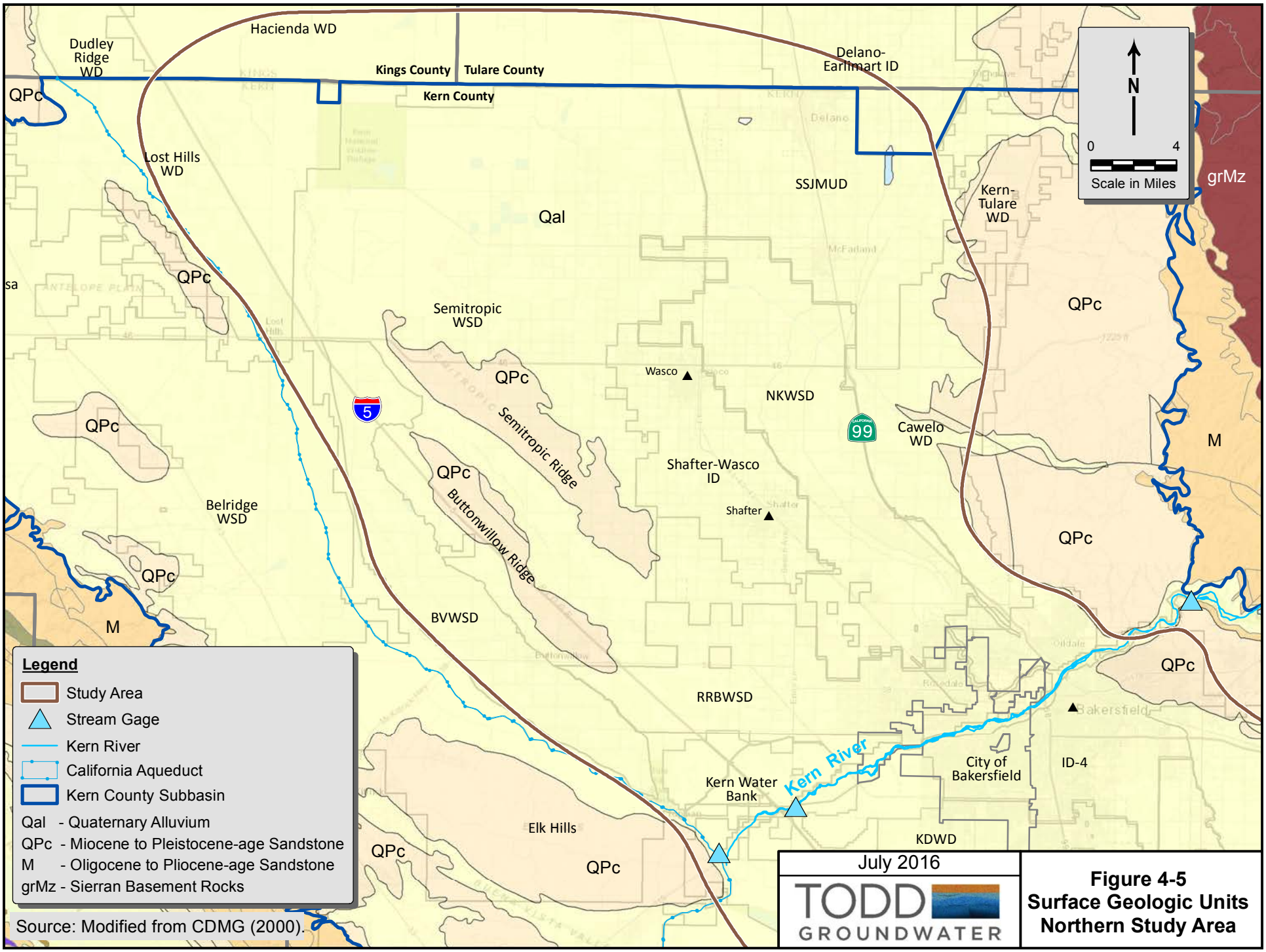
Source: SWSD, 2012.

July 2016

TODD GROUNDWATER

Figure 4-3
Cropping Pattern Changes
Semitropic WSD


Hacienda WD
Dudley Ridge WD
Kings County
Tulare County
Kern County
Delano-Earlimart ID
Lost Hills WD
SSJMUD
Kern-Tulare WD
Semitropic WSD
Wasco
NKWSD
Poso Creek
Cawelo WD
Shafter-Wasco ID
Shafter
Belridge WSD
BVWSD
RRBWSD
Kern River
First Point
COB 2800
City of Bakersfield WSA
ID-4
Berrenda Mesa
Pioneer
2nd Point
KDWD
Kern Water Bank
Intertie
West Kern WD
N
0
8
Scale in Miles
Legend
Study Area
Stream Gage
Kern River
Canals and Creeks
Recharge Facilities
California Aqueduct
Kern County Subbasin
June 2017
TODD GROUNDWATER
Figure 4-4
Canals and Recharge Facilities
Northern Study Area



Source: Modified from CDMG (2000).

July 2016

TODD GROUNDWATER

Figure 4-5
Surface Geologic Units
Northern Study Area

N

0 10

Scale in Miles

Kern County Subbasin

Study Area

Approximate Extent of the Kern River Fan

Tulare Lake Bed

Kern River

CORRELATION OF MAP UNITS

Qs Qb Qr	Holocene	QUATERNARY
QTl	Pliocene to Holocene	TERTIARY AND QUATERNARY
QTc	Miocene to Holocene	
Tvd Tcpm Tcmd	Miocene and Pliocene	TERTIARY
Tm	Eocene, Oligocene, Miocene, and Pliocene	
Tcmo	Oligocene and Miocene	
Tcme	Eocene to Miocene	
Tce	Eocene	
	Unconformity	
pTs		PRE-TERTIARY
pTg		
pTm		

Contact Approximately located

Fault Dashed where approximately located, dotted where concealed

D — D' Line of geologic section

• 34A Well and number

Kern County Subbasin

Study Area

Approximate Extent Kern River Fan

DESCRIPTION OF MAP UNITS

Qs **Sand dunes (Holocene)** Windblown sand and dune sand

Qb **Flood-basin deposits (Holocene)** Clay, silt, and some sand; near Stockton consist of muck, peat, and other organic soils. In places may include part of the Modesto Formation (Pleistocene)

Qr **River deposits (Holocene)** Gravel, sand, silt, and minor amounts of clay; deposited along channels, flood plains, and natural levees of main streams. In places may include part of Modesto Formation (Pleistocene)

QTl **Lacustrine and marsh deposits (Pliocene to Holocene)** Clay, silt, and some sand; in subsurface include three widespread clays: A clay (Pleistocene and Holocene?); C clay (Pleistocene); and modified E clay (Pleistocene), includes Corcoran Clay Member of Tulare and Turlock Lake Formations

QTc **Continental rocks and deposits (Miocene to Holocene)** Heterogeneous mix of generally poorly sorted clay, silt, sand, and gravel; some beds of claystone, siltstone, sandstone, and conglomerate. Include some informal units: younger alluvium (Holocene), older alluvium (Pleistocene and Holocene?) and continental deposits (Pliocene and Pleistocene); three formations of Pleistocene age: Modesto, Riverbank, and Turlock Lake; Tulare Formation (Pliocene and Pleistocene) on western side of valley; Laguna Formation (Pliocene) on eastern side, and Kern River Formation (Miocene to Pleistocene?) on southeastern part

Tvd **Volcanic rocks and deposits (Miocene and Pliocene)** Massive tuff with large fragments of vesicular basalt northwest of Tracy; tuff, and volcanic breccia at south end of valley

Tcpm **Continental rocks and deposits (Miocene and Pliocene)** Gravel, sand, silt, clay, conglomerate, sandstone, siltstone, and claystone, contain andesitic material. Principally Mehrten Formation (Miocene and Pliocene) on eastern side of valley; include continental equivalents of Etchegoin Formation (Miocene and Pliocene) on western side of valley, and Chanac Formation (Miocene) on southern part

Tcmd **Continental and marine rocks and deposits (Miocene and Pliocene)** Gravel, sand, silt, clay, silty sandstone, and siltstone. Include continental and marine equivalents of San Joaquin Formation (Pliocene) and Etchegoin Formation (Miocene and Pliocene)

Tm **Marine rocks and deposits (Eocene, Oligocene, Miocene, and Pliocene)** Sand, clay, silt, sandstone, shale, mudstone, and siltstone. On western side of valley include the San Joaquin and Etchegoin Formations, Temblor Formation (Oligocene and Miocene) and Kreyenhagen Formation (Eocene). On southeastern side include the Santa Margarita Formation of various authors, the Round Mountain Silt, the Olcese Sand, the Freeman Silt, and the Jewett Sand (including the Pyramid Hill Sand Member) (all Miocene), and the Vedder Sand (Oligocene)

Tcmo **Continental rocks and deposits (Oligocene and Miocene)** Gravel, conglomerate, sand, tuffaceous sand, clay, and sandy clay; contain rhyolitic material on eastern side of valley. Principally Valley Springs Formation (Oligocene and Miocene) on eastern side of valley; unnamed fanglomerates (Miocene) and Bena Gravel (Miocene) in the southern part

Tcme **Continental rocks and deposits (Eocene to Miocene)** Conglomerate, sandstone, consolidated fanglomerate, claystone, tuff and tuff breccia; near Fresno consist of tuffaceous sand and gravel. Near Bakersfield include the Bealville Fanglomerate (Oligocene and Miocene) and the Walker Formation (Eocene to Miocene)

Tce **Continental rocks and deposits (Eocene)** Conglomerate and sandstone; along eastern side of valley contain anauxite. Principally Ione Formation (Eocene) on eastern side of valley

Unconformity

pTs **Marine rocks (Pre-Tertiary)** Sandstone, shale, siltstone, and some limestone, chiefly on western side of valley; in places contain abundant secondary gypsum. Include Moreno Formation (Cretaceous and Paleocene) and Panoche Formation (Cretaceous)

pTg **Granitic rocks (Pre-Tertiary)** Chiefly granitic rocks on eastern side of valley, in places consists of mafic intrusive rocks

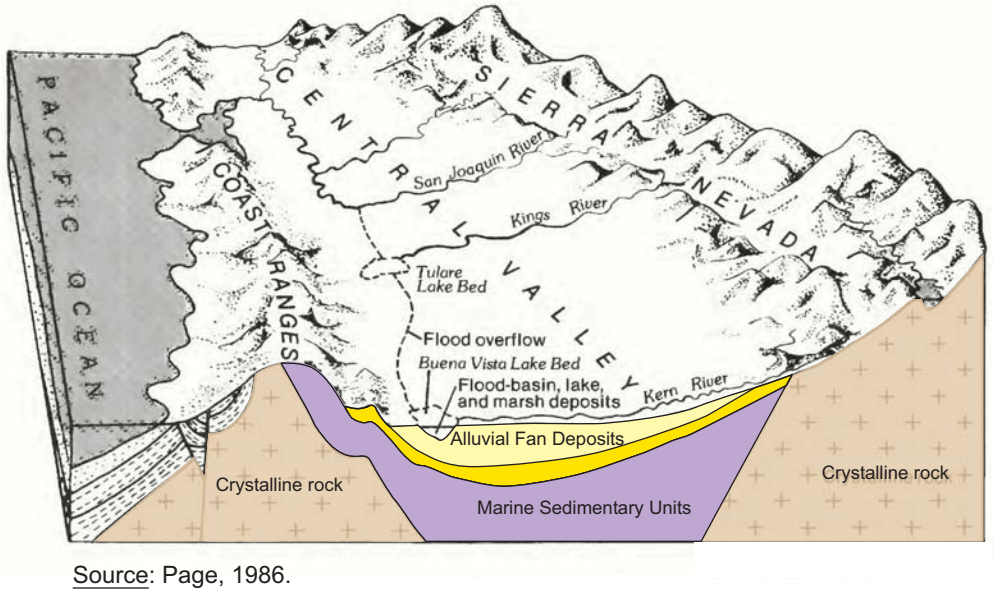
pTm **Metamorphic rocks (Pre-Tertiary)** Metasedimentary, metavolcanic and other metamorphic rocks on eastern side of valley

Source: Page,1986: Boockoff, 2005.

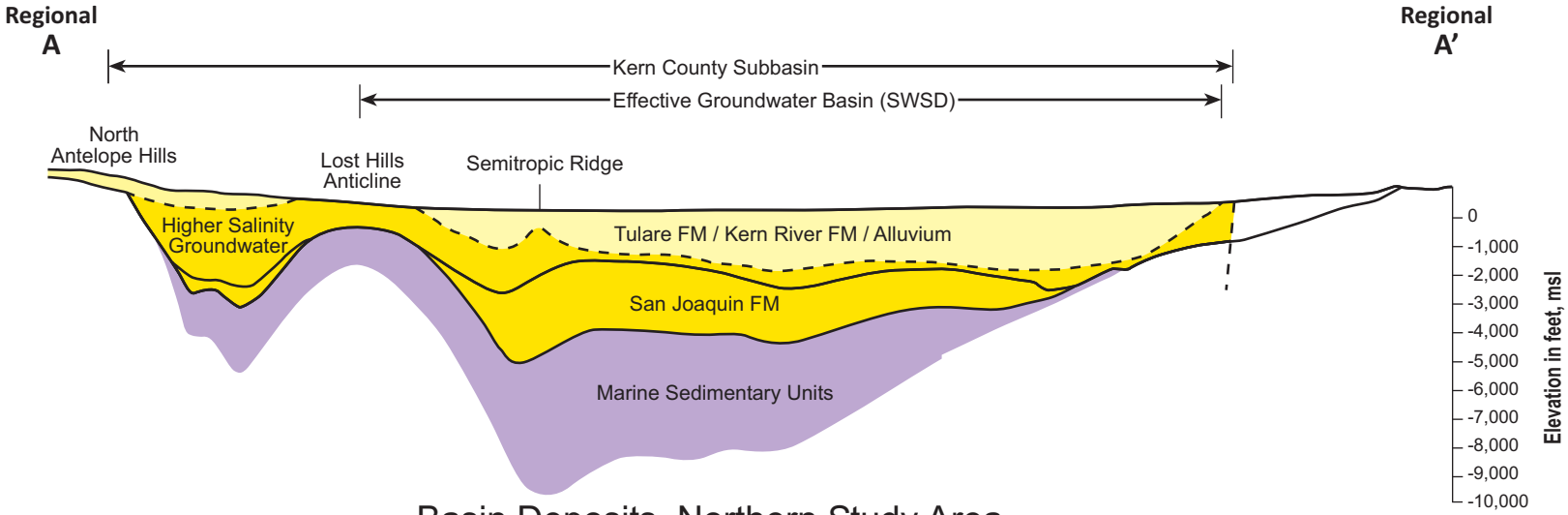
July 2016

TODD GROUNDWATER

Figure 4-6
Geologic Map and Kern River Fan



Source: Page, 1986.



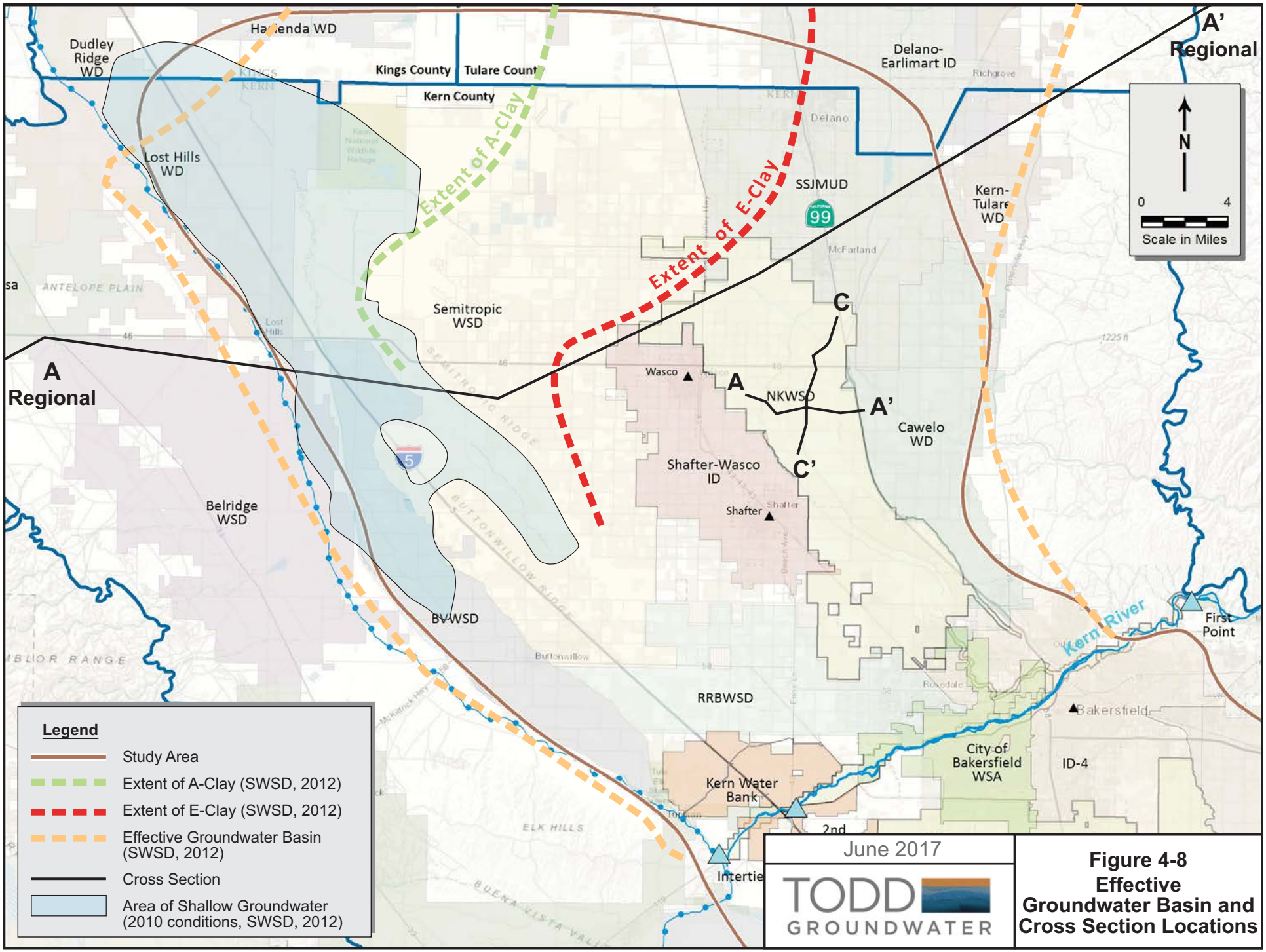
Basin Deposits, Northern Study Area

Source: SWSD, 2012.

June 2017

TODD GROUNDWATER

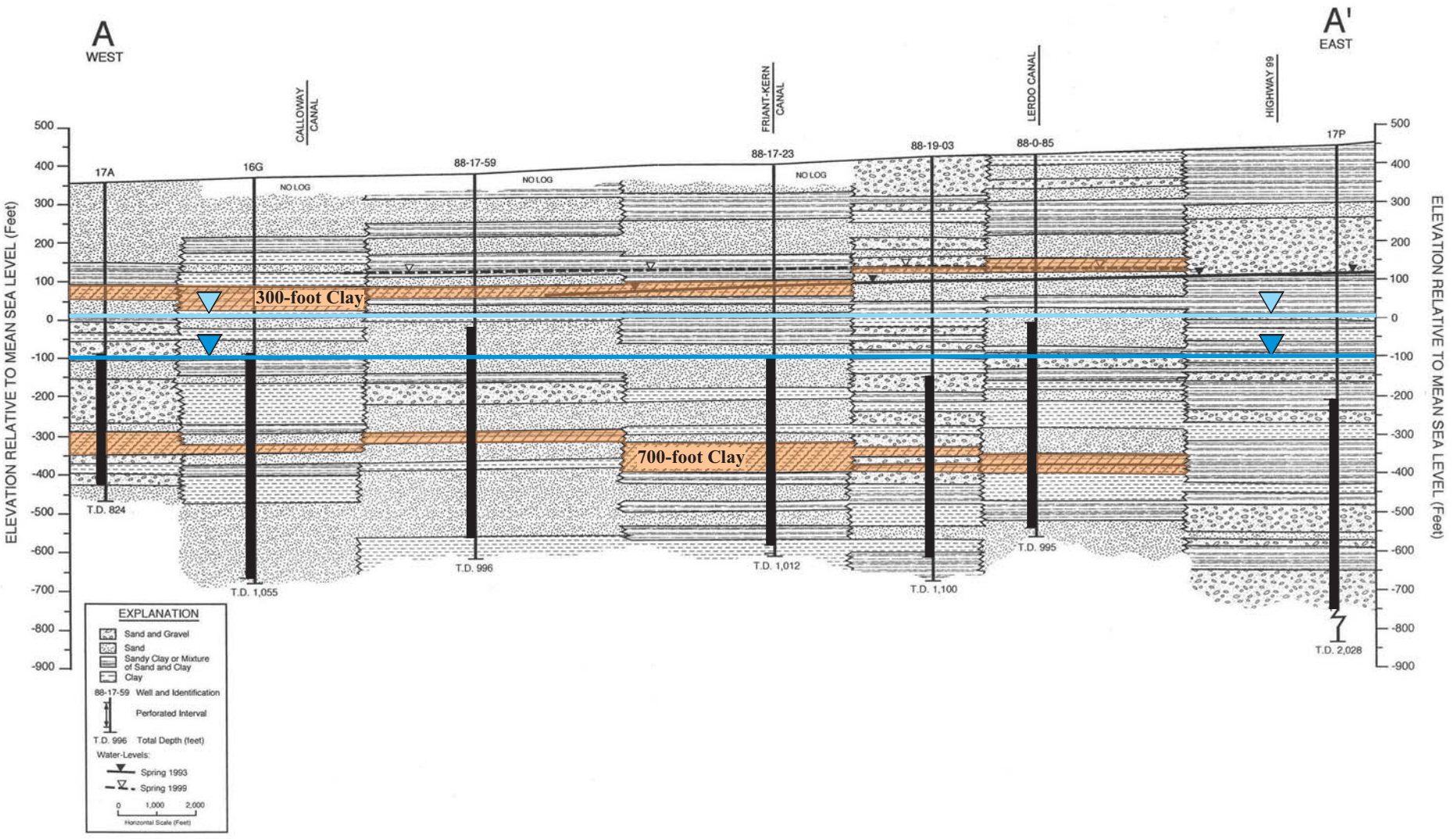
Figure 4-7
Subsurface Geology and Subbasin Boundary



June 2017

TODD GROUNDWATER

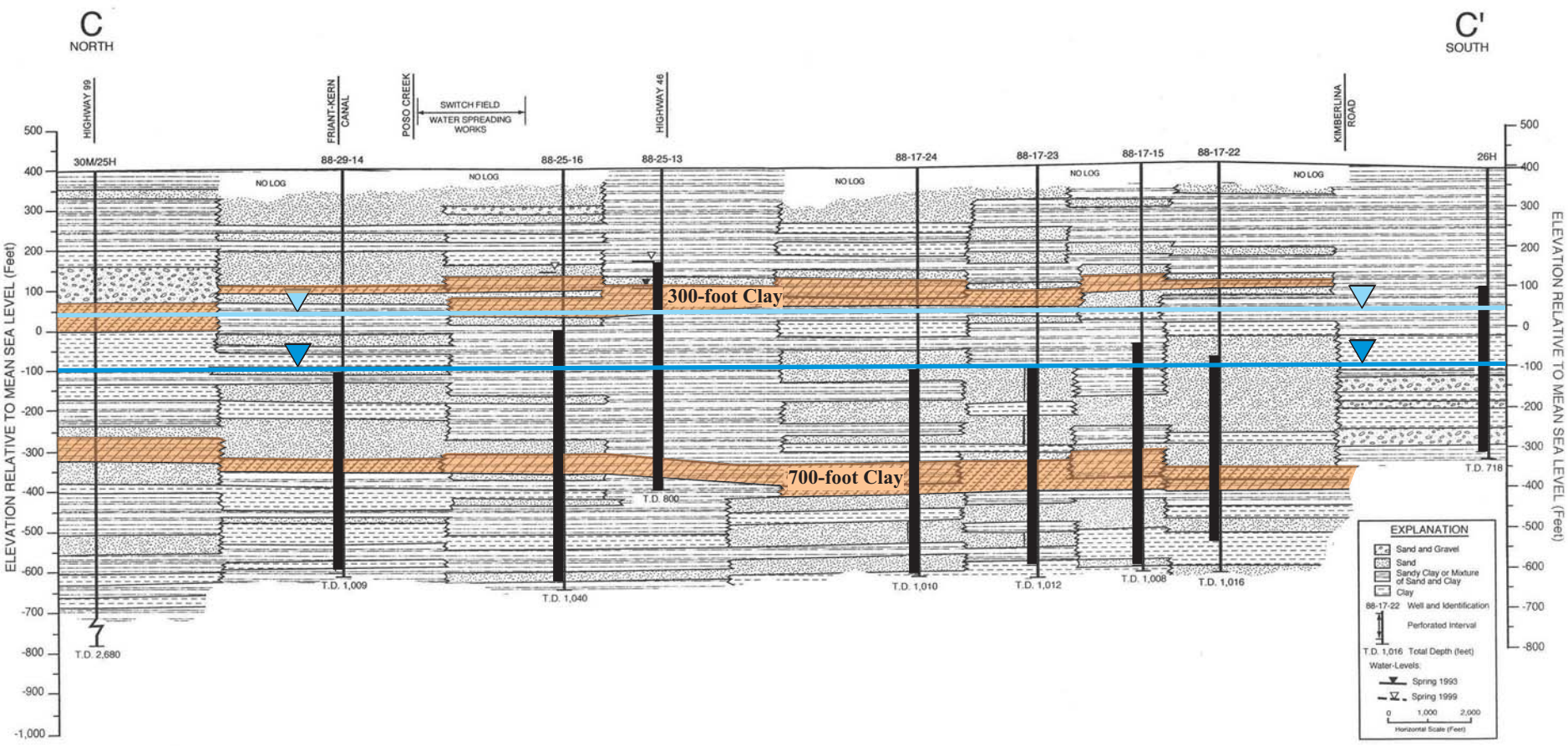
Figure 4-8
Effective Groundwater Basin and Cross Section Locations



Water Level, Spring 2014 (approximate)

Water Level, November 2014 (approximate)

Source: Modified from NKWSD (2012), Figure 9 by Kenneth D. Schmidt and Associates.



Water Level, Spring 2014 (approximate)

Water Level, November 2014 (approximate)

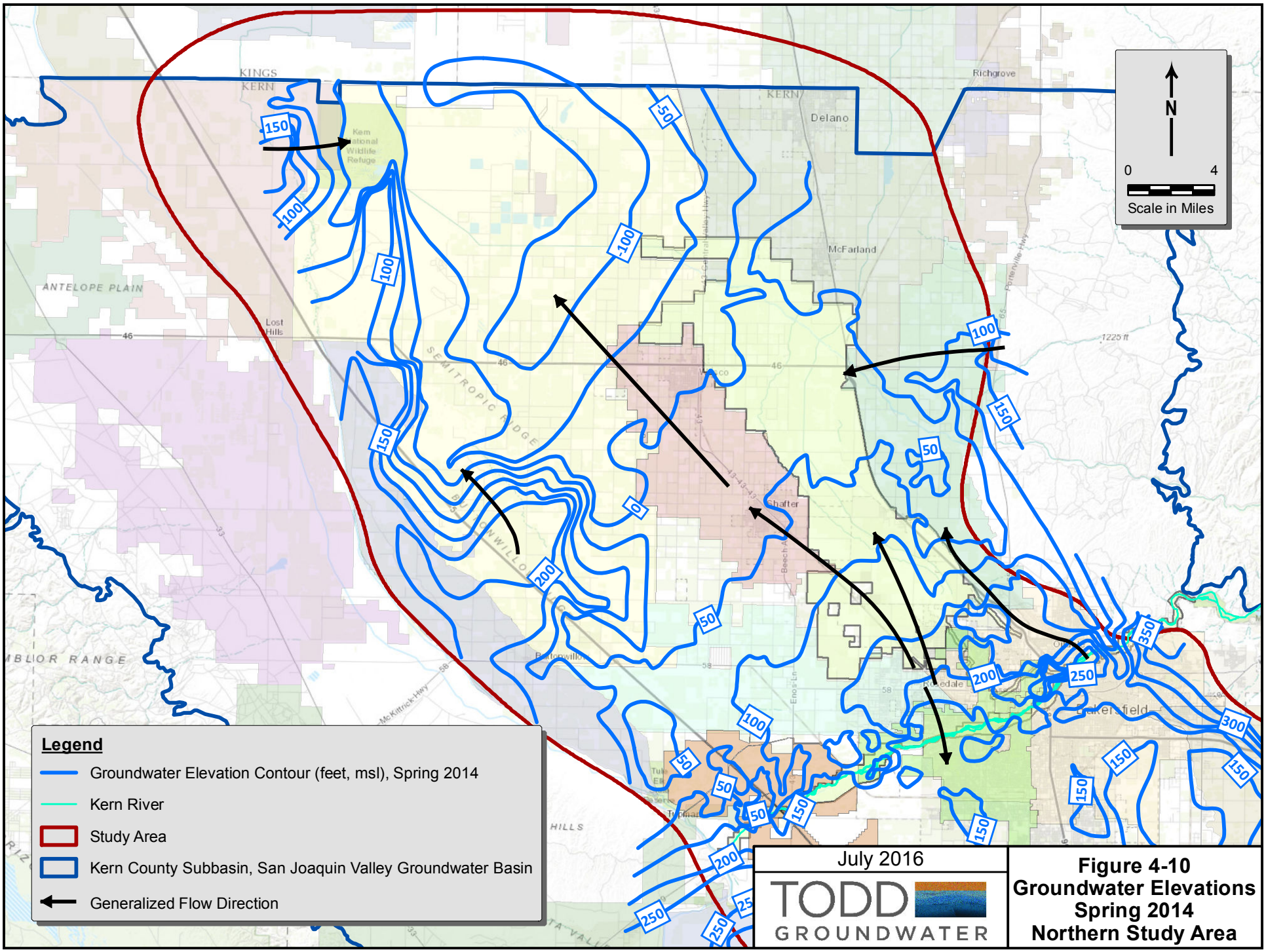
Source: Modified from NKWSD (2012), Figure 10 by Kenneth D. Schmidt and Associates.

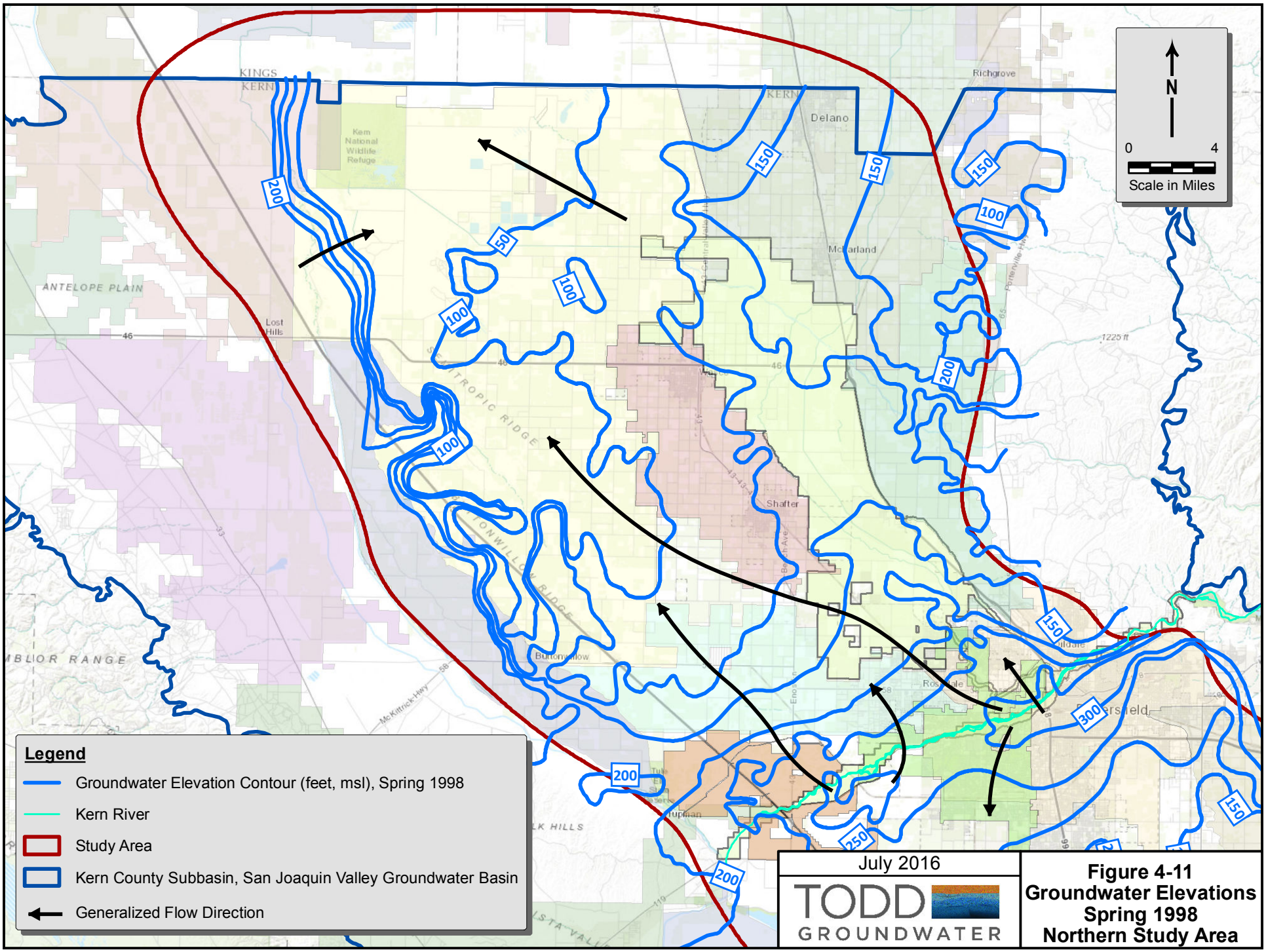
See Figure 4-8 for Cross Section Locations

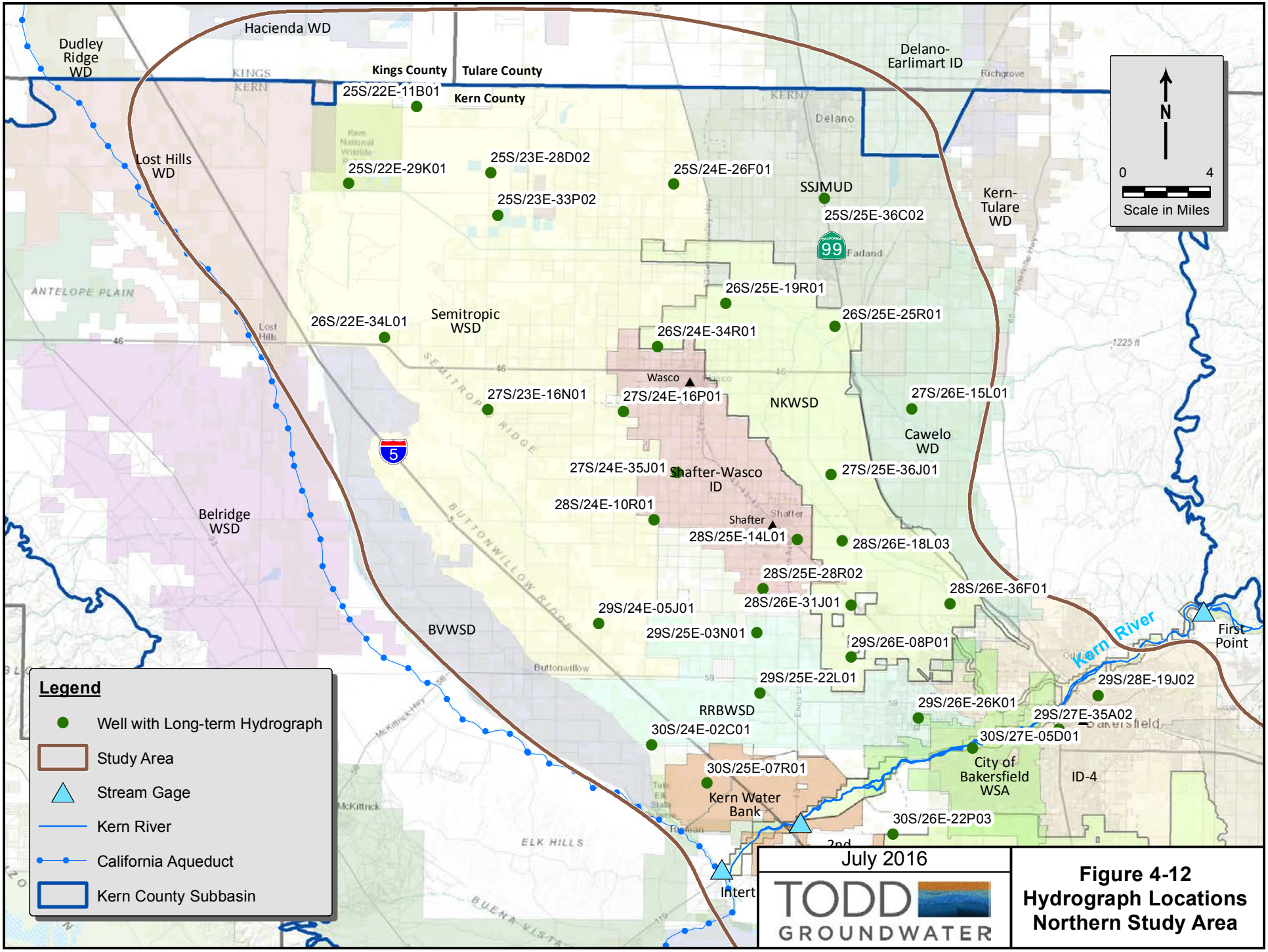
February 2017

TODD GROUNDWATER

Figure 4-9
Aquifer Textures and Confining Layers NKWSD


N
0
4
Scale in Miles
Legend
Groundwater Elevation Contour (feet, msl), Spring 2014
Kern River
Study Area
Kern County Subbasin, San Joaquin Valley Groundwater Basin
Generalized Flow Direction
July 2016
TODD GROUNDWATER
Figure 4-10
Groundwater Elevations
Spring 2014
Northern Study Area

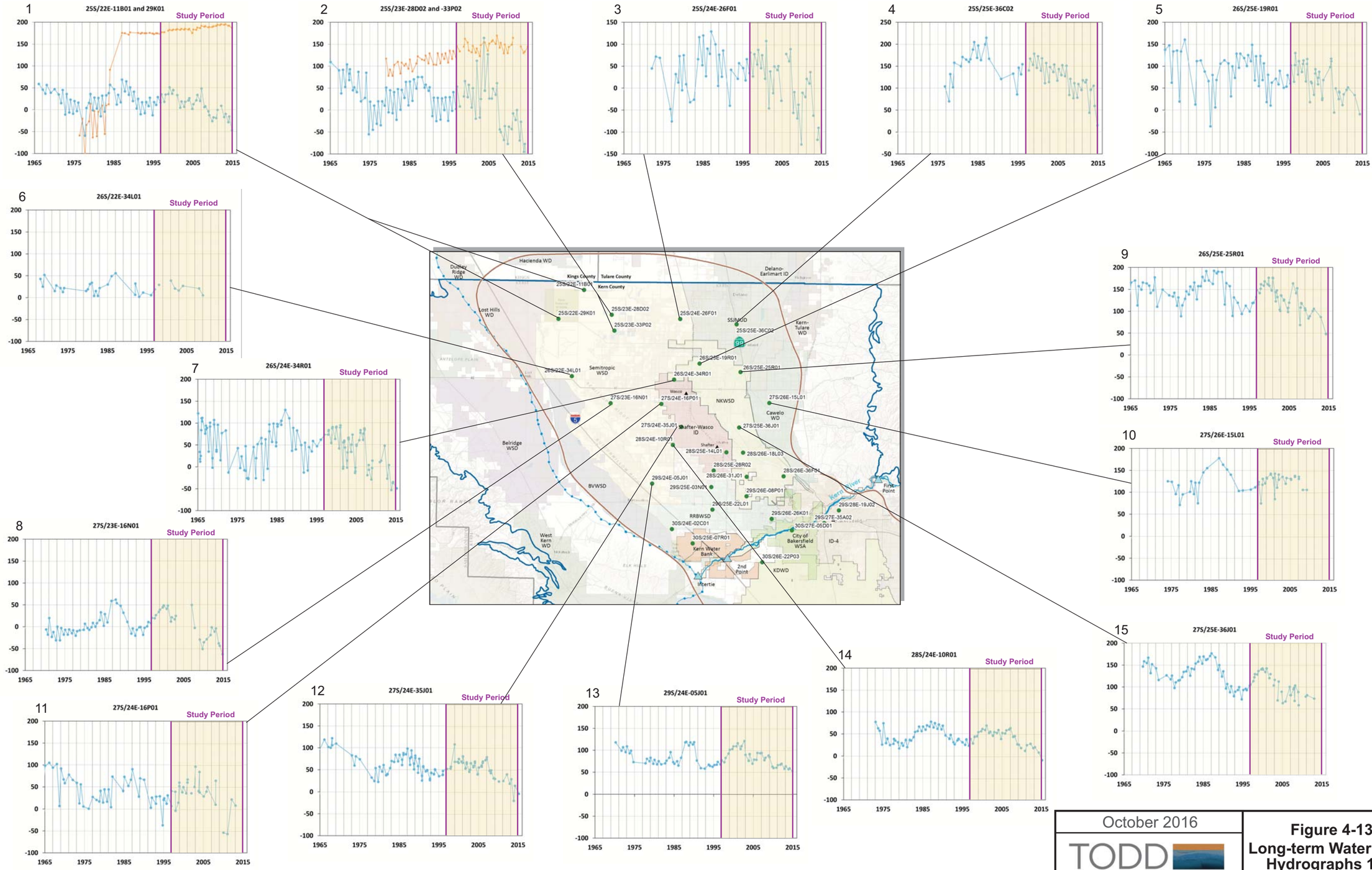

N
0
4
Scale in Miles
Legend
Groundwater Elevation Contour (feet, msl), Spring 1998
Kern River
Study Area
Kern County Subbasin, San Joaquin Valley Groundwater Basin
Generalized Flow Direction
July 2016
TODD GROUNDWATER
Figure 4-11
Groundwater Elevations
Spring 1998
Northern Study Area



July 2016

TODD GROUNDWATER

Figure 4-12
Hydrograph Locations
Northern Study Area

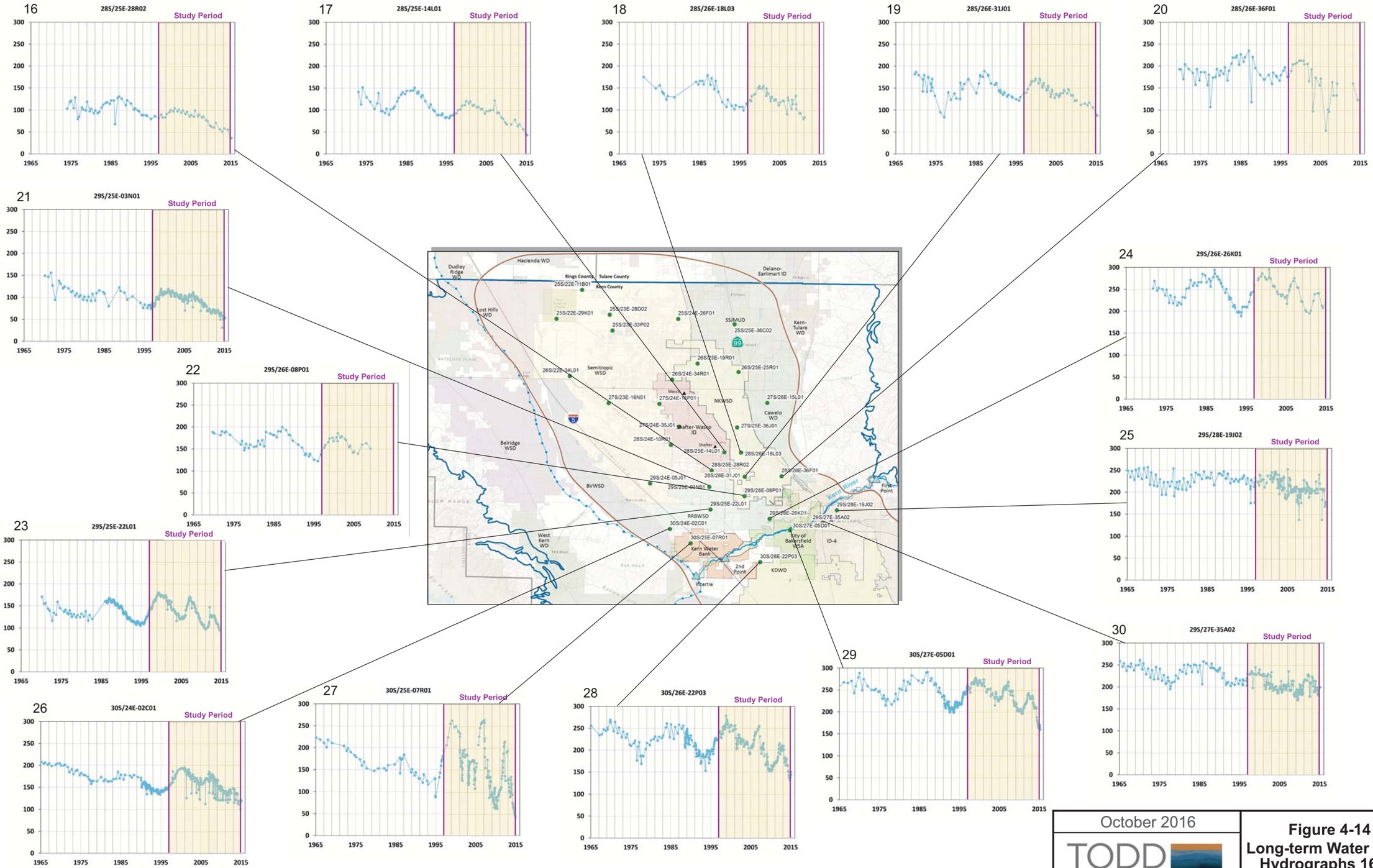


Vertical axis shows groundwater elevation in feet msl. Horizontal axis shows calendar years 1965 - 2015.

October 2016

TODD GROUNDWATER

Figure 4-13
Long-term Water Level Hydrographs 1-15
Northern Study Area

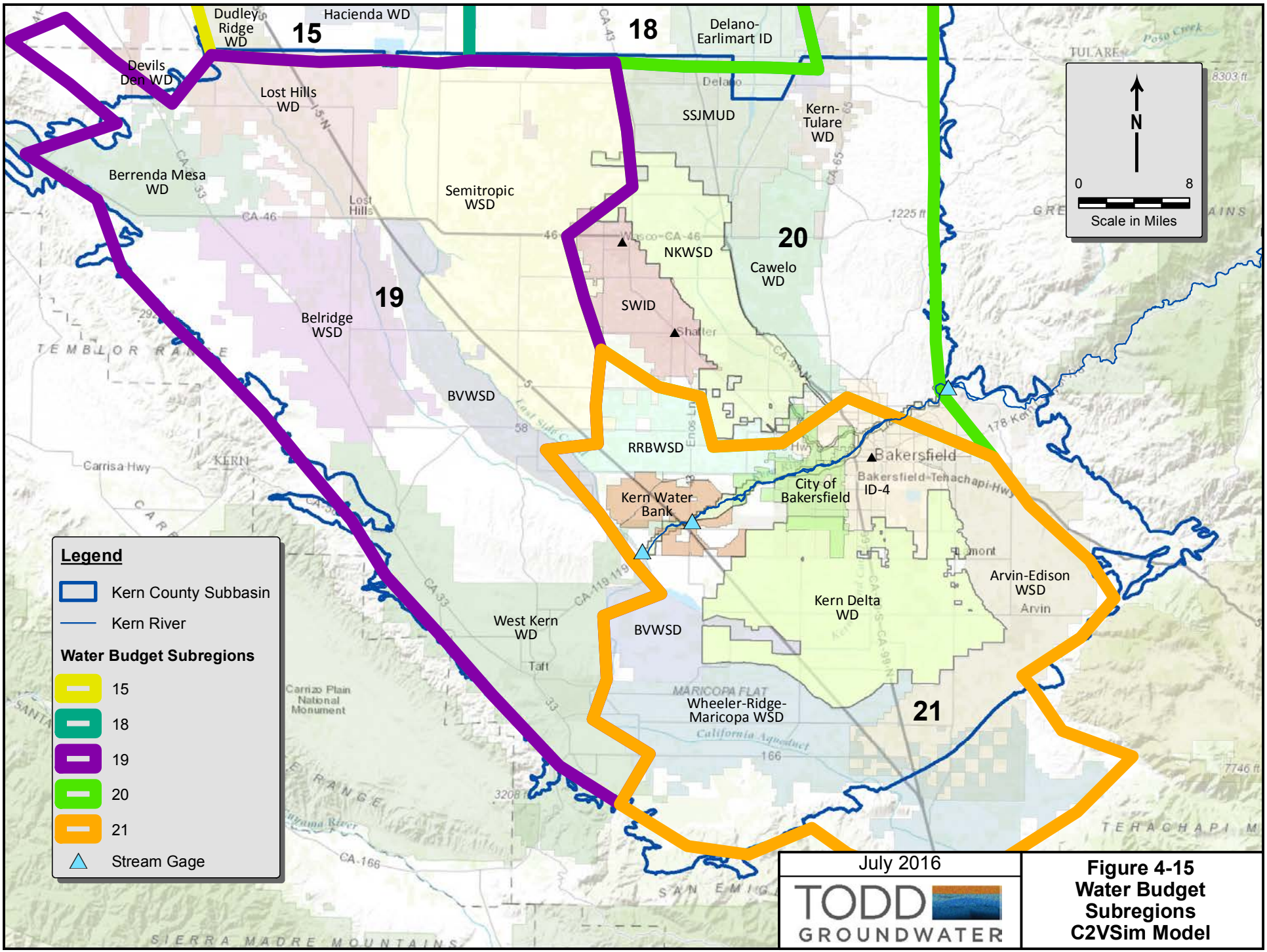


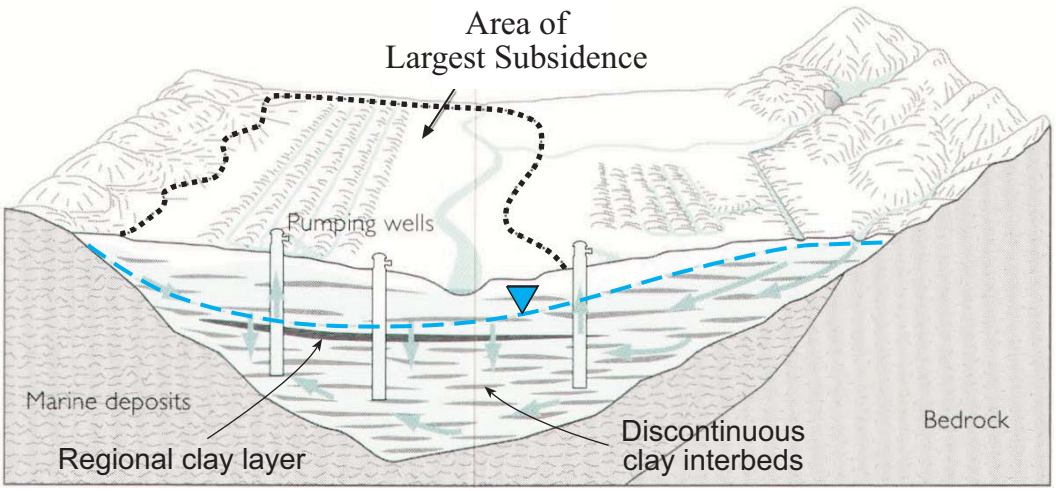
Vertical axis shows groundwater elevation in feet msl. Horizontal axis shows calendar years 1965 - 2015.

October 2016

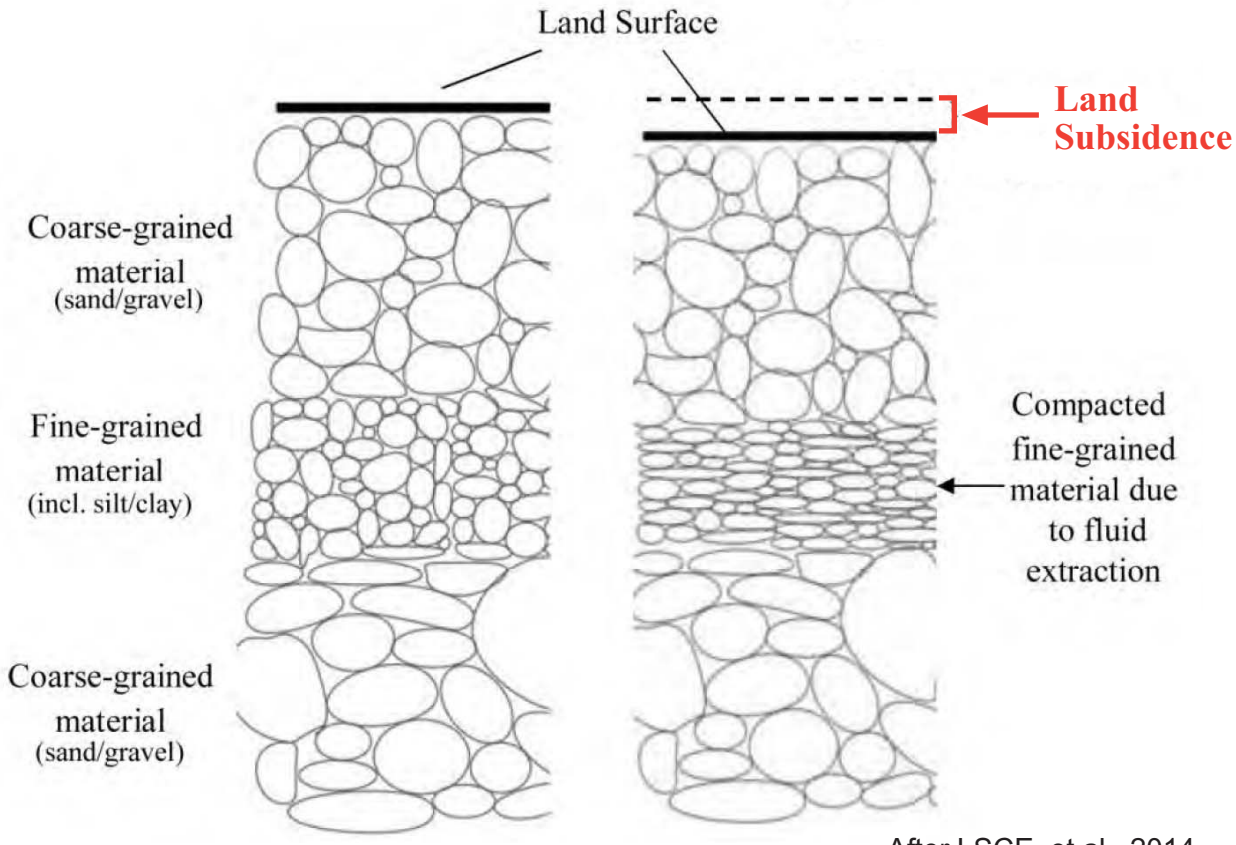
TODD GROUNDWATER

Figure 4-14
Long-term Water Level Hydrographs 16-30 Northern Study Area


Dudley Ridge WD
Hacienda WD
15
18
Delano-Earlimart ID
Devils Den WD
Lost Hills WD
SSJMUD
Kern-Tulare WD
Berrenda Mesa WD
Semitropic WSD
Lost Hills
NKWSD
20
Cawelo WD
19
SWID
Belridge WSD
BVWSD
RRBWSD
Bakersfield
City of Bakersfield
ID-4
Kern Water Bank
Arvin-Edison WSD
Kern Delta WD
West Kern WD
BVWSD
Wheeler-Ridge-Maricopa WSD
21
N
0
8
Scale in Miles
Legend
Kern County Subbasin
Kern River
Water Budget Subregions
15
18
19
20
21
Stream Gage
July 2016
TODD GROUNDWATER
Figure 4-15
Water Budget Subregions
C2VSim Model



Source: Galloway, et al., 1999.

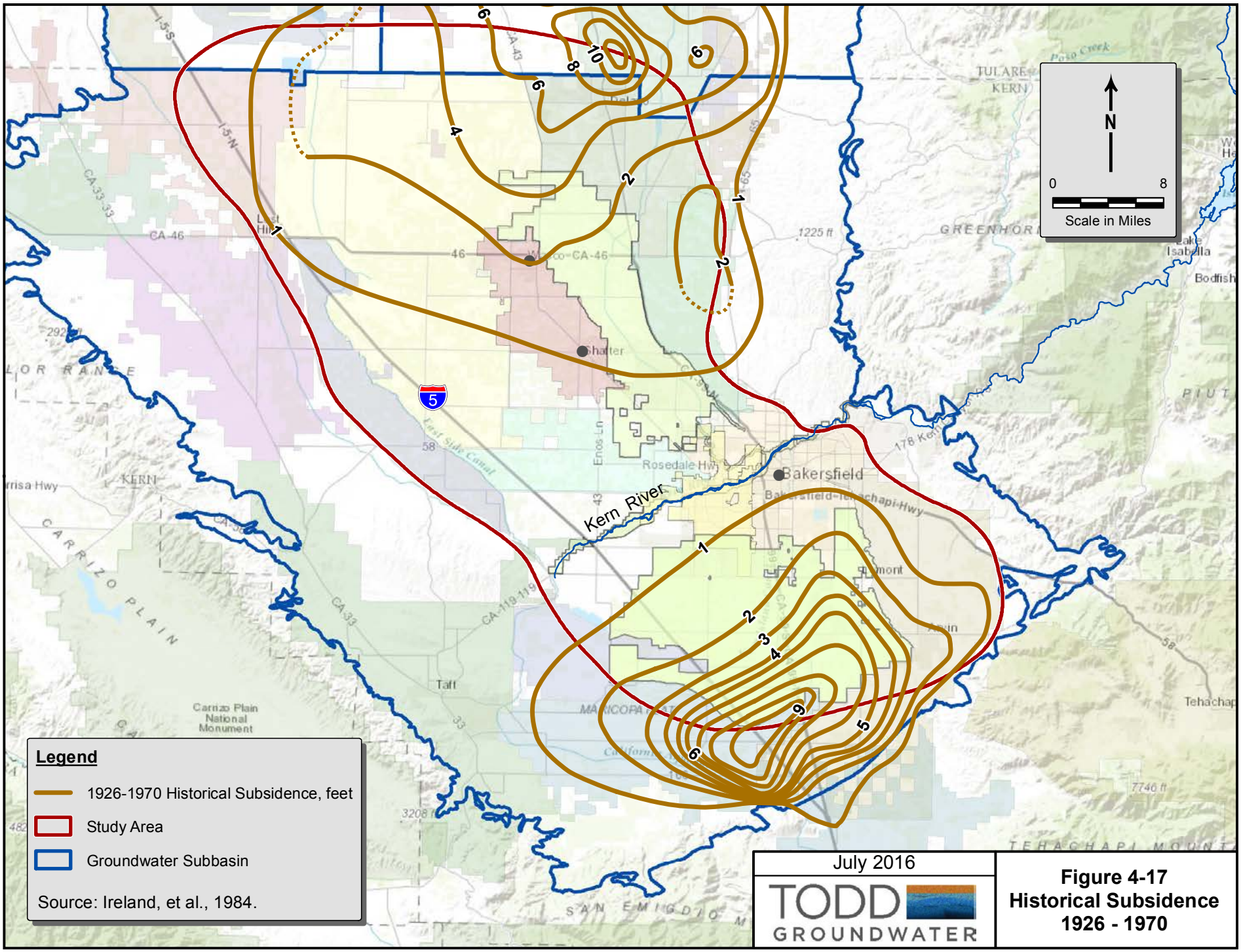


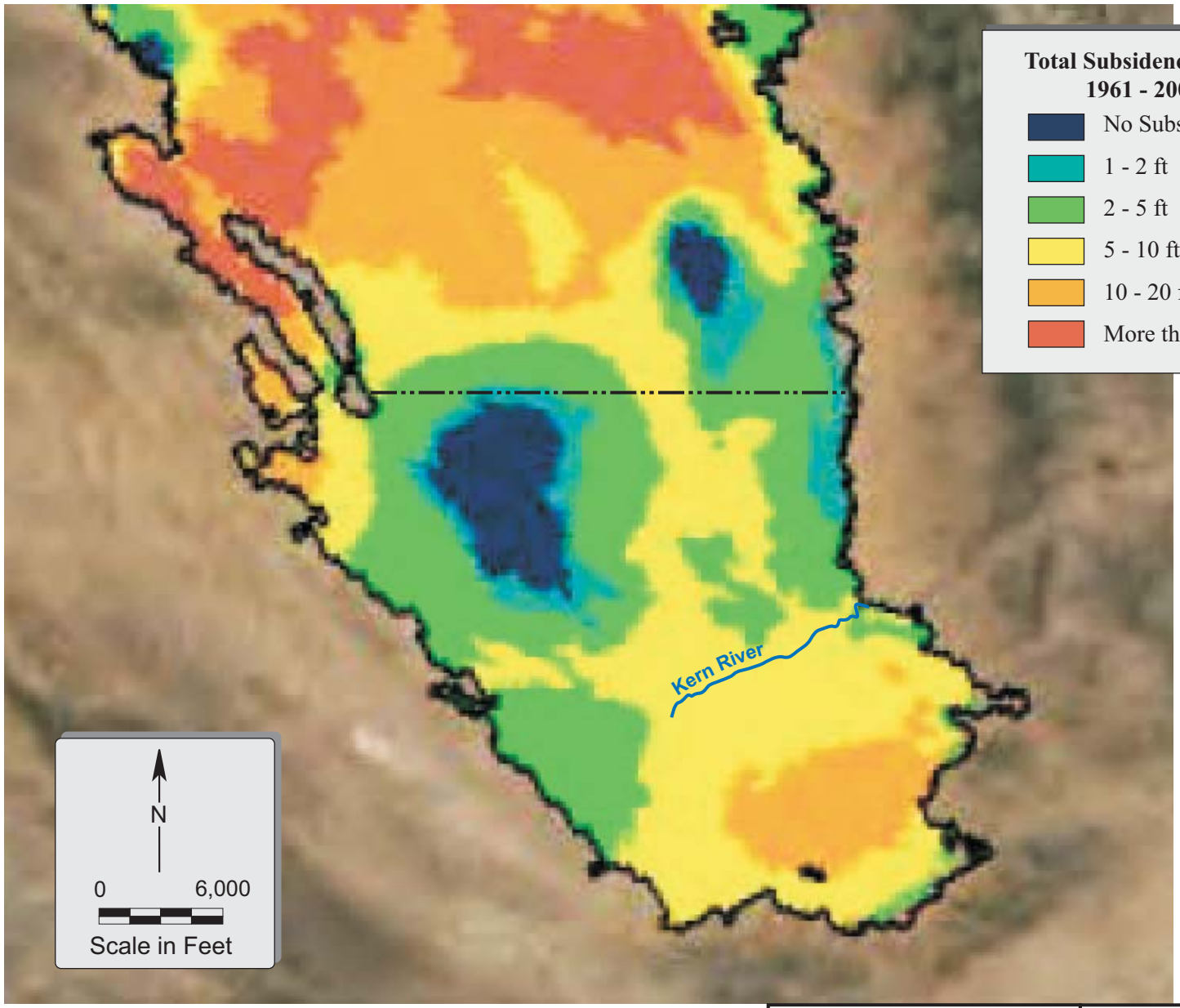
After LSCE, et al., 2014.

July 2016

TODD GROUNDWATER

Figure 4-16
Concepts of Land Subsidence


N
0
8
Scale in Miles
Legend
1926-1970 Historical Subsidence, feet
Study Area
Groundwater Subbasin
Source: Ireland, et al., 1984.
Kern River
Bakersfield
Shafter
Taft
Carrizo Plain National Monument
July 2016
TODD GROUNDWATER
Figure 4-17
Historical Subsidence
1926 - 1970

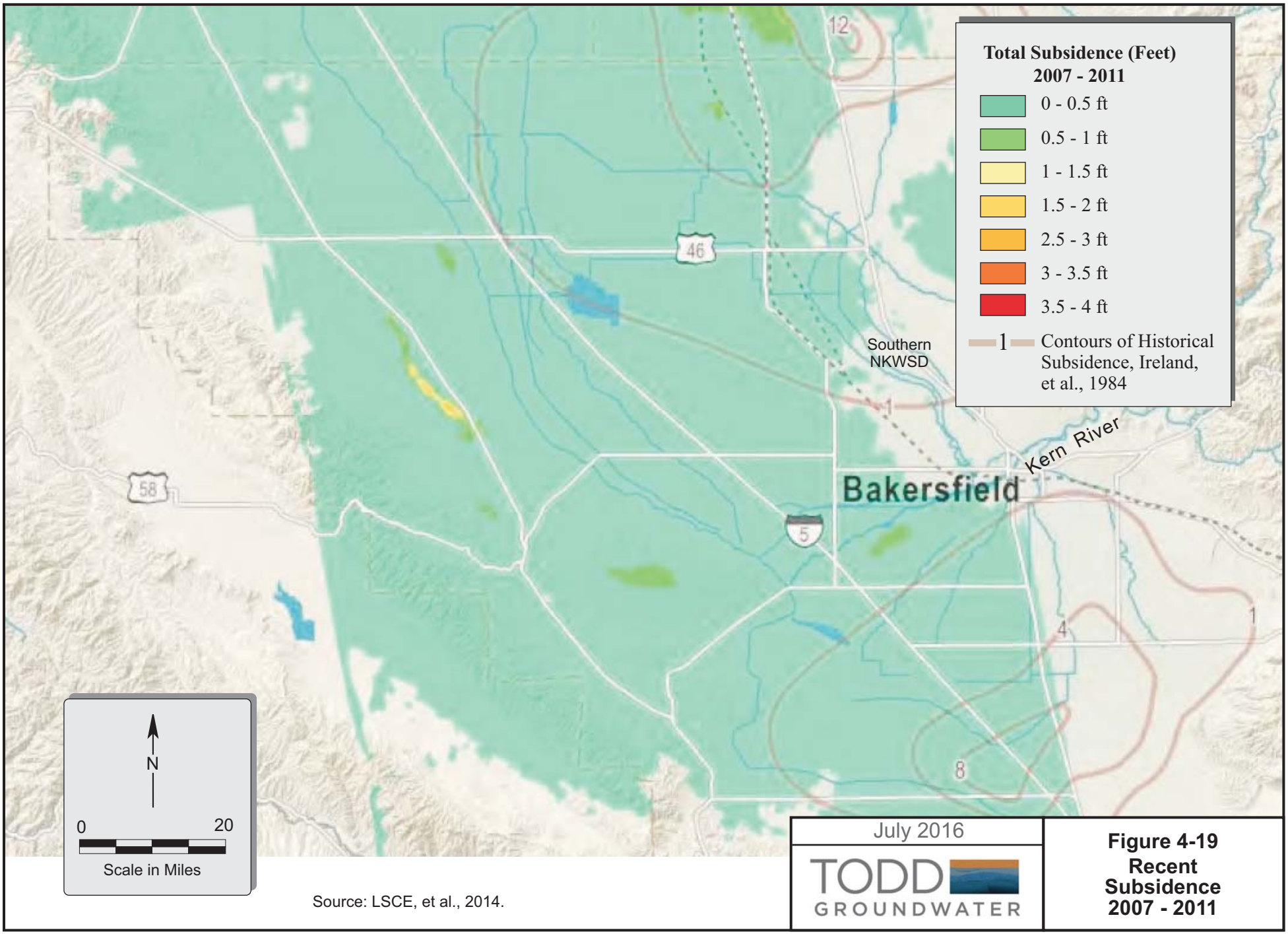


Source: Faunt and Phillips, 2014.

July 2016

TODD GROUNDWATER

Figure 4-18
Simulated Land Subsidence 1961 - 2009

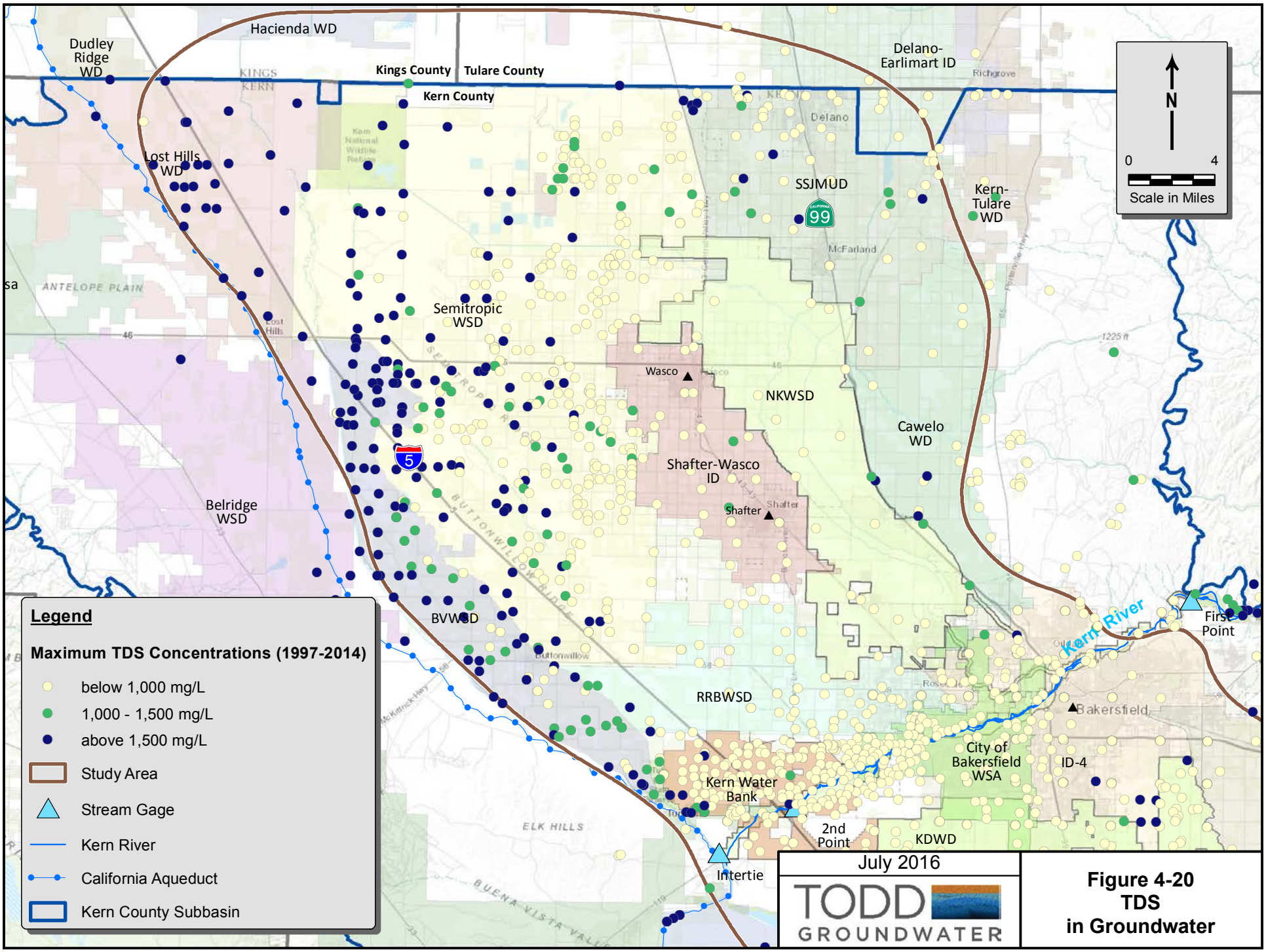


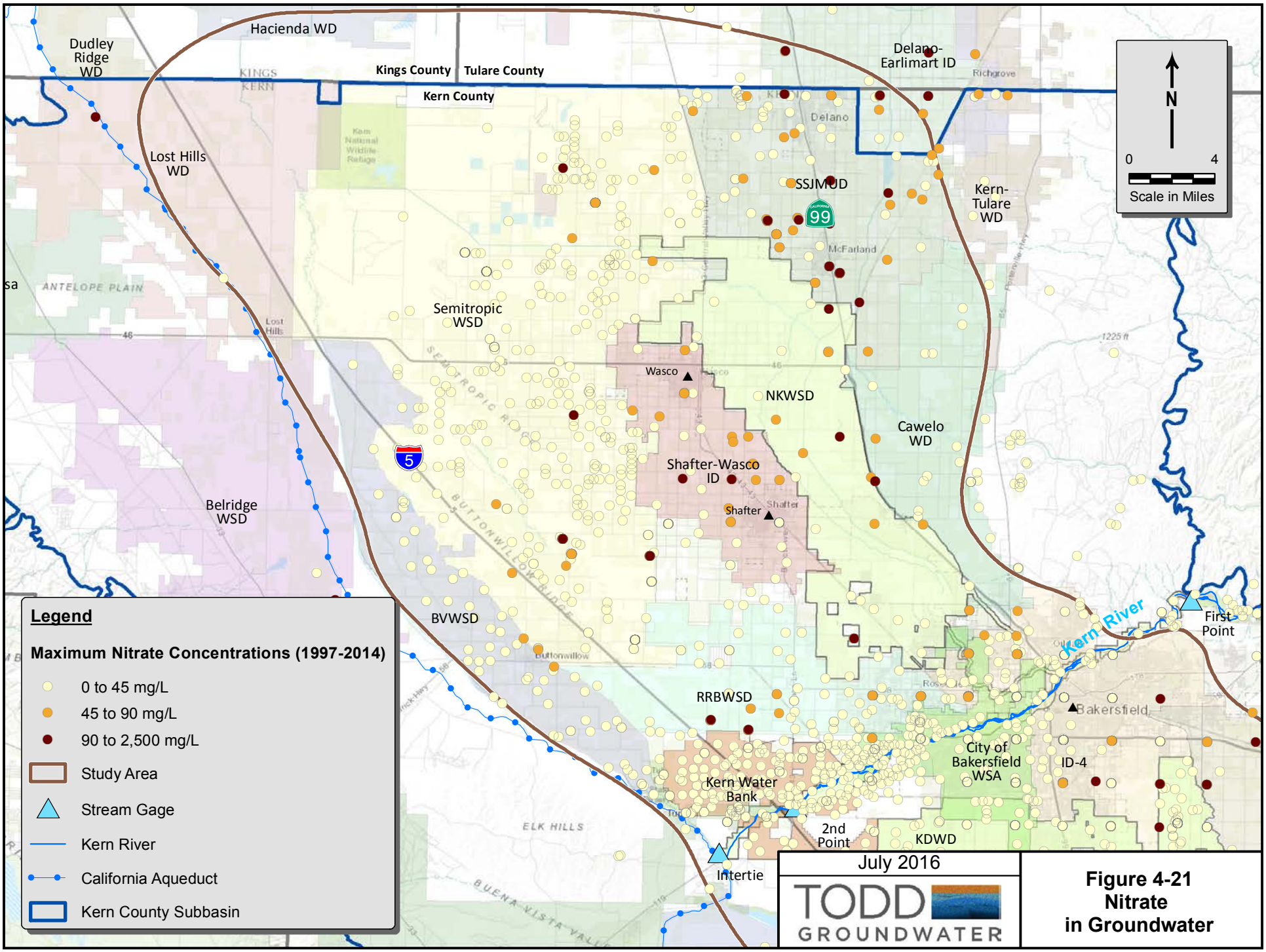
Source: LSCE, et al., 2014.

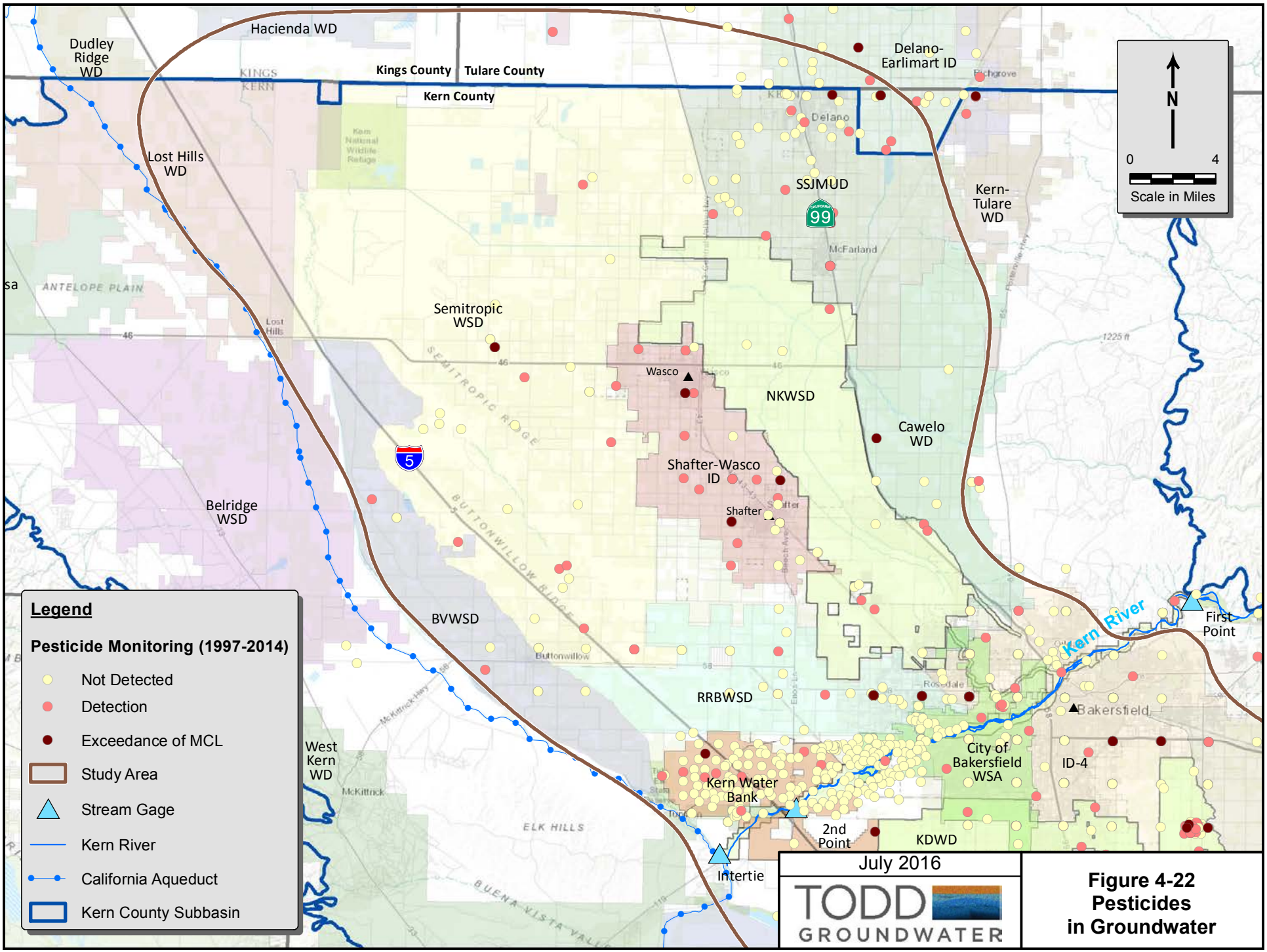
July 2016

TODD GROUNDWATER

Figure 4-19
Recent Subsidence 2007 - 2011


Hacienda WD
Dudley Ridge WD
Kings County
Tulare County
Kern County
Delano-Earlimart ID
Lost Hills WD
SSJMUD
Kern-Tulare WD
Semitropic WSD
Wasco
NKWSD
Cawelo WD
Shafter-Wasco ID
Shafter
Belridge WSD
BVWSD
RRBWSD
Kern River
First Point
Bakersfield
City of Bakersfield WSA
ID-4
Kern Water Bank
2nd Point
KDWD
Intertie
ELK HILLS
ANTELOPE PLAIN
McFarland
Delano
Richgrove
Buttonwillow
N
0
4
Scale in Miles
Legend
Maximum TDS Concentrations (1997-2014)
below 1,000 mg/L
1,000 - 1,500 mg/L
above 1,500 mg/L
Study Area
Stream Gage
Kern River
California Aqueduct
Kern County Subbasin
July 2016
TODD GROUNDWATER
Figure 4-20
TDS
in Groundwater


Hacienda WD
Dudley Ridge WD
Kings County
Tulare County
Kern County
Delano-Earlimart ID
Richgrove
Delano
Lost Hills WD
SSJMUD
Kern-Tulare WD
99
McFarland
ANTELOPE PLAIN
Semitropic WSD
Wasco
NKWSD
Cawelo WD
Shafter-Wasco ID
Shafter
5
Belridge WSD
BVWSD
Buttonwillow
Kern River
First Point
RRBWSD
Bakersfield
City of Bakersfield WSA
ID-4
Kern Water Bank
2nd Point
KDWD
ELK HILLS
Intertie
N
0
4
Scale in Miles
Legend
Maximum Nitrate Concentrations (1997-2014)
0 to 45 mg/L
45 to 90 mg/L
90 to 2,500 mg/L
Study Area
Stream Gage
Kern River
California Aqueduct
Kern County Subbasin
July 2016
TODD GROUNDWATER
Figure 4-21
Nitrate
in Groundwater


Hacienda WD
Dudley Ridge WD
Kings County
Tulare County
Kern County
Delano-Earlimart ID
Lost Hills WD
SSJMUD
Kern-Tulare WD
Delano
McFarland
99
5
Semitropic WSD
Wasco
NKWSD
Cawelo WD
Shafter-Wasco ID
Shafter
Belridge WSD
BVWSD
Buttonwillow
RRBWSD
Kern River
First Point
Bakersfield
City of Bakersfield WSA
ID-4
West Kern WD
McKittrick
Kern Water Bank
2nd Point
KDWD
Intertie
ELK HILLS
ANTELOPE PLAIN
SEMITROPIC RIDGE
BUTTONWILLOW RIDGE
BUENA VISTA VALLEY
N
0
4
Scale in Miles
Legend
Pesticide Monitoring (1997-2014)
Not Detected
Detection
Exceedance of MCL
Study Area
Stream Gage
Kern River
California Aqueduct
Kern County Subbasin
July 2016
TODD GROUNDWATER
Figure 4-22
Pesticides in Groundwater

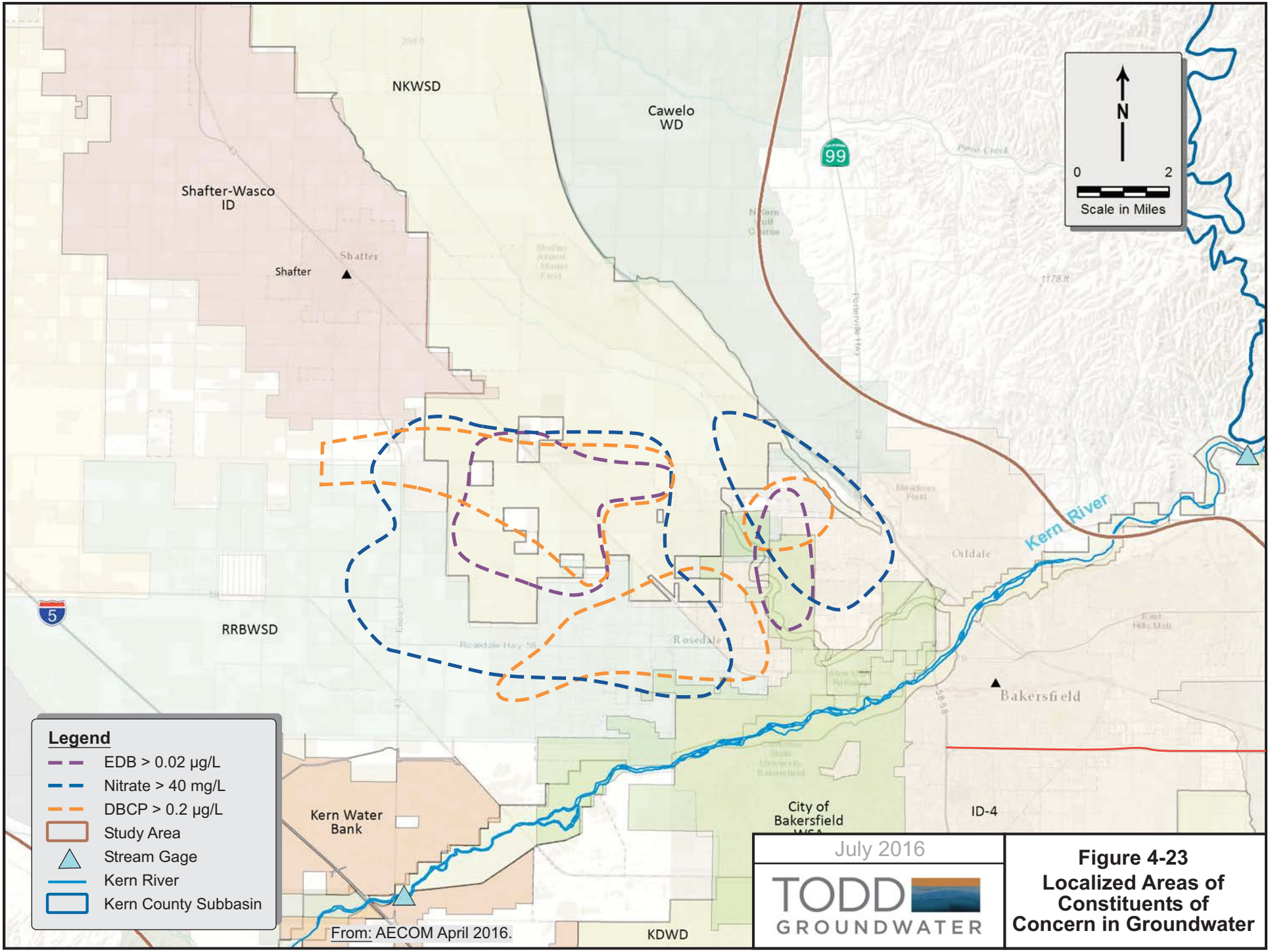
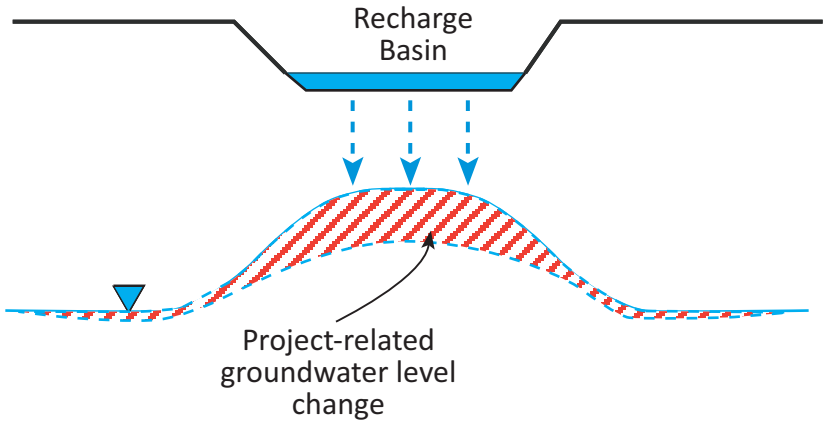


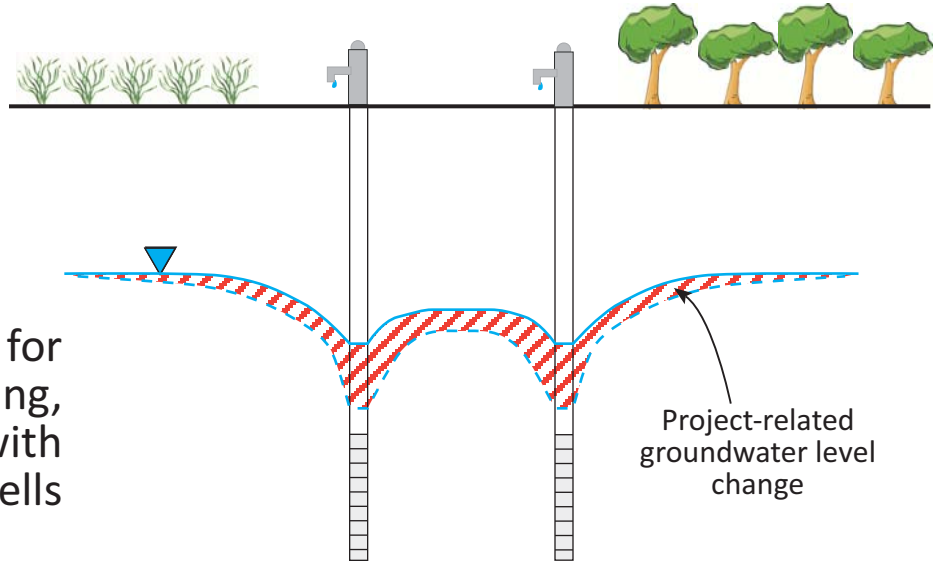
Figure 4-23
Localized Areas of Constituents of Concern in Groundwater



Reduction in surface water available for *local recharge or banking* results in lower groundwater levels with largest impact underneath facility

The volume of water in the zone of "Project-related groundwater level change" represents the change in groundwater storage in the aquifer

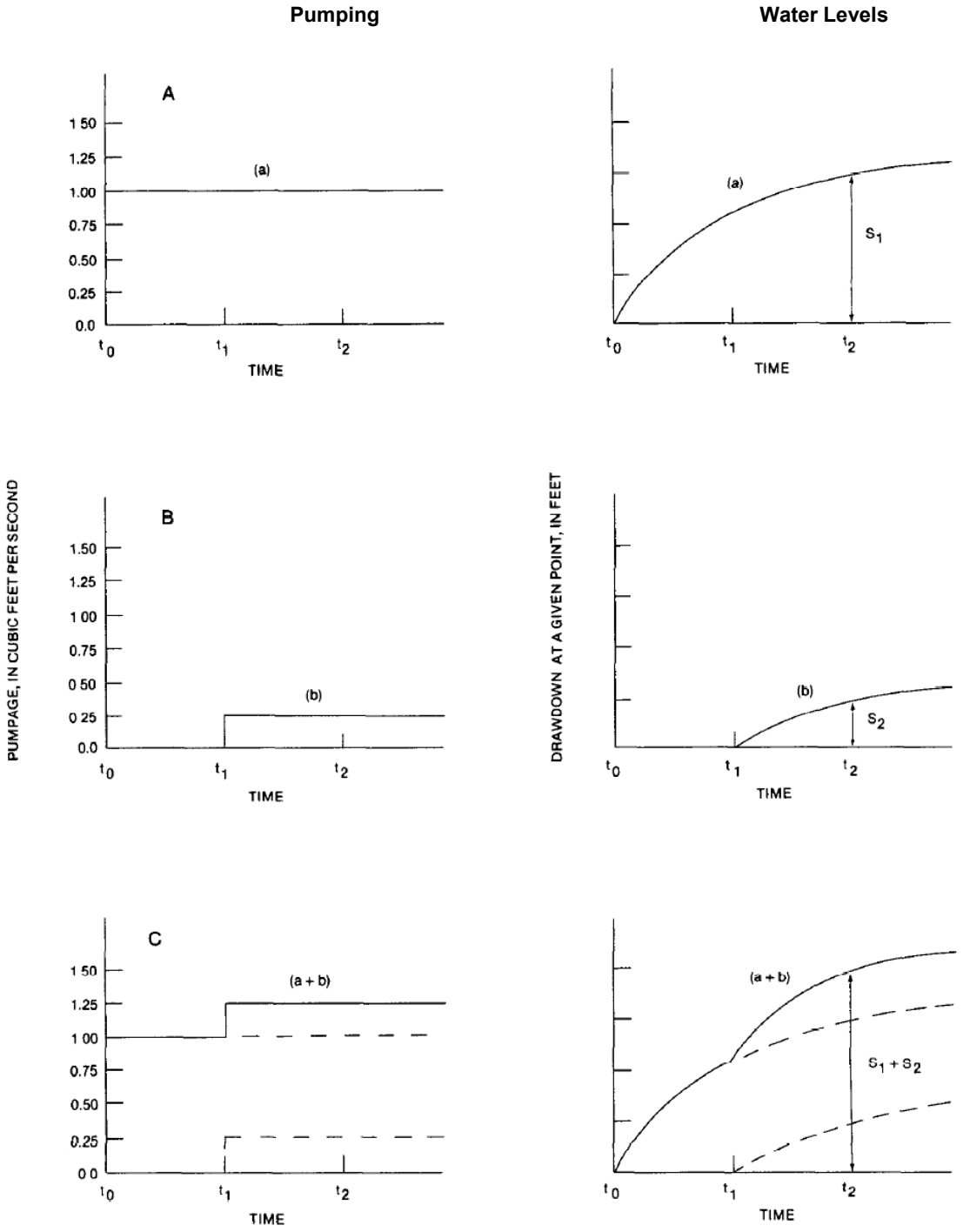
Reduction in surface water available for *irrigation* results in increased pumping, which lowers groundwater levels with largest impact at pumping wells



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TODD GROUNDWATER

Figure 5-1
Conceptual Project Impacts on Groundwater Levels



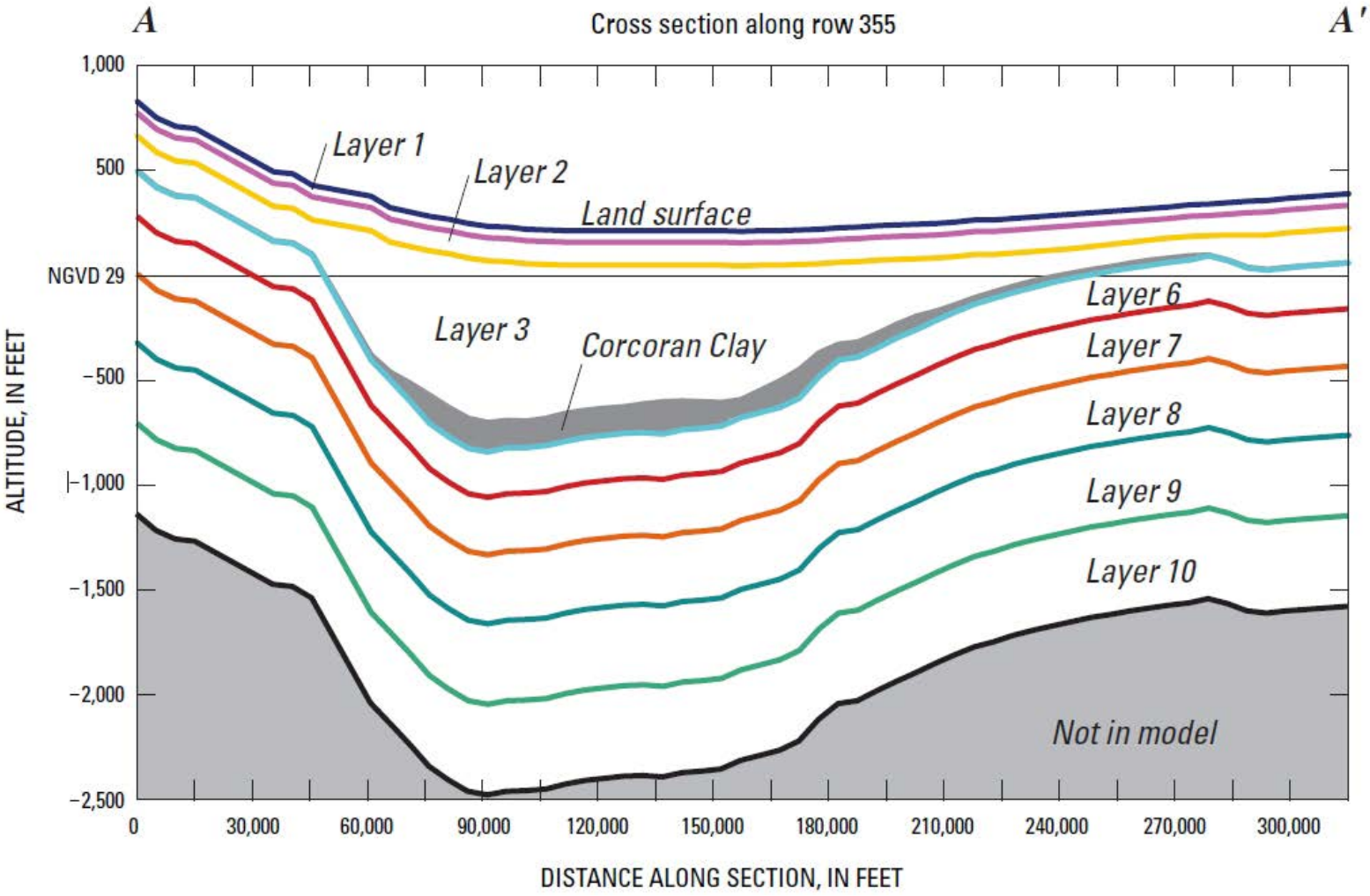
Superposition of well solutions: A, Initial pumpage starting at t_1, and its resulting drawdown, s_2, at t_2
B, Change in pumpage from the initial rate starting at t_1 and its resulting drawdown, s_2, at t_2
C, Total pumpage starting at initial rate and increasing at t_1, and its resulting drawdown, $s_{1+}+s_{2,}$ as obtained by superposition.

Source: Figure 6 from Reilly, Franke and Bennett, 1987, The Principle of Superposition and Its Application in Ground-Water Hydraulics, U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 3, Chapter B6

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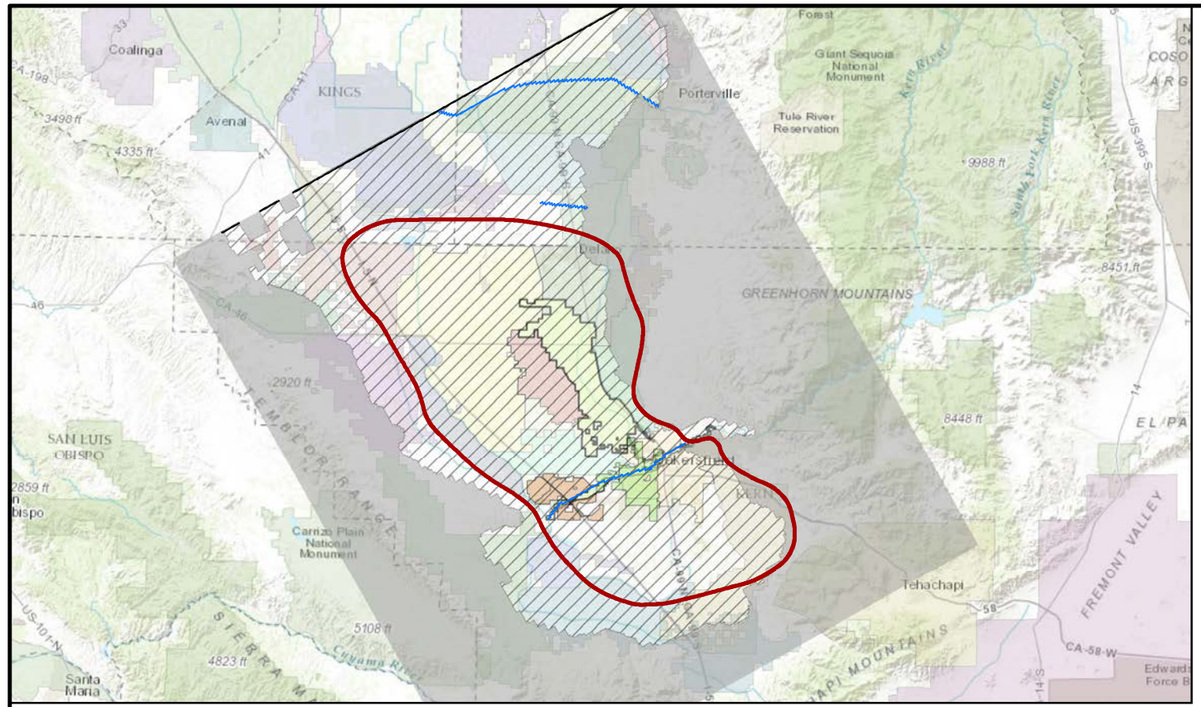
Figure 5-2
USGS Example of Principle of Superposition



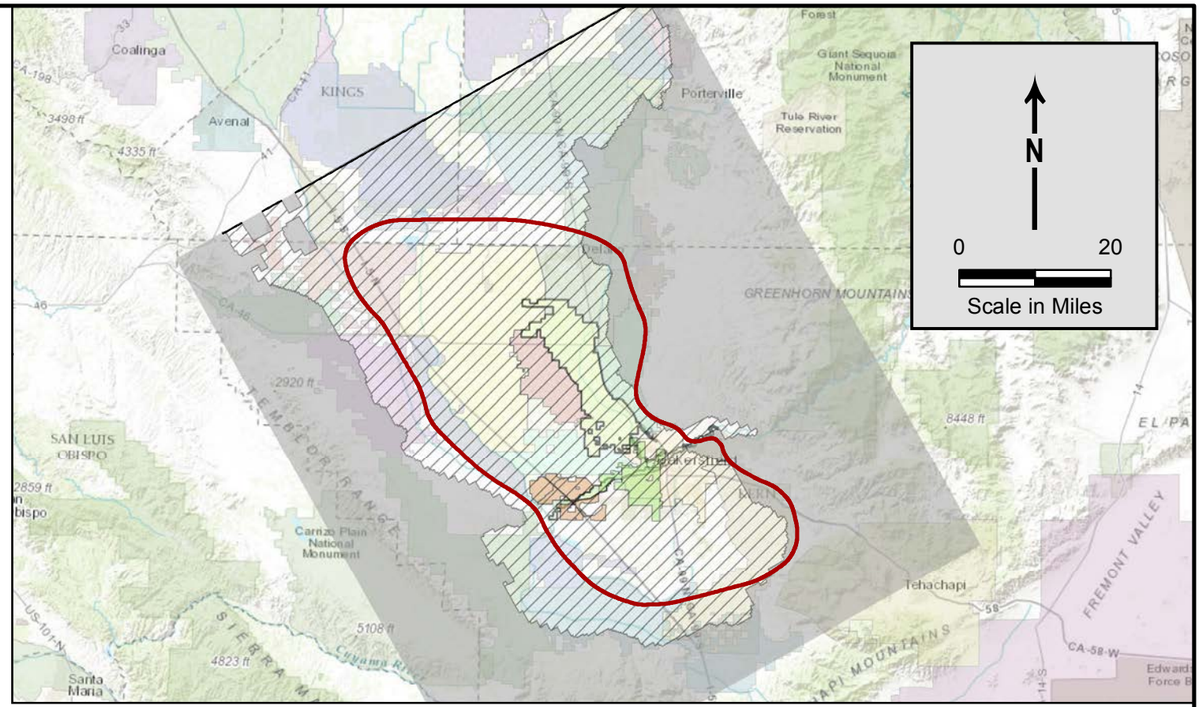
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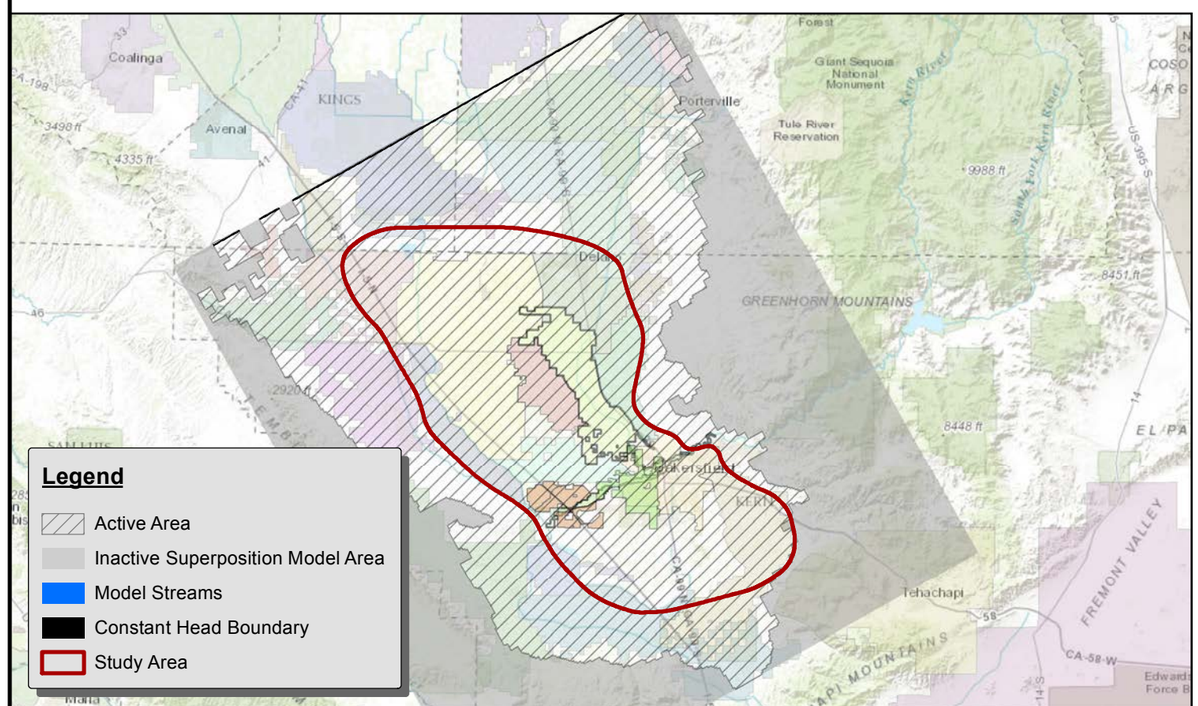
Figure 5-3
Conceptual Cross Section Showing Model Layers in USGS Central Valley Hydrologic Model



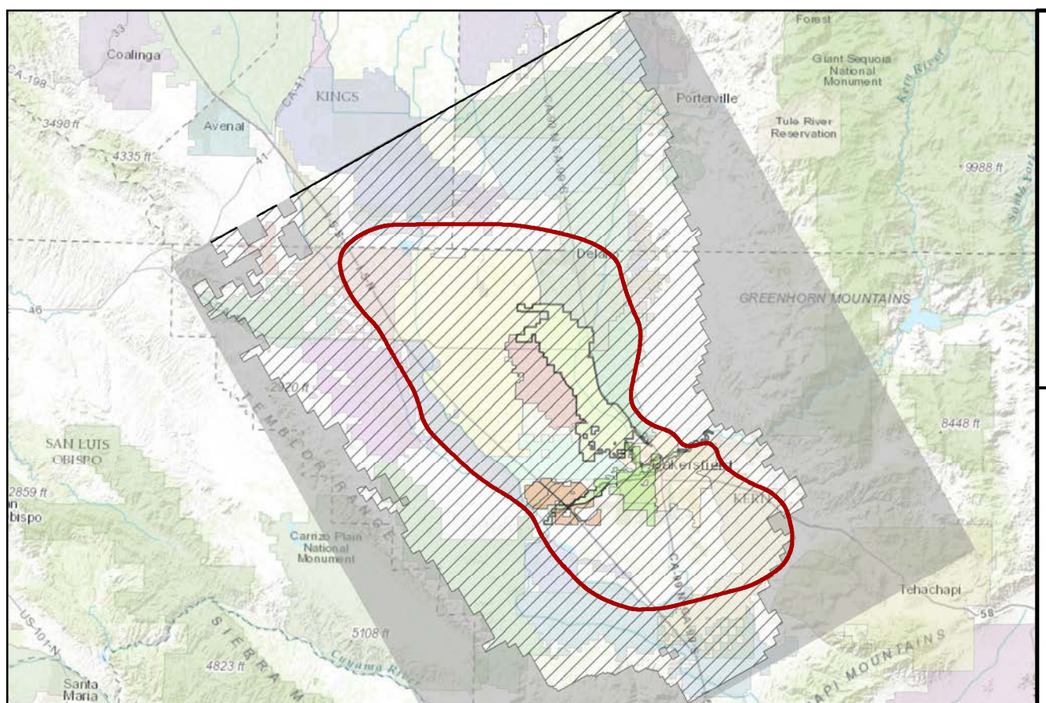
Layer 1



Layer 2



Layer 3

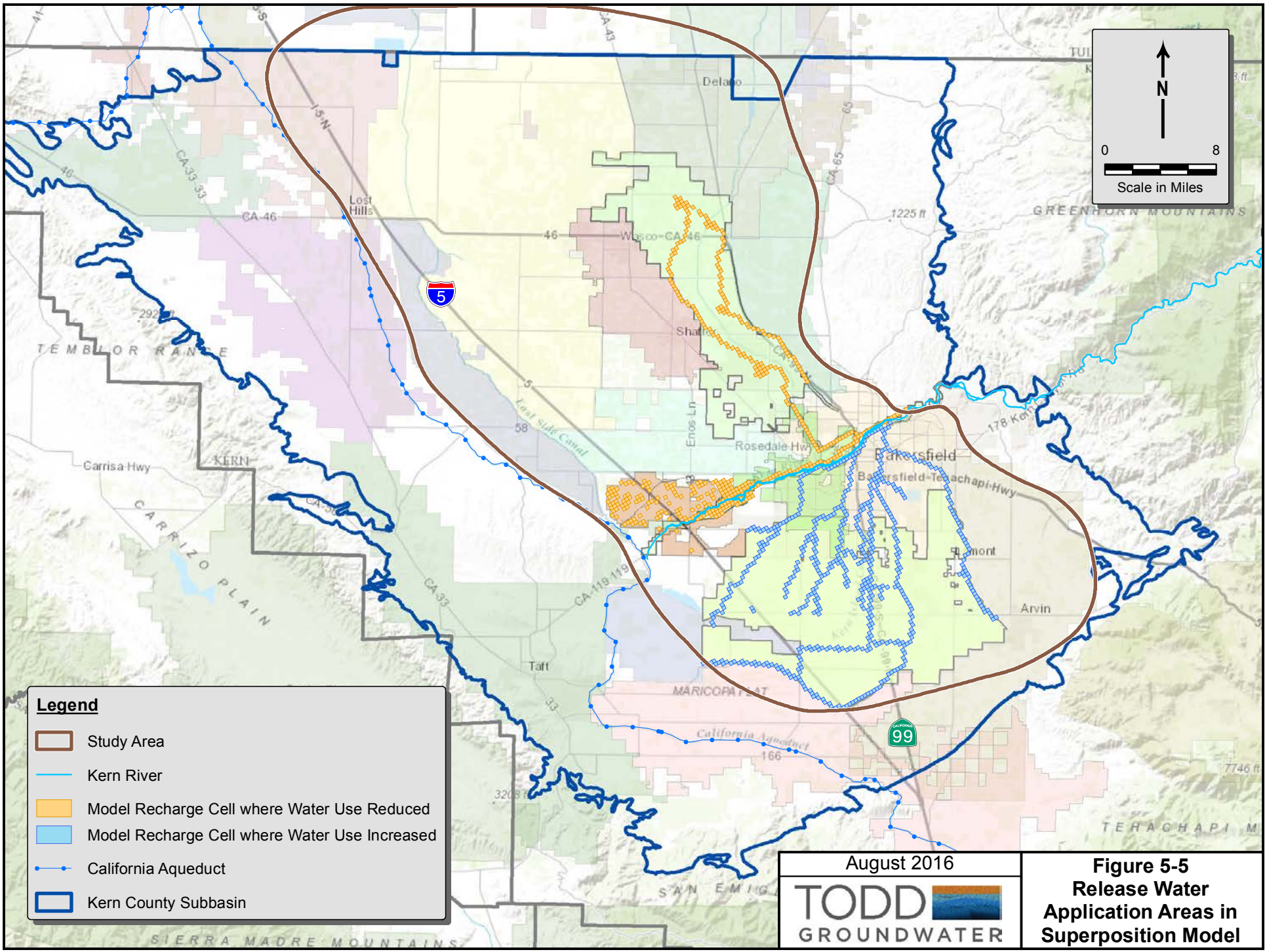


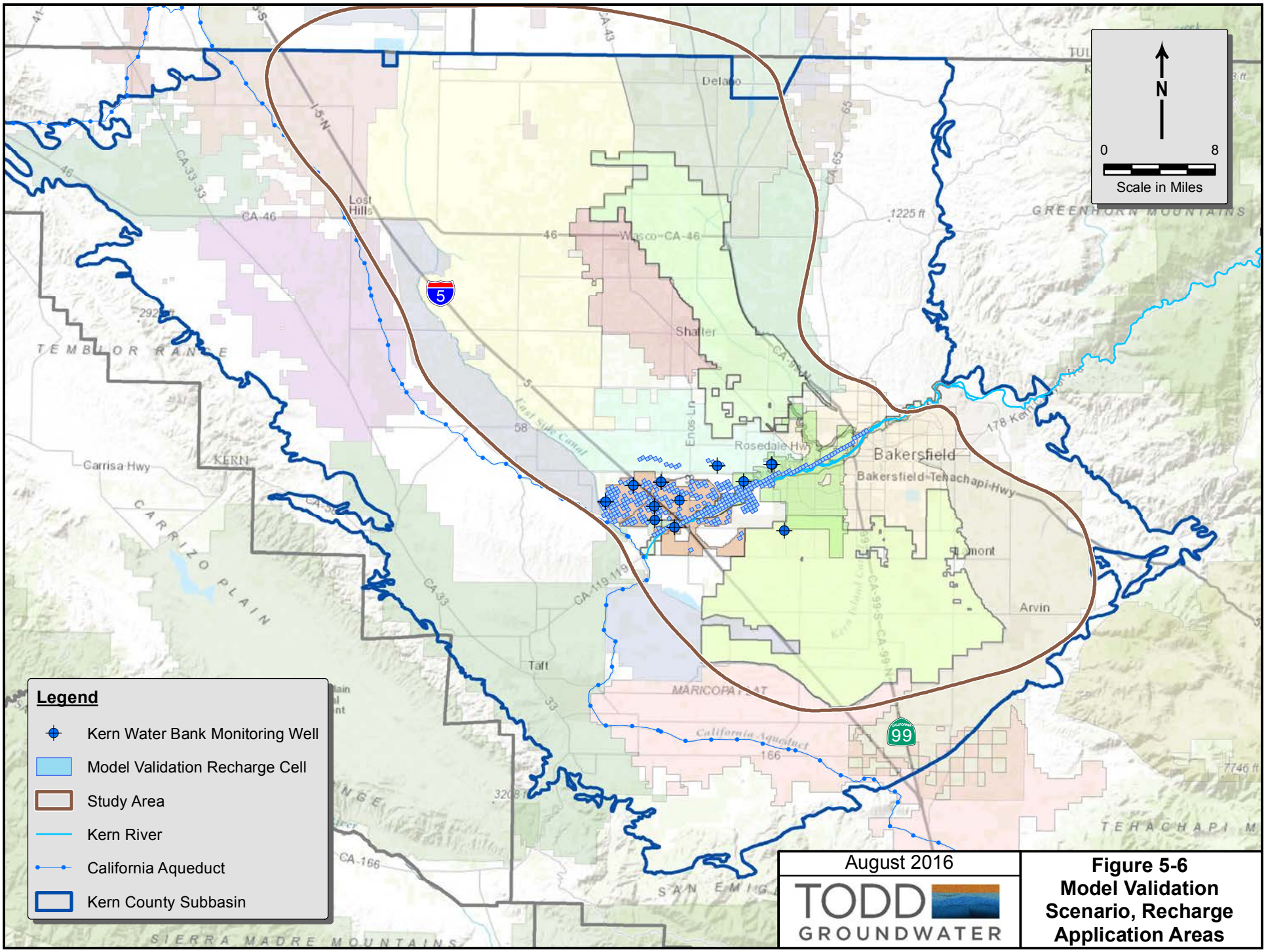
Layer 4

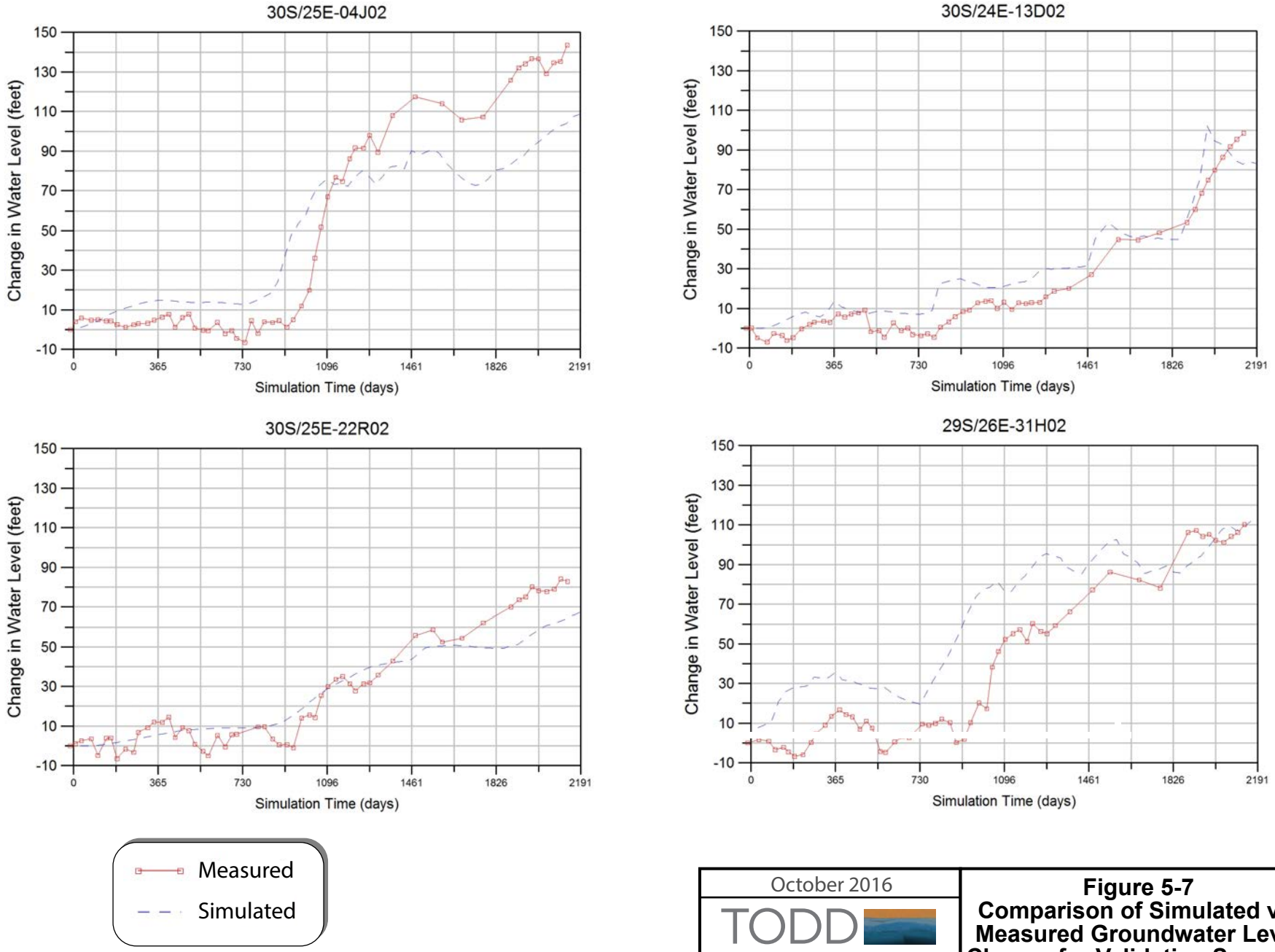
Figure 5-4
KDWD Superposition Model Domain with Boundary Conditions

October 2016

TODD GROUNDWATER


N
0
8
Scale in Miles
Legend
Study Area
Kern River
Model Recharge Cell where Water Use Reduced
Model Recharge Cell where Water Use Increased
California Aqueduct
Kern County Subbasin
Delano
Lost Hills
Wasco
Shafter
Rosedale Hwy
Bakersfield
Arvin
Taft
Carrisa Hwy
KERN
TEMBLOR RANGE
CARRIZO PLAIN
SIERRA MADRE MOUNTAINS
GREENHORN MOUNTAINS
TEHACHAPI M
MARICOPA FLAT
Lost Side Canal
California Aqueduct
Enos Ln
I-5 N
CA-46
CA-43
CA-65
CA-119
CA-33
5
46
58
99
166
1225 ft
7746 ft
August 2016
TODD GROUNDWATER
Figure 5-5
Release Water Application Areas in Superposition Model

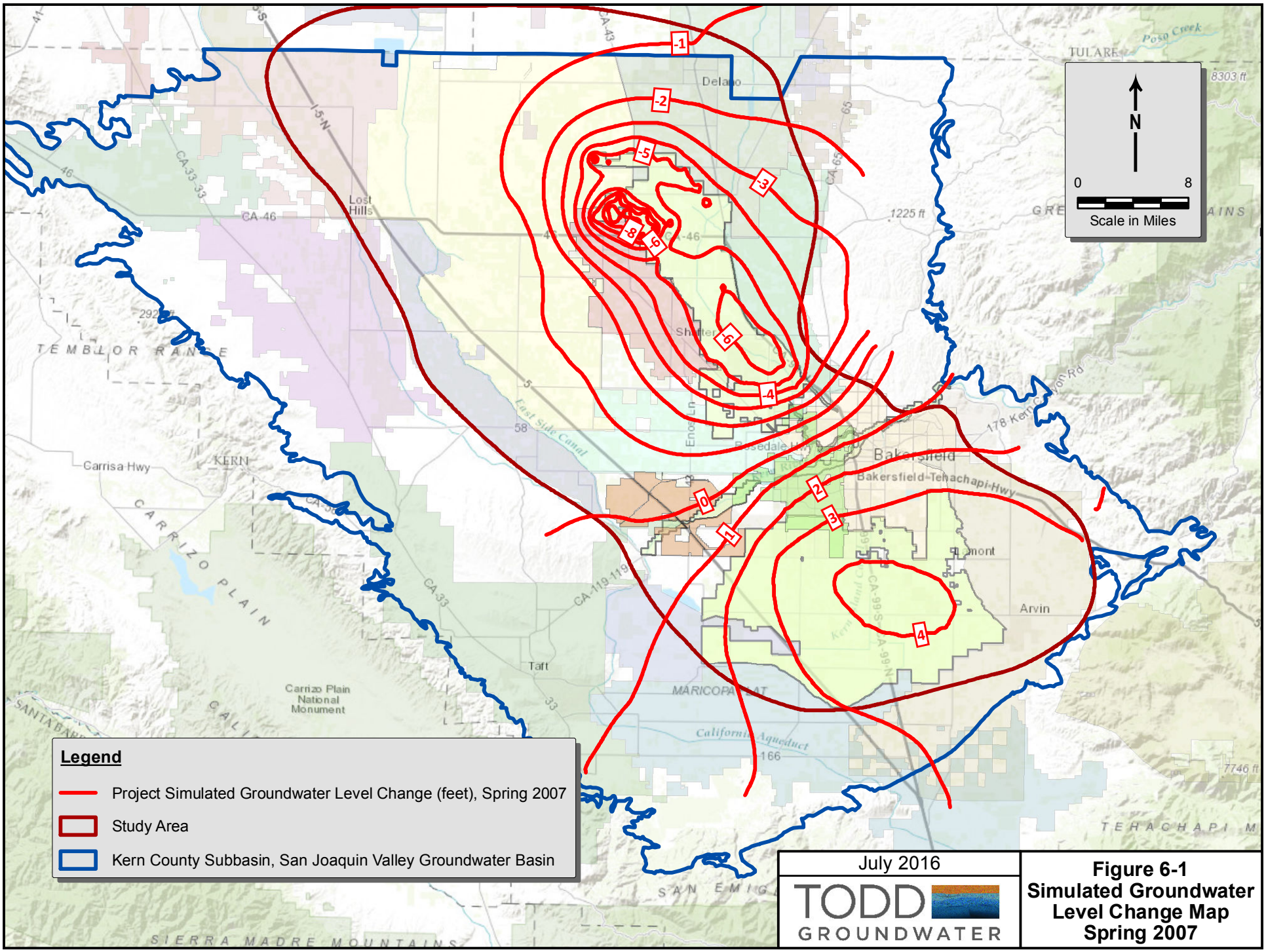

N
0
8
Scale in Miles
Legend
Kern Water Bank Monitoring Well
Model Validation Recharge Cell
Study Area
Kern River
California Aqueduct
Kern County Subbasin
Delano
Lost Hills
Wasco
Shafter
Bakersfield
Arvin
Taft
Carrisa Hwy
KERN
TEMBLOR RANGE
CARRIZO PLAIN
SIERRA MADRE MOUNTAINS
GREENHORN MOUNTAINS
TEHACHAPI M
MARICOPA FLAT
Rosedale Hwy
Bakersfield-Tehachapi-Hwy
Enos Ln
I-5 N
CA-46
CA-33
CA-119
CA-166
CA-65
CA-99
California Aqueduct
East Side Canal
1225 ft
7746 ft
August 2016
TODD GROUNDWATER
Figure 5-6
Model Validation Scenario, Recharge Application Areas

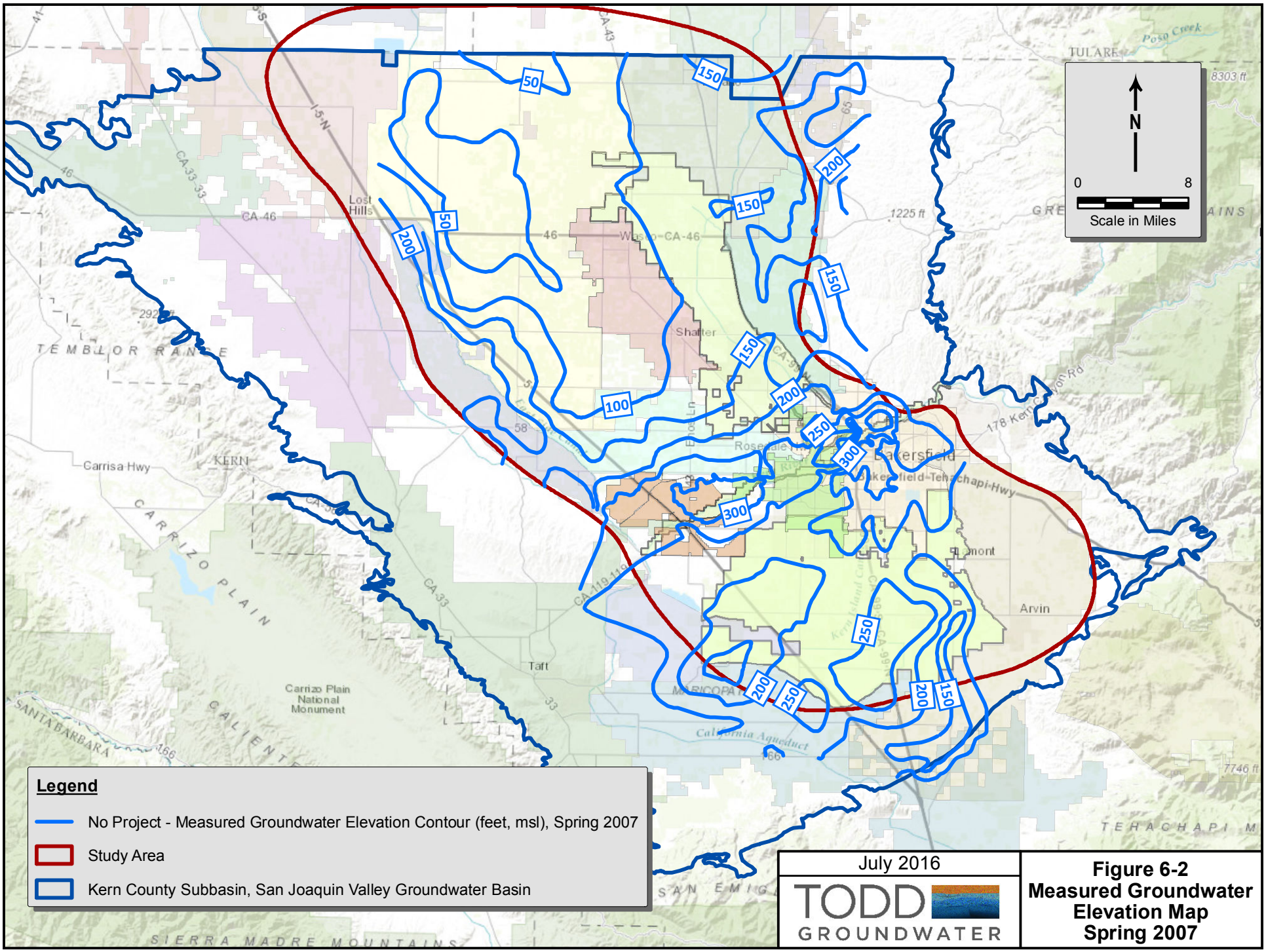


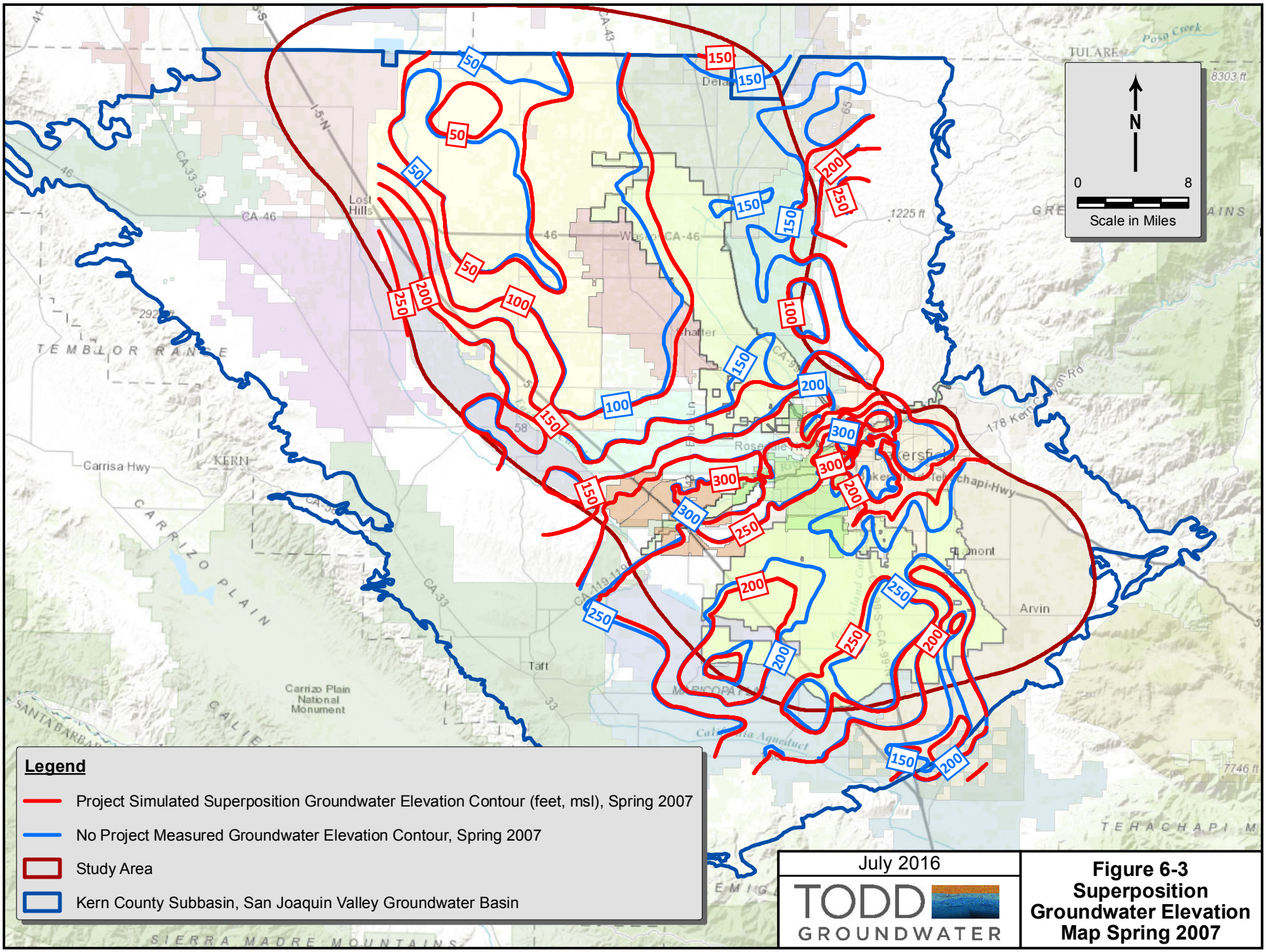
October 2016

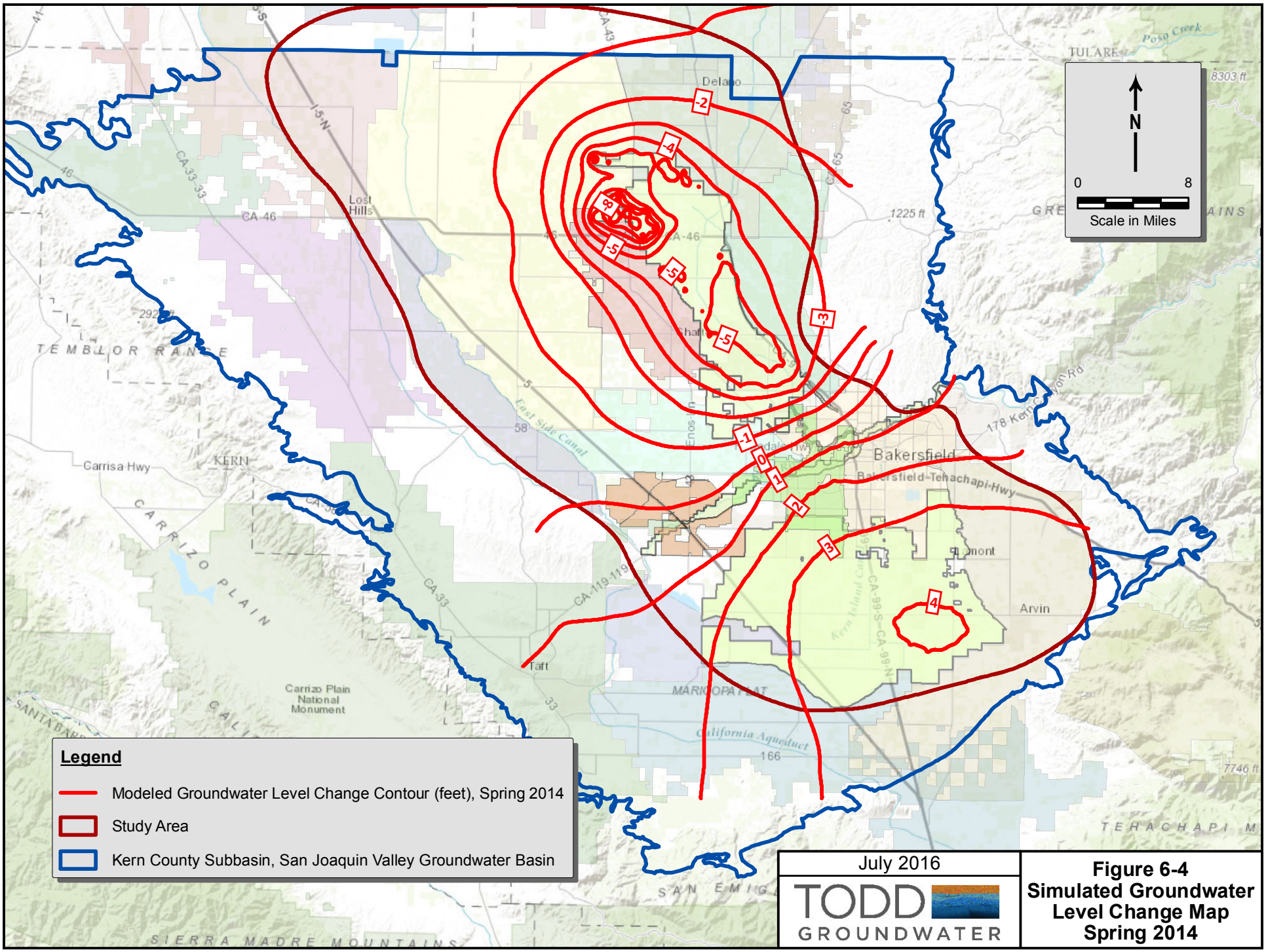
TODD GROUNDWATER

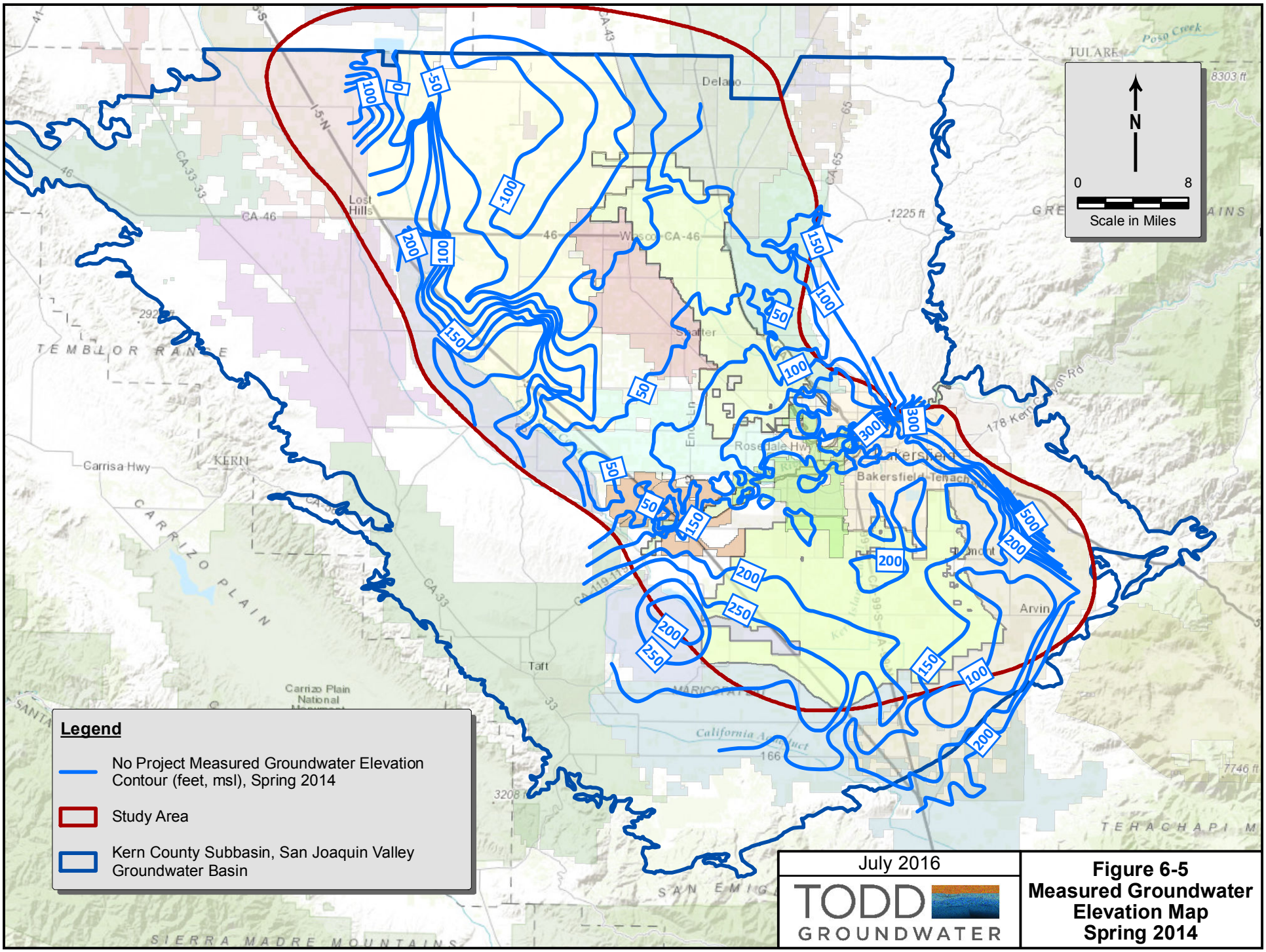
Figure 5-7
Comparison of Simulated vs. Measured Groundwater Level Change for Validation Scenario

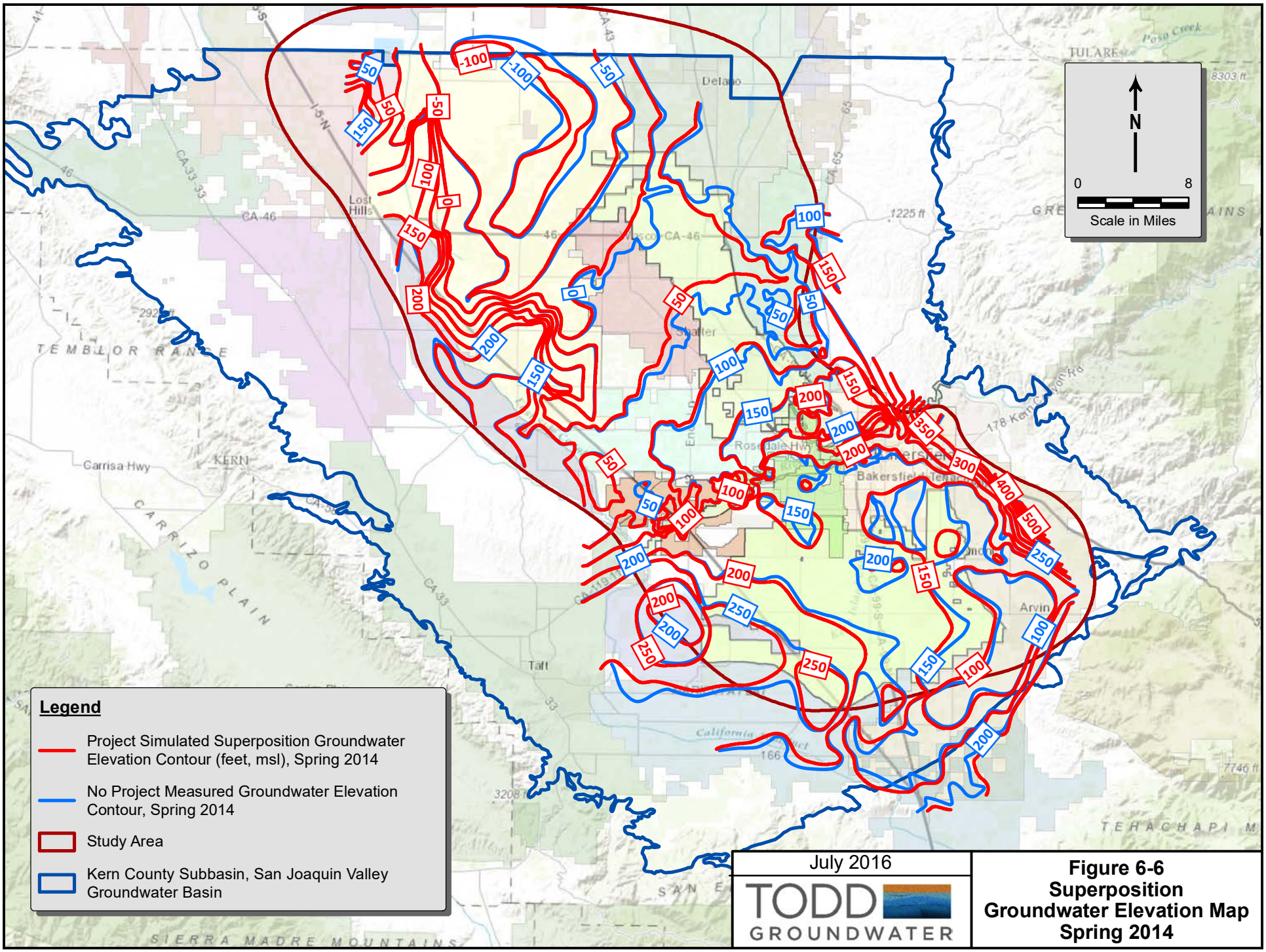

-1
-2
-5
-3
-8
-9
-6
-4
0
1
2
3
4
N
0
8
Scale in Miles
Legend
Project Simulated Groundwater Level Change (feet), Spring 2007
Study Area
Kern County Subbasin, San Joaquin Valley Groundwater Basin
Delano
Lost Hills
Shafter
Bakersfield
Arvin
Taft
Carrizo Plain National Monument
TULARE
KERN
TEHACHAPI M
SIERRA MADRE MOUNTAINS
July 2016
TODD GROUNDWATER
Figure 6-1
Simulated Groundwater Level Change Map
Spring 2007

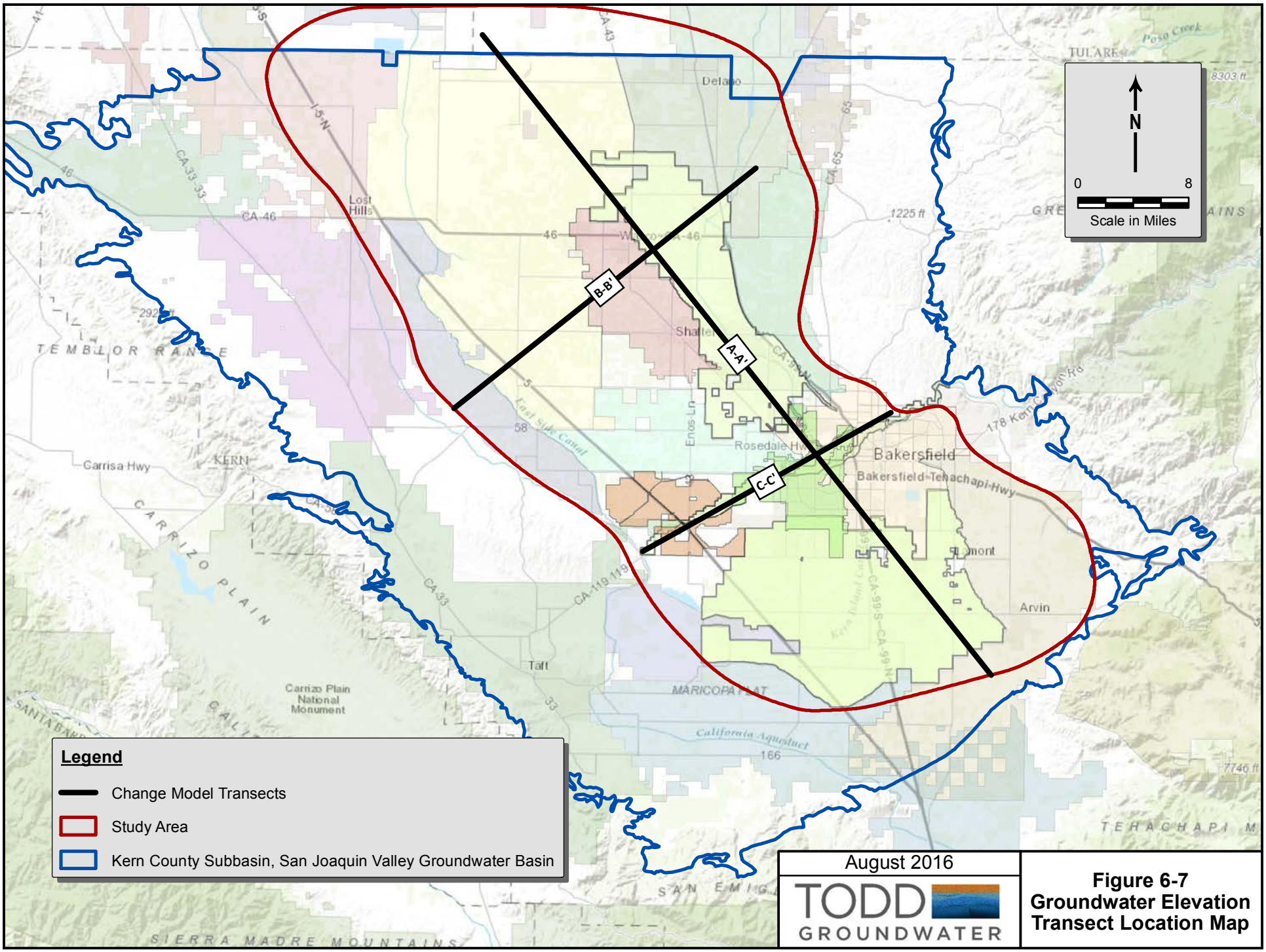

N
0
8
Scale in Miles
50
150
200
150
50
200
150
150
100
200
250
300
300
250
200
250
200
150
Legend
No Project - Measured Groundwater Elevation Contour (feet, msl), Spring 2007
Study Area
Kern County Subbasin, San Joaquin Valley Groundwater Basin
July 2016
TODD GROUNDWATER
Figure 6-2
Measured Groundwater Elevation Map
Spring 2007
TULARE
Lost Hills
Shafter
Bakersfield
Arvin
Taft
Carrisa Hwy
KERN
TEMBLOR RANGE
CARRIZO PLAIN
Carrizo Plain National Monument
SIERRA MADRE MOUNTAINS
TEHACHAPI M
California Aqueduct
1225 ft
8303 ft
7746 ft


N
0
8
Scale in Miles
Legend
Project Simulated Superposition Groundwater Elevation Contour (feet, msl), Spring 2007
No Project Measured Groundwater Elevation Contour, Spring 2007
Study Area
Kern County Subbasin, San Joaquin Valley Groundwater Basin
July 2016
TODD GROUNDWATER
Figure 6-3
Superposition
Groundwater Elevation
Map Spring 2007
TULARE
Lost Hills
Carrisa Hwy
KERN
Taft
Arvin
Carrizo Plain National Monument
TEMBLOR RANGE
CARRIZO PLAIN
SIERRA MADRE MOUNTAINS
TEHACHAPI M
Chatter
Rosedale
Lamont
1225 ft
8303 ft
7746 ft


N
0
8
Scale in Miles
-2
-4
-6
-5
-5
-5
-3
-1
0
1
2
3
4
Legend
Modeled Groundwater Level Change Contour (feet), Spring 2014
Study Area
Kern County Subbasin, San Joaquin Valley Groundwater Basin
Bakersfield
Delano
Lost Hills
Taft
Arvin
Carrizo Plain National Monument
TULARE
KERN
Carrisa Hwy
TEHACHAPI M
SIERRA MADRE MOUNTAINS
July 2016
TODD GROUNDWATER
Figure 6-4
Simulated Groundwater Level Change Map
Spring 2014


N
0
8
Scale in Miles
Legend
No Project Measured Groundwater Elevation Contour (feet, msl), Spring 2014
Study Area
Kern County Subbasin, San Joaquin Valley Groundwater Basin
Delano
Lost Hills
Wasco
Shafter
Bakersfield
Arvin
Taft
Carrizo Plain National Monument
TEMBLOR RANGE
CARRIZO PLAIN
SIERRA MADRE MOUNTAINS
TEHACHAPI M
Carrisa Hwy
KERN
TULARE
CA-46
CA-33
CA-65
I-5-N
1225 ft
8303 ft
7746 ft
3208 ft
July 2016
TODD GROUNDWATER
Figure 6-5
Measured Groundwater Elevation Map
Spring 2014


N
0
8
Scale in Miles
Legend
Project Simulated Superposition Groundwater Elevation Contour (feet, msl), Spring 2014
No Project Measured Groundwater Elevation Contour, Spring 2014
Study Area
Kern County Subbasin, San Joaquin Valley Groundwater Basin
July 2016
TODD GROUNDWATER
Figure 6-6
Superposition Groundwater Elevation Map
Spring 2014

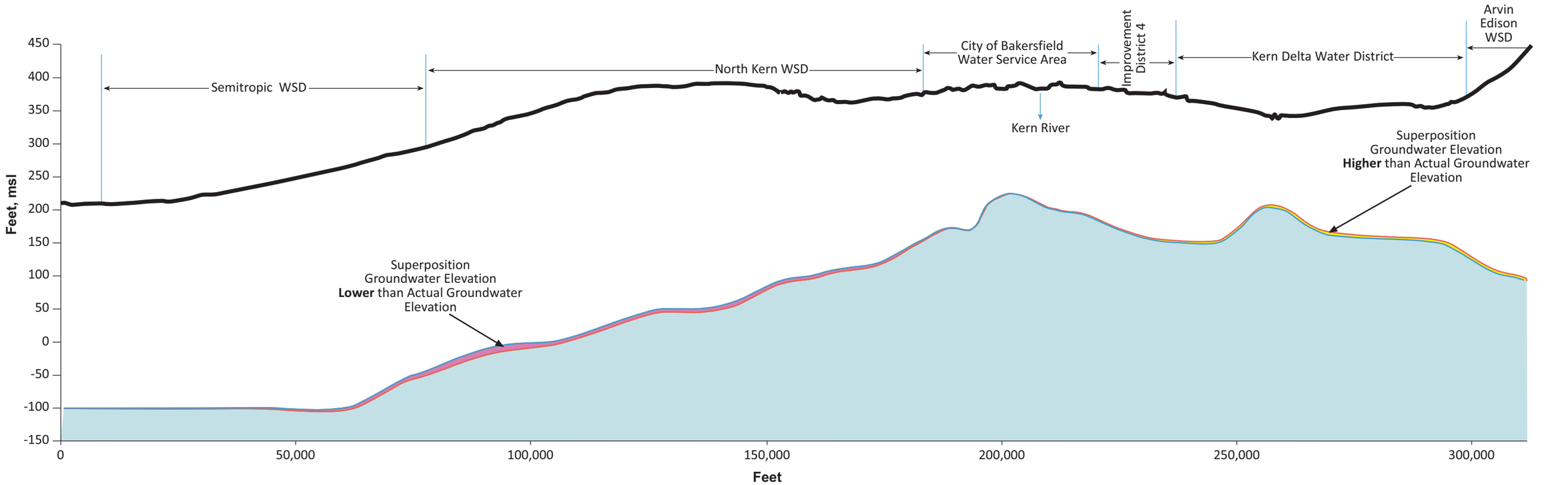


August 2016

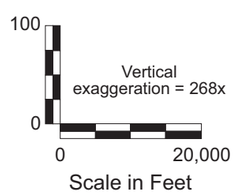
TODD GROUNDWATER

Figure 6-7
Groundwater Elevation Transect Location Map

Northwest **Southeast**



Transect A

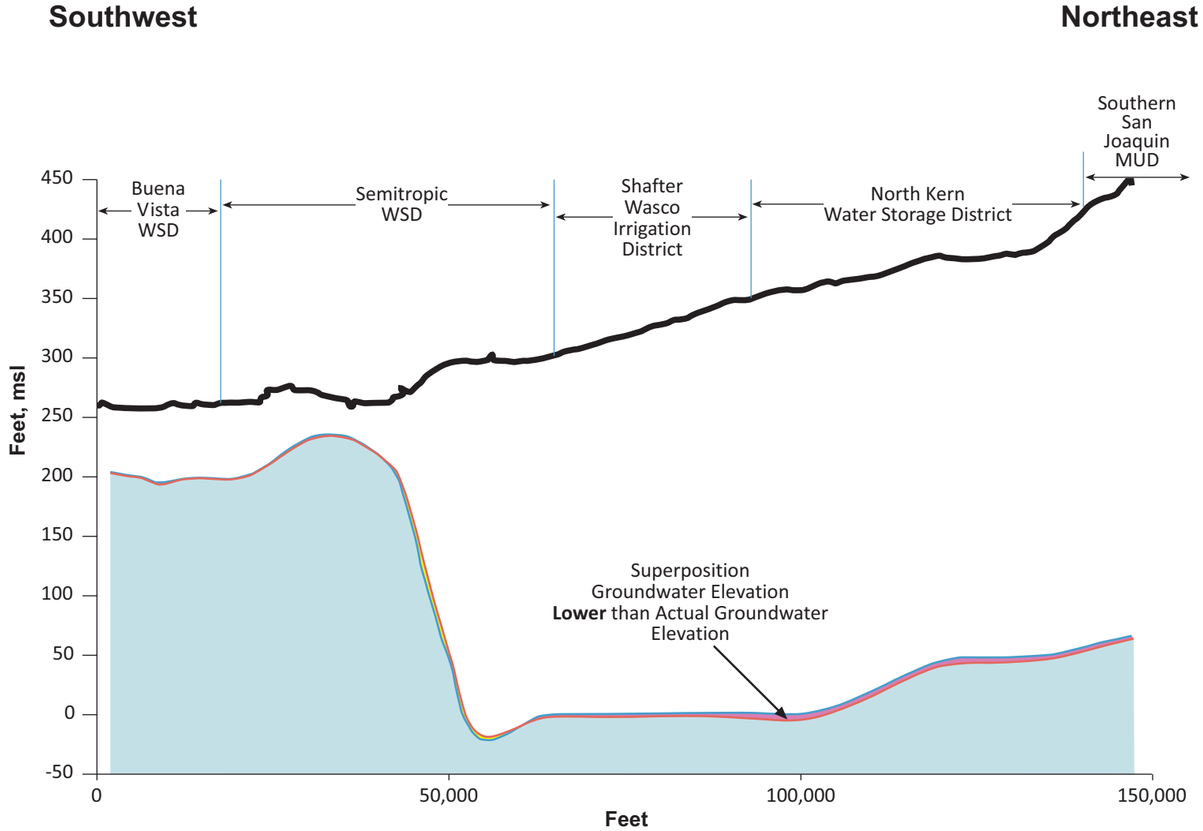


- Ground Surface
- Measured Groundwater Elevation
- Simulated Superposition Groundwater Elevation
- Simulated Superposition Elevation Lower than Measured Elevation
- Superposition Elevation Higher than Measured Elevation

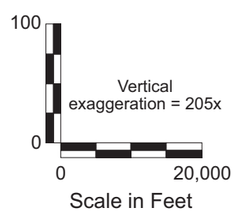
October 2016

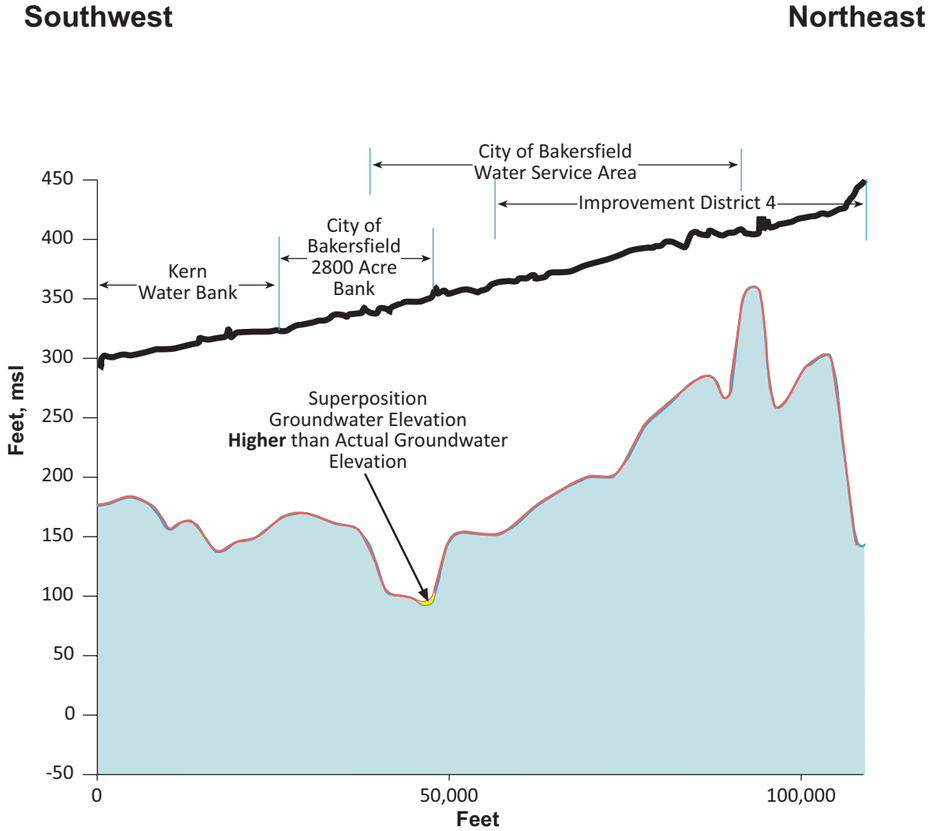
TODD GROUNDWATER

Figure 6-8
Actual and Superposition Groundwater Elevation - Transect A
Spring 2014

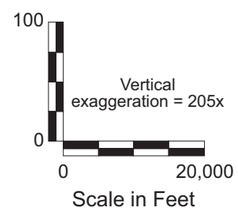


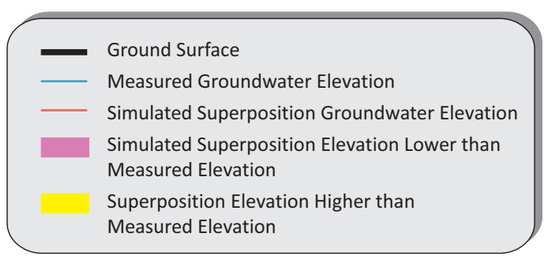
Transect B





Transect C

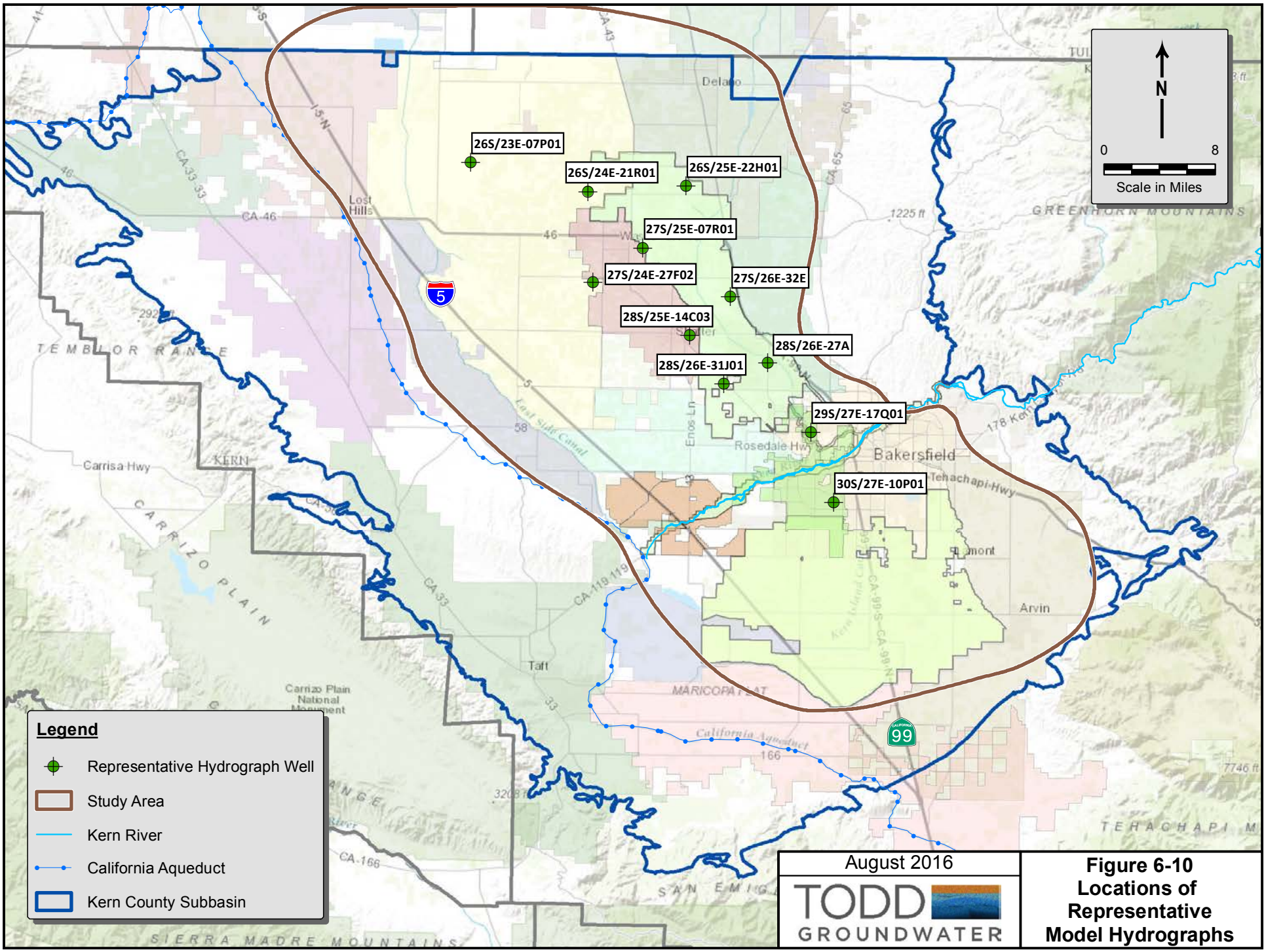


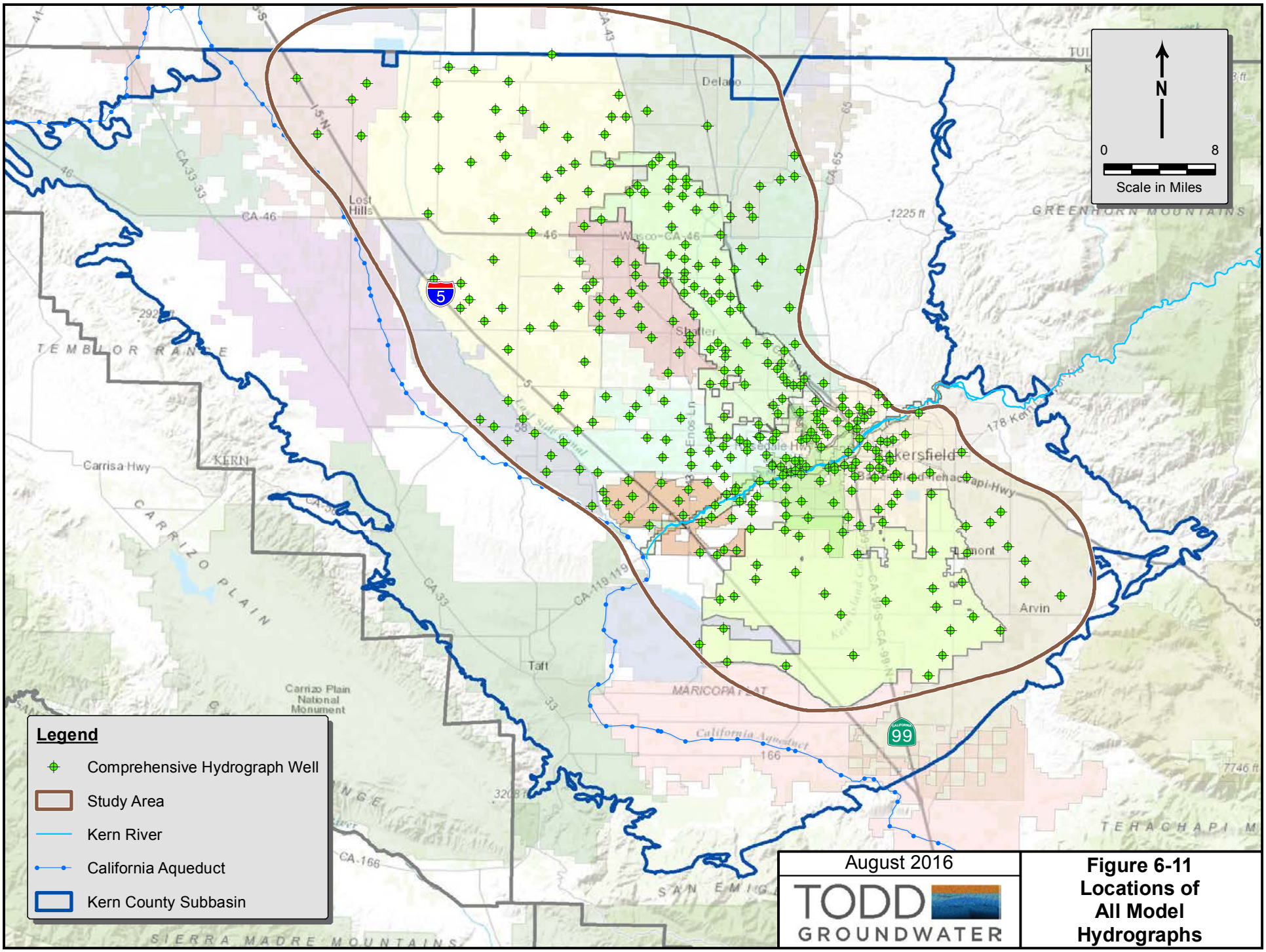


October 2016

TODD GROUNDWATER

Figure 6-9
Actual and Superposition Groundwater Elevation - Transects B and C
Spring 2014

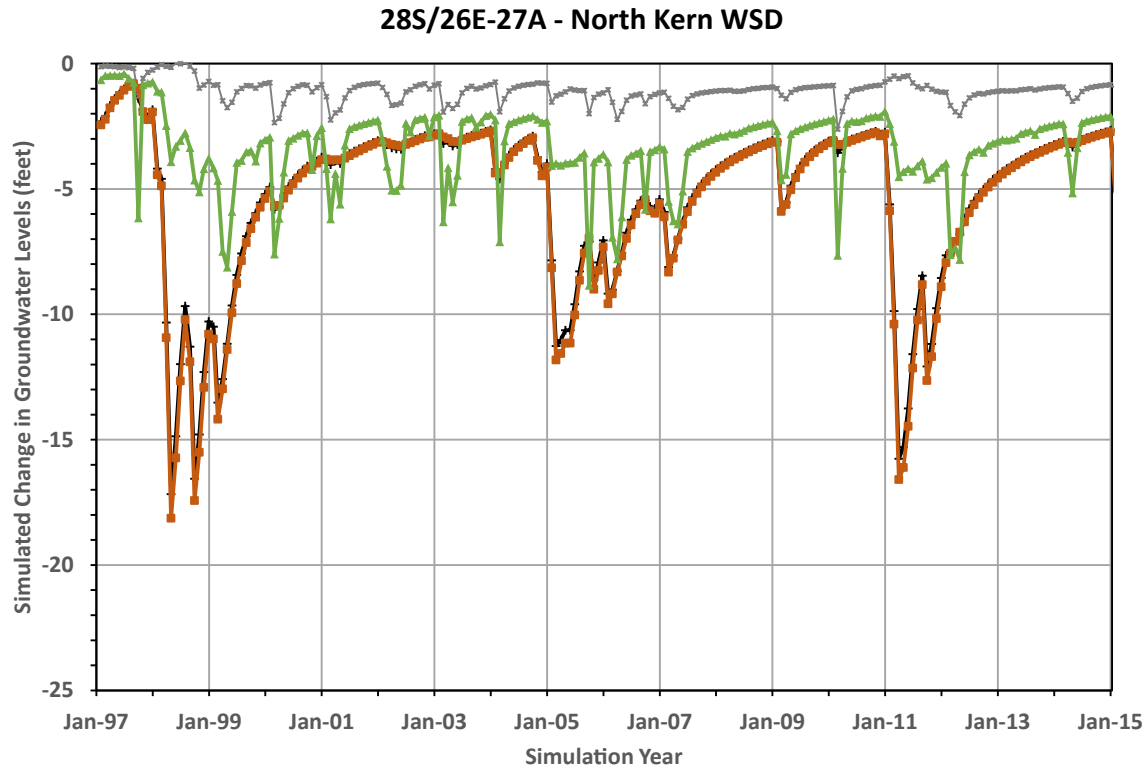

26S/23E-07P01
26S/24E-21R01
26S/25E-22H01
27S/25E-07R01
27S/24E-27F02
27S/26E-32E
28S/25E-14C03
28S/26E-27A
28S/26E-31J01
29S/27E-17Q01
30S/27E-10P01
N
0
8
Scale in Miles
Legend
Representative Hydrograph Well
Study Area
Kern River
California Aqueduct
Kern County Subbasin
Delano
Lost Hills
Bakersfield
Arvin
Taft
Carrizo Plain National Monument
TEMBLOR RANGE
CARRIZO PLAIN
SIERRA MADRE MOUNTAINS
GREENHORN MOUNTAINS
TEHACHAPI M
KERN
Carrisa Hwy
Rosedale Hwy
Tehachapi Hwy
Enos Ln
Lost Side Canal
MARICOPA FLAT
California Aqueduct
CA-46
CA-33
CA-119
CA-166
CA-65
CA-99
I-5 N
5
46
58
99
166
1225 ft
7746 ft
August 2016
TODD GROUNDWATER
Figure 6-10
Locations of Representative Model Hydrographs

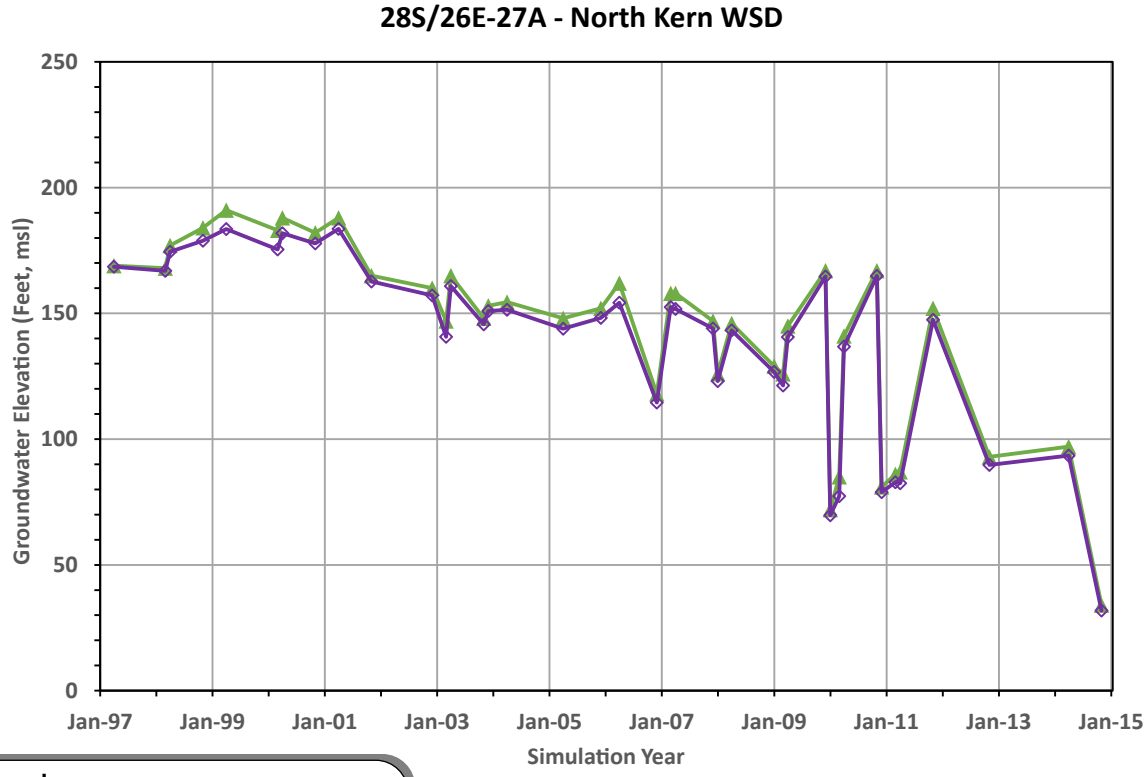


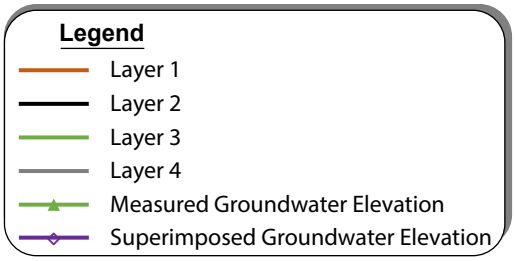
August 2016

TODD GROUNDWATER

Figure 6-11
Locations of All Model Hydrographs



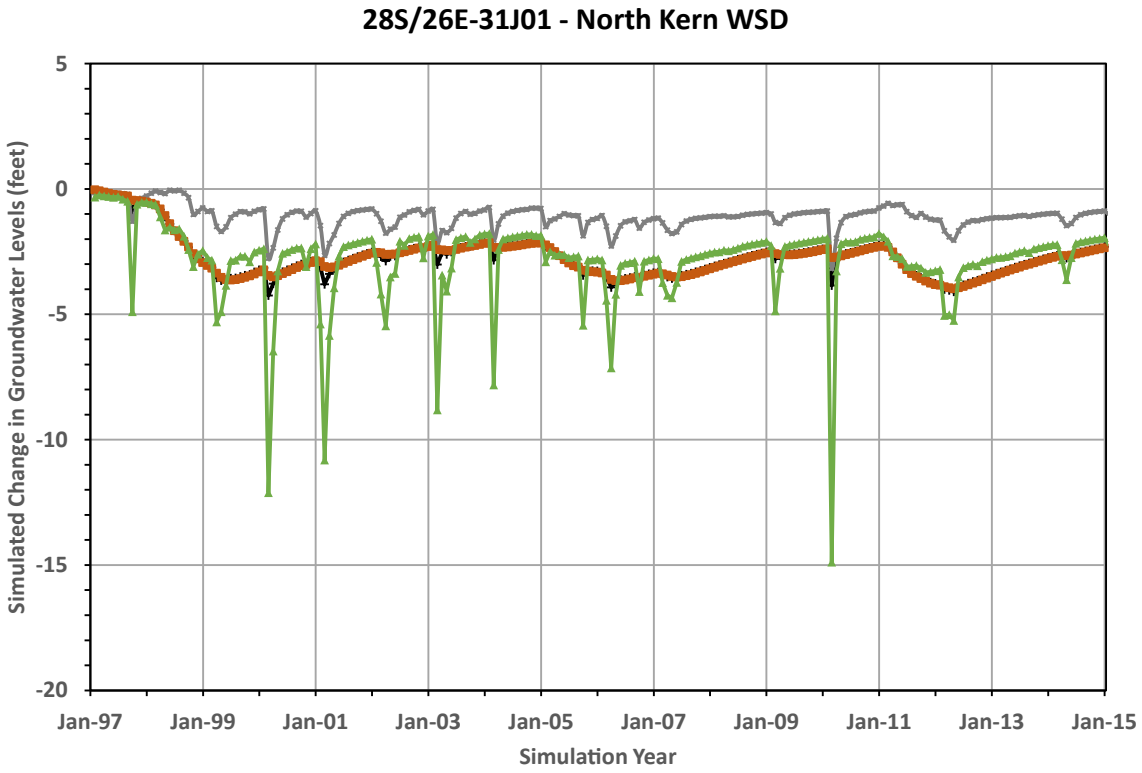


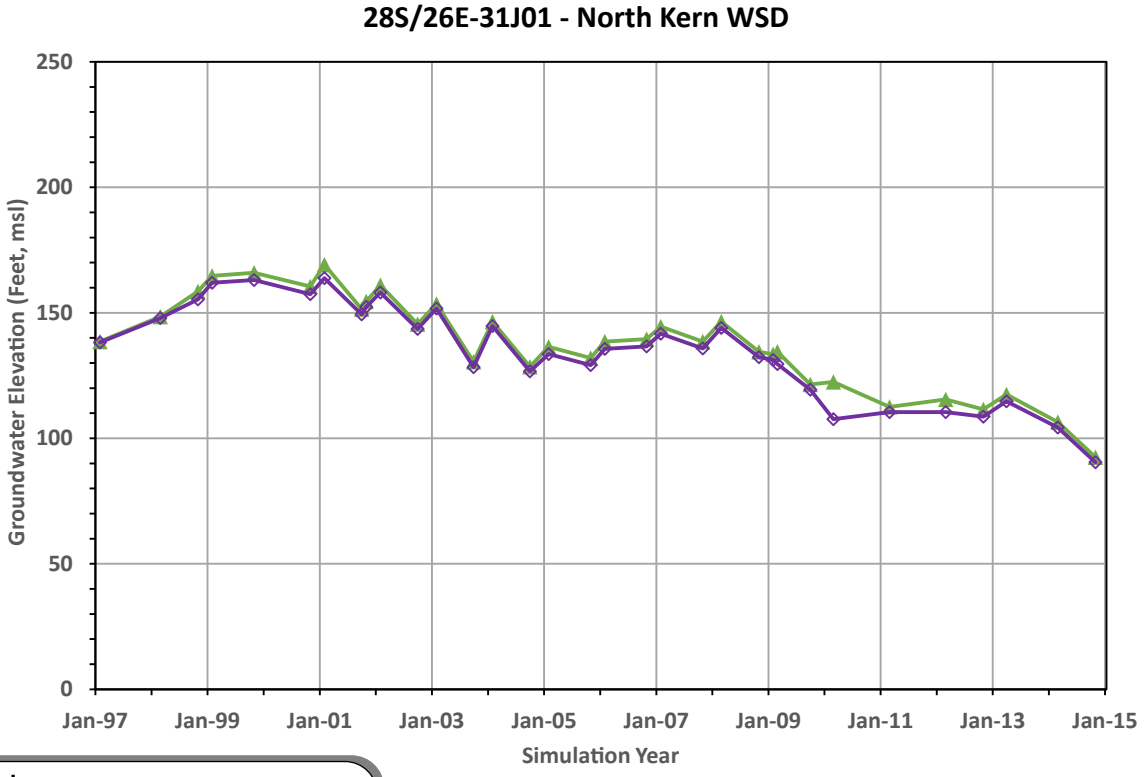


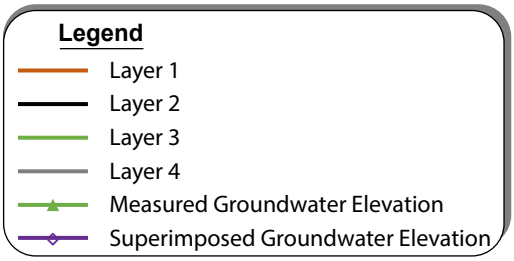
October 2016

TODD GROUNDWATER

Figure 6-12a
Change and Superposition Hydrographs
Baseline Scenario



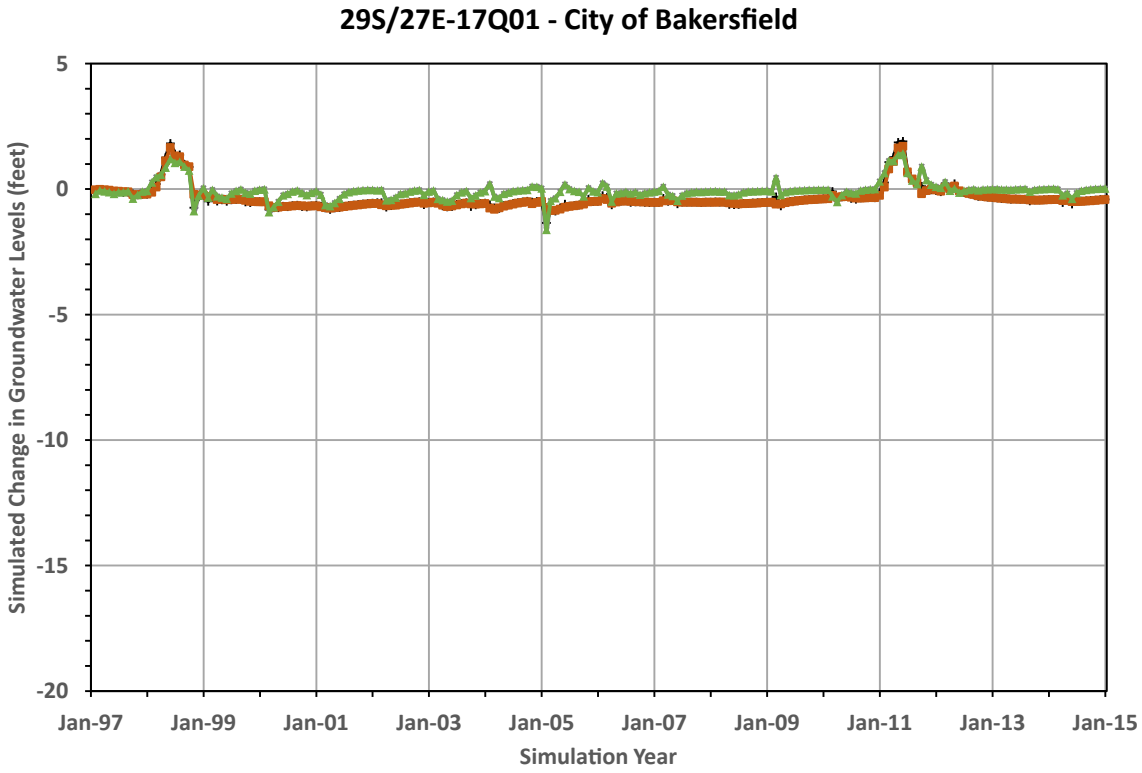


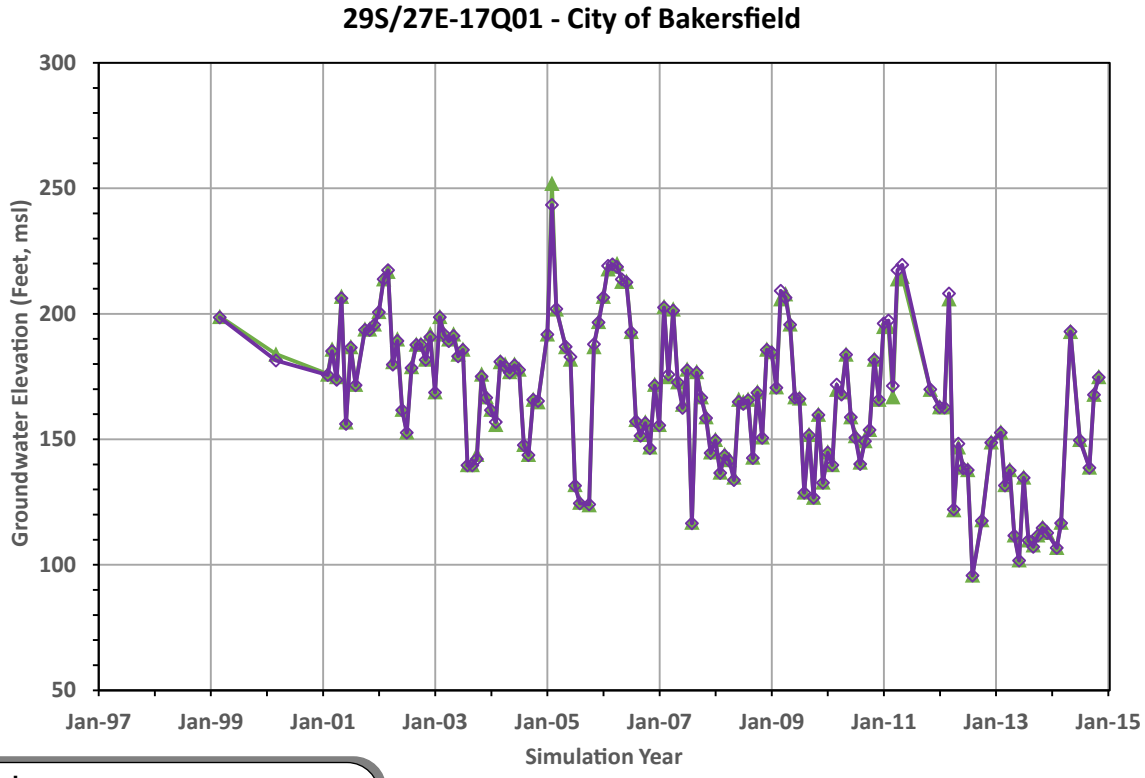


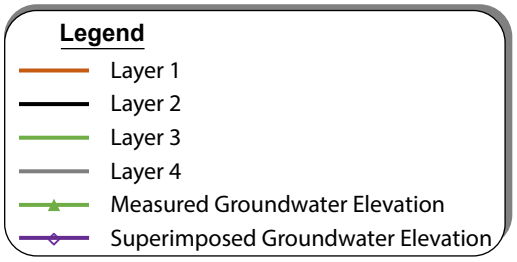
October 2016

TODD GROUNDWATER

Figure 6-12b
Change and Superposition Hydrographs
Baseline Scenario



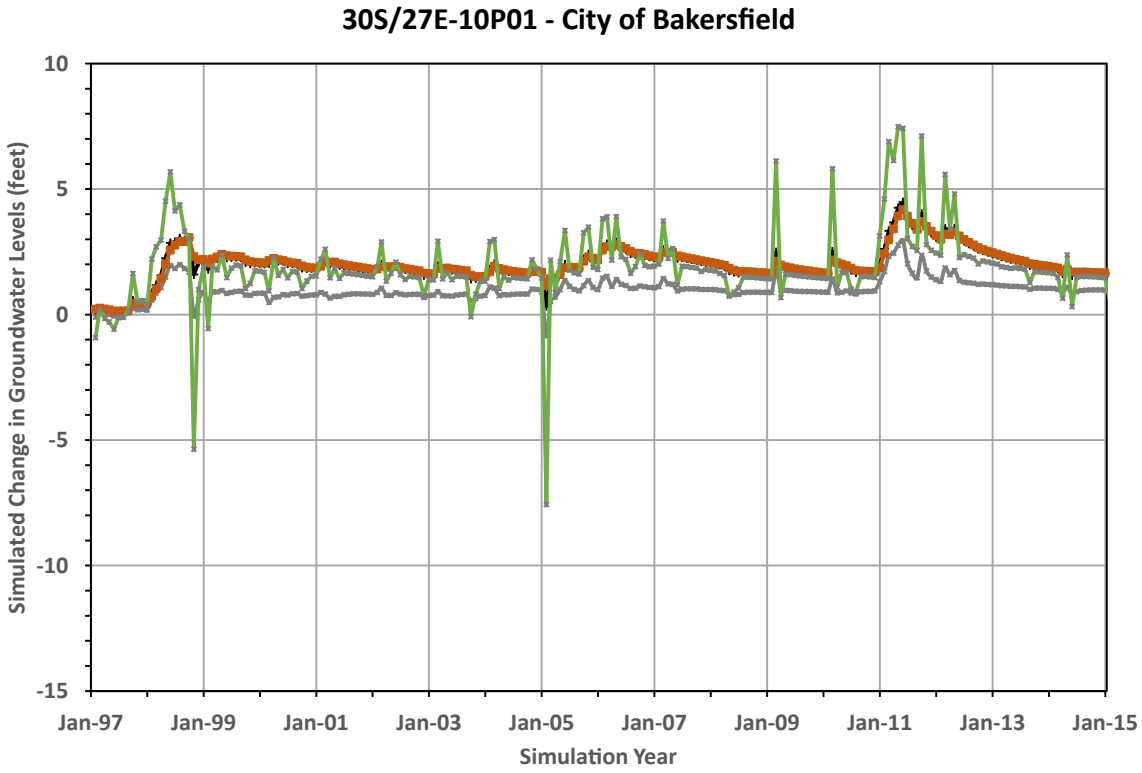


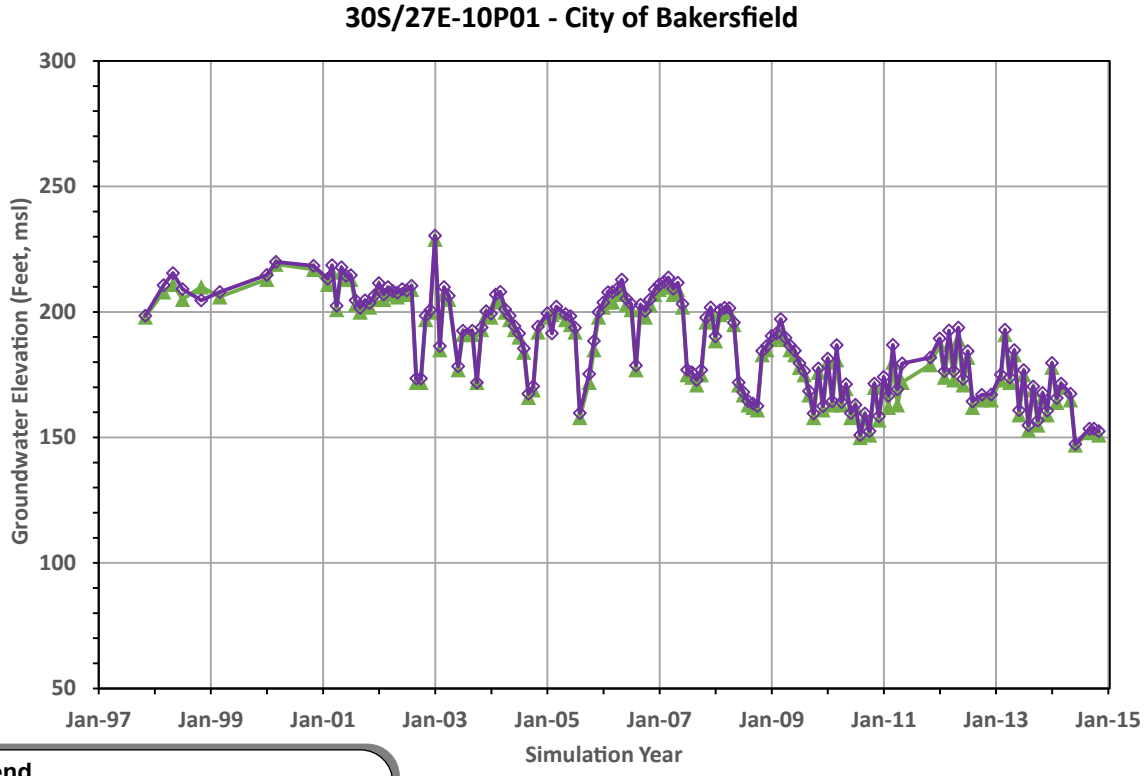


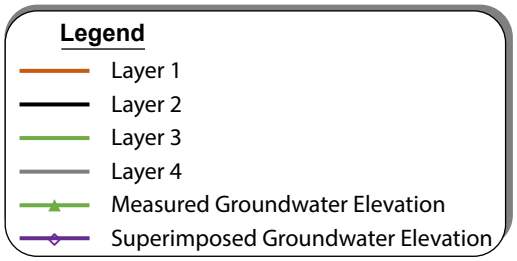
October 2016

TODD GROUNDWATER

Figure 6-12c
Change and Superposition Hydrographs
Baseline Scenario



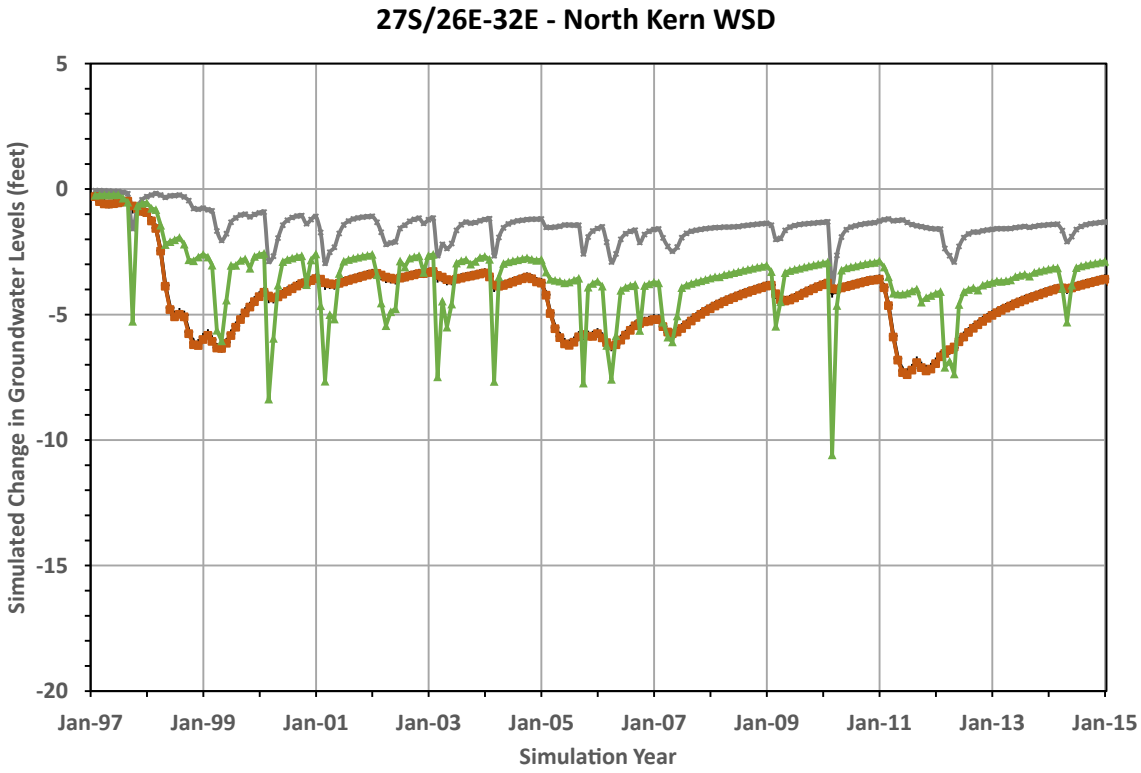


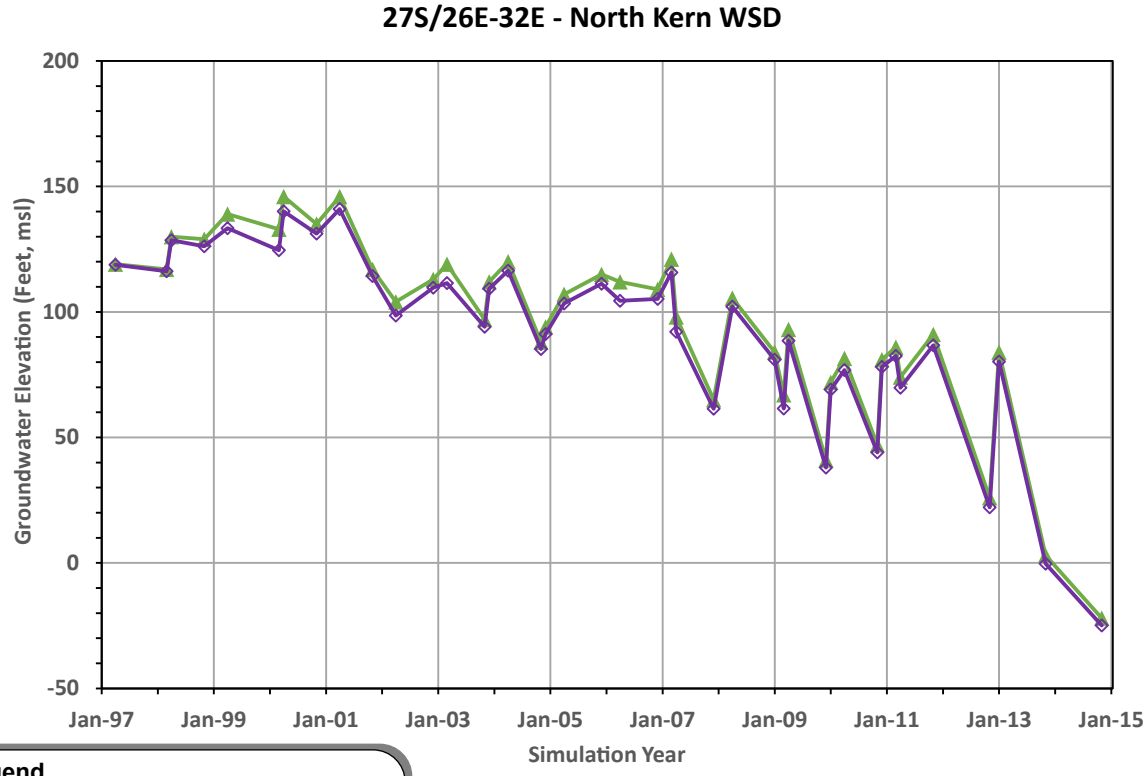


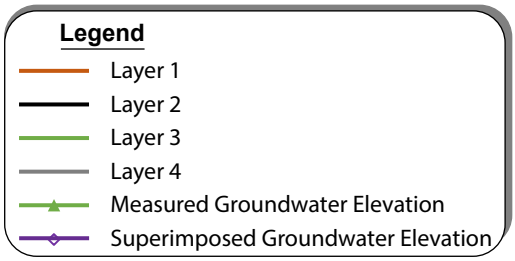
October 2016

TODD GROUNDWATER

Figure 6-12d
Change and Superposition Hydrographs
Baseline Scenario



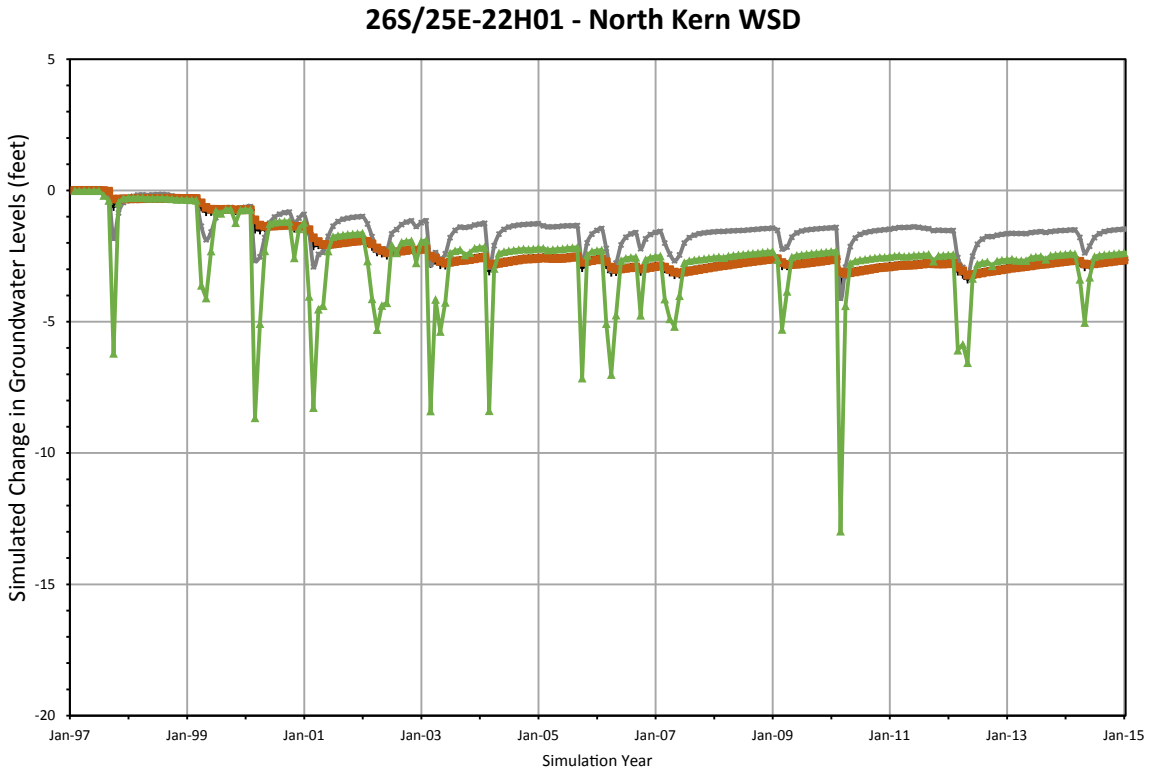


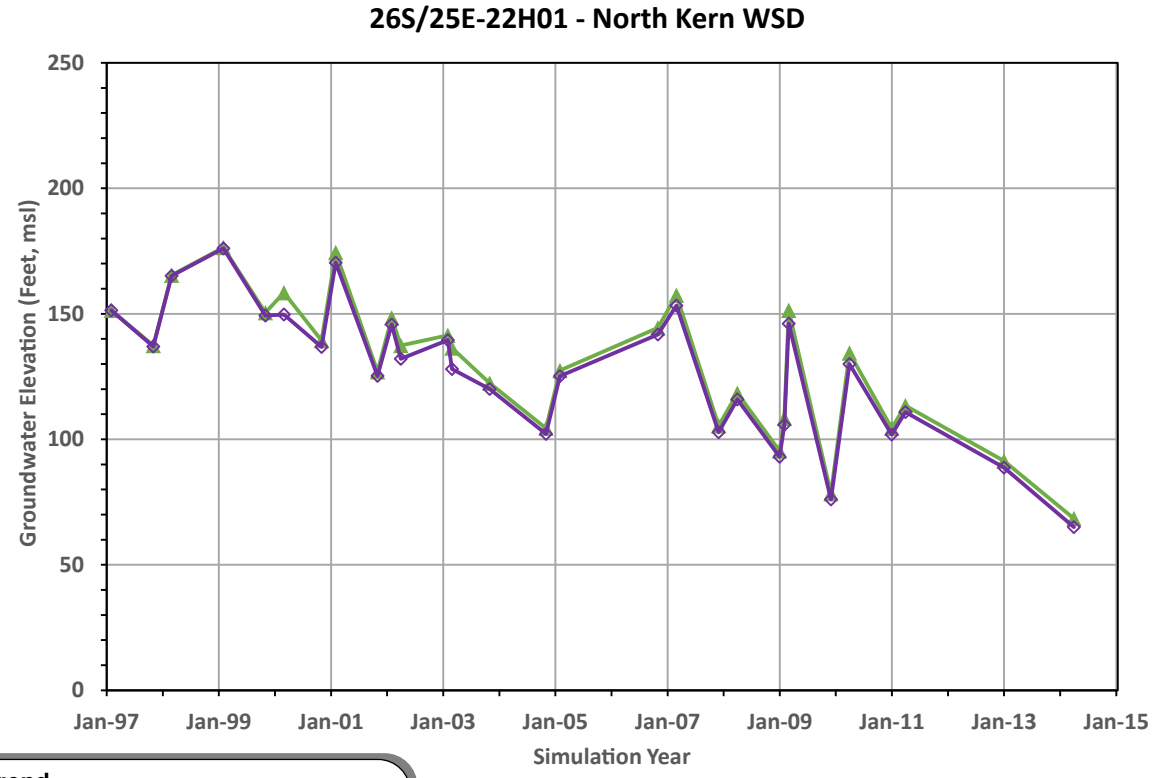


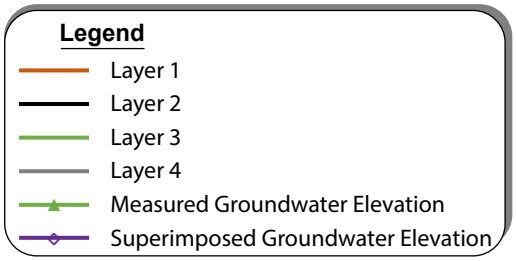
October 2016

TODD GROUNDWATER

Figure 6-12e
Change and Superposition Hydrographs
Baseline Scenario



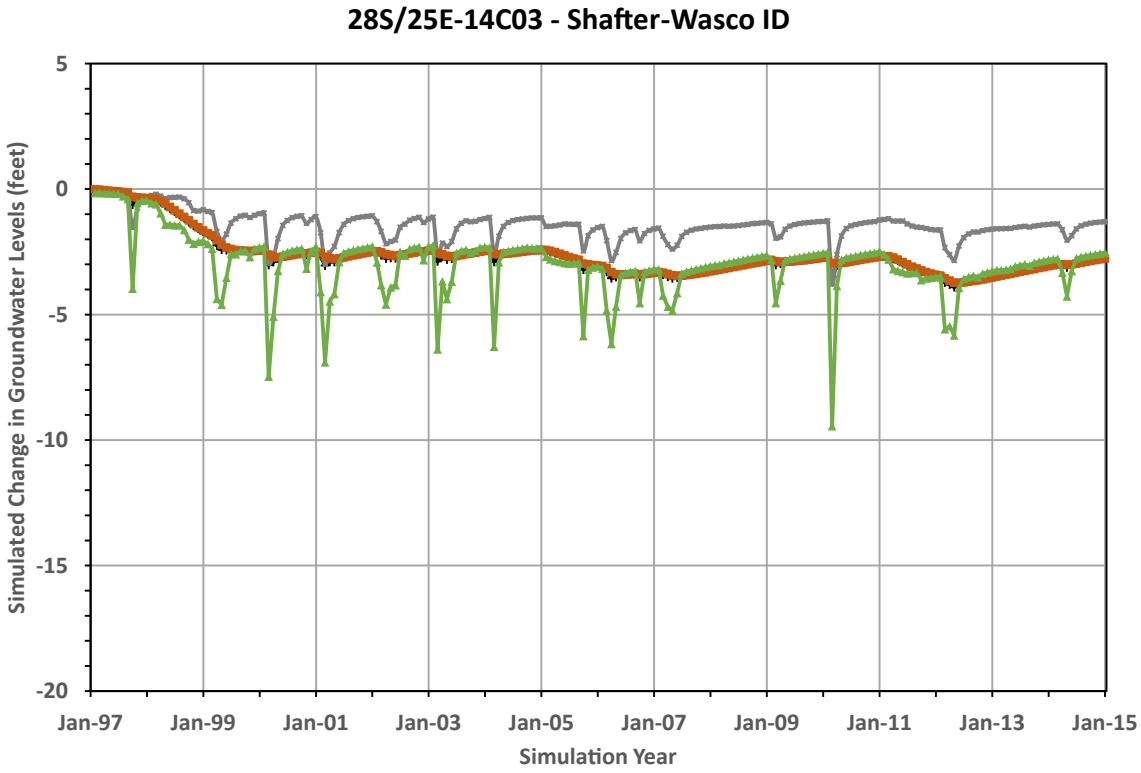


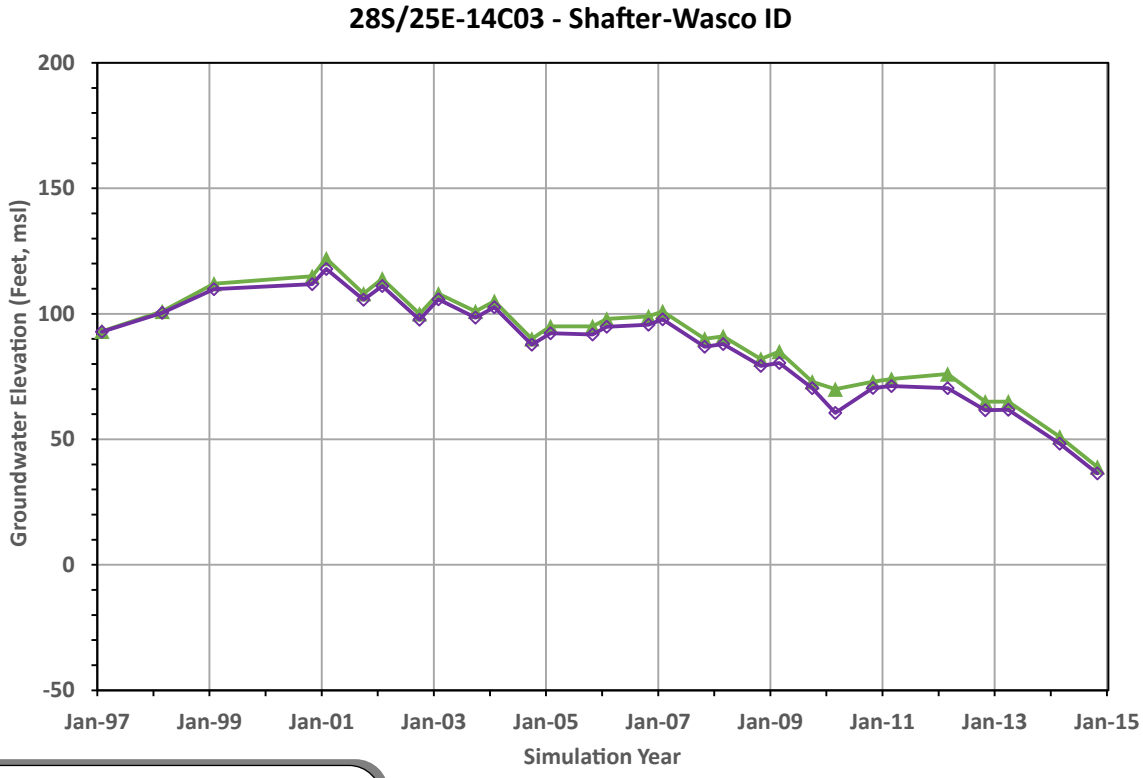


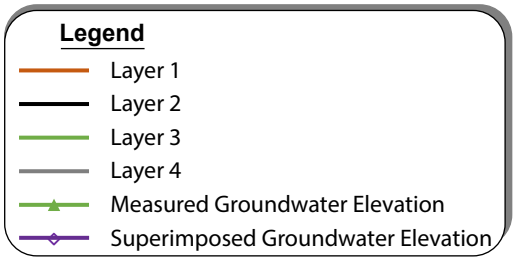
October 2016

TODD GROUNDWATER

Figure 6-12f
Change and Superposition Hydrographs
Baseline Scenario



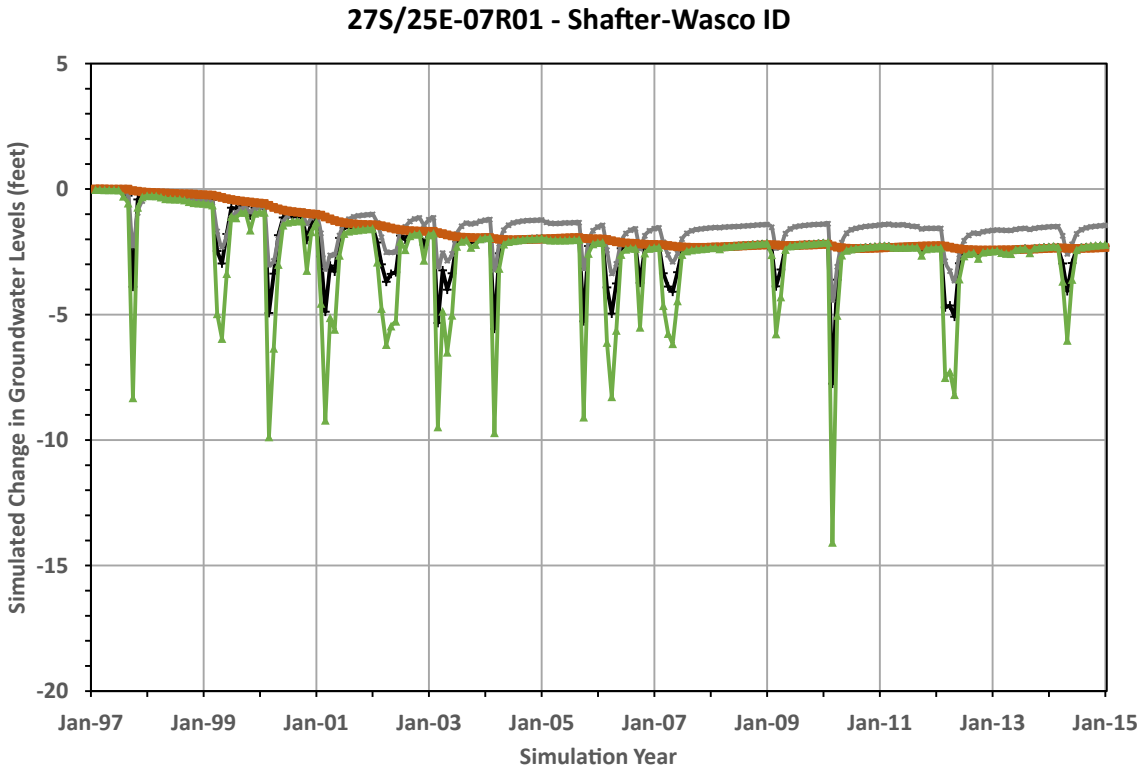


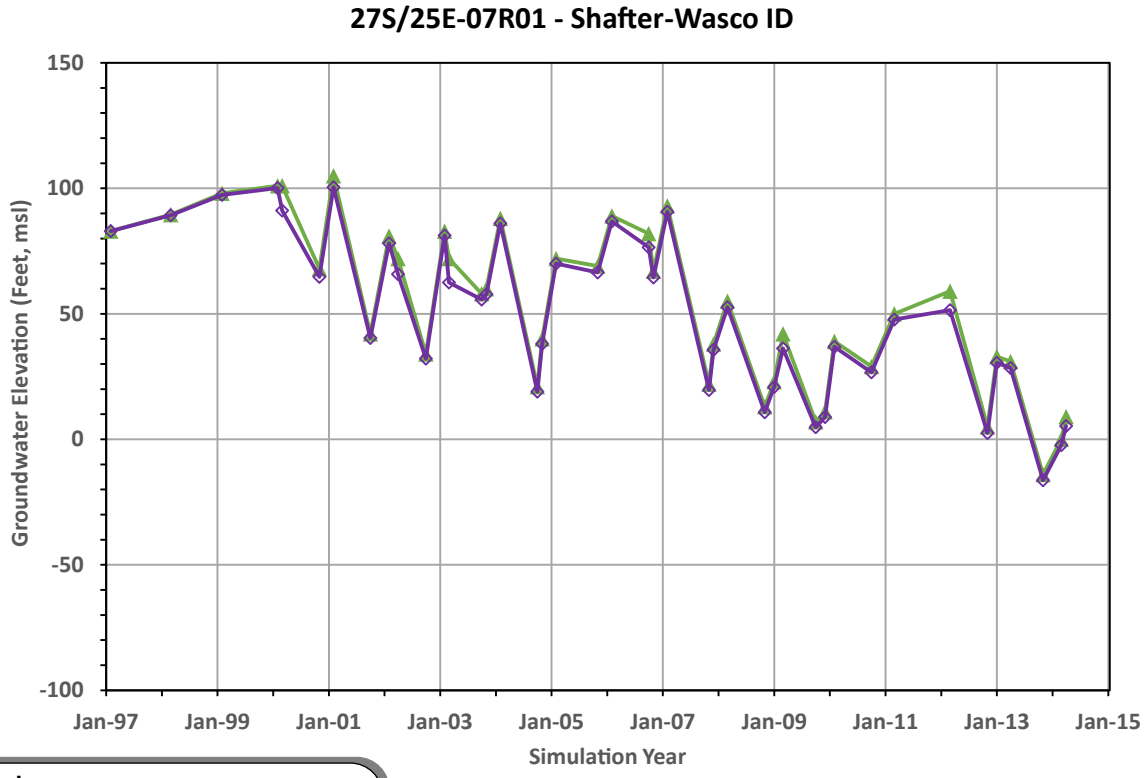


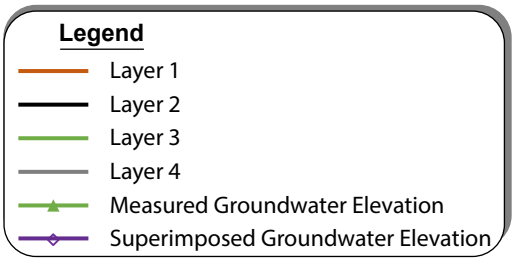
October 2016

TODD GROUNDWATER

Figure 6-12g
Change and Superposition Hydrographs
Baseline Scenario



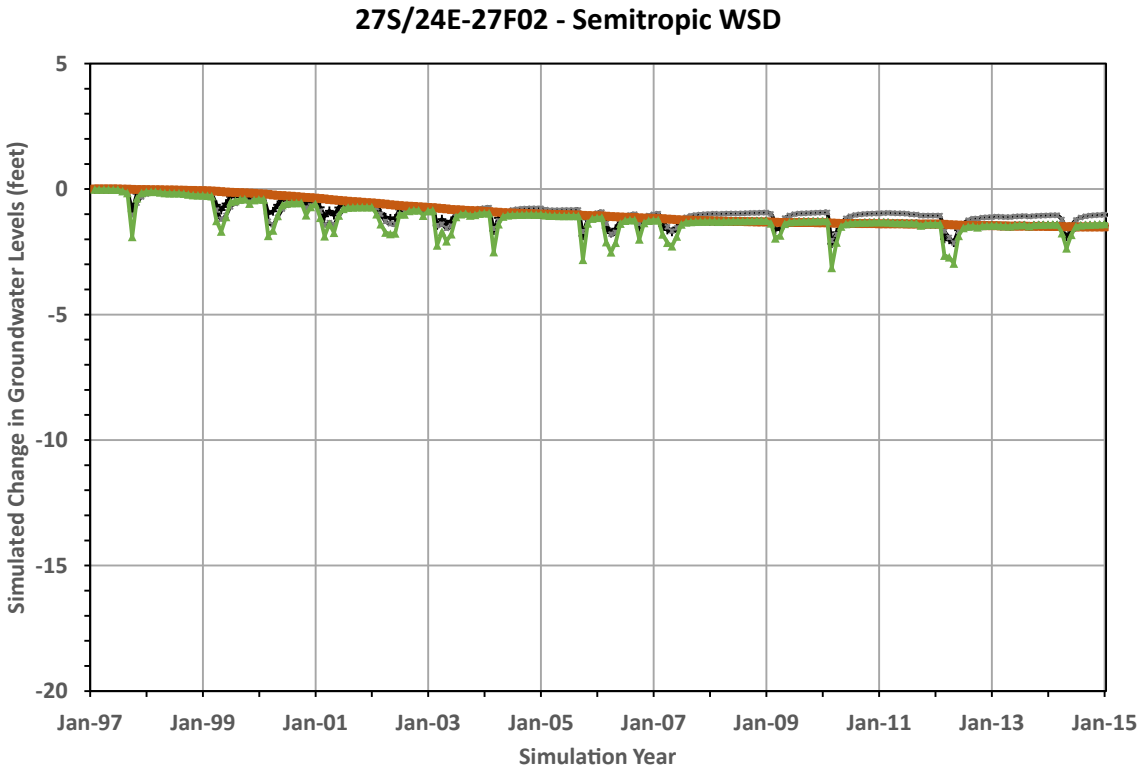


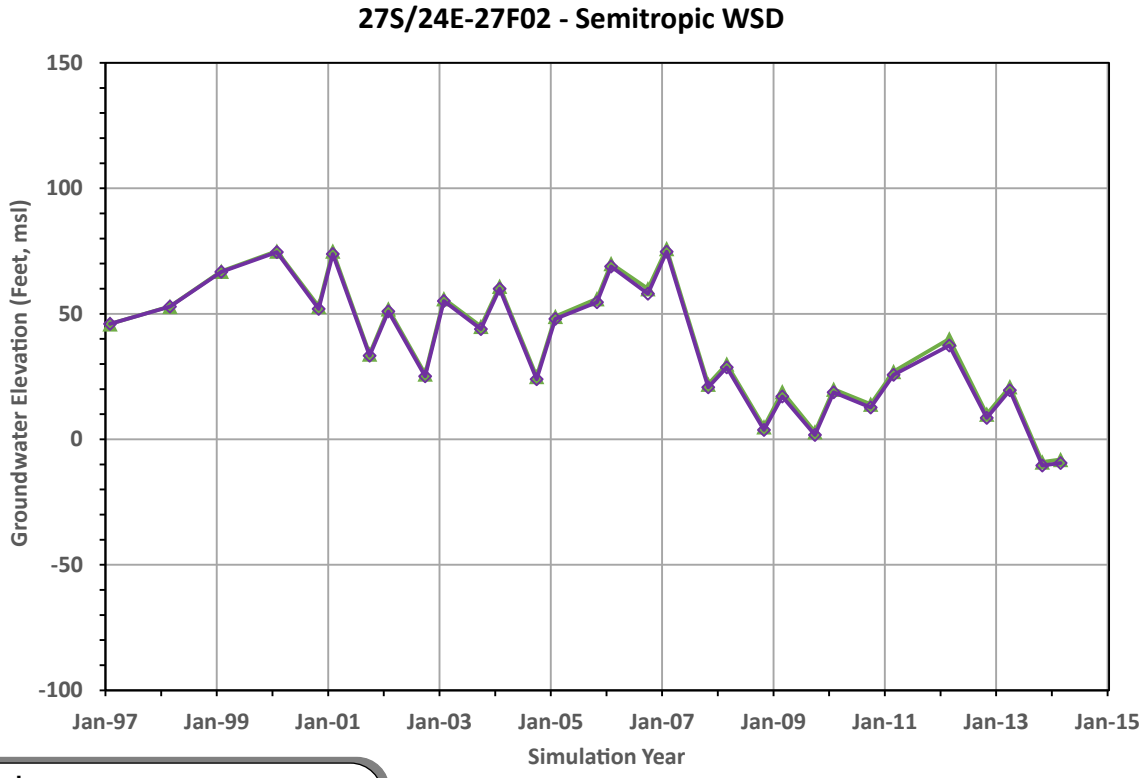


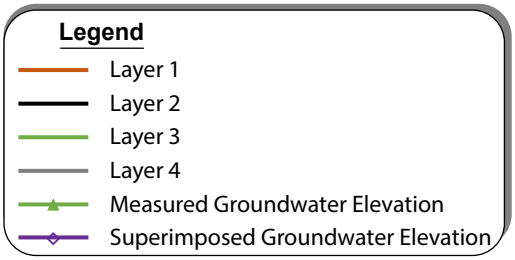
October 2016

TODD GROUNDWATER

Figure 6-12h
Change and Superposition Hydrographs
Baseline Scenario



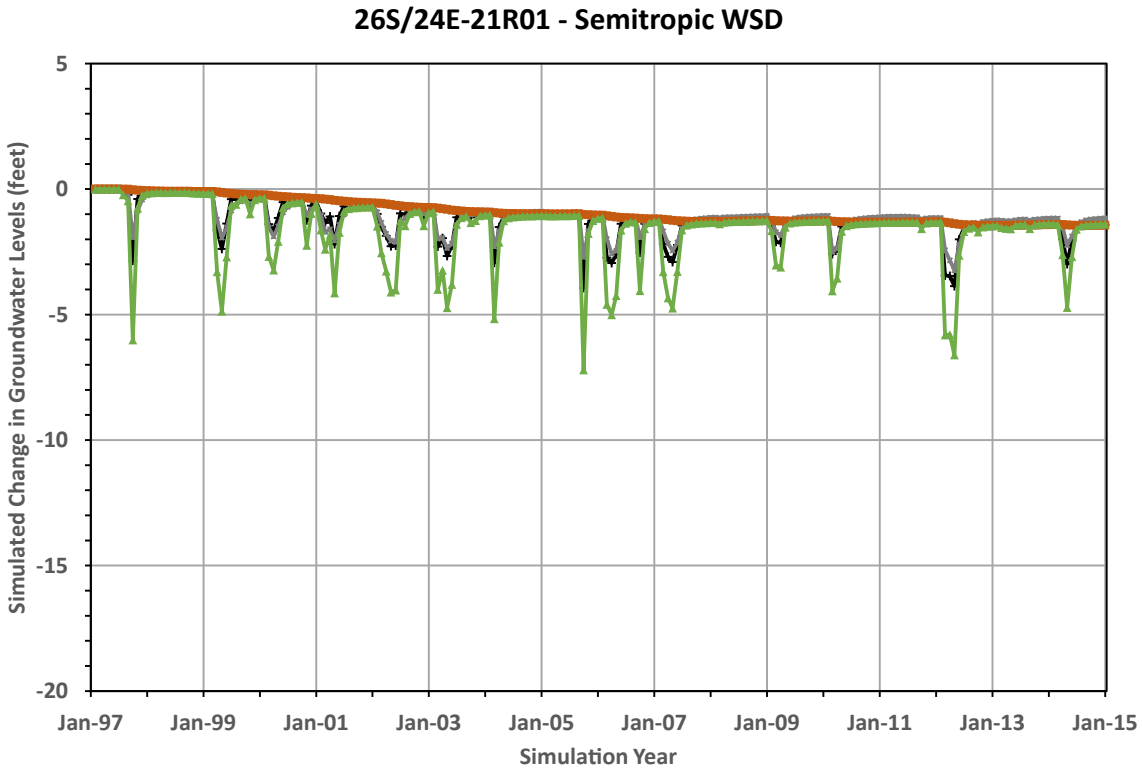


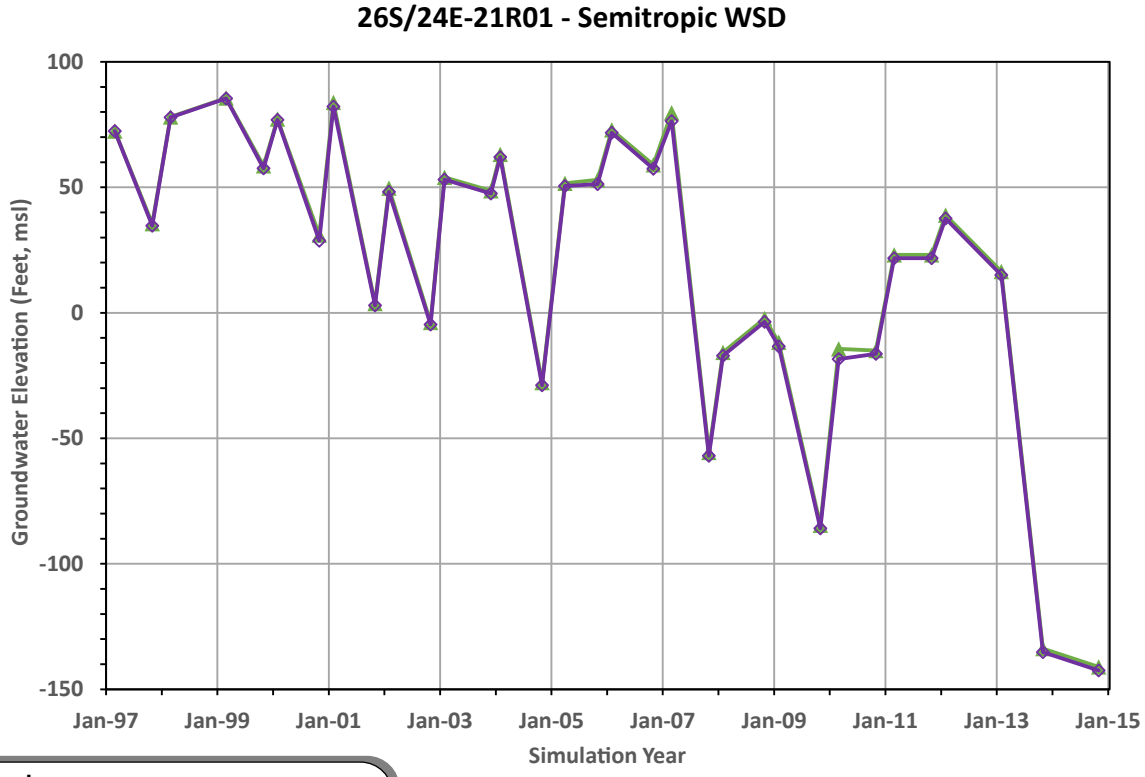


October 2016

TODD GROUNDWATER

Figure 6-12i
Change and Superposition Hydrographs
Baseline Scenario





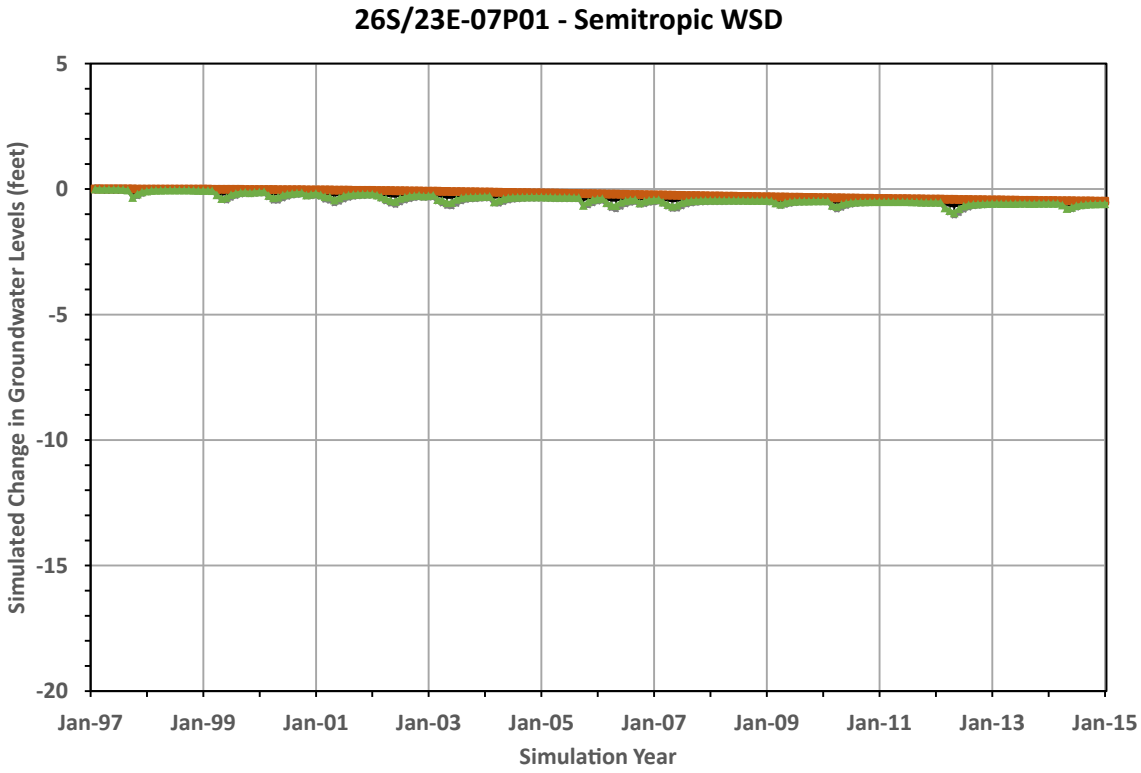
Legend

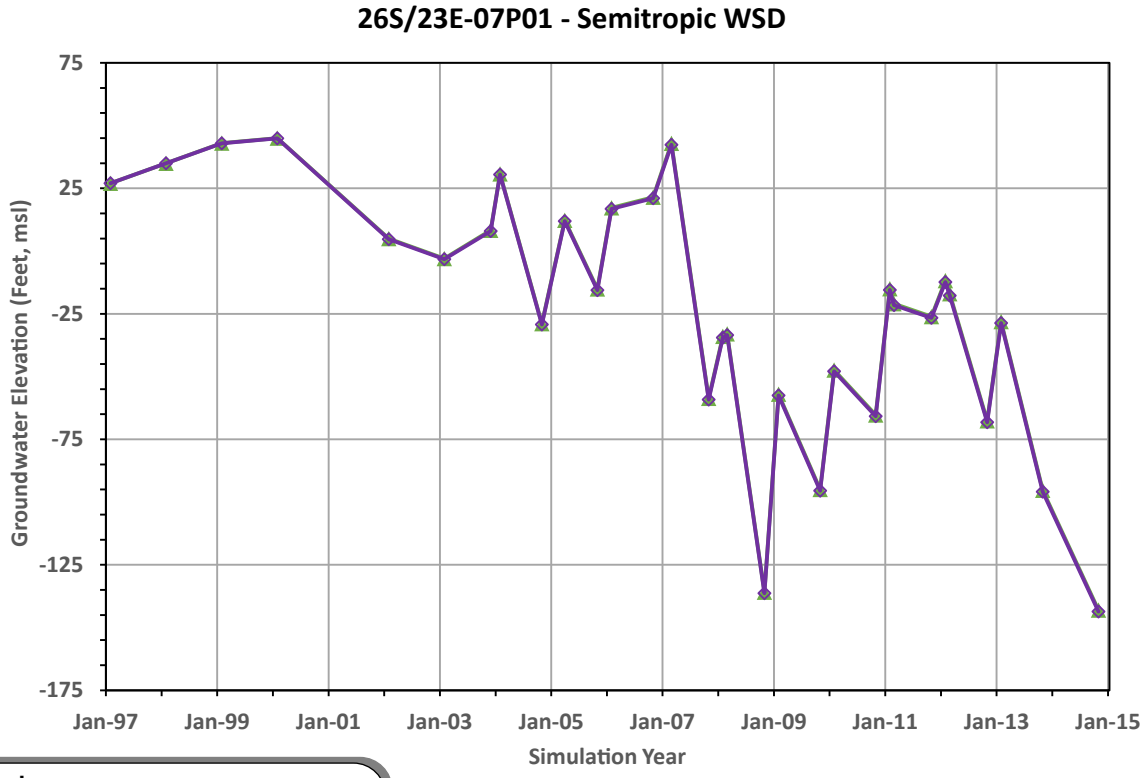
- Layer 1
- Layer 2
- Layer 3
- Layer 4
- Measured Groundwater Elevation
- Superimposed Groundwater Elevation

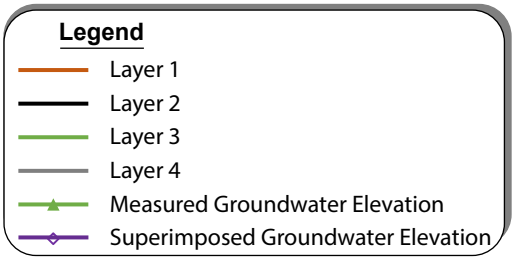
October 2016

TODD GROUNDWATER

Figure 6-12j
Change and Superposition Hydrographs
Baseline Scenario



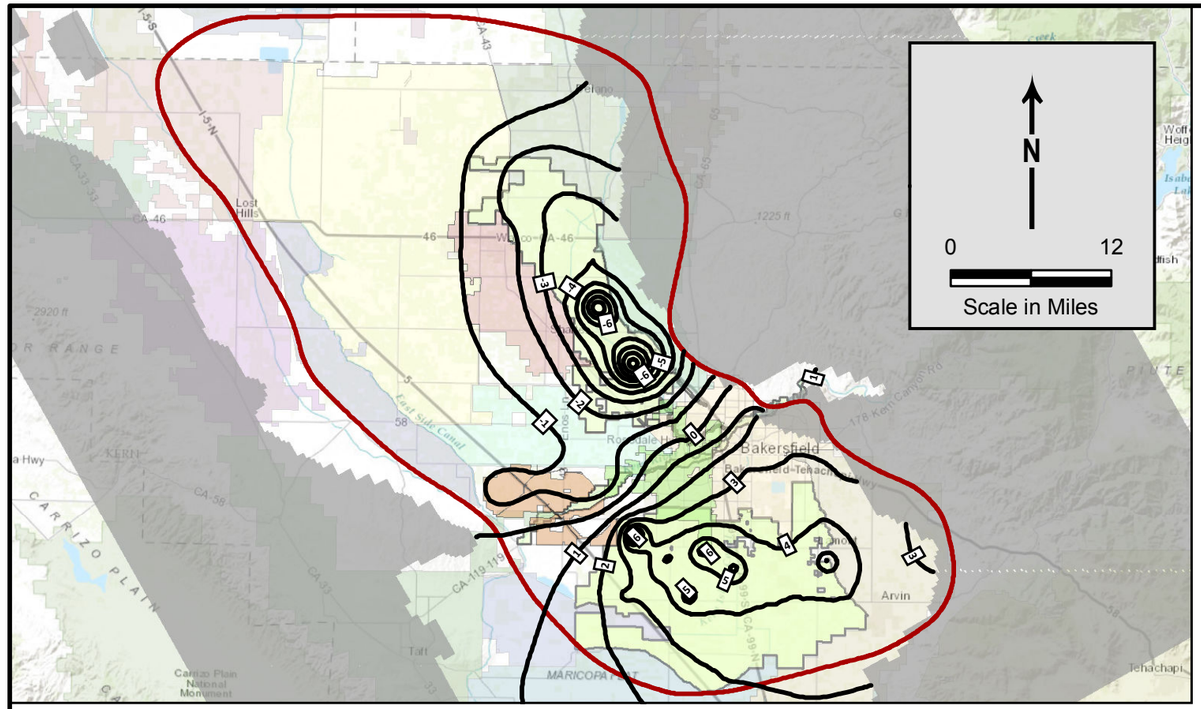




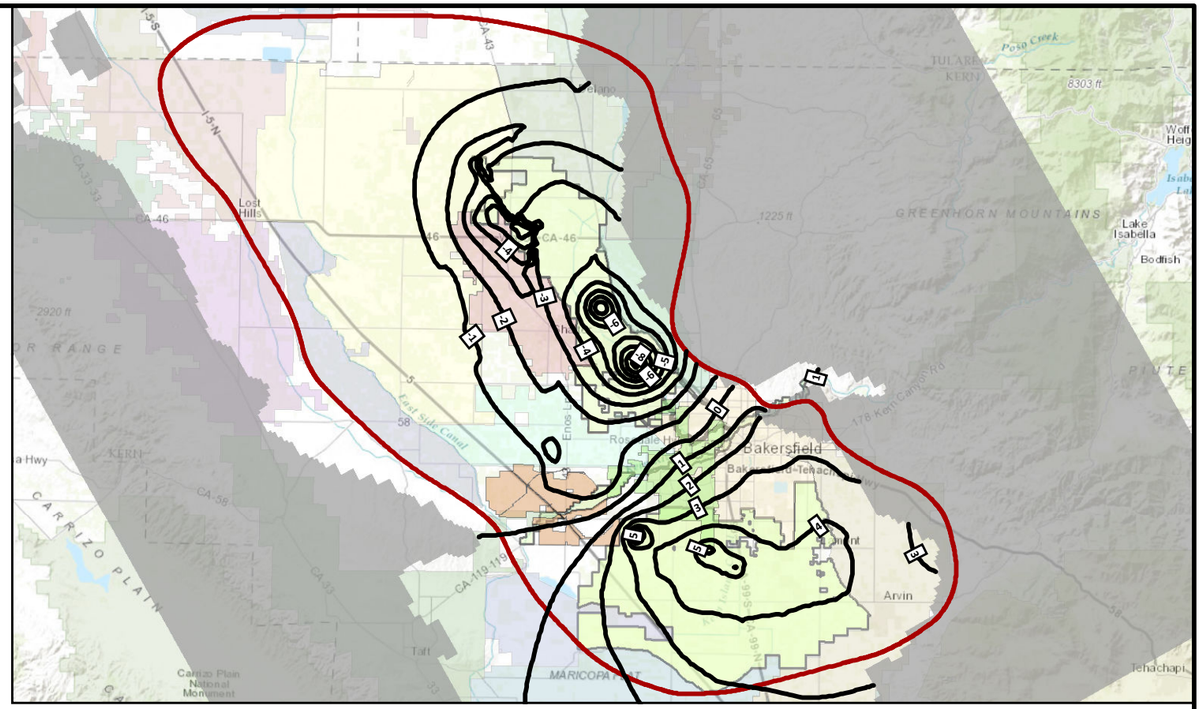
October 2016

TODD GROUNDWATER

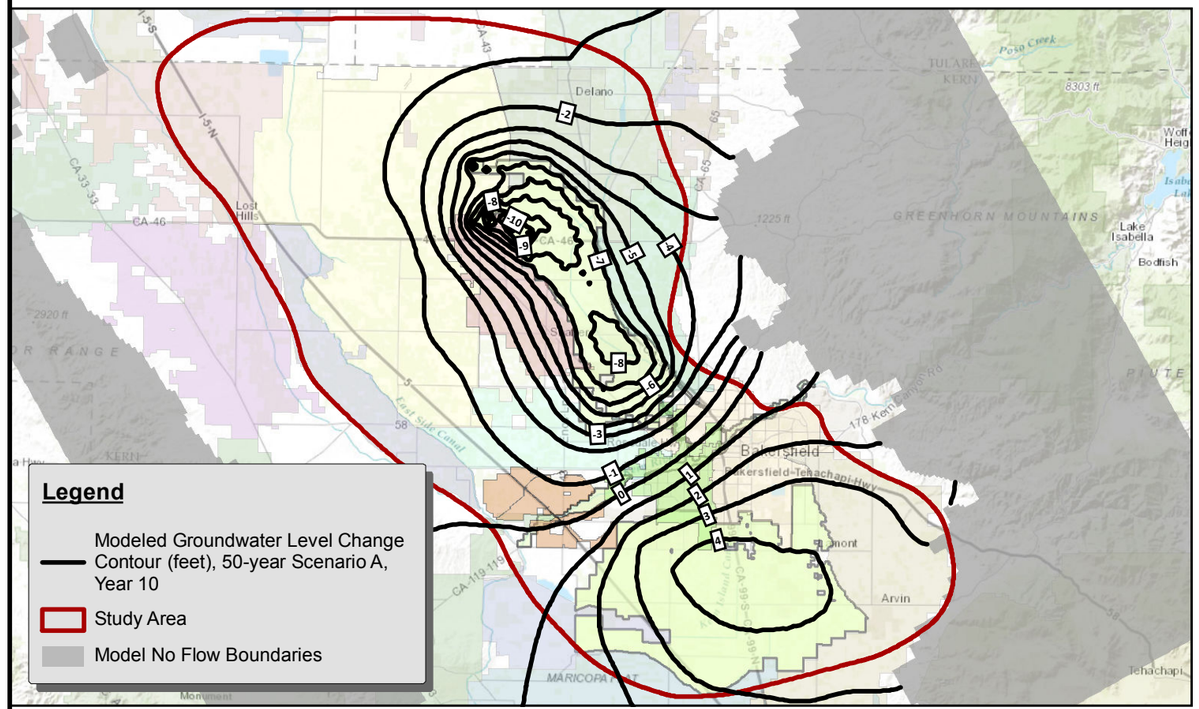
Figure 6-12k
Change and Superposition Hydrographs
Baseline Scenario



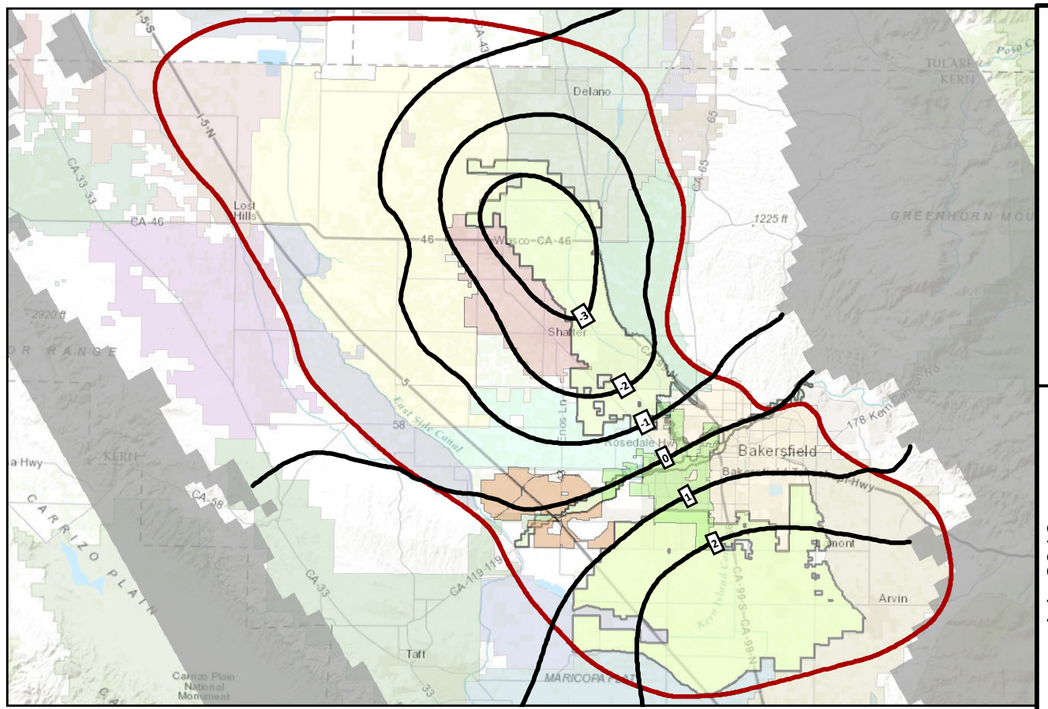
Layer 1



Layer 2



Layer 3

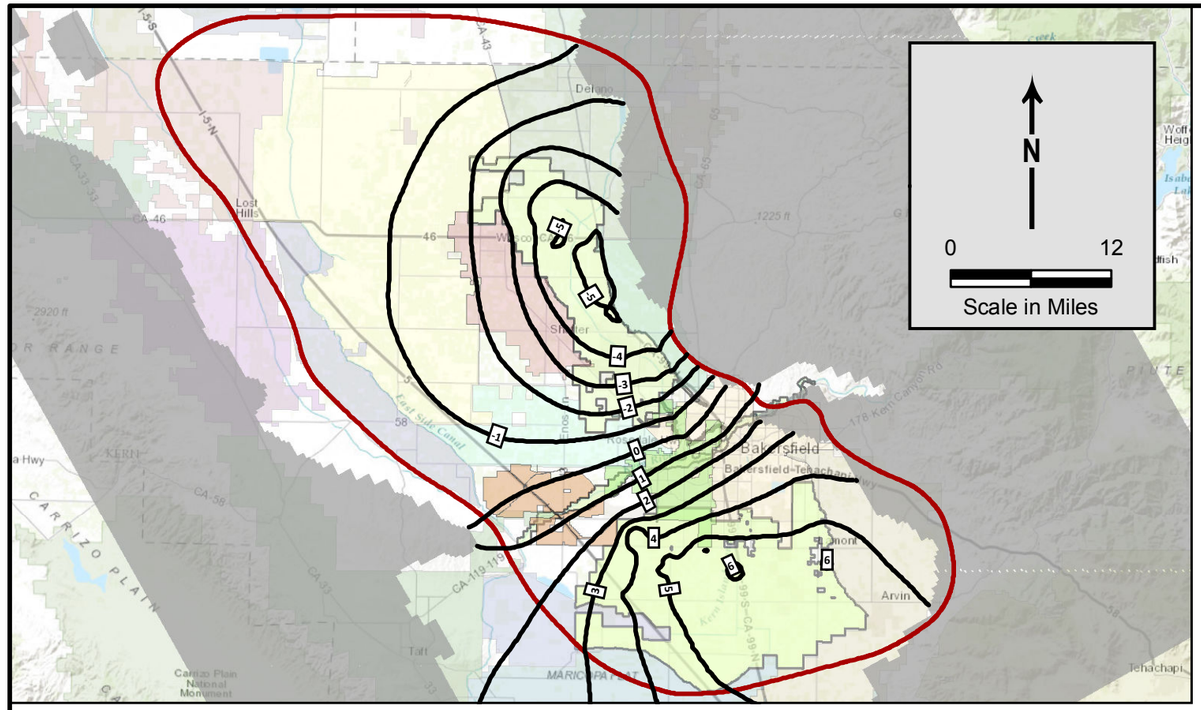


Layer 4

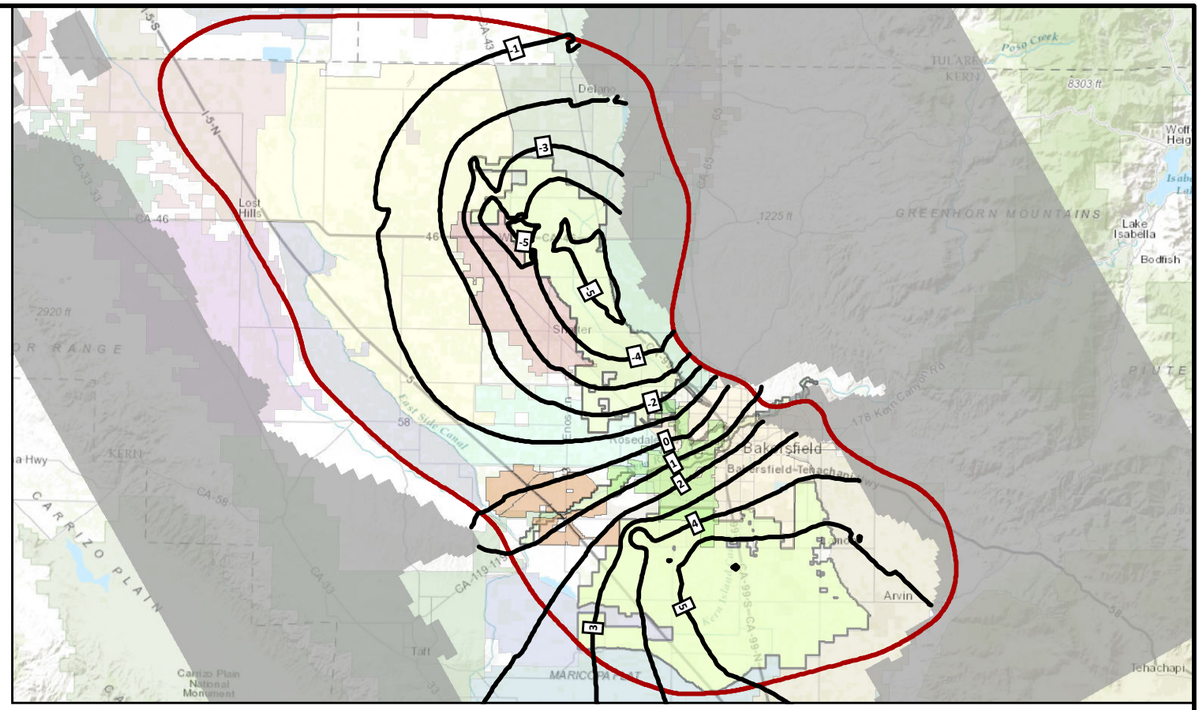
Figure 6-13
Simulated Groundwater Change for Year 10 of 50-year Scenario A

July 2016

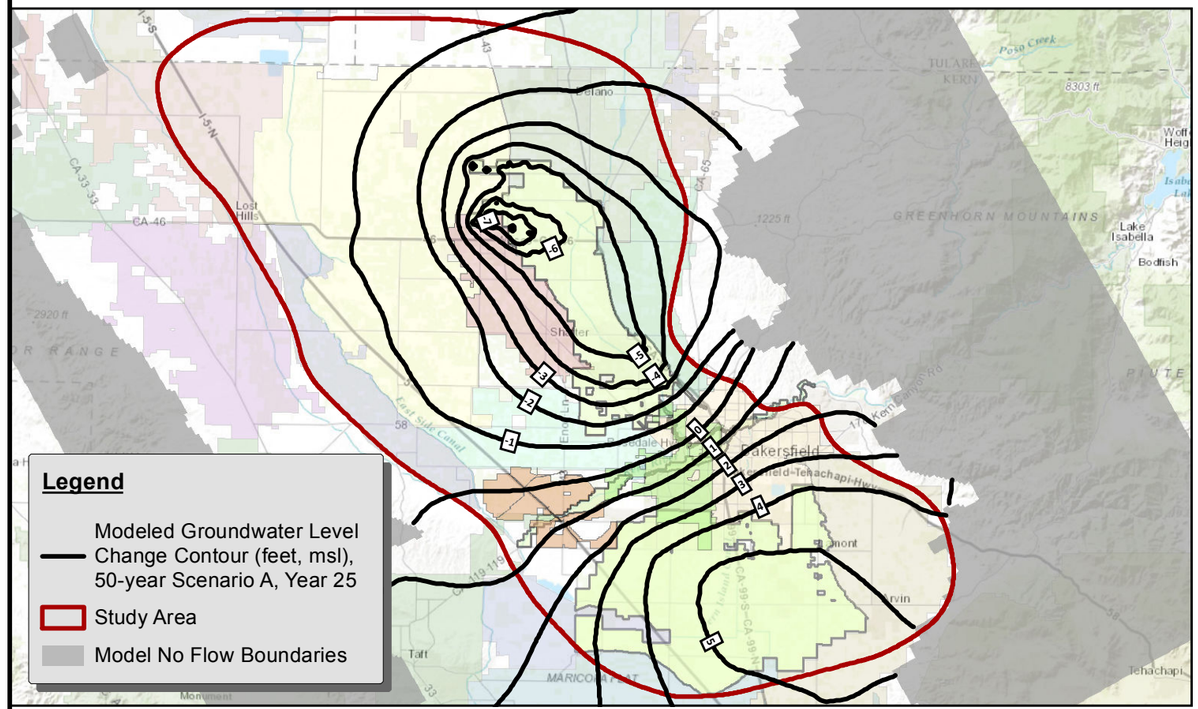
TODD GROUNDWATER



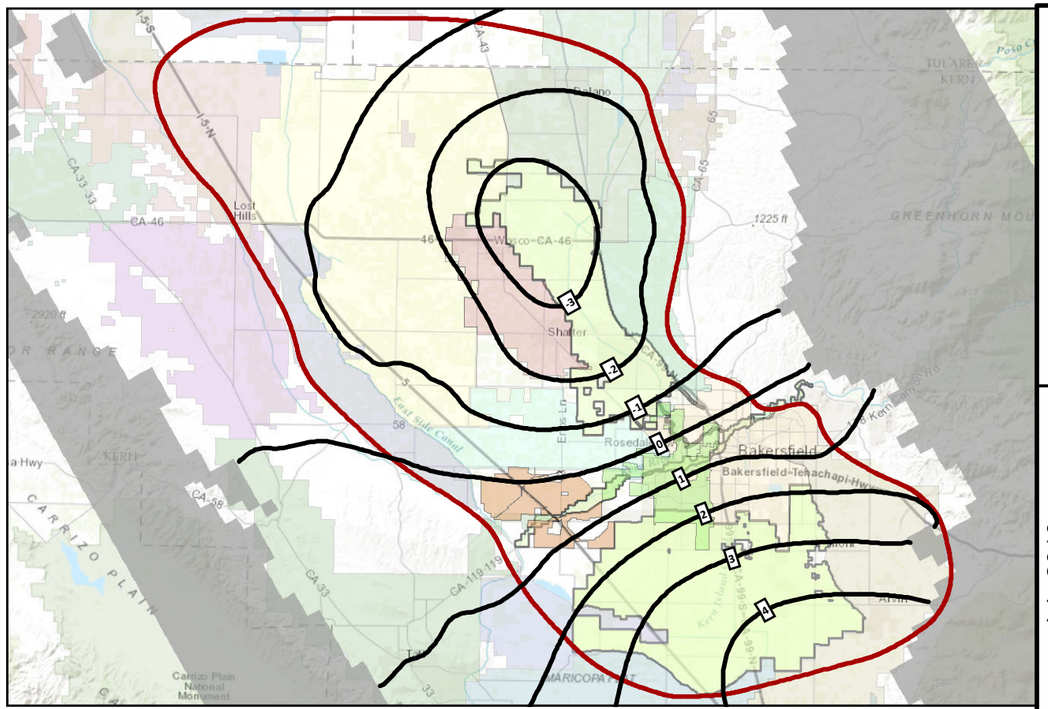
Layer 1



Layer 2



Layer 3

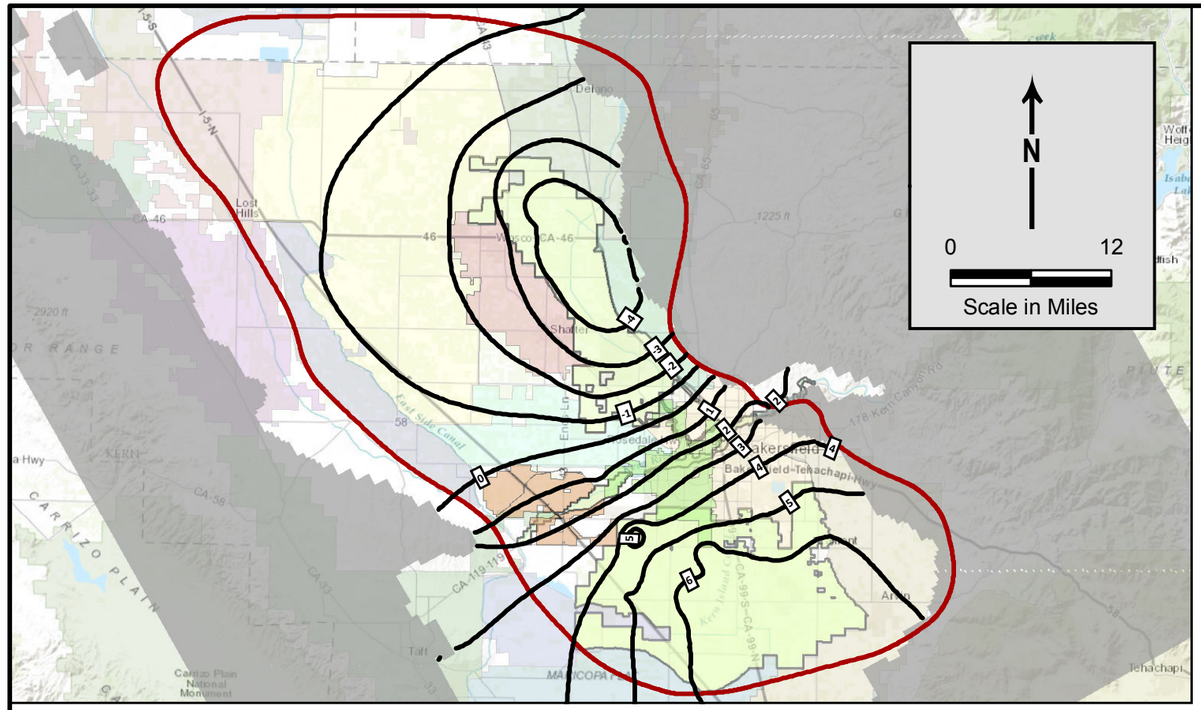


Layer 4

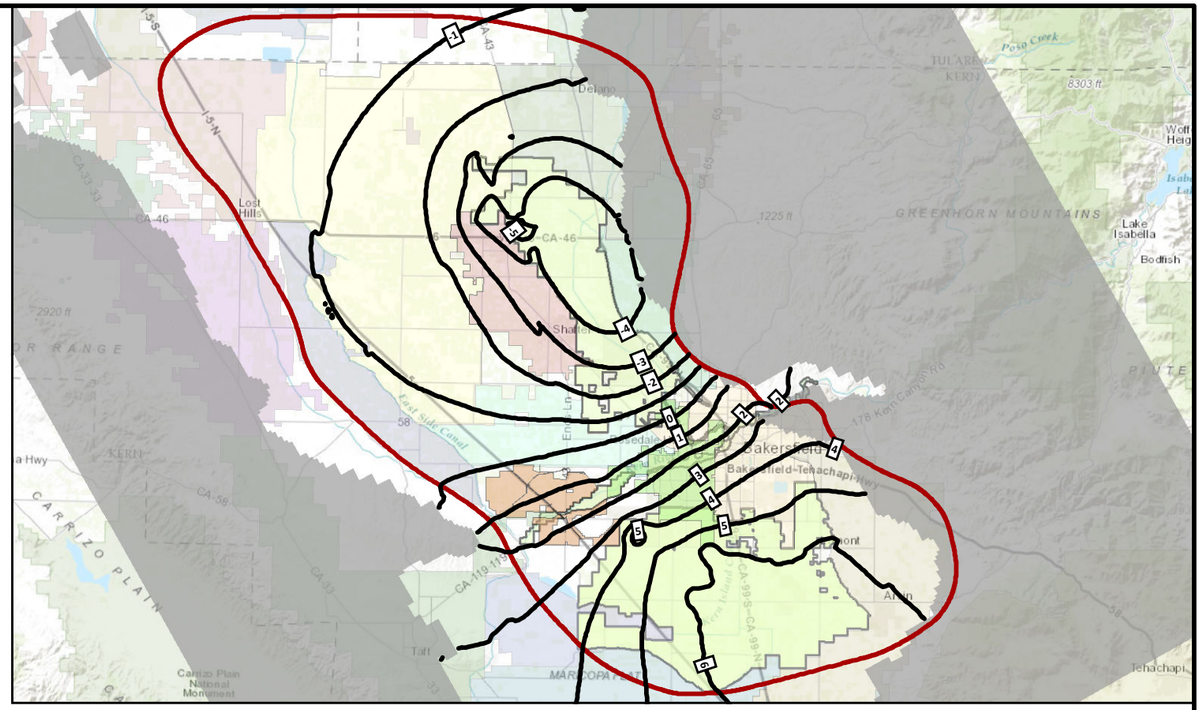
Figure 6-14
Simulated Groundwater Change for Year 25 of 50-year Scenario A

July 2016

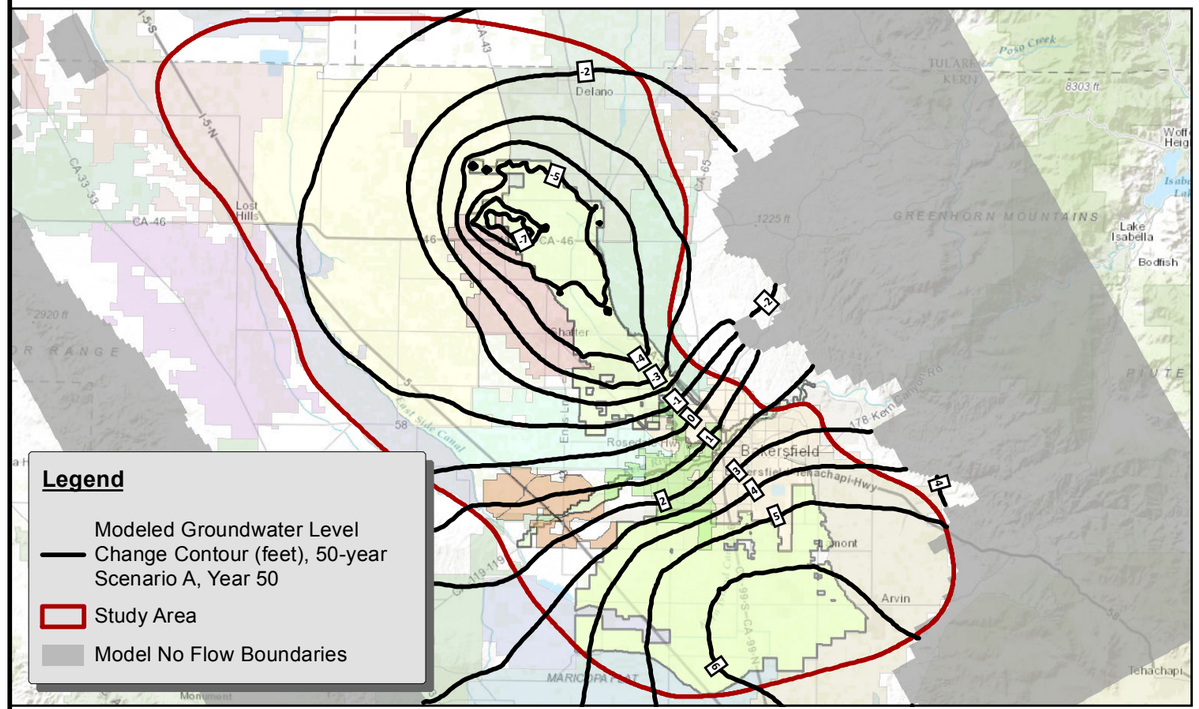
TODD GROUNDWATER



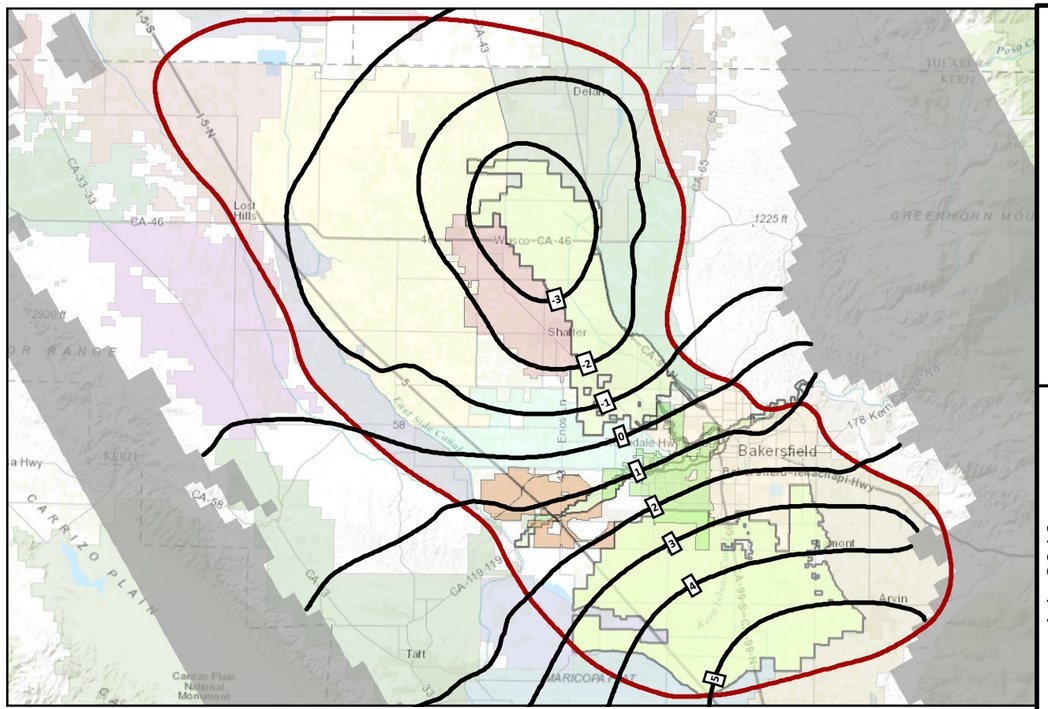
Layer 1



Layer 2



Layer 3

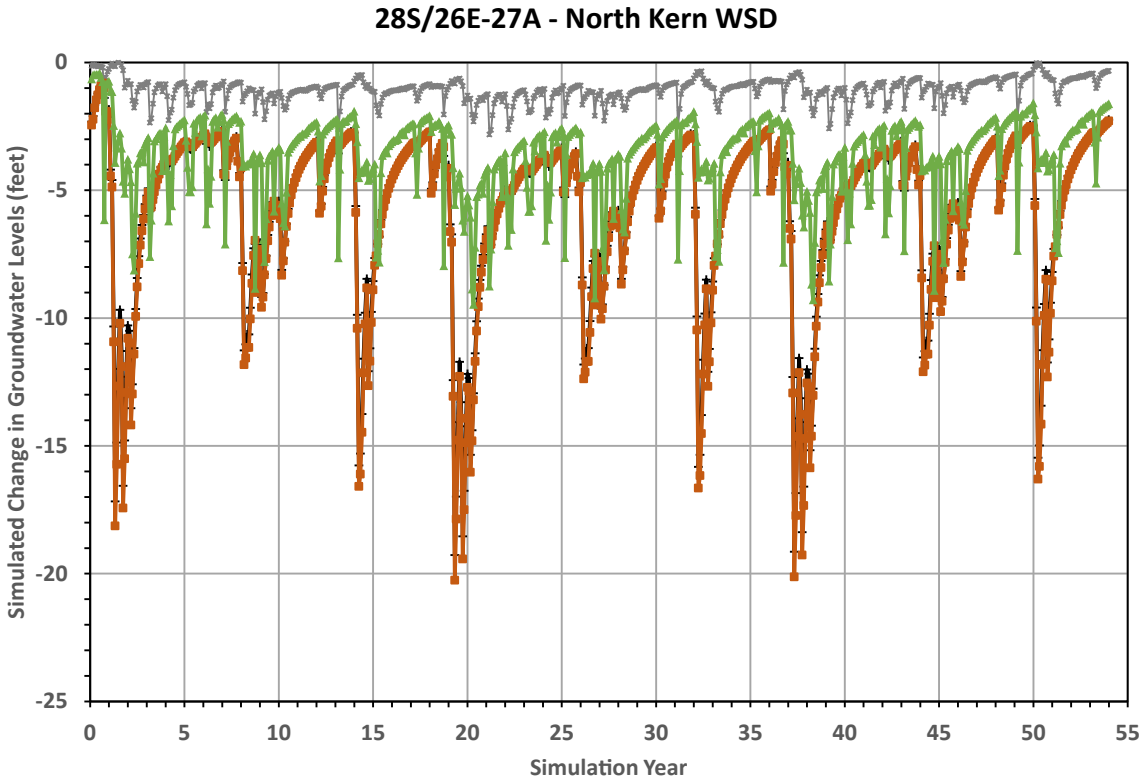


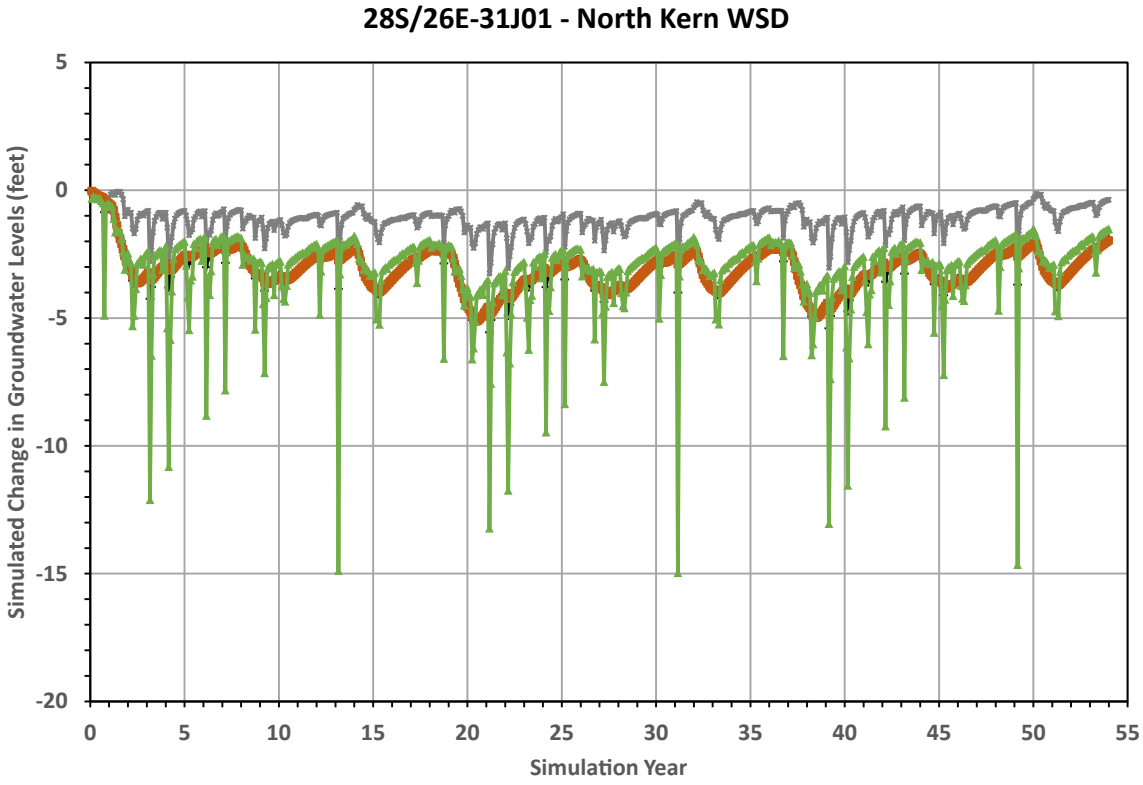
Layer 4

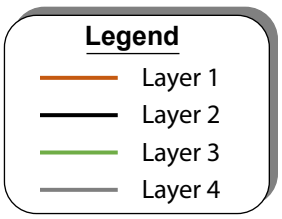
Figure 6-15
Simulated Groundwater Change for Year 50 of 50-year Scenario A

July 2016

TODD GROUNDWATER



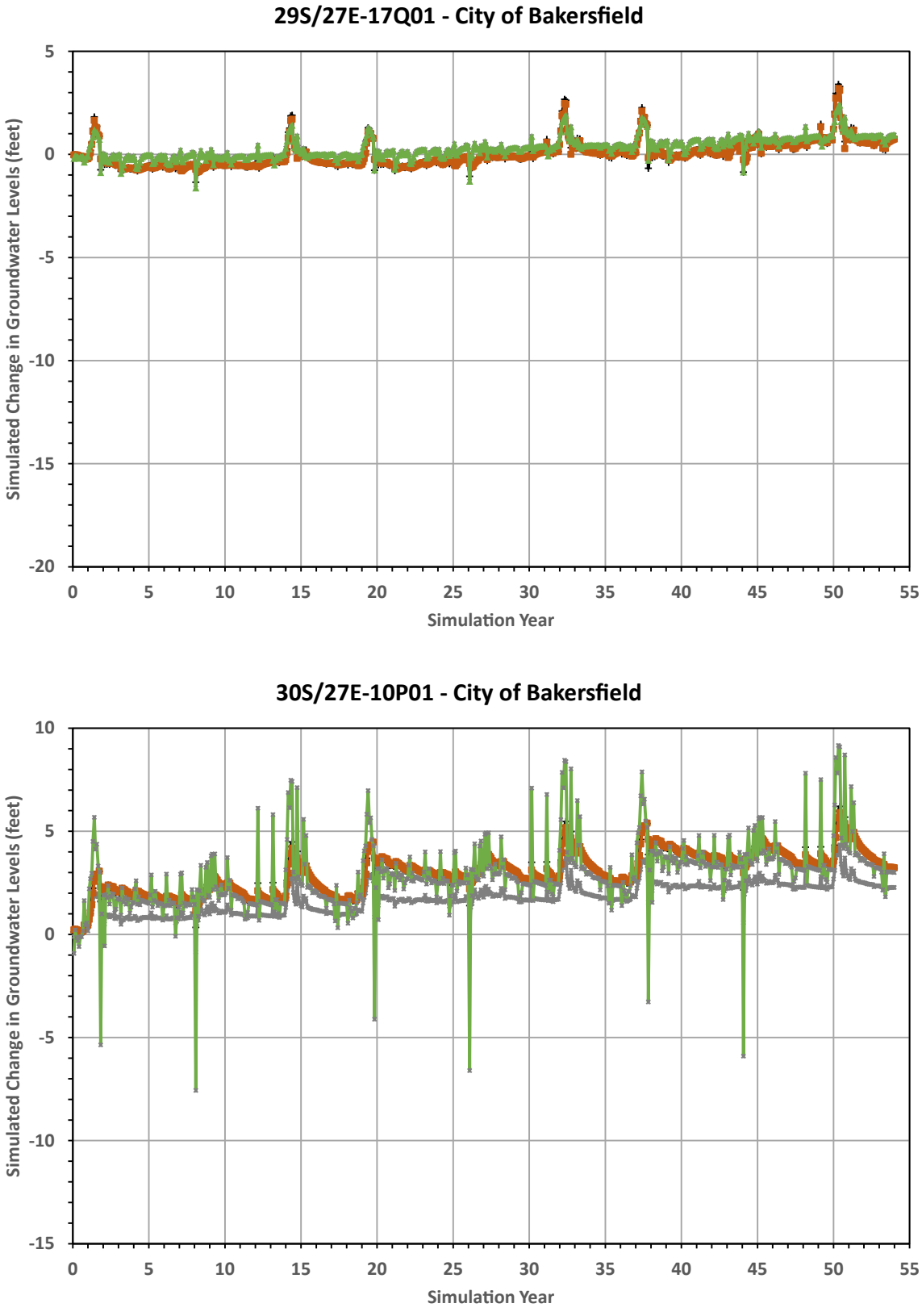




October 2016

TODD GROUNDWATER

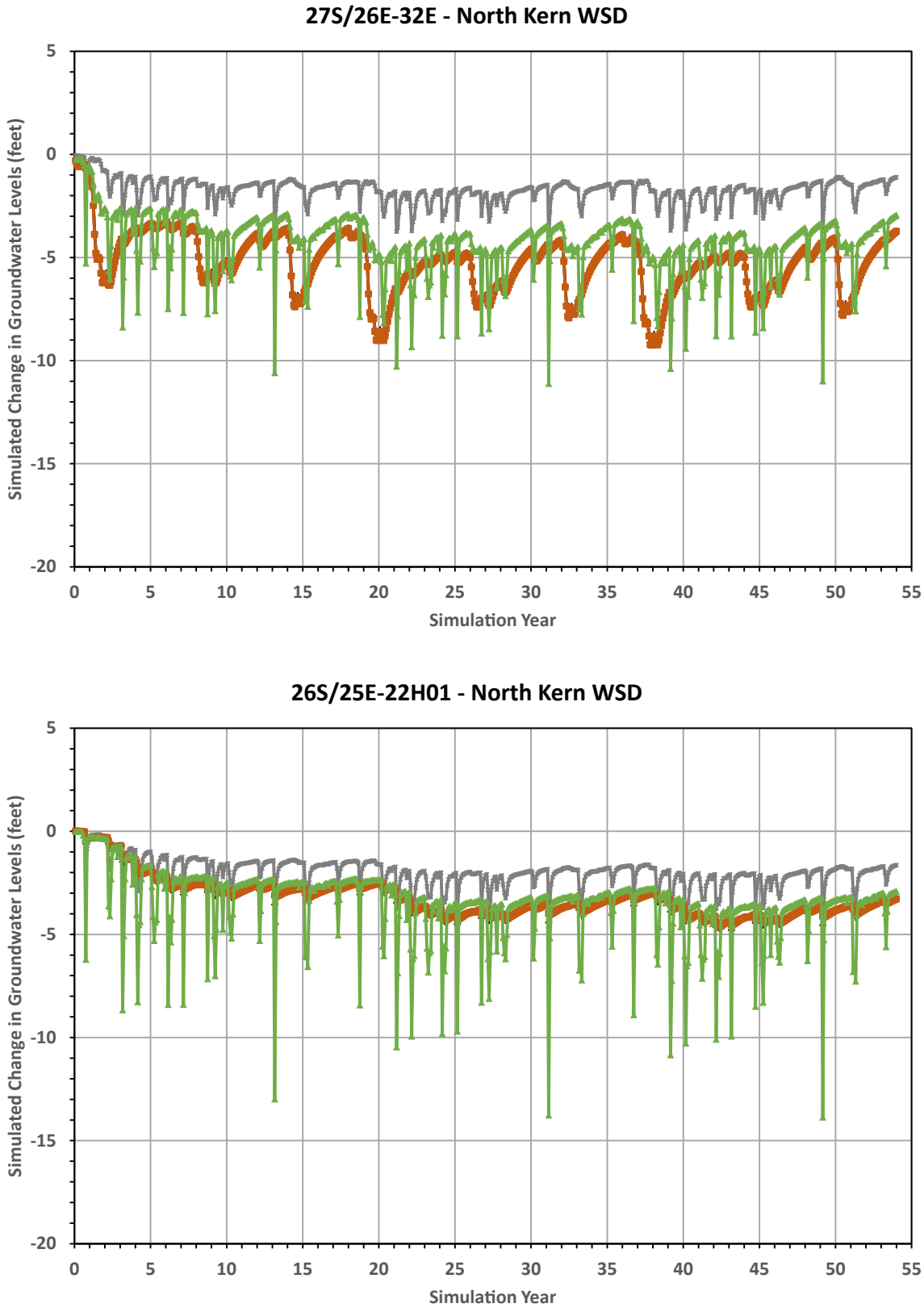
Figure 6-16a
Change Hydrographs
50-year Scenario A



October 2016

TODD GROUNDWATER

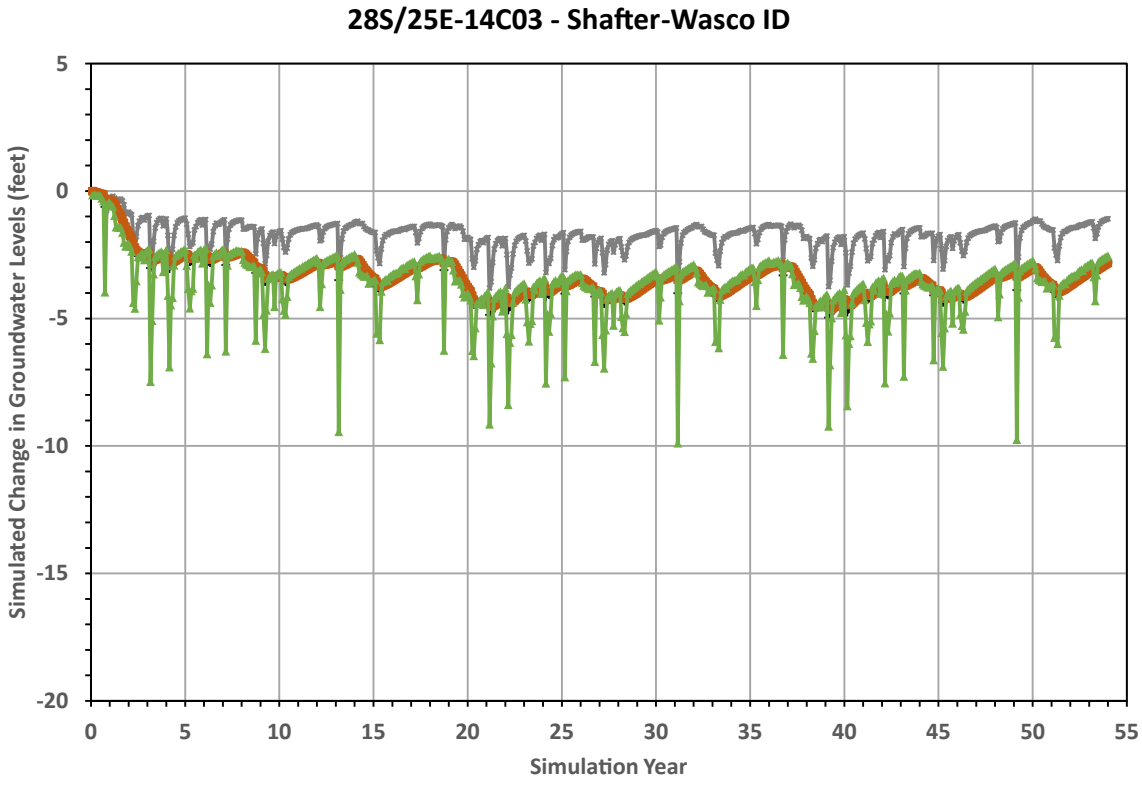
Figure 6-16b
Change Hydrographs
50-year Scenario A

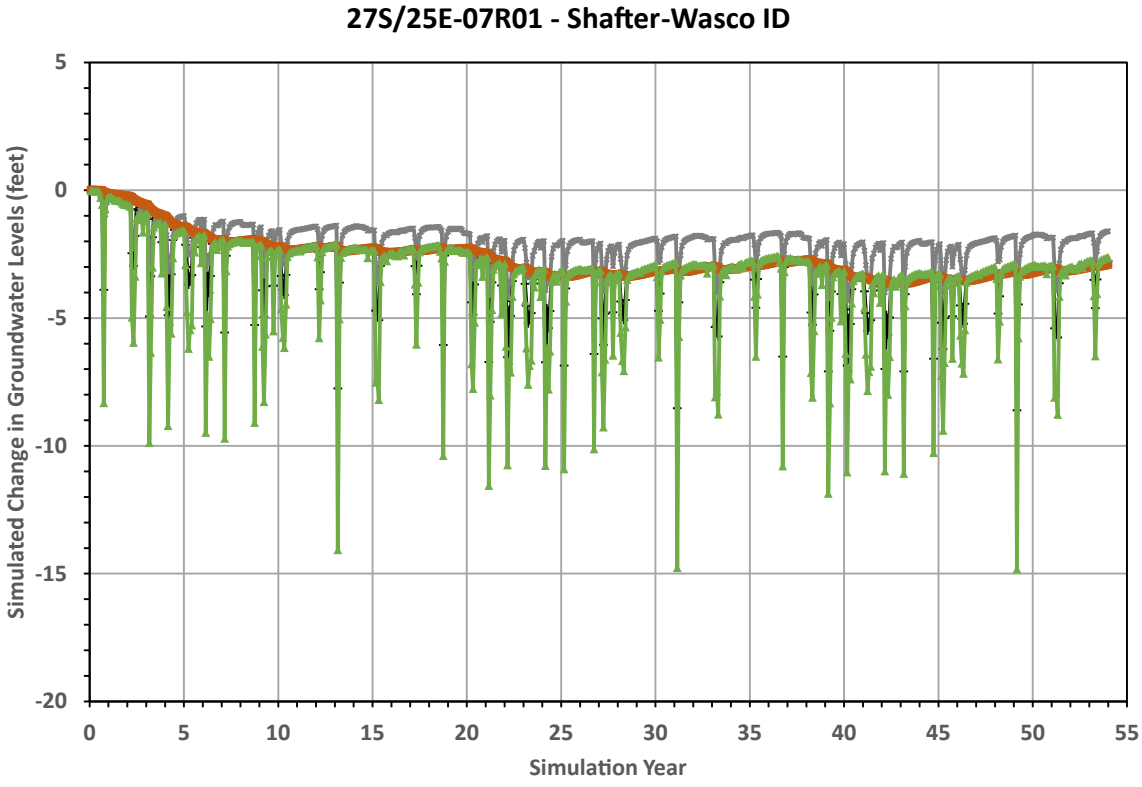


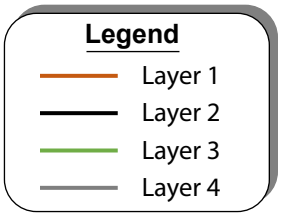
October 2016

TODD GROUNDWATER

Figure 6-16c
Change Hydrographs
50-year Scenario A



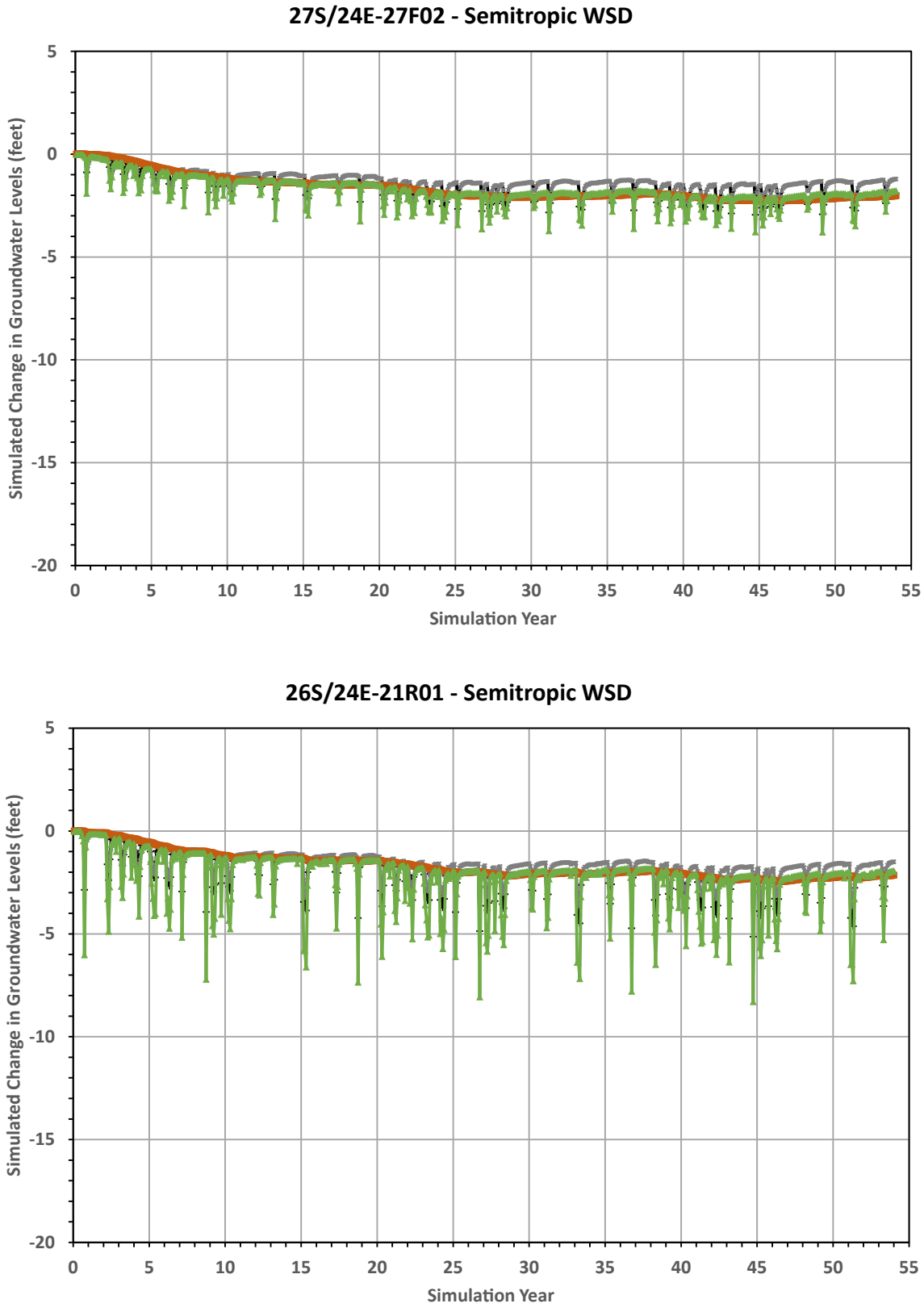




October 2016

TODD GROUNDWATER

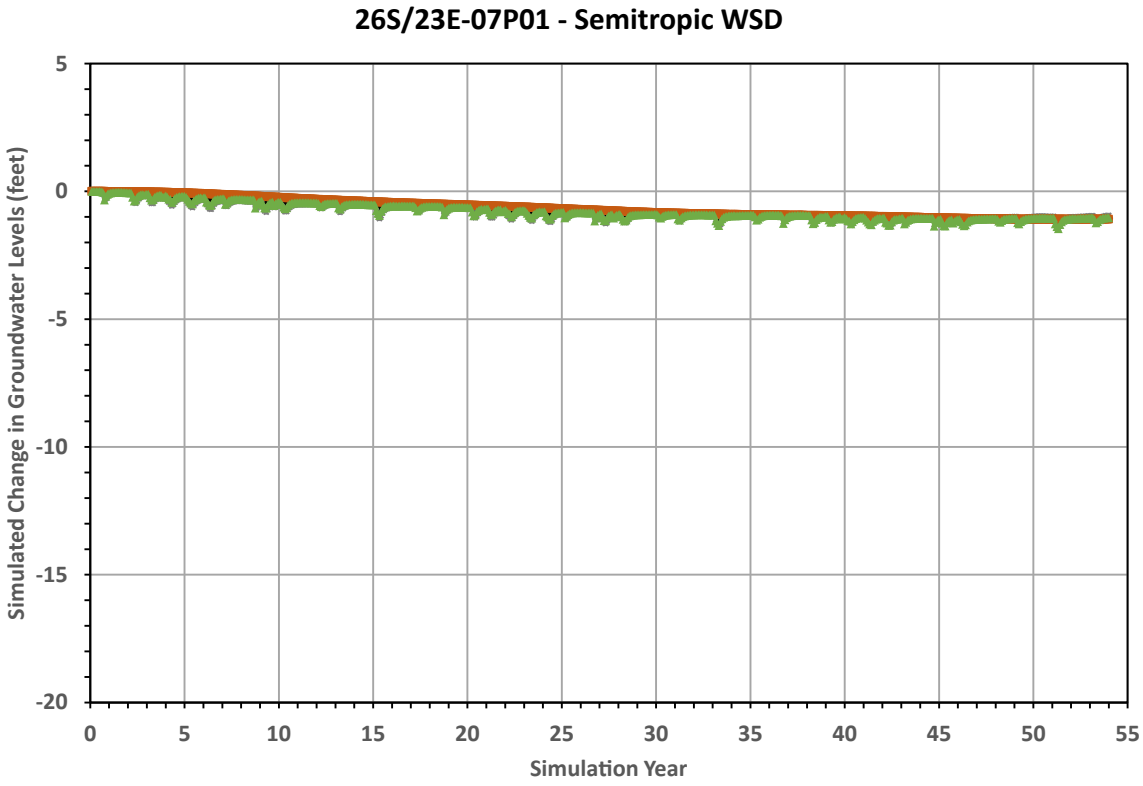
Figure 6-16d
Change Hydrographs
50-year Scenario A



October 2016

TODD GROUNDWATER

Figure 6-16e
Change Hydrographs
50-year Scenario A



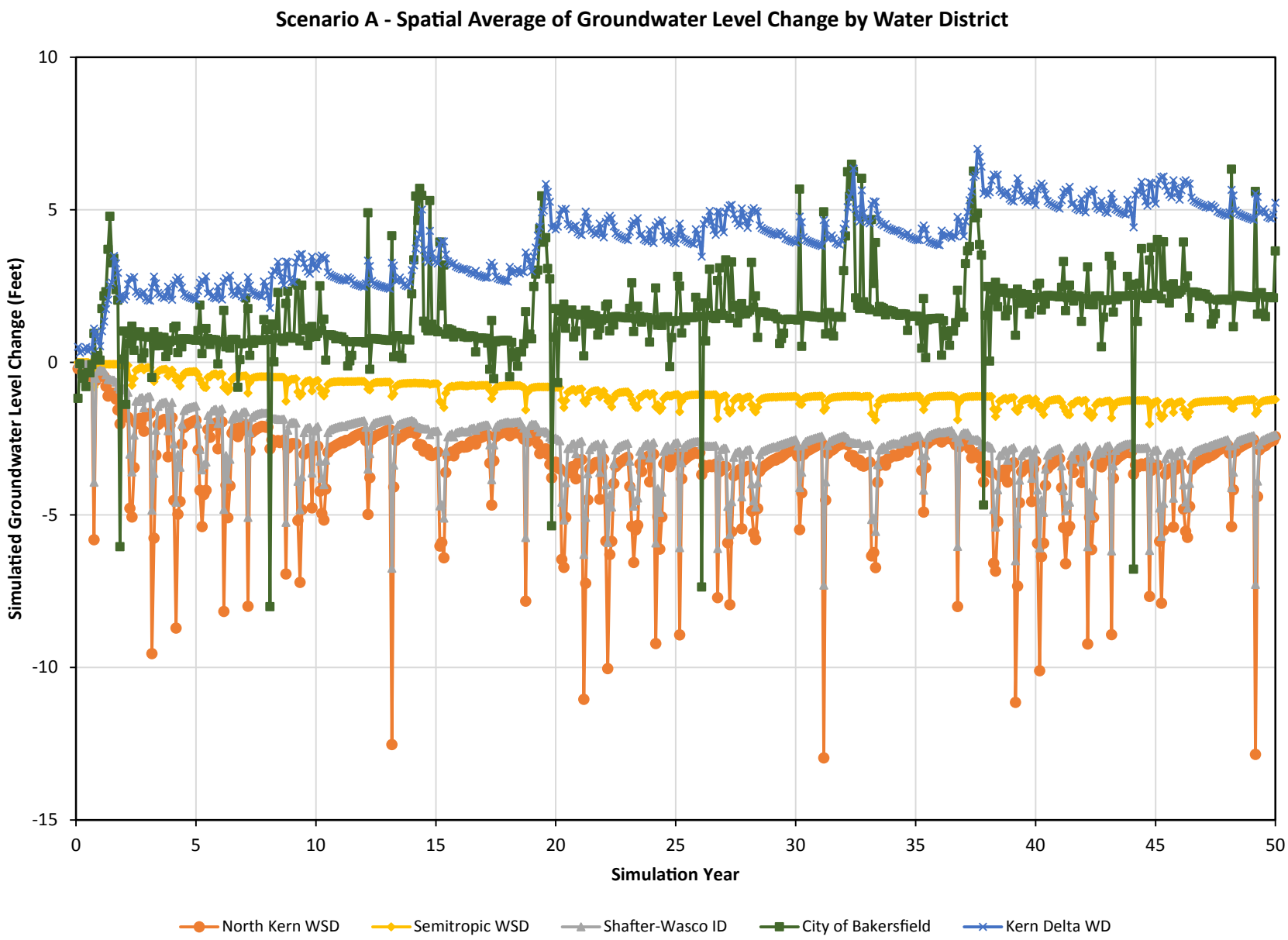
Legend

- Layer 1
- Layer 2
- Layer 3
- Layer 4

October 2016

TODD GROUNDWATER

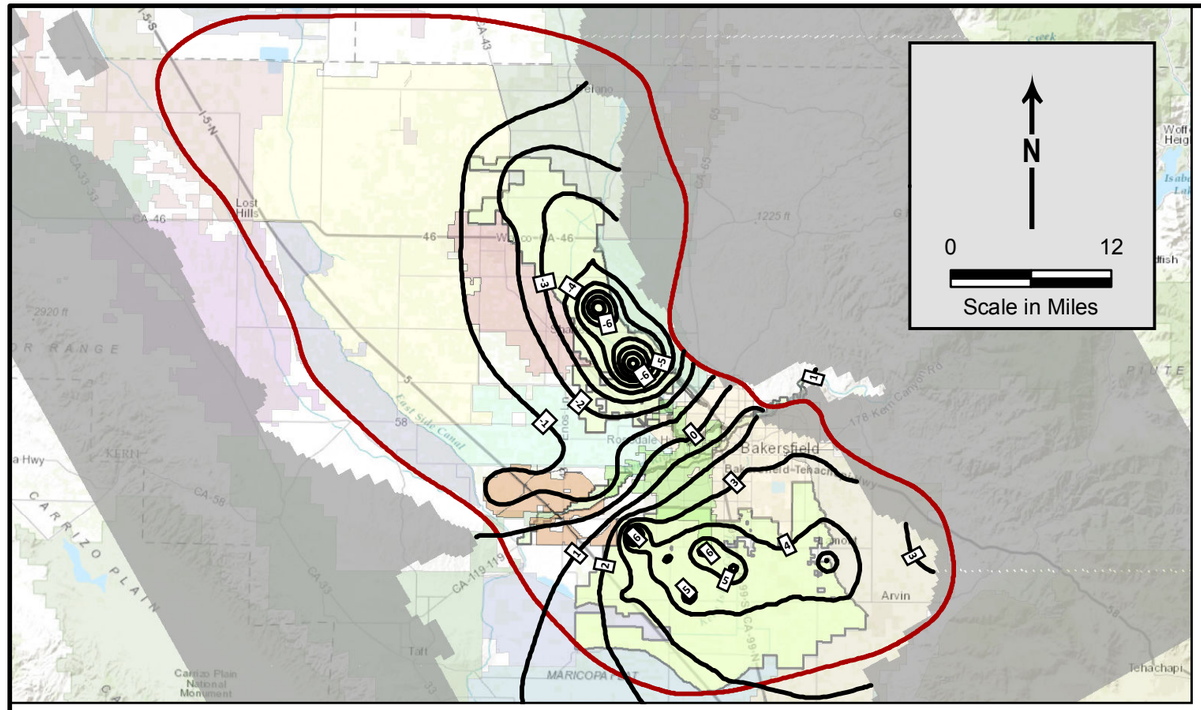
Figure 6-16f
Change Hydrographs
50-year Scenario A



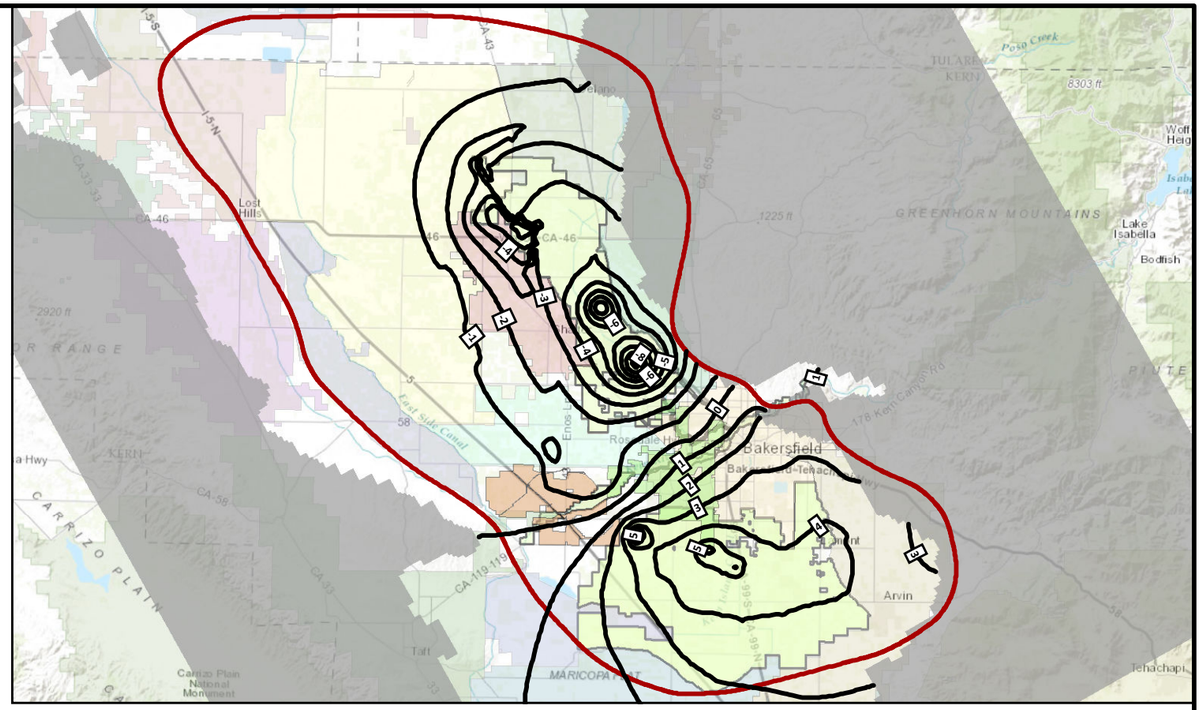
October 2016

TODD GROUNDWATER

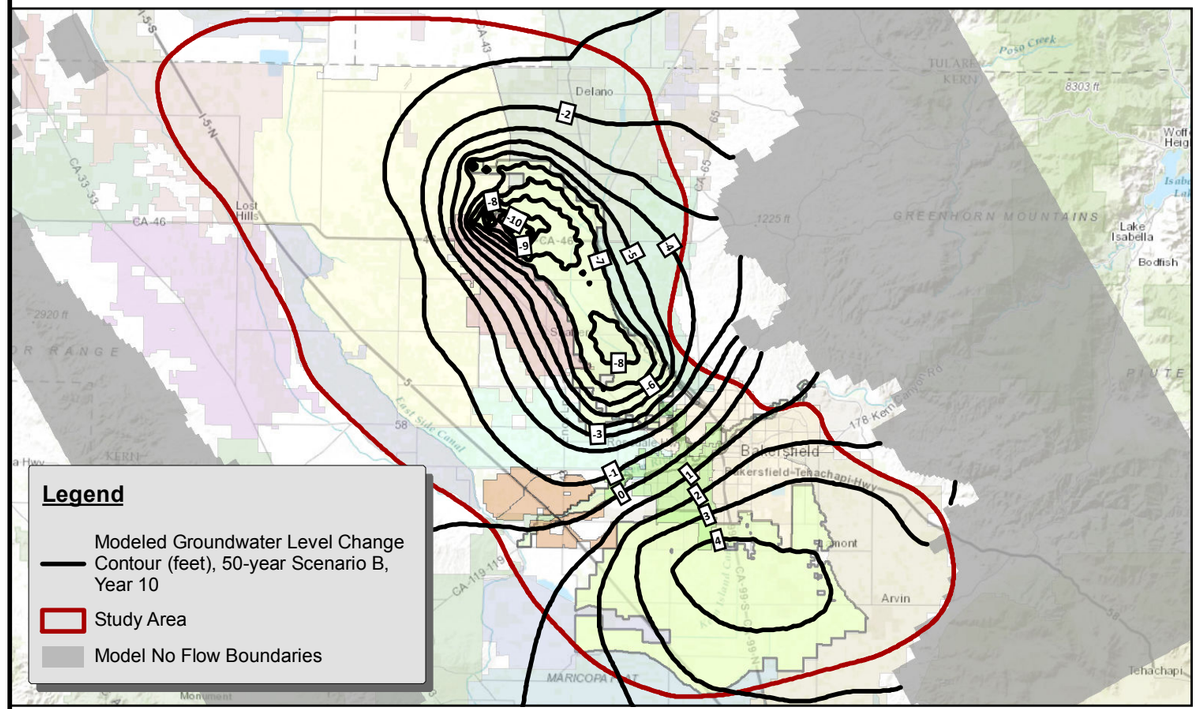
Figure 6-17
Scenario A
Spatial Average
Groundwater Level Change



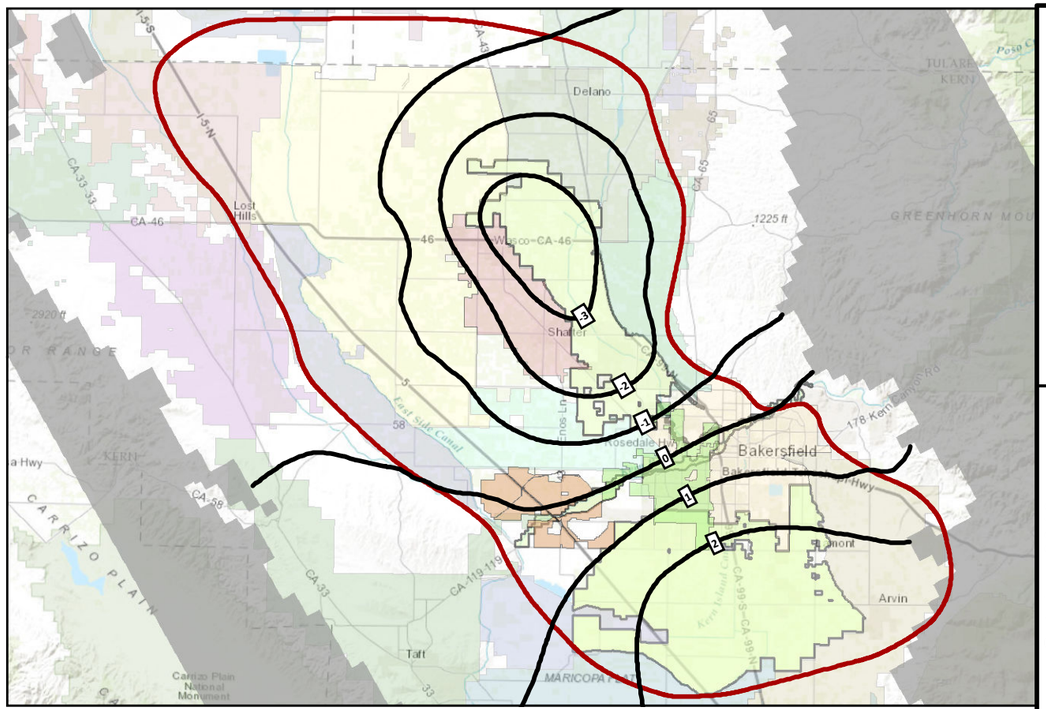
Layer 1



Layer 2



Layer 3

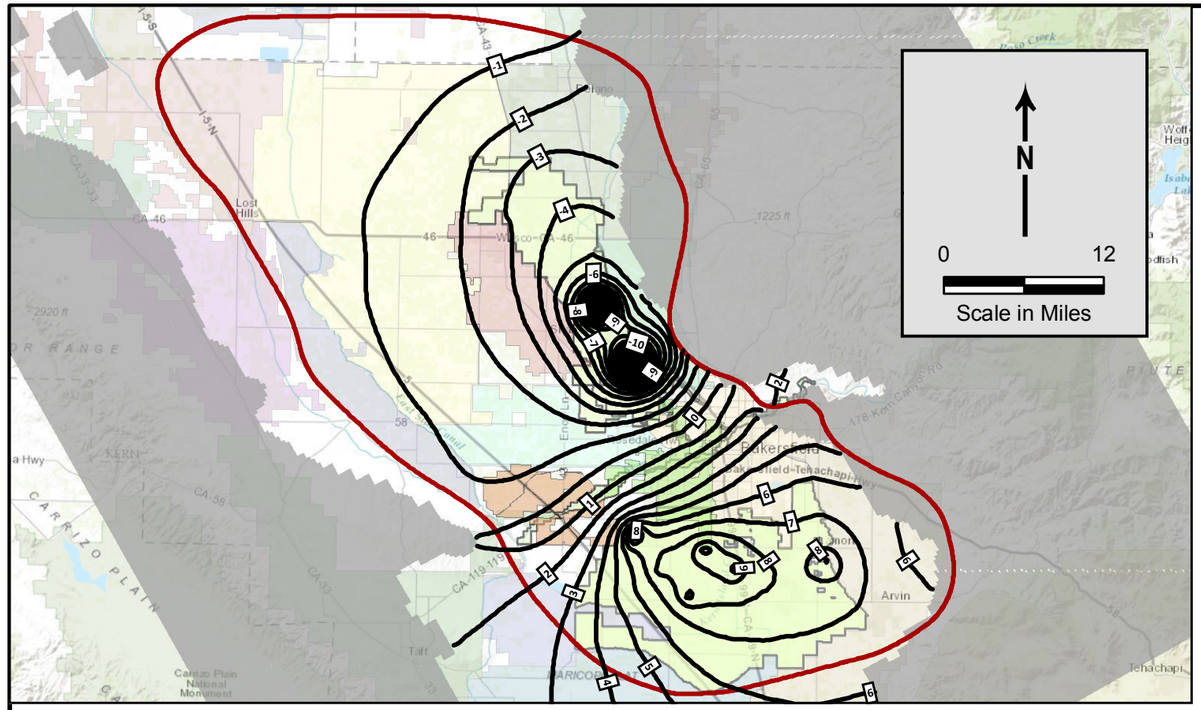


Layer 4

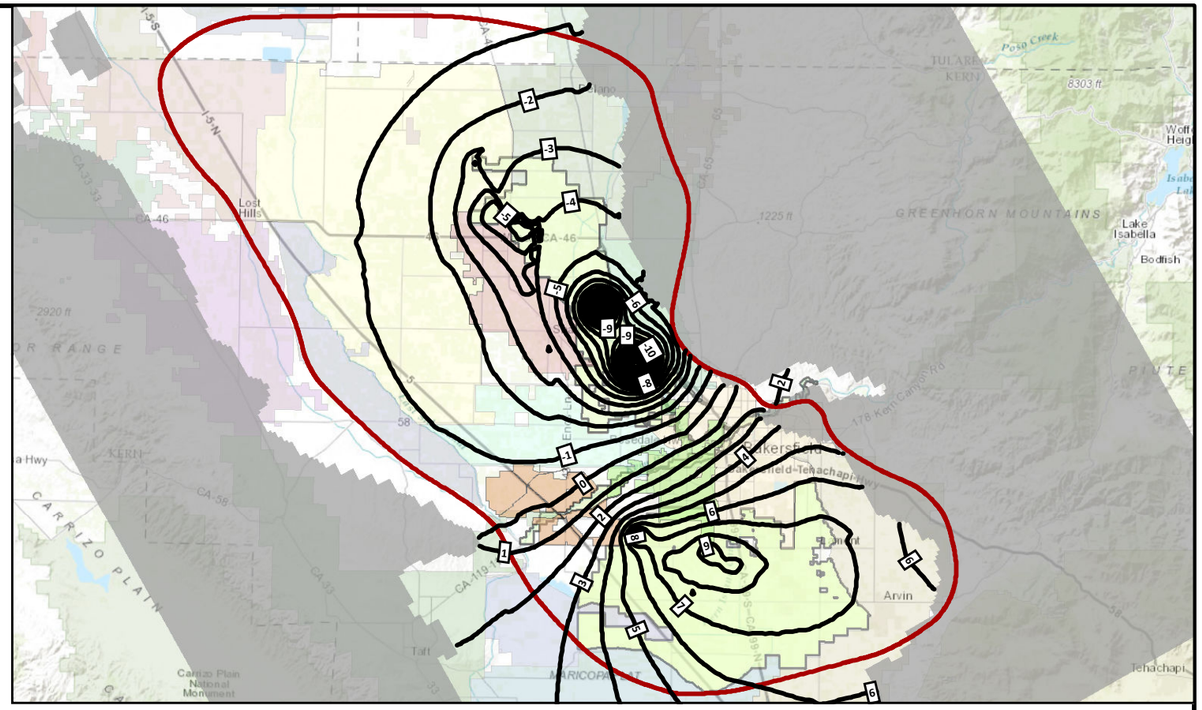
Figure 6-18
Simulated Groundwater Change for Year 10 of 50-year Scenario B

October 2016

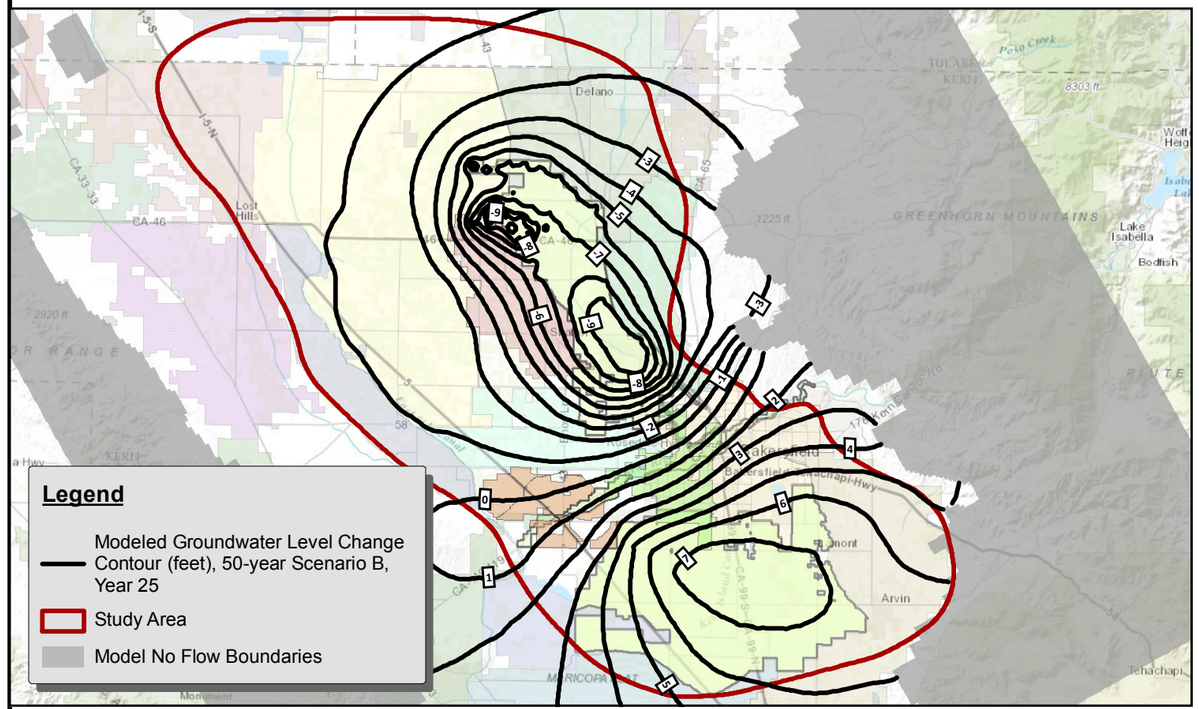
TODD GROUNDWATER



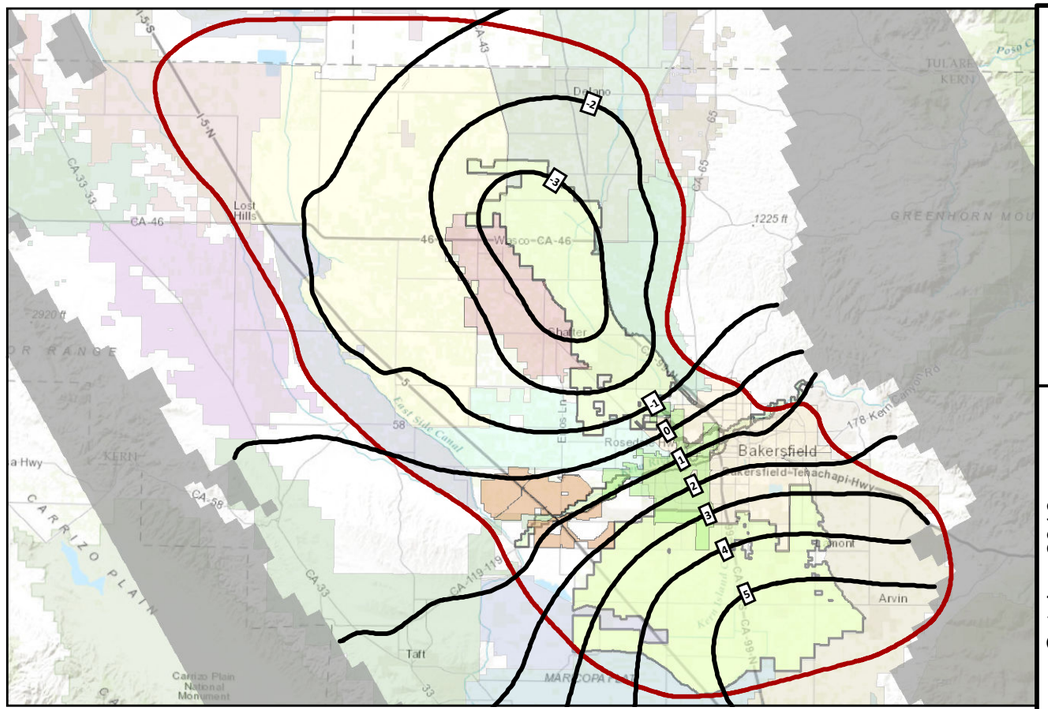
Layer 1



Layer 2



Layer 3

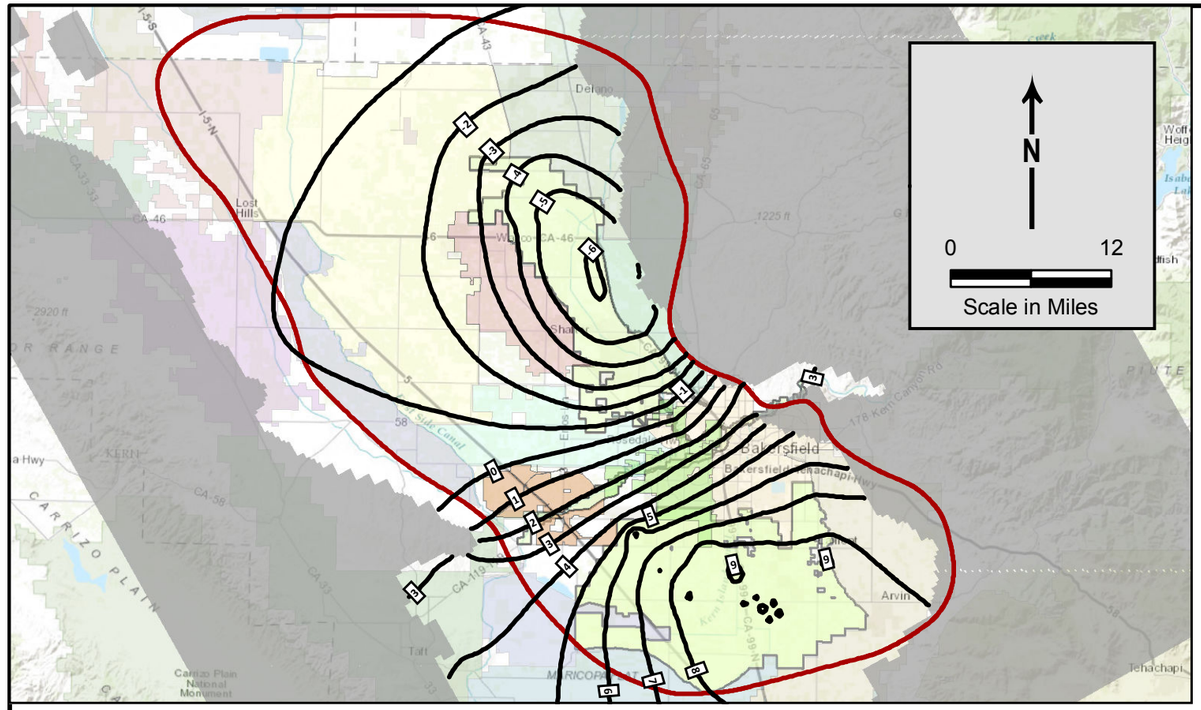


Layer 4

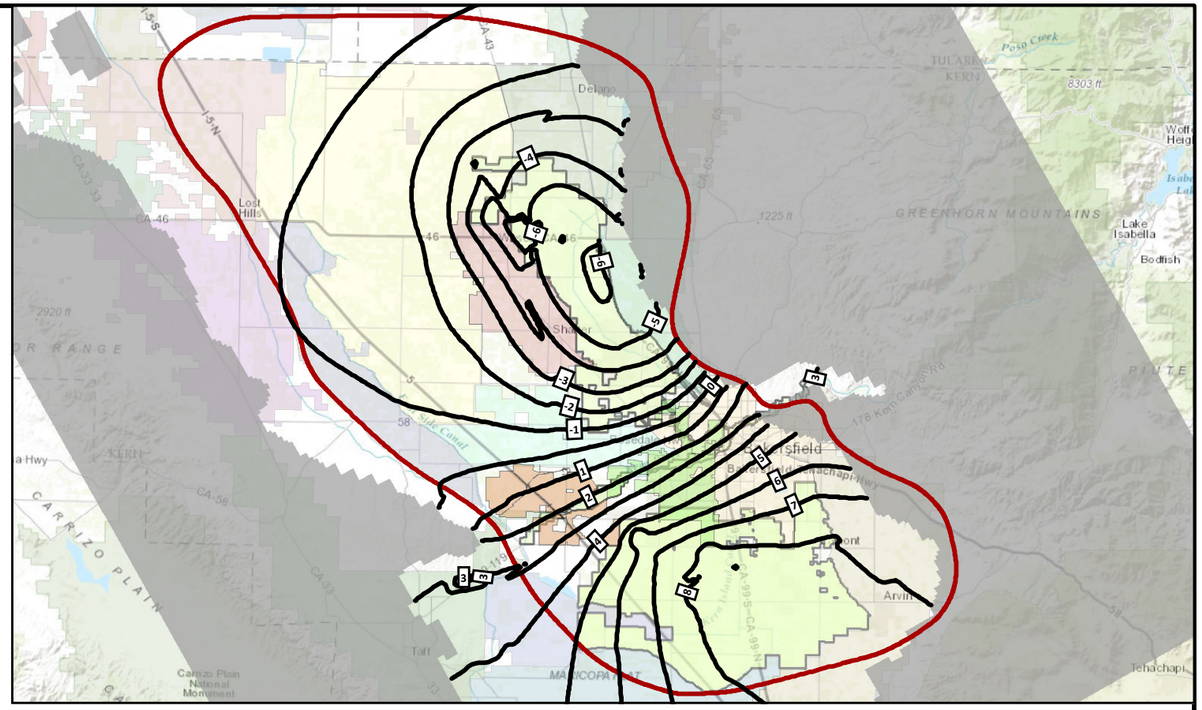
Figure 6-19
Simulated Groundwater Change for Year 25 of 50-year Scenario B

October 2016

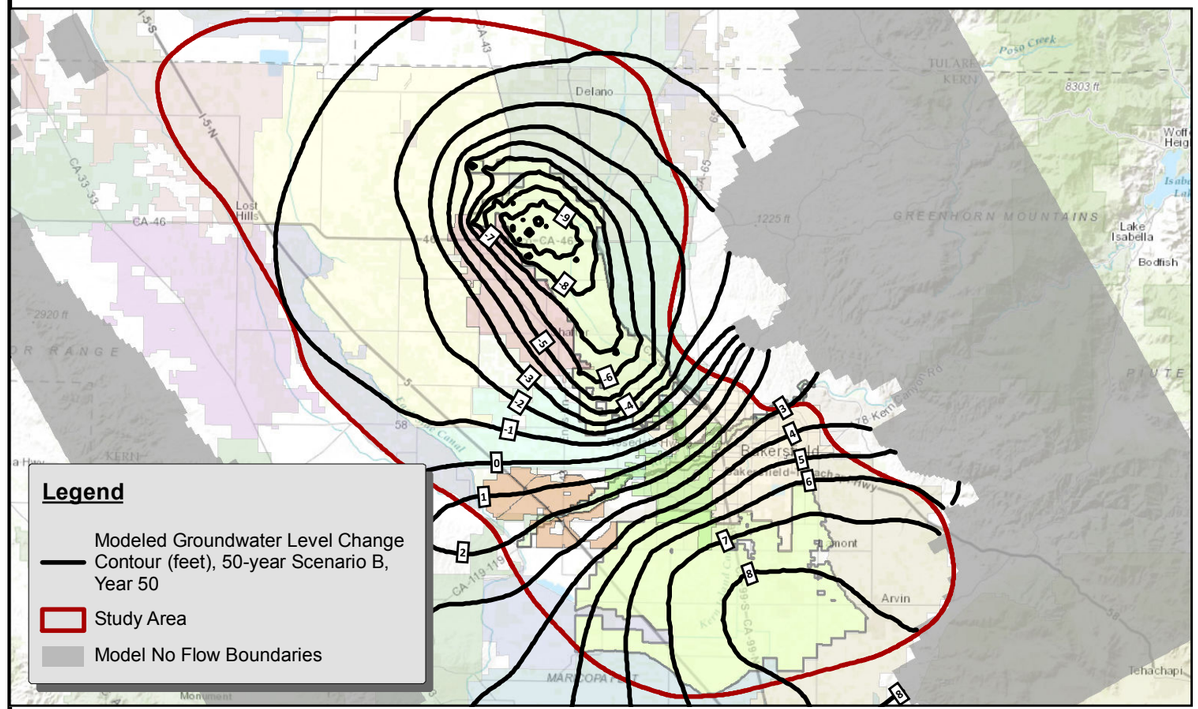
TODD GROUNDWATER



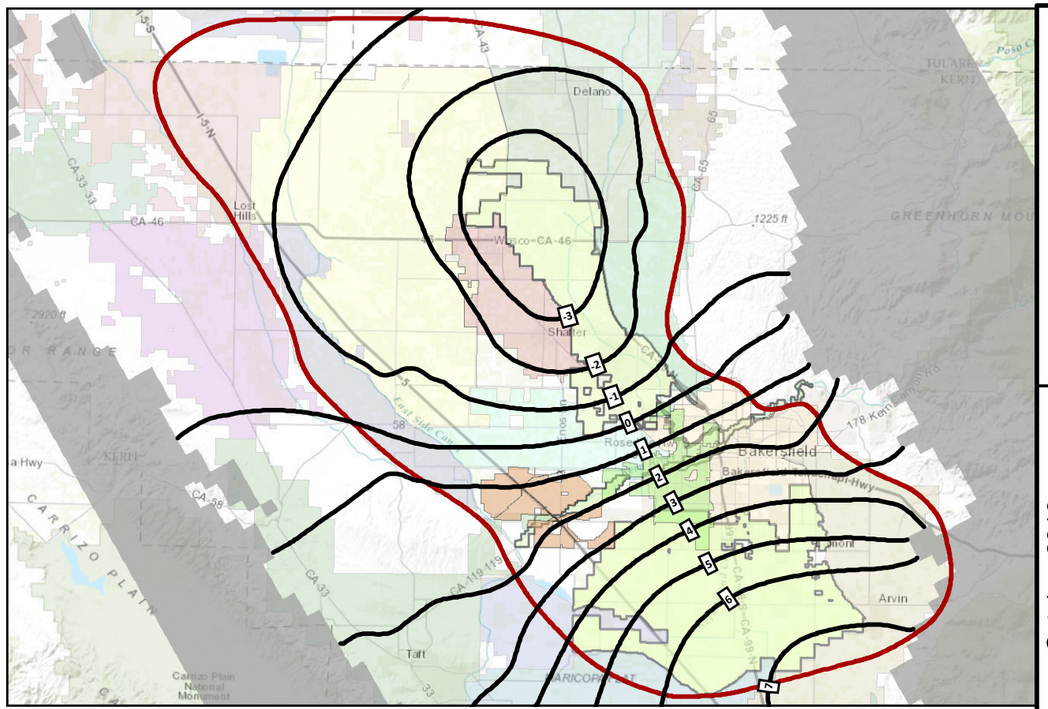
Layer 1



Layer 2



Layer 3

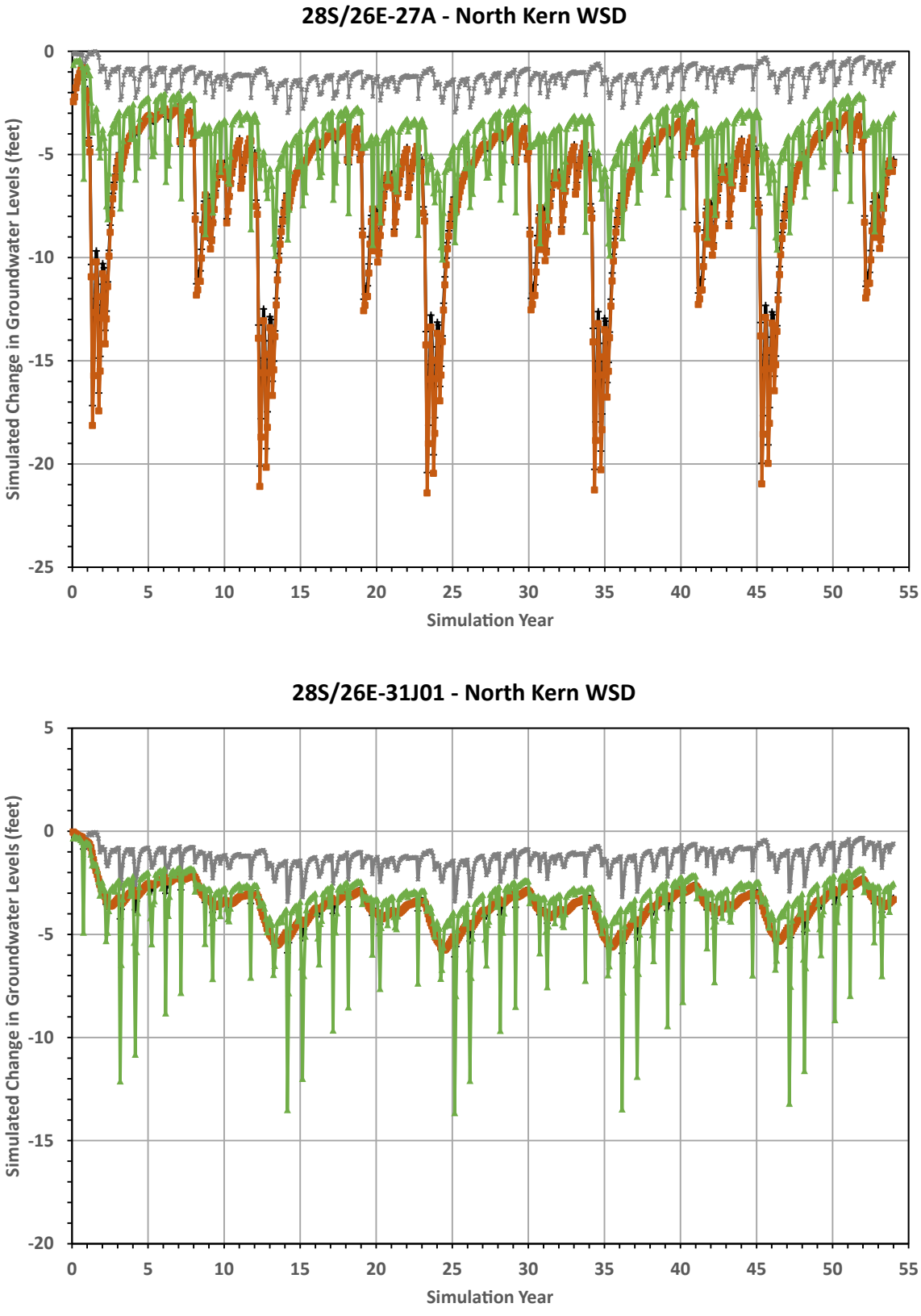


Layer 4

Figure 6-20
Simulated Groundwater Change for Year 50 of 50-year Scenario B

October 2016

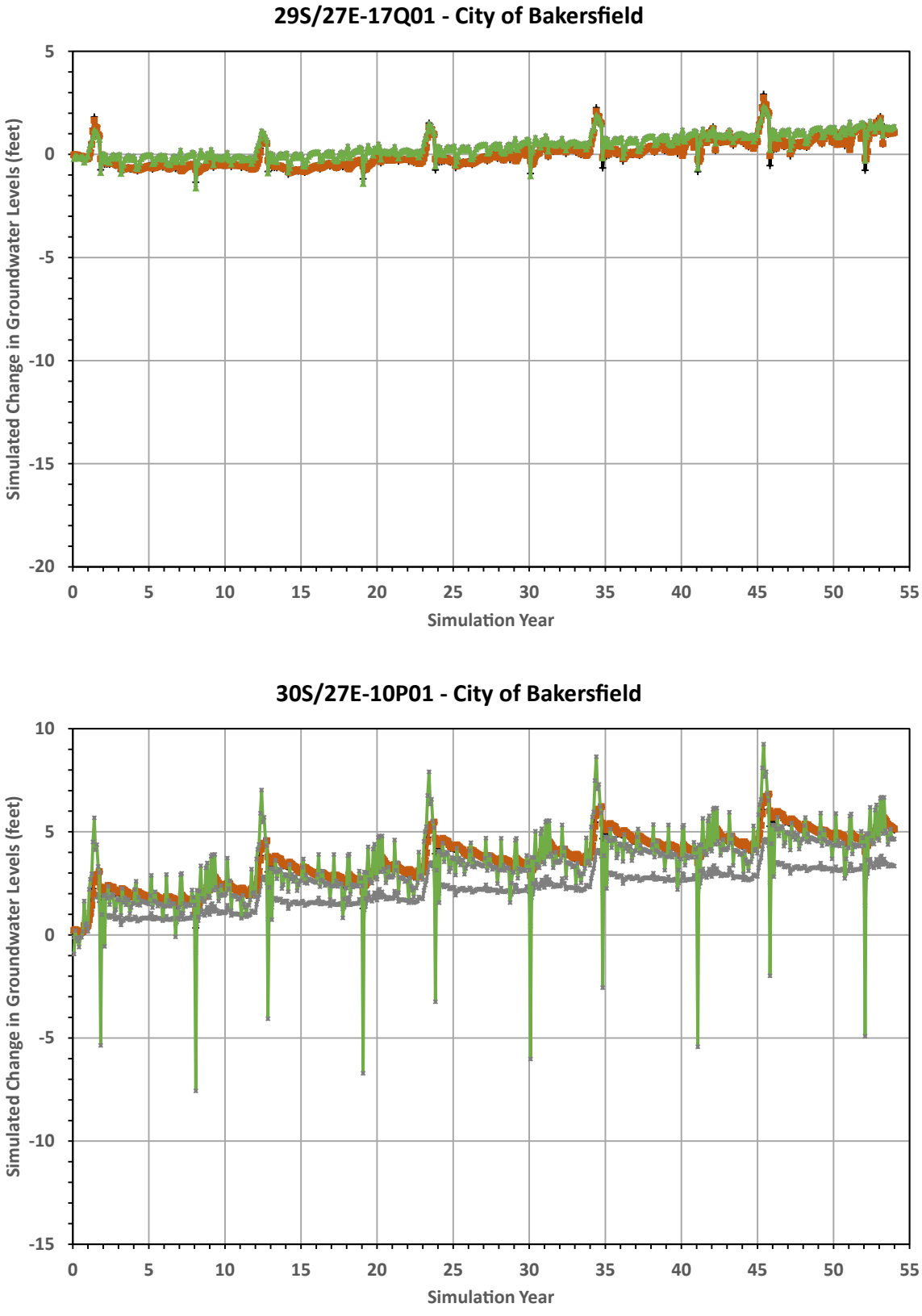
TODD GROUNDWATER



October 2016

TODD GROUNDWATER

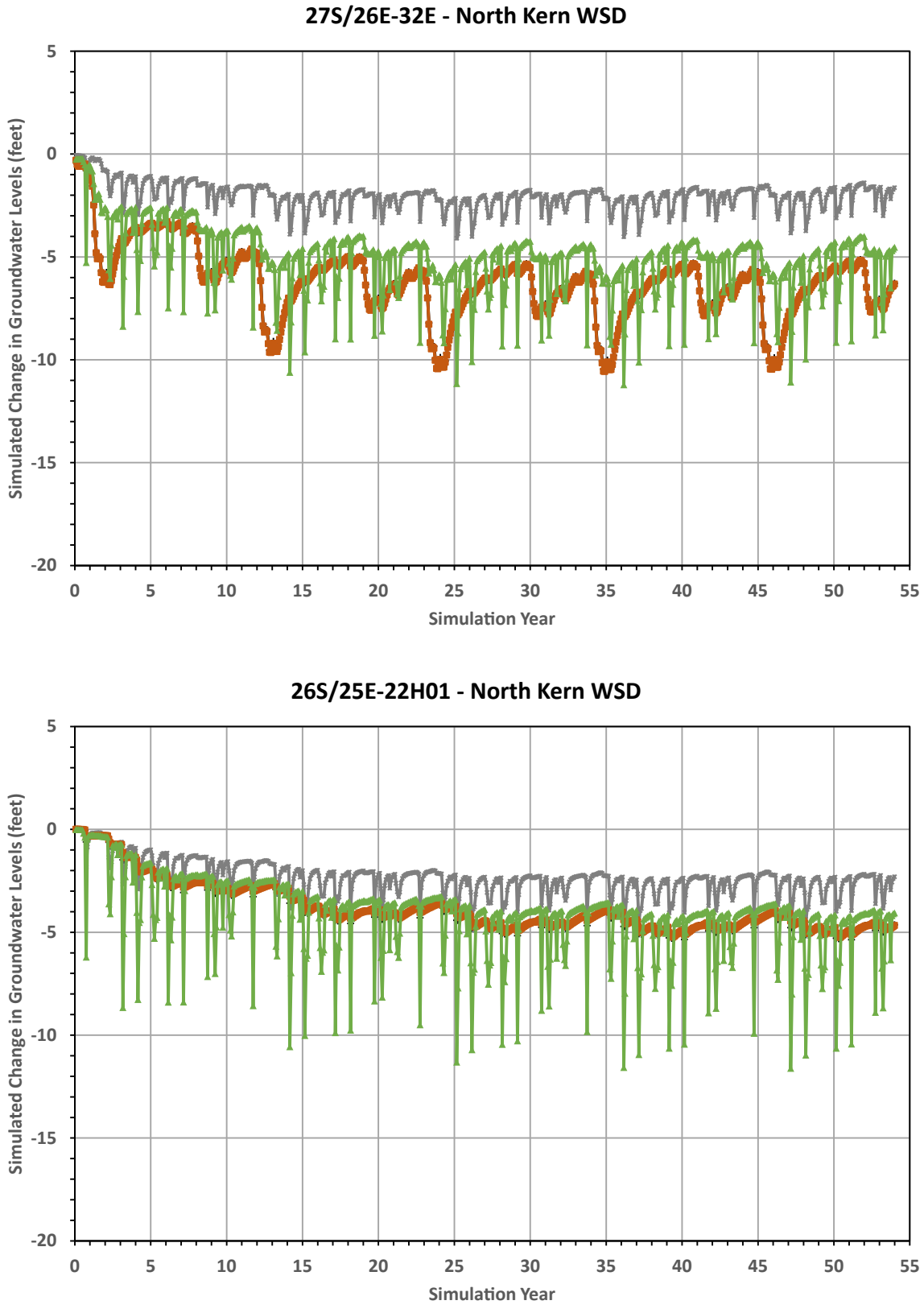
Figure 6-21a
Change Hydrographs
50-year Scenario B



October 2016

TODD GROUNDWATER

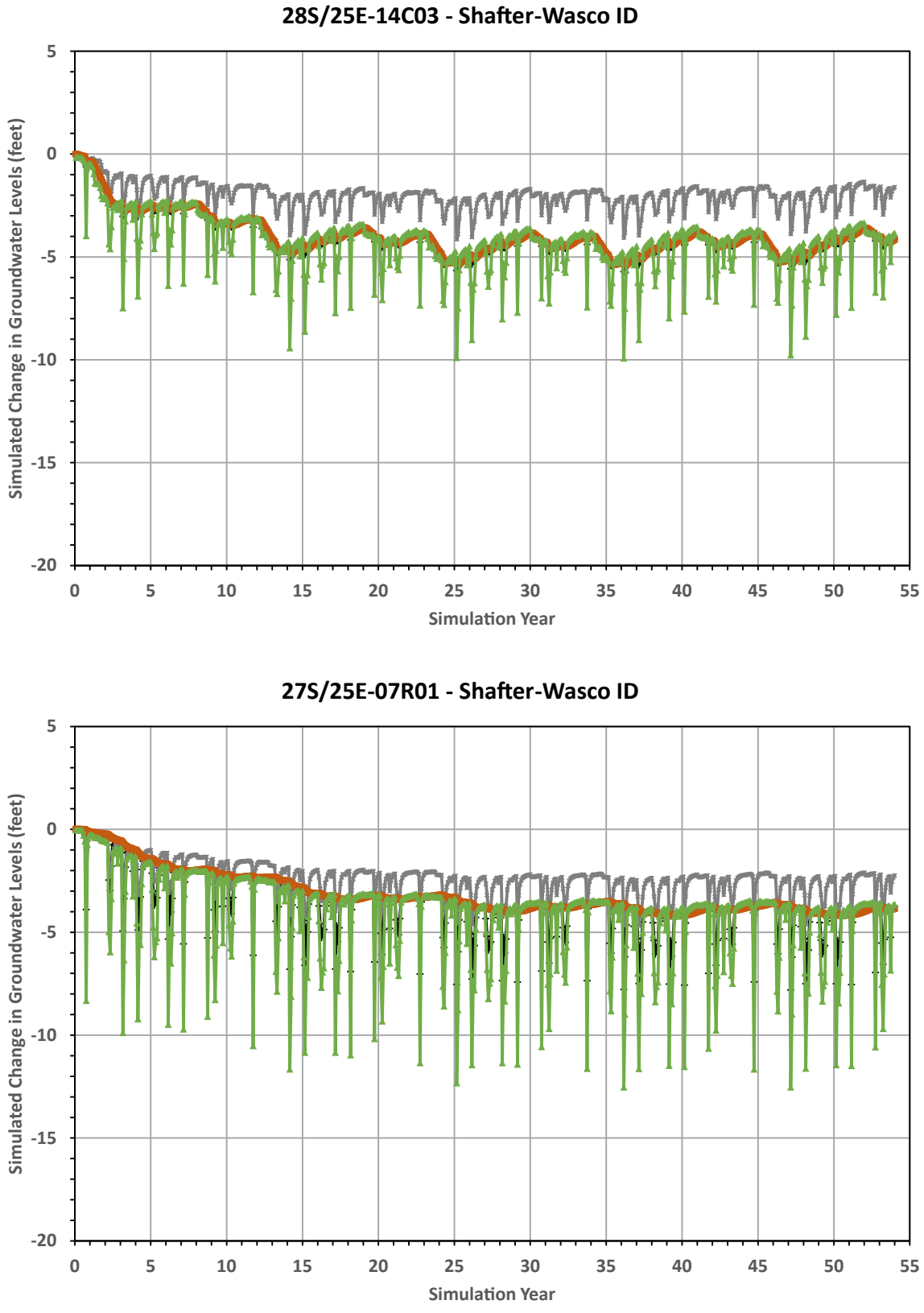
Figure 6-21b
Change Hydrographs
50-year Scenario B



October 2016

TODD GROUNDWATER

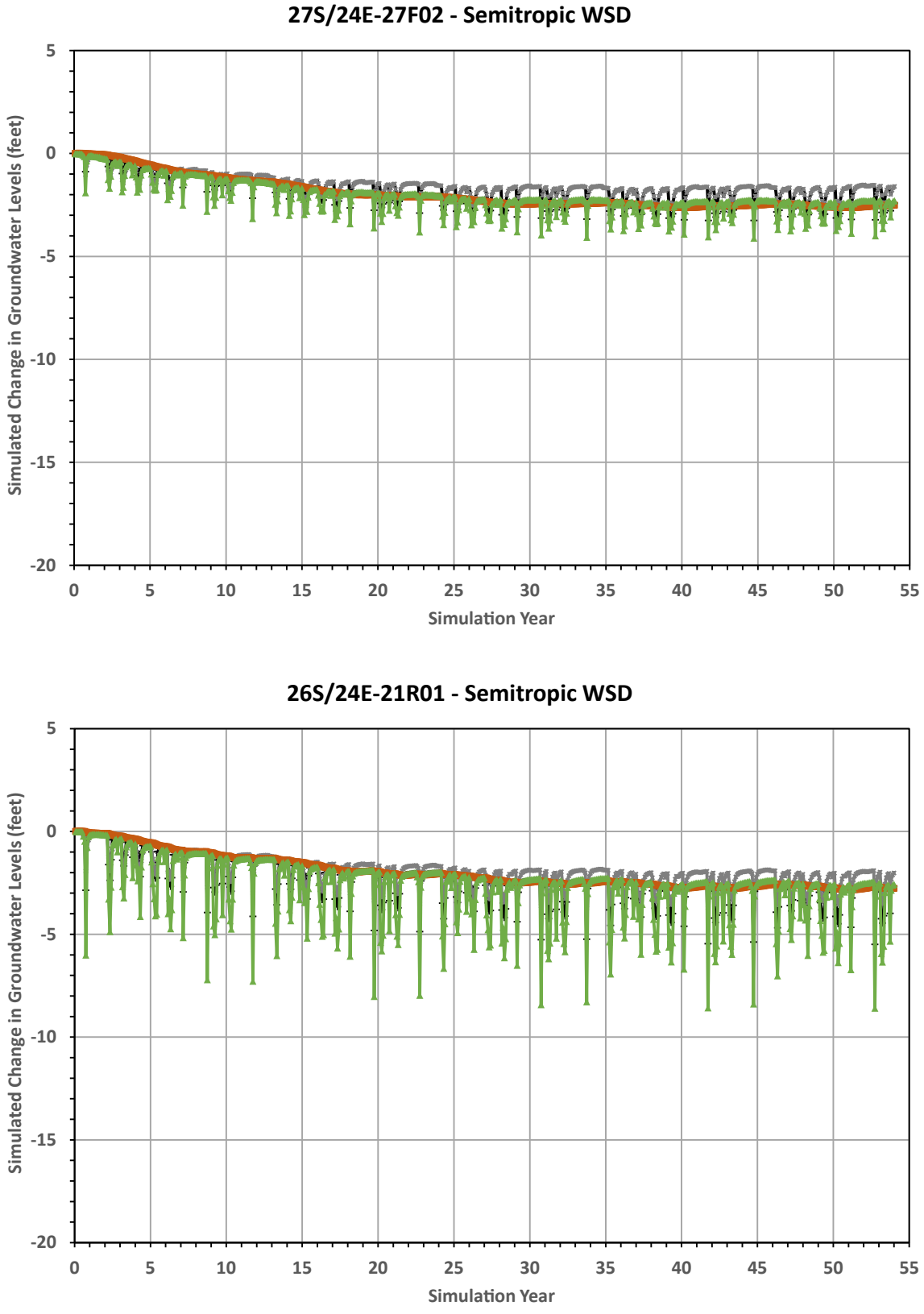
Figure 6-21c
Change Hydrographs
50-year Scenario B



October 2016

TODD GROUNDWATER

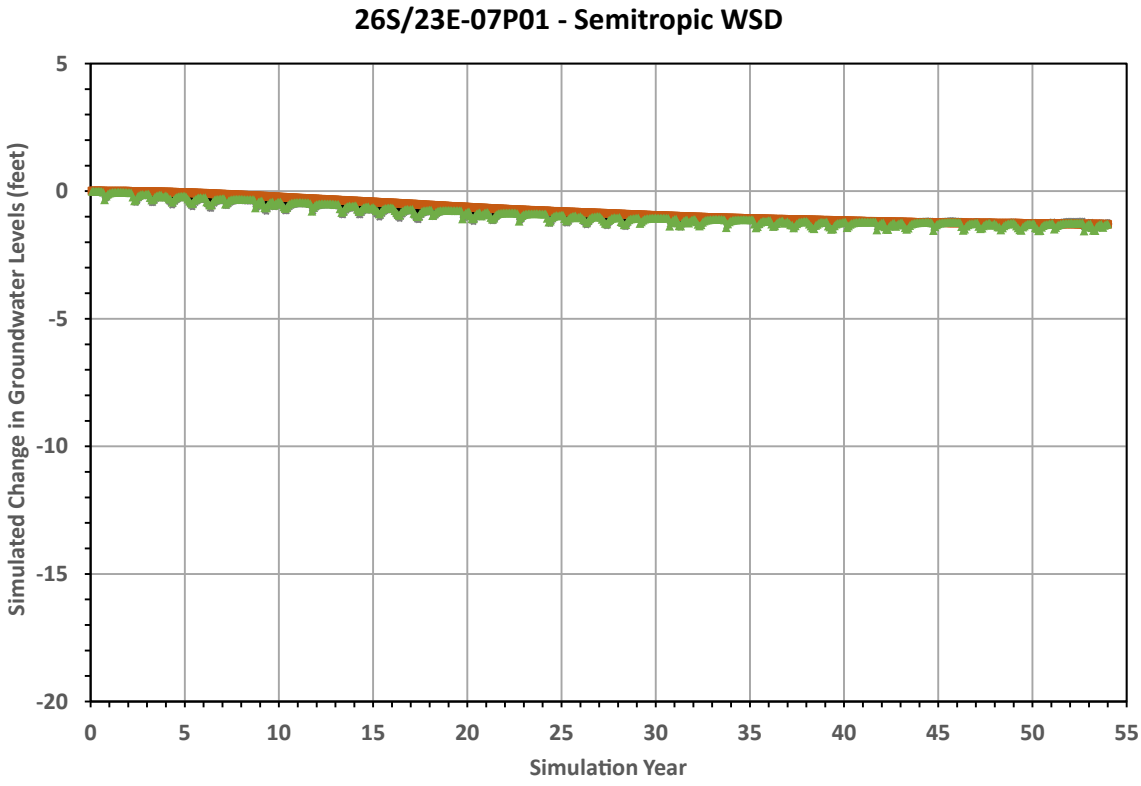
Figure 6-21d
Change Hydrographs
50-year Scenario B



October 2016

TODD GROUNDWATER

Figure 6-21e
Change Hydrographs
50-year Scenario B



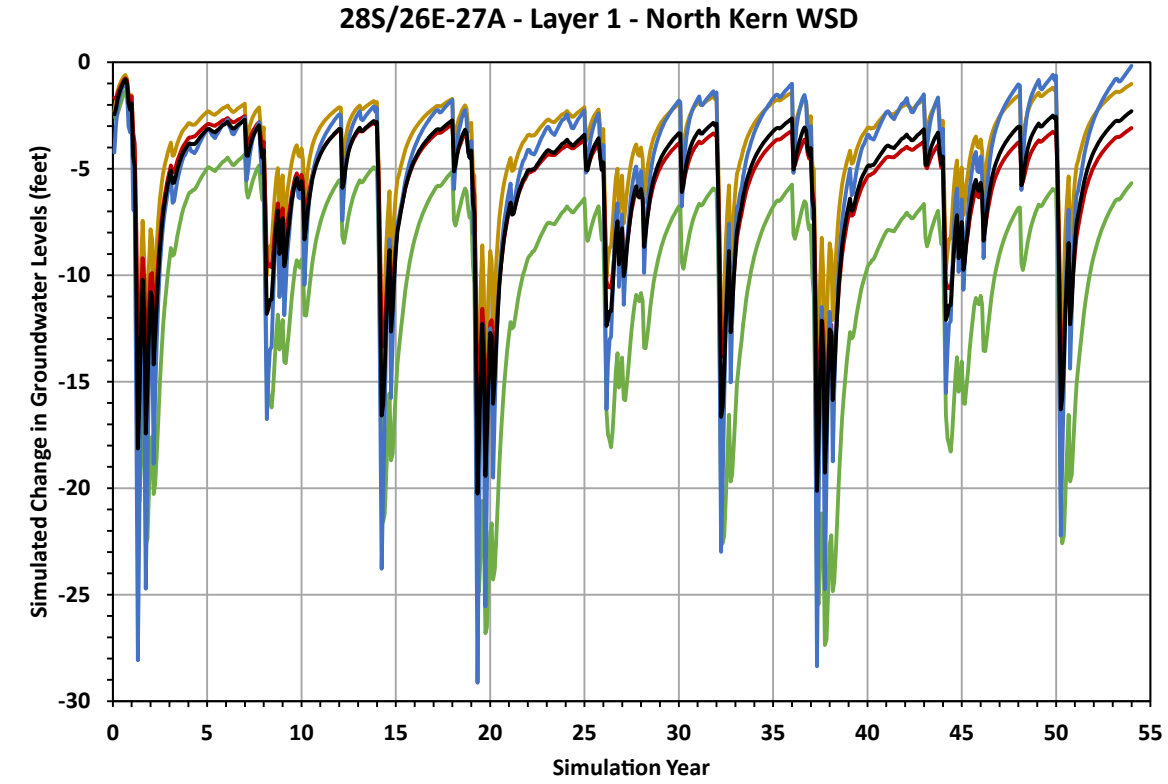
Legend

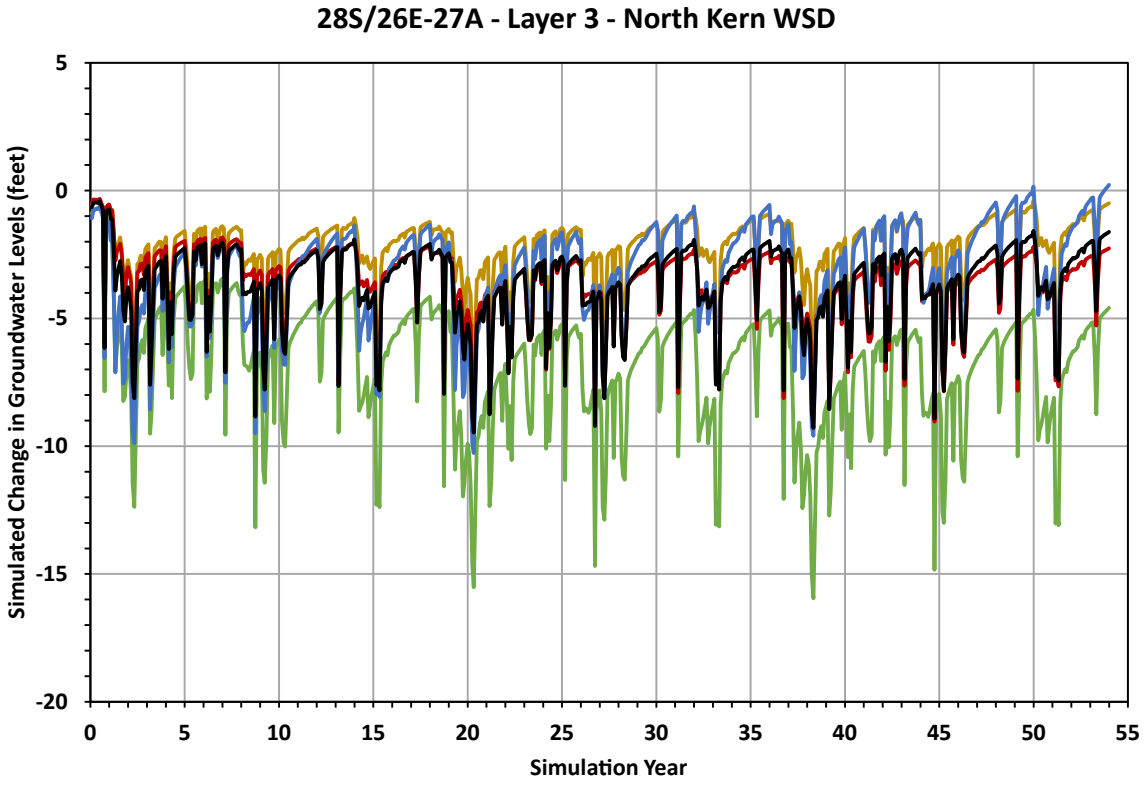
- Layer 1
- Layer 2
- Layer 3
- Layer 4

October 2016

TODD GROUNDWATER

Figure 6-21f
Change Hydrographs
50-year Scenario B





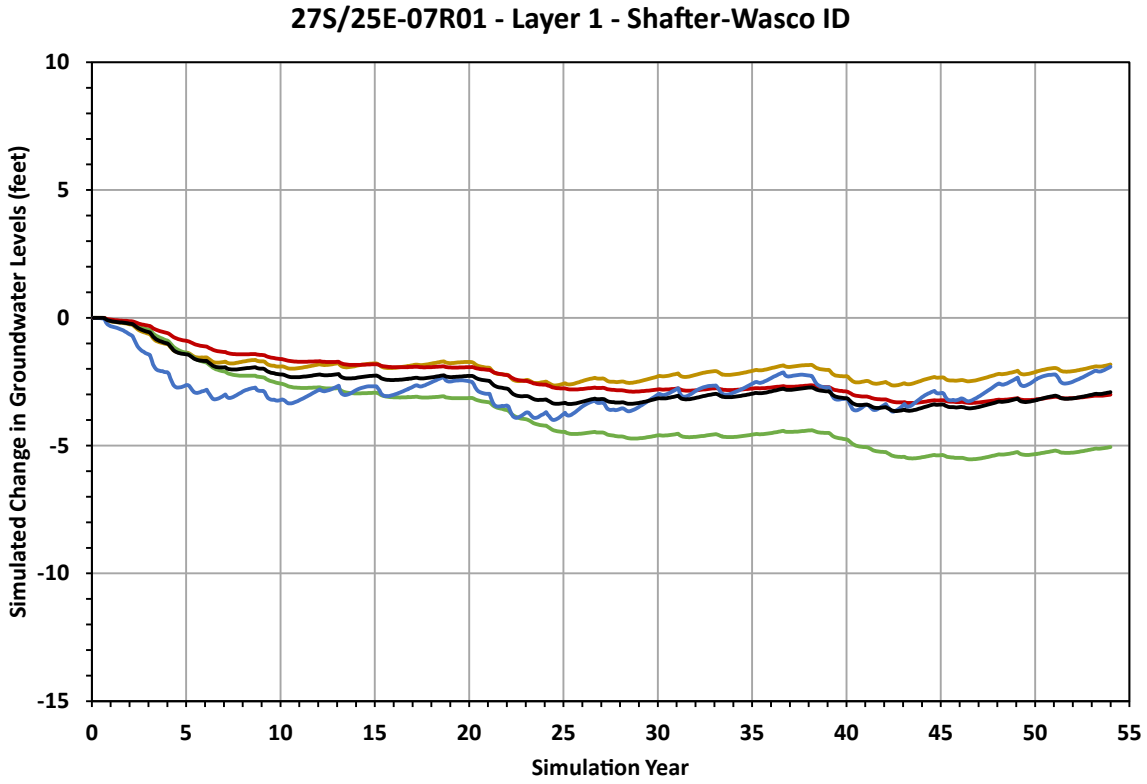
Legend

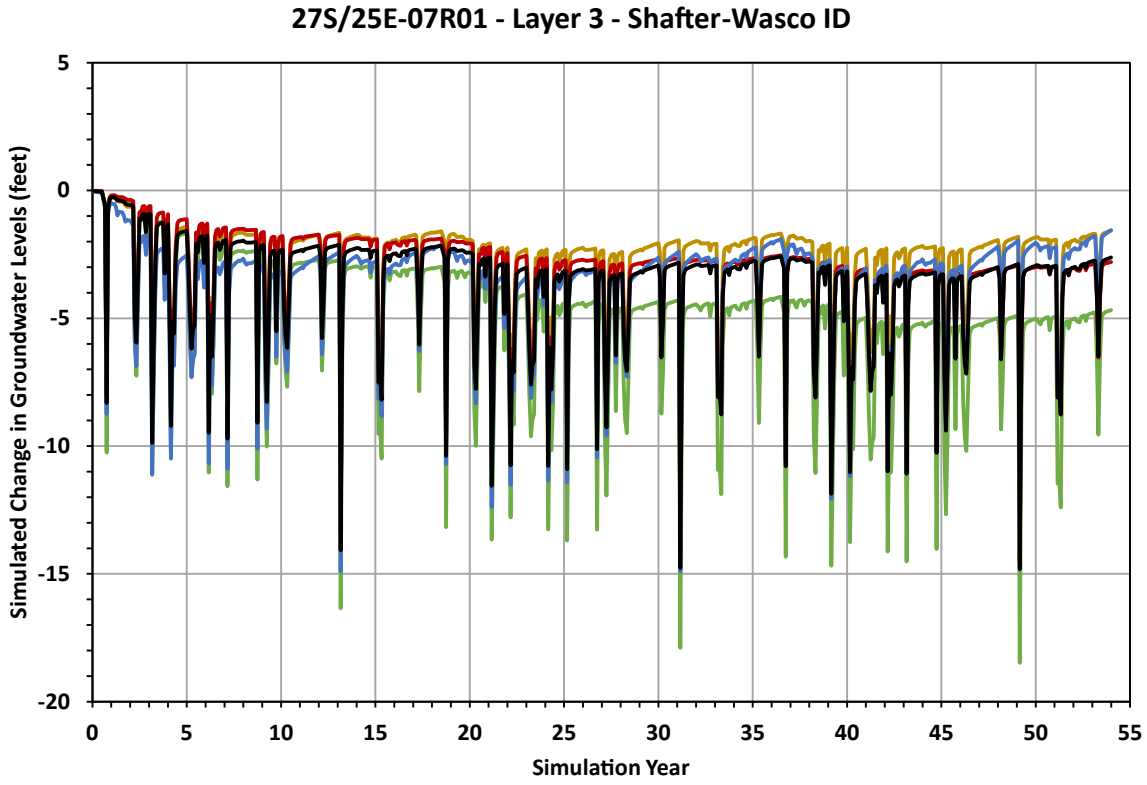
- Hydraulic conductivity (Kx) increased 50%
- Hydraulic conductivity (Kx) decreased 50%
- Storage properties (Kx) increased 50%
- Storage properties (Kx) decreased 50%
- Scenario A

October 2016

TODD GROUNDWATER

Figure 6-22a
Change Hydrographs
Sensitivity Analysis





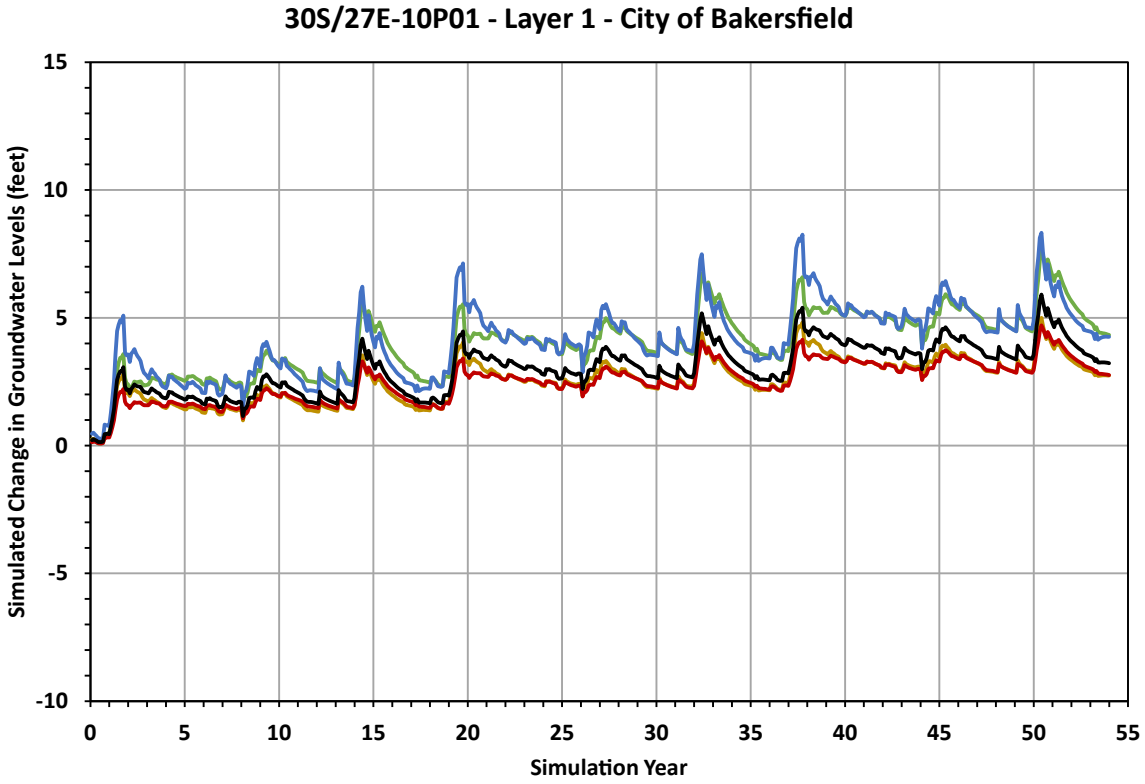
Legend

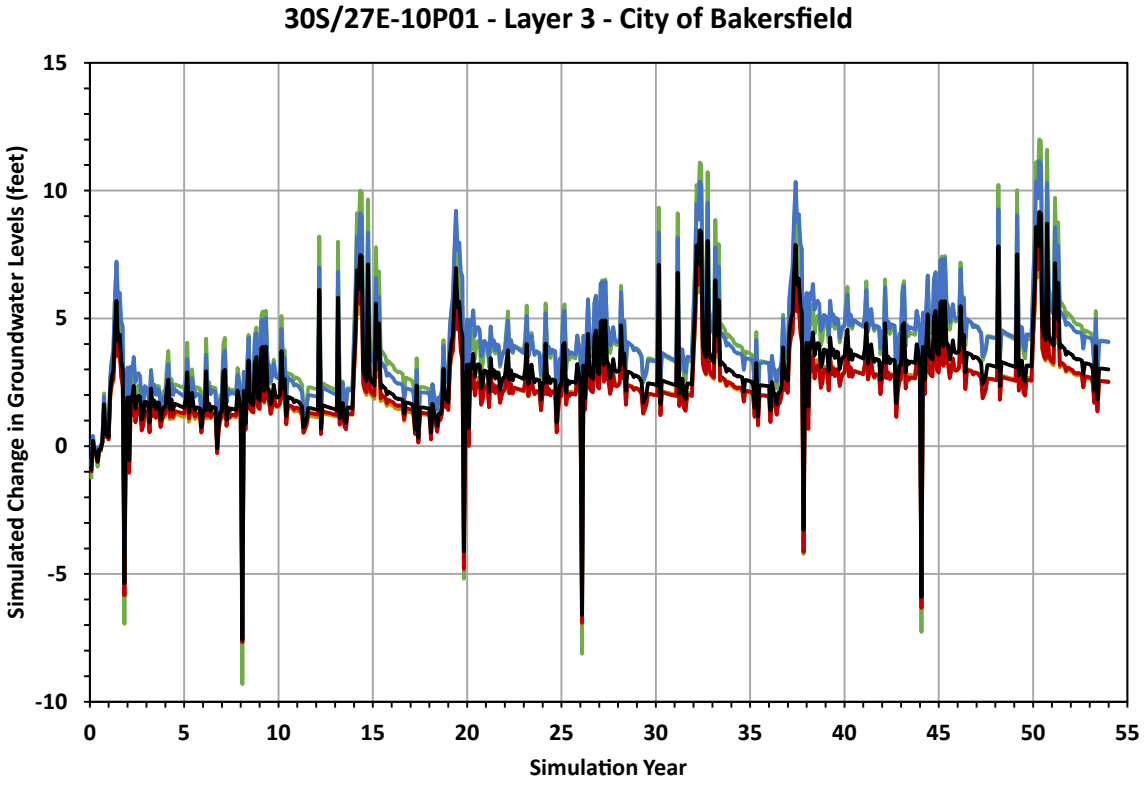
- Hydraulic conductivity (Kx) increased 50%
- Hydraulic conductivity (Kx) decreased 50%
- Storage properties (Kx) increased 50%
- Storage properties (Kx) decreased 50%
- Scenario A

October 2016

TODD GROUNDWATER

Figure 6-22b
Change Hydrographs
Sensitivity Analysis





Legend

- Hydraulic conductivity (Kx) increased 50%
- Hydraulic conductivity (Kx) decreased 50%
- Storage properties (Kx) increased 50%
- Storage properties (Kx) decreased 50%
- Scenario A

October 2016

TODD GROUNDWATER

Figure 6-22c
Change Hydrographs
Sensitivity Analysis

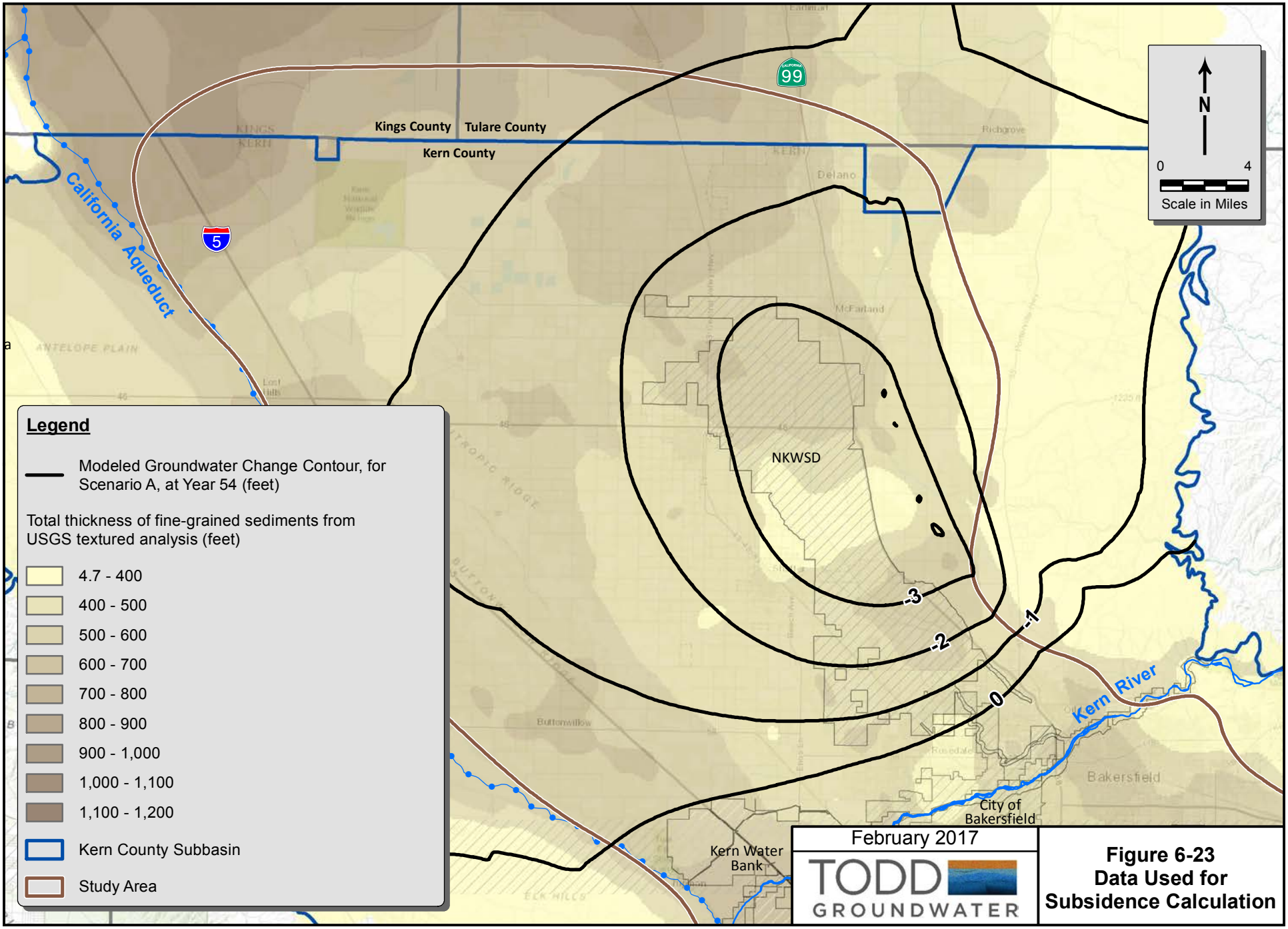
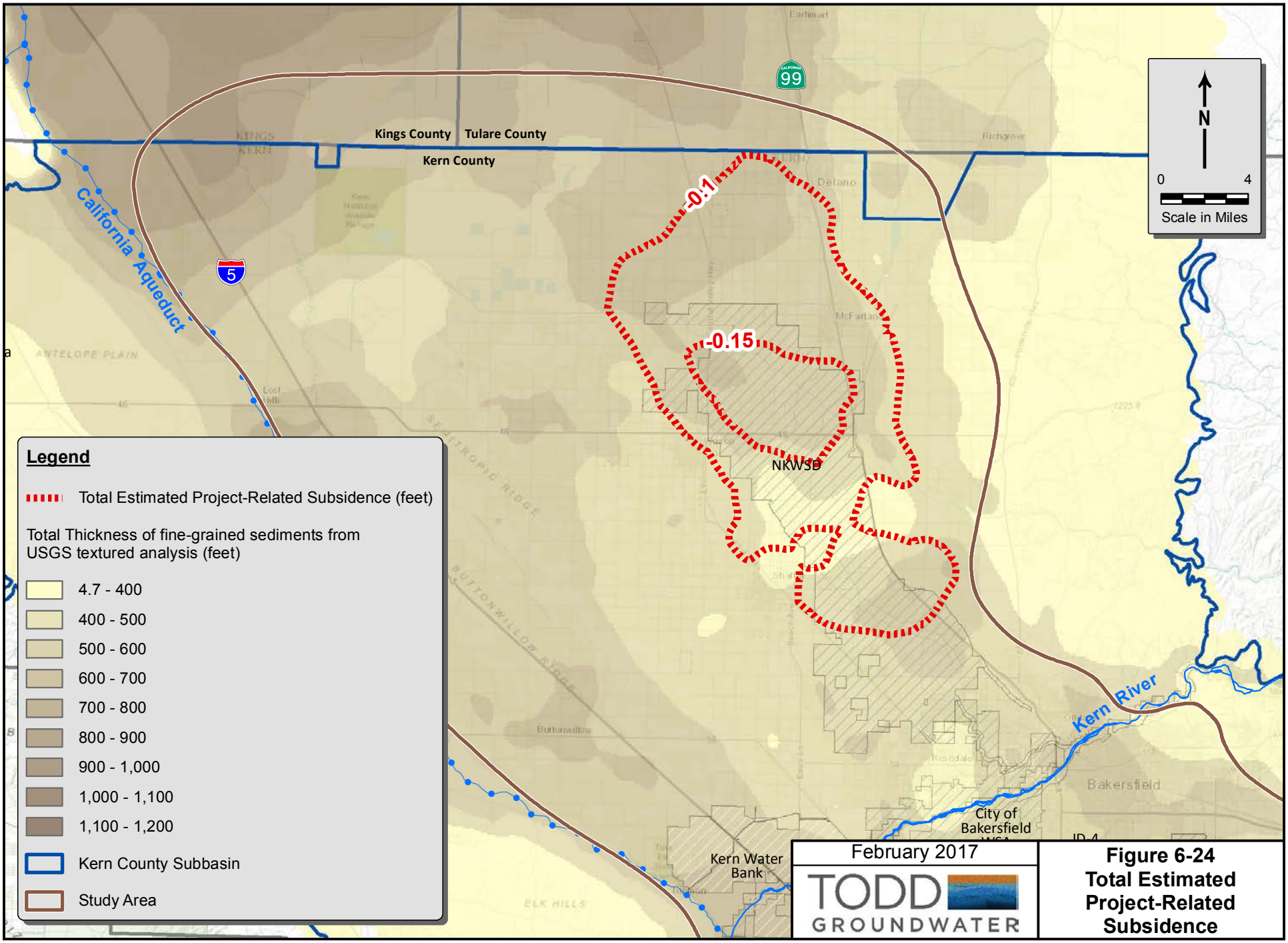


Figure 6-23
Data Used for Subsidence Calculation



February 2017

TODD GROUNDWATER

Figure 6-24
Total Estimated Project-Related Subsidence

APPENDIX A

KDWD Monthly Kern River Releases

1997-2014

Appendix A
KDWD Monthly Kern River Releases 1997-2014

Table A-1. Monthly KDWD Releases

Year	Jan Release	Feb Release	Mar Release	Apr Release	May Release	Jun Release	Jul Release	Aug Release	Sep Release	Oct Release	Nov Release	Dec Release	Total Release
1997	21,147	0	430	636	1,031	321	737	561	10,434	1,702	779	0	37,778
1998	6,950	7,694	12,394	17,597	15,204	7,181	8,505	5,913	11,868	6,099	1,385	0	100,790
1999	5,264	7,847	5,775	4,720	2,479	122	224	0	787	923	0	0	28,141
2000	60	11,372	5,696	1,236	127	272	0	0	517	2,023	253	0	21,556
2001	4,359	8,180	4,621	3,675	708	0	0	0	0	0	0	0	21,543
2002	1,526	3,566	5,510	3,550	3,228	0	601	0	0	0	1,890	0	19,871
2003	-561	7,396	4,030	4,967	2,433	0	0	0	1,695	495	0	0	20,455
2004	3,653	7,729	848	0	113	0	0	0	0	2,755	1,365	0	16,463
2005	14,898	8,312	2,586	2,859	5,637	1,077	319	0	8,191	4,159	0	0	48,038
2006	12,707	3,677	7,099	3,259	874	473	351	150	3,096	1,167	673	0	33,526
2007	1,366	5,580	3,173	3,258	1,924	0	0	0	0	66	0	0	15,367
2008	-1,643	98	126	850	640	420	0	0	0	-1,588	-272	-158	-1,527
2009	505	8,683	2,184	0	0	0	0	0	0	-1,456	-38	-156	9,722
2010	-492	11,545	2,688	0	357	948	635	0	0	-1,026	581	2,897	18,133
2011	17,022	10,570	12,450	13,062	8,187	372	0	-732	9,644	393	-835	-229	69,904
2012	-80	4,201	4,535	4,890	655	0	0	0	357	-343	-22	-219	13,974
2013	-1,531	135	161	172	0	0	0	604	0	-22	-6	-12	-499
2014	-287	148	1,900	3,812	1,644	0	0	0	0	0	-236	0	6,981
1997-2014 Avg	4,715	5,930	4,234	3,808	2,513	621	632	361	2,588	853	307	118	**26,679**
1997-2007 Avg	6,488	6,487	4,742	4,160	3,069	859	976	602	3,326	1,763	577	0	**33,048**
2008-2014 Avg	1,928	5,054	3,435	3,255	1,640	249	91	-18	1,429	-577	-118	303	16,670

Table A-2. Modified Monthly KDWD Releases*

Year	Jan Release	Feb Release	Mar Release	Apr Release	May Release	Jun Release	Jul Release	Aug Release	Sep Release	Oct Release	Nov Release	Dec Release	Total Release
1997	21,147	0	430	636	1,031	321	737	561	10,434	1,702	779	0	37,778
1998	6,950	7,694	12,394	17,597	15,204	7,181	8,505	5,913	11,868	6,099	1,385	0	100,790
1999	5,264	7,847	5,775	4,720	2,479	122	224	0	787	923	0	0	28,141
2000	60	11,372	5,696	1,236	127	272	0	0	517	2,023	253	0	21,556
2001	4,359	8,180	4,621	3,675	708	0	0	0	0	0	0	0	21,543
2002	1,526	3,566	5,510	3,550	3,228	0	601	0	0	0	1,890	0	19,871
2003	0	7,396	4,030	4,967	2,433	0	0	0	1,695	495	0	0	21,016
2004	3,653	7,729	848	0	113	0	0	0	0	2,755	1,365	0	16,463
2005	14,898	8,312	2,586	2,859	5,637	1,077	319	0	8,191	4,159	0	0	48,038
2006	12,707	3,677	7,099	3,259	874	473	351	150	3,096	1,167	673	0	33,526
2007	1,366	5,580	3,173	3,258	1,924	0	0	0	0	66	0	0	15,367
2008	0	98	126	850	640	420	0	0	0	0	0	0	2,134
2009	505	8,683	2,184	0	0	0	0	0	0	0	0	0	11,372
2010	0	11,545	2,688	0	357	948	635	0	0	0	581	2,897	19,651
2011	17,022	10,570	12,450	13,062	8,187	372	0	0	9,644	393	0	0	71,700
2012	0	4,201	4,535	4,890	655	0	0	0	357	0	0	0	14,638
2013	0	135	161	172	0	0	0	604	0	0	0	0	1,072
2014	0	148	1,900	3,812	1,644	0	0	0	0	0	0	0	7,504
1997-2014 Avg	4,970	5,930	4,234	3,808	2,513	621	632	402	2,588	1,099	385	161	**27,342**
1997-2007 Avg	6,539	6,487	4,742	4,160	3,069	859	976	602	3,326	1,763	577	0	**33,099**
2008-2014 Avg	2,504	5,054	3,435	3,255	1,640	249	91	86	1,429	56	83	414	18,296

Table A-1 summarizes KDWD releases based on monthly tabulations by water right (canal service area) in the annual Kern River Hydrographic Reports, with 1997-2007 values adjusted for court restrictions. Kern River water is allocated to First Point diverters on a daily basis according to each water right's legal and contractual rights and priorities. Any allocated water that is not needed or requested is subsequently released to other users starting with the next junior right holder. Consequently, KDWD service areas with junior rights can use water released from any senior water right, including senior water rights within KDWD, when available. Water released by a senior water right to a KDWD junior water right may result in a monthly negative release value. This occurs when the monthly sum of Kern River water used by all KDWD service areas is greater than the monthly sum of the service areas' entitlements. In other words, holders of KDWD junior rights were able to make use of water released by senior right holders.

Table A-2 modifies the negative numbers in **Table A-1** to zero to avoid confusion and to allow for a more conservative approach for estimating the impacts of the Project. Negative values were zeroed out in 23 separate months of the 216-month (18-year) Study Period, as shown by the shaded cells in **Table A-2**.

This modification changes the average amounts of release water (compare the bottom three rows of **Table A-1** to **Table A-2**). For the historical average Study Period of 1997-2007, the average release amount changes from 33,048 AFY to 33,099 AFY. We note that the judgment refers to 33,048 AFY on numerous occasions; that amount is equivalent to 33,099 AFY when negative release totals are removed.

APPENDIX B

KDWD Superposition Model Documentation

APPENDIX B
KDWD SUPERPOSITION MODEL DOCUMENTATION

The model analysis described in this report uses the principle of superposition for simulating impacts to groundwater as a result of the Proposed Project. The principle of superposition, as applied to a groundwater system, means that the result of multiple stresses on an aquifer system is equal to the sum of the results of the individual stresses. For a detailed discussion of the application of superposition to groundwater problems, the reader is referred to Reilly et al. (1987). This appendix provides additional documentation of the model setup and results to supplement the discussion in **Sections 5** and **6** of the report.

B.1 KDWD SUPERPOSITION MODEL SETUP

This appendix provides additional documentation on the adaptation of the USGS Central Valley Hydrologic Model (CVHM) for developing the KDWD Superposition Model to supplement the discussion presented in **Section 5.4** of the report.

B.1.1 Model Setup

The KDWD Superposition Model is derived from the CVHM, which covers the entire Central Valley. The CVHM was developed using the MODFLOW One-Water Hydrologic Flow Model (OWHM), which utilizes the MODFLOW-2005 Farm Process Package (FMP2) (Schmid and Hanson, 2009). The Superposition Model does not use FMP2, so the Superposition Model is setup to run in MODFLOW 2005 with the Groundwater Vistas version 6 MODFLOW interface. Length units used in the KDWD Superposition Model were converted from meters, used in the CVHM, to feet for convenience of analysis.

B.1.2 Model Domain

The CVHM (Faunt, 2009) simulates groundwater flow over the entire Central Valley. For the KDWD Superposition Model, the model domain needed to cover the Study Area and sufficient areas beyond the Study Area so that boundary effects did not influence simulation results. For the western, southern and eastern boundaries of the KDWD Superposition Model, the model domain could be extended to the natural boundary of the Central Valley Aquifer that represents the transition from the alluvial sediments in the Central Valley to the bedrock units of the surrounding Coast Range, Tehachapi Mountains and Sierra Nevada. Using the natural boundaries is preferable because the model can simulate the natural boundary effects associated with the margin of the groundwater basin.

To the north and northwest, the CVHM extends hundreds of miles beyond the Study Area. To reduce the computational overhead of simulating areas unnecessary for this analysis, a standard modeling technique was applied for defining a constant head boundary at a distance sufficiently distant from the Study Area so that the constant head boundary would not influence groundwater simulations in the Study Area. Using the MODFLOW processor Groundwater Vistas (Version 6) (ESI 2011), the Telescopic Mesh Refinement (TMR) feature was used to setup a more refined model within a subregion of the larger-scale model.

Using the TMR process, the model grid spacing was changed from 5,280 feet to 1,320 feet. This results in a 16-fold increase in grid spacing over CVHM, with each model cell 40 acres in size. This grid spacing

increases the resolution for assessing drawdown and mounding during the KDWD Superposition Model simulations.

To determine the extent of the KDWD Superposition Model domain, preliminary simulations were conducted using CVHM. For these preliminary simulations, the general water balance for the Proposed Project was applied in the appropriate areas of NKWSD, City of Bakersfield and KDWD. The extent of the change in groundwater levels was evaluated after simulating the first 10 years of the Study Period. Based on these simulations, the northern boundary was selected at a sufficient distance from the Study Area where the simulated changes in groundwater levels were below 0.1 feet. In most cases, the simulated changes in groundwater levels along the proposed northern boundary of the KDWD Superposition Model were less than 0.01 feet.

Based on this preliminary evaluation, the northern boundary of the KDWD Superposition Model was selected as shown on **Figure B-1**.

B.1.3 Model Layering

The CVHM characterizes the Central Valley utilizing ten model layers. For the Superposition Model, these ten layers were grouped together to form four model layers to simplify the analysis and presentation of results.

- Superposition Model Layer 1 groups together CVHM model layers 1, 2 and 3 to simulate the Shallow Aquifer above the local regional confining layers in Kern County.
- Superposition Model Layer 2 groups together CVHM model layers 4 and 5 to simulate an interval with increased clay layers, including E-clay member of the Tulare Formation, the 300-foot clay, or the local equivalent, that locally can form an aquitard limiting vertical flow.
- Superposition Model Layer 3 groups together CVHM model layers 6 and 7 to simulate the main production zone for the Deep Aquifer in Kern County.
- Superposition Model Layer 4 groups together CVHM model layers 8, 9 and 10 to simulate the lower portions of the Deep Aquifer in Kern County that is generally below the primary production zone.

Following the process outlined by Reilly et al. (1987), the top surface of the superposition model was set as the top of the water table. The upper surface of the KDWD Superposition Model was defined as the water table prior to January 1997. The CVHM simulation results for December 1996 groundwater elevations were used to define the top of KDWD Model Layer 1. Areas along the margin of the groundwater basin where the 1997 water table was below the bottom of a superposition model layer were considered to be unsaturated and were converted to No Flow cells in the KDWD Superposition Model. The outlines of the active model areas for KDWD Model Layers 1, 2, 3 and 4 are shown on **Figures B-2**, **B-3**, **B-4** and **B-5**.

Also following the process outlined by Reilly et al. (1987), the top surface of the KDWD Superposition Model was set to have a zero groundwater elevation. Therefore, the bottom elevations of the KDWD Superposition Model layers represent the saturated aquifer thicknesses as of December 1996. A spreadsheet process was used to calculate the depth of the appropriate CVHM model layer elevation below the upper surface of the KDWD Superposition Model. The bottom elevations of the KDWD model layers are shown on **Figures B-6**, **B-7**, **B-8** and **B-9**.

B.1.4 Boundary Conditions

For the conversion of CVHM to the KDWD Superposition Model, "background" boundary conditions (i.e., inflows and outflows not associated with the Proposed Project) were removed (as per Reilly et al., 1987). This step is consistent with the principle of superposition in that the result of multiple stresses on an aquifer system is equal to the sum of the results of the individual stresses. Therefore, the boundary conditions for recharge, evapotranspiration, pumping wells, and farm processes present in the CVHM were not included in the KDWD Superposition Model since these parameters do not change as a result of the Proposed Project.

Streams were simulated using the Streamflow Routing (SFR) Package in CVHM. In the KDWD Superposition Model domain, the CVHM simulated the Kern, White and Tule rivers. These rivers are generally situated above the top of the groundwater surface except at their westernmost extent; however, these rivers typically are not flowing across the valley. Therefore, the rivers were converted to the MODFLOW drain package. The drain package allows groundwater to exit from the aquifer to the streambed, but does not allow for induced recharge from the streams to the aquifer. This is considered a realistic representation of actual river conditions across the valley and provides a conservative assessment of impacts to groundwater elevations. Following the process outlined by Reilly et al. (1987), the elevations of the drain package were modified to represent the vertical distance between the bottom of the riverbed and the top of the KDWD Superposition Model. The rivers are simulated in KDWD Model Layer 1 and their locations are shown in **Figure B-2**.

Boundary conditions representing faults in the CVHM were remapped onto the finer grid of the KDWD Superposition Model. The same aquifer properties were used to define the fault flow properties. The faults are represented in all four model layers as show on **Figures B-2**, **B-3**, **B-4**, and **B-5**.

As noted above, a constant head boundary was placed at the northern boundary of the KDWD Superposition Model to simulate interactions of subsurface groundwater flow in the Central Valley outside of the KDWD Superposition Model. The constant head boundaries are represented in all four model layers as show on **Figures B-2**, **B-3**, **B-4**, and **B-5**.

B.1.5 Aquifer Properties

For the KDWD Superposition Model, the aquifer properties of hydraulic conductivity and aquifer storage are derived directly from the CVHM. A key part of using CVHM is to take advantage of the USGS Sediment Texture Analysis (Faunt, Hanson and Belitz, 2009) used to develop the spatial distribution of aquifer properties from a comprehensive analysis of geologic data from well logs. The final aquifer properties used for the CVHM were extracted and applied to the Superposition Model in a manner to preserve the hydraulic characteristics. These aquifer properties include:

- Horizontal Hydraulic Conductivity (K_h)
- Vertical Hydraulic Conductivity (K_z)
- Specific Yield (S_y)
- Specific Storage (S_s)

To correlate the aquifer properties from multiple CVHM model layers to the KDWD model layers, standard techniques were applied for calculating aquifer properties in layered aquifer systems. For

determining the equivalent K_h for a layered aquifer, a weighted average based on layer thickness was applied (Todd and Mays, 2004; Bear and Verruijt, 1987, Freeze and Cherry, 1979; Bouwer, 1978) using the following equation:

$$K_h = \sum \frac{K_i \, d_i}{d} \qquad (B1)$$

where K_h = horizontal hydraulic conductivity of the multilayer system
K_i = horizontal hydraulic conductivity of an individual layer within the multilayer system
d_i = thickness of an individual layer within the multilayer system
d = thickness of the entire multilayer system.

Equation B1 states that the K_h of the multilayer system is equal to the sum of the product of the K_h times the percentage thickness of the layer to the total thickness of the multilayer system. In other words, the contribution of each layer to the composite K_h is the proportional to its thickness relative to the total thickness. This same process can also be used for calculating the composite values for the storage properties of S_y and S_s.

K_z requires use of a different equation. For determining the equivalent K_z for a layered aquifer, a harmonic mean is applied (Todd and Mays, 2004; Bear and Verruijt, 1987, Freeze and Cherry, 1979; Bouwer, 1978) using the following equation:

$$K_z = \frac{d}{\sum {d_i}/{K_i}} \qquad (B2)$$

where K_z = vertical hydraulic conductivity of the multilayer system
K_i = vertical hydraulic conductivity of an individual layer within the multilayer system
d_i = thickness of an individual layer within the multilayer system
d = thickness of the entire multilayer system.

For the vertical groundwater flow, Equation B2 calculates K_z as the total thickness of the multilayer system divided by the summation of the layer thickness divided by the K_i of the individual layer. In this manner, the K_z calculated by Equation B2 is controlled by the most resistive layer to groundwater flow. In physical terms, a single continuous clay layer can strongly limit vertical groundwater flow and form a confining layer. Therefore, a single clay layer has a strong influence on determining the K_z. A high K_z would require a continuous vertical sequence of permeable sediments without intervening clay layers.

In CVHM, the aquifer properties from the USGS Sediment Texture Analysis were input into the MODFLOW Layer Property Flow Package and then modified using the MODFLOW Multiplier File, which applies multiplier arrays to modify aquifer properties during calibration. Therefore, the final aquifer properties were derived from the output files rather than the input files. The final distribution of the CVHM aquifer properties applied to the KDWD model layers is shown as follows:

- **Figures B-10**, **B-11**, **B-12**, and **B-13** show the distribution of horizontal hydraulic conductivity (K_h) for KDWD Model Layers 1, 2, 3 and 4, respectively.
- **Figures B-14**, **B-15**, **B-16** and **B-17** show the distribution of vertical hydraulic conductivity (K_z) for KDWD Model Layers 1, 2, 3 and 4, respectively.
- **Figure B-18** shows the distribution of Specific Yield (S_y) for KDWD Model Layer 1.

- **Figures B-19**, **B-20**, **B-21** and **B-22** show the distribution of Specific Storage (S_s) for KDWD Model Layers 1, 2, 3 and 4, respectively.

B.1.6 Proposed Project Input Data

The KDWD Superposition Model is the primary tool for the quantitative impacts analysis of groundwater levels. The methodology used for the modeling is discussed in **Section 5** of the report. The model was used to evaluate groundwater impacts using different conditions based on the study periods discussed in **Section 1.4** of the report. In summary:

- *The Average Hydrologic Conditions Study Period (1997-2007)* was the Study Period used for the 2011 Impacts Assessment with an annual average release water of 33,048 AFY to be used by KDWD as part of the Proposed Project. During this period, the Annual River Index was 100 percent of the long-term average, so this period is representative of average hydrologic conditions.
- *The Combined Study Period (1997-2014)* extends the analysis of the release water through 2014 to include current hydrologic conditions of water availability and use on the Kern River. This period has an annual average release water of 26,679 AFY to be used by KDWD as part of the Proposed Project. During this period, the Annual River Index was 92 percent of the long-term average. This period includes the effects of the recent drought on hydrologic conditions.

Table B-1 provides a monthly summary of the KDWD Superposition Model input for the Combined Study Period. These are the data that were input into the KDWD Superposition Model following the procedures outlined in **Section 5.5** of the report. Subtotals for each category are provided for the 1997 to 2007 and 1997 to 2014 Study Periods, and the annual averages match the annual averages for the same categories on **Tables 5**, **6**, and **8** in the report to demonstrate that the Proposed Project was input into the KDWD Superposition Model as described. For the 50-year groundwater scenarios, these sequences were repeated as noted. The locations where groundwater pumping was applied in the KDWD Superposition Model are shown on **Figures B-23** and **B-24** for KDWD Model Layers 1 and 3, respectively.

B.2 Proposed Project Scenario Water Balance Summary

The results of the KDWD Superposition Model for determining groundwater impacts as a result of the Proposed Project are discussed in **Sections 6.1** through **6.6** of the report. This appendix provides additional documentation of the model scenario results. The following provides a summary of the tables provided.

B.2.1 Baseline Scenario

The Baseline Scenario simulates change in groundwater levels by applying the Proposed Project over the Combined Study Period of 1997 through 2014. The results of the Baseline Scenario were evaluated by superimposing the model results onto the historical groundwater elevation data across the Study Area to assess the impacts as if the Proposed Project had been initiated in 1997. The analysis includes an assessment specifically of the 1997-2007 period to be in compliance with the 2014 Order, which specifically references the average annual release water amount of 33,048 AFY.

Tables B-2 and **B-3** provide a year-by-year summary of the MODFLOW-derived water balance results for the Baseline Scenario for the Southern and Northern Study Areas, respectively. The Northern Study Area includes the Kern River and portions of the Study Area north of the Kern River. The Southern Study Area includes the areas south of, but not including, the Kern River. The Kern River was selected as a common reference location; however, locations of reductions and additions of release water due to the Proposed Project straddle the Kern River, so there are some reductions in the Southern Study Area and additions in the Northern Study Area.

The results shown in **Tables B-2** and **B-3** are model-based output. MODFLOW summarizes the water balance in terms of how the data were input into MODFLOW for the Basins & Canals and Wells categories using the Well and Recharge Packages. In the case of the City of Bakersfield municipal wells and the Pioneer Spreading Grounds, these locations were assigned both reductions and additions in volume due to the Proposed Project. Since these reductions and additions were assigned to the same boundary conditions in the KDWD Superposition Model, the model output provides the net of the combined change for these boundary conditions. As a result, the totals vary from the input shown in **Table B-1**. To verify that the Proposed Project is accurately reflected, the sum of the Basins & Canals and Wells categories in **Tables B-2** and **B-3** for the Southern and Northern Study Areas is equal to the average *Release Water Lost to Intertie* shown on **Table 4**.

The Streams and Exchange categories shown on **Tables B-2** and **B-3** are model-derived components. The Exchange category is the net volume of subsurface flow into or out of the Study Area from adjacent areas. The Streams category reflects outflows to the MODFLOW drain package due to changes in groundwater levels; although there are no such flows, the category is included for documentation.

B.2.2 Scenario A

Scenario A projects the Average Hydrologic Conditions (1997-2007) over 50 years to evaluate the cumulative changes in groundwater conditions resulting from the Proposed Project calculated after 10, 25, and 50 years following the end of the Study Period. This assessment incorporates the period analyzed in the 2011 Impacts Assessment (1997-2007) to represent average hydrologic conditions.

Tables B-4 and **B-5** provide a year-by-year summary of the MODFLOW-derived water balance results for Scenario A for the Southern and Northern Study Areas, respectively.

B.2.3 Scenario B

Scenario B projects the Combined Study Period (1997-2014) over 50 years to evaluate the cumulative changes in groundwater conditions resulting from the Proposed Project calculated after 10, 25, and 50 years following the end of the Study Period. The inclusion of 2008-2014 allows dry years from the recent drought and current water use on the Kern River to be incorporated into the assessment.

Tables B-6 and **B-7** provide a year-by-year summary of the MODFLOW-derived water balance results for Scenario B for the Southern and Northern Study Areas, respectively.

B.3 SPATIAL ANALYSIS OF GROUNDWATER LEVELS

In order to provide a quantitative assessment of the Project-related changes in groundwater levels on a water-district-wide basis, spatial averages were calculated for specific water districts. The spatial

average provides another appropriate and reasonable method to assess the groundwater impacts over the Study Area.

To calculate the spatial average, the cumulative changes in groundwater levels are averaged for all grid cells located within a water district service area at a specified time interval. Model Layer 3 is used in this process because this is the primary aquifer for groundwater pumping in the northern Study Area and would represent impacts to pumping wells.

Tables B-8 provides a monthly summary of the spatial averaging of groundwater level change for eleven different areas based on simulation results for Scenario A. **Table B-9** provides annual summary statistics for the spatial average for KDWD, City of Bakersfield WSA, NKWSD, SWID, and SWSD.

B.4 GROUNDWATER IN STORAGE ANALYSIS

The KDWD Superposition Model calculates the monthly change in groundwater in storage over the simulation period. Since superposition models simulate change, a positive groundwater in storage change represents either a net increase in inflow or a net decrease in outflow, whereas a negative groundwater in storage change represents the opposite conditions.

To evaluate how the change to groundwater in storage varies over time, a moving average analysis was performed for Scenarios A and B. The moving average was calculated over one scenario-based hydrologic cycle to filter out year-to-year effects. For Scenario A, the moving average is calculated over an 18-year cycle, whereas for Scenario B, it is over an 11-year cycle. **Tables B4, B5, B6 and B7** provide the results of the moving average analysis to groundwater in storage. **Figure B-25** illustrates the change in storage over time in the Northern Study Area for both Scenarios A and B.

In the Northern Study Area, the simulation results indicate that initially the change of groundwater in storage exhibits a large decline for both scenarios. However, as the simulation progresses, the moving average becomes less until it eventually switches to exhibit an increase to groundwater in storage over the remainder of the scenario. The moving average results show that the first period to exhibit an increase of groundwater in storage is the moving average over the following time periods:

- For Scenario A, simulation years 33 to 50.
- For Scenario B, simulation years 35 to 45.

The decline in the rate of storage is compensated by an increase in subsurface flows primarily from the Southern Study Area (**Tables B4, B5, B6 and B7**). Because of the Project, there is increased recharge south of the river and increased groundwater use north of the river that results in increased groundwater flow from south to north. Due to the increased groundwater flow, the loss to groundwater in storage in the Northern Study Area decreases over time as subsurface groundwater flow, primarily from the Southern Study Area, increases. By the end of 50 years, the moving average of the change in groundwater in storage begins to show a slight increase (**Figure B-25**).

The moving average analysis provides a means to approximate the long-term equilibration of groundwater conditions where, based on modeling results, there would be no further long-term declines to groundwater in storage in the Northern Study Area; however, the cumulative loss of storage from the earlier time periods would remain. Because equilibration occurs over an extended period, the

approximate time to reach long-term equilibration is conservatively assumed as the last year of the above listed time periods for Scenario A (50 years) and Scenario B (45 years).

B.5 VALIDATION SCENARIO SUMMARY

As described in **Section 5.6** of the report, a Validation Scenario was constructed to test the ability of the KDWD Superposition Model. This Validation Scenario tested the model's ability to simulate groundwater level changes resulting from recharge operations at the Kern Water Bank and other Kern Fan banking projects from 1993 to 1998 – a time period of significant recharge and changes in groundwater levels. Detailed public records of the volume of groundwater recharged are available for the various groundwater banking operations in and around the Kern Water Bank (see **Figure 5-6** of the report). Unpublished groundwater banking data used for the Validation Scenario were provided directly by Kern County Water Agency, Kern Water Bank Authority and neighboring agencies for the following facilities:

- Kern Water Bank
- Pioneer Project
- COB 2800 Project
- Rosedale-Rio Bravo recharge facilities
- Buena Vista Water Storage District recharge facilities
- Berrenda Mesa
- Kern River channel recharge.

Table B-10 provides the monthly recharge data for each of the recharge facilities input into the KDWD Superposition Model for the Validation Scenario. **Table B-11** provides a year-by-year summary of the MODFLOW-derived water balance results for the Validation Scenario in the Study Area.

Table B-1 - Monthly Proposed Project Input Data for KDWD Superposition Model (in acre-feet per month)

		North Kern WSD					City of Bakersfield WSA				Kern Delta WD						
Month	Year	Spreading	Canal Losses - Spreading	Irrigation Pumping	Canal Losses - Irrigation	Other	KDWD	Kern Water Bank	Other Spreading	Other	Irrigation Reduction	COB Pumping	Recharge Basins	Canal Recharge	Pioneer Basin	Other	Water Not Used by NKWSD or City
Jan	1997	-3,756	0	0	0	0	-24	-4,250	-8,772	-4,345	1,202	3,491	8,700	4,000	750	3,004	0
Feb	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	1997	-67	0	0	0	0	-34	0	0	-244	430	0	0	0	0	0	-85
Apr	1997	-104	0	0	0	0	-54	0	0	-318	636	0	0	0	0	0	-160
May	1997	-123	0	0	0	0	-81	0	0	-518	1,031	0	0	0	0	0	-309
Jun	1997	0	0	0	0	0	-64	0	0	-168	321	0	0	0	0	0	-89
Jul	1997	-10	-1	-187	0	0	-163	0	0	-188	737	0	0	0	0	0	-188
Aug	1997	0	0	-379	0	0	-119	0	0	0	561	0	0	0	0	0	-63
Sep	1997	0	0	-4,709	-942	-1,767	-24	0	0	-220	2,162	971	5,001	2,300	0	0	-2,772
Oct	1997	-1,517	-113	0	0	0	-10	0	0	-62	1,646	37	13	6	0	0	0
Nov	1997	-764	0	0	0	0	-12	0	0	-3	659	80	27	13	0	0	0
Dec	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	1998	-4,322	0	0	0	0	0	-2,628	0	0	1,037	971	3,385	1,557	0	0	0
Feb	1998	-1,370	0	0	0	0	0	-5,385	0	0	1,356	971	3,676	1,691	0	0	-939
Mar	1998	-10,696	0	0	0	0	-4	-1,007	0	0	2,059	971	6,414	2,950	0	0	-687
Apr	1998	-13,398	0	0	0	0	0	-437	-644	0	1,446	1,594	8,700	4,000	750	1,107	0
May	1998	0	0	0	0	0	0	0	0	0	2,092	2,074	6,292	2,893	750	1,103	0
Jun	1998	0	0	0	0	0	0	0	0	0	2,251	971	2,712	1,247	0	0	0
Jul	1998	0	0	0	0	0	0	0	0	0	5,258	971	1,559	717	0	0	0
Aug	1998	-5,305	0	0	0	0	0	0	0	-608	4,000	971	645	297	0	0	0
Sep	1998	-11,014	0	0	0	0	0	0	0	-854	2,162	971	5,983	2,751	0	0	0
Oct	1998	-254	0	0	0	0	0	0	0	-5,845	1,646	971	2,385	1,097	0	0	0
Nov	1998	0	0	0	0	0	0	0	-365	-1,020	659	484	166	76	0	0	0
Dec	1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	1999	-2,682	0	0	0	0	0	0	0	-2,582	1,141	971	2,159	993	0	0	0
Feb	1999	-6,772	0	0	0	0	0	0	0	-1,075	1,356	971	3,781	1,739	0	0	0
Mar	1999	-313	-80	-2,526	-645	-984	-18	0	0	-1,193	2,059	971	1,880	865	0	0	-16
Apr	1999	-185	-33	-3,598	0	0	-49	0	0	-835	1,446	971	1,577	725	0	0	-20
May	1999	0	0	-1,636	0	0	-63	0	0	-696	2,092	258	88	41	0	0	-84
Jun	1999	0	0	0	0	0	-16	0	0	-92	122	0	0	0	0	0	-14
Jul	1999	0	0	-162	0	0	-34	0	0	-6	224	0	0	0	0	0	-22
Aug	1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	1999	0	0	0	0	0	0	0	0	-516	787	0	0	0	0	0	-271
Oct	1999	0	0	-549	0	0	0	0	0	-374	923	0	0	0	0	0	0
Nov	1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2000	-50	-1	0	0	0	0	0	0	-9	60	0	0	0	0	0	0
Feb	2000	-948	-279	-686	-202	-7,798	0	0	0	-1,459	1,356	971	6,196	2,849	0	0	0
Mar	2000	-194	-50	-1,714	-438	-2,530	-14	0	0	-756	2,059	971	1,826	840	0	0	0
Apr	2000	0	0	-1,014	0	0	-8	0	0	-214	1,236	0	0	0	0	0	0
May	2000	0	0	0	0	0	-93	0	0	-6	127	0	0	0	0	0	-28
Jun	2000	0	0	0	0	0	-22	0	0	-192	272	0	0	0	0	0	-58
Jul	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2000	0	0	0	0	0	0	0	0	-379	517	0	0	0	0	0	-138
Oct	2000	0	0	-1,494	-58	0	0	0	0	-471	1,646	251	86	40	0	0	0
Nov	2000	0	0	-216	0	0	0	0	0	-37	253	0	0	0	0	0	0
Dec	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2001	0	0	-505	-540	-2,701	0	0	0	-613	1,785	971	1,098	505	0	0	0
Feb	2001	0	0	-244	-410	-6,911	-168	0	0	-446	1,356	971	4,009	1,844	0	0	0
Mar	2001	0	0	-315	-243	-2,843	0	0	0	-1,202	2,059	971	1,090	501	0	0	-18
Apr	2001	0	0	-2,721	0	0	0	0	0	-954	1,446	971	862	396	0	0	0
May	2001	0	0	-515	0	0	0	0	0	-193	708	0	0	0	0	0	0
Jun	2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table B-1 - Monthly Proposed Project Input Data for KDWD Superposition Model (in acre-feet per month)

		North Kern WSD					City of Bakersfield WSA				Kern Delta WD						
Month	Year	Spreading	Canal Losses - Spreading	Irrigation Pumping	Canal Losses - Irrigation	Other	KDWD	Kern Water Bank	Other Spreading	Other	Irrigation Reduction	COB Pumping	Recharge Basins	Canal Recharge	Pioneer Basin	Other	Water Not Used by NKWSD or City
Nov	2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2002	0	0	-568	-218	-621	0	0	0	-119	1,008	346	118	54	0	0	0
Feb	2002	0	0	-1,157	-852	-1,314	0	0	0	-243	1,356	971	849	390	0	0	0
Mar	2002	0	0	-1,638	-410	-2,256	0	0	0	-1,202	2,059	971	1,699	781	0	0	-4
Apr	2002	0	0	-2,503	-68	0	0	0	0	-979	1,446	971	776	357	0	0	0
May	2002	0	0	-2,417	-289	0	0	0	0	-522	2,092	758	259	119	0	0	0
Jun	2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	2002	0	0	-419	0	0	0	0	0	-119	601	0	0	0	0	0	-63
Aug	2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	2002	0	0	-412	-364	-512	0	0	0	-601	1,720	113	39	18	0	0	0
Dec	2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	2003	0	0	-1,693	-574	-4,974	0	0	0	-155	1,356	971	3,472	1,597	0	0	0
Mar	2003	0	0	-1,574	-877	-444	0	0	0	-1,135	2,059	971	685	315	0	0	0
Apr	2003	0	0	-2,834	-745	-429	0	0	0	-959	1,446	971	1,747	803	0	0	0
May	2003	0	0	-2,021	0	0	0	0	0	-412	2,092	227	78	36	0	0	0
Jun	2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2003	0	0	-232	0	0	0	0	0	-986	1,695	0	0	0	0	0	-477
Oct	2003	0	0	-154	0	0	0	0	0	-341	495	0	0	0	0	0	0
Nov	2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2004	-2,463	-1,139	0	0	0	0	0	0	-51	500	971	1,495	687	0	0	0
Feb	2004	0	0	-2,799	-1,052	-3,726	0	0	0	-152	1,356	971	3,700	1,702	0	0	0
Mar	2004	0	0	-472	0	0	0	0	0	-376	848	0	0	0	0	0	0
Apr	2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	2004	0	0	0	0	0	0	0	0	-83	113	0	0	0	0	0	-30
Jun	2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	2004	-1,728	-683	0	0	0	0	0	0	-344	1,654	734	251	115	0	0	0
Nov	2004	-1,216	0	0	0	0	0	0	0	-149	891	316	108	50	0	0	0
Dec	2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2005	-6,699	0	0	0	0	0	0	-1,458	-6,741	500	971	8,700	4,000	242	485	0
Feb	2005	-6,988	-800	0	0	0	0	0	0	-524	1,356	971	4,100	1,885	0	0	0
Mar	2005	-1,770	0	0	0	0	0	0	0	-816	2,059	352	120	55	0	0	0
Apr	2005	-2,032	0	0	0	0	0	0	0	-623	1,446	942	322	148	0	0	-204
May	2005	-2,524	0	0	0	0	0	0	-2,510	0	2,092	971	1,763	811	0	0	-603
Jun	2005	-563	0	0	0	0	0	0	-389	0	1,077	0	0	0	0	0	-125
Jul	2005	0	0	0	0	0	0	0	-256	0	319	0	0	0	0	0	-63
Aug	2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2005	0	0	-5,168	0	0	-2	0	0	-126	2,162	971	3,465	1,593	0	0	-2,895
Oct	2005	-4,105	0	0	0	0	0	0	0	-54	1,646	971	1,056	486	0	0	0
Nov	2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2006	-4,616	0	0	0	0	0	-6,282	-1,809	0	1,172	971	7,236	3,328	0	0	0
Feb	2006	-349	-250	-2,729	-302	0	0	0	0	-46	1,356	971	925	425	0	0	0
Mar	2006	0	0	-2,630	-995	-2,422	0	0	0	-1,052	2,059	971	2,787	1,282	0	0	0
Apr	2006	-380	-86	-2,132	-104	0	0	-139	-418	0	1,446	971	577	265	0	0	0
May	2006	0	0	0	0	0	0	0	0	0	874	0	0	0	0	0	0
Jun	2006	0	0	0	0	0	0	0	0	0	473	0	0	0	0	0	0
Jul	2006	0	0	0	0	0	0	0	0	-297	351	0	0	0	0	0	-54
Aug	2006	0	0	-28	0	0	0	0	0	-80	150	0	0	0	0	0	-42

Table B-1 - Monthly Proposed Project Input Data for KDWD Superposition Model (in acre-feet per month)

		North Kern WSD					City of Bakersfield WSA				Kern Delta WD						
Month	Year	Spreading	Canal Losses - Spreading	Irrigation Pumping	Canal Losses - Irrigation	Other	KDWD	Kern Water Bank	Other Spreading	Other	Irrigation Reduction	COB Pumping	Recharge Basins	Canal Recharge	Pioneer Basin	Other	Water Not Used by NKWSD or City
Sep	2006	0	0	-2,333	0	0	0	0	0	-468	2,162	623	213	98	0	0	-295
Oct	2006	-1,083	0	0	0	0	0	0	0	-84	1,167	0	0	0	0	0	0
Nov	2006	-604	0	0	0	0	0	0	0	-69	673	0	0	0	0	0	0
Dec	2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2007	-1,366	0	0	0	0	0	0	0	0	1,366	0	0	0	0	0	0
Feb	2007	-3,907	0	-1,596	0	0	0	0	0	-77	1,356	971	2,228	1,025	0	0	0
Mar	2007	0	0	-2,459	0	0	0	0	0	-714	2,059	743	254	117	0	0	0
Apr	2007	0	0	-2,589	0	0	0	0	0	-669	1,446	971	576	265	0	0	0
May	2007	0	0	-1,331	0	0	0	0	0	-593	1,924	0	0	0	0	0	0
Jun	2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	2007	0	0	0	0	0	0	0	0	-66	66	0	0	0	0	0	0
Nov	2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	2008	0	0	-52	0	0	0	0	0	-46	98	0	0	0	0	0	0
Mar	2008	0	0	0	0	0	0	0	0	-81	126	0	0	0	0	0	-45
Apr	2008	0	0	0	0	0	0	0	0	-577	850	0	0	0	0	0	-273
May	2008	0	0	0	0	0	0	0	0	-440	640	0	0	0	0	0	-200
Jun	2008	0	0	0	0	0	0	0	0	-293	420	0	0	0	0	0	-127
Jul	2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2009	-111	-18	-355	0	0	0	0	0	-20	505	0	0	0	0	0	0
Feb	2009	-4,463	-935	-1,077	-226	-1,896	0	0	0	-87	1,356	2,598	3,239	1,490	0	0	0
Mar	2009	0	0	-1,395	0	0	0	0	0	-789	2,146	25	9	4	0	0	0
Apr	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	2010	-36	-11	-583	-185	-10,535	0	0	0	-195	1,356	2,598	5,200	2,391	0	0	0
Mar	2010	0	0	-1,525	-167	0	0	0	0	-891	2,146	362	124	57	0	0	-105
Apr	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	2010	0	0	0	0	0	0	0	-274	0	357	0	0	0	0	0	-83
Jun	2010	0	0	0	0	0	0	0	-73	-405	948	0	0	0	0	0	-470
Jul	2010	0	0	0	0	0	0	0	0	-434	635	0	0	0	0	0	-201
Aug	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	2010	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	2010	-455	-92	0	0	0	0	0	0	-33	581	0	0	0	0	0	0
Dec	2010	0	0	0	0	0	0	0	-2,211	0	1,518	920	315	145	0	0	-686
Jan	2011	-4,860	0	0	0	0	0	0	-11,130	-1,032	568	2,598	8,700	4,000	0	1,156	0
Feb	2011	-7,517	0	0	0	0	0	0	-274	-117	1,356	2,598	4,532	2,084	0	0	-2,662
Mar	2011	-11,710	0	0	0	0	0	0	-146	-594	2,146	2,598	5,279	2,427	0	0	0
Apr	2011	-2,302	0	0	0	0	0	0	-10,760	0	1,446	2,598	6,177	2,841	0	0	0
May	2011	-1,679	0	0	0	0	0	0	-6,508	0	4,495	2,463	842	387	0	0	0
Jun	2011	-18	0	0	0	0	0	0	-97	0	372	0	0	0	0	0	-257

Table B-1 - Monthly Proposed Project Input Data for KDWD Superposition Model (in acre-feet per month)

		North Kern WSD					City of Bakersfield WSA				Kern Delta WD						
Month	Year	Spreading	Canal Losses - Spreading	Irrigation Pumping	Canal Losses - Irrigation	Other	KDWD	Kern Water Bank	Other Spreading	Other	Irrigation Reduction	COB Pumping	Recharge Basins	Canal Recharge	Pioneer Basin	Other	Water Not Used by NKWSD or City
Jul	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2011	-7,640	-1,741	-213	0	0	0	0	-51	0	2,162	2,598	3,346	1,538	0	0	0
Oct	2011	-391	0	0	0	0	0	0	-2	0	393	0	0	0	0	0	0
Nov	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	2012	-270	-92	-3,662	-100	0	0	0	0	-78	1,356	1,898	649	298	0	0	0
Mar	2012	0	0	-3,424	0	0	0	0	0	-1,111	2,146	1,593	545	251	0	0	0
Apr	2012	0	0	-3,926	0	0	0	0	0	-964	1,446	2,297	786	361	0	0	0
May	2012	0	0	-478	0	0	0	0	0	-177	655	0	0	0	0	0	0
Jun	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2012	0	0	-177	0	0	0	0	0	-119	357	0	0	0	0	0	-61
Oct	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	2013	0	0	-65	0	0	0	0	0	-46	135	0	0	0	0	0	-24
Mar	2013	0	0	-99	0	0	0	0	0	-40	161	0	0	0	0	0	-22
Apr	2013	0	0	-110	0	0	0	0	0	-40	172	0	0	0	0	0	-22
May	2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2013	0	0	-140	0	0	0	0	0	-317	604	0	0	0	0	0	-147
Sep	2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	2014	0	0	-26	0	0	0	0	0	-81	148	0	0	0	0	0	-41
Mar	2014	0	0	-1,070	0	0	0	0	0	-634	1,900	0	0	0	0	0	-196
Apr	2014	0	0	-2,687	0	0	0	0	0	-1,125	1,446	1,578	540	248	0	0	0
May	2014	0	0	-793	0	0	0	0	0	-851	1,644	0	0	0	0	0	0
Jun	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997-2007																	
Total		-106,236	-3,516	-67,057	-10,329	-42,233	-1,076	-20,128	-16,621	-50,722	115,925	50,328	129,908	59,736	2,492	5,700	-10,816
Average		-9,658	-320	-6,096	-939	-3,839	-98	-1,830	-1,511	-4,611	10,539	4,575	11,810	5,431	227	518	-983
1997-2014																	
Total		-147,687	-6,405	-88,914	-11,006	-54,663	-1,076	-20,128	-48,147	-62,338	154,715	79,649	170,189	78,259	2,492	6,856	-16,438
Average		-8,205	-356	-4,940	-611	-3,037	-60	-1,118	-2,675	-3,463	8,595	4,425	9,455	4,348	138	381	-913

Table B-2 - Baseline Scenario Water Balance - Southern Study Area (in acre-feet per year)

	INFLOWS			OUTFLOWS				EXCHANGE			
Simulation Year	Basins & Canals	Wells	Total Inflow	Basins & Canals	Wells	Streams	Total Outflow	Outside Study Area	North Study Area	Total Exchange	Storage Change
1	23,214	9,858	33,072	-5,990	-1,538	0	-7,527	-1,446	-1,200	-2,646	22,900
2	63,703	29,111	92,814	-833	-3,091	0	-3,924	-5,082	-8,736	-13,818	75,072
3	13,848	10,228	24,076	-140	-1,923	0	-2,062	-6,408	-9,407	-15,815	6,198
4	11,836	7,649	19,485	-101	-882	0	-983	-6,396	-9,181	-15,576	2,926
5	10,305	7,868	18,173	-107	-242	0	-349	-6,192	-8,894	-15,086	2,738
6	5,459	10,962	16,421	-13	-483	0	-497	-5,669	-8,164	-13,833	2,091
7	8,732	9,616	18,349	0	-958	0	-958	-5,309	-8,175	-13,484	3,907
8	8,108	6,674	14,783	-6	-262	0	-268	-4,651	-7,997	-12,648	1,866
9	29,038	14,657	43,695	-3,430	-3,563	0	-6,992	-5,503	-8,751	-14,253	22,449
10	17,135	13,610	30,745	-1,550	-349	0	-1,899	-6,017	-12,127	-18,144	10,702
11	4,465	8,917	13,382	0	-377	0	-377	-5,493	-10,247	-15,739	-2,734
12	0	2,131	2,131	-129	-820	0	-949	-4,043	-8,536	-12,578	-11,397
13	4,742	5,442	10,184	0	-448	0	-448	-3,525	-8,406	-11,931	-2,196
14	8,231	9,440	17,671	-1,879	-801	0	-2,680	-3,377	-8,347	-11,724	3,267
15	43,546	20,871	64,417	-18,287	0	0	-18,287	-5,321	-8,273	-13,594	32,537
16	2,857	7,955	10,812	-9	-169	0	-178	-4,672	-11,433	-16,105	-5,471
17	0	1,072	1,072	-8	-253	0	-261	-3,408	-9,442	-12,851	-12,040
18	788	5,397	6,185	0	-895	0	-895	-2,968	-8,494	-11,463	-6,173
Average Hydrologic Conditions (1997 to 2007)											
Average	17,804	11,741	29,545	-1,106	-1,242	0	-2,349	-5,288	-8,443	-13,731	13,465
Total	195,843	129,151	324,994	-12,169	-13,667	0	-25,836	-58,164	-92,878	-151,042	148,116
Combined Study Period (1997 to 2014)											
Average	14,223	10,081	24,304	-1,804	-947	0	-2,752	-4,749	-8,656	-13,405	8,147
Total	256,006	181,459	437,465	-32,481	-17,053	0	-49,534	-85,479	-155,808	-241,288	146,643
Range in Year-to-Year Change over Combined Study Period (1997 to 2014)											
Minimum	0	1,072	1,072	-18,287	-3,563	0	-18,287	-6,408	-12,127	-18,144	-12,040
Maximum	63,703	29,111	92,814	0	0	0	-178	-1,446	-1,200	-2,646	75,072

Table B-3 - Baseline Scenario Water Balance - Northern Study Area (in acre-feet per year)

	INFLOWS			OUTFLOWS				EXCHANGE			
Simulation Year	Basins & Canals	Wells	Total Inflow	Basins & Canals	Wells	Streams	Total Outflow	Outside Study Area	South Study Area	Total Exchange	Storage Change
1	600	355	955	-16,351	-10,149	0	-26,500	1,299	1,200	2,499	-23,046
2	1,200	3,859	5,059	-57,623	-2,318	0	-59,941	1,934	8,736	10,670	-44,212
3	0	58	58	-11,166	-10,905	0	-22,072	1,942	9,407	11,349	-10,664
4	0	92	92	-2,481	-16,114	0	-18,594	1,943	9,181	11,124	-7,378
5	0	386	386	-1,273	-16,936	0	-18,209	2,102	8,894	10,996	-6,827
6	0	510	510	-2,254	-14,180	0	-16,434	2,288	8,164	10,452	-5,472
7	0	355	355	-2,673	-15,073	0	-17,746	2,560	8,175	10,735	-6,656
8	0	984	984	-8,305	-7,194	0	-15,498	2,510	7,997	10,507	-4,007
9	194	1,500	1,694	-30,556	-7,840	0	-38,396	2,977	8,751	11,728	-24,975
10	0	1,295	1,295	-16,259	-12,536	0	-28,795	3,944	12,127	16,071	-11,428
11	0	525	525	-5,273	-8,257	0	-13,530	3,611	10,247	13,857	852
12	0	0	0	-516	-665	0	-1,181	3,269	8,536	11,804	10,623
13	0	1,076	1,076	-5,753	-5,059	0	-10,812	3,346	8,406	11,752	2,016
14	0	1,425	1,425	-3,171	-13,243	0	-16,414	3,536	8,347	11,883	-3,106
15	0	5,913	5,913	-51,831	-213	0	-52,044	3,639	8,273	11,912	-34,218
16	0	1,532	1,532	-497	-11,669	0	-12,166	4,419	11,433	15,851	5,217
17	0	0	0	-207	-604	0	-811	3,945	9,442	13,387	12,577
18	0	194	194	-237	-5,247	0	-5,484	3,901	8,494	12,395	7,105
Average Hydrologic Conditions (1997 to 2007)											
Average	181	902	1,083	-14,019	-11,046	0	-25,065	2,465	8,443	10,908	-13,074
Total	1,994	9,920	11,913	-154,213	-121,503	0	-275,716	27,111	92,878	119,989	-143,813
Combined Study Period (1997 to 2014)											
Average	111	1,114	1,225	-12,024	-8,789	0	-20,813	2,954	8,656	11,610	-7,978
Total	1,994	20,060	22,054	-216,425	-158,203	0	-374,627	53,166	155,808	208,975	-143,599
Range in Year-to-Year Change over Combined Study Period (1997 to 2014)											
Minimum	0	0	0	-57,623	-16,936	0	-59,941	1,299	1,200	2,499	-44,212
Maximum	1,200	5,913	5,913	-207	-213	0	-811	4,419	12,127	16,071	12,577

Table B-4 - Scenario A Water Balance - Southern Study Area (in acre-feet per year)

	INFLOWS			OUTFLOWS				EXCHANGE			STORAGE	
Simulation Year	Basins & Canals	Wells	Total Inflow	Basins & Canals	Wells	Streams	Total Outflow	Outside Study Area	North Study Area	Total Exchange	Annual Storage Change	18-Year Moving Average
1	23,214	9,858	33,072	-5,990	-1,538	0	-7,527	-1,446	-1,200	-2,646	22,900	n/a
2	63,703	29,111	92,814	-833	-3,091	0	-3,924	-5,082	-8,736	-13,818	75,072	n/a
3	13,848	10,228	24,076	-140	-1,923	0	-2,062	-6,408	-9,407	-15,815	6,198	n/a
4	11,836	7,649	19,485	-101	-882	0	-983	-6,396	-9,181	-15,576	2,926	n/a
5	10,305	7,868	18,173	-107	-242	0	-349	-6,192	-8,894	-15,086	2,738	n/a
6	5,459	10,962	16,421	-13	-483	0	-497	-5,669	-8,164	-13,833	2,091	n/a
7	8,732	9,616	18,349	0	-958	0	-958	-5,309	-8,175	-13,484	3,907	n/a
8	8,108	6,674	14,783	-6	-262	0	-268	-4,651	-7,997	-12,648	1,866	n/a
9	29,038	14,657	43,695	-3,430	-3,563	0	-6,992	-5,503	-8,751	-14,253	22,449	n/a
10	17,135	13,610	30,745	-1,550	-349	0	-1,899	-6,017	-12,127	-18,144	10,702	n/a
11	4,465	8,917	13,382	0	-377	0	-377	-5,493	-10,247	-15,739	-2,734	n/a
12	0	2,131	2,131	-129	-820	0	-949	-4,043	-8,536	-12,578	-11,397	n/a
13	4,742	5,442	10,184	0	-448	0	-448	-3,525	-8,406	-11,931	-2,196	n/a
14	8,231	9,440	17,671	-1,879	-801	0	-2,680	-3,377	-8,347	-11,724	3,267	n/a
15	43,546	20,871	64,417	-18,287	0	0	-18,287	-5,321	-8,273	-13,594	32,537	n/a
16	2,857	7,955	10,812	-9	-169	0	-178	-4,672	-11,433	-16,105	-5,471	n/a
17	0	1,072	1,072	-8	-253	0	-261	-3,408	-9,442	-12,851	-12,040	n/a
18	788	5,397	6,185	0	-895	0	-895	-2,968	-8,494	-11,463	-6,173	8,147
19	23,214	9,858	33,072	-5,990	-1,538	0	-7,527	-3,557	-8,760	-12,318	13,228	7,610
20	63,703	29,111	92,814	-833	-3,091	0	-3,924	-6,564	-15,481	-22,045	66,845	7,152
21	13,848	10,228	24,076	-140	-1,923	0	-2,062	-7,287	-15,120	-22,407	-393	6,786
22	11,524	7,602	19,127	-101	-872	0	-974	-6,892	-14,480	-21,372	-3,219	6,445
23	10,305	7,868	18,173	-107	-242	0	-349	-6,498	-13,821	-20,319	-2,495	6,154
24	5,459	10,962	16,421	-13	-483	0	-497	-5,843	-12,710	-18,553	-2,629	5,892
25	8,732	9,616	18,349	0	-958	0	-958	-5,398	-12,418	-17,816	-425	5,651
26	8,108	6,674	14,783	-6	-262	0	-268	-4,683	-11,848	-16,531	-2,017	5,436
27	29,038	14,657	43,695	-3,430	-3,563	0	-6,992	-5,497	-12,458	-17,955	18,748	5,230
28	17,135	13,610	30,745	-1,550	-349	0	-1,899	-6,000	-15,444	-21,445	7,402	5,047
29	4,465	8,917	13,382	0	-377	0	-377	-5,458	-13,447	-18,905	-5,900	4,871
30	0	2,134	2,134	-129	-821	0	-950	-4,007	-11,611	-15,618	-14,434	4,702
31	4,742	5,442	10,184	0	-448	0	-448	-3,478	-11,152	-14,630	-4,895	4,552
32	8,231	9,440	17,671	-1,879	-801	0	-2,680	-3,334	-10,998	-14,331	659	4,407
33	43,310	20,772	64,081	-18,263	0	0	-18,263	-5,274	-10,746	-16,020	29,798	4,255
34	2,857	7,955	10,812	-9	-169	0	-178	-4,658	-13,791	-18,448	-7,814	4,125
35	0	1,072	1,072	-8	-253	0	-261	-3,380	-11,695	-15,075	-14,264	4,001
36	788	5,397	6,185	0	-895	0	-895	-2,938	-10,609	-13,546	-8,256	3,885
37	23,214	9,858	33,072	-5,990	-1,538	0	-7,527	-3,538	-10,811	-14,348	11,197	3,773
38	63,703	29,111	92,814	-833	-3,091	0	-3,924	-6,571	-17,034	-23,605	65,285	3,686
39	13,848	10,228	24,076	-140	-1,923	0	-2,062	-7,282	-17,068	-24,350	-2,336	3,578
40	11,524	7,602	19,127	-101	-872	0	-974	-6,878	-16,270	-23,148	-4,995	3,479
41	10,514	7,927	18,441	-110	-242	0	-353	-6,510	-15,487	-21,996	-3,908	3,401
42	5,459	10,962	16,421	-13	-483	0	-497	-5,841	-14,216	-20,057	-4,133	3,317
43	8,732	9,616	18,349	0	-958	0	-958	-5,401	-13,877	-19,278	-1,887	3,236
44	7,922	6,611	14,533	-6	-262	0	-268	-4,676	-13,128	-17,804	-3,539	3,151
45	29,038	14,657	43,695	-3,430	-3,563	0	-6,992	-5,508	-13,903	-19,411	17,292	3,071
46	17,135	13,610	30,745	-1,550	-349	0	-1,899	-6,014	-16,693	-22,707	6,139	3,000
47	4,465	8,917	13,382	0	-377	0	-377	-5,473	-14,618	-20,091	-7,086	2,935
48	0	2,134	2,134	-129	-821	0	-950	-4,024	-12,755	-16,779	-15,596	2,870
49	4,742	5,442	10,184	0	-448	0	-448	-3,498	-12,178	-15,677	-5,941	2,812
50	8,231	9,440	17,671	-1,879	-801	0	-2,680	-3,357	-12,031	-15,389	-398	2,753
10-Year												
Average	19,138	12,023	31,161	-1,217	-1,329	0	-2,546	-5,267	-8,263	-13,530	15,085	n/a
Total	191,378	120,234	311,613	-12,169	-13,291	0	-25,460	-52,671	-82,631	-135,303	150,850	n/a
25-Year												
Average	15,712	10,668	26,380	-1,587	-1,046	0	-2,633	-5,101	-9,944	-15,045	8,702	n/a
Total	392,791	266,705	659,496	-39,664	-26,161	0	-65,825	-127,517	-248,598	-376,116	217,555	n/a
50-Year												
Average	14,400	10,178	24,578	-1,582	-997	0	-2,579	-5,016	-11,649	-16,665	5,334	n/a
Total	719,990	508,892	1,228,882	-79,119	-49,826	0	-128,945	-250,795	-582,467	-833,262	266,676	n/a
Range in Year-to-Year Change over 50-year simulation period												
Minimum	0	1,072	1,072	-18,287	-3,563	0	-18,287	-7,287	-17,068	-24,350	-15,596	2,753
Maximum	63,703	29,111	92,814	0	0	0	-178	-1,446	-1,200	-2,646	75,072	8,147

Table B-5 - Scenario A Water Balance - Northern Study Area (in acre-feet per year)

	INFLOWS			OUTFLOWS				EXCHANGE			STORAGE	
Simulation Year	Basins & Canals	Wells	Total Inflow	Basins & Canals	Wells	Streams	Total Outflow	Outside Study Area	South Study Area	Total Exchange	Annual Storage Change	18-Year Moving Average
1	600	355	955	-16,351	-10,149	0	-26,500	1,299	1,200	2,499	-23,046	n/a
2	1,200	3,859	5,059	-57,623	-2,318	0	-59,941	1,934	8,736	10,670	-44,212	n/a
3	0	58	58	-11,166	-10,905	0	-22,072	1,942	9,407	11,349	-10,664	n/a
4	0	92	92	-2,481	-16,114	0	-18,594	1,943	9,181	11,124	-7,378	n/a
5	0	386	386	-1,273	-16,936	0	-18,209	2,102	8,894	10,996	-6,827	n/a
6	0	510	510	-2,254	-14,180	0	-16,434	2,288	8,164	10,452	-5,472	n/a
7	0	355	355	-2,673	-15,073	0	-17,746	2,560	8,175	10,735	-6,656	n/a
8	0	984	984	-8,305	-7,194	0	-15,498	2,510	7,997	10,507	-4,007	n/a
9	194	1,500	1,694	-30,556	-7,840	0	-38,396	2,977	8,751	11,728	-24,975	n/a
10	0	1,295	1,295	-16,259	-12,536	0	-28,795	3,944	12,127	16,071	-11,428	n/a
11	0	525	525	-5,273	-8,257	0	-13,530	3,611	10,247	13,857	852	n/a
12	0	0	0	-516	-665	0	-1,181	3,269	8,536	11,804	10,623	n/a
13	0	1,076	1,076	-5,753	-5,059	0	-10,812	3,346	8,406	11,752	2,016	n/a
14	0	1,425	1,425	-3,171	-13,243	0	-16,414	3,536	8,347	11,883	-3,106	n/a
15	0	5,913	5,913	-51,831	-213	0	-52,044	3,639	8,273	11,912	-34,218	n/a
16	0	1,532	1,532	-497	-11,669	0	-12,166	4,419	11,433	15,851	5,217	n/a
17	0	0	0	-207	-604	0	-811	3,945	9,442	13,387	12,577	n/a
18	0	194	194	-237	-5,247	0	-5,484	3,901	8,494	12,395	7,105	-7,978
19	600	355	955	-16,351	-10,149	0	-26,500	4,822	8,760	13,583	-11,962	-7,362
20	1,200	3,859	5,059	-57,623	-2,318	0	-59,941	5,255	15,481	20,736	-34,146	-6,803
21	0	58	58	-11,166	-10,905	0	-22,072	5,126	15,120	20,246	-1,768	-6,308
22	0	92	92	-2,431	-15,814	0	-18,245	4,991	14,480	19,472	1,319	-5,825
23	0	386	386	-1,273	-16,936	0	-18,209	4,997	13,821	18,817	994	-5,391
24	0	510	510	-2,254	-14,180	0	-16,434	5,011	12,710	17,720	1,796	-4,987
25	0	355	355	-2,673	-15,073	0	-17,746	5,123	12,418	17,541	150	-4,609
26	0	984	984	-8,305	-7,194	0	-15,498	4,906	11,848	16,754	2,240	-4,262
27	194	1,500	1,694	-30,556	-7,840	0	-38,396	5,224	12,458	17,681	-19,021	-3,931
28	0	1,295	1,295	-16,259	-12,536	0	-28,795	6,008	15,444	21,452	-6,048	-3,632
29	0	525	525	-5,273	-8,257	0	-13,530	5,607	13,447	19,054	6,048	-3,343
30	0	0	0	-516	-668	0	-1,184	5,168	11,611	16,780	15,596	-3,067
31	0	1,076	1,076	-5,753	-5,059	0	-10,812	5,107	11,152	16,260	6,524	-2,817
32	0	1,425	1,425	-3,171	-13,243	0	-16,414	5,189	10,998	16,187	1,198	-2,578
33	0	5,875	5,875	-51,481	-213	0	-51,694	5,159	10,746	15,906	-29,913	-2,338
34	0	1,532	1,532	-497	-11,669	0	-12,166	5,861	13,791	19,652	9,018	-2,127
35	0	0	0	-207	-604	0	-811	5,320	11,695	17,015	16,204	-1,926
36	0	194	194	-237	-5,247	0	-5,484	5,200	10,609	15,809	10,519	-1,736
37	600	355	955	-16,351	-10,149	0	-26,500	5,997	10,811	16,808	-8,737	-1,557
38	1,200	3,859	5,059	-57,623	-2,318	0	-59,941	6,315	17,034	23,348	-31,534	-1,412
39	0	58	58	-11,166	-10,905	0	-22,072	6,219	17,068	23,287	1,273	-1,243
40	0	92	92	-2,431	-15,814	0	-18,245	6,038	16,270	22,308	4,155	-1,085
41	0	394	394	-1,290	-17,192	0	-18,482	5,990	15,487	21,477	3,389	-952
42	0	510	510	-2,254	-14,180	0	-16,434	5,919	14,216	20,134	4,210	-818
43	0	355	355	-2,673	-15,073	0	-17,746	5,974	13,877	19,851	2,460	-690
44	0	972	972	-8,269	-6,969	0	-15,237	5,680	13,128	18,808	4,543	-562
45	194	1,500	1,694	-30,556	-7,840	0	-38,396	5,967	13,903	19,870	-16,832	-440
46	0	1,295	1,295	-16,259	-12,536	0	-28,795	6,657	16,693	23,350	-4,150	-335
47	0	525	525	-5,273	-8,257	0	-13,530	6,272	14,618	20,890	7,885	-233
48	0	0	0	-516	-668	0	-1,184	5,792	12,755	18,548	17,364	-135
49	0	1,076	1,076	-5,753	-5,059	0	-10,812	5,682	12,178	17,860	8,125	-46
50	0	1,425	1,425	-3,171	-13,243	0	-16,414	5,724	12,031	17,756	2,767	41
10-Year												
Average	199	939	1,139	-14,894	-11,325	0	-26,219	2,350	8,263	10,613	-14,467	n/a
Total	1,994	9,395	11,388	-148,940	-113,245	0	-262,186	23,501	82,631	106,132	-144,665	n/a
25-Year												
Average	152	1,027	1,179	-12,408	-9,743	0	-22,151	3,540	9,944	13,484	-7,489	n/a
Total	3,794	25,675	29,469	-310,196	-243,579	0	-553,774	88,492	248,598	337,090	-187,215	n/a
50-Year												
Average	120	1,050	1,170	-11,921	-9,126	0	-21,047	4,629	11,649	16,279	-3,599	n/a
Total	5,981	52,499	58,480	-596,034	-456,312	0	-1,052,346	231,467	582,467	813,934	-179,931	n/a
Range in Year-to-Year Change over 50-year simulation period												
Minimum	0	0	0	-57,623	-17,192	0	-59,941	1,299	1,200	2,499	-44,212	-7,978
Maximum	1,200	5,913	5,913	-207	-213	0	-811	6,657	17,068	23,350	17,364	41

Table B-6 - Scenario B Water Balance - Southern Study Area (in acre-feet per year)

	INFLOWS			OUTFLOWS				EXCHANGE			STORAGE	
Simulation Year	Basins & Canals	Wells	Total Inflow	Basins & Canals	Wells	Streams	Total Outflow	Outside Study Area	North Study Area	Total Exchange	Annual Storage Change	11-Year Moving Average
1	23,214	9,858	33,072	-5,990	-1,538	0	-7,527	-1,446	-1,200	-2,646	22,900	n/a
2	63,703	29,111	92,814	-833	-3,091	0	-3,924	-5,082	-8,736	-13,818	75,072	n/a
3	13,848	10,228	24,076	-140	-1,923	0	-2,062	-6,408	-9,407	-15,815	6,198	n/a
4	11,836	7,649	19,485	-101	-882	0	-983	-6,396	-9,181	-15,576	2,926	n/a
5	10,305	7,868	18,173	-107	-242	0	-349	-6,192	-8,894	-15,086	2,738	n/a
6	5,459	10,962	16,421	-13	-483	0	-497	-5,669	-8,164	-13,833	2,091	n/a
7	8,732	9,616	18,349	0	-958	0	-958	-5,309	-8,175	-13,484	3,907	n/a
8	8,108	6,674	14,783	-6	-262	0	-268	-4,651	-7,997	-12,648	1,866	n/a
9	29,038	14,657	43,695	-3,430	-3,563	0	-6,992	-5,503	-8,751	-14,253	22,449	n/a
10	17,135	13,610	30,745	-1,550	-349	0	-1,899	-6,017	-12,127	-18,144	10,702	n/a
11	4,465	8,917	13,382	0	-377	0	-377	-5,493	-10,247	-15,739	-2,734	13,465
12	23,214	9,858	33,072	-5,990	-1,538	0	-7,527	-5,410	-9,820	-15,230	10,315	12,321
13	63,703	29,111	92,814	-833	-3,091	0	-3,924	-7,969	-16,243	-24,212	64,678	11,376
14	13,848	10,228	24,076	-140	-1,923	0	-2,062	-8,331	-15,540	-23,871	-1,858	10,644
15	11,836	7,649	19,485	-101	-882	0	-983	-7,673	-14,772	-22,445	-3,943	10,019
16	10,305	7,868	18,173	-107	-242	0	-349	-7,037	-13,977	-21,015	-3,191	9,480
17	5,459	10,962	16,421	-13	-483	0	-497	-6,222	-12,794	-19,016	-3,092	9,009
18	8,732	9,616	18,349	0	-958	0	-958	-5,660	-12,441	-18,100	-710	8,589
19	8,108	6,674	14,783	-6	-262	0	-268	-4,862	-11,859	-16,721	-2,207	8,219
20	29,038	14,657	43,695	-3,430	-3,563	0	-6,992	-5,617	-12,397	-18,013	18,689	7,877
21	17,135	13,610	30,745	-1,550	-349	0	-1,899	-6,078	-15,403	-21,482	7,365	7,574
22	4,465	8,917	13,382	0	-377	0	-377	-5,508	-13,387	-18,894	-5,889	7,287
23	23,214	9,858	33,072	-5,990	-1,538	0	-7,527	-5,402	-12,767	-18,169	7,376	7,020
24	63,703	29,111	92,814	-833	-3,091	0	-3,924	-7,968	-18,779	-26,747	62,143	6,789
25	13,848	10,228	24,076	-140	-1,923	0	-2,062	-8,298	-18,190	-26,488	-4,474	6,552
26	11,836	7,649	19,485	-101	-882	0	-983	-7,621	-17,265	-24,886	-6,384	6,330
27	10,305	7,868	18,173	-107	-242	0	-349	-6,987	-16,245	-23,232	-5,408	6,128
28	5,459	10,962	16,421	-13	-483	0	-497	-6,177	-14,911	-21,088	-5,164	5,940
29	8,732	9,616	18,349	0	-958	0	-958	-5,621	-14,458	-20,080	-2,689	5,760
30	8,108	6,674	14,783	-6	-262	0	-268	-4,830	-13,703	-18,533	-4,019	5,595
31	29,038	14,657	43,695	-3,430	-3,563	0	-6,992	-5,589	-14,285	-19,874	16,828	5,426
32	17,135	13,610	30,745	-1,550	-349	0	-1,899	-6,058	-17,066	-23,124	5,723	5,277
33	4,465	8,917	13,382	0	-377	0	-377	-5,490	-14,964	-20,454	-7,449	5,135
34	23,214	9,858	33,072	-5,990	-1,538	0	-7,527	-5,389	-14,400	-19,788	5,757	4,988
35	63,703	29,111	92,814	-833	-3,091	0	-3,924	-7,968	-19,990	-27,957	60,933	4,878
36	13,848	10,228	24,076	-140	-1,923	0	-2,062	-8,296	-19,664	-27,961	-5,947	4,744
37	11,836	7,649	19,485	-101	-882	0	-983	-7,619	-18,622	-26,241	-7,739	4,621
38	10,305	7,868	18,173	-107	-242	0	-349	-6,989	-17,475	-24,463	-6,639	4,509
39	5,459	10,962	16,421	-13	-483	0	-497	-6,182	-16,057	-22,239	-6,315	4,404
40	8,732	9,616	18,349	0	-958	0	-958	-5,630	-15,567	-21,196	-3,805	4,302
41	8,108	6,674	14,783	-6	-262	0	-268	-4,841	-14,722	-19,563	-5,049	4,209
42	29,038	14,657	43,695	-3,430	-3,563	0	-6,992	-5,603	-15,383	-20,986	15,717	4,108
43	17,135	13,610	30,745	-1,550	-349	0	-1,899	-6,072	-18,047	-24,119	4,727	4,017
44	4,465	8,917	13,382	0	-377	0	-377	-5,505	-15,866	-21,371	-8,366	3,934
45	23,214	9,858	33,072	-5,990	-1,538	0	-7,527	-5,404	-15,396	-20,800	4,745	3,842
46	63,703	29,111	92,814	-833	-3,091	0	-3,924	-7,986	-20,698	-28,684	60,206	3,776
47	13,848	10,228	24,076	-140	-1,923	0	-2,062	-8,315	-20,556	-28,871	-6,857	3,693
48	11,836	7,649	19,485	-101	-882	0	-983	-7,639	-19,441	-27,080	-8,578	3,617
49	10,305	7,868	18,173	-107	-242	0	-349	-7,009	-18,206	-25,216	-7,392	3,548
50	5,459	10,962	16,421	-13	-483	0	-497	-6,203	-16,734	-22,937	-7,013	3,485
10-Year												
Average	19,138	12,023	31,161	-1,217	-1,329	0	-2,546	-5,267	-8,263	-13,530	15,085	n/a
Total	191,378	120,234	311,613	-12,169	-13,291	0	-25,460	-52,671	-82,631	-135,303	150,850	n/a
25-Year												
Average	19,698	12,300	31,998	-1,252	-1,355	0	-2,607	-6,008	-11,650	-17,658	11,733	n/a
Total	492,451	307,500	799,951	-31,300	-33,886	0	-65,187	-150,201	-291,246	-441,446	293,318	n/a
50-Year												
Average	18,235	11,846	30,080	-1,117	-1,257	0	-2,374	-6,224	-14,219	-20,444	7,263	n/a
Total	911,737	592,282	1,504,019	-55,860	-62,828	0	-118,688	-311,223	-710,966	-1,022,189	363,141	n/a
Range in Year-to-Year Change over 50-year simulation period												
Minimum	4,465	6,674	13,382	-5,990	-3,563	0	-7,527	-8,331	-20,698	-28,871	-8,578	3,485
Maximum	63,703	29,111	92,814	0	-242	0	-268	-1,446	-1,200	-2,646	75,072	13,465

Table B-7 - Scenario B Water Balance - Northern Study Area (in acre-feet per year)

	INFLOWS			OUTFLOWS				EXCHANGE			STORAGE	
Simulation Year	Basins & Canals	Wells	Total Inflow	Basins & Canals	Wells	Streams	Total Outflow	Outside Study Area	South Study Area	Total Exchange	Annual Storage Change	11-Year Moving Average
1	600	355	955	-16,351	-10,149	0	-26,500	1,299	1,200	2,499	-23,046	n/a
2	1,200	3,859	5,059	-57,623	-2,318	0	-59,941	1,934	8,736	10,670	-44,212	n/a
3	0	58	58	-11,166	-10,905	0	-22,072	1,942	9,407	11,349	-10,664	n/a
4	0	92	92	-2,481	-16,114	0	-18,594	1,943	9,181	11,124	-7,378	n/a
5	0	386	386	-1,273	-16,936	0	-18,209	2,102	8,894	10,996	-6,827	n/a
6	0	510	510	-2,254	-14,180	0	-16,434	2,288	8,164	10,452	-5,472	n/a
7	0	355	355	-2,673	-15,073	0	-17,746	2,560	8,175	10,735	-6,656	n/a
8	0	984	984	-8,305	-7,194	0	-15,498	2,510	7,997	10,507	-4,007	n/a
9	194	1,500	1,694	-30,556	-7,840	0	-38,396	2,977	8,751	11,728	-24,975	n/a
10	0	1,295	1,295	-16,259	-12,536	0	-28,795	3,944	12,127	16,071	-11,428	n/a
11	0	525	525	-5,273	-8,257	0	-13,530	3,611	10,247	13,857	852	-13,074
12	600	355	955	-16,351	-10,149	0	-26,500	4,499	9,820	14,319	-11,226	-11,999
13	1,200	3,859	5,059	-57,623	-2,318	0	-59,941	4,996	16,243	21,238	-33,644	-11,039
14	0	58	58	-11,166	-10,905	0	-22,072	4,890	15,540	20,430	-1,584	-10,213
15	0	92	92	-2,481	-16,114	0	-18,594	4,814	14,772	19,586	1,084	-9,444
16	0	386	386	-1,273	-16,936	0	-18,209	4,840	13,977	18,817	994	-8,733
17	0	510	510	-2,254	-14,180	0	-16,434	4,882	12,794	17,676	1,752	-8,076
18	0	355	355	-2,673	-15,073	0	-17,746	5,015	12,441	17,456	64	-7,465
19	0	984	984	-8,305	-7,194	0	-15,498	4,814	11,859	16,673	2,159	-6,905
20	194	1,500	1,694	-30,556	-7,840	0	-38,396	5,142	12,397	17,539	-19,163	-6,376
21	0	1,295	1,295	-16,259	-12,536	0	-28,795	5,944	15,403	21,347	-6,152	-5,897
22	0	525	525	-5,273	-8,257	0	-13,530	5,536	13,387	18,922	5,917	-5,436
23	600	355	955	-16,351	-10,149	0	-26,500	6,283	12,767	19,050	-6,495	-5,006
24	1,200	3,859	5,059	-57,623	-2,318	0	-59,941	6,633	18,779	25,412	-29,470	-4,627
25	0	58	58	-11,166	-10,905	0	-22,072	6,496	18,190	24,686	2,672	-4,240
26	0	92	92	-2,481	-16,114	0	-18,594	6,344	17,265	23,609	5,107	-3,874
27	0	386	386	-1,273	-16,936	0	-18,209	6,266	16,245	22,511	4,687	-3,538
28	0	510	510	-2,254	-14,180	0	-16,434	6,214	14,911	21,125	5,201	-3,225
29	0	355	355	-2,673	-15,073	0	-17,746	6,263	14,458	20,721	3,330	-2,928
30	0	984	984	-8,305	-7,194	0	-15,498	5,983	13,703	19,686	5,172	-2,654
31	194	1,500	1,694	-30,556	-7,840	0	-38,396	6,238	14,285	20,522	-16,180	-2,383
32	0	1,295	1,295	-16,259	-12,536	0	-28,795	6,934	17,066	24,000	-3,499	-2,142
33	0	525	525	-5,273	-8,257	0	-13,530	6,512	14,964	21,476	8,471	-1,909
34	600	355	955	-16,351	-10,149	0	-26,500	7,171	14,400	21,570	-3,974	-1,680
35	1,200	3,859	5,059	-57,623	-2,318	0	-59,941	7,429	19,990	27,419	-27,463	-1,498
36	0	58	58	-11,166	-10,905	0	-22,072	7,316	19,664	26,981	4,967	-1,289
37	0	92	92	-2,481	-16,114	0	-18,594	7,124	18,622	25,746	7,244	-1,095
38	0	386	386	-1,273	-16,936	0	-18,209	6,987	17,475	24,461	6,638	-918
39	0	510	510	-2,254	-14,180	0	-16,434	6,886	16,057	22,944	7,019	-752
40	0	355	355	-2,673	-15,073	0	-17,746	6,890	15,567	22,457	5,066	-594
41	0	984	984	-8,305	-7,194	0	-15,498	6,566	14,722	21,288	6,773	-449
42	194	1,500	1,694	-30,556	-7,840	0	-38,396	6,785	15,383	22,168	-14,534	-299
43	0	1,295	1,295	-16,259	-12,536	0	-28,795	7,421	18,047	25,468	-2,031	-166
44	0	525	525	-5,273	-8,257	0	-13,530	6,995	15,866	22,861	9,855	-40
45	600	355	955	-16,351	-10,149	0	-26,500	7,605	15,396	23,001	-2,544	90
46	1,200	3,859	5,059	-57,623	-2,318	0	-59,941	7,779	20,698	28,477	-26,405	186
47	0	58	58	-11,166	-10,905	0	-22,072	7,731	20,556	28,287	6,273	305
48	0	92	92	-2,481	-16,114	0	-18,594	7,512	19,441	26,953	8,451	415
49	0	386	386	-1,273	-16,936	0	-18,209	7,337	18,206	25,543	7,719	513
50	0	510	510	-2,254	-14,180	0	-16,434	7,204	16,734	23,938	8,013	603
10-Year												
Average	199	939	1,139	-14,894	-11,325	0	-26,219	2,350	8,263	10,613	-14,467	n/a
Total	1,994	9,395	11,388	-148,940	-113,245	0	-262,186	23,501	82,631	106,132	-144,665	n/a
25-Year												
Average	231	964	1,196	-15,743	-10,655	0	-26,398	4,076	11,650	15,726	-9,476	n/a
Total	5,787	24,112	29,899	-393,566	-266,379	0	-659,945	101,895	291,246	393,140	-236,905	n/a
50-Year												
Average	195	899	1,094	-14,160	-11,132	0	-25,292	5,508	14,219	19,727	-4,471	n/a
Total	9,775	44,939	54,714	-708,000	-556,614	0	-1,264,614	275,388	710,966	986,354	-223,547	n/a
Range in Year-to-Year Change over 50-year simulation period												
Minimum	0	58	58	-57,623	-16,936	0	-59,941	1,299	1,200	2,499	-44,212	-13,074
Maximum	1,200	3,859	5,059	-1,273	-2,318	0	-13,530	7,779	20,698	28,477	9,855	603

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
Jan	1	0.08	0.00	0.00	-0.05	-0.21	-0.12	-0.01	0.05	-0.41	0.50	0.24	0.00	-1.18
Feb	1	0.17	0.00	0.00	-0.05	-0.14	-0.08	-0.01	0.01	-0.23	0.32	0.18	0.00	-0.05
Mar	1	0.25	0.00	0.00	-0.05	-0.16	-0.10	-0.01	0.02	-0.29	0.37	0.19	0.00	-0.39
Apr	1	0.33	0.00	0.00	-0.06	-0.17	-0.11	-0.02	0.03	-0.32	0.42	0.21	0.00	-0.52
May	1	0.42	0.00	0.00	-0.06	-0.19	-0.14	-0.02	0.05	-0.38	0.50	0.25	-0.01	-0.80
June	1	0.50	0.00	0.00	-0.06	-0.17	-0.12	-0.02	0.02	-0.30	0.37	0.22	0.00	-0.34
July	1	0.58	0.00	-0.02	-0.19	-0.33	-0.20	-0.02	0.04	-0.32	0.46	0.25	0.00	-0.34
Aug	1	0.67	0.00	-0.06	-0.33	-0.49	-0.27	-0.02	0.04	-0.29	0.45	0.26	0.00	-0.08
Sep	1	0.75	-0.01	-0.80	-3.93	-5.81	-2.61	-0.11	0.10	-0.85	1.11	0.45	-0.07	0.95
Oct	1	0.83	-0.01	-0.22	-0.52	-0.60	-0.50	-0.11	0.13	-0.37	0.99	0.45	-0.02	0.10
Nov	1	0.92	-0.01	-0.13	-0.29	-0.44	-0.37	-0.11	0.10	-0.30	0.75	0.42	-0.01	0.21
Dec	1	1.00	0.00	-0.10	-0.25	-0.43	-0.34	-0.10	0.05	-0.31	0.53	0.37	-0.01	0.07
Jan	2	1.08	0.00	-0.08	-0.28	-0.46	-0.33	-0.10	0.13	-0.08	1.02	0.52	0.02	1.76
Feb	2	1.17	0.00	-0.07	-0.29	-0.46	-0.31	-0.10	0.17	-0.07	1.34	0.64	0.03	2.17
Mar	2	1.25	0.00	-0.06	-0.41	-0.78	-0.50	-0.10	0.24	-0.14	1.75	0.83	0.04	2.31
Apr	2	1.33	0.00	-0.06	-0.56	-1.11	-0.70	-0.10	0.29	0.01	2.05	0.99	0.06	3.70
May	2	1.42	0.00	-0.06	-0.56	-1.00	-0.64	-0.10	0.38	0.21	2.54	1.19	0.09	4.78
June	2	1.50	0.00	-0.06	-0.58	-1.05	-0.69	-0.10	0.42	-0.03	2.61	1.28	0.08	3.25
July	2	1.58	0.00	-0.06	-0.58	-1.01	-0.68	-0.10	0.60	-0.01	3.49	1.56	0.10	3.40
Aug	2	1.67	0.00	-0.06	-0.65	-1.21	-0.84	-0.10	0.59	-0.20	3.24	1.59	0.09	2.38
Sep	2	1.75	0.00	-0.07	-0.79	-1.56	-1.09	-0.10	0.52	-0.33	2.93	1.61	0.08	2.03
Oct	2	1.83	0.00	-0.08	-0.88	-2.02	-1.53	-0.12	0.38	-1.73	2.08	1.50	-0.01	-6.04
Nov	2	1.92	0.00	-0.09	-0.86	-1.65	-1.34	-0.13	0.35	-0.73	2.21	1.47	0.03	0.10
Dec	2	2.00	0.00	-0.09	-0.86	-1.55	-1.29	-0.13	0.33	-0.55	2.06	1.43	0.03	1.02
Jan	3	2.08	0.00	-0.10	-0.91	-1.74	-1.45	-0.13	0.36	-0.98	2.17	1.51	0.01	-1.38
Feb	3	2.17	0.00	-0.10	-0.98	-1.80	-1.50	-0.13	0.42	-0.65	2.56	1.63	0.04	0.94
Mar	3	2.25	-0.01	-0.51	-3.01	-4.79	-2.85	-0.15	0.48	-1.09	2.76	1.72	-0.01	0.61
Apr	3	2.33	-0.03	-0.75	-3.59	-5.07	-3.21	-0.17	0.48	-0.91	2.72	1.74	-0.03	1.18
May	3	2.42	-0.04	-0.53	-2.39	-3.45	-2.51	-0.17	0.51	-0.93	2.79	1.80	-0.02	0.39
June	3	2.50	-0.04	-0.26	-1.28	-1.99	-1.80	-0.15	0.43	-0.72	2.31	1.70	0.00	0.86
July	3	2.58	-0.03	-0.22	-1.28	-2.02	-1.78	-0.15	0.42	-0.69	2.26	1.70	0.01	0.99
Aug	3	2.67	-0.03	-0.18	-1.16	-1.84	-1.69	-0.14	0.41	-0.67	2.16	1.70	0.01	0.99
Sep	3	2.75	-0.02	-0.17	-1.15	-1.84	-1.70	-0.14	0.44	-0.81	2.26	1.74	0.01	0.12
Oct	3	2.83	-0.02	-0.25	-1.49	-2.26	-1.90	-0.14	0.45	-0.81	2.30	1.77	0.01	0.30
Nov	3	2.92	-0.01	-0.18	-1.17	-1.76	-1.67	-0.14	0.42	-0.68	2.09	1.73	0.02	0.84
Dec	3	3.00	-0.01	-0.17	-1.13	-1.71	-1.63	-0.14	0.42	-0.66	2.04	1.73	0.02	0.84
Jan	4	3.08	-0.01	-0.17	-1.12	-1.67	-1.61	-0.14	0.42	-0.66	2.02	1.74	0.02	0.82
Feb	4	3.17	-0.02	-0.55	-4.84	-9.55	-4.37	-0.19	0.48	-2.77	2.45	1.90	-0.07	-0.50
Mar	4	3.25	-0.04	-0.63	-3.64	-5.76	-3.46	-0.21	0.56	-1.51	2.81	1.99	-0.05	1.00
Apr	4	3.33	-0.04	-0.49	-2.23	-3.04	-2.49	-0.20	0.54	-0.95	2.59	1.97	-0.03	0.54
May	4	3.42	-0.04	-0.31	-1.45	-2.04	-1.96	-0.17	0.49	-0.78	2.27	1.91	-0.01	0.84
June	4	3.50	-0.04	-0.26	-1.36	-1.98	-1.89	-0.16	0.49	-0.80	2.23	1.92	0.00	0.54
July	4	3.58	-0.03	-0.24	-1.33	-1.92	-1.83	-0.15	0.49	-0.73	2.14	1.91	0.01	0.82
Aug	4	3.67	-0.03	-0.23	-1.31	-1.88	-1.80	-0.15	0.49	-0.71	2.11	1.91	0.01	0.81
Sep	4	3.75	-0.03	-0.23	-1.30	-1.88	-1.80	-0.15	0.51	-0.81	2.17	1.93	0.01	0.18
Oct	4	3.83	-0.03	-0.45	-2.25	-3.10	-2.39	-0.16	0.58	-0.87	2.48	2.02	-0.01	0.39
Nov	4	3.92	-0.03	-0.31	-1.52	-2.06	-1.91	-0.16	0.54	-0.74	2.17	1.96	0.01	0.66
Dec	4	4.00	-0.03	-0.26	-1.31	-1.81	-1.77	-0.15	0.52	-0.70	2.05	1.93	0.01	0.72
Jan	5	4.08	-0.03	-0.41	-2.67	-4.52	-2.72	-0.17	0.61	-1.25	2.57	2.08	-0.01	1.13
Feb	5	4.17	-0.04	-0.58	-4.58	-8.71	-4.16	-0.22	0.63	-2.36	2.68	2.14	-0.06	1.18
Mar	5	4.25	-0.04	-0.51	-3.03	-4.98	-3.11	-0.23	0.66	-1.59	2.78	2.20	-0.04	0.32
Apr	5	4.33	-0.05	-0.78	-3.44	-4.56	-3.25	-0.23	0.66	-1.02	2.70	2.20	-0.05	0.77
May	5	4.42	-0.05	-0.50	-2.03	-2.68	-2.36	-0.22	0.62	-0.88	2.45	2.16	-0.02	0.51
June	5	4.50	-0.05	-0.37	-1.59	-2.14	-2.04	-0.19	0.59	-0.77	2.24	2.11	-0.01	0.77
July	5	4.58	-0.04	-0.33	-1.52	-2.07	-1.98	-0.18	0.58	-0.74	2.19	2.10	0.00	0.77
Aug	5	4.67	-0.04	-0.32	-1.50	-2.03	-1.94	-0.17	0.59	-0.72	2.16	2.10	0.00	0.76
Sep	5	4.75	-0.04	-0.31	-1.48	-2.00	-1.91	-0.17	0.59	-0.70	2.13	2.10	0.01	0.76
Oct	5	4.83	-0.04	-0.30	-1.46	-1.96	-1.88	-0.17	0.60	-0.69	2.10	2.09	0.01	0.75
Nov	5	4.92	-0.04	-0.30	-1.44	-1.93	-1.85	-0.17	0.60	-0.68	2.08	2.09	0.01	0.73
Dec	5	5.00	-0.03	-0.30	-1.43	-1.90	-1.83	-0.17	0.60	-0.67	2.06	2.09	0.01	0.72
Jan	6	5.08	-0.04	-0.41	-2.02	-2.88	-2.21	-0.18	0.66	-0.78	2.34	2.16	0.01	1.03
Feb	6	5.17	-0.04	-0.56	-2.86	-4.19	-2.74	-0.20	0.72	-0.88	2.60	2.24	0.00	1.88
Mar	6	5.25	-0.05	-0.70	-3.52	-5.39	-3.29	-0.22	0.75	-1.38	2.70	2.30	-0.04	0.28
Apr	6	5.33	-0.05	-0.81	-3.35	-4.33	-3.12	-0.23	0.74	-0.92	2.63	2.30	-0.04	0.69
May	6	5.42	-0.06	-0.83	-3.27	-4.19	-3.06	-0.23	0.79	-0.82	2.82	2.36	-0.03	1.11
June	6	5.50	-0.06	-0.49	-1.75	-2.20	-2.11	-0.22	0.69	-0.70	2.26	2.24	-0.01	0.77

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
July	6	5.58	-0.06	-0.48	-1.87	-2.45	-2.19	-0.21	0.71	-0.73	2.32	2.26	-0.01	0.59
Aug	6	5.67	-0.05	-0.41	-1.60	-2.07	-1.98	-0.20	0.68	-0.66	2.16	2.22	0.00	0.74
Sep	6	5.75	-0.05	-0.39	-1.56	-2.03	-1.94	-0.20	0.68	-0.65	2.12	2.21	0.01	0.74
Oct	6	5.83	-0.05	-0.38	-1.53	-1.99	-1.90	-0.19	0.68	-0.63	2.09	2.20	0.01	0.73
Nov	6	5.92	-0.05	-0.45	-2.01	-2.84	-2.25	-0.20	0.77	-0.91	2.49	2.31	0.00	-0.06
Dec	6	6.00	-0.04	-0.39	-1.56	-2.00	-1.92	-0.20	0.71	-0.64	2.12	2.23	0.01	0.66
Jan	7	6.08	-0.04	-0.38	-1.52	-1.95	-1.87	-0.20	0.70	-0.62	2.06	2.21	0.01	0.67
Feb	7	6.17	-0.05	-0.83	-4.82	-8.17	-4.14	-0.24	0.79	-1.77	2.64	2.36	-0.05	1.69
Mar	7	6.25	-0.06	-0.75	-3.05	-4.02	-2.96	-0.24	0.84	-0.98	2.76	2.42	-0.03	0.50
Apr	7	6.33	-0.07	-0.95	-3.83	-5.09	-3.46	-0.25	0.83	-1.00	2.70	2.43	-0.05	0.68
May	7	6.42	-0.08	-0.86	-3.18	-4.05	-3.05	-0.25	0.87	-0.89	2.84	2.48	-0.04	0.47
June	7	6.50	-0.07	-0.56	-1.86	-2.32	-2.20	-0.23	0.78	-0.69	2.32	2.37	-0.02	0.75
July	7	6.58	-0.07	-0.49	-1.73	-2.22	-2.10	-0.22	0.77	-0.66	2.24	2.34	-0.01	0.75
Aug	7	6.67	-0.06	-0.46	-1.69	-2.17	-2.05	-0.22	0.77	-0.64	2.20	2.33	0.00	0.74
Sep	7	6.75	-0.06	-0.49	-1.83	-2.43	-2.19	-0.22	0.84	-0.92	2.51	2.42	-0.01	-0.82
Oct	7	6.83	-0.06	-0.48	-1.77	-2.29	-2.11	-0.22	0.80	-0.75	2.29	2.37	0.00	0.09
Nov	7	6.92	-0.05	-0.45	-1.65	-2.10	-2.00	-0.22	0.78	-0.64	2.17	2.34	0.00	0.61
Dec	7	7.00	-0.05	-0.44	-1.62	-2.07	-1.96	-0.22	0.78	-0.62	2.13	2.33	0.01	0.63
Jan	8	7.08	-0.05	-0.44	-1.63	-2.05	-1.94	-0.21	0.83	-0.38	2.42	2.39	0.02	2.10
Feb	8	7.17	-0.06	-1.01	-5.08	-7.99	-4.30	-0.26	0.90	-1.50	2.79	2.51	-0.05	1.76
Mar	8	7.25	-0.07	-0.66	-2.30	-2.89	-2.52	-0.25	0.87	-0.84	2.52	2.47	-0.02	0.22
Apr	8	7.33	-0.07	-0.53	-1.80	-2.30	-2.18	-0.24	0.83	-0.66	2.30	2.41	-0.01	0.74
May	8	7.42	-0.07	-0.50	-1.74	-2.24	-2.12	-0.23	0.83	-0.66	2.27	2.40	0.00	0.62
June	8	7.50	-0.06	-0.49	-1.71	-2.19	-2.07	-0.23	0.83	-0.63	2.22	2.39	0.00	0.73
July	8	7.58	-0.06	-0.48	-1.69	-2.16	-2.04	-0.22	0.83	-0.61	2.20	2.38	0.01	0.73
Aug	8	7.67	-0.06	-0.47	-1.68	-2.13	-2.01	-0.22	0.84	-0.60	2.18	2.37	0.01	0.72
Sep	8	7.75	-0.06	-0.47	-1.66	-2.10	-1.99	-0.22	0.84	-0.59	2.16	2.36	0.01	0.72
Oct	8	7.83	-0.06	-0.47	-1.66	-2.10	-1.98	-0.22	0.94	-0.49	2.65	2.49	0.02	1.40
Nov	8	7.92	-0.06	-0.47	-1.67	-2.13	-1.99	-0.22	0.93	-0.53	2.50	2.47	0.02	1.07
Dec	8	8.00	-0.06	-0.47	-1.66	-2.12	-1.99	-0.22	0.88	-0.58	2.21	2.41	0.02	0.74
Jan	9	8.08	-0.06	-0.48	-1.79	-2.84	-2.51	-0.24	0.81	-2.17	1.78	2.43	-0.07	-8.01
Feb	9	8.17	-0.06	-0.48	-1.82	-2.55	-2.33	-0.24	0.95	-0.67	2.85	2.61	0.01	1.25
Mar	9	8.25	-0.06	-0.48	-1.84	-2.63	-2.38	-0.24	1.02	-0.86	2.99	2.67	0.01	0.01
Apr	9	8.33	-0.06	-0.49	-1.85	-2.59	-2.36	-0.24	1.03	-0.67	2.99	2.67	0.02	1.20
May	9	8.42	-0.06	-0.49	-1.86	-2.56	-2.33	-0.23	1.09	-0.53	3.29	2.78	0.03	2.29
June	9	8.50	-0.06	-0.49	-1.87	-2.62	-2.38	-0.24	1.04	-0.79	2.94	2.73	0.02	0.79
July	9	8.58	-0.06	-0.49	-1.87	-2.59	-2.37	-0.24	0.99	-0.80	2.68	2.67	0.02	0.71
Aug	9	8.67	-0.06	-0.49	-1.86	-2.55	-2.36	-0.24	0.96	-0.80	2.53	2.63	0.01	0.68
Sep	9	8.75	-0.08	-1.27	-5.25	-6.94	-4.44	-0.30	1.09	-1.03	3.30	2.83	-0.04	1.93
Oct	9	8.83	-0.08	-0.68	-2.23	-2.81	-2.59	-0.28	1.11	-0.68	3.29	2.86	0.01	2.33
Nov	9	8.92	-0.08	-0.58	-2.01	-2.72	-2.52	-0.27	1.02	-0.89	2.73	2.75	0.00	0.85
Dec	9	9.00	-0.08	-0.55	-1.97	-2.67	-2.48	-0.26	1.00	-0.88	2.63	2.72	0.01	0.79
Jan	10	9.08	-0.08	-0.55	-1.97	-2.67	-2.48	-0.26	1.00	-0.88	2.63	2.72	0.01	0.79
Feb	10	9.17	-0.07	-0.54	-1.99	-2.67	-2.45	-0.27	1.08	-0.70	3.27	2.93	0.03	2.58
Mar	10	9.25	-0.08	-0.97	-3.90	-5.18	-3.65	-0.30	1.13	-0.90	3.43	2.98	0.00	2.53
Apr	10	9.33	-0.09	-1.11	-4.83	-7.21	-4.44	-0.34	1.15	-1.75	3.53	3.05	-0.05	0.70
May	10	9.42	-0.10	-1.03	-3.76	-4.83	-3.66	-0.34	1.16	-0.95	3.55	3.06	-0.02	2.53
June	10	9.50	-0.10	-0.70	-2.30	-3.01	-2.79	-0.33	1.12	-1.01	3.25	3.02	-0.01	1.11
July	10	9.58	-0.10	-0.63	-2.18	-2.90	-2.69	-0.32	1.09	-0.99	3.09	2.99	0.00	1.05
Aug	10	9.67	-0.09	-0.60	-2.14	-2.87	-2.67	-0.31	1.07	-1.05	2.97	2.97	0.00	0.54
Sep	10	9.75	-0.09	-0.60	-2.13	-2.83	-2.63	-0.31	1.06	-0.99	2.90	2.95	0.01	0.82
Oct	10	9.83	-0.09	-0.94	-3.63	-4.77	-3.55	-0.33	1.18	-1.09	3.46	3.09	-0.02	1.17
Nov	10	9.92	-0.09	-0.67	-2.25	-2.89	-2.70	-0.32	1.15	-1.00	3.22	3.06	0.00	0.86
Dec	10	10.00	-0.09	-0.62	-2.14	-2.81	-2.63	-0.32	1.12	-0.98	3.06	3.03	0.01	0.84
Jan	11	10.08	-0.09	-0.60	-2.10	-2.75	-2.58	-0.31	1.15	-0.94	3.17	3.06	0.02	0.95
Feb	11	10.17	-0.09	-0.85	-3.24	-4.23	-3.27	-0.33	1.20	-0.80	3.44	3.14	0.01	2.51
Mar	11	10.25	-0.10	-1.02	-3.80	-4.96	-3.69	-0.34	1.24	-1.11	3.50	3.18	-0.02	1.04
Apr	11	10.33	-0.11	-1.10	-4.01	-5.17	-3.83	-0.36	1.23	-1.07	3.42	3.18	-0.03	1.41
May	11	10.42	-0.11	-0.94	-3.21	-4.16	-3.40	-0.36	1.23	-1.21	3.40	3.20	-0.03	0.07
June	11	10.50	-0.11	-0.72	-2.31	-2.95	-2.79	-0.34	1.15	-0.97	2.95	3.09	-0.01	0.90
July	11	10.58	-0.10	-0.67	-2.21	-2.86	-2.71	-0.34	1.13	-0.94	2.87	3.06	0.00	0.90
Aug	11	10.67	-0.10	-0.65	-2.18	-2.81	-2.66	-0.33	1.13	-0.92	2.83	3.05	0.00	0.89
Sep	11	10.75	-0.10	-0.64	-2.16	-2.77	-2.63	-0.33	1.13	-0.91	2.80	3.04	0.01	0.87
Oct	11	10.83	-0.10	-0.64	-2.14	-2.73	-2.60	-0.33	1.13	-0.91	2.78	3.04	0.01	0.77
Nov	11	10.92	-0.10	-0.63	-2.12	-2.69	-2.56	-0.33	1.13	-0.89	2.75	3.02	0.01	0.85
Dec	11	11.00	-0.09	-0.63	-2.10	-2.65	-2.53	-0.33	1.13	-0.88	2.72	3.01	0.01	0.83

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
Jan	12	11.08	-0.09	-0.63	-2.08	-2.61	-2.50	-0.33	1.14	-0.86	2.69	3.00	0.01	0.83
Feb	12	11.17	-0.09	-0.64	-2.10	-2.63	-2.50	-0.33	1.14	-0.87	2.69	3.00	0.01	0.74
Mar	12	11.25	-0.10	-0.63	-2.06	-2.56	-2.46	-0.33	1.14	-0.87	2.67	2.99	0.01	0.67
Apr	12	11.33	-0.10	-0.63	-2.05	-2.58	-2.47	-0.33	1.18	-1.00	2.79	3.02	0.01	-0.12
May	12	11.42	-0.10	-0.63	-2.03	-2.53	-2.44	-0.33	1.17	-0.97	2.74	3.01	0.01	0.05
June	12	11.50	-0.10	-0.63	-2.01	-2.50	-2.41	-0.33	1.17	-0.94	2.68	2.99	0.01	0.23
July	12	11.58	-0.10	-0.63	-1.99	-2.44	-2.36	-0.33	1.15	-0.85	2.58	2.96	0.01	0.67
Aug	12	11.67	-0.10	-0.63	-1.97	-2.41	-2.33	-0.33	1.15	-0.83	2.55	2.94	0.01	0.67
Sep	12	11.75	-0.10	-0.63	-1.96	-2.38	-2.30	-0.34	1.15	-0.82	2.53	2.93	0.02	0.67
Oct	12	11.83	-0.10	-0.63	-1.94	-2.35	-2.27	-0.34	1.15	-0.81	2.51	2.92	0.02	0.67
Nov	12	11.92	-0.10	-0.63	-1.93	-2.32	-2.25	-0.34	1.15	-0.80	2.49	2.91	0.02	0.66
Dec	12	12.00	-0.10	-0.63	-1.91	-2.29	-2.22	-0.34	1.15	-0.79	2.47	2.89	0.02	0.66
Jan	13	12.08	-0.10	-0.68	-2.12	-2.57	-2.34	-0.34	1.18	-0.81	2.58	2.91	0.01	0.63
Feb	13	12.17	-0.11	-0.88	-3.50	-4.98	-3.19	-0.36	1.30	-0.62	3.33	3.08	0.03	4.90
Mar	13	12.25	-0.11	-0.91	-3.00	-3.78	-3.01	-0.37	1.31	-1.08	3.15	3.10	-0.01	-0.23
Apr	13	12.33	-0.11	-0.72	-2.09	-2.53	-2.40	-0.36	1.22	-0.80	2.67	2.98	0.01	0.77
May	13	12.42	-0.11	-0.68	-2.00	-2.45	-2.33	-0.35	1.20	-0.77	2.59	2.95	0.01	0.78
June	13	12.50	-0.11	-0.66	-1.97	-2.41	-2.30	-0.35	1.19	-0.76	2.55	2.93	0.02	0.77
July	13	12.58	-0.11	-0.66	-1.96	-2.38	-2.27	-0.35	1.19	-0.75	2.53	2.92	0.02	0.76
Aug	13	12.67	-0.11	-0.65	-1.94	-2.35	-2.24	-0.35	1.19	-0.74	2.50	2.90	0.02	0.75
Sep	13	12.75	-0.11	-0.65	-1.92	-2.32	-2.21	-0.35	1.19	-0.73	2.48	2.89	0.02	0.74
Oct	13	12.83	-0.11	-0.65	-1.91	-2.29	-2.19	-0.35	1.19	-0.72	2.46	2.87	0.02	0.73
Nov	13	12.92	-0.11	-0.65	-1.89	-2.26	-2.17	-0.35	1.19	-0.72	2.44	2.86	0.02	0.73
Dec	13	13.00	-0.11	-0.65	-1.88	-2.23	-2.14	-0.35	1.19	-0.71	2.43	2.85	0.02	0.72
Jan	14	13.08	-0.11	-0.65	-1.86	-2.21	-2.12	-0.35	1.19	-0.70	2.41	2.84	0.02	0.71
Feb	14	13.17	-0.12	-1.12	-6.75	-12.53	-5.53	-0.42	1.31	-2.70	3.26	3.04	-0.05	4.14
Mar	14	13.25	-0.13	-1.03	-3.37	-4.08	-3.23	-0.42	1.34	-1.13	3.17	3.06	-0.03	0.17
Apr	14	13.33	-0.14	-0.79	-2.19	-2.56	-2.42	-0.40	1.25	-0.79	2.67	2.94	0.00	0.87
May	14	13.42	-0.13	-0.74	-2.06	-2.46	-2.31	-0.38	1.25	-0.76	2.68	2.94	0.00	0.88
June	14	13.50	-0.13	-0.71	-2.03	-2.46	-2.29	-0.37	1.28	-0.86	2.78	2.97	0.01	0.22
July	14	13.58	-0.13	-0.70	-2.00	-2.43	-2.26	-0.37	1.27	-0.87	2.69	2.95	0.01	0.13
Aug	14	13.67	-0.13	-0.69	-1.98	-2.36	-2.21	-0.37	1.24	-0.75	2.55	2.90	0.01	0.75
Sep	14	13.75	-0.13	-0.69	-1.96	-2.33	-2.17	-0.37	1.23	-0.73	2.51	2.88	0.02	0.76
Oct	14	13.83	-0.13	-0.69	-1.94	-2.30	-2.14	-0.37	1.23	-0.72	2.49	2.87	0.02	0.76
Nov	14	13.92	-0.13	-0.68	-1.93	-2.29	-2.13	-0.37	1.27	-0.71	2.63	2.90	0.02	0.73
Dec	14	14.00	-0.13	-0.68	-1.90	-2.17	-2.03	-0.36	1.34	-0.50	3.02	3.00	0.04	2.24
Jan	15	14.08	-0.13	-0.68	-1.93	-2.24	-2.01	-0.37	1.33	-0.50	3.18	3.13	0.06	3.36
Feb	15	14.17	-0.13	-0.68	-1.99	-2.33	-2.03	-0.36	1.42	-0.25	3.73	3.29	0.09	5.44
Mar	15	14.25	-0.13	-0.68	-2.12	-2.72	-2.26	-0.37	1.50	-0.44	4.07	3.45	0.09	4.64
Apr	15	14.33	-0.13	-0.68	-2.14	-2.69	-2.22	-0.37	1.50	-0.43	4.19	3.56	0.11	5.69
May	15	14.42	-0.13	-0.68	-2.16	-2.71	-2.23	-0.37	1.66	-0.57	5.00	3.81	0.12	5.47
June	15	14.50	-0.13	-0.69	-2.18	-2.91	-2.41	-0.38	1.44	-1.24	3.68	3.56	0.06	1.35
July	15	14.58	-0.13	-0.69	-2.18	-2.89	-2.44	-0.39	1.36	-1.28	3.38	3.47	0.05	1.12
Aug	15	14.67	-0.13	-0.69	-2.18	-2.86	-2.45	-0.39	1.33	-1.28	3.28	3.44	0.04	1.03
Sep	15	14.75	-0.13	-0.73	-2.38	-3.04	-2.54	-0.39	1.50	-0.61	4.31	3.68	0.09	5.30
Oct	15	14.83	-0.13	-0.70	-2.28	-3.06	-2.62	-0.40	1.41	-1.24	3.58	3.56	0.05	1.25
Nov	15	14.92	-0.14	-0.70	-2.27	-3.02	-2.63	-0.40	1.37	-1.26	3.36	3.50	0.04	1.09
Dec	15	15.00	-0.14	-0.70	-2.26	-2.98	-2.62	-0.40	1.35	-1.25	3.29	3.48	0.04	1.04
Jan	16	15.08	-0.14	-0.70	-2.25	-2.94	-2.61	-0.41	1.35	-1.24	3.24	3.46	0.04	1.00
Feb	16	15.17	-0.15	-1.27	-4.71	-6.02	-4.05	-0.44	1.46	-0.98	3.87	3.58	0.02	3.94
Mar	16	15.25	-0.16	-1.35	-4.66	-5.91	-4.12	-0.46	1.51	-1.32	3.97	3.65	-0.01	1.85
Apr	16	15.33	-0.18	-1.49	-5.11	-6.41	-4.38	-0.48	1.51	-1.14	3.96	3.66	-0.02	3.19
May	16	15.42	-0.18	-1.01	-2.92	-3.61	-3.12	-0.46	1.44	-1.28	3.53	3.59	0.00	0.92
June	16	15.50	-0.17	-0.86	-2.44	-3.07	-2.81	-0.44	1.40	-1.18	3.31	3.53	0.01	1.10
July	16	15.58	-0.17	-0.81	-2.37	-2.99	-2.74	-0.43	1.38	-1.15	3.24	3.51	0.02	1.07
Aug	16	15.67	-0.16	-0.79	-2.34	-2.95	-2.70	-0.43	1.38	-1.13	3.20	3.49	0.02	1.04
Sep	16	15.75	-0.16	-0.80	-2.44	-3.07	-2.75	-0.43	1.40	-1.16	3.25	3.50	0.02	0.83
Oct	16	15.83	-0.16	-0.77	-2.31	-2.87	-2.65	-0.42	1.38	-1.10	3.15	3.47	0.02	0.98
Nov	16	15.92	-0.15	-0.77	-2.29	-2.83	-2.62	-0.42	1.38	-1.08	3.11	3.46	0.03	0.96
Dec	16	16.00	-0.15	-0.76	-2.27	-2.79	-2.59	-0.42	1.38	-1.06	3.08	3.44	0.03	0.95
Jan	17	16.08	-0.15	-0.76	-2.25	-2.75	-2.56	-0.42	1.38	-1.05	3.05	3.43	0.03	0.93
Feb	17	16.17	-0.15	-0.77	-2.28	-2.78	-2.57	-0.42	1.39	-1.05	3.06	3.43	0.03	0.84
Mar	17	16.25	-0.15	-0.77	-2.28	-2.78	-2.56	-0.43	1.39	-1.03	3.04	3.42	0.03	0.84
Apr	17	16.33	-0.15	-0.78	-2.28	-2.76	-2.54	-0.43	1.39	-1.02	3.02	3.40	0.03	0.81
May	17	16.42	-0.15	-0.76	-2.19	-2.63	-2.47	-0.43	1.38	-0.99	2.96	3.38	0.03	0.86
June	17	16.50	-0.15	-0.76	-2.17	-2.59	-2.44	-0.43	1.38	-0.97	2.93	3.37	0.03	0.86

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
July	17	16.58	-0.15	-0.76	-2.15	-2.56	-2.41	-0.43	1.38	-0.96	2.90	3.35	0.03	0.85
Aug	17	16.67	-0.16	-0.77	-2.23	-2.68	-2.47	-0.43	1.41	-1.04	3.00	3.37	0.02	0.33
Sep	17	16.75	-0.16	-0.76	-2.12	-2.51	-2.37	-0.43	1.39	-0.94	2.87	3.33	0.03	0.79
Oct	17	16.83	-0.16	-0.75	-2.10	-2.48	-2.34	-0.43	1.38	-0.92	2.84	3.31	0.03	0.79
Nov	17	16.92	-0.16	-0.75	-2.09	-2.45	-2.32	-0.43	1.38	-0.91	2.81	3.30	0.03	0.79
Dec	17	17.00	-0.16	-0.75	-2.07	-2.42	-2.29	-0.43	1.38	-0.89	2.79	3.28	0.03	0.79
Jan	18	17.08	-0.16	-0.75	-2.05	-2.39	-2.26	-0.43	1.38	-0.88	2.77	3.27	0.03	0.78
Feb	18	17.17	-0.16	-0.75	-2.06	-2.40	-2.26	-0.43	1.39	-0.89	2.78	3.26	0.03	0.63
Mar	18	17.25	-0.16	-0.91	-2.71	-3.30	-2.71	-0.44	1.47	-1.11	3.16	3.36	0.01	-0.23
Apr	18	17.33	-0.17	-1.19	-3.84	-4.68	-3.36	-0.47	1.49	-0.95	3.26	3.37	0.00	1.37
May	18	17.42	-0.17	-0.98	-2.72	-3.22	-2.74	-0.47	1.48	-1.16	3.15	3.37	-0.01	-0.54
June	18	17.50	-0.17	-0.83	-2.12	-2.43	-2.32	-0.46	1.41	-0.88	2.81	3.27	0.01	0.67
July	18	17.58	-0.17	-0.80	-2.05	-2.37	-2.25	-0.45	1.40	-0.85	2.75	3.24	0.02	0.70
Aug	18	17.67	-0.17	-0.78	-2.02	-2.33	-2.21	-0.44	1.39	-0.83	2.72	3.23	0.02	0.71
Sep	18	17.75	-0.17	-0.77	-2.00	-2.30	-2.18	-0.44	1.39	-0.82	2.70	3.21	0.02	0.71
Oct	18	17.83	-0.17	-0.77	-1.98	-2.27	-2.15	-0.44	1.39	-0.80	2.68	3.20	0.03	0.71
Nov	18	17.92	-0.17	-0.77	-1.97	-2.25	-2.13	-0.44	1.39	-0.79	2.66	3.19	0.03	0.71
Dec	18	18.00	-0.17	-0.76	-1.95	-2.22	-2.10	-0.44	1.39	-0.78	2.64	3.17	0.03	0.71
Jan	19	18.08	-0.17	-0.77	-1.99	-2.41	-2.20	-0.46	1.44	-1.18	3.13	3.39	0.02	-0.48
Feb	19	18.17	-0.17	-0.76	-1.98	-2.32	-2.14	-0.46	1.40	-0.99	2.93	3.31	0.03	0.65
Mar	19	18.25	-0.17	-0.76	-1.97	-2.32	-2.13	-0.46	1.41	-1.04	2.96	3.32	0.03	0.31
Apr	19	18.33	-0.17	-0.76	-1.96	-2.31	-2.13	-0.46	1.42	-1.06	2.99	3.33	0.03	0.17
May	19	18.42	-0.17	-0.76	-1.95	-2.31	-2.13	-0.47	1.44	-1.11	3.06	3.35	0.02	-0.13
June	19	18.50	-0.17	-0.76	-1.94	-2.25	-2.09	-0.47	1.41	-1.02	2.91	3.31	0.03	0.34
July	19	18.58	-0.17	-0.79	-2.04	-2.39	-2.14	-0.47	1.43	-1.02	2.98	3.32	0.03	0.33
Aug	19	18.67	-0.17	-0.82	-2.16	-2.52	-2.20	-0.47	1.43	-0.98	2.95	3.31	0.03	0.60
Sep	19	18.75	-0.18	-1.56	-5.75	-7.82	-4.51	-0.56	1.48	-1.53	3.60	3.49	-0.04	1.66
Oct	19	18.83	-0.19	-0.97	-2.33	-2.59	-2.38	-0.54	1.52	-1.04	3.47	3.48	0.01	0.81
Nov	19	18.92	-0.19	-0.87	-2.08	-2.42	-2.22	-0.53	1.48	-0.96	3.21	3.42	0.02	0.92
Dec	19	19.00	-0.18	-0.84	-2.03	-2.38	-2.18	-0.52	1.44	-0.96	2.98	3.36	0.02	0.77
Jan	20	19.08	-0.18	-0.82	-2.04	-2.38	-2.14	-0.52	1.51	-0.71	3.46	3.50	0.05	2.48
Feb	20	19.17	-0.18	-0.81	-2.04	-2.37	-2.11	-0.53	1.56	-0.70	3.76	3.61	0.06	2.89
Mar	20	19.25	-0.18	-0.81	-2.14	-2.67	-2.28	-0.54	1.63	-0.75	4.16	3.78	0.07	3.02
Apr	20	19.33	-0.18	-0.81	-2.28	-2.99	-2.47	-0.54	1.67	-0.60	4.44	3.93	0.09	4.38
May	20	19.42	-0.18	-0.81	-2.28	-2.87	-2.39	-0.54	1.76	-0.39	4.92	4.11	0.12	5.45
June	20	19.50	-0.18	-0.81	-2.28	-2.90	-2.42	-0.54	1.80	-0.62	4.98	4.18	0.11	3.93
July	20	19.58	-0.18	-0.80	-2.27	-2.84	-2.39	-0.53	1.99	-0.60	5.84	4.45	0.13	4.08
Aug	20	19.67	-0.18	-0.80	-2.32	-3.01	-2.53	-0.53	1.97	-0.78	5.58	4.47	0.12	3.07
Sep	20	19.75	-0.18	-0.81	-2.45	-3.34	-2.76	-0.54	1.90	-0.89	5.26	4.48	0.11	2.73
Oct	20	19.83	-0.18	-0.82	-2.52	-3.79	-3.17	-0.55	1.76	-2.28	4.40	4.34	0.02	-5.36
Nov	20	19.92	-0.18	-0.82	-2.50	-3.40	-2.96	-0.55	1.73	-1.27	4.52	4.30	0.06	0.82
Dec	20	20.00	-0.18	-0.82	-2.48	-3.27	-2.88	-0.56	1.70	-1.08	4.35	4.25	0.07	1.75
Jan	21	20.08	-0.18	-0.82	-2.52	-3.45	-3.03	-0.56	1.73	-1.51	4.45	4.32	0.05	-0.67
Feb	21	20.17	-0.19	-0.83	-2.57	-3.49	-3.06	-0.56	1.80	-1.16	4.83	4.43	0.07	1.68
Mar	21	20.25	-0.19	-1.23	-4.59	-6.46	-4.40	-0.59	1.85	-1.59	5.02	4.50	0.03	1.33
Apr	21	20.33	-0.21	-1.48	-5.17	-6.72	-4.73	-0.62	1.85	-1.41	4.97	4.51	0.01	1.91
May	21	20.42	-0.22	-1.25	-3.95	-5.08	-4.02	-0.62	1.87	-1.42	5.03	4.55	0.02	1.11
June	21	20.50	-0.22	-0.98	-2.83	-3.61	-3.30	-0.60	1.79	-1.21	4.53	4.44	0.04	1.59
July	21	20.58	-0.21	-0.94	-2.82	-3.62	-3.26	-0.59	1.78	-1.16	4.47	4.43	0.05	1.71
Aug	21	20.67	-0.21	-0.90	-2.69	-3.43	-3.15	-0.58	1.76	-1.13	4.36	4.41	0.05	1.71
Sep	21	20.75	-0.20	-0.89	-2.66	-3.42	-3.15	-0.58	1.79	-1.27	4.45	4.44	0.05	0.83
Oct	21	20.83	-0.20	-0.96	-2.99	-3.82	-3.33	-0.58	1.81	-1.26	4.48	4.46	0.05	1.02
Nov	21	20.92	-0.20	-0.90	-2.65	-3.30	-3.08	-0.58	1.77	-1.12	4.26	4.41	0.06	1.56
Dec	21	21.00	-0.20	-0.88	-2.61	-3.23	-3.02	-0.57	1.77	-1.10	4.20	4.39	0.06	1.56
Jan	22	21.08	-0.20	-0.88	-2.59	-3.19	-2.99	-0.57	1.77	-1.09	4.17	4.38	0.06	1.54
Feb	22	21.17	-0.21	-1.26	-6.30	-11.04	-5.74	-0.63	1.83	-3.19	4.59	4.53	-0.03	0.21
Mar	22	21.25	-0.22	-1.34	-5.08	-7.24	-4.81	-0.65	1.90	-1.92	4.94	4.62	-0.01	1.71
Apr	22	21.33	-0.23	-1.19	-3.66	-4.51	-3.83	-0.63	1.89	-1.36	4.71	4.58	0.01	1.25
May	22	21.42	-0.22	-1.01	-2.87	-3.50	-3.28	-0.61	1.83	-1.18	4.38	4.51	0.03	1.56
June	22	21.50	-0.22	-0.96	-2.77	-3.42	-3.20	-0.60	1.83	-1.19	4.33	4.50	0.04	1.26
July	22	21.58	-0.22	-0.94	-2.73	-3.34	-3.13	-0.59	1.82	-1.12	4.23	4.47	0.05	1.53
Aug	22	21.67	-0.21	-0.93	-2.70	-3.29	-3.08	-0.59	1.82	-1.10	4.19	4.46	0.05	1.52
Sep	22	21.75	-0.21	-0.92	-2.68	-3.28	-3.07	-0.58	1.84	-1.18	4.24	4.48	0.05	0.89
Oct	22	21.83	-0.22	-1.14	-3.61	-4.48	-3.64	-0.60	1.91	-1.24	4.54	4.55	0.04	1.11
Nov	22	21.92	-0.22	-1.00	-2.88	-3.44	-3.15	-0.59	1.86	-1.10	4.22	4.48	0.05	1.37
Dec	22	22.00	-0.22	-0.95	-2.66	-3.17	-2.99	-0.59	1.84	-1.05	4.09	4.44	0.05	1.43

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
Jan	23	22.08	-0.22	-1.10	-4.01	-5.86	-3.93	-0.61	1.94	-1.60	4.60	4.57	0.03	1.84
Feb	23	22.17	-0.23	-1.27	-5.90	-10.04	-5.35	-0.65	1.95	-2.70	4.71	4.63	-0.02	1.90
Mar	23	22.25	-0.23	-1.20	-4.34	-6.30	-4.30	-0.65	1.98	-1.93	4.80	4.67	0.00	1.03
Apr	23	22.33	-0.24	-1.46	-4.75	-5.86	-4.42	-0.65	1.98	-1.36	4.71	4.66	0.00	1.48
May	23	22.42	-0.24	-1.18	-3.33	-3.97	-3.51	-0.63	1.94	-1.21	4.45	4.60	0.02	1.22
June	23	22.50	-0.24	-1.05	-2.87	-3.42	-3.19	-0.62	1.90	-1.08	4.23	4.55	0.04	1.49
July	23	22.58	-0.24	-1.01	-2.80	-3.34	-3.11	-0.61	1.90	-1.05	4.17	4.53	0.04	1.49
Aug	23	22.67	-0.23	-0.99	-2.76	-3.29	-3.05	-0.60	1.90	-1.02	4.13	4.51	0.05	1.49
Sep	23	22.75	-0.23	-0.98	-2.73	-3.24	-3.01	-0.60	1.90	-1.00	4.10	4.50	0.05	1.48
Oct	23	22.83	-0.23	-0.98	-2.70	-3.19	-2.97	-0.59	1.90	-0.98	4.06	4.49	0.05	1.47
Nov	23	22.92	-0.23	-0.97	-2.68	-3.15	-2.93	-0.59	1.90	-0.97	4.03	4.47	0.06	1.46
Dec	23	23.00	-0.23	-0.97	-2.65	-3.11	-2.89	-0.59	1.91	-0.95	4.00	4.46	0.06	1.45
Jan	24	23.08	-0.23	-1.07	-3.24	-4.07	-3.26	-0.60	1.96	-1.06	4.27	4.52	0.05	1.76
Feb	24	23.17	-0.23	-1.23	-4.06	-5.37	-3.79	-0.61	2.02	-1.15	4.53	4.58	0.04	2.60
Mar	24	23.25	-0.24	-1.36	-4.72	-6.56	-4.33	-0.63	2.05	-1.65	4.62	4.64	0.01	1.00
Apr	24	23.33	-0.25	-1.47	-4.54	-5.49	-4.14	-0.64	2.04	-1.18	4.54	4.62	0.01	1.42
May	24	23.42	-0.26	-1.49	-4.45	-5.34	-4.07	-0.65	2.08	-1.07	4.72	4.67	0.01	1.83
June	24	23.50	-0.26	-1.15	-2.92	-3.34	-3.11	-0.63	1.98	-0.95	4.15	4.55	0.03	1.51
July	24	23.58	-0.25	-1.13	-3.04	-3.58	-3.17	-0.62	1.99	-0.98	4.21	4.55	0.04	1.31
Aug	24	23.67	-0.25	-1.06	-2.75	-3.19	-2.96	-0.61	1.97	-0.90	4.04	4.51	0.05	1.47
Sep	24	23.75	-0.25	-1.03	-2.70	-3.13	-2.90	-0.60	1.96	-0.88	3.99	4.49	0.05	1.47
Oct	24	23.83	-0.24	-1.02	-2.67	-3.09	-2.86	-0.60	1.96	-0.86	3.96	4.47	0.05	1.46
Nov	24	23.92	-0.24	-1.10	-3.13	-3.92	-3.20	-0.60	2.05	-1.13	4.34	4.57	0.04	0.66
Dec	24	24.00	-0.24	-1.03	-2.68	-3.07	-2.85	-0.60	1.98	-0.86	3.97	4.47	0.05	1.39
Jan	25	24.08	-0.24	-1.02	-2.63	-3.01	-2.79	-0.60	1.97	-0.83	3.91	4.44	0.06	1.40
Feb	25	24.17	-0.25	-1.46	-5.92	-9.22	-5.05	-0.64	2.06	-1.98	4.48	4.58	0.00	2.43
Mar	25	24.25	-0.26	-1.39	-4.14	-5.07	-3.86	-0.65	2.11	-1.19	4.59	4.63	0.01	1.22
Apr	25	24.33	-0.27	-1.59	-4.92	-6.12	-4.35	-0.66	2.10	-1.20	4.53	4.63	0.00	1.40
May	25	24.42	-0.27	-1.49	-4.25	-5.07	-3.93	-0.66	2.14	-1.08	4.65	4.67	0.01	1.20
June	25	24.50	-0.27	-1.19	-2.92	-3.33	-3.07	-0.63	2.05	-0.88	4.13	4.55	0.03	1.48
July	25	24.58	-0.27	-1.12	-2.78	-3.22	-2.96	-0.62	2.03	-0.84	4.04	4.52	0.04	1.48
Aug	25	24.67	-0.26	-1.09	-2.74	-3.16	-2.90	-0.61	2.03	-0.81	4.00	4.50	0.05	1.49
Sep	25	24.75	-0.26	-1.11	-2.87	-3.42	-3.04	-0.61	2.10	-1.10	4.30	4.58	0.03	-0.15
Oct	25	24.83	-0.26	-1.10	-2.80	-3.27	-2.94	-0.61	2.06	-0.93	4.07	4.51	0.04	0.80
Nov	25	24.92	-0.26	-1.07	-2.67	-3.07	-2.82	-0.61	2.03	-0.81	3.94	4.47	0.05	1.34
Dec	25	25.00	-0.26	-1.06	-2.64	-3.02	-2.77	-0.60	2.03	-0.78	3.90	4.45	0.05	1.36
Jan	26	25.08	-0.25	-1.05	-2.64	-2.99	-2.75	-0.60	2.08	-0.53	4.18	4.51	0.07	2.81
Feb	26	25.17	-0.26	-1.62	-6.08	-8.93	-5.10	-0.65	2.15	-1.65	4.54	4.62	0.00	2.49
Mar	26	25.25	-0.27	-1.27	-3.30	-3.81	-3.31	-0.64	2.12	-0.98	4.27	4.57	0.03	0.96
Apr	26	25.33	-0.27	-1.14	-2.79	-3.21	-2.95	-0.62	2.08	-0.80	4.04	4.50	0.04	1.48
May	26	25.42	-0.27	-1.11	-2.72	-3.15	-2.88	-0.62	2.07	-0.79	4.01	4.49	0.05	1.36
June	26	25.50	-0.27	-1.09	-2.68	-3.09	-2.83	-0.61	2.07	-0.75	3.95	4.46	0.05	1.48
July	26	25.58	-0.26	-1.08	-2.65	-3.05	-2.78	-0.61	2.07	-0.74	3.92	4.45	0.06	1.47
Aug	26	25.67	-0.26	-1.07	-2.63	-3.01	-2.75	-0.60	2.07	-0.72	3.90	4.43	0.06	1.47
Sep	26	25.75	-0.26	-1.07	-2.61	-2.97	-2.71	-0.60	2.07	-0.71	3.87	4.41	0.06	1.47
Oct	26	25.83	-0.26	-1.06	-2.60	-2.97	-2.70	-0.60	2.17	-0.60	4.36	4.53	0.07	2.13
Nov	26	25.92	-0.26	-1.06	-2.60	-2.98	-2.70	-0.60	2.16	-0.64	4.20	4.50	0.07	1.83
Dec	26	26.00	-0.26	-1.06	-2.58	-2.96	-2.69	-0.60	2.10	-0.68	3.90	4.43	0.07	1.50
Jan	27	26.08	-0.26	-1.07	-2.70	-3.68	-3.22	-0.61	2.02	-2.28	3.46	4.44	-0.02	-7.37
Feb	27	26.17	-0.26	-1.07	-2.73	-3.38	-3.03	-0.61	2.17	-0.78	4.53	4.61	0.06	1.94
Mar	27	26.25	-0.27	-1.07	-2.74	-3.46	-3.07	-0.61	2.23	-0.96	4.66	4.66	0.06	0.70
Apr	27	26.33	-0.27	-1.07	-2.74	-3.40	-3.03	-0.61	2.24	-0.76	4.65	4.66	0.07	1.92
May	27	26.42	-0.27	-1.07	-2.75	-3.37	-2.99	-0.61	2.30	-0.62	4.96	4.76	0.09	3.04
June	27	26.50	-0.27	-1.06	-2.75	-3.42	-3.04	-0.61	2.25	-0.87	4.60	4.70	0.07	1.53
July	27	26.58	-0.27	-1.06	-2.74	-3.38	-3.02	-0.61	2.20	-0.88	4.33	4.64	0.07	1.45
Aug	27	26.67	-0.27	-1.06	-2.73	-3.33	-3.00	-0.61	2.17	-0.88	4.18	4.59	0.06	1.42
Sep	27	26.75	-0.28	-1.84	-6.11	-7.71	-5.08	-0.66	2.30	-1.10	4.94	4.78	0.01	2.68
Oct	27	26.83	-0.29	-1.25	-3.08	-3.58	-3.22	-0.64	2.31	-0.75	4.93	4.80	0.07	3.09
Nov	27	26.92	-0.29	-1.15	-2.85	-3.48	-3.13	-0.63	2.22	-0.95	4.36	4.68	0.06	1.59
Dec	27	27.00	-0.29	-1.11	-2.81	-3.42	-3.09	-0.62	2.19	-0.94	4.26	4.65	0.06	1.54
Jan	28	27.08	-0.28	-1.10	-2.82	-3.41	-3.04	-0.63	2.28	-0.75	4.89	4.85	0.09	3.35
Feb	28	27.17	-0.29	-1.53	-4.73	-5.92	-4.24	-0.66	2.32	-0.94	5.05	4.89	0.05	3.29
Mar	28	27.25	-0.30	-1.66	-5.65	-7.94	-5.04	-0.69	2.34	-1.80	5.14	4.95	0.00	1.43
Apr	28	27.33	-0.31	-1.58	-4.57	-5.55	-4.25	-0.69	2.35	-0.99	5.16	4.95	0.03	3.29
May	28	27.42	-0.31	-1.25	-3.11	-3.72	-3.37	-0.67	2.31	-1.04	4.85	4.91	0.05	1.86
June	28	27.50	-0.30	-1.18	-2.97	-3.60	-3.26	-0.66	2.28	-1.02	4.69	4.87	0.05	1.80

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
July	28	27.58	-0.30	-1.15	-2.93	-3.57	-3.23	-0.65	2.26	-1.08	4.56	4.84	0.05	1.29
Aug	28	27.67	-0.30	-1.14	-2.92	-3.52	-3.19	-0.65	2.24	-1.02	4.49	4.81	0.06	1.57
Sep	28	27.75	-0.30	-1.48	-4.41	-5.46	-4.10	-0.67	2.36	-1.11	5.04	4.95	0.04	1.92
Oct	28	27.83	-0.30	-1.21	-3.02	-3.57	-3.24	-0.66	2.33	-1.02	4.79	4.91	0.06	1.61
Nov	28	27.92	-0.30	-1.16	-2.91	-3.48	-3.17	-0.65	2.30	-1.00	4.63	4.87	0.06	1.58
Dec	28	28.00	-0.30	-1.14	-2.87	-3.42	-3.12	-0.65	2.26	-0.96	4.41	4.81	0.06	1.64
Jan	29	28.08	-0.30	-1.13	-2.86	-3.41	-3.11	-0.64	2.32	-0.94	4.72	4.89	0.07	1.70
Feb	29	28.17	-0.30	-1.38	-3.99	-4.88	-3.79	-0.66	2.37	-0.80	4.99	4.97	0.07	3.27
Mar	29	28.25	-0.31	-1.55	-4.54	-5.60	-4.20	-0.68	2.40	-1.10	5.05	5.00	0.04	1.79
Apr	29	28.33	-0.32	-1.63	-4.75	-5.81	-4.33	-0.69	2.39	-1.06	4.96	4.99	0.03	2.17
May	29	28.42	-0.32	-1.47	-3.94	-4.79	-3.89	-0.69	2.39	-1.21	4.94	5.00	0.03	0.81
June	29	28.50	-0.32	-1.25	-3.03	-3.57	-3.28	-0.67	2.31	-0.96	4.49	4.89	0.05	1.64
July	29	28.58	-0.31	-1.20	-2.93	-3.47	-3.19	-0.66	2.29	-0.92	4.40	4.85	0.05	1.65
Aug	29	28.67	-0.31	-1.17	-2.89	-3.42	-3.14	-0.66	2.28	-0.90	4.36	4.83	0.06	1.64
Sep	29	28.75	-0.31	-1.16	-2.86	-3.37	-3.10	-0.65	2.28	-0.89	4.32	4.82	0.06	1.63
Oct	29	28.83	-0.31	-1.15	-2.84	-3.33	-3.06	-0.65	2.28	-0.89	4.30	4.80	0.06	1.51
Nov	29	28.92	-0.30	-1.15	-2.81	-3.28	-3.02	-0.65	2.28	-0.86	4.26	4.79	0.07	1.59
Dec	29	29.00	-0.30	-1.14	-2.79	-3.23	-2.99	-0.65	2.28	-0.84	4.23	4.77	0.07	1.59
Jan	30	29.08	-0.30	-1.14	-2.77	-3.19	-2.95	-0.65	2.28	-0.83	4.20	4.75	0.07	1.57
Feb	30	29.17	-0.30	-1.14	-2.78	-3.21	-2.94	-0.65	2.28	-0.83	4.19	4.74	0.07	1.49
Mar	30	29.25	-0.30	-1.14	-2.73	-3.13	-2.89	-0.64	2.28	-0.83	4.17	4.73	0.07	1.42
Apr	30	29.33	-0.30	-1.13	-2.71	-3.14	-2.90	-0.64	2.31	-0.96	4.27	4.76	0.06	0.61
May	30	29.42	-0.30	-1.13	-2.69	-3.09	-2.86	-0.64	2.31	-0.93	4.22	4.74	0.06	0.78
June	30	29.50	-0.31	-1.13	-2.67	-3.04	-2.83	-0.64	2.30	-0.89	4.16	4.71	0.07	0.95
July	30	29.58	-0.31	-1.13	-2.64	-2.98	-2.77	-0.64	2.28	-0.80	4.06	4.67	0.07	1.40
Aug	30	29.67	-0.31	-1.12	-2.62	-2.94	-2.74	-0.64	2.28	-0.78	4.02	4.65	0.07	1.41
Sep	30	29.75	-0.31	-1.12	-2.60	-2.91	-2.70	-0.64	2.27	-0.76	3.99	4.63	0.07	1.41
Oct	30	29.83	-0.31	-1.12	-2.58	-2.87	-2.67	-0.64	2.27	-0.75	3.97	4.61	0.07	1.40
Nov	30	29.92	-0.31	-1.12	-2.56	-2.84	-2.64	-0.64	2.27	-0.74	3.94	4.59	0.07	1.41
Dec	30	30.00	-0.31	-1.11	-2.53	-2.81	-2.61	-0.64	2.27	-0.72	3.92	4.57	0.07	1.41
Jan	31	30.08	-0.31	-1.16	-2.74	-3.08	-2.72	-0.64	2.29	-0.74	4.03	4.59	0.07	1.38
Feb	31	30.17	-0.31	-1.36	-4.11	-5.48	-3.57	-0.66	2.41	-0.54	4.77	4.75	0.09	5.67
Mar	31	30.25	-0.32	-1.39	-3.60	-4.28	-3.38	-0.66	2.43	-1.00	4.59	4.77	0.05	0.52
Apr	31	30.33	-0.32	-1.19	-2.69	-3.02	-2.77	-0.65	2.33	-0.72	4.10	4.64	0.07	1.53
May	31	30.42	-0.32	-1.15	-2.60	-2.93	-2.69	-0.65	2.31	-0.69	4.02	4.60	0.07	1.53
June	31	30.50	-0.32	-1.14	-2.57	-2.89	-2.65	-0.64	2.30	-0.68	3.98	4.58	0.07	1.52
July	31	30.58	-0.32	-1.13	-2.54	-2.85	-2.61	-0.64	2.30	-0.66	3.95	4.55	0.08	1.52
Aug	31	30.67	-0.31	-1.12	-2.52	-2.82	-2.58	-0.64	2.29	-0.65	3.92	4.54	0.08	1.51
Sep	31	30.75	-0.31	-1.12	-2.50	-2.78	-2.55	-0.64	2.29	-0.64	3.90	4.52	0.08	1.49
Oct	31	30.83	-0.31	-1.11	-2.48	-2.75	-2.52	-0.63	2.29	-0.63	3.88	4.50	0.08	1.49
Nov	31	30.92	-0.31	-1.11	-2.46	-2.71	-2.49	-0.63	2.29	-0.62	3.85	4.48	0.08	1.48
Dec	31	31.00	-0.31	-1.11	-2.44	-2.68	-2.46	-0.63	2.29	-0.60	3.83	4.46	0.08	1.48
Jan	32	31.08	-0.31	-1.11	-2.42	-2.65	-2.43	-0.63	2.29	-0.59	3.81	4.44	0.08	1.46
Feb	32	31.17	-0.32	-1.57	-7.30	-12.96	-5.84	-0.70	2.40	-2.59	4.66	4.64	0.01	4.93
Mar	32	31.25	-0.33	-1.49	-3.92	-4.52	-3.54	-0.69	2.43	-1.02	4.56	4.66	0.03	0.93
Apr	32	31.33	-0.33	-1.25	-2.73	-2.99	-2.72	-0.67	2.34	-0.68	4.06	4.53	0.05	1.62
May	32	31.42	-0.33	-1.19	-2.60	-2.88	-2.61	-0.65	2.34	-0.64	4.07	4.52	0.06	1.63
June	32	31.50	-0.33	-1.16	-2.56	-2.88	-2.58	-0.65	2.36	-0.75	4.16	4.55	0.07	0.97
July	32	31.58	-0.33	-1.15	-2.53	-2.84	-2.55	-0.64	2.35	-0.76	4.06	4.52	0.07	0.86
Aug	32	31.67	-0.32	-1.14	-2.50	-2.77	-2.49	-0.64	2.32	-0.63	3.92	4.47	0.07	1.49
Sep	32	31.75	-0.32	-1.13	-2.48	-2.73	-2.45	-0.63	2.31	-0.61	3.88	4.45	0.08	1.49
Oct	32	31.83	-0.32	-1.13	-2.45	-2.69	-2.42	-0.63	2.31	-0.59	3.86	4.43	0.08	1.50
Nov	32	31.92	-0.32	-1.12	-2.44	-2.68	-2.40	-0.63	2.34	-0.59	3.99	4.46	0.08	1.47
Dec	32	32.00	-0.32	-1.12	-2.41	-2.56	-2.30	-0.63	2.41	-0.37	4.38	4.55	0.10	3.00
Jan	33	32.08	-0.32	-1.12	-2.43	-2.62	-2.27	-0.63	2.40	-0.37	4.53	4.68	0.12	4.14
Feb	33	32.17	-0.32	-1.11	-2.49	-2.70	-2.27	-0.62	2.49	-0.11	5.08	4.84	0.15	6.24
Mar	33	32.25	-0.32	-1.11	-2.61	-3.08	-2.49	-0.62	2.57	-0.30	5.42	4.99	0.16	5.44
Apr	33	32.33	-0.32	-1.11	-2.62	-3.05	-2.45	-0.62	2.57	-0.28	5.54	5.09	0.17	6.49
May	33	32.42	-0.32	-1.11	-2.64	-3.07	-2.45	-0.63	2.72	-0.42	6.35	5.34	0.18	6.26
June	33	32.50	-0.32	-1.11	-2.66	-3.26	-2.63	-0.63	2.50	-1.10	5.02	5.09	0.13	2.11
July	33	32.58	-0.32	-1.11	-2.66	-3.24	-2.67	-0.64	2.42	-1.14	4.72	5.00	0.11	1.86
Aug	33	32.67	-0.32	-1.11	-2.65	-3.21	-2.68	-0.64	2.39	-1.14	4.62	4.95	0.11	1.76
Sep	33	32.75	-0.32	-1.14	-2.84	-3.38	-2.76	-0.64	2.56	-0.46	5.64	5.19	0.15	6.03
Oct	33	32.83	-0.32	-1.12	-2.74	-3.40	-2.84	-0.64	2.47	-1.10	4.90	5.06	0.11	1.98
Nov	33	32.92	-0.33	-1.12	-2.72	-3.36	-2.85	-0.64	2.42	-1.11	4.68	5.00	0.11	1.82
Dec	33	33.00	-0.33	-1.12	-2.71	-3.32	-2.84	-0.64	2.40	-1.10	4.61	4.97	0.10	1.76

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
Jan	34	33.08	-0.33	-1.11	-2.70	-3.27	-2.83	-0.64	2.39	-1.09	4.55	4.95	0.10	1.72
Feb	34	33.17	-0.34	-1.68	-5.15	-6.35	-4.26	-0.67	2.50	-0.83	5.18	5.07	0.08	4.67
Mar	34	33.25	-0.35	-1.75	-5.10	-6.23	-4.33	-0.70	2.55	-1.17	5.27	5.13	0.05	2.58
Apr	34	33.33	-0.36	-1.89	-5.54	-6.73	-4.59	-0.71	2.55	-0.98	5.26	5.13	0.04	3.93
May	34	33.42	-0.37	-1.42	-3.36	-3.93	-3.32	-0.70	2.48	-1.12	4.83	5.05	0.06	1.65
June	34	33.50	-0.36	-1.26	-2.87	-3.38	-3.01	-0.68	2.43	-1.01	4.60	4.99	0.07	1.83
July	34	33.58	-0.35	-1.21	-2.80	-3.30	-2.94	-0.66	2.42	-0.98	4.53	4.97	0.08	1.79
Aug	34	33.67	-0.35	-1.18	-2.77	-3.25	-2.89	-0.66	2.41	-0.96	4.49	4.94	0.08	1.77
Sep	34	33.75	-0.35	-1.20	-2.86	-3.37	-2.94	-0.65	2.43	-0.99	4.53	4.95	0.08	1.55
Oct	34	33.83	-0.34	-1.17	-2.73	-3.17	-2.83	-0.65	2.41	-0.93	4.42	4.92	0.09	1.70
Nov	34	33.92	-0.34	-1.16	-2.70	-3.12	-2.80	-0.65	2.41	-0.91	4.39	4.89	0.09	1.69
Dec	34	34.00	-0.34	-1.15	-2.67	-3.08	-2.76	-0.65	2.40	-0.89	4.35	4.87	0.09	1.67
Jan	35	34.08	-0.34	-1.15	-2.65	-3.04	-2.73	-0.65	2.40	-0.87	4.32	4.86	0.09	1.65
Feb	35	34.17	-0.34	-1.15	-2.68	-3.07	-2.74	-0.65	2.41	-0.87	4.32	4.85	0.09	1.56
Mar	35	34.25	-0.34	-1.16	-2.68	-3.06	-2.72	-0.64	2.41	-0.86	4.30	4.84	0.09	1.56
Apr	35	34.33	-0.34	-1.16	-2.67	-3.03	-2.71	-0.64	2.41	-0.84	4.28	4.82	0.09	1.54
May	35	34.42	-0.34	-1.14	-2.58	-2.90	-2.63	-0.64	2.40	-0.81	4.21	4.80	0.09	1.59
June	35	34.50	-0.34	-1.13	-2.55	-2.86	-2.59	-0.64	2.39	-0.79	4.18	4.78	0.09	1.58
July	35	34.58	-0.34	-1.13	-2.53	-2.83	-2.56	-0.64	2.39	-0.77	4.15	4.76	0.09	1.57
Aug	35	34.67	-0.34	-1.15	-2.60	-2.94	-2.62	-0.64	2.41	-0.85	4.24	4.77	0.08	1.04
Sep	35	34.75	-0.34	-1.13	-2.50	-2.77	-2.52	-0.64	2.39	-0.75	4.11	4.72	0.09	1.50
Oct	35	34.83	-0.34	-1.12	-2.47	-2.73	-2.49	-0.64	2.39	-0.73	4.07	4.70	0.09	1.51
Nov	35	34.92	-0.34	-1.12	-2.45	-2.70	-2.46	-0.64	2.38	-0.71	4.05	4.68	0.09	1.51
Dec	35	35.00	-0.34	-1.12	-2.43	-2.66	-2.43	-0.64	2.38	-0.69	4.02	4.66	0.09	1.51
Jan	36	35.08	-0.34	-1.11	-2.41	-2.63	-2.40	-0.64	2.38	-0.68	4.00	4.65	0.09	1.51
Feb	36	35.17	-0.34	-1.12	-2.41	-2.63	-2.39	-0.63	2.38	-0.70	4.01	4.64	0.09	1.35
Mar	36	35.25	-0.35	-1.27	-3.06	-3.54	-2.84	-0.64	2.47	-0.91	4.38	4.72	0.07	0.46
Apr	36	35.33	-0.36	-1.55	-4.19	-4.91	-3.49	-0.67	2.48	-0.75	4.48	4.74	0.06	2.09
May	36	35.42	-0.36	-1.34	-3.06	-3.45	-2.86	-0.66	2.47	-0.96	4.36	4.73	0.06	0.16
June	36	35.50	-0.36	-1.19	-2.46	-2.65	-2.44	-0.65	2.40	-0.68	4.02	4.63	0.08	1.39
July	36	35.58	-0.36	-1.15	-2.39	-2.59	-2.37	-0.64	2.38	-0.64	3.95	4.60	0.08	1.42
Aug	36	35.67	-0.35	-1.13	-2.36	-2.55	-2.33	-0.64	2.38	-0.62	3.92	4.58	0.09	1.43
Sep	36	35.75	-0.35	-1.12	-2.33	-2.52	-2.29	-0.64	2.37	-0.61	3.90	4.56	0.09	1.43
Oct	36	35.83	-0.35	-1.12	-2.31	-2.49	-2.26	-0.63	2.37	-0.59	3.88	4.54	0.09	1.43
Nov	36	35.92	-0.35	-1.11	-2.29	-2.45	-2.23	-0.63	2.37	-0.58	3.86	4.52	0.09	1.44
Dec	36	36.00	-0.35	-1.11	-2.27	-2.43	-2.20	-0.63	2.37	-0.56	3.83	4.51	0.09	1.44
Jan	37	36.08	-0.35	-1.11	-2.31	-2.61	-2.29	-0.64	2.42	-0.97	4.32	4.72	0.09	0.23
Feb	37	36.17	-0.35	-1.11	-2.29	-2.52	-2.23	-0.64	2.38	-0.78	4.11	4.64	0.09	1.36
Mar	37	36.25	-0.35	-1.10	-2.28	-2.51	-2.23	-0.64	2.38	-0.83	4.14	4.64	0.09	1.00
Apr	37	36.33	-0.35	-1.10	-2.27	-2.50	-2.22	-0.65	2.39	-0.84	4.17	4.64	0.09	0.86
May	37	36.42	-0.35	-1.10	-2.25	-2.50	-2.22	-0.65	2.41	-0.90	4.23	4.66	0.09	0.55
June	37	36.50	-0.35	-1.10	-2.24	-2.44	-2.17	-0.65	2.38	-0.80	4.08	4.61	0.09	1.03
July	37	36.58	-0.35	-1.12	-2.34	-2.57	-2.22	-0.65	2.40	-0.81	4.15	4.62	0.09	1.02
Aug	37	36.67	-0.35	-1.15	-2.45	-2.70	-2.28	-0.65	2.39	-0.77	4.12	4.61	0.09	1.30
Sep	37	36.75	-0.37	-1.89	-6.04	-8.00	-4.59	-0.73	2.45	-1.31	4.76	4.79	0.03	2.36
Oct	37	36.83	-0.37	-1.30	-2.61	-2.77	-2.46	-0.71	2.49	-0.82	4.63	4.77	0.07	1.51
Nov	37	36.92	-0.37	-1.19	-2.36	-2.59	-2.29	-0.70	2.44	-0.73	4.37	4.72	0.08	1.63
Dec	37	37.00	-0.37	-1.16	-2.31	-2.55	-2.24	-0.69	2.40	-0.73	4.13	4.65	0.09	1.48
Jan	38	37.08	-0.37	-1.14	-2.32	-2.54	-2.20	-0.69	2.47	-0.47	4.61	4.78	0.11	3.23
Feb	38	37.17	-0.36	-1.13	-2.31	-2.53	-2.16	-0.70	2.52	-0.46	4.92	4.89	0.13	3.65
Mar	38	37.25	-0.36	-1.12	-2.41	-2.82	-2.33	-0.70	2.59	-0.50	5.31	5.06	0.14	3.79
Apr	38	37.33	-0.36	-1.12	-2.55	-3.13	-2.51	-0.70	2.63	-0.34	5.60	5.21	0.16	5.18
May	38	37.42	-0.36	-1.12	-2.54	-3.00	-2.42	-0.70	2.72	-0.12	6.07	5.38	0.19	6.26
June	38	37.50	-0.36	-1.12	-2.54	-3.03	-2.45	-0.69	2.76	-0.35	6.13	5.46	0.18	4.73
July	38	37.58	-0.36	-1.11	-2.52	-2.97	-2.42	-0.69	2.94	-0.32	6.99	5.72	0.20	4.88
Aug	38	37.67	-0.36	-1.11	-2.58	-3.14	-2.55	-0.69	2.92	-0.50	6.73	5.73	0.19	3.85
Sep	38	37.75	-0.36	-1.11	-2.70	-3.47	-2.78	-0.69	2.85	-0.62	6.41	5.74	0.18	3.51
Oct	38	37.83	-0.36	-1.12	-2.77	-3.92	-3.21	-0.71	2.70	-2.03	5.53	5.60	0.09	-4.67
Nov	38	37.92	-0.36	-1.12	-2.74	-3.53	-3.00	-0.71	2.67	-1.01	5.65	5.56	0.13	1.54
Dec	38	38.00	-0.36	-1.12	-2.72	-3.40	-2.92	-0.71	2.64	-0.82	5.49	5.50	0.14	2.48
Jan	39	38.08	-0.36	-1.12	-2.76	-3.58	-3.06	-0.71	2.67	-1.25	5.58	5.56	0.12	0.03
Feb	39	38.17	-0.37	-1.12	-2.81	-3.62	-3.09	-0.71	2.73	-0.90	5.96	5.67	0.14	2.39
Mar	39	38.25	-0.38	-1.53	-4.83	-6.58	-4.43	-0.74	2.78	-1.34	6.15	5.74	0.09	2.03
Apr	39	38.33	-0.39	-1.77	-5.40	-6.84	-4.76	-0.76	2.78	-1.15	6.09	5.74	0.07	2.62
May	39	38.42	-0.40	-1.55	-4.18	-5.20	-4.05	-0.76	2.81	-1.16	6.15	5.78	0.08	1.82
June	39	38.50	-0.40	-1.27	-3.06	-3.73	-3.32	-0.74	2.72	-0.95	5.65	5.67	0.11	2.29

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
July	39	38.58	-0.39	-1.23	-3.04	-3.73	-3.28	-0.73	2.71	-0.90	5.58	5.66	0.11	2.42
Aug	39	38.67	-0.39	-1.19	-2.91	-3.54	-3.16	-0.72	2.69	-0.87	5.47	5.63	0.12	2.42
Sep	39	38.75	-0.38	-1.17	-2.88	-3.53	-3.16	-0.71	2.72	-1.01	5.56	5.66	0.12	1.52
Oct	39	38.83	-0.38	-1.25	-3.21	-3.92	-3.35	-0.72	2.73	-1.00	5.58	5.67	0.11	1.71
Nov	39	38.92	-0.38	-1.18	-2.87	-3.41	-3.09	-0.71	2.70	-0.86	5.36	5.62	0.12	2.26
Dec	39	39.00	-0.38	-1.16	-2.82	-3.33	-3.04	-0.71	2.69	-0.84	5.30	5.60	0.13	2.26
Jan	40	39.08	-0.38	-1.15	-2.80	-3.28	-2.99	-0.70	2.69	-0.82	5.26	5.59	0.13	2.24
Feb	40	39.17	-0.39	-1.53	-6.50	-11.14	-5.76	-0.76	2.75	-2.93	5.68	5.73	0.03	0.88
Mar	40	39.25	-0.40	-1.62	-5.29	-7.34	-4.82	-0.78	2.82	-1.66	6.02	5.81	0.06	2.39
Apr	40	39.33	-0.40	-1.47	-3.86	-4.60	-3.83	-0.76	2.80	-1.10	5.79	5.77	0.08	1.94
May	40	39.42	-0.40	-1.28	-3.07	-3.59	-3.28	-0.74	2.75	-0.91	5.46	5.70	0.10	2.25
June	40	39.50	-0.40	-1.23	-2.97	-3.51	-3.19	-0.72	2.74	-0.93	5.41	5.68	0.11	1.94
July	40	39.58	-0.39	-1.21	-2.93	-3.43	-3.12	-0.71	2.73	-0.85	5.31	5.66	0.12	2.22
Aug	40	39.67	-0.39	-1.20	-2.89	-3.37	-3.07	-0.71	2.73	-0.83	5.26	5.64	0.12	2.22
Sep	40	39.75	-0.39	-1.19	-2.87	-3.36	-3.06	-0.71	2.75	-0.92	5.31	5.65	0.12	1.57
Oct	40	39.83	-0.39	-1.40	-3.80	-4.56	-3.63	-0.72	2.82	-0.97	5.61	5.73	0.10	1.79
Nov	40	39.92	-0.39	-1.27	-3.06	-3.51	-3.14	-0.71	2.77	-0.83	5.29	5.65	0.12	2.06
Dec	40	40.00	-0.39	-1.21	-2.84	-3.24	-2.98	-0.70	2.74	-0.78	5.15	5.61	0.12	2.12
Jan	41	40.08	-0.39	-1.36	-4.19	-5.94	-3.91	-0.72	2.84	-1.32	5.66	5.74	0.10	2.53
Feb	41	40.17	-0.40	-1.53	-6.08	-10.11	-5.34	-0.76	2.85	-2.43	5.77	5.79	0.05	2.59
Mar	41	40.25	-0.41	-1.45	-4.51	-6.37	-4.28	-0.76	2.88	-1.65	5.86	5.83	0.07	1.71
Apr	41	40.33	-0.41	-1.72	-4.92	-5.93	-4.40	-0.76	2.87	-1.08	5.77	5.82	0.06	2.17
May	41	40.42	-0.41	-1.43	-3.50	-4.03	-3.49	-0.74	2.83	-0.93	5.51	5.76	0.09	1.91
June	41	40.50	-0.41	-1.30	-3.04	-3.48	-3.16	-0.73	2.80	-0.80	5.28	5.70	0.10	2.18
July	41	40.58	-0.41	-1.26	-2.96	-3.40	-3.08	-0.71	2.79	-0.77	5.22	5.68	0.11	2.18
Aug	41	40.67	-0.40	-1.24	-2.92	-3.34	-3.02	-0.70	2.79	-0.74	5.18	5.66	0.12	2.18
Sep	41	40.75	-0.40	-1.23	-2.89	-3.29	-2.97	-0.70	2.79	-0.72	5.14	5.65	0.12	2.17
Oct	41	40.83	-0.40	-1.22	-2.86	-3.24	-2.93	-0.70	2.79	-0.70	5.10	5.63	0.12	2.16
Nov	41	40.92	-0.40	-1.22	-2.84	-3.20	-2.89	-0.69	2.79	-0.68	5.07	5.61	0.13	2.16
Dec	41	41.00	-0.39	-1.21	-2.81	-3.15	-2.85	-0.69	2.79	-0.66	5.04	5.59	0.13	2.14
Jan	42	41.08	-0.40	-1.31	-3.39	-4.11	-3.22	-0.70	2.85	-0.77	5.31	5.65	0.12	2.46
Feb	42	41.17	-0.40	-1.47	-4.21	-5.42	-3.74	-0.71	2.90	-0.85	5.56	5.71	0.11	3.30
Mar	42	41.25	-0.41	-1.60	-4.87	-6.60	-4.28	-0.73	2.93	-1.35	5.65	5.77	0.08	1.69
Apr	42	41.33	-0.42	-1.71	-4.69	-5.53	-4.10	-0.74	2.92	-0.89	5.57	5.75	0.08	2.11
May	42	41.42	-0.42	-1.72	-4.59	-5.37	-4.02	-0.74	2.96	-0.78	5.75	5.79	0.08	2.52
June	42	41.50	-0.42	-1.38	-3.06	-3.37	-3.06	-0.72	2.86	-0.65	5.18	5.66	0.11	2.20
July	42	41.58	-0.42	-1.36	-3.18	-3.61	-3.12	-0.71	2.87	-0.68	5.23	5.67	0.11	2.00
Aug	42	41.67	-0.41	-1.29	-2.88	-3.22	-2.90	-0.70	2.84	-0.60	5.06	5.62	0.12	2.17
Sep	42	41.75	-0.41	-1.26	-2.83	-3.15	-2.84	-0.69	2.83	-0.58	5.01	5.60	0.12	2.16
Oct	42	41.83	-0.41	-1.25	-2.80	-3.11	-2.79	-0.69	2.83	-0.56	4.98	5.58	0.13	2.16
Nov	42	41.92	-0.41	-1.32	-3.26	-3.94	-3.14	-0.69	2.91	-0.84	5.36	5.67	0.11	1.34
Dec	42	42.00	-0.40	-1.26	-2.81	-3.09	-2.79	-0.69	2.85	-0.56	4.98	5.58	0.13	2.08
Jan	43	42.08	-0.40	-1.24	-2.75	-3.02	-2.72	-0.68	2.84	-0.53	4.92	5.54	0.13	2.10
Feb	43	42.17	-0.41	-1.68	-6.04	-9.23	-4.98	-0.73	2.93	-1.67	5.49	5.68	0.07	3.12
Mar	43	42.25	-0.42	-1.61	-4.26	-5.08	-3.80	-0.73	2.97	-0.89	5.60	5.73	0.09	1.89
Apr	43	42.33	-0.43	-1.80	-5.03	-6.14	-4.29	-0.74	2.97	-0.90	5.53	5.72	0.07	2.07
May	43	42.42	-0.43	-1.71	-4.37	-5.08	-3.86	-0.74	3.00	-0.78	5.66	5.76	0.08	1.88
June	43	42.50	-0.43	-1.40	-3.04	-3.34	-3.00	-0.72	2.90	-0.57	5.13	5.63	0.10	2.16
July	43	42.58	-0.43	-1.33	-2.90	-3.22	-2.88	-0.70	2.88	-0.53	5.04	5.60	0.11	2.17
Aug	43	42.67	-0.42	-1.30	-2.85	-3.16	-2.82	-0.69	2.88	-0.50	5.00	5.58	0.12	2.18
Sep	43	42.75	-0.42	-1.32	-2.98	-3.43	-2.96	-0.69	2.95	-0.80	5.29	5.65	0.11	0.50
Oct	43	42.83	-0.41	-1.31	-2.91	-3.27	-2.87	-0.68	2.91	-0.62	5.06	5.59	0.11	1.47
Nov	43	42.92	-0.41	-1.28	-2.78	-3.07	-2.74	-0.68	2.88	-0.50	4.93	5.55	0.12	2.02
Dec	43	43.00	-0.41	-1.27	-2.74	-3.02	-2.69	-0.67	2.88	-0.47	4.89	5.52	0.13	2.05
Jan	44	43.08	-0.41	-1.26	-2.74	-2.99	-2.67	-0.67	2.93	-0.23	5.17	5.58	0.14	3.47
Feb	44	43.17	-0.42	-1.82	-6.18	-8.92	-5.02	-0.72	2.99	-1.34	5.53	5.68	0.07	3.18
Mar	44	43.25	-0.43	-1.47	-3.39	-3.80	-3.22	-0.71	2.97	-0.67	5.25	5.63	0.10	1.64
Apr	44	43.33	-0.42	-1.34	-2.88	-3.20	-2.86	-0.69	2.92	-0.49	5.02	5.56	0.12	2.17
May	44	43.42	-0.42	-1.30	-2.81	-3.13	-2.79	-0.68	2.92	-0.48	4.98	5.54	0.12	2.05
June	44	43.50	-0.42	-1.29	-2.77	-3.08	-2.73	-0.67	2.91	-0.44	4.93	5.52	0.13	2.17
July	44	43.58	-0.42	-1.28	-2.74	-3.03	-2.69	-0.67	2.91	-0.42	4.90	5.50	0.13	2.17
Aug	44	43.67	-0.41	-1.27	-2.71	-2.99	-2.65	-0.66	2.91	-0.40	4.87	5.48	0.13	2.16
Sep	44	43.75	-0.41	-1.26	-2.69	-2.95	-2.62	-0.66	2.91	-0.39	4.84	5.47	0.13	2.16
Oct	44	43.83	-0.41	-1.26	-2.68	-2.94	-2.60	-0.66	3.00	-0.27	5.33	5.58	0.15	2.81
Nov	44	43.92	-0.41	-1.25	-2.68	-2.96	-2.60	-0.66	2.99	-0.31	5.17	5.55	0.15	2.52
Dec	44	44.00	-0.41	-1.25	-2.66	-2.93	-2.58	-0.65	2.94	-0.35	4.87	5.47	0.14	2.19

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

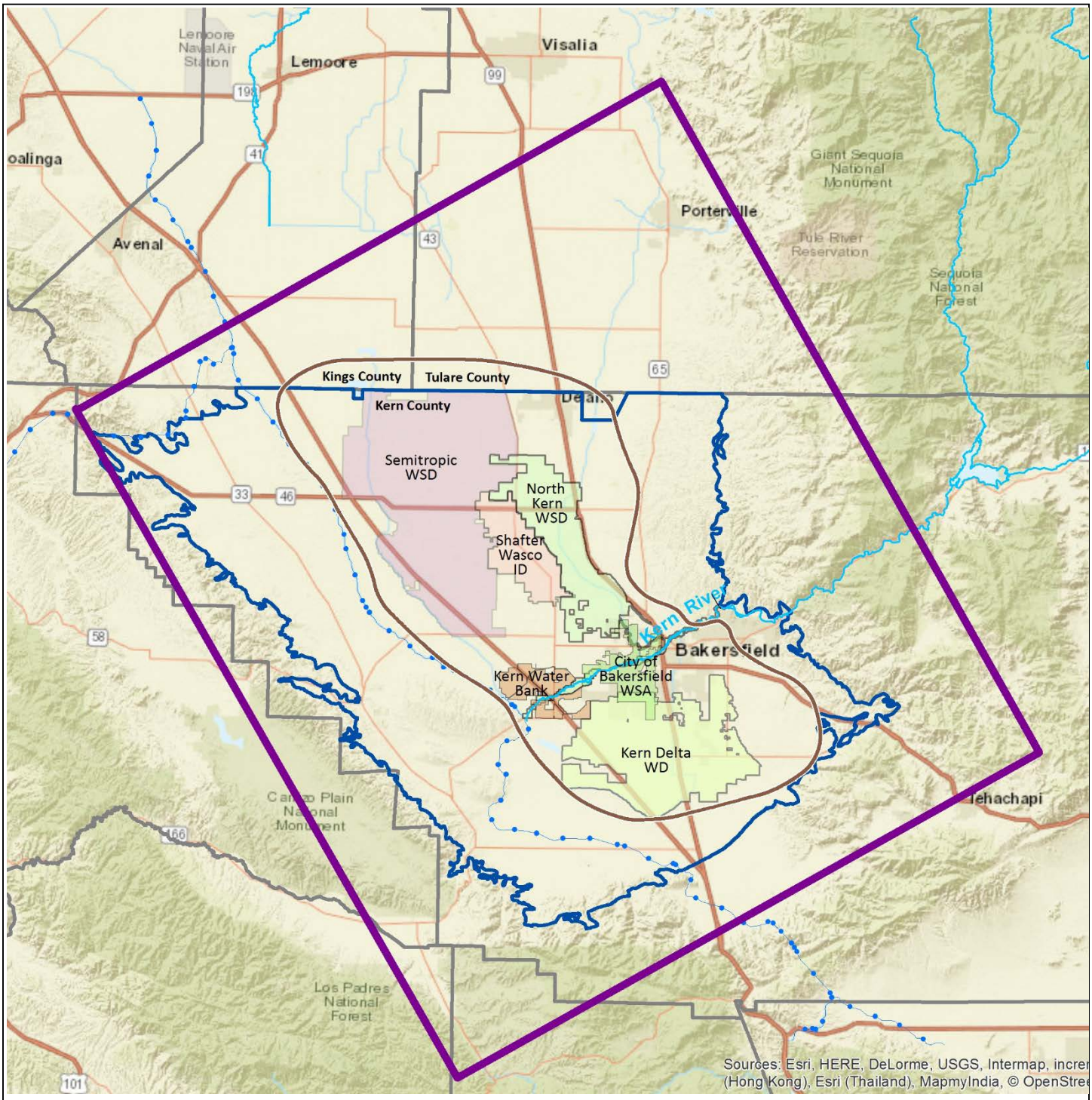
Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
Jan	45	44.08	-0.41	-1.25	-2.79	-3.66	-3.13	-0.67	2.86	-1.98	4.42	5.48	0.05	-6.78
Feb	45	44.17	-0.41	-1.26	-2.81	-3.36	-2.93	-0.66	2.99	-0.48	5.49	5.65	0.13	2.55
Mar	45	44.25	-0.41	-1.25	-2.82	-3.43	-2.98	-0.66	3.06	-0.66	5.62	5.69	0.13	1.33
Apr	45	44.33	-0.41	-1.25	-2.82	-3.37	-2.93	-0.66	3.07	-0.45	5.61	5.69	0.14	2.58
May	45	44.42	-0.41	-1.25	-2.82	-3.34	-2.88	-0.66	3.12	-0.31	5.91	5.79	0.16	3.72
June	45	44.50	-0.41	-1.25	-2.82	-3.39	-2.93	-0.66	3.08	-0.56	5.55	5.73	0.14	2.20
July	45	44.58	-0.41	-1.24	-2.81	-3.35	-2.91	-0.65	3.02	-0.57	5.28	5.66	0.14	2.11
Aug	45	44.67	-0.41	-1.24	-2.79	-3.30	-2.89	-0.65	2.99	-0.57	5.13	5.61	0.14	2.09
Sep	45	44.75	-0.43	-2.02	-6.17	-7.67	-4.97	-0.70	3.11	-0.79	5.89	5.80	0.08	3.34
Oct	45	44.83	-0.43	-1.42	-3.14	-3.54	-3.10	-0.69	3.13	-0.43	5.87	5.82	0.14	3.77
Nov	45	44.92	-0.43	-1.32	-2.91	-3.44	-3.01	-0.67	3.03	-0.63	5.30	5.70	0.13	2.26
Dec	45	45.00	-0.43	-1.29	-2.87	-3.38	-2.97	-0.67	3.01	-0.62	5.20	5.67	0.13	2.20
Jan	46	45.08	-0.42	-1.27	-2.88	-3.37	-2.92	-0.67	3.09	-0.43	5.83	5.87	0.16	4.03
Feb	46	45.17	-0.43	-1.70	-4.78	-5.87	-4.12	-0.70	3.14	-0.62	5.99	5.90	0.12	3.95
Mar	46	45.25	-0.44	-1.83	-5.70	-7.90	-4.92	-0.73	3.16	-1.48	6.08	5.96	0.08	2.08
Apr	46	45.33	-0.45	-1.75	-4.62	-5.51	-4.13	-0.73	3.16	-0.67	6.09	5.96	0.11	3.95
May	46	45.42	-0.45	-1.42	-3.16	-3.67	-3.24	-0.71	3.12	-0.72	5.78	5.91	0.12	2.52
June	46	45.50	-0.44	-1.35	-3.02	-3.55	-3.14	-0.70	3.09	-0.70	5.62	5.87	0.13	2.45
July	46	45.58	-0.44	-1.32	-2.98	-3.52	-3.10	-0.69	3.06	-0.76	5.49	5.84	0.13	1.94
Aug	46	45.67	-0.43	-1.31	-2.96	-3.47	-3.06	-0.68	3.05	-0.69	5.41	5.81	0.13	2.22
Sep	46	45.75	-0.44	-1.65	-4.46	-5.40	-3.98	-0.70	3.16	-0.79	5.97	5.94	0.11	2.57
Oct	46	45.83	-0.44	-1.37	-3.06	-3.51	-3.12	-0.69	3.13	-0.69	5.72	5.90	0.13	2.26
Nov	46	45.92	-0.43	-1.32	-2.95	-3.42	-3.04	-0.68	3.10	-0.67	5.55	5.86	0.14	2.23
Dec	46	46.00	-0.43	-1.30	-2.91	-3.36	-2.99	-0.68	3.06	-0.63	5.33	5.80	0.14	2.29
Jan	47	46.08	-0.43	-1.29	-2.89	-3.35	-2.97	-0.67	3.12	-0.61	5.64	5.88	0.14	2.36
Feb	47	46.17	-0.43	-1.54	-4.02	-4.81	-3.65	-0.68	3.17	-0.47	5.91	5.95	0.14	3.94
Mar	47	46.25	-0.44	-1.70	-4.58	-5.54	-4.06	-0.70	3.20	-0.77	5.97	5.98	0.11	2.45
Apr	47	46.33	-0.45	-1.78	-4.78	-5.74	-4.20	-0.71	3.19	-0.72	5.88	5.97	0.10	2.83
May	47	46.42	-0.45	-1.62	-3.97	-4.72	-3.76	-0.71	3.19	-0.87	5.85	5.98	0.10	1.46
June	47	46.50	-0.45	-1.40	-3.06	-3.50	-3.14	-0.70	3.10	-0.62	5.39	5.86	0.12	2.30
July	47	46.58	-0.44	-1.34	-2.96	-3.40	-3.05	-0.68	3.08	-0.59	5.31	5.83	0.13	2.30
Aug	47	46.67	-0.44	-1.32	-2.92	-3.35	-3.00	-0.68	3.08	-0.57	5.26	5.81	0.13	2.29
Sep	47	46.75	-0.44	-1.31	-2.88	-3.30	-2.96	-0.67	3.07	-0.55	5.22	5.79	0.14	2.28
Oct	47	46.83	-0.43	-1.30	-2.86	-3.25	-2.92	-0.67	3.07	-0.55	5.20	5.77	0.14	2.16
Nov	47	46.92	-0.43	-1.29	-2.83	-3.20	-2.88	-0.67	3.07	-0.52	5.16	5.75	0.14	2.25
Dec	47	47.00	-0.43	-1.29	-2.81	-3.16	-2.84	-0.66	3.07	-0.50	5.13	5.73	0.14	2.24
Jan	48	47.08	-0.43	-1.28	-2.78	-3.11	-2.80	-0.66	3.06	-0.49	5.09	5.71	0.14	2.22
Feb	48	47.17	-0.43	-1.29	-2.80	-3.13	-2.80	-0.66	3.07	-0.49	5.09	5.70	0.14	2.14
Mar	48	47.25	-0.43	-1.28	-2.74	-3.04	-2.75	-0.66	3.07	-0.49	5.06	5.69	0.14	2.07
Apr	48	47.33	-0.43	-1.27	-2.72	-3.06	-2.75	-0.66	3.09	-0.63	5.17	5.71	0.14	1.25
May	48	47.42	-0.43	-1.27	-2.70	-3.01	-2.72	-0.65	3.09	-0.60	5.11	5.69	0.14	1.41
June	48	47.50	-0.43	-1.26	-2.68	-2.96	-2.68	-0.65	3.08	-0.56	5.05	5.66	0.14	1.59
July	48	47.58	-0.43	-1.26	-2.65	-2.90	-2.62	-0.65	3.06	-0.46	4.94	5.62	0.15	2.04
Aug	48	47.67	-0.43	-1.26	-2.62	-2.86	-2.58	-0.65	3.05	-0.44	4.91	5.59	0.15	2.06
Sep	48	47.75	-0.43	-1.25	-2.60	-2.82	-2.55	-0.65	3.05	-0.42	4.88	5.57	0.15	2.06
Oct	48	47.83	-0.43	-1.25	-2.58	-2.78	-2.51	-0.65	3.05	-0.41	4.85	5.55	0.15	2.05
Nov	48	47.92	-0.43	-1.25	-2.56	-2.75	-2.48	-0.64	3.05	-0.39	4.83	5.54	0.15	2.05
Dec	48	48.00	-0.43	-1.24	-2.53	-2.71	-2.45	-0.64	3.04	-0.38	4.80	5.52	0.15	2.05
Jan	49	48.08	-0.43	-1.29	-2.74	-2.98	-2.56	-0.64	3.07	-0.39	4.91	5.53	0.15	2.02
Feb	49	48.17	-0.43	-1.49	-4.11	-5.38	-3.40	-0.66	3.18	-0.19	5.65	5.69	0.17	6.33
Mar	49	48.25	-0.44	-1.51	-3.60	-4.18	-3.22	-0.66	3.20	-0.65	5.47	5.70	0.13	1.17
Apr	49	48.33	-0.44	-1.32	-2.68	-2.92	-2.60	-0.65	3.10	-0.37	4.98	5.57	0.15	2.18
May	49	48.42	-0.44	-1.28	-2.59	-2.83	-2.53	-0.64	3.08	-0.34	4.89	5.53	0.15	2.18
June	49	48.50	-0.44	-1.26	-2.56	-2.79	-2.48	-0.64	3.07	-0.33	4.85	5.51	0.15	2.18
July	49	48.58	-0.43	-1.25	-2.53	-2.75	-2.45	-0.63	3.06	-0.31	4.82	5.48	0.15	2.17
Aug	49	48.67	-0.43	-1.24	-2.51	-2.71	-2.41	-0.63	3.06	-0.30	4.79	5.46	0.15	2.16
Sep	49	48.75	-0.43	-1.24	-2.49	-2.67	-2.38	-0.63	3.06	-0.29	4.77	5.44	0.16	2.15
Oct	49	48.83	-0.43	-1.23	-2.46	-2.64	-2.35	-0.63	3.05	-0.27	4.74	5.42	0.16	2.14
Nov	49	48.92	-0.43	-1.23	-2.44	-2.60	-2.32	-0.62	3.05	-0.26	4.72	5.40	0.16	2.13
Dec	49	49.00	-0.43	-1.22	-2.42	-2.57	-2.29	-0.62	3.05	-0.25	4.69	5.38	0.16	2.13
Jan	50	49.08	-0.43	-1.22	-2.40	-2.54	-2.26	-0.62	3.05	-0.24	4.67	5.36	0.16	2.12
Feb	50	49.17	-0.44	-1.69	-7.28	-12.85	-5.67	-0.69	3.16	-2.23	5.52	5.56	0.08	5.59
Mar	50	49.25	-0.45	-1.60	-3.90	-4.40	-3.36	-0.68	3.19	-0.66	5.42	5.58	0.11	1.57
Apr	50	49.33	-0.45	-1.36	-2.71	-2.87	-2.55	-0.66	3.09	-0.33	4.91	5.45	0.13	2.27
May	50	49.42	-0.45	-1.30	-2.57	-2.77	-2.43	-0.64	3.09	-0.29	4.93	5.44	0.14	2.28
June	50	49.50	-0.44	-1.27	-2.53	-2.76	-2.41	-0.63	3.12	-0.40	5.02	5.46	0.14	1.60

Table B-8 - Cumulative Change to Date for Scenario A Groundwater Levels Spatially Averaged Over Water District

Water District	Year	Year	Lost Hills	Semitropic WSD	Shafter-Wasco ID	North Kern WSD	Cawelo	Buena Vista North	Buena Vista South	Rosedale-Rio Bravo	Kern Delta WD	Arvin	Other Areas	City of Bakersfield
July	50	49.58	-0.44	-1.26	-2.50	-2.73	-2.37	-0.63	3.10	-0.41	4.91	5.43	0.15	1.50
Aug	50	49.67	-0.44	-1.24	-2.47	-2.65	-2.31	-0.62	3.07	-0.28	4.77	5.38	0.15	2.13
Sep	50	49.75	-0.44	-1.24	-2.45	-2.61	-2.27	-0.62	3.06	-0.26	4.73	5.36	0.15	2.14
Oct	50	49.83	-0.44	-1.23	-2.42	-2.57	-2.24	-0.61	3.06	-0.24	4.70	5.33	0.16	2.14
Nov	50	49.92	-0.43	-1.23	-2.41	-2.56	-2.22	-0.61	3.09	-0.23	4.84	5.36	0.16	2.11
Dec	50	50.00	-0.43	-1.22	-2.37	-2.44	-2.11	-0.61	3.16	-0.02	5.23	5.45	0.18	3.64
Range in Cumulative Change to Date over Average Hydrologic Conditions (1997 - 2007)														
Minimum			-0.1	-1.3	-5.2	-9.5	-4.4	-0.4	0.0	-2.8	0.3	0.2	-0.1	-8.0
Maximum			0.0	0.0	0.0	-0.1	-0.1	0.0	1.2	0.2	3.5	3.2	0.1	-8.0
Range in Cumulative Change to Date over Combined Study Period (1997 - 2014)														
Minimum			-0.2	-1.5	-6.8	-12.5	-5.5	-0.5	0.0	-2.8	0.3	0.2	-0.1	-8.0
Maximum			0.0	0.0	0.0	-0.1	-0.1	0.0	1.7	0.2	5.0	3.8	0.1	-8.0
Range in Cumulative Change to Date over 50-year simulation period														
Minimum			-0.5	-2.0	-7.3	-13.0	-5.8	-0.8	0.0	-3.2	0.3	0.2	-0.1	-8.0
Maximum			0.0	0.0	0.0	-0.1	-0.1	0.0	3.2	0.2	7.0	6.0	0.2	-8.0

Table B-9 - Summary of Spatial Average of Scenario A Groundwater Level Change over Key Water Districts

	KDWD					COB					NKWD					Shafter-Wasco					Semitropic				
Simulation Year	Net Annual Change	Average Cumulative Change	Cumulative Change to Date	Maximum Monthly Decline	Maximum Monthly Rise	Net Annual Change	Average Cumulative Change	Cumulative Change to Date	Maximum Monthly Decline	Maximum Monthly Rise	Net Annual Change	Average Cumulative Change	Cumulative Change to Date	Maximum Monthly Decline	Maximum Monthly Rise	Net Annual Change	Average Cumulative Change	Cumulative Change to Date	Maximum Monthly Decline	Maximum Monthly Rise	Net Annual Change	Average Cumulative Change	Cumulative Change to Date	Maximum Monthly Decline	Maximum Monthly Rise
1	0.53	0.56	0.53	-0.24	0.66	0.07	-0.20	0.07	-1.18	1.13	-0.43	-0.76	-0.43	-5.33	5.22	-0.25	-0.49	-0.25	-3.60	3.41	-0.10	-0.11	-0.10	-0.75	0.58
2	1.53	2.28	2.06	-0.85	0.88	0.96	1.74	1.02	-8.08	6.15	-1.12	-1.16	-1.55	-0.47	0.37	-0.61	-0.61	-0.86	-0.15	0.02	0.01	-0.07	-0.09	-0.01	0.02
3	-0.02	2.37	2.04	-0.49	0.39	-0.18	0.56	0.84	-2.41	2.33	-0.16	-2.52	-1.71	-2.98	1.62	-0.27	-1.63	-1.13	-2.03	1.21	-0.08	-0.29	-0.17	-0.41	0.27
4	0.01	2.29	2.05	-0.31	0.43	-0.12	0.57	0.72	-1.32	1.50	-0.11	-3.06	-1.81	-7.87	3.79	-0.18	-1.97	-1.31	-3.72	1.41	-0.08	-0.34	-0.26	-0.38	0.18
5	0.01	2.34	2.06	-0.25	0.52	0.00	0.76	0.72	-0.86	0.45	-0.09	-3.29	-1.90	-4.19	3.73	-0.11	-2.18	-1.43	-1.91	1.56	-0.05	-0.42	-0.30	-0.27	0.28
6	0.06	2.39	2.12	-0.56	0.39	-0.06	0.76	0.66	-1.59	0.84	-0.10	-3.05	-2.00	-1.32	1.99	-0.13	-2.24	-1.56	-0.83	1.52	-0.09	-0.52	-0.39	-0.16	0.34
7	0.01	2.41	2.13	-0.52	0.58	-0.03	0.56	0.63	-1.56	1.02	-0.07	-3.24	-2.07	-6.22	4.14	-0.06	-2.38	-1.62	-3.30	1.77	-0.05	-0.60	-0.44	-0.45	0.30
8	0.08	2.37	2.21	-0.29	0.49	0.12	0.96	0.74	-1.54	1.47	-0.05	-2.70	-2.12	-5.95	5.11	-0.03	-2.02	-1.66	-3.45	2.78	-0.03	-0.54	-0.47	-0.57	0.34
9	0.43	2.83	2.63	-0.56	1.07	0.05	0.40	0.79	-8.75	9.26	-0.55	-3.00	-2.67	-4.39	4.12	-0.31	-2.18	-1.97	-3.38	3.02	-0.08	-0.58	-0.55	-0.78	0.59
10	0.43	3.20	3.06	-0.30	0.64	0.05	1.29	0.84	-1.83	1.83	-0.14	-3.72	-2.81	-2.51	2.38	-0.17	-2.77	-2.14	-1.91	1.45	-0.07	-0.75	-0.62	-0.43	0.33
11	-0.34	3.05	2.72	-0.45	0.27	-0.01	1.00	0.83	-1.47	1.55	0.16	-3.39	-2.65	-1.48	1.21	0.04	-2.63	-2.10	-1.14	0.91	-0.01	-0.76	-0.63	-0.25	0.22
12	-0.25	2.62	2.47	-0.10	0.11	-0.17	0.53	0.66	-0.79	0.44	0.36	-2.47	-2.29	-0.02	0.07	0.19	-2.00	-1.91	-0.02	0.05	0.00	-0.63	-0.63	-0.01	0.01
13	-0.04	2.64	2.43	-0.49	0.75	0.06	1.00	0.72	-5.13	4.27	0.06	-2.71	-2.23	-2.41	1.25	0.03	-2.18	-1.88	-1.38	0.91	-0.02	-0.70	-0.65	-0.20	0.19
14	0.60	2.74	3.02	-0.50	0.86	1.52	1.03	2.24	-3.97	3.43	0.06	-3.35	-2.17	-10.32	8.44	-0.02	-2.50	-1.90	-4.89	3.38	-0.03	-0.76	-0.68	-0.47	0.24
15	0.27	3.76	3.29	-1.32	1.02	-1.20	3.06	1.04	-4.12	4.27	-0.81	-2.79	-2.98	-0.38	0.04	-0.36	-2.17	-2.26	-0.20	0.10	-0.02	-0.69	-0.70	-0.03	0.02
16	-0.21	3.41	3.08	-0.43	0.63	-0.09	1.48	0.95	-2.27	2.94	0.19	-3.79	-2.79	-3.08	2.80	-0.01	-3.01	-2.27	-2.46	2.19	-0.06	-0.95	-0.76	-0.57	0.47
17	-0.29	2.94	2.79	-0.12	0.09	-0.16	0.79	0.79	-0.51	0.45	0.37	-2.62	-2.42	-0.12	0.17	0.20	-2.18	-2.07	-0.08	0.10	0.01	-0.76	-0.75	-0.02	0.02
18	-0.15	2.84	2.64	-0.34	0.38	-0.07	0.58	0.71	-1.91	1.60	0.19	-2.68	-2.22	-1.37	1.45	0.12	-2.29	-1.95	-1.13	1.13	-0.01	-0.84	-0.76	-0.29	0.21
19	0.34	3.10	2.98	-0.25	0.65	0.06	0.50	0.77	-1.19	1.13	-0.15	-2.84	-2.38	-5.30	5.23	-0.08	-2.35	-2.03	-3.59	3.42	-0.07	-0.87	-0.84	-0.73	0.59
20	1.38	4.64	4.35	-0.86	0.87	0.98	2.44	1.75	-8.10	6.19	-0.90	-2.99	-3.27	-0.45	0.39	-0.45	-2.30	-2.48	-0.14	0.03	0.01	-0.81	-0.82	-0.01	0.02
21	-0.16	4.59	4.20	-0.50	0.38	-0.19	1.28	1.56	-2.42	2.34	0.04	-4.14	-3.23	-2.97	1.64	-0.13	-3.17	-2.61	-2.01	1.22	-0.06	-1.01	-0.88	-0.41	0.27
22	-0.10	4.38	4.09	-0.33	0.42	-0.14	1.28	1.43	-1.33	1.50	0.06	-4.49	-3.17	-7.86	3.80	-0.05	-3.38	-2.66	-3.71	1.42	-0.07	-1.04	-0.95	-0.38	0.19
23	-0.09	4.33	4.00	-0.26	0.51	0.02	1.48	1.45	-0.87	0.45	0.06	-4.56	-3.11	-4.17	3.74	0.01	-3.46	-2.65	-1.90	1.57	-0.02	-1.10	-0.97	-0.27	0.28
24	-0.03	4.28	3.97	-0.57	0.38	-0.06	1.49	1.39	-1.60	0.84	0.03	-4.18	-3.07	-1.31	2.00	-0.02	-3.41	-2.68	-0.82	1.53	-0.06	-1.18	-1.03	-0.15	0.34
25	-0.07	4.21	3.90	-0.52	0.57	-0.03	1.29	1.36	-1.64	1.03	0.05	-4.25	-3.02	-6.21	4.15	0.04	-3.44	-2.64	-3.29	1.78	-0.03	-1.22	-1.06	-0.44	0.30
26	0.00	4.09	3.90	-0.30	0.49	0.15	1.70	1.50	-1.53	1.45	0.06	-3.59	-2.96	-5.94	5.12	0.06	-2.99	-2.58	-3.44	2.78	0.00	-1.14	-1.06	-0.56	0.35
27	0.35	4.49	4.26	-0.57	1.07	0.03	1.13	1.54	-8.87	9.31	-0.46	-3.80	-3.42	-4.38	4.13	-0.23	-3.06	-2.81	-3.38	3.03	-0.06	-1.16	-1.11	-0.78	0.60
28	0.15	4.81	4.41	-0.30	0.64	0.11	2.05	1.64	-1.85	1.85	0.00	-4.43	-3.42	-2.50	2.39	-0.06	-3.58	-2.87	-1.90	1.46	-0.03	-1.30	-1.14	-0.43	0.33
29	-0.18	4.58	4.23	-0.45	0.32	-0.06	1.75	1.59	-1.47	1.57	0.18	-4.01	-3.23	-1.47	1.22	0.08	-3.35	-2.79	-1.13	0.91	0.00	-1.28	-1.14	-0.25	0.22
30	-0.30	4.09	3.92	-0.11	0.11	-0.18	1.27	1.41	-0.81	0.45	0.43	-3.01	-2.81	-0.01	0.08	0.25	-2.66	-2.53	-0.02	0.05	0.03	-1.13	-1.11	-0.01	0.01
31	-0.09	4.07	3.83	-0.49	0.74	0.07	1.76	1.48	-5.15	4.29	0.12	-3.19	-2.68	-2.40	1.26	0.09	-2.77	-2.44	-1.37	0.91	0.01	-1.17	-1.11	-0.20	0.19
32	0.55	4.12	4.38	-0.51	0.86	1.52	1.78	3.00	-4.00	3.47	0.12	-3.76	-2.56	-10.31	8.45	0.03	-3.03	-2.41	-4.88	3.38	-0.01	-1.21	-1.12	-0.47	0.24
33	0.22	5.09	4.61	-1.33	1.02	-1.24	3.82	1.76	-4.15	4.26	-0.76	-3.14	-3.32	-0.38	0.04	-0.30	-2.65	-2.71	-0.19	0.10	0.00	-1.12	-1.12	-0.03	0.02
34	-0.26	4.70	4.35	-0.43	0.63	-0.09	2.21	1.67	-2.28	2.96	0.24	-4.10	-3.08	-3.07	2.80	0.04	-3.44	-2.67	-2.45	2.19	-0.03	-1.35	-1.15	-0.57	0.47
35	-0.33	4.19	4.02	-0.13	0.09	-0.16	1.51	1.51	-0.53	0.46	0.42	-2.88	-2.66	-0.11	0.17	0.24	-2.56	-2.43	-0.07	0.10	0.03	-1.14	-1.12	-0.02	0.02
36	-0.19	4.05	3.83	-0.35	0.38	-0.07	1.30	1.44	-1.94	1.63	0.23	-2.90	-2.43	-1.37	1.46	0.16	-2.63	-2.27	-1.13	1.13	0.01	-1.19	-1.11	-0.28	0.21
37	0.30	4.27	4.13	-0.25	0.64	0.04	1.19	1.48	-1.21	1.13	-0.12	-3.02	-2.55	-5.30	5.24	-0.04	-2.65	-2.31	-3.58	3.42	-0.05	-1.20	-1.16	-0.73	0.59
38	1.35	5.79	5.49	-0.87	0.86	1.00	3.20	2.48	-8.18	6.21	-0.86	-3.12	-3.40	-0.46	0.40	-0.41	-2.56	-2.72	-0.14	0.03	0.04	-1.12	-1.12	-0.01	0.02
39	-0.19	5.70	5.30	-0.50	0.38	-0.22	1.98	2.26	-2.45	2.36	0.07	-4.25	-3.33	-2.97	1.64	-0.10	-3.40	-2.82	-2.01	1.22	-0.04	-1.30	-1.16	-0.41	0.27
40	-0.14	5.46	5.15	-0.33	0.42	-0.14	1.97	2.12	-1.36	1.51	0.09	-4.58	-3.24	-7.86	3.81	-0.02	-3.57	-2.84	-3.71	1.43	-0.05	-1.31	-1.21	-0.38	0.19
41	-0.12	5.38	5.04	-0.26	0.51	0.02	2.17	2.14	-0.87	0.45	0.09	-4.62	-3.15	-4.17	3.74	0.04	-3.63	-2.81	-1.89	1.57	0.00	-1.35	-1.21	-0.26	0.28
42	-0.05	5.30	4.98	-0.57	0.38	-0.06	2.18	2.08	-1.61	0.84	0.06	-4.21	-3.09	-1.31	2.00	0.00	-3.55	-2.81	-0.82	1.53	-0.05	-1.41	-1.26	-0.15	0.34
43	-0.10	5.21	4.89	-0.52	0.57	-0.04	1.97	2.05	-1.67	1.03	0.08	-4.25	-3.02	-6.21	4.15	0.06	-3.55	-2.74	-3.29	1.78	-0.01	-1.44	-1.27	-0.44	0.31
44	-0.02	5.07	4.87	-0.30	0.49	0.15	2.39	2.19	-1.53	1.43	0.08	-3.58	-2.93	-5.94	5.12	0.08	-3.08	-2.66	-3.44	2.79	0.02	-1.34	-1.25	-0.56	0.35
45	0.33	5.44	5.20	-0.57	1.07	0.00	1.78	2.20	-8.98	9.34	-0.44	-3.77	-3.38	-4.37	4.13	-0.21	-3.13	-2.87	-3.38	3.03	-0.04	-1.34	-1.29	-0.78	0.60
46	0.13	5.74	5.33	-0.31	0.64	0.10	2.71	2.29	-1.86	1.86	0.02	-4.38	-3.36	-2.50	2.39	-0.04	-3.62	-2.91	-1.90	1.46	-0.01	-1.47	-1.30	-0.43	0.33
47	-0.20	5.49	5.13	-0.46	0.32	-0.06	2.40	2.24	-1.48	1.58	0.20	-3.94	-3.16	-1.46	1.22	0.10	-3.38	-2.81	-1.13	0.91	0.01	-1.43	-1.29	-0.25	0.22
48	-0.32	4.98	4.80	-0.11	0.11	-0.18	1.92	2.05	-0.82	0.45	0.45	-2.93	-2.71	-0.01	0.08	0.27	-2.66	-2.53	-0.01	0.06	0.04	-1.26	-1.24	0.00	0.01
49	-0.11	4.94	4.69	-0.49	0.74	0.07	2.41	2.13	-5.16	4.31	0.14	-3.09	-2.57	-2.40	1.26	0.11	-2.76	-2.42	-1.37	0.92	0.02	-1.30	-1.22	-0.20	0.19
50	0.53	4.97	5.23	-0.51	0.85	1.52	2.42	3.64	-4.02	3.47	0.13	-3.65	-2.44	-10.31	8.44	0.05	-3.00	-2.37	-4.88	3.39	0.00	-1.32	-1.22	-0.47	0.24



N

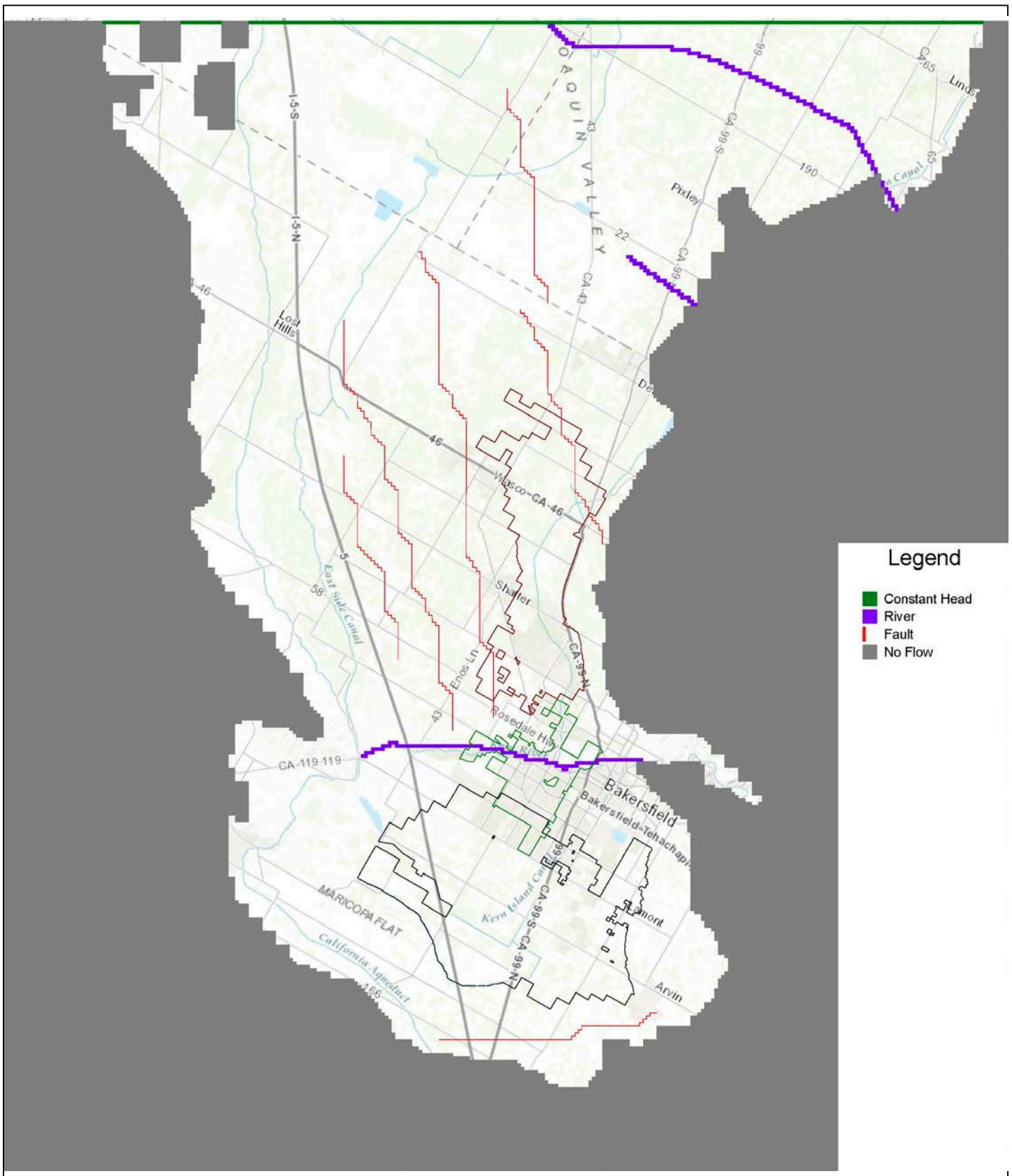
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Scale: Miles

June 2017

TODD GROUNDWATER

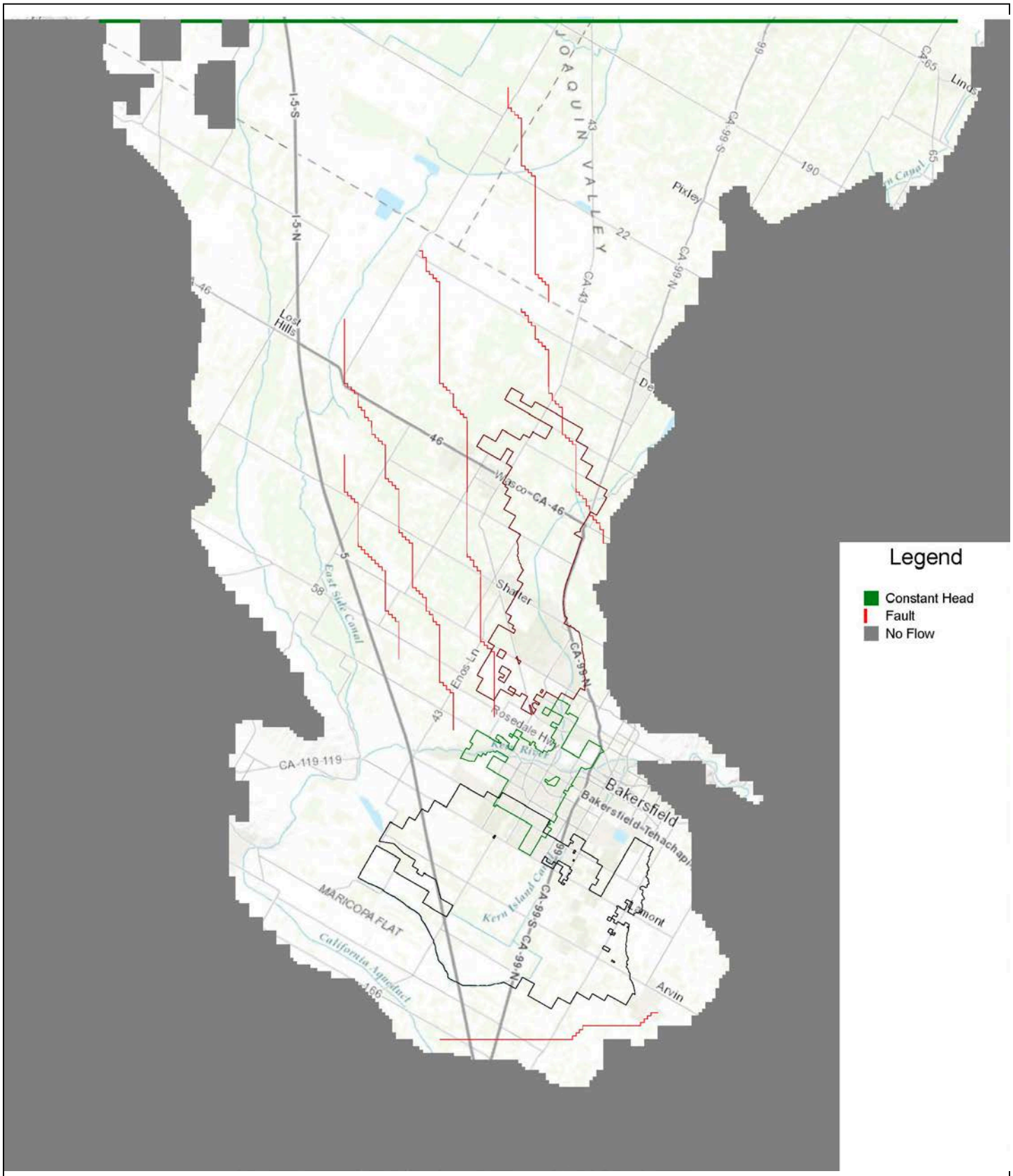
Figure B 1
KDWD Superposition Model Domain



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Figure B 2
Boundary Conditions
Model Layer 1
KDWD Superposition Model



N

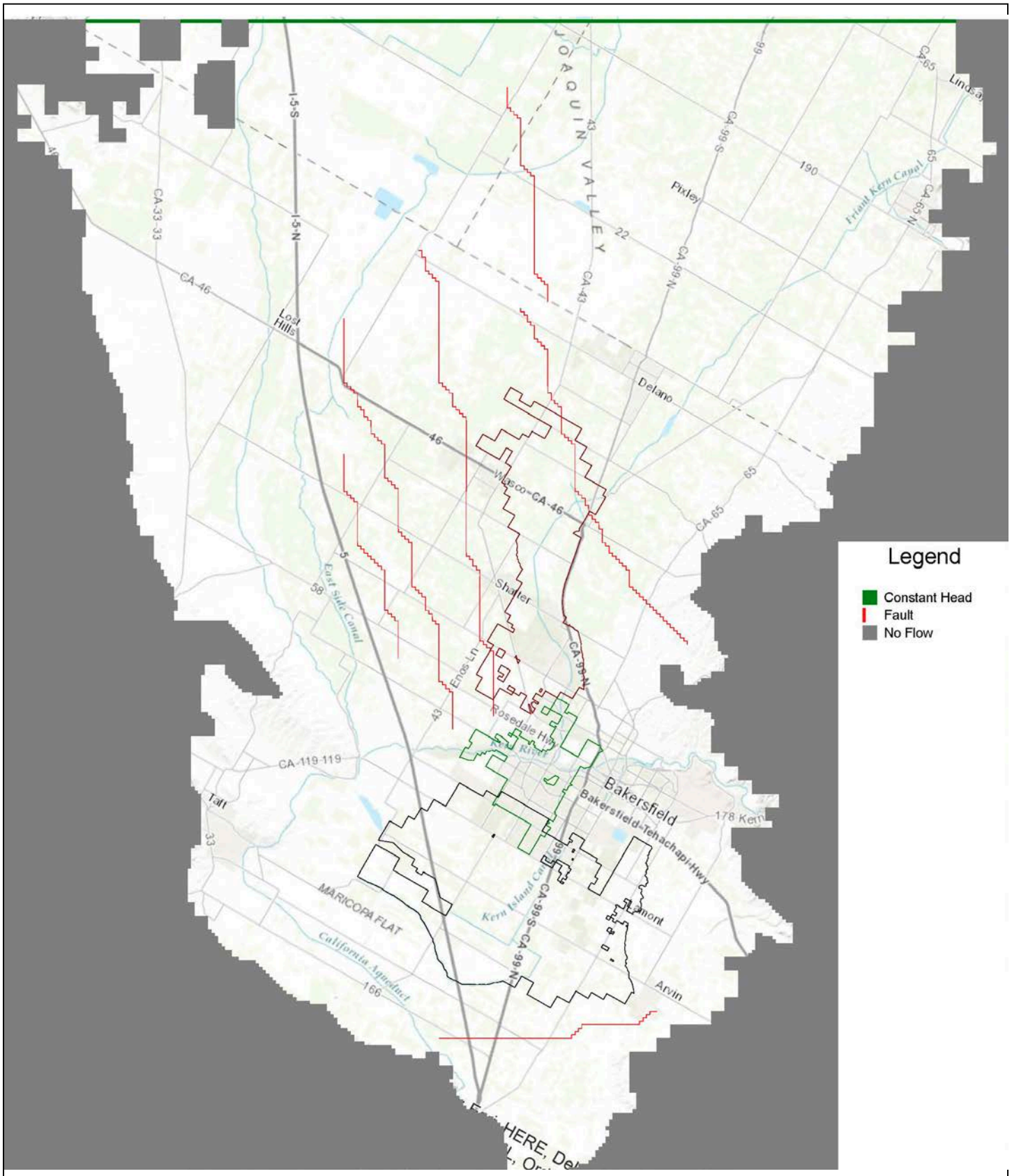
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Scale: Miles

June 2017

TODD GROUNDWATER

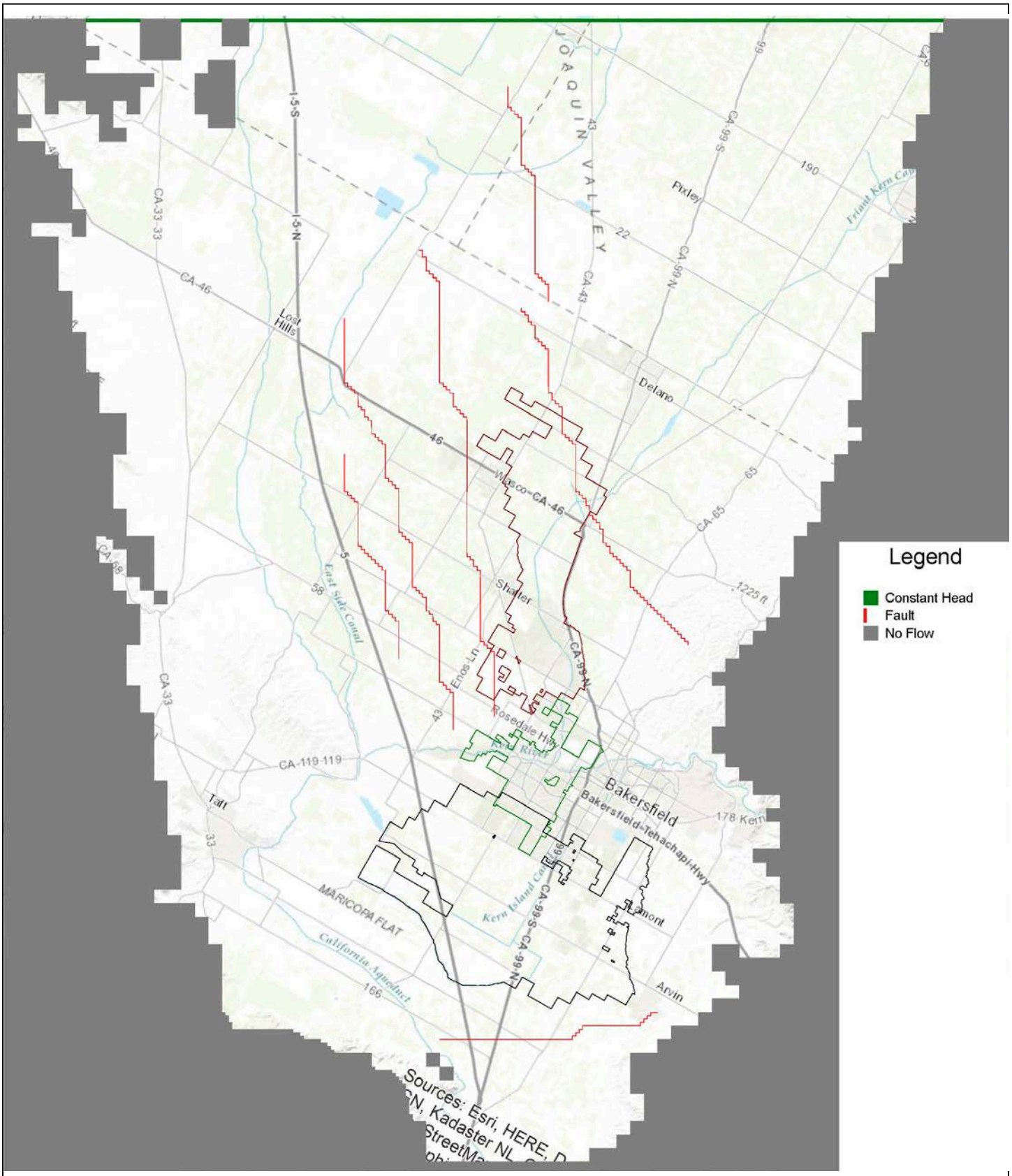
Figure B 3
Boundary Conditions
Model Layer 2
KDWD Superposition Model



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Figure B 4
Boundary Conditions
Model Layer 3
KDWD Superposition Model



N

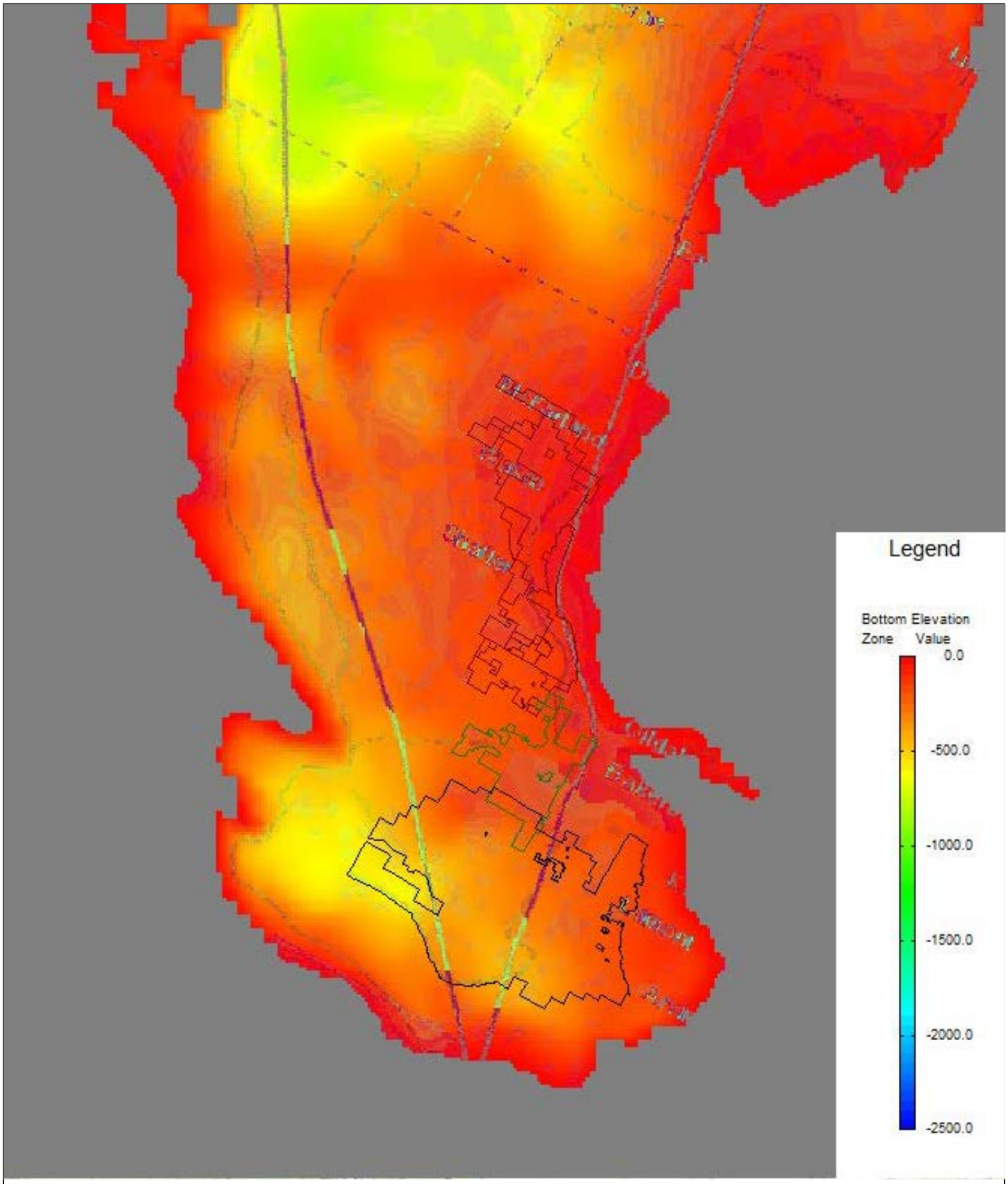
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Scale: Miles

June 2017

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Figure B 5
Boundary Conditions
Model Layer 4
KDWD Superposition Model



N

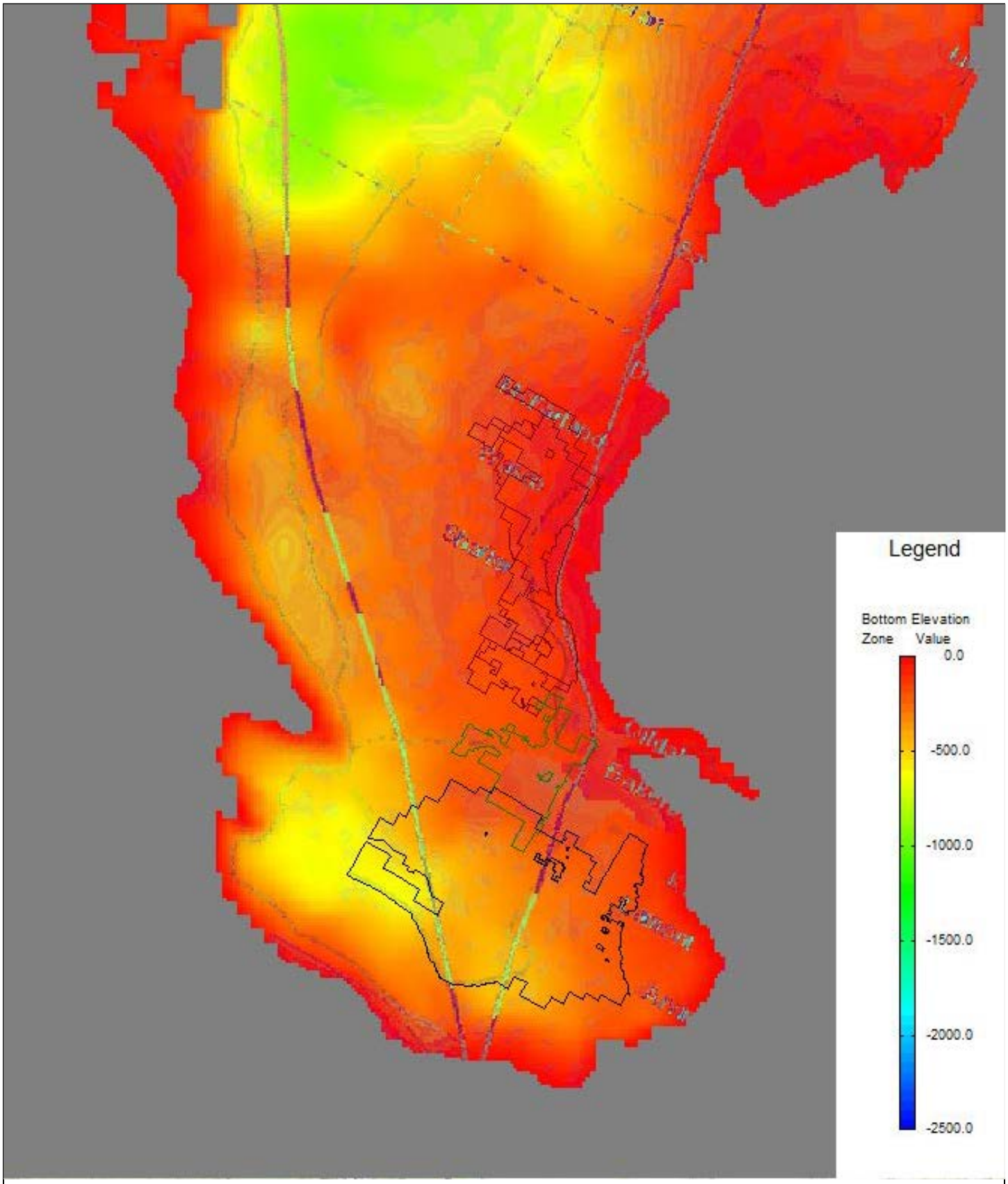
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Scale: Miles

June 2017

TODD GROUNDWATER

Figure B 6
Elevation of Bottom of Model Layer 1
KDWD Superposition Model



N

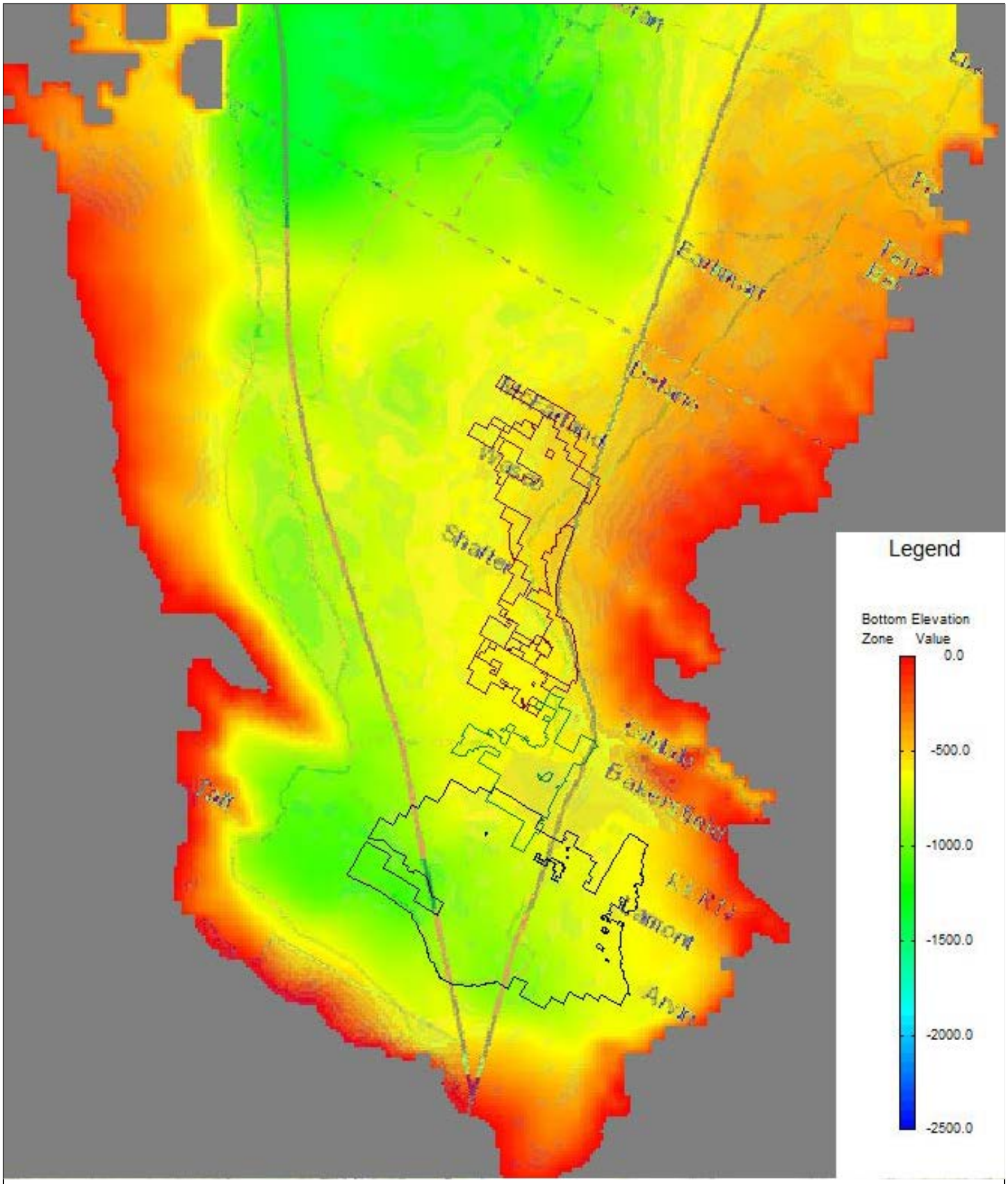
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Scale: Miles

June 2017

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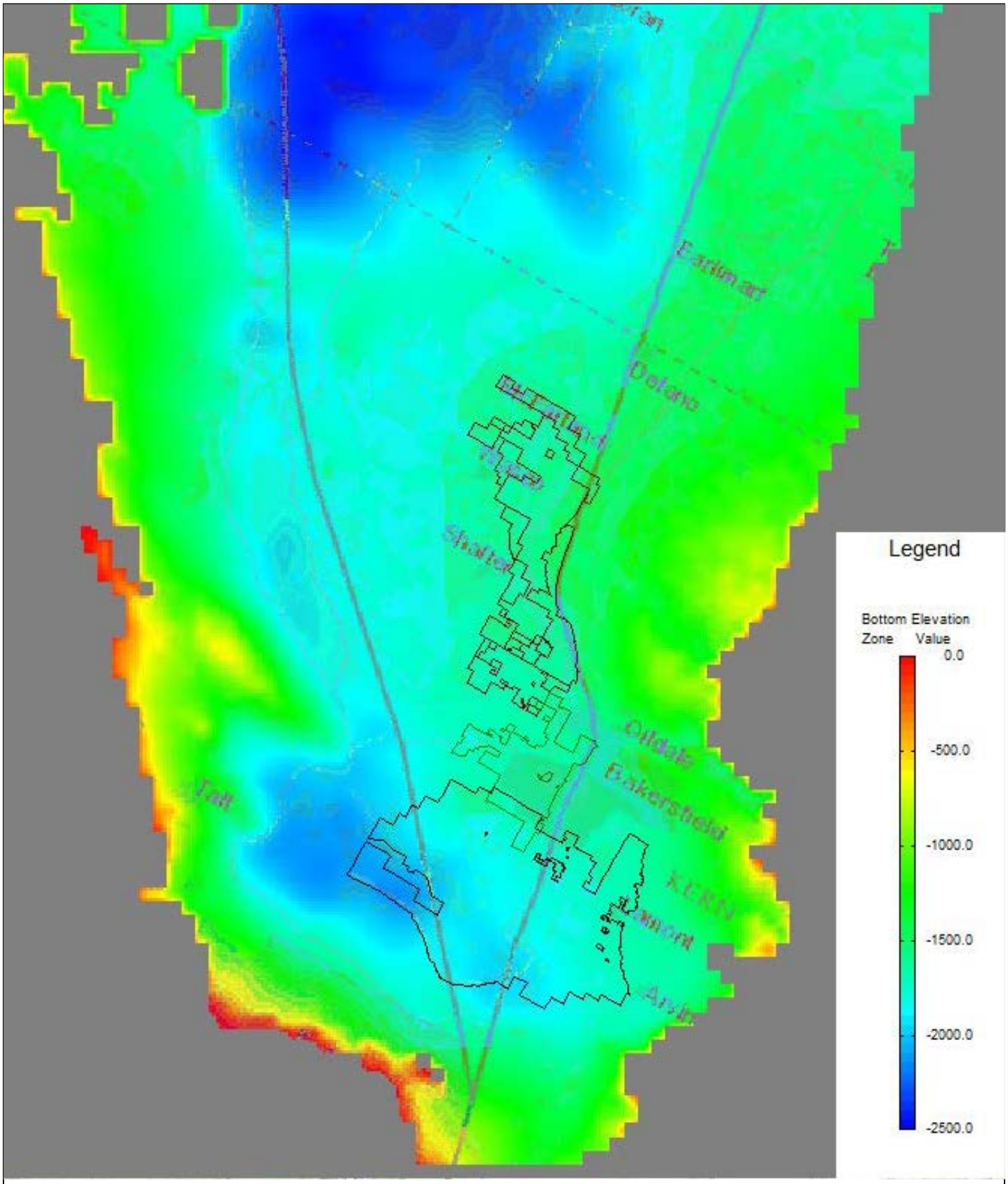
Figure B 7
Elevation of Bottom of Model Layer 2
KDWD Superposition Model



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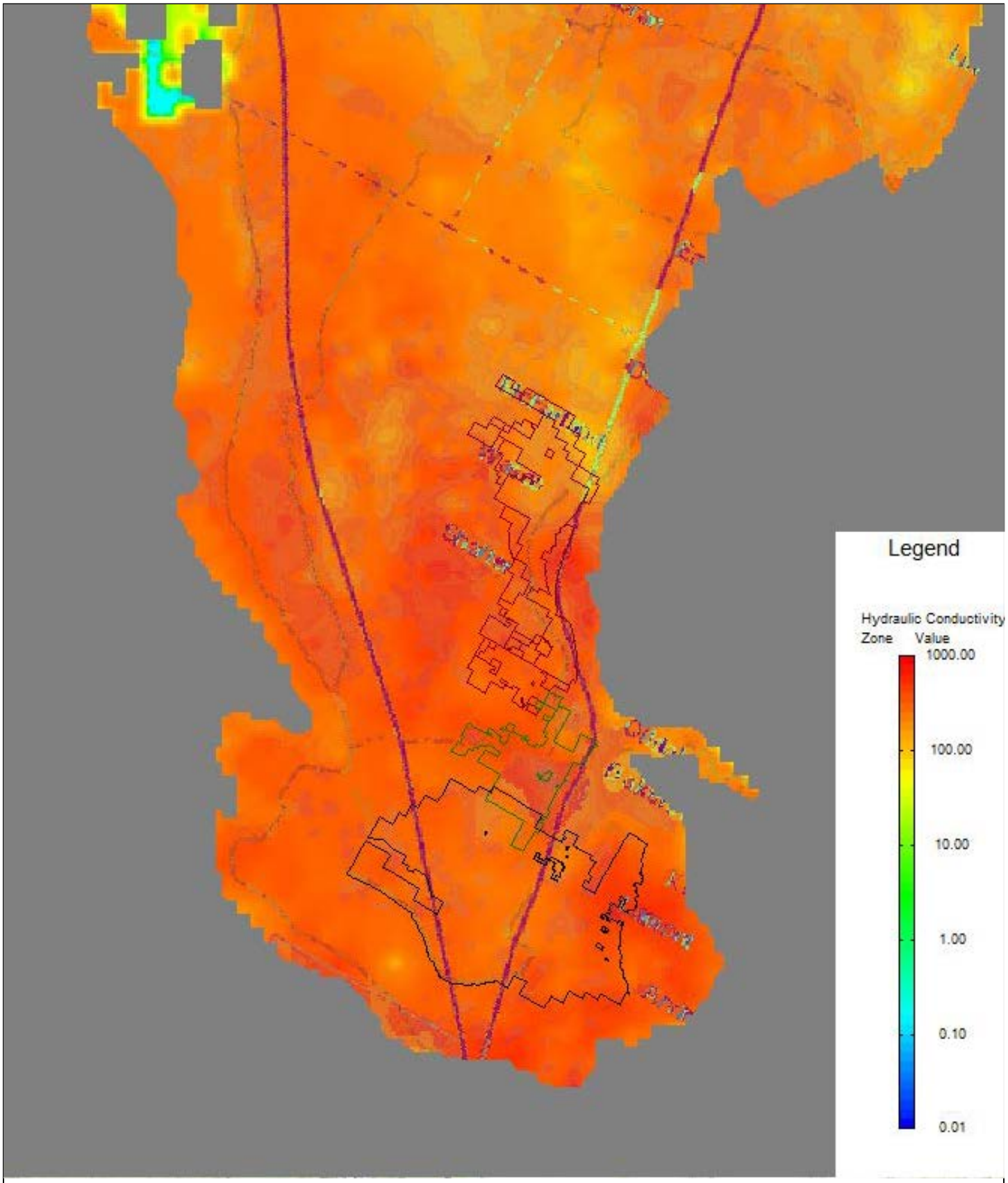
Figure B 8
Elevation of Bottom of Model Layer 3
KDWD Superposition Model



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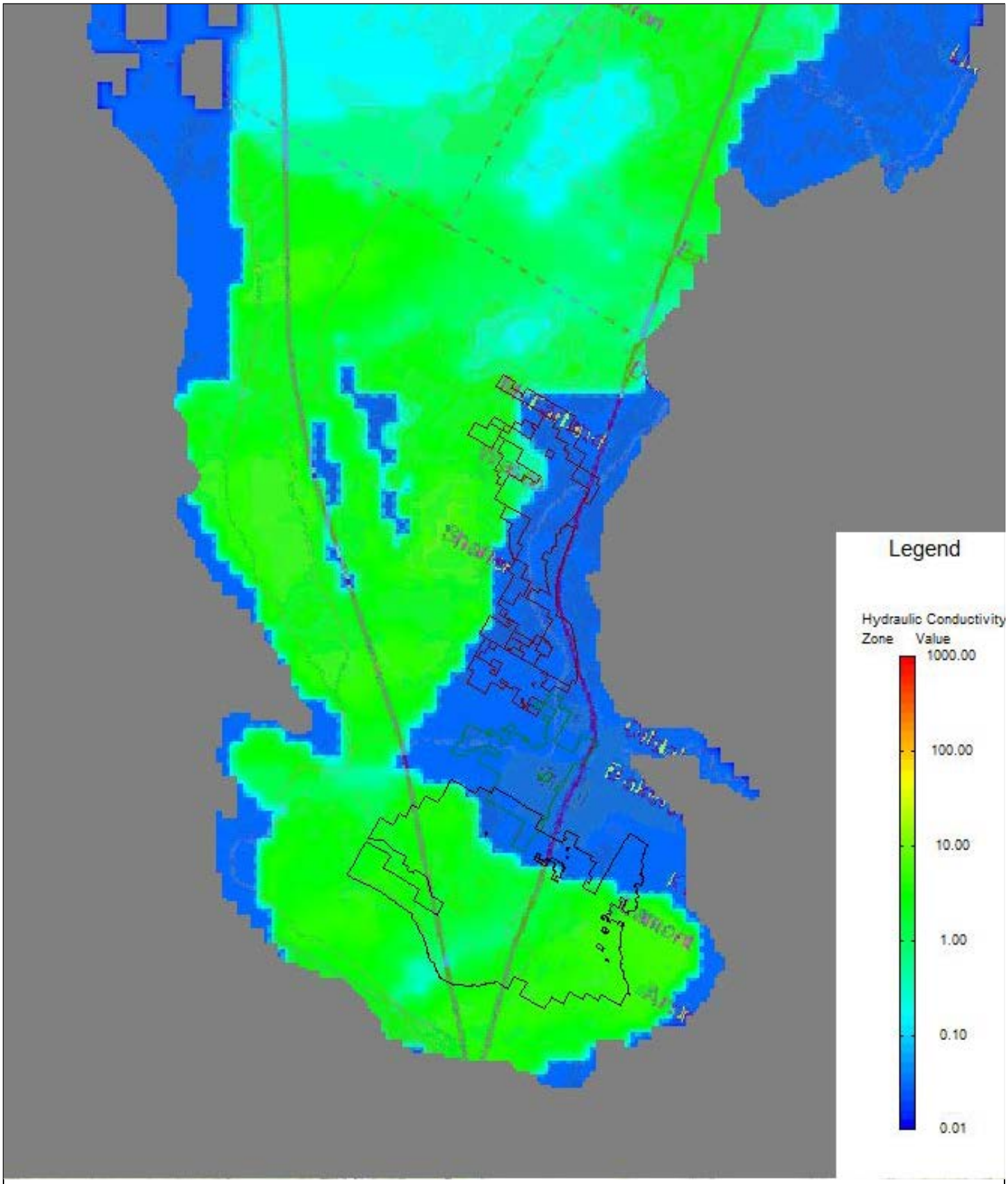
Figure B 9
Elevation of Bottom of Model Layer 4
KDWD Superposition Model



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Figure B 10
Horizontal Hydraulic Conductivity of Model Layer 1
KDWD Superposition Model



N

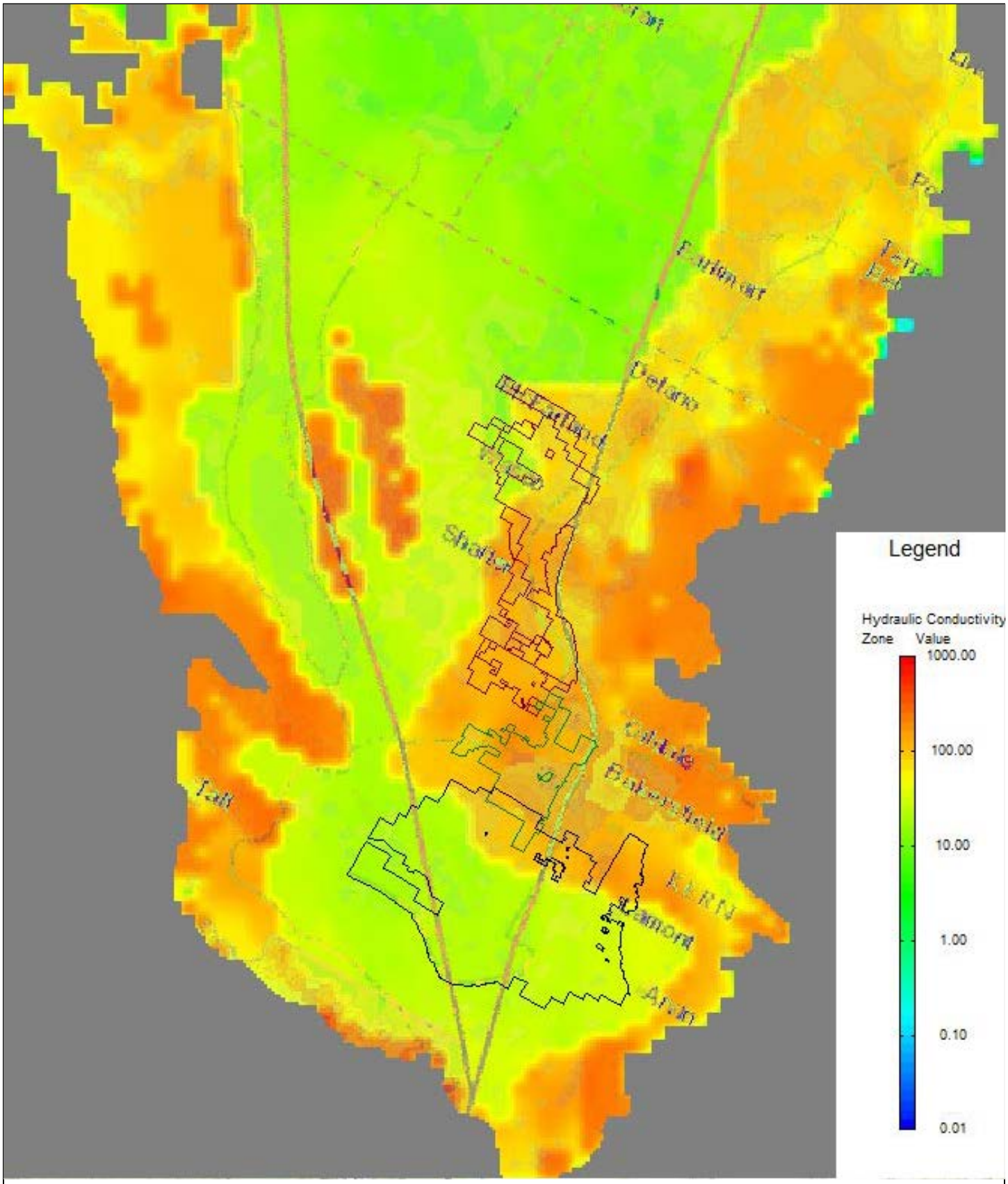
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Scale: Miles

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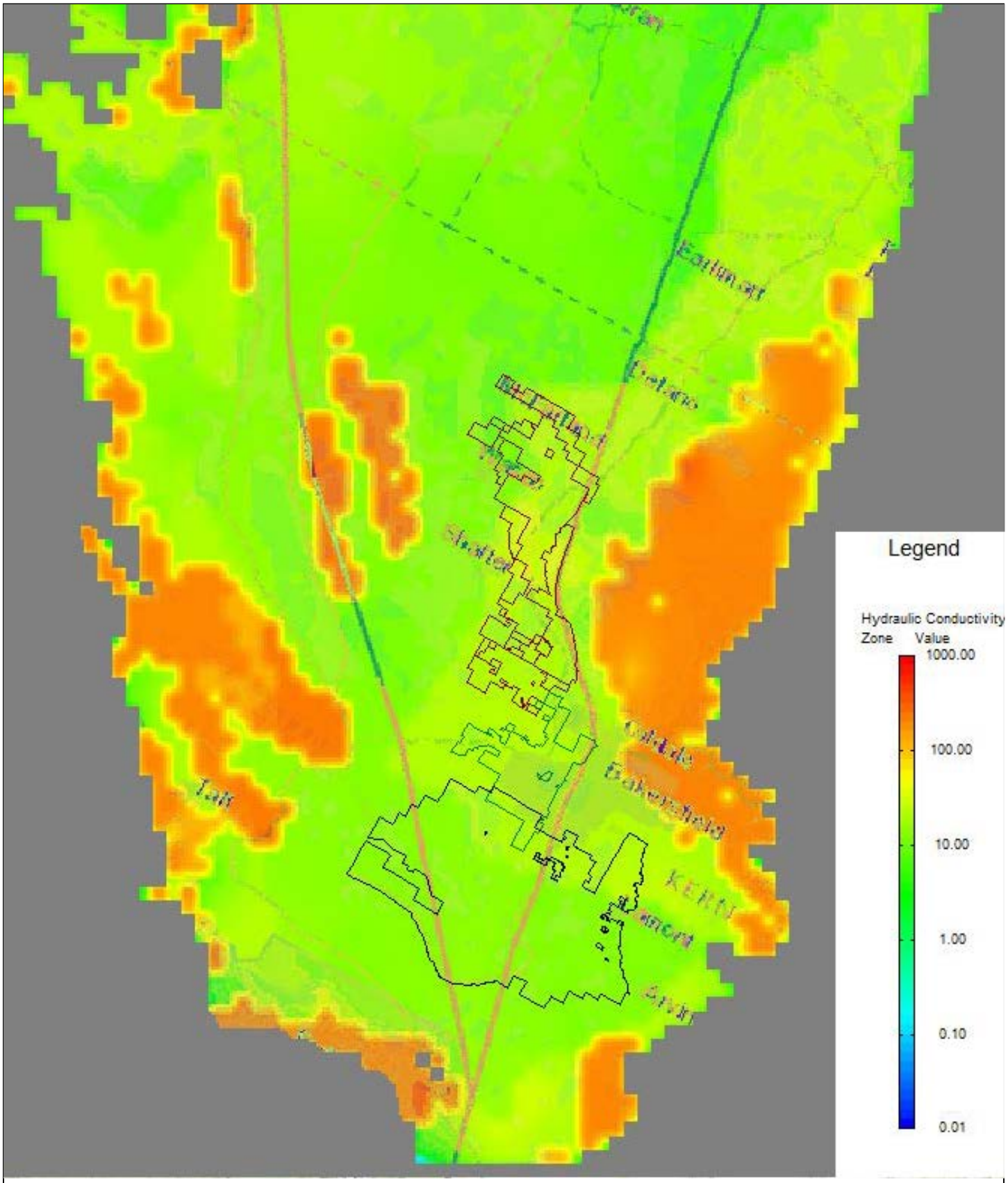
Figure B 11
Horizontal Hydraulic Conductivity of Model Layer 2
KDWD Superposition Model



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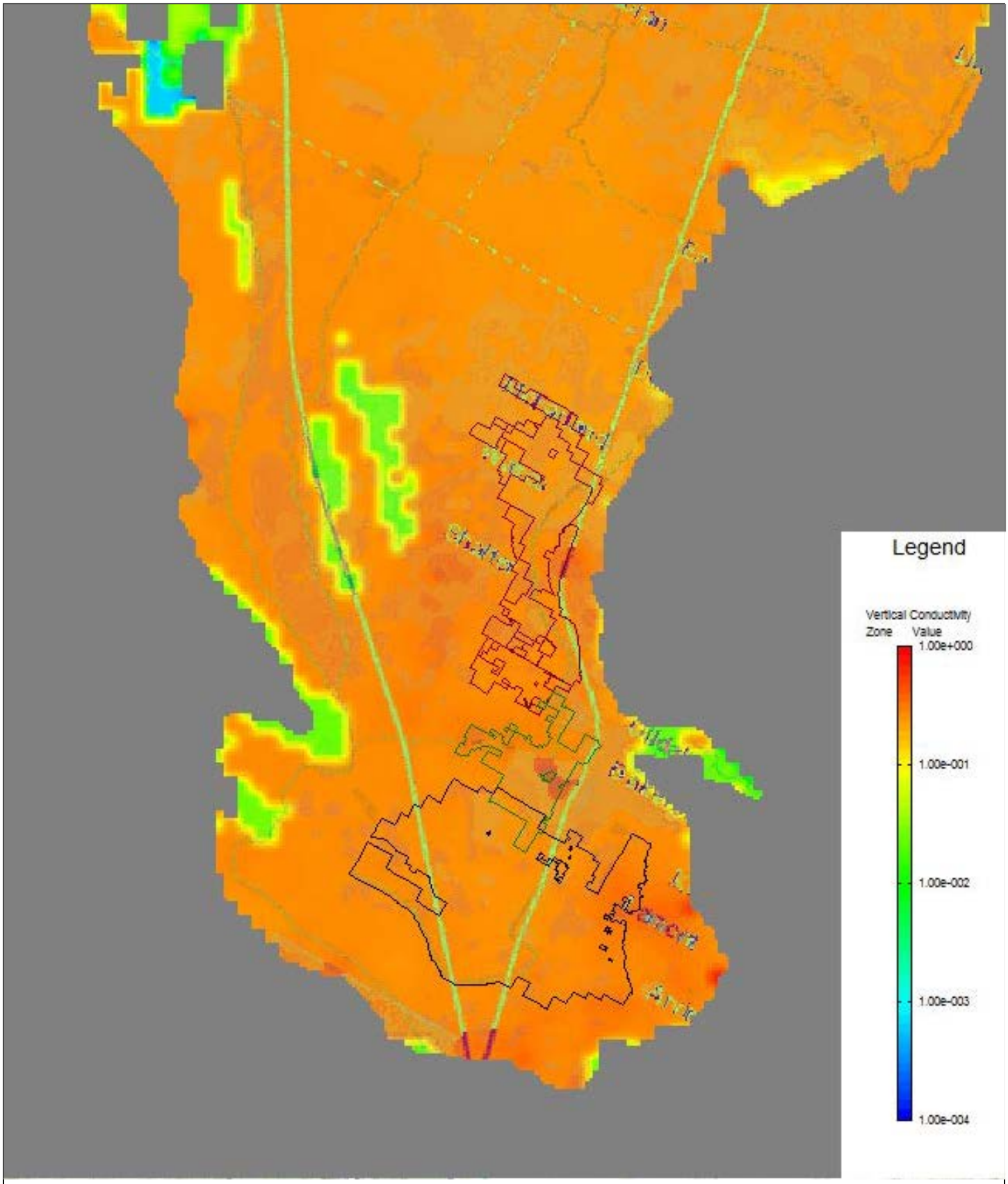
Figure B 12
Horizontal Hydraulic Conductivity of Model Layer 3
KDWD Superposition Model



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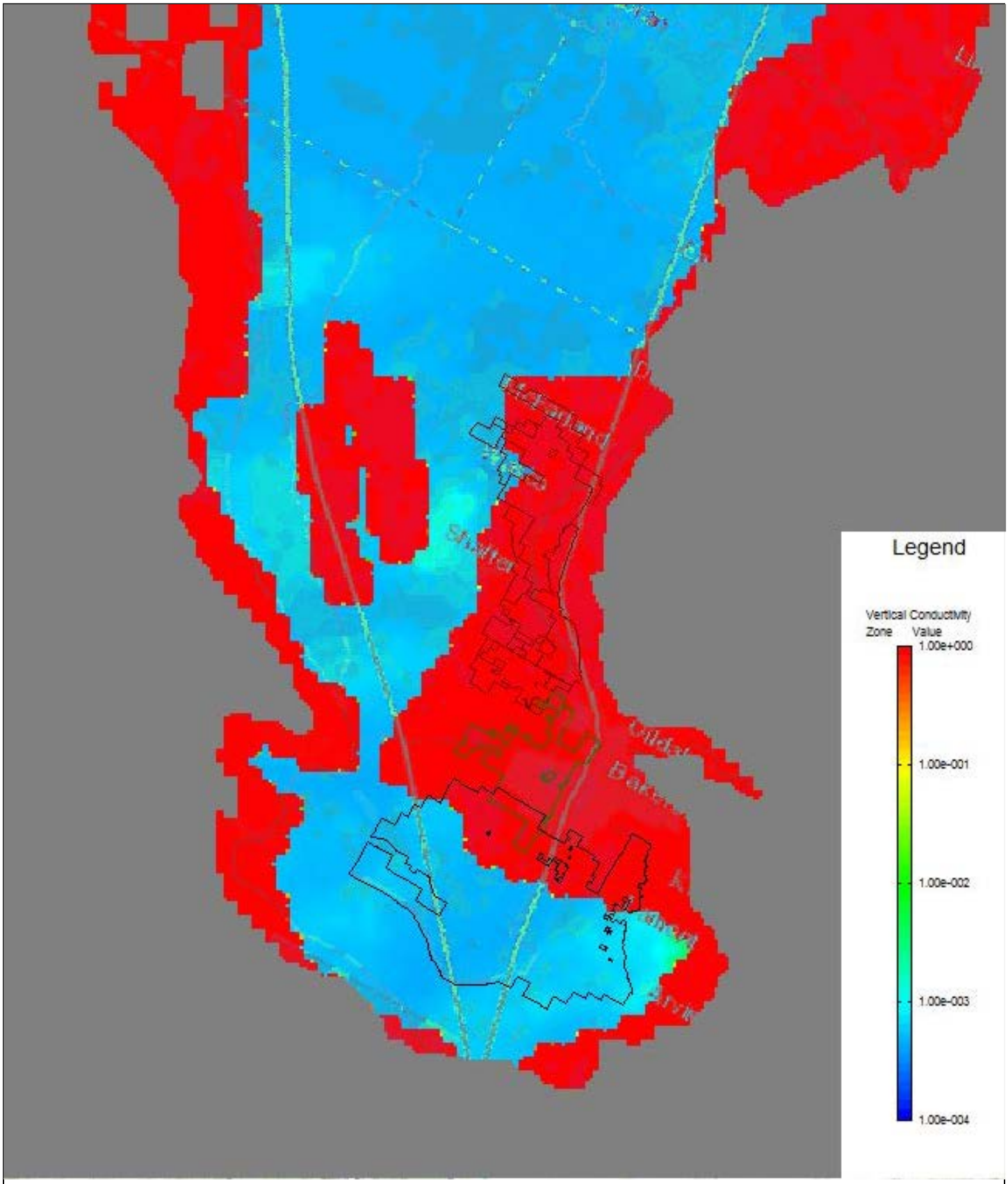
Figure B 13
Horizontal Hydraulic Conductivity of Model Layer 4
KDWD Superposition Model



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TODD GROUNDWATER

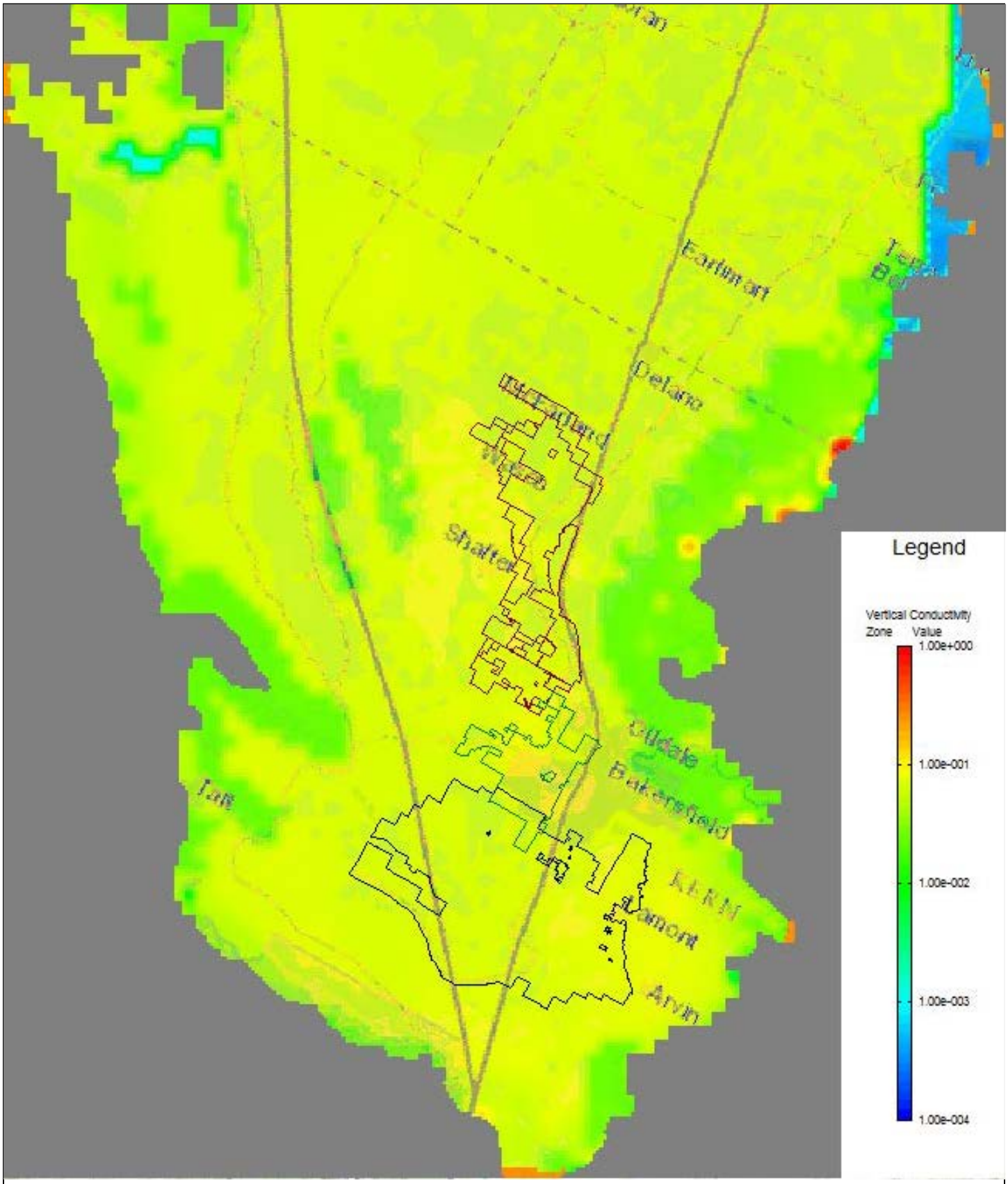
Figure B 14
Vertical Hydraulic Conductivity of Model Layer 1
KDWD Superposition Model



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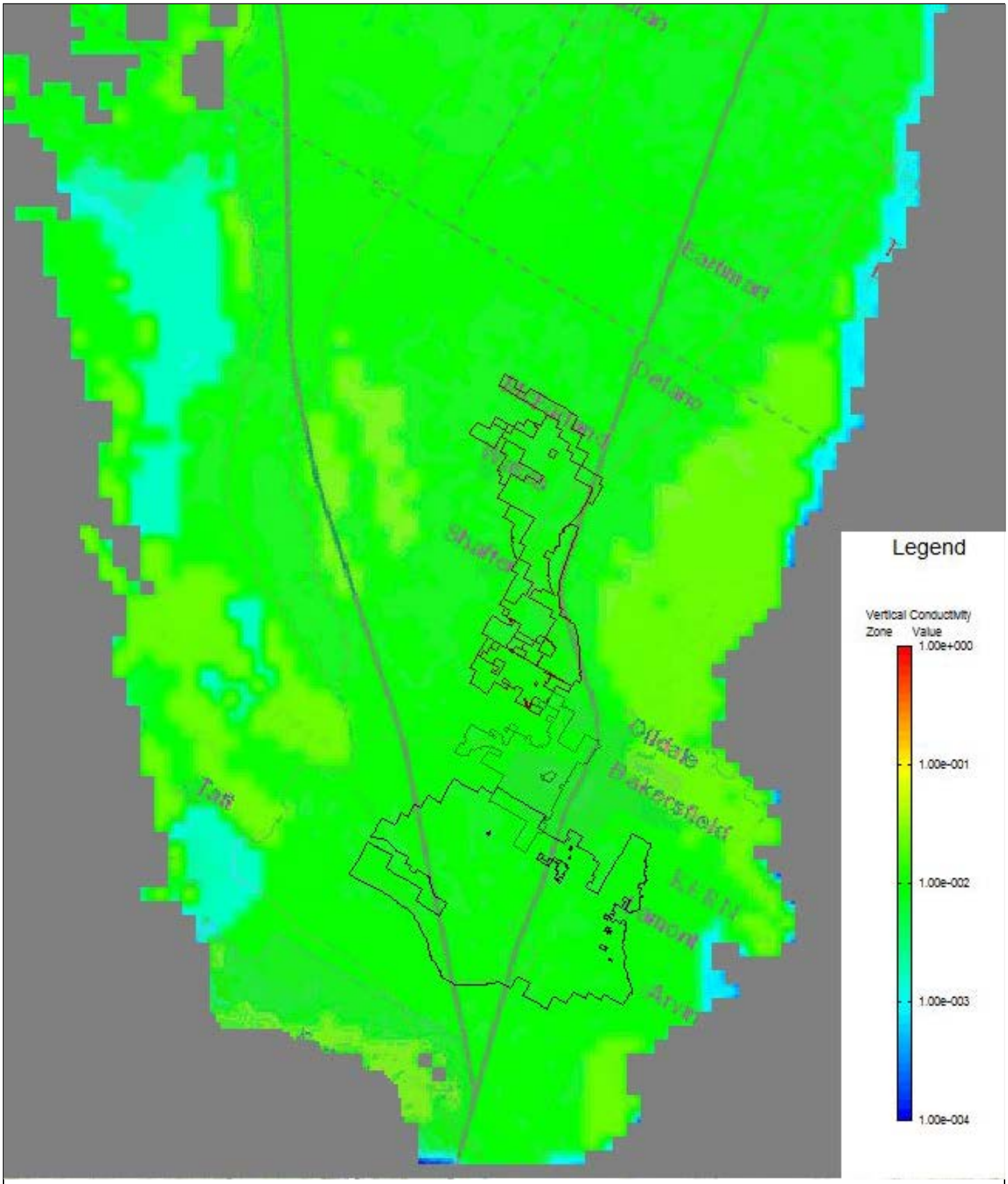
Figure B 15
Vertical Hydraulic Conductivity of Model Layer 2
KDWD Superposition Model



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Figure B 16
Vertical Hydraulic Conductivity of Model Layer 3
KDWD Superposition Model



N

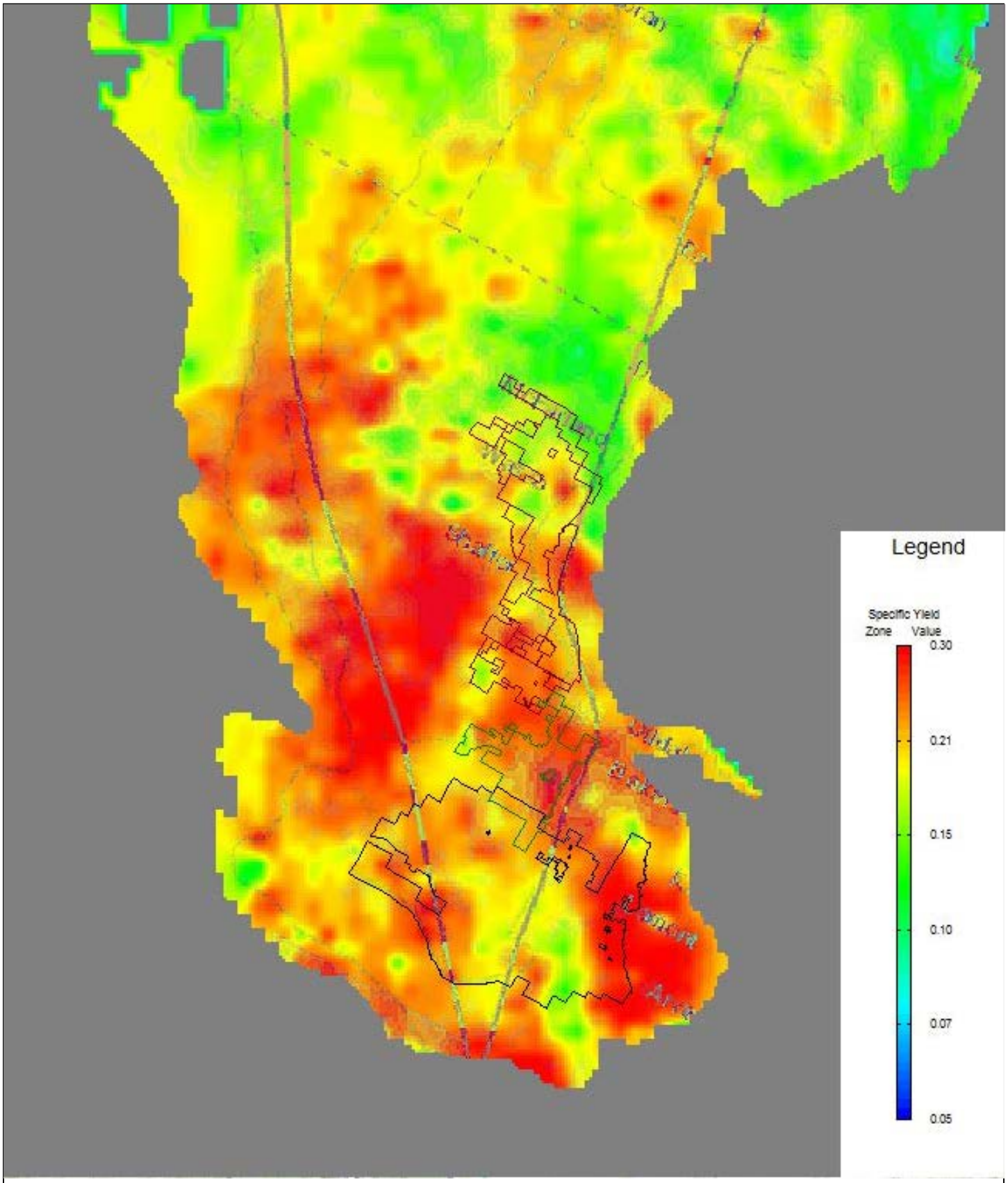
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Scale: Miles

June 2017

TODD GROUNDWATER

Figure B 17
Vertical Hydraulic Conductivity of Model Layer 4
KDWD Superposition Model



N

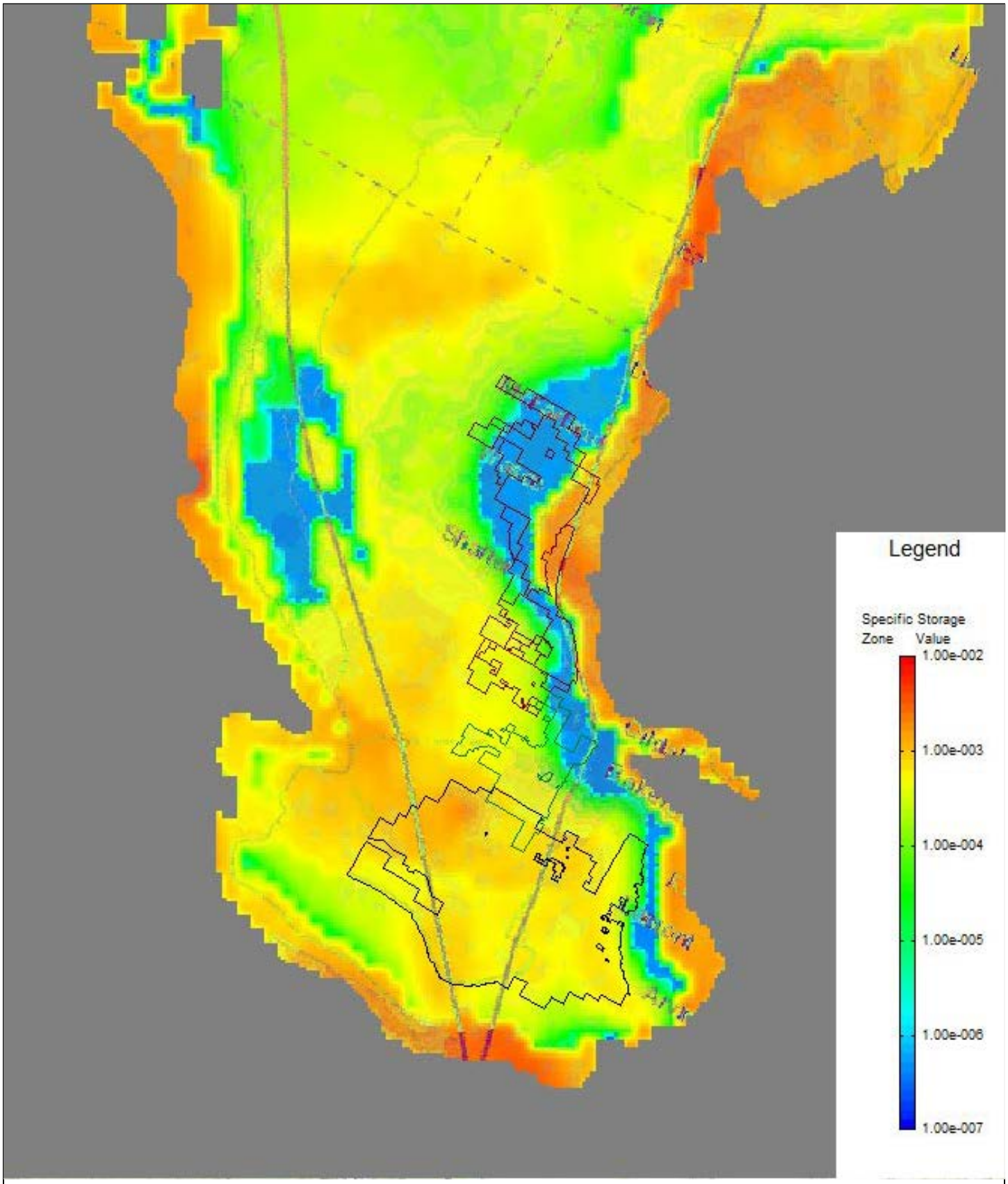
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Scale: Miles

June 2017

TODD GROUNDWATER

Figure B 18
Specific Yield
of Model Layer 1
KDWD Superposition Model



N

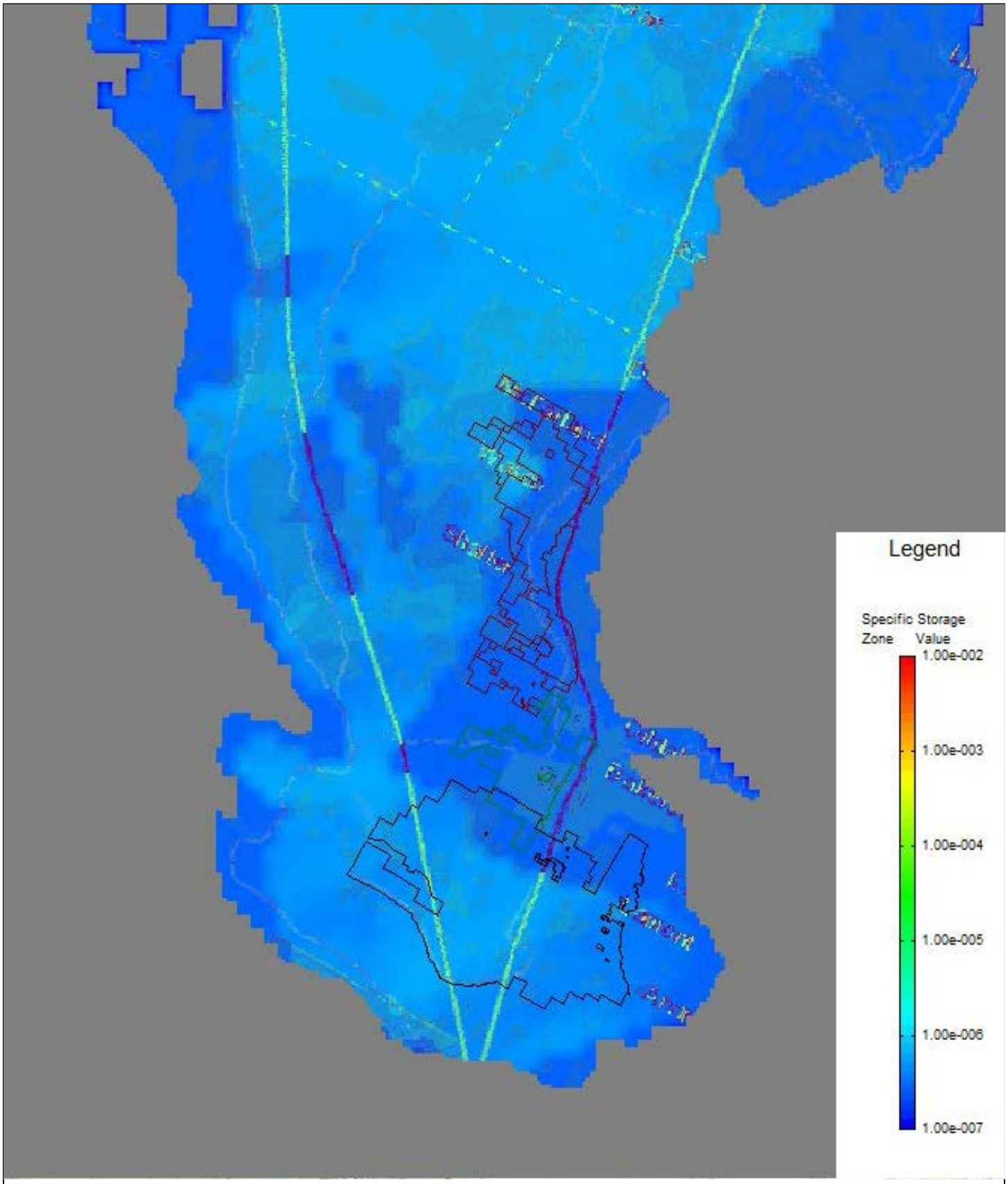
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Scale: Miles

June 2017

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Figure B 19
Specific Storage
of Model Layer 1
KDWD Superposition Model



N

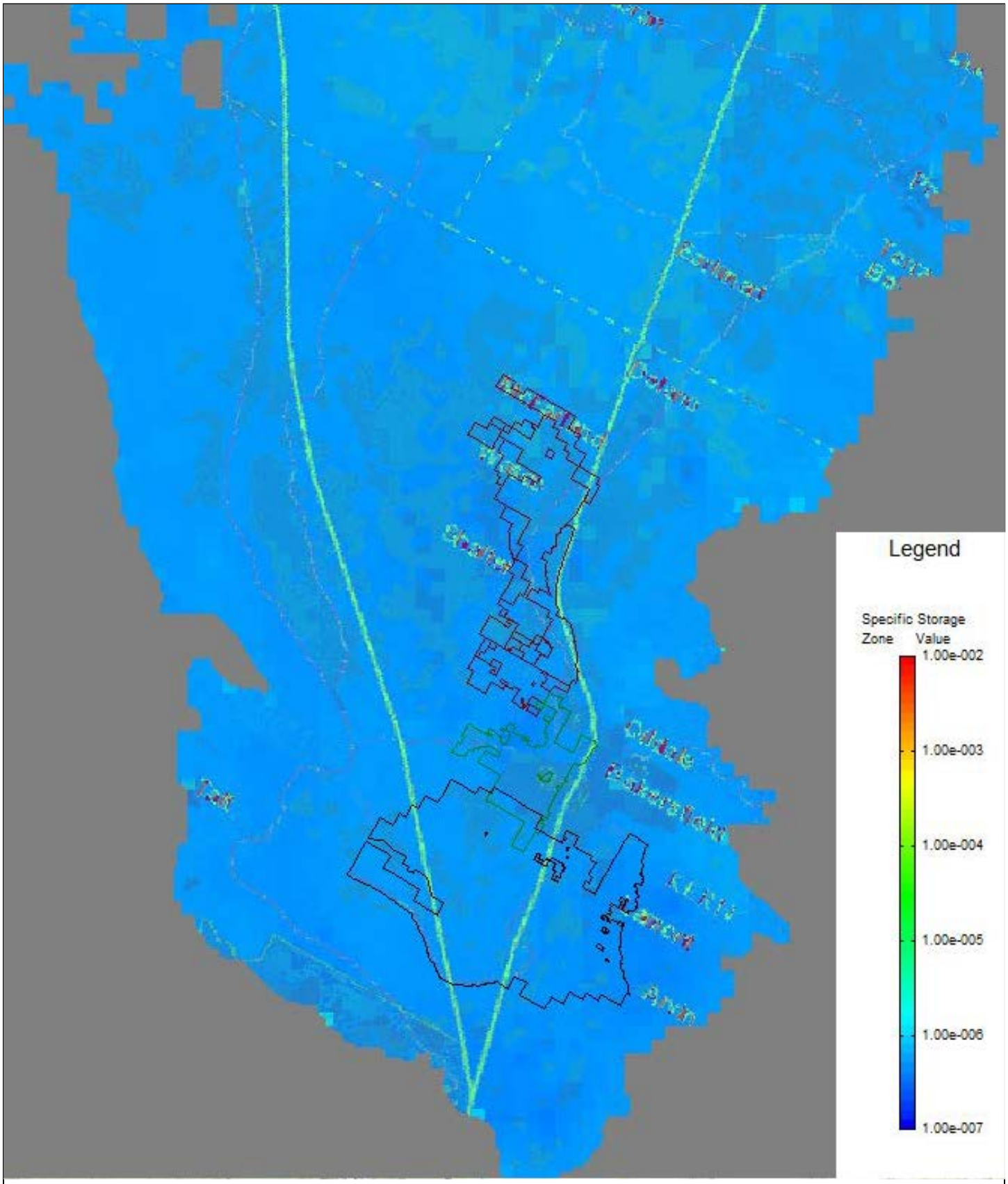
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Scale: Miles

June 2017

TODD GROUNDWATER

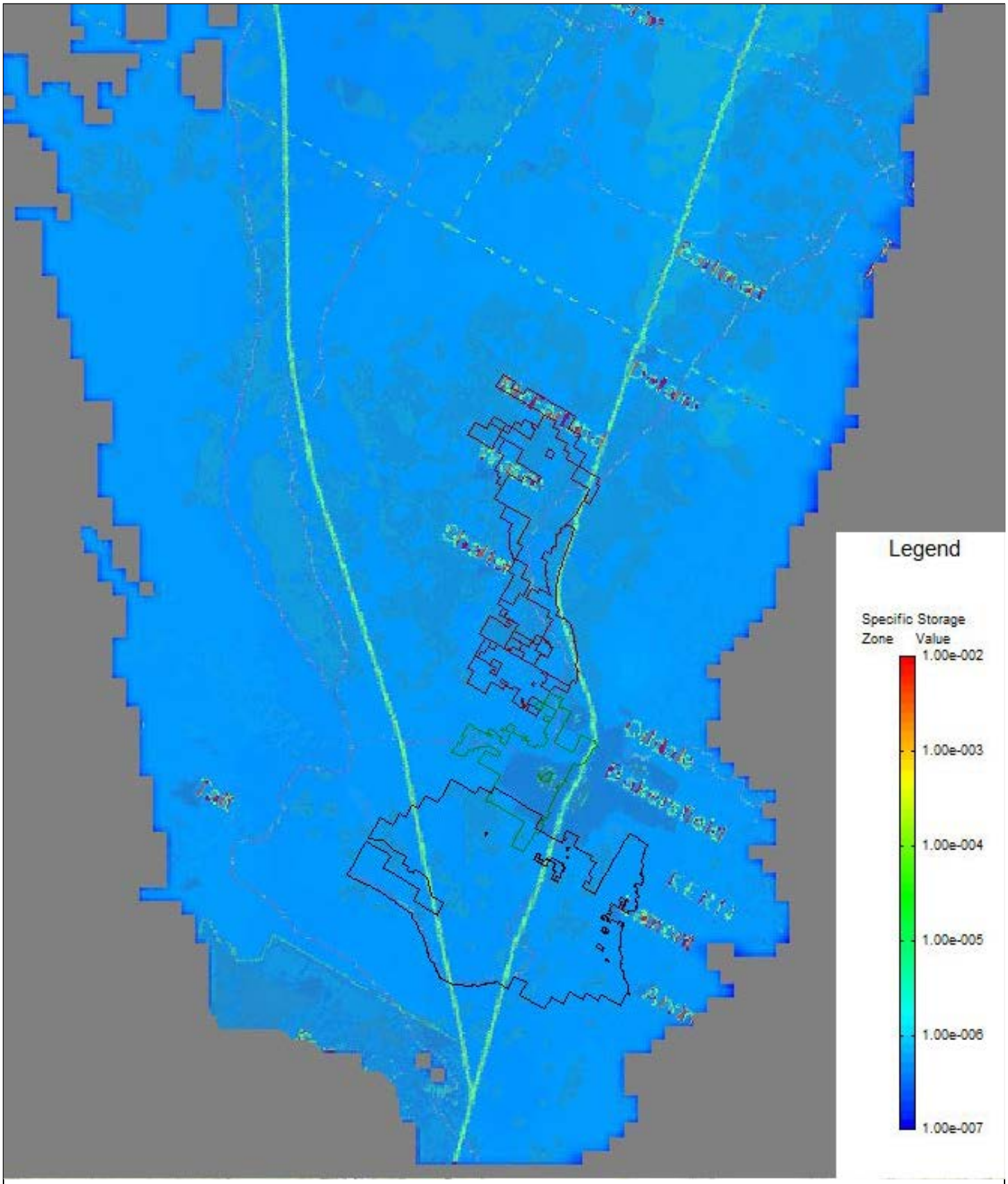
Figure B 20
Specific Storage
of Model Layer 2
KDWD Superposition Model



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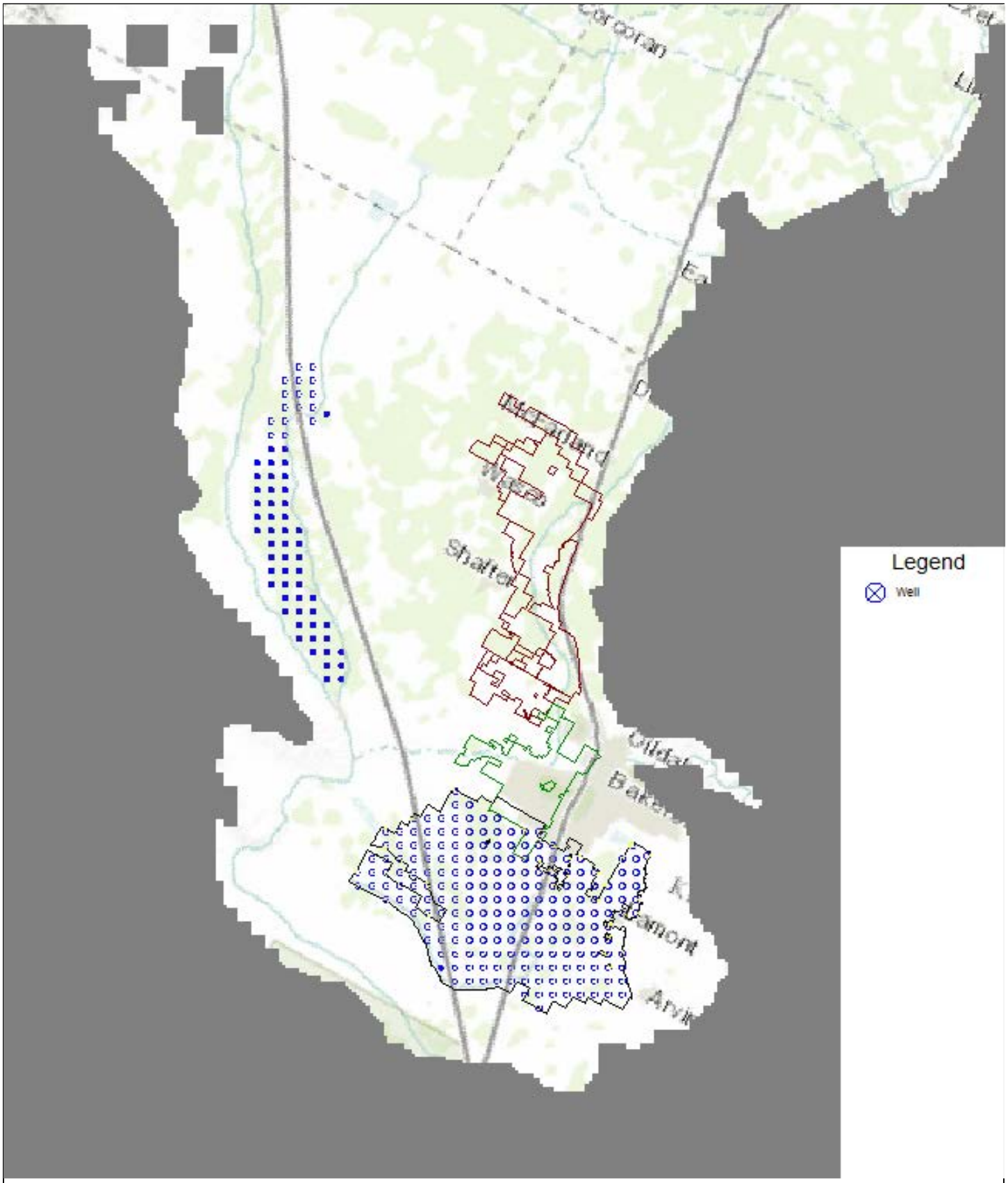
Figure B 21
Specific Storage
of Model Layer 3
KDWD Superposition Model



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Figure B 22
Specific Storage
of Model Layer 4
KDWD Superposition Model



N

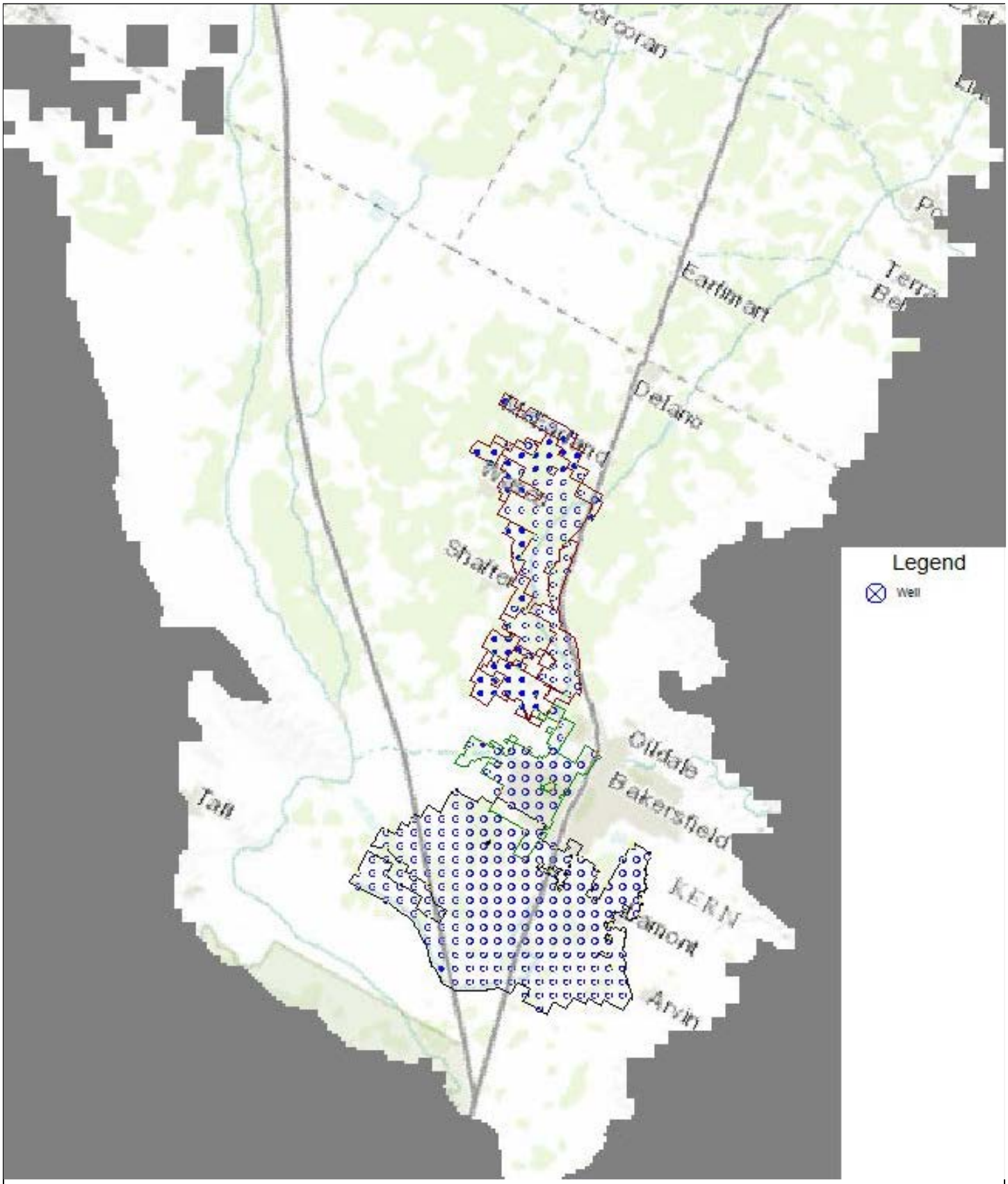
0 5 10

Scale: Miles

June 2017

TODD GROUNDWATER

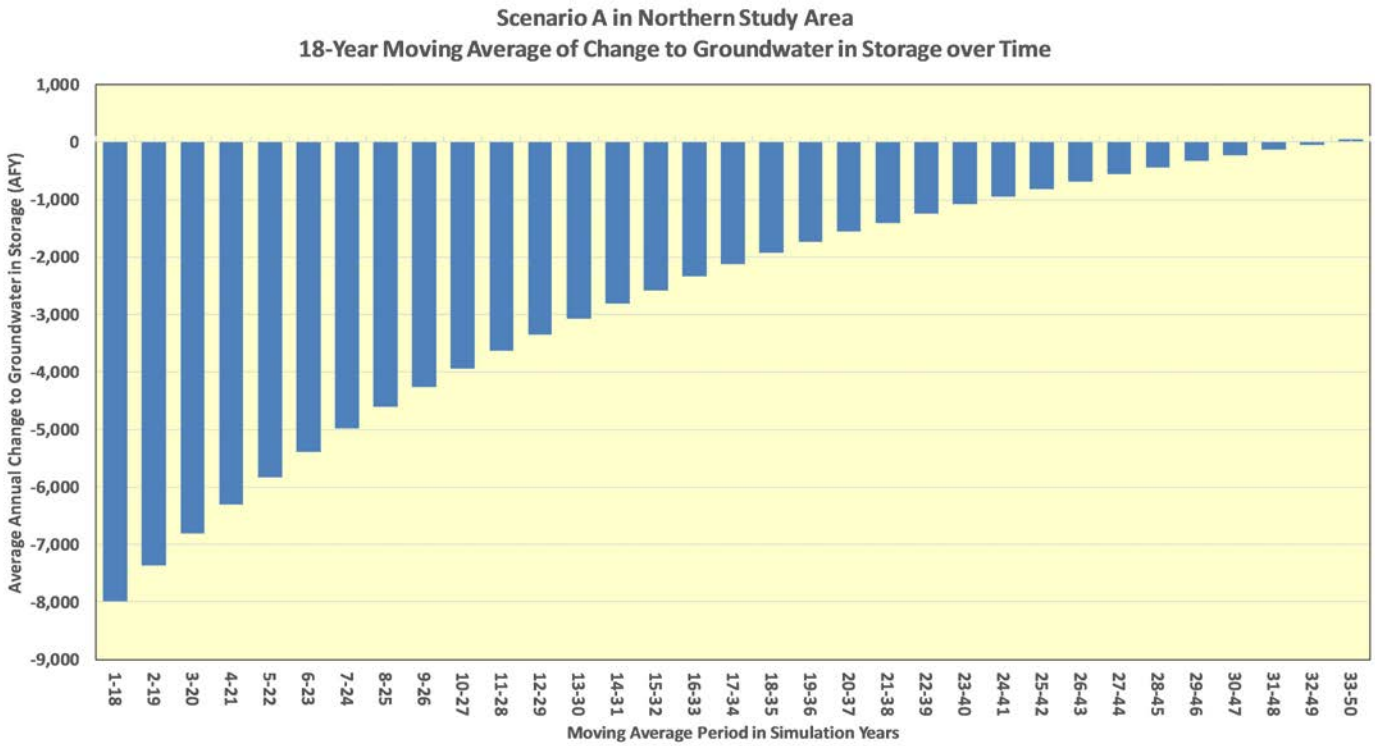
Figure B 23
Proposed Project Pumping Locations for Model Layer 1
KDWD Superposition Model

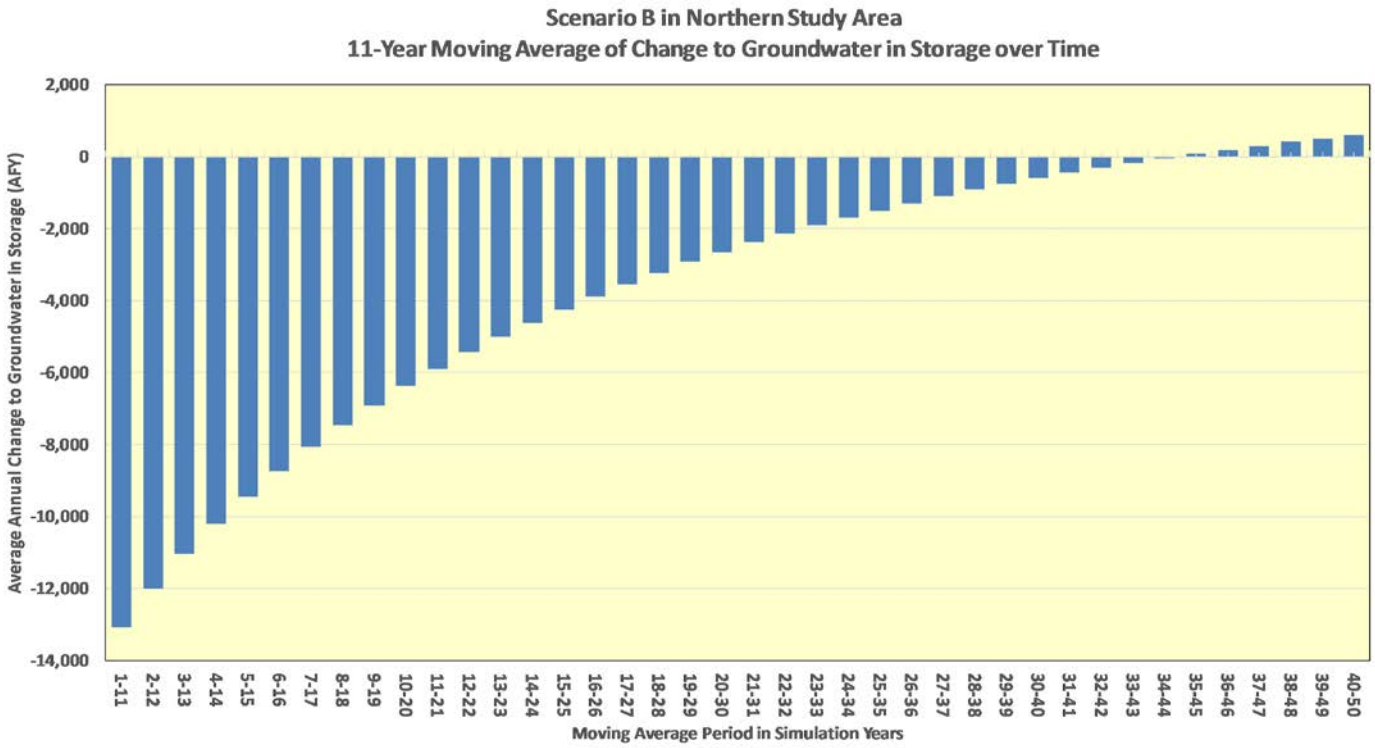


June 2017

TODD GROUNDWATER

Figure B 24
Proposed Project Pumping Locations for Model Layer 3
KDWD Superposition Model





June 2017

TODD GROUNDWATER

Figure B 25
Moving Average Analysis of Groundwater in Storage Over Time in Northern Study Area

KERN FAN MODEL

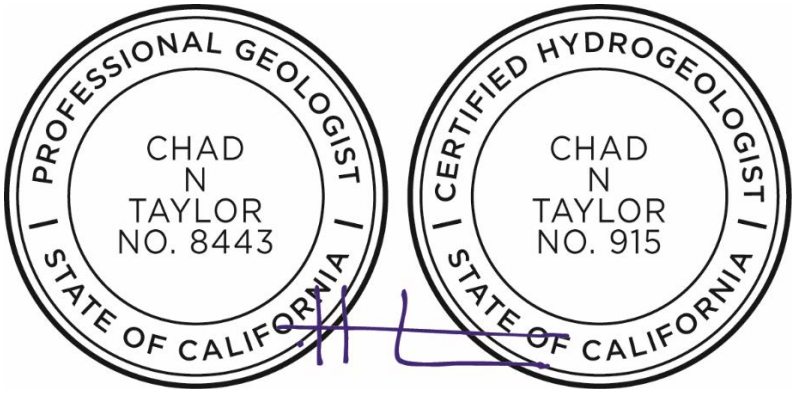
FINAL REPORT

February 2018



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Appendices

Appendix A KCWA Annual (Spring) Water Level Contour Maps

Appendix B Subsurface Inflow Outflow

Appendix C Well Construction Information

Appendix D Maps and Hydrographs of Measured and Simulated Water Levels

Appendix E Deep Percolation of Precipitation for Non-Irrigated and Native Areas

Appendix F Agricultural Irrigation Estimates

Appendix G Without Project Scenario Simulated Water Levels Hydrographs

Appendix H Difference Between With and Without Project Scenarios Hydrographs

Appendix I Without Project Scenario Simulated Water Level Contour Maps

LIST OF ACRONYMS

Acre feet	AF
Acre-feet per year	AFY
Acre-feet per month	AFM
ASTM International	ASTM
Below ground surface	bgs
Berrenda Mesa	BM
Buena Vista Water Storage District	BVWSD
California Department of Water Resources	DWR
California Water Service Company	CalWater
Central Valley Project	CVP
City of Bakersfield	COB
County Water District	CWD
Cubic feet per second	cfs
Cumulative departure curve	CDC
Evapotranspiration	ET
Geographic Information Systems	GIS
Groundwater Modeling System	GMS
Horizontal hydraulic conductivity	Kh
Improvement District 4	ID4
James Pioneer Irrigation District	JPID
Kern County Water Agency	KCWA
Kern Delta Water District	KDWD
Kern Fan Monitoring Committee - Technical Subcommittee	KFMC-TS
Kern Fan Monitoring Committee	KFMC
Kern River Canal and Irrigation	KRCI
Kern Water Bank	KWB
Mean absolute error	MAE
Mean error	ME
Mean sea level	msl

Memoranda of Understanding	MOU
Mutual Water Company	MWC
North Kern Water Storage District	NKWSD
North of the River Municipal Water District	NORMWD
North of the River Sanitary District #1	NORSD
Pioneer Project	Pioneer
Rosedale Rio Bravo Water Storage District	RRBWSD
Semitropic Water Storage District	Semitropic
Specific storage	Ss
Specific yield	Sy
State Water Project	SWP
United States Geologic Survey	USGS
Vaughn Water Company	VWC
Vertical hydraulic conductivity	Kz
Wastewater treatment plants	WWTP
West Kern Water District	WKWD

1. INTRODUCTION

The Kern Fan Monitoring Committee (KFMC) has been working cooperatively to monitor groundwater conditions in the alluvial aquifers underlying the lower Kern River, referred to as the Kern Fan. In this area, favorable hydrogeologic conditions, the availability of imported and local water, and the cooperation of numerous water agencies and stakeholders have allowed for subsurface storage of significant water supplies in the local groundwater basin. Although significant intentional recharge has occurred in the County for almost 50 years, more focused large-scale groundwater banks have operated along the apex of the Kern River Fan since the 1990s.

In compliance with various memoranda of understanding (MOUs) associated with groundwater banking projects, the KFMC has evaluated potential groundwater impacts from various banking projects over time. The basis of the evaluation is defined as the groundwater conditions that would have occurred in the *absence* of banking. The comparison of conditions with groundwater banking to conditions without groundwater banking is referred to as a *with and without* evaluation in this report.

To assist in the with and without evaluation of various banking projects, the KFMC decided to construct, calibrate, and apply a numerical groundwater flow model (also referred to as the Kern Fan Model). Working with the Technical Subcommittee of the KFMC (KFMC-TS), Todd Groundwater[1] constructed the groundwater model in 2012 and 2013. The model was revised and re-calibrated in 2014 to better define vertical anisotropy and adjust boundary conditions. In late 2014, the Technical Subcommittee recommended subdividing the upper model layer into two layers to allow hydraulic properties to better represent the more permeable portions of the Upper Aquifer; the revision and re-calibration was initiated in Spring 2015 and the revised model was approved by the Technical Subcommittee in 2016. The Technical Subcommittee subsequently developed scenarios for the *without banking* evaluation. Final model runs were completed in Spring-Summer 2017.

This Final Report describes the construction, calibration, and application of a three-dimensional numerical groundwater flow model developed to assist in characterization of groundwater flow at the site, generally referred to as the Kern Fan. The MODFLOW model is based on the hydrogeologic site conceptual model presented in *Technical Memorandum No. 1 Site Conceptual Model "With and Without" Banking, Kern Fan Area* (TM-1, Todd, 2012) and in accordance with comments made by the technical subcommittee of the Kern Fan Monitoring Committee (KFMC-TS). Figure 1-1 shows the regional setting, including water and irrigation districts and the model domain. Figure 1-2 shows the primary recharge facilities simulated in the model.

[1] Formerly Todd Engineers. Todd Engineers changed its name to Todd Groundwater in 2014, during the project. Some work products, included herein for completeness, were developed prior to 2014 and maintain a Todd Engineers footer.

The modeling objectives, approach, and scope (including general descriptions of model features) are summarized below. Subsequent sections present the hydrogeological conceptual model, water balance, model construction and calibration process, modeling application and results, and simulated groundwater elevation trends and maps.

1.1. OBJECTIVES

The objectives of the groundwater flow model are 1) to aid in characterizing groundwater flow conditions (sources, sinks, groundwater flow rates and directions, and changes over time) in the area of banking and recovery facilities, and 2) to evaluate groundwater conditions that would have occurred in the absence of banking. Banking projects selected for the *with and without* evaluations include the Kern Water Bank (KWB), Kern County Water Agency (KCWA) Pioneer Project, Berrenda Mesa, and projects operated by Rosedale Rio Bravo Water Storage District (RRBWSD), West Kern Water District, and Buena Vista Water Storage (BVWSD); these projects and districts are shown in Figure 1-3. The comparison of conditions with groundwater banking to conditions without groundwater banking is referred to as the *with and without* evaluation.

The Kern Fan Model is capable of simulating:

- Three-dimensional transient groundwater flow within and between the shallow and deeper aquifer zones;
- Surface recharge from banking facilities and canals;
- Horizontal and vertical flow around and into municipal and agricultural production wells; and
- Groundwater elevations for *with and without* banking projects.

The model was calibrated to the observed site conditions, and provides a reasonable approximation of the Kern Fan groundwater system to meet the objectives of the project.

1.2. MODEL APPROACH AND SCOPE

The model uses the United States Geologic Survey (USGS) finite difference flow model MODFLOW 2005 (Harbaugh 2005) with the Newton Formulation solver (MODFLOW-NWT, Niswonger et al. 2011) to simulate three-dimensional groundwater flow in the model domain. MODFLOW was selected for its usability, manageability, efficiency and transportability. In particular, the transportability of the public domain MODFLOW program and model input files are advantageous for future modeling.

Most model construction and calibration work was performed using the Groundwater Modeling System (GMS) v9.1.4, which was developed by Aquaveo, LLC (Aquaveo 2013) and pre-processes and post-processes the MODFLOW files. The input data for the MODFLOW model were constructed from a variety of sources using database and geographic information systems (GIS) software packages. These data were imported and stored in GMS as coverage and grid files prior to the generation of MODFLOW specific input files. GMS

software is not required to run the Kern Fan MODFLOW model. The MODFLOW 2005 files created by GMS can be imported to other MODFLOW pre- and post-processing software packages (i.e., Visual MODFLOW or Groundwater Vistas) with some modifications, or run using only the freely available MODFLOW executable code.

2. SITE CONCEPTUAL MODEL

The development of the site conceptual model involved a review of the hydrologic and hydrogeologic conditions in the regional study area surrounding the Model Area, Figure 1-1. This review provided the foundational data to quantify volumes and sources of water moving into and through the groundwater system. These data are incorporated into a site-specific water balance and numerical model, subject to calibration as discussed below.

2.1. PHYSICAL SETTING

The study area is characterized by a relatively flat alluvial plain surrounded by the dissected uplands of the Coast Ranges to the west and the Sierra Nevada to the east, Figure 1-1. Within the Model Area (shown on Figures 1-1 and 1-2), ground surface elevations range from about 600 feet mean sea level (msl) at the east-central edge to below 250 feet at the northwest corner. Ground surface elevations along the Kern River range from about 415 feet msl in the east to about 300 feet in the west across the Model Area, with an overall slope of about 6 feet per mile. Most of the Model Area has ground surface elevations between 300 feet and 400 feet msl.

2.1.1. Climate and Precipitation

The Model Area is characterized by cool, moist winters and hot, dry summers. The mean annual temperature is 65^{o} F and summer highs frequently exceed 100^{o} F. Average precipitation in the Model Area is about 6 inches per year.

Annual precipitation from 1890 through 2010 at the Bakersfield station is shown on the upper graph of Figure 2-1 with the Model Period of 1986 – 2010 indicated on the graph. The period of record demonstrates the variability of rainfall in the Model Area ranging from less than 3 inches in extreme dry years to more than 10 inches in very wet years.

Figure 2-1 also shows monthly precipitation during the Model Period plotted on the lower graph with a cumulative departure curve (CDC). The CDC is used to more readily identify wet and dry periods in relation to average precipitation, which is shown as zero on the right-hand scale of Figure 2-1. When the curve is rising, conditions are wetter than average; a declining curve indicates dry conditions. Average precipitation for the Model Period is approximately 6.45 inches per year, slightly wetter than the long-term average. The cumulative departure curve also indicates a relatively wet period, but almost all the change is controlled by the much wetter than normal conditions in December 2010, the last month of the Model Period. But for December rainfall, the Model Period would be very close to average hydrologic conditions.

With an average annual evapotranspiration (ET) rate of 57 inches, most of the rainfall evaporates, producing runoff only during intense rainfall events. Groundwater recharge from rainfall only occurs during wet years. Additional analysis of recharge from rainfall is presented in the Water Balance in Section 3.

2.1.2. Land Use

Land use data have been accessed from the California Department of Water Resources (DWR) and the Kern County Agricultural Commissioner's Office to better understand groundwater use and water supply and how those conditions have changed over the model period. The DWR land use maps identify areas of irrigated agriculture (including crop types), urban and industrial uses, native vegetation and numerous other uses. Land use data available from the Kern County Agricultural Commissioner's Office provide more detail on crop use because the maps are generated based on permit applications from growers. Both sources provide sufficient detail from which to estimate irrigation demand, the primary use of the maps for this project.

DWR land use maps are available for the years 1984, 1990, 1998, and 2006. The most recent DWR maps have been downloaded in electronic format and geo-referenced to the project GIS. The 1984 land use map was available in paper format only and has been digitized for use in the project. Electronic maps from the County are available in GIS format on an annual basis beginning in 1997, but 1997 and 1998 maps were found to be incomplete. A quality control check has been made by comparing DWR and County maps for overlapping time periods; this check indicates that acreages are generally within 15 percent and both sources are judged equally usable for the project. Because data are unavailable for each year of the model period, data have been reviewed for quality and representativeness over time for assignment to various years of the model. Based on this review, the following maps have been assigned to model years as summarized below in Table 2-1.

Table 2-1 Land Use Maps

Years in Model Period	Land Use Maps	Source
1986 - 1988	1984	DWR
1989 - 1995	1990	DWR
1996-1998	1998	DWR
1999 - 2010	1999 - 2010	Kern County

The 2010 crop map from Kern County is shown on Figure 2-2 to illustrate cropping patterns and water use conditions at the end of the model period.

Agricultural Land

As seen on Figure 2-2, most of the Model Area contains irrigated agriculture. For recent years, irrigated agriculture has covered about 159,258 acres of the 290,500-acre Model Area, or about 55 percent. Another 6,790 acres have been determined to represent non-irrigated agriculture, or to be related to agricultural activities, adding another 2 percent to

the agricultural coverage in the Model Area. Although the number of acres of irrigated agricultural changes over the Model Period, it represents more than one-half of the acreage for all years in the model. In addition, cropping patterns, and resulting irrigation demands, have changed significantly over the Model Period. In general, irrigation demand has increased from 1986 to 2010 based on changes in crops throughout the area.

Numerous water districts in the area develop internal district-specific crop surveys, which were requested during the data collection process for this project. However, these surveys are limited in ways that restrict their use. Surveys are not available for most years of the model period. Most of the surveys are simple tables of annual acreage for crop groups and these categories vary from survey to survey. In addition, many surveys group similar-type crops together even when irrigation demands vary significantly among those crops. Most surveys are not location-specific and typically do not account for double-cropping. Further, many districts have now abandoned the crop surveys and have adopted use of the County land use maps, which are used in this project. To facilitate a comparison of the land use data against the crop survey tables, cropping acreages and irrigation demand have been developed on a district-basis. Most of the data compare relatively well (typically within about 15 to 20 percent) for time periods when data are sufficient for comparison. In general, the land use maps often indicate slightly larger acreages due to double-cropping and multiple crops grown on a parcel. Because the land use maps provide more detail on cropping patterns, are location-specific, are based on actual permits, and are available on an annual basis for most years of the Model Period, they are judged the more reliable source for analysis of irrigation demand.

Urbanized Areas

The Model Area includes much of the metropolitan area of the Cities of Bakersfield and Shafter, as well as several smaller communities. Urban areas have increased over time and currently represent about 75,266 acres of the Model Area, or about 26 percent of the area. This has increased from about 12 percent at the beginning of the Model Period.

2.1.3. Groundwater Banking Areas

As shown on Figure 1-2, the west-central portion of the Model Area contains most of the large banking facilities located along the Kern River. Due to the permeable nature of the Kern River Fan sediments, almost all of the enhanced recharge facilities (both along the river and away from the river) involve surface spreading through ponds, low-lying fields, or basins. These recharge areas, designated as “water” on the DWR land use maps, cover about 20,276 acres on recent maps, representing about 7 percent of the Model Area. With the exception of the COB 2800 banking area (which began operation in 1978), most of these banking projects began after the mid- 1990s. Prior to that time, much of the land was irrigated agriculture, with only minor areas designated for intentional recharge (e.g., intentional flooding of open fields in the James Pioneer ID, where the KWB is currently located). Land use maps for pre-banking time periods (DWR 1984 and 1990) have been used to reflect conditions through 1995 (see Table 2-1 above).

2.1.4. Surface Water Features

The Kern River is the primary drainage of the study area and provides most of the water coming into the Model Area (Figure 1-1). The river is approximately 165 miles long and is fed by snowmelt and runoff in the Sierra Nevada, including areas near Mount Whitney, the highest peak in the contiguous United States. River flows are highly variable but have been regulated somewhat by operations at Isabella Dam since its construction in 1953 (Figure 1-1). A stream gage downstream of the dam has recorded an average annual mean discharge of 946 cubic feet per second (cfs) (equivalent to about 680,000 acre feet per year (AFY)). Most of the river water is diverted into numerous canals (most unlined) for conveyance to agricultural fields, groundwater recharge facilities, and other uses. At a downstream gage west of Bakersfield, the river's average mean discharge is 312 cfs (about 226,000 AFY) or about one third of the discharge near the dam.

Prior to development, the Kern River terminated into a series of inland lakes (now dry), the largest of which is Tulare Lake located about 20 miles north of the model domain. In recent times, almost all river discharge has been diverted for water supply or groundwater recharge prior to the drainage turning north at the western edge of the basin. Flood flows in the Kern River that cannot be used locally can exit the basin through the Kern River-California Aqueduct Intertie, located at the intersection of the lower Kern River and the aqueduct on the west-central boundary of the model (Figure 1-1).

River diversions are operated according to a complex system of water rights dating back to the 1800s. Three entities, Kern Delta Water District (KDWD), North Kern Water Storage District (NKWSD), and the City of Bakersfield (COB) hold various senior water rights determined by flows at a stream gage just east of the Model Area, referred to as First Point (Figure 1-1). The City of Bakersfield operates a system of stream gages and weirs along the channel and at diversion points to account for flows and losses (including groundwater recharge) throughout the area. The City reports these diversions and losses in annual hydrographic reports, referred to as Kern River Annual Reports. Canal losses and return flows from irrigated agricultures represent a large percentage of groundwater recharge in the Model Area.

2.2. HYDROGEOLOGIC SETTING

The study area is located in the southern portion of the San Joaquin Valley, a long structural trough filled with more than 10,000 feet of marine and continental sediments. The continental sediments represent a variety of depositional environments including fluvial, deltaic, lacustrine, and alluvial fan sequences and form an alluvial wedge that thickens to the west across the valley.

Numerous investigators have described and mapped geologic units and water-bearing sediments throughout the valley for more than 100 years. That work has been presented and summarized in hundreds of publications and is not repeated here. Summarized herein

are the key elements of the geologic and hydrogeologic setting that describe the site conceptual model and are relevant to the construction of the numerical model.

2.2.1. Groundwater Basin

The study area is located within the Kern County Groundwater Subbasin, the southern-most portion of the San Joaquin Valley Groundwater Basin as defined by DWR. The subbasin covers approximately 2,833 square miles[2], 454 of which are in the Model Area. The subbasin has been estimated to contain approximately 40,000,000 AF of groundwater in storage with another 10,000,000 AF of storage capacity including areas where groundwater elevations have declined (DWR, 2006). A groundwater balance prepared by DWR and KCWA for a normalized year representing 1990 conditions included estimates for subbasin inflows and outflows. In that water balance, total subbasin inflows were estimated at 1,534,000 AFY with outflows estimated at 1,400,300 AFY for a change in storage of 133,700 AFY under these conditions. The largest component of inflow was return flows from agricultural irrigation with both surface water and groundwater (843,000 AFY) and the largest outflow component was groundwater pumping for irrigation (1,600,000 AFY). A long-term water balance prepared by KCWA from 1970 to 1998 indicated a negative change in storage (average of -325,000 AFY), but did not consider all water balance components including subsurface flows. A detailed water balance has been prepared for this project as a part of the conceptual model and is presented in Section 3.

2.2.2. Geology

A simplified geologic map is presented on Figure 2-3 that shows the Neogene and Holocene (late Tertiary and younger) basin sediments rimmed by Tertiary and pre-Tertiary bedrock to the east, south, and west. The Model Area is shown on the geologic map for reference. The Kern River bisects the area, underlain by recent channel deposits. Much of the area has been infilled with alluvial fan sediments, the morphology of which is indicated by the trajectory of the canal systems south of the river (Figure 2-3). The terminus of the ancestral river occurred at inland lakes including the Kern Lake and Buena Vista Lake beds, shown on the map. During long periods of large flows, the river drained north to the Tulare Lake Bed. These paleo-drainages are associated with the deposition of fine-grained sediments, shown as flood-basin deposits and older lacustrine deposits on Figure 2-3. As shown by the Model Area, the presence of fine-grained sediments influenced the delineation of the boundaries of the model, especially along the southwestern edge.

While previous investigators have mapped Pleistocene-age lacustrine deposits, labeled units A – E by Croft (1972), the KFMC Technical Subcommittee (KFMC-TS) indicated that these clay layers could not be readily mapped beneath the entire Kern Fan and used to delineate model layers. Nonetheless, a series of interbedded sands and clays appear to create both unconfined and semi-confined conditions based on groundwater elevation data, with increasing confinement with depth. The character of these interbedded layers were the

[2] As modified in 2016.

basis for delineation of hydrostratigraphic units and the initial definition of model layers, as described below. The unconfined and semi-confined to confined conditions are addressed through hydraulic parameters in the model.

2.2.3. Hydrostratigraphy and Aquifers

More than 220 electric logs have been reviewed to develop a hydrostratigraphic understanding on which to base numerical model layers. Regionally extensive low-resistivity units provide relatively reliable markers to assist in the interpretation. Low resistivity units are typically associated with low permeability sediments such as silts or clays that represent relatively slow deposition that often extends over large areas. The objective of the review was to identify aquifer packages that function as a hydraulic unit and are separated and delineated by relatively finer-grained aquitards. Originally, three hydrostratigraphic units were identified. Through calibration and discussions with KFMC-TS, further discretization of the upper layer was necessary to better reflect discrete coarse-grained and fine-grained intervals, and to adjust parameter zones within each layer. The resulting additional vertical and spatial discretization facilitated the revision of aquifer parameters to better match the conceptual model.

Using this methodology, four hydrostratigraphic units have been defined as illustrated by the electric log on Figure 2-4. The log was recorded in a well at the Pioneer Project, just north of the Kern River (for the general location, see the Pioneer Project on Figure 1-3).

As shown on the log (Figure 2-4), Unit 1 is characterized by an approximate 150-foot sequence of primarily coarse-grained material (sands and gravels) as indicated by the higher resistivity readings. The geologic descriptions on the accompanying driller's logs indicate only minor amounts of silt and clay throughout this upper alluvial sequence. The character of this unit changes to the northwest (beneath Semitropic WSD near the northwestern portion of the model) where the sand sequences are replaced by a thinner sequence of finer-grained sediments. Unit 1 contains the water table throughout the model area and is variably saturated.

The second layer, Unit 2 is characterized by a similar alluvial sequence as Unit 1, defined from approximately 150 feet to approximately 300 feet below ground surface. The sands in this unit (and in the well on Figure 2-4) are screened in most wells throughout the Kern Fan area. This unit is saturated throughout the model domain during the model time period. Unit 2 contains a mix of sediments and is generally more heterogeneous than Unit 1. In particular, a segment of interbedded sands and silts occur within the unit (see depths from 210 feet to 270 feet on Figure 2-4). These fine-grained interbeds are likely responsible for semi-confined conditions locally. In time periods and areas where Unit 1 is dewatered, Unit 2 contains the water table.

Below the upper 300 feet of sediments, Unit 3 is characterized by interbeds of sand/gravel and silt/clay with portions that vary throughout the model area. The upper and lower boundaries of Unit 3 are defined by the occurrence of lower resistivity units in the Kern Fan area, typically below 15 to 20 ohm-meters on the Resistivity Long Normal curve (RLN), which

is the resistivity curve more representative of conditions in the aquifer away from the borehole. In the well on Figure 2-4, the actual resistivity readings for these defining layers are below 15 ohm-meters in the upper portion of Unit 3 (see arrows on Figure 2-4 and scale at the bottom of the log). The top of Unit 3 has been adjusted in some wells to accommodate construction data for representation in the model as described in Section 4 (e.g., the screen on Figure 2-4 is shown to extend from Unit 2 into Unit 3.)

The lower-most hydrostratigraphic unit defined for the model development is referred to as Unit 4 (Figure 2-4). Unit 4 begins at an approximate depth of 600 to 650 feet throughout the model area; it is characterized by higher-resistivity, layers below the base of Unit 3. Below about 700 feet, higher resistivity layers occur with resistivity readings exceeding 50 ohm-m. The relatively high resistivity readings that occur below most of the screened intervals in Unit 4 may also indicate more consolidated conditions as shown on Figure 2-4. Although the well on Figure 2-4 does not extend below about 740 feet, logs from several deeper wells in the area indicate that the nature of the sediments changes once again at about 800 feet, a depth used to define the bottom of Unit 4 for the purposes of the groundwater model. For the few deep wells with available electric logs, this depth indicates more homogeneous consolidated units than seen in the upper intervals, with Unit 4 functioning as a transition zone.

This methodology has been extended across the entire Model Area, recognizing that the textures and character of the units change significantly, especially with distance from the river. In general, Units 1 – 4 were translated into model layers 1-4, as discussed in Section 2.4. Unit boundaries were smoothed to develop the model layers across the area. Variability in the character of the units was accommodated in the model through the assignment of aquifer parameters, as discussed in Section 4. Smoothed model layers and the variability in sediment character across the Kern Water Bank area are illustrated by the resistivity logs on Figure 2-5 (the location of the cross section is shown on Figure 2-9).

2.3. LOCAL WATER AGENCIES AND INSTITUTIONAL FRAMEWORK

Surface water and groundwater are managed conjunctively throughout the study area to effectively match water supplies with demands. Although the site conceptual model focuses on the groundwater system, a brief description of local water agencies and the institutional framework provides some understanding as to which demands are met with each water source.

Several water sources are actively used and managed in the Kern Fan Area. Kern River water enters the Model Area through the river channel or from a series of unlined canals. Water is diverted from the river channel into lined or unlined canals in accordance with water rights administered by the Kern River Watermaster. Water is often transferred or re-directed to other destinations in real time when excess supplies are available. Most of the water is used for agricultural irrigation or groundwater recharge.

Local surface water is supplemented by imported water from the State Water Project (SWP) and Federal Central Valley Project (CVP). SWP water is conveyed into the study area via the California Aqueduct by KCWA, the local contracting agency. SWP water can be diverted into several canals on the west side of the Model Area or recharged in banking facilities on behalf of the agency or others. The Friant Water Users Authority operates the Friant-Kern Canal to convey CVP into the area. CVP water can be conveyed from the canal into a regional transmission canal (e.g., the Cross-Valley Canal) or into the Kern River channel. CVP water enters the study area primarily through the Friant-Kern Canal. Local and imported water is often involved in an exchange to facilitate conveyance.

Contracts, exchanges, and a network of shared conveyance facilities offer Kern County water managers flexibility in water use, but complicate the ability to track the physical movement of water from various sources throughout the Model Area and time period. The focus of the conceptual model has been to evaluate the inflows and outflows relating to the groundwater system regardless of water source while maintaining as detailed accounting as possible to minimize any double-counting in the water balance.

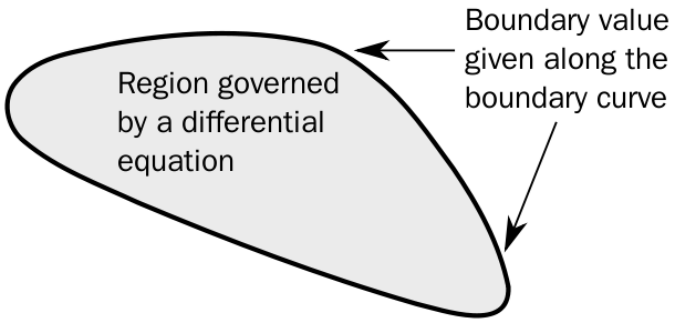
2.4. REPRESENTATION OF THE SITE CONCEPTUAL MODEL IN THE NUMERICAL MODEL

The site conceptual model of the Kern Fan area includes a quantitative assessment for developing model layers, assigning aquifer parameters spatially and vertically, and providing a water balance for the study period. When the data analysis has involved multiple data sets and/or several analytical steps, details of the analysis are provided in a separate appendix and summarized in the text. Collectively, these data and analyses discussed below provide the basis on which the numerical model has been constructed.

2.4.1. Model Area and Boundary Conditions

Groundwater data throughout the study area have been used to characterize the numerical Model Area, which covers 454 square miles. The study area extends beyond the Model Area and its boundaries, which were identified and located on the basis of data over the larger study area.

Model boundaries are used in flow simulations of a large system (e.g., groundwater flow in the Southern Central Valley) by modeling a small part (e.g., the KWB area) that is far from its edges. Boundary conditions represent the dynamic sources of water (or no sources) that flow into or out of the model, and are used to constrain the mathematical solution of three-dimensional groundwater flow within the Model Area. The model domain (area) must have boundary conditions defined on all sides of the three-dimensional volume (top, bottom, and sides) as indicated by the schematic.



For the Kern Fan Model, a combination of time-varying specified head and time-varying specified flux (no flow and finite flow) conditions were used for lateral boundaries in the numerical model. The top boundary for the model is the land surface and/or water table with areal recharge over time. The sources and distribution of areal recharge which compose the top boundary are discussed in detail in Section 3.4. The bottom boundary is discussed further in Section 4.2.3 and is defined as a no-flow boundary for the initial calibration simulations.

The lateral or side boundaries of the numerical model have been developed in conjunction with input from the KFMC, and were discussed at Project Meetings held on December 13, 2011 and April 18, 2012. Model boundaries have been identified and constructed with consideration of geology/hydrogeology and regional groundwater flow directions throughout the study period, and have accounted for potential impacts on simulated flow from localized surface recharge from the river and canals. The lateral boundaries have been located at distances away from the KWB to minimize undue influence on the with and without evaluations. Locations of boundaries have been optimized to meet the multiple goals of 1) properly constraining the flow model simulations with suitable values of specified head or flux, 2) minimizing potential influence of the boundaries on simulation of flow in critical areas around the banking projects, and 3) limiting the model and input data area to a manageable size.

To the degree possible, natural hydrologic boundaries in the study area, such as persistent groundwater flowpaths and geologic boundaries, have been selected. Some boundaries have been located on the basis of both groundwater elevations and geology. Other boundaries have been selected on the basis of groundwater elevation or flux irrespective of geology.

The available KCWA annual (spring) groundwater elevation contour maps over 21 years (1980, 1987, 1991, 1993, 1995, and 1998 – 2010; see Appendix A), along with hydrographs for key study area wells, have been reviewed to identify spatial and temporal trends in groundwater elevations. The individual spring maps between 1980 and 2010 also were digitally averaged to produce an average flow map (Figure 2-6). This map, along with the maps for individual years, has been used to assist the identification of areas with consistent flowlines. Where contours and flowlines have been consistent over time, potential boundaries have been identified. However, in some potential model boundary areas, local flow directions change from year to year in response to changing recharge and pumping patterns. In those areas, model boundaries have been selected to be time-varying specified heads, to account for dynamic flux into and out of these boundaries. These boundaries have been aligned with observed conditions where heads were well-documented.

Figure 2-7 presents the Model Area boundaries and boundary types. Each boundary arc segment is numbered and color-coded by type to facilitate the discussion of boundary conditions below.

For time-varying specified head and specified flux boundaries, head and flux values are assigned to multiple arc 'nodes' along each boundary arc. Different head or flux values are assigned to different boundary nodes along a single arc segment, and can vary over time. Boundary heads or flux along the entire arc can then be extrapolated between nodes. Using this approach, local variations in hydraulic gradient through the different sub-portions of the boundary arc segments can be simulated accurately. Head values used for the boundary arcs are based on groundwater elevations measured in properly constructed wells adjacent or near to the arcs, along with regional groundwater elevation maps and hydrographs. Vertical variations in boundary heads between model layers were simulated where local groundwater elevation data confirm the presence of vertical gradients between shallow and deep aquifers along the boundaries. Flux rates assigned to boundaries were based on estimated inflows (or outflows) such as values of river leakage.

The lateral boundary conditions are described below. Beginning in the east, near the Kern River, boundary ***Segment 1*** was aligned with a generalized northwestern flowpath from the River to the north-northeast is represented as a no flow boundary.

Segment 2 represents a time-varying head boundary along the northern edge of the model. This segment is also aligned roughly along a groundwater flow path from east-southeast to west-northwest. However, review of groundwater elevation contour maps indicates dynamic flow directions likely due to variable pumping and recharge over time. Accordingly, use of an 'open' boundary type (as represented by time-varying specified heads) is appropriate to allow inflow and outflow through the boundary segment. The heads assigned to this boundary segment (and the other time varying specified head segments) were developed based on groundwater elevations monitored over time in appropriately-constructed wells. No vertical difference in head was assigned between the three model layers. Average 1980 to 2010 groundwater elevations along this boundary range from around 160 to 100 feet msl.

Segment 3 continues west-northwest of Segment 2 and represents a no-flow boundary aligned with a consistent east-southeast to west-northwest flowpath. Mapped flow directions along this boundary appear to be more consistent than along Segment 2; therefore, the arc was aligned parallel to the flow path. Average groundwater elevations along this boundary from east to west decline from about 100 to about 70 feet msl.

Segment 4 represents a time-varying specified head boundary in the northwest portion of the model. The curvilinear arc alignment for this boundary was drawn parallel to relatively consistent groundwater elevation contours as presented on the KCWA Spring groundwater elevation maps. Based on groundwater elevation data over time, groundwater outflow from the southeast to the northwest through this boundary occurs during most water years. However, during a few years, inflow occurs from the northwest to the southeast. Recharge and pumping operations in the North Kern WSD and Semitropic Water Storage District (Semitropic) affect heads along boundary Segments 2 and 4. The water banking and pumping activities of North Kern WSD and Semitropic outside the Model Area are addressed with the time-varying heads assigned to the boundary arcs, which reflect the effects of these influences without including the North Kern WSD and Semitropic activities inside the model domain. Average groundwater elevations along the Segment 4 boundary range between about 60 to 80 feet msl.

Segment 5 represents a time-varying specified head boundary in the northwest portion of the model. Contour maps generally show Segment 5 to be perpendicular to groundwater contours, which is commonly interpreted as a flowpath and a no-flow boundary. However, during model calibration it appeared that simulated heads in the northwestern corner of the model were higher than those observed in target wells. As a result, Segment 5 was changed to a time-varying specified head boundary. No layer-specific data were available to generate layer specific datasets for this boundary, so the same time-varying head values were assigned to all three model layers. Time-varying head values for each of these nodes were based on observed groundwater elevations in the area.

Segment 6 represents the western model boundary near Interstate Highway 5. This boundary was created using ground surface elevations and geology. This segment was originally conceptualized as a specified flux boundary to represent leakage from managed recharge near the boundary and any mountain-front recharge from the southwest. KFMC-TS indicated that the boundary should be no-flow, as it was assumed that flow across the boundary would be minimal in all but extreme groundwater elevation ranges.

It should be noted that groundwater elevation data indicate some discontinuities in the area and that monitoring wells within one mile of each other on the western edge of the KWB record very different groundwater elevation fluctuations (e.g., 19R and 19N). Faulting in the area may contribute to this head change. Average groundwater elevations along this boundary range from around 170 to 200 feet msl.

Segment 7 represents the southwestern model boundary and is aligned with the northern edge of lower permeability sediments mapped as overbank and lacustrine deposits (Kern and Buena Vista Lake Bed). Mapped groundwater elevations and inferred flow directions in

this area vary more than in most other areas within the model. Average groundwater elevations along this boundary range from around 160 to 220 feet msl. Large differences in hydraulic heads are measured in wells separated by relatively small distances and between wells screened in shallow and deep aquifer zones. These head variations reflect local recharge and pumping influences and the hydraulic resistance of the low permeability deposits. Groundwater elevation contour maps indicate that some groundwater is moving across the boundary. Moreover, there are some transmissive sand units in this area (e.g., as logged in several wells in the Henry Miller Water District); therefore, flow in this area may not be fully-constrained by the local thick sequences of clay. Accordingly, the southern boundary was located south of the contact of the clay units to minimize the potential artificial influence of this boundary. As located, the low-permeability sediments are hypothesized to impede or restrict the amount of flow through the southern boundary. The southern boundary is also aligned along a persistent flow divide between areas of high and low groundwater elevations. It should be noted that the boundary is relatively far away from the banking projects and these are unlikely to affect model results near the KWB area.

Segment 8 represents the southeastern model boundary near the Central Branch Canal. The groundwater flow regime, along with known canal loss rates at this location, has been used to locate a logical boundary. Heads indicate that recharge from the canal losses creates local linear mounds with divergent groundwater flow beneath the canal. This observation is consistent with water level contour maps, which do not indicate significant subsurface flows across the trace of the canal. Therefore, this boundary was assigned time-varying specified flux boundary with 50 percent of monthly Canal losses assigned to the boundary arc. Groundwater elevations along this boundary average from around 180 to 280 feet msl.

Segment 9 is oriented across the Kern River where it enters the model and is defined as a time-varying specified head boundary, with no head distinction between the four layers of the model. This boundary was originally proposed as a flux boundary but preliminary estimates from data on both sides of the boundary indicated variable inflow and outflow. Accordingly, the segment was changed to a time varying head boundary to allow flow both into and out of the model beneath the River.

Data and calculations to support the flux rates for the boundary conditions are provided in Appendix B: Subsurface Inflow and Outflow. For the specified head and flux boundaries, estimates of associated volumetric flow into and out of the model have been made for the purposes of developing a conceptual model water balance. The methods used to quantify these and other water balance components are described in Section 3.

2.4.2. Model Layers

Three-dimensional models like MODFLOW require discretization of the entire flow domain. The flow region is subdivided into model cells, both horizontally and vertically. The dimensions of the cells in the ***x*** and ***y*** directions are referred to as grid size. The grid size in the ***x*** and ***y*** directions should be sufficiently small to allow accurate simulation of areas of large hydraulic gradient, and the effects of sources and sinks, with a focus on model objectives. Vertical stacks of cells form model layers. Within each cell the various input

parameters are maintained constant, but they may vary horizontally between the cells and vertically between layers.

Ultimately, the numerical model utilizes aquifer hydraulic properties (including horizontal and vertical hydraulic conductivity, and storage properties – along with layer top and bottom elevations) as key input parameters for each model cell and layer.

The numbers and thicknesses of constructed model layers should account for the objectives of the flow simulations (e.g., what is the depth interval of interest, what are the potential inflows and outflows from un-modeled deeper layers to the target depth interval of interest), depth of key facilities such as production wells, presence or absence of vertical hydraulic gradients, and available data. Model layers can sometimes represent major stratigraphic layers, if present. The top and bottom elevations of continuous geologic layers can be simulated, and aquifer hydraulic properties assigned to the layer. This approach can provide a relatively accurate numerical model if the hydraulic properties of the stratigraphic units are well known. If continuous stratigraphic layers are not present, model layers can be defined simply on the basis of aquifer hydraulic property distributions, well completion depths, or other parameters.

The number and depths of layers for the Kern Fan Model have been developed with input from the KFMC-TS, as discussed at the Project Meetings held April 18, 2012, May 10, 2012, and June 20, 2012. At the May 2012 Project Meeting, Todd proposed an initial 3-layer model with generalized layer depth ranges of approximately 0 to 300+, 300+ to 500+, and 500+ to 800 feet below ground surface (bgs). This was revised after the first round of calibration to create a 4-layer model, as recommended by Todd Engineers in a scope of services dated October 13, 2014.

For the model, both hydrogeologic conditions and well depths have been used to define model layers. Most production wells in the study area have a maximum depth of around 700 to 800 feet. Appendix C lists the depths and perforated intervals of wells with known construction information. Figure 2-8 shows wells within the study area. Of the 4,047 wells in the Model Area, almost all have total depths less than 800 feet bgs. The few deeper wells do not appear to pump significant volumes of groundwater below this depth during the study period.

As discussed previously, the presence and distribution of hydrostratigraphic packages and relatively low permeability stratigraphic layers have also been used to construct model layers. Some low-permeability confining units appear to be laterally continuous or semi-continuous over portions of the Model Area, but the low-permeability units are generally not continuous in the KWB area. Higher vertical gradients are measured in the areas where the low permeability units are present, and in areas with dynamic recharge and pumping operations.

During the Project Meetings, KFMC-TS members recommended that model layers honor well construction and the presence of any continuous low permeability materials as much as possible. Electric logs were subsequently reviewed and hydrogeologic cross sections

developed to map the depths of confining units and, insofar as possible, to build model layer geometries around these units (discussed in Section 2.2.3 and illustrated on Figure 2-4). Because distribution of aquifer hydraulic properties is a critical input parameter for the numerical model, model layer development considered wells with high quality aquifer tests, recovery wells, and wells used for contouring depth discrete aquifer units.

Table 2-2 lists the depths of the hydrostratigraphic zones identified in the geophysical logs evaluated for this project (including those wells with high quality aquifer test results available). Model layer elevation surfaces were then constructed on the basis of these point elevations. Although the first approximation of model layers was based on connection and extrapolation of these hydrostratigraphic contact points, the model layer elevation surfaces were smoothed somewhat to provide layer bottom surfaces without large discontinuities. During this process, a number of numerical interpolation methods were tested and some outlying contact elevation points were removed in order to construct layer surfaces. Ultimately, an inverse-distance weighted interpolation method was applied. The resulting layer elevation surfaces honor the hydrostratigraphic data and present functional surfaces for use in the numerical model.

Non-uniform elevations were defined to form elevation surfaces for the bottoms of Layers 1, 2, and 3. The bottom of Layer 4 was set to a constant depth of 800 feet bgs. The upper layer is unconfined and has variable saturated thickness. Layers 2, 3 and 4 are convertible (the layer can change from confined or unconfined based on groundwater elevation). Aquifer hydraulic properties were assigned to each layer based on normalized hydraulic conductivities from high-quality pumping tests and specific sand intervals at locations with high quality lithologic information (see Section 3.2) and adjusted during calibration to match observed groundwater elevations.

In general, model layers are characterized as follows:

- Model Layer 1 - an upper higher permeability alluvial package with only minor silt and clay that extends down to around 150 feet as indicated on geophysical and lithologic logs
- Model Layer 2 - high permeability alluvial package containing a higher percentage of interbedded sand and clay layers than Layer 1; Layer 2 extends from about 150 feet to about 300 feet below ground surface
- Model Layer 3 - a series of interbedded sands and silty clays down to about 550 feet or 600 feet; in many areas, Layer 3 is separated from overlying and underlying model layers by low-resistivity sediments
- Model Layer 4 - a deeper section of interbedded sands and clays, extending to the bottom of most logs with total depths of around 700 to 800 feet.

Deeper wells to the north indicate that the third zone transitions into fewer screened intervals and indications of more consolidation at about 800 feet, used as the bottom of the model.

Figure 2-9 shows locations of the cross sections presented on Figures 2-10 through 2-15. These cross sections illustrate the model layer boundaries and the range of historical groundwater elevations along the cross sections.

Figures 2-16 through 2-19 show the final interpolated surfaces for the bottoms of Model Layers 1, 2, 3 and 4, respectively. Elevations of the bottom of Layer 1 (Figure 2-16) range from about 140 to 340 feet msl. Elevations of the bottom of Layer 2 (Figure 2-17) range from about -10 to 120 feet msl. Elevations of the bottom of Layer 3 range from about -330 to -190 feet msl (Figure 2-18) The bottom of Layer 4 is set at a constant depth of 800 feet bgs; accordingly, elevations range from about -510 to -370 feet msl (Figure 2-19).

These elevations form the geometrical framework of the numerical flow model. Aquifer hydraulic properties including heterogeneous horizontal and vertical hydraulic conductivities, specific yields, and storage coefficients were assigned to each model layer as discussed below.

2.4.3. Model Calibration Period

Selection of the historical model calibration period has been based on the following criteria:

- availability and reliability of key data sets compiled for the site conceptual model,
- inclusion of variable wet and dry conditions in order to validate the predictive model,
- sufficiently long transient simulation period to simulate conditions before and during operation of the major banking projects targeted for the evaluation including recharge and recovery (i.e., before about 1993),
- relatively stable groundwater elevations at initial conditions
- selection of appropriate initial conditions to allow sufficient time for the model to ”attenuate” any errors caused by initial conditions.

In general, key data sets beginning in the 1980s were more readily available and better-documented than older data. For example, the KCWA groundwater elevation database did not contain data prior to 1986; this database represents the most comprehensive compilation of consistently monitored wells in the basin and was the key data source for model calibration. The only groundwater elevation data available prior to 1986 are from the Department of Water Resources (DWR); however, historical data from DWR are much more limited and the number of wells increases significantly in 1986.

In addition, the early 1980s were dominated by dynamic conditions associated with significant wet periods and rising water levels. By 1986, water levels were more stable than throughout most of the previous decade. Figure 2-1 shows annual precipitation data (presented on a calendar year basis) and a portion of the long-term (1890-2010) cumulative departure curve. Several wet and dry cycles occurred over the 25-year study period. The post-1986 period precedes a major drought, with a very dry period occurring in 1990 and 1991, while relatively wet periods occurred in the late 1990s. Dry conditions returned in the late 2000s approaching the end of the historical simulation period. Simulation of these

alternating dry and wet cycles allows validation of the model under differing recharge conditions.

Based on these criteria, a simulation period of 1986 through 2010 was selected. Rationale for the 25-year period selection included the timing of banking projects, wet and dry hydrologic cycles, about three years of relatively stable groundwater elevations for initial conditions, and data availability. Recharge at the KWB and at other recharge facilities began in the mid-1990s, so inclusion of the earlier period beginning in 1986 allows evaluation of calibration quality before initiation of banking.

2.5. INITIAL HYDRAULIC PARAMETERS FOR THE KERN FAN MODEL

2.5.1. Basis for Selection of Initial Aquifer Parameters

For this project, a methodology was developed to assign initial aquifer parameters in the numerical model based on the distribution of coarse- and fine-grain deposits (also referred to as sediment textures). The distributions of textures were derived from more than 220 electrical resistivity logs from wells across the study area. The texture data were used to supplement the calculated aquifer hydraulic parameters from high quality pumping tests in order to develop initial aquifer properties throughout the entire model domain; initial aquifer parameters were modified during calibration. Key aquifer parameters and methods used to assign these parameters are discussed in more detail below.

2.5.2. Aquifer Hydraulic Properties

Aquifer hydraulic properties are important input parameters for the numerical model. The key parameters are vertical and horizontal *hydraulic conductivity*, measures of the aquifer permeability, and *storage coefficients*, which affect the dynamic aquifer response to transient stresses such as recharge and pumping. These parameters, along with the model layer thickness, form the physical framework or 'plumbing' of the groundwater system for the numerical model.

Some estimates of aquifer hydraulic properties within the study area previously were made from well pumping tests. Pumping test data and results have been obtained from KCWA and participating water agencies and districts. Additional estimates of hydraulic properties were made by previous investigators using undisturbed core samples from boreholes. Data from the pumping tests compiled for the Kern Fan Model are summarized in Table 2-3.

Estimates of aquifer *transmissivity* can be derived from pumping tests. Transmissivity is the rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient. Transmissivity divided by the saturated thickness of aquifer is equal to the horizontal hydraulic conductivity. While a constant-rate, long-term pumping test is the best method of determining transmissivity, it can also be estimated based on the ratio of pumping rate of the well and the observed drawdown (specific capacity). Storage properties of the aquifer include s*pecific yield* for unconfined aquifers and *confined storage coefficient* or *specific storage* (equivalent to storage coefficient divided by the saturated thickness of

aquifer) for confined aquifers. Representative three-dimensional distributions of these hydraulic properties allow accurate model predictions of the aquifer hydraulic response to dynamic recharge and pumping.

These aquifer hydraulic properties vary spatially across the study area because of the variability in depositional environments and resulting aquifer textures. Well-sorted, coarse-grained sands and gravels are generally associated with higher hydraulic conductivity and storage coefficients than fine-grained silts and clays.

The approach and methodology for representing aquifer hydraulic parameters in the numerical model has been developed in conjunction with the KFMC-TS, as discussed at the Project Meetings held April 18, 2012, May 10, 2012, and June 20, 2012. Each of the four model layers were 'populated' with initial hydraulic conductivities and storage parameters; these parameters were adjusted through calibration. The model contains true-layer elevations for the top and bottom of each layer along with assigned hydraulic conductivities and storage parameters representing a composite value for the layer. Aquifer pumping test transmissivity results along with borehole lithologies (sand and silt/clay intervals) at different locations within the Model Area were used to estimate the distribution of horizontal hydraulic conductivities for each layer. Vertical hydraulic conductivities were estimated initially on the presence or absence of clay layers and supplemented with limited core sample permeameter tests. Storage coefficients include specific yield for the uppermost unconfined aquifer and confined or 'mixed' (semi-confined) storage coefficients for the deeper layers.

Aquifer Transmissivity and Horizontal Hydraulic Conductivity

Aquifer transmissivity values from high quality pumping tests were used to estimate horizontal hydraulic conductivities of the sand fraction at each test well location. Composite hydraulic conductivities at different locations were then developed based on the normalized hydraulic conductivities and actual percentages of coarse and fine aquifer materials at different locations.

Figure 2-8 shows locations of wells in the study area, indicating those with aquifer pumping test data. The most accurate aquifer transmissivity values are from wells with high quality constant-rate pumping tests, observation wells, and correct data analyses. The highest quality transmissivity values are from the constant-rate pumping tests with observation wells performed on ID4 wells at Allen Road, Rosedale ENNS Pond Wells, Strand Ranch wells, and West Kern wells. For this set of tests, both drawdown and recovery data from pumping and observation wells were evaluated. Additional high-quality tests were performed by KCWA on wells on and in the vicinity of the KWB. This set of tests involved single-well constant-rate pumping tests with 24-hour durations. Groundwater elevation recovery data from the pumping wells were analyzed to estimate aquifer transmissivities. Of similar good quality were a third set of pumping tests and estimated aquifer transmissivities provided by the KFMC. As shown in Table 2-3, aquifer transmissivities for these high and good quality test wells range from 2,270 to 110,000 square feet per day (ft^2/day). The average transmissivity is about 20,080 ft^2/day.

Figure 2-20 shows the distribution of transmissivity values estimated from high quality aquifer tests. Relatively high transmissivities are present in the center of the alluvial fan and KWB area; generally lower transmissivities are mapped in the northern and southern portions of the Model Area.

After discussion with the KFMC-TS, it was determined that aquifer transmissivities estimated from specific capacity values are of relatively lower quality, and would need to be normalized for the test duration and well screen interval. Therefore, these lower quality data have not been used to estimate horizontal hydraulic conductivities.

For each reliable pumping test, the electrical resistivity logs were reviewed and sand intervals identified. The total saturated sand thicknesses for each reliable test well were summed and the estimated transmissivities were divided by the total sand thickness to obtain a horizontal hydraulic conductivity for all sand layers at each well. This approach assumes that the inflow to the pumping well occurs via the sand intervals only, and that the horizontal hydraulic conductivity of each sand interval is the same. Using the normalized hydraulic conductivities and fractions of sand and lower permeability silts and clays, the hydraulic properties were further partitioned by model layer. The horizontal hydraulic conductivity at each well for each layer was scaled based on the percentage of saturated sand logged in each depth interval. The resulting composite hydraulic conductivities for each model layer were reduced (scaled) based on the percentage of sand in each layer. Using this approach, the total aquifer transmissivity at each test well has been preserved and partitioned by model layer.

Representative values of horizontal hydraulic conductivity for the sand fractions from the analyses range from around 10 to 100 feet per day. The final analyses and hydraulic conductivity distribution used in the numerical model are documented in the following section.

Vertical Hydraulic Conductivity

Vertical hydraulic conductivities are generally lower than horizontal hydraulic conductivities. This is due to the stratified nature of alluvium, including sediment grain imbrications that cause lower pore connectivity in the vertical direction as compared with horizontal, and the presence of discrete fine-grained silt and clay layers on both micro and macro scales. In areas where relatively continuous fine-grained stratigraphic layers are present, vertical groundwater flow is impeded due to the low vertical permeability.

Zones of vertical to horizontal hydraulic conductivity anisotropy ratios were mapped initially (in part based on the distribution of coarse and fine-grained deposits) and adjusted during calibration. In areas where coarse-grained deposit predominate, higher vertical-to-horizontal hydraulic conductivity anisotropy ratios are simulated.

Storage Coefficients

Both unconfined and confined aquifer storage properties have been tabulated from published studies (USGS, DWR, and others), aquifer pumping tests, laboratory tests, and previous modeling of the KWB. Table 2-3 contains the storage coefficients estimated for

high-quality pumping tests; these include tests performed on West Kern and Strand Ranch wells. The relatively low storage values from these tests indicate confined or semi-confined conditions. The storage coefficients range from around 0.0008 to 0.03 (unitless), and are appropriate for simulation of the semiconfined and confined model Layers 2, 3, and 4.

For the unconfined aquifer zones (Model Layers 1 and 2), specific yields are used. Table 2-4 lists a range of specific yield values for different soil classifications (sand, clayey sand, etc.) in the Central Valley. Coarse-grained sediments (such as well-sorted sand) have the highest specific yields (up to 35 percent), with lower values for finer-grained sediments. DWR estimated specific yields between 5.3 to 19.6 percent in the Kern County Subbasin (DWR 2006).

As with hydraulic conductivity, three-dimensional distributions of specific yield and storage coefficients have been developed during model calibration. During calibration, storage coefficients (specific yield and specific storage) were found to be a sensitive parameter with respect to matching observed water levels over time. These parameters were adjusted to better fit the model-simulated groundwater elevations with the observed data.

2.6. GROUNDWATER OCCURRENCE AND FLOW

Groundwater elevation data have been evaluated across the study area in order to assess horizontal and vertical hydraulic gradients, to define groundwater flow rates and directions, to estimate subsurface inflow and outflow, and to evaluate change in storage over time. Groundwater elevation data also have been used to locate and align the model boundaries (Section 2.4.1). Groundwater elevation data from a subset of these wells were used to assess model calibration quality.

2.6.1. Groundwater Levels

Groundwater elevation databases have been obtained from the KCWA and DWR. The KCWA began a groundwater elevation monitoring program in the 1980s. Groundwater monitoring of selected wells in the study area has been conducted on a monthly or semi-annual basis, and supports the generation of annual (Spring) groundwater elevation contour maps by KCWA. These maps, along with hydrographs for key wells in the KWB area, are reported in the Annual Operations Reports prepared by the KFMC. Figure 2-8 shows wells in the study area; many of these wells have reported groundwater elevation data and are used in the groundwater flow evaluation.

The range of groundwater elevations over the study period is illustrated on the cross sections (Figures 2-10 through 2-15). As illustrated on the cross sections, during periods of high groundwater, the water table is sometimes near the ground surface along the western and southern model boundaries, and depth to water beneath the KWB is less than 50 feet. In other areas and during dry periods, depth to water exceeds 300 feet. This range of groundwater elevations reflects the dynamic nature of recharge and pumping in the study area.

Groundwater elevation changes over time are also shown on hydrographs prepared by the KFMC and included in the Kern Fan Area Operations and Monitoring Reports. Changes in groundwater elevations over time and by depth are documented in these hydrographs from key wells, Appendix D.

Vertical hydraulic gradients are present in several portions of the study area. Downward vertical gradients have been measured beneath and adjacent to some of the recharge ponds and in other areas where fine-grained confining units are present. Vertical hydraulic gradients are present in several areas. These areas include the northernmost and southernmost portions of the model and generally correspond to locations where fine-grained confining units are present. At some locations, the magnitude of the vertical hydraulic gradient exceeds that of horizontal gradients. Vertical hydraulic gradients present near the KWB are measured in "nested" well pairs within and between shallow and deep aquifer zones.

Groundwater elevation data have been used to assess model calibration. Maps and hydrographs of measured and simulated groundwater elevations in space and time have been developed, and are documented in Section 6 and Appendix D of this document.

2.6.2. Groundwater Flow

Horizontal flow conditions are characterized using the KCWA Spring groundwater elevation contour maps. Annual (spring) groundwater elevation contour maps for individual years are included in Appendix A.

As illustrated on the annual groundwater elevation maps, groundwater generally flows from natural and artificial recharge areas toward discharge points. For any given period, the highest groundwater elevations generally occur near the eastern model boundary as a result of subsurface inflow from the Kern River and infiltration in the channel and adjacent canals. A divergent groundwater flow divide typically coincides with the Kern River channel with flow away from the river. Groundwater flow across the southern portion of the study area is generally from north to south, with local perturbations around local recharge and pumping sources particularly in the southernmost areas of the model. Groundwater flow through the northern portion of the study area is generally from southeast to northwest, away from the River and KWB and toward Semitropic Water Storage District.

The annual groundwater elevation contour maps illustrate fluctuations in groundwater elevations from year to year over the model domain. Overall increases and decreases in basin storage are reflected in these groundwater elevations and are correlated to the variability in annual recharge and discharge (primarily pumping). These groundwater elevation changes over time have been used to estimate the change in groundwater storage over the model period for comparison with the initial water balance of measured and estimated inflows and outflows from the groundwater system, as discussed in the following section (Section 3).

3. WATER BALANCE

To better understand the volumes of water moving through the groundwater system and to develop inputs for the numerical model, a water balance has been developed for the Model Area. The water balance presented in this section accounts for inflows and outflows to groundwater, the subtraction of which represents changes in groundwater in storage over time. The balance presented in this section does not provide for spatial variation, which is handled in the numerical model by assigning appropriate portions of the inflows and outflows to the corresponding locations. This water balance represents a first approximation of change in groundwater in storage that was assessed further during model development and calibration. A summary of water balance components is shown on Table 3-1.

Data have been compiled monthly for model input; annual totals are summarized here to illustrate the annual average and cumulative change in groundwater in storage in the Model Area for the entire Model Period. The data and methodology are described for each of the water balance components below.

3.1. INFLOWS

Inflows into the groundwater system include subsurface inflow, deep percolation from precipitation, return flows from agricultural and municipal uses, canal losses, and managed recharge including groundwater banking. Each inflow component is described briefly below, followed by a presentation of the data from 1986 through 2010.

3.1.1. Subsurface Inflow

Groundwater flow occurs into and out of the model area through lateral boundaries. As described in Section 2.4.1, time-varying specified head and specified flux boundaries allow subsurface flow into the model. The areas of inflow and methodology used to calculate the amounts over time are provided in Appendix B. As summarized in Table 3-1, the estimated rate of inflow varies over time, with a range from zero (in 2000) to 15,556 AFY (in 1991).

3.1.2. Recharge from Rainfall

For the purposes of this water balance, recharge from rainfall has been subdivided into several different inflow components of the water balance. Percolation from rainfall on areas with native vegetation has been estimated using a simple soil moisture balance, as documented in Appendix E. Deep percolation in these areas occurs only in very wet years: 1995, 1998, and 2010, and as shown in Table 3-1, total volumes of rainfall recharge are small. It should be noted that rainfall on agricultural areas and municipal areas are included in the irrigation return flows and municipal return flows (see sections below).

3.1.3. Irrigation Return Flows

This inflow component accounts for the portion of agricultural irrigation water that is applied in excess of the evapotranspiration (ET) of the crop, as well as excess precipitation that either percolates directly or runs off and percolates in nearby areas (defined herein as irrigation return flows). For agricultural areas, individual crops are associated with different amounts of return flows based on crop ET and irrigation efficiencies. The methodology used to develop agricultural demand (including crop ET and documentation of irrigation efficiencies used in the analysis) are described in more detail in Appendix F. Irrigation return flows include irrigation from both surface water and groundwater. The irrigation return flows for urban areas, including lawns and swimming pools used by individual homeowners, are developed separately based on municipal water demands and are summarized in the next subsection as *municipal return flows*. Table 3-2 shows the estimated irrigation return flow for agricultural areas by Water District and service area. Figure 3-1 shows the Water Districts and Service Areas.

It is recognized that return flows do not recharge groundwater immediately upon application of irrigation, and instead percolate through the vadose zone based on local sediment properties and depths. This process creates a lag time between irrigation and groundwater recharge from return flows. For this project, various scenarios of vadose zone transport times have been evaluated. However, for the purposes of this water balance, no lag has been incorporated. Recognizing that most of the Model Area has consisted of irrigated agriculture throughout the entire Model Period, a relatively steady state of recharge has likely been established, although actual amounts may vary temporally with changes in crop and irrigation patterns. The water balance is being used as a first approximation for the groundwater system that was modified in the groundwater model. Therefore, this annual water balance does not provide for a time lag of irrigation return flows and is judged sufficient for the purposes of the water balance and numerical model.

3.1.4. Municipal Return Flows

Some water supplies to municipal users are applied as urban irrigation and other recreational uses. Based on estimates in the Bakersfield area, 50 to 70 percent of municipal supply is used outdoors in some capacity. It is assumed that 12 percent of the outdoor use recharges the aquifer as return flow.

This evaluation of return flows addresses only municipal use of groundwater. It is recognized that river water and SWP water also provide a portion of the municipal supply. The water balance addresses the return of water used indoors through wastewater return flows. Percolation of outdoor uses of surface and imported water is small (on the order of 7 percent of surface water and imported water urban use) and has not been included in the water balance because of the level of complexity to estimate monthly returns compared to the order of magnitude of other components in the water balance. Municipal return flows (percolation) from outdoor uses are shown on Table 3-3.

3.1.5. Canal and River Seepage

Many of the canals and the part of the Kern River used to transport water in the area are unlined, and leakage from these canals contributes to the underlying groundwater system. Figure 3-2 shows the location of the major unlined canals.

Seepage losses have been calculated based on the difference of flow between various points less deliveries. Monthly canal losses are reported in the Kern River Annual Hydrographic Reports for the major canals in Kern Delta Water District (KDWD), City of Bakersfield (COB), North Kern Water Storage District (NKWSD), Rosedale Ranch Improvement District (RRID), Cawelo Water District (CWD), and the former James Pioneer Irrigation District. Losses along the Kern River are also reported in the Kern River Annual Reports for several reaches. Canal losses were also supplied by Semitropic Water Storage District and Buena Vista Water Storage District for canals in their service areas. The portion of the canal losses that occur within the Model Area have been estimated to be equivalent to the portion of the canal that overlies the Model Area. For the Kern Island Service Area of KDWD, canal losses for the entire service area were divided over the Kern Island canal and the Central Branch canal based on the total length of these canals. The Central Branch canal is located on the model boundary and it has been assumed that one half of losses occurring here recharge the model, while the remaining half does not enter the Model Area. Table 3-4 and Figure 3-3 show annual canal losses by major canals.

3.1.6. Enhanced Recharge and Banking

Enhanced recharge and banking are performed in the area by multiple water agencies through various mechanisms (canal spreading, recharge ponds, and in lieu supplies). For the purposes of this report, no distinction is made between enhanced recharge conducted by water agencies (and others) to increase groundwater resources and more formal banking projects where water is recharged on behalf of an outside party for the purposes of recovery.

Monthly recharge data have been received from the Kern Water Bank Authority for the KWB recharge by individual ponds from 1995 to 2011. Annual recharge data (along with recovery data) are shown on Figure 3-4. KCWA provided monthly recharge for the Pioneer Project and Berrenda Mesa Project from 1995 to 2011. Annual recharge data (along with recovery data) are shown for these projects on Figures 3-5 and 3-6, respectively. The Kern River Annual Reports contain monthly recharge volumes for COB projects with the Model Area (including the COB 2800 facility, Truxtun Lakes, The Park at River Walk, and Aera Park); annual banking recharge volumes for the COB 2800 facility are summarized on Figure 3-7. Kern River Annual Hydrographic Reports also contain monthly intentional recharge data for NKWSD, Rosedale Ranch ID, and KDWD banking data. Additional recharge data have been provided by various water districts for their respective recharge projects including KDWD, Semitropic WSD, RRBWSD, BVWSD, and WKWD. Annual recharge data for RRBWSD, BVWSD, and WKWD are summarized on Figures 3-8, 3-9, and 3-10, respectively. Table 3-5 shows the annual recharge by major project and Figures 1-2 and 1-3 show the general locations of the recharge facilities.

3.1.7. Wastewater Discharge

Several wastewater treatment plants (WWTP) serve the metro Bakersfield area. Two WWTPs are within the Model Area. These are the City of Bakersfield WWTP #3 and the North of the River Sanitary District #1 WWTP as shown on Figure 3-11. Discharge from these two WWTPs also occurs within the Model Area and is discussed in this section.

Other WWTPs operate within the metro Bakersfield region but are outside the Model Area. These include the City of Bakersfield WWTP #2 and the Kern Sanitation Authority WWTP, which are just east of the model's eastern boundary, and the Shafter-Minter Field WWTP which is just north of the model's northern boundary. Discharge from these WWTPs is not included in the water balance because it occurs outside the Model Area. Wastewater infiltration from individual septic systems may also occur within the model boundaries but volumes are likely to be small and inconsequential compared to the other water balance components. Accordingly, estimates of septic system return flows were not included in the water balance.

City of Bakersfield WWTP #3

WWTP #3 serves the City of Bakersfield area that lies west of Highway 99 while WWTP #2 serves the area east of Highway 99. WWTP #3 is between McCutchen Road and Highway 119 to the north and south and between Ashe and Gosford roads to the east and west. During the 1986-2010 Model Period, plant capacity doubled from 8 million gallons per day (MGD) to 16 MGD. Since 1989, most effluent has been piped to a site called Green Acres Farm just west of Interstate 5 for irrigation. When irrigation demands are low in the winter, effluent is discharged to four onsite ponds for storage and percolation.

The City has provided monthly effluent flow data for 2000 through 2010. Annual effluent flows for 1986 through 1999 were estimated using population growth trends and a typical per capita effluent flow rate. Annual flows were divided evenly over each 12-month period.

Between 1986 and 1988, it was assumed that all effluent went to the onsite ponds. An onsite pond infiltration rate of 900 AF/month was estimated from a groundwater conditions study of WWTP #3 by Schmidt (July 2006). For 1989 through 2010, all effluent discharged between February and September went to Green Acres Farm, located southwest of the Kern Water Bank. October through January effluent went to the onsite ponds first (up to a percolation rate of 900 AF/month) with the remainder going to Green Acre Farms. An irrigation efficiency of 80 percent was assumed for Green Acre Farm irrigation, the same as the rest of the Model Area irrigation. This results in 20 percent agricultural return flows for the applied effluent.

North of the River Sanitary District #1 WWTP

The North of the River Sanitary District #1 (NORSD) WWTP is located in the City of Shafter and treats wastewater from the Oildale Mutual Water Company and the City of Shafter service areas (see Figure 3-11, purple triangle in northern model domain between the City of Shafter WSA and Buttonwillow WSA). As of 1990, the City owns one-third of the plant's

7.5 MGD capacity. Wastewater is used to irrigate crops near the current plant location (Figure 3-11). Onsite ponds are used for winter storage and percolation.

Annual effluent volumes for 1998-2001 and 2008 are available from KCWA annual reports. Data for 2010 were obtained from the Tulare Lake IRWMP. Annual effluent flow between 2002 and 2009 was assumed to increase linearly. Effluent flows between 1986 and 1997 were estimated using population growth trends and a typical per capita effluent flow rate. Annual flow was then divided up evenly over each 12-month year. The effluent was then assumed to be available for local irrigation.

3.2. OUTFLOWS

The primary components of outflow from the Model Area include groundwater pumping and subsurface outflow. For the purposes of the water balance, types of groundwater pumping are defined separately. Groundwater pumping amounts for recovery at the major banking projects have been documented by the operators of each project. Groundwater pumping for municipal and industrial purposes by the City of Bakersfield, Cal Water, and various smaller mutual water companies has been provided at various levels of detail by each purveyor. Groundwater pumping amounts by water districts for supplemental irrigation deliveries have been generally available from various data sources. The actual amount of agricultural irrigation groundwater pumping by private well owners in the Model Area is unknown and requires additional analysis.

Each component of outflow is described briefly below, followed by a presentation of the data from 1986 through 2010.

3.2.1. Groundwater Pumping for Banking Project Recovery

Groundwater that has been recharged or banked is recovered either by dedicated recovery wells or through increased production for municipal or agricultural supplies. For this report, recovery pumping includes only dedicated recovery wells. The banking projects with dedicated recovery wells include KWB (Figure 3-4), Pioneer Project (Figure 3-5), and Berrenda Mesa Project (Figure 3-6). Monthly pumping records by well have been provided by the KWB Authority and KCWA for these banking projects for 2001 through 2011 and annual data provided from 1996 to 2000. Table 3-6 shows the recovery pumping by general banking project. Other recharge projects (including COB 2800 acres and West Kern Water District) do not differentiate banking recovery pumping from municipal use pumping and those amounts are included in the section on municipal pumping.

3.2.2. Agricultural Groundwater Pumping

The amount of groundwater pumped to satisfy agricultural demand has been estimated by first calculating the total crop demand for all agricultural irrigated areas. The amount of surface water used to meet a portion of this crop demand has been subtracted from the total (corrected for irrigation efficiencies) to estimate a remaining crop demand satisfied with groundwater. The sources of the surface water subtraction include all surface water

deliveries to crops including local Kern River water, imported water, or groundwater pumped by agencies and delivered through surface facilities. Because this analysis has been conducted in several steps that involve numerous data types, the details of this analysis are presented in Appendix F.

The results of the analysis, the agricultural demand that is satisfied by private groundwater pumping, is shown by Water District and Service Area in Table 3-7 (Figure 3-1 shows the areas of these Water Districts and Service Areas). The estimated amount of irrigation demand supplied by groundwater and surface water in the Model Area is shown on Figure 3-12. The exact location of this local pumping is not well known. In most cases, a private well is used to supply a relatively small amount of water. Some water districts have inventories of private agricultural wells while others do not. For the purposes of the model, estimates of the distribution of pumping were made based on the model cell size and magnitude of pumping per cell.

As noted above, additional groundwater is pumped by Water Districts and supplied to agricultural land through surface facilities. Total groundwater pumping by these districts (BVWSD, Semitropic WSD, and NKWSD) is available from BVWSD, Semitropic WSD, and the Kern River Annual Hydrographic Reports, respectively. The amount of pumping within the Model Area has been estimated based on the percent of wells with the Model Area. The estimated groundwater pumping by District is shown on Table 3-8.

3.2.3. Municipal Groundwater Pumping

Municipal water is served in the Model Area by three major purveyors (California Water Company, City of Bakersfield, and Vaughn Water Company) and several smaller purveyors. The service areas of the water purveyors and water districts are shown on Figure 3-11 and the annual pumping is shown in Table 3-9. Municipal supplies include groundwater, surface water, and imported water sources. This section focuses on groundwater pumping for municipal use. Figure 3-13 presents annual municipal pumping by purveyor over the Model Period. For the purposes of this water balance, municipal groundwater pumping includes all groundwater uses other than agricultural irrigation. The water balance includes subtraction of pumped groundwater for municipal uses and addition of municipal use return flows (in the form of percolation) from wastewater (see Section 3.1.7) and through percolation of water used for irrigation of lawns, car washing, and other outside uses (see Section 3.1.4).

Most of the municipal pumping occurs in the eastern portion of the model. The water balance includes pumping from the purveyors listed below. Recent (2010) pumping is listed followed by the general range of groundwater pumping that occurred during the Model Period.

- California Water Company – 45,700 AFY (44,000-74,000 AFY)
- City of Bakersfield – 37,400 AFY (14,500-45,500 AFY)
- West Kern Water District – 21,700 AFY (9,600-28,300 AFY)
- Vaughn Water Company – 11,500 AFY (3,800-12,800 AFY)

- City of Shafter – 4,700 AFY (3,100-5,300 AFY)
- Greenfield County Water District – 2,300 AFY (870-2,600 AFY)
- North of the River Municipal Water Company – 400 AFY (0-1,000 AFY)
- Stockdale Mutual Water Company – 230 AFY (180-280 AFY)
- Buttonwillow County Water District – 210 AFY (160-210 AFY)
- Oildale Mutual Water Company – 150 AFY (0-2,100 AFY)
- Stockdale Annex Mutual Water Company – 120 AFY (90-140 AFY)

West Kern Water District municipal wells are within the Model Area, although almost all of the district lies outside the Model Boundaries. Recent pumping has amounted to about 22,000 AFY. This pumping has been included in the water balance, but return flows have not because they occur outside the Model Area.

Some private domestic wells most likely pump within the Model Area but net consumption of this water is small and within the error of other water balance numbers. Because of the lack of documentation of this pumping and its likely insignificant volumes, it has not been included in the water balance.

Groundwater provides most of the area's municipal supply, which is replenished locally from natural recharge, canal seepage, spreading basins, and recycled water. The use of treated imported SWP water has increased in recent years with the expansion of local water treatment plants. The following text discusses groundwater pumping by purveyors within the Model Area.

California Water Service Company (Cal Water)

Cal Water is the largest municipal water supplier in Bakersfield. Their system serves a large portion of the City and segments of unincorporated lands adjacent to the City (encompassing about 49 square miles and a population of about 225,000) (Figure 3-11). Groundwater has historically supplied up to 80 percent of Cal Water's demands with surface and imported water making up the remainder. In 2011, Cal Water operated about 115 active wells with a design capacity of 142,000 AFY. About 14 percent of these wells are within the Model Area.

Cal Water has provided monthly production by well for the 2000 through 2010 period. Data between 1986 and 1999 have been provided in the form of handwritten monthly production sheets. These data have been hand entered into the database and consist of over 28,000 lines of data. Only pumping from wells within the Model Area have been used in the water balance. Also, only outside return flows from the 48 percent of the Cal Water service area that is inside the Model Area have been included. Inside return flows are incorporated within the wastewater return flows.

City of Bakersfield Water System (City Water System)

The City's Water System service area covers about 35 percent of the western portion of the Bakersfield (about 38 square miles) and provides water to a population of about 118,600 (Figure 3-11). Similar to Cal Water, the City relies on a variety of water sources including

groundwater, Kern River water, and imported SWP water. The City has contracted with Cal Water to operate its water distribution system. Groundwater supply is pumped from approximately 50 active groundwater wells within City boundaries. The City has provided monthly data by well for 1988 through 2010, while annual pumping totals are available for 1986 and 1987. The pumping distribution (by well and by month) in 1988 has been applied to 1986 and 1987.

Vaughn Water Company (VWC)

Vaughn Water Company has provided municipal water supply to the northwest portion of the City of Bakersfield and to areas of Kern County since 1928 and currently serves more than 9,300 connections (Figure 3-11). Groundwater is the only source of supply. In 2010, VWC pumped about 11,400 AFY from 12 production wells. VWC has provided monthly pumping data by well for 1992 through 2010. Only annual totals are available for 1987 through 1991, so pumping has been distributed to the same wells at the same percentages as in 1992. Pumping in 1986 is assumed the same as 1987.

West Kern Water District (WKWD)

WKWD has eight groundwater wells within the Model Area. WKWD provided monthly pumping by well from July 1998 through 2010 and monthly system totals from 1986 through 1998. While all WKWD wells are located within the Model Area, the service area lies almost entirely outside the Model Area. For this reason, municipal return flows are not included in the water balance.

City of Shafter (Shafter)

The City of Shafter is about 15 miles northwest of metropolitan Bakersfield and serves a population of about 18,200. Customers include those within Shafter City limits as well as some surrounding unincorporated County customers. Shafter currently has seven wells and groundwater is the sole source.

Shafter has provided 2002 through 2010 monthly totals but does not have monthly pumping by well information. Annual 1998 through 2001 data were obtained from its 2010 UWMP. For 1986 through 1997 data, an appropriate per capita use value was multiplied by estimated annual populations. Population estimates were obtained by assuming linear growth rates between known population values, accounting for those outside city limits as well. Annual 1986 through 2001 pumping totals were distributed monthly in the same monthly pattern as 2002 data.

Greenfield County Water District (Greenfield CWD)

Greenfield CWD supplies groundwater to a population of about 8,500 from five wells. Greenfield provided monthly pumping data for 2005 through 2010 and annual pumping totals for 2003 and 2004. Data from KCWA annual reports (1998-2001) provided annual pumping totals for those years. Pumping in 2002 was assumed as halfway between 2001 and 2003 values. For 1986 through 1997, pumping was estimated based on pumping increase data provided by Greenfield CWD. Monthly pumping averages from 2005 through 2010 were used to distribute 1986 through 2004 annual pumping.

North of the River Municipal Water District (NORMWD)
NORMWD is on the northern boundary of the Model Area and provides groundwater and ID4 water (surface and imported) to its customers. About 71 percent of NORMWD is within the Model Area. It currently serves a population of about 6,000 and has five wells. KCWA provided pumping data in six-month intervals for 1989 through 2010. Pumping was divided up evenly between the six months in each time period. Data for 1989 were used for 1986 through 1988. All pumping and 71 percent of outside return flows were assumed to occur within the Model Area.

Stockdale Mutual Water Company (Stockdale MWC)
The Stockdale MWC is located in the City of Bakersfield (Figure 3-11). The mutual water company provides groundwater from two wells to about 80 connections. Stockdale MWC provided 1986 through 2010 pumping in six-month intervals. The pumping was divided evenly over each six-month period.

Buttonwillow County Water District (Buttonwillow CWD)
Buttonwillow CWD provides groundwater to a population of about 1,500 in the northwestern portion of the Model Area. The system has three wells. Data from KCWA annual reports (1998-2001 and 2008) provided annual pumping totals for those years. Data for the remaining years were estimated based on an appropriate per capita use value and estimated annual populations. Population estimates were obtained by assuming linear growth rates between known population values. Annual pumping was distributed monthly using the same average pumping percentages as those in Greenfield CWD.

Oildale Mutual Water Company (Oildale MWC)
Oildale MWC straddles the northern boundary of the Model, with 13 percent inside the Model Area. It serves a population of about 26,000. Oildale MWC supplies imported ID4 water and groundwater to its customers. Currently, groundwater provides about five percent of the supply from about nine wells, all located within the Model Area. Oildale provided 1986 through 2010 pumping in six-month intervals. This was divided up evenly over each six-month period. All pumping and 13 percent of outside return flows have been assumed to occur within the Model Area.

Stockdale Annex MWC (Stockdale Annex MWC)
Stockdale Annex MWC is next to Stockdale MWC within the City of Bakersfield but is operated as a separate entity. It has one active well and one standby/emergency well that supply water to about 140 connections. Pumping is not metered and not available from the mutual water company. However, the 2008 KCWA Annual Report listed annual pumping at about half of the Stockdale MWC pumping. Therefore, Stockdale Annex MWC pumping is assumed half of the Stockdale MWC pumping.

3.2.4. Subsurface Outflow

Groundwater flow occurs out of the model area through lateral boundaries. As described in Section 2.4.1, time-varying specified head and specified flux boundaries allow subsurface flow out of the model. The areas of outflow and methodology used to calculate the amounts

over time are provided in Appendix B. The rate of outflow varies over time, and is estimated to range from zero to 8,361 AFY (Table 3-1). Additional outflow may occur out of the eastern boundary along the Kern River. This outflow is expected to be relatively small and has not been quantified for the water balance.

3.3. INFLOW AND OUTFLOW TOTALS

Table 3-1 summarizes the annual inflows and outflows, which are illustrated in Figure 3-14, with inflows stacked above the zero line and outflows below the zero line. The most salient feature of Figure 3-14 is the variability of annual inflows relative to outflows. Total inflows range from less than 300,000 AFY to more than 1,500,000 AFY, while total outflows range between 500,000 AFY and about 1,000,000 AFY. Recharge and canal losses are the water balance components that vary the most from year to year. Less variation is seen in agricultural pumping and return flows as well as municipal pumping and return flows.

3.3.1. Changes in Groundwater in Storage

Changes in the amount of groundwater in storage (also shortened to "change in storage") is derived in two ways for the initial water balance to support the model. The first method is a simple accounting of the water balance elements described above and shown on Figure 3-14. Total inflows minus the total outflows is equal to the change in storage for the Model Area. The second method examines the change in groundwater elevations over time and applies a storativity coefficient (specific yield), which characterizes the volume of groundwater that an aquifer can release per unit volume of the aquifer. This method is a rough approximation due to the application of one general value to represent the overall storativity in the groundwater system. Further, the groundwater elevations are generally from wells screened in multiple aquifers and correlation to model layers is not exact. Nonetheless, the analysis was conducted to determine a first order estimate of the change in groundwater in storage for comparison to the tabulated inflows and outflows of the first method.

For analysis using this second method, groundwater elevation maps from KCWA for spring groundwater elevations have been used to calculate changes in groundwater elevation on an annual basis from the beginning of the model period to the end. A general specific yield of 0.15 has been used for this analysis, based on the published characterization of Model Area hydrogeology. For this simplistic analysis, the specific yield is used to represent the largest changes in the aquifer system (recognizing that changes in deeper confined layers have a much lower storage coefficient). It should be noted that during calibration, storativity values were lowered to match observed groundwater elevation data.

The annual changes in storage from both methods are shown on Table 3-1 and on Figure 3-15. In brief, both methods capture the major trends in the Model Area and provide a reasonable check to the water balance.

Comparison of the change in storage calculated by each method on Figure 3-15 shows the close similarity in both trends and volumes of the change in storage over time. Figure 3-15

also indicates that the groundwater elevation method results in a more muted response for years with large volumes of managed recharge. This may reflect the timing and regional nature of groundwater elevation monitoring and local nature of recharge. The groundwater elevations, generally measured in the spring, represent a regional snapshot in time. Managed recharge can result in mounding in the area of the recharge facilities that may not be captured in spring groundwater measurements. Accordingly, the lag between the two methods reflects possible differences between the surface recharge date and response in groundwater measurements. Nonetheless, the close correlation of the two methods suggests that the components of the overall water budget inflows and outflows are reasonable for incorporation into the numerical model.

Overall, the groundwater in storage is reduced in years with less than average recharge and increased in years with more than average recharge. The analysis estimates an average annual change in storage over the Model Period of -45,000 AFY or -116,000 AFY, based on the water balance element calculation method or the groundwater elevation method, respectively. Because of the groundwater elevation lag response, the average change in storage based on groundwater elevations would likely be closer to the water balance element method if early 2011 groundwater elevations were included.

3.4. MODEL WATER BUDGET

The previous sections have presented the water balance for the conceptual model. This information was used to construct, calibrate, and apply a numerical model, the Kern Fan Model, to analyze potential impacts of certain recharge and banking projects along the Kern Fan, also called the *with and without* evaluations. The change in storage graph (Figure 3-15), showing storage changes derived by two independent methods, affirms that the model water balance inflows and outflows reasonably represent the groundwater system and changes in groundwater elevations.

4. MODEL CONSTRUCTION AND REVISIONS

4.1. MODEL CONSTRUCTION PROCESS

The Kern Fan Model has been through multiple iterations during model development. Todd Groundwater, working closely with the KFMC-TS, responded to suggestions and concerns by the subcommittee to improve the overall calibration and performance of the numerical model. Only the final version of the model is presented here. Key model adjustments and revisions over time are summarized below.

After initial calibration of the model, additional calibration steps were recommended, and subsequently performed, to improve simulation of vertical gradients in the recharge project areas. The KFMC-TS was also concerned about subsurface inflow and outflow from the foothills on the western model boundary that occurred during certain time periods in the model. Conceptually, the KFMC-TS thought that there was likely very little subsurface inflow; accordingly, the western model boundary condition was revised subsequently as a no-flow boundary. Additional calibration runs were conducted after the adjustment of vertical parameters and the no-flow boundary. Those calibration runs improved the accuracy of the model, especially in areas where vertical gradients are present, and along the western and northwestern boundaries. Vertical gradients are generally well-simulated in the area of the Kern Water Bank (KWB) and simulated hydrograph peaks and troughs (corresponding to wet and dry periods) generally match observed groundwater elevation trends.

The re-calibration of parameters to better match vertical gradients resulted in lower-than-expected specific yield values in banking areas. It was recognized that these values represented average storage values for a relatively thick model layer, yet the low specific yield values did not conform closely with the conceptual model. Specifically, the simulated storage coefficients for the upper model layer was calibrated as low as 1 percent (and ranging to 24 percent), with an average value of 8 percent) - values lower than considered representative for the banking areas (e.g., 12 to 18 percent). The difference between calibrated values and expected values were the likely result of the simplification of geology and lithology.

Layer 1 previously represented the upper 300 feet of the aquifer; this composite model layer contained both high-permeability sands along with lower permeability zones of silt and clay that may impede flow. While the actual specific yield for shallow aquifer sand intervals may be 16 percent, an interval containing 50 percent sand and 50 percent fine-grained sediments would be assigned an average specific yield value of about 8 percent. Even if flow were actually impeded by a single thin and localized layer, the storage coefficient of the entire model layer might need to be lowered significantly in order to match local head values. Because the calibrated model assigns a single average value for each aquifer parameter to the entire thickness of each model layer zone, assignment of parameters

associated only with the sand-rich aquifer zones did not allow the model to match observed head values.

Accordingly, Todd Groundwater further discretized the upper model layer into two layers, which allowed the associated aquifer parameters to be closer to expected values while still maintaining model calibration. This allowed the former upper layer to be represented by two parameter zones instead of one. The resulting additional vertical and spatial discretization facilitates the revision of aquifer parameters and allows these values to more closely match the conceptual model.

In addition, model zones within each of the two new layers were further discretized based on the distribution of coarse-grained material. Each zone contains one value for storage, horizontal conductivity, and vertical conductivity. These zones were refined and subdivided to allow more flexibility during calibration, to better match simulated groundwater elevations to observed groundwater elevations in local areas, and to use aquifer parameters that more closely match the conceptual model.

The revised model has been re-calibrated to achieve calibration standards and match simulated heads to observed heads throughout the model domain with a focus on the Kern Fan banking areas. The current version of the model meets established calibration criteria with respect to head residuals, calibration statistics, and overall agreement with the hydrogeologic conceptual model, as discussed in more detail in Section 5.

4.2. FINAL BASELINE MODEL CONSTRUCTION

4.2.1. Model Input

Model input files were compiled from data sets presented in the previous section. The KFMC-TS reviewed model input data and concurred with the approaches for developing input parameter values. This allowed the KFMC-TS to ensure that the model was calibrated in such a way to generate meaningful flow predictions for the *with and without* evaluations. Existing data were used to formulate the initial model input parameters. As described below, initial estimates of some input parameter values were modified during model calibration. Input parameters that were defined on the basis of measurements or rigorous previous analyses in Section 3 (such as recharge and well pumping) were not varied, while other parameters (including aquifer parameters and boundary conditions) were adjusted within defined ranges to achieve model calibration.

4.2.2. Domain and Discretization

The model area covers approximately 454 square miles and extends across the valley floor from an eastern boundary near the foothills to the California Aqueduct. From north to south the model domain generally extends from the City of Shafter to the northern edge of the Buena Vista and Kern Dry Lake beds. The model domain and boundaries by type are shown on Figure 2-7.

A finite difference model grid with variable row and column spacing was used, as shown on Figure 4-1. The grid is finer in the areas of the model where most of the active banking, managed recharge, and recovery pumping have occurred historically. The minimum cell dimensions of 250 feet square occur in these areas of greatest discretization. The grid coarsens away from these areas toward the model boundaries, where cell sizes of 1,500 feet square were used. The model comprises 265 rows by 366 columns, with an active area defined by the model boundaries discussed below.

Four model layers were defined representing shallow (two layers), intermediate, and deep aquifer zones. The geometries, depth, and thicknesses of the model layers are further discussed below. All four layers of the model share the same active area, which is defined by the boundaries shown in Figure 2-7 and the grid shown on Figure 4-1.

As discussed in Section 2, the Model Period was selected to accommodate both wet and dry hydrologic cycles and to pre-date the major banking projects of interest. The Model Period is a 25-year interval beginning January 1986 and extending through December 2010. Monthly stress periods were used to simulate the dynamic conditions of the system indicated by the conceptual model. This resulted in a total simulation length of 300 stress periods.

4.2.3. Boundary Conditions

The model boundaries were identified and constructed with consideration of geology, hydrogeology, regional historical groundwater flow directions, and the potential for impacts on simulated flow from sources of localized surface recharge. The top boundary for the model has been defined as ground surface with recharge applied as an areal input as described in Section 3. The bottom of the model is defined as a no-flow boundary coincident with the bottom of Layer 4.

GMS uses line segments (arcs) to define lateral model boundaries. The boundary type is assigned to the line segment, and nodes along the segment are chosen to represent known or interpreted values specific to that location. GMS then interpolates between nodes to define values for every point along the line segment at each specified time.

A lengthy discussion of the methods employed to delineate the lateral boundaries and assignment of boundary types was presented in Section 2. During construction and calibration of the model, the original locations and orientations of the lateral boundaries were maintained, while adjustments were made to some of the boundary types. Specifically, lateral boundary segments representing the western model boundary and Kern River were changed from specified flux to specified head as described below.

For the lateral time-varying specified head boundaries, head values were developed based on available groundwater elevation data in the boundary areas. Groundwater elevation contour maps were used to guide general flow patterns at the boundaries, and groundwater elevations over time from selected monitoring wells near the boundaries were used to

develop datasets used to define time-varying constant head nodes along the specified head boundary arcs. The lateral boundaries are shown by type on Figure 2-7.

4.2.4. Layer Distribution and Depth

The model was constructed with four layers to simulate vertical and horizontal flow. The top and bottom elevations of these layers were developed based on the hydrostratigraphy and aquifer delineation component of the conceptual model presented in Section 2. The top and bottom surfaces of the units as described were used directly in the preparation of the model layers. A summary of the method employed to generate the model layers is presented below:

- Geophysical logs from wells throughout the study area were evaluated to identify aquifer packages that likely function as hydraulic units separated and delineated by relatively finer-grained sediments. The locations of wells used in the evaluation are shown on Figure 4-2.
- Regionally extensive low-resistivity units were chosen to delineate these hydraulic units and serve as relatively reliable markers.
- Using this methodology, four units were defined throughout the model area:
    - Model Layer 1 is characterized by an approximate 150-foot sequence of primarily coarse-grained material (sands and gravels) characterized by relatively higher electrical resistivity.
    - Model Layer 2 is an approximate 150-foot sequence of relatively coarse-grained sand intervals overlying a zone of more inter-bedded sediments. This unit/layer occurs from approximately 150 feet to about 300 feet below ground surface and contains more fine-grained interbeds than Layer 1.
    - Model Layer 3 is an approximate 300- to 350-foot sequence of relatively thick inter-bedded coarse and fine-grained sediments. This unit/layer occurs from approximately 300 feet to about 600 to 650 feet below ground surface.
    - Model Layer 4 is an approximate 200-foot sequence and is characterized by higher-resistivity but heterogeneous layers. This unit has been defined at an approximate depth of 600 to 650 feet to the model bottom at 800 feet, where deep logs indicate another lithologic/texture change.
    - In some cases, the layer/unit depths identified from geophysical logs were modified slightly to reflect discrete well screen intervals.
- The layer depths, along with surface elevations, were used to generate elevations representing the bottom of each model layer.
- The layer bottom elevations from each log/well location were then interpolated to a grid to create a surface for the bottom of each of the three model layers.
- Multiple gridding interpolation approaches (linear, kriging, inverse-distance weighting) were used to generate model layer bottoms. An inverse distance weighted interpolation method resulted in the most suitable model layer bottom surfaces.

The data used in the development of the model layers and contour maps showing the layer bottom surfaces are provided in Table 4-1 and on Figures 2-16 through 2-19. The surfaces represented by these contour maps were imported directly into GMS along with the ground surface NED of Kern County. The model was constructed to use layer bottom elevations directly to define layer divisions and thicknesses. After being imported into GMS, the layer bottom surfaces were interpolated directly to the model grid for the appropriate layer bottom elevation input and the ground surface was similarly interpolated to represent the top of the model (top of Layer 1).

4.2.5. Aquifer Hydraulic Properties

Aquifer hydraulic properties (including horizontal hydraulic conductivities, storage coefficients, and vertical anisotropy ratios) control the flow of groundwater, making them important model input parameters.

Using the methodology described in Section 2, the geophysical logs used to develop model layers were evaluated to estimate the thickness of saturated coarse-grained material in each layer throughout the model area. Each log was manually reviewed to sum the coarse fraction by model layer for that well. The data set resulting from the log analysis in each model layer is presented in Table 4-1.

The data shown in Table 4-1 were interpolated using inverse-distance weighted methods to develop grid coverages of the coarse-grained percentage for each layer over the model area. The same interpolation was used in Layers 1 and 2 because the shallow sediments in Layer 1 were frequently either unsaturated or not represented in geophysical logs, which prevented textural analysis. These grid coverages were then used to generate layer-specific zones of similar coarse-grained content, as shown on Figures 4-3 through 4-5.

These zones, based on the spatial distribution of coarse fraction, are used in the model to represent areas of similar hydraulic properties. The locations and orientations of the zones vary between the four model layers, based on the layer-specific coarse-grained distributions. For this zonation approach, the initial and final calibrated aquifer parameter values for model cells in a zone are constant. Each layer-specific zone has a unique identifier that can be applied to those grid cells within the zone. This zone approach is especially useful in auto-calibration, as it allows spatial control of parameter values assigned by PEST over model areas where aquifer properties are similar. They were further refined to allow more flexibility in calibration. Note that zones of vertical anisotropy are also shown on these figures for convenience, but are not directly related to the percent coarse analysis. The assignment of initial horizontal and vertical hydraulic conductivity is discussed in more detail below.

Horizontal Hydraulic Conductivity, Kh

The total coarse-grained thickness in each model layer was extrapolated from the dataset described above for each well with transmissivity data. The transmissivity values were divided by the total saturated coarse-grained thickness of the layers in which that well is perforated; this method generates a Kh value for the well that is normalized by the coarse

fraction (see Table 4-2). As noted above, this approach includes the simplifying assumptions that inflow to the pumping well occurs through the coarse-grained intervals only, and that the Kh of each coarse interval is the same.

The normalized Kh values were applied to the layer specific zones shown on Figures 4-3 through 4-5 to generate initial Kh values for each zone in each model layer. This was accomplished by scaling the average normalized Kh value by the average percentage of coarse-grained sediment in each of the zones. Using this approach, the total aquifer transmissivity at each aquifer test location has been preserved and partitioned into initial Kh values for each model layer zone. The parameters were then adjusted during calibration to match simulate and observed groundwater elevations. The final values are presented in the next section with the calibrated model results.

Vertical Anisotropy, Kh/Kz

Vertical anisotropy is the ratio of the horizontal hydraulic conductivity to the vertical hydraulic conductivity (Kh/Kz). Vertical anisotropy is used as a means of applying vertical hydraulic conductivity (Kz) in models where Kz is not well known. Zones of vertical anisotropy were based on the conceptual distribution of low permeability material in Layers 1 and 2. This conceptual distribution was based on evaluation of geophysical logs, previously completed mapping of low permeability materials, and reports from members of the KFMC regarding the presence of local or semi-regional fine-grained deposits. In Layers 1, 2 and 3, the zones were divided into areas of high, medium, and low initial vertical anisotropy, which were assigned initial values of 100, 10, and 1. The distribution of these areas is shown on Figures 4-3 and 4-4. As shown in Figure 4-5, Layer 4 showed less variation in fine grained content than the upper layers, so all zones in this layer were given a low/moderate initial vertical anisotropy value of 5. The values were varied during calibration and the final values are presented in the next section with the calibrated model results.

Storage Properties, Sy and Ss

Section 2 provided available unconfined and confined storage values from previously completed studies and aquifer tests. These data were used in conjunction with the zonal distribution of coarse grained percentages to develop zone specific storage properties for each model layer.

Model Layer 1 is unconfined and uses specific yield (Sy) to represent the storage coefficient. For Model Layer 2, specific yield was originally set the same as Layer 1 but was adjusted based on calibration. The specific storage (Ss) of Model Layer 2 was set equal to specific yield divided by aquifer thickness. For Model Layers 3 and 4, specific yield is not used unless the layer becomes unconfined. Specific storage (Ss) is equal to specific yield divided by aquifer thickness. The initial estimates of specific yield for Layers 3 and 4 were the same as for Layer 1, except that the mean specific yield value was assumed to be 0.0015. The average percent coarse value for each zone in Layer 1 was used to generate initial specific yield values for each zone in each layer using these relationships. The storage coefficients were also assumed to be equal or lower at depth. For example, specific storage (Ss) for Layer 4 was assumed equal or lower than Ss in Layer 3.

All aquifer hydraulic parameters were imported to GMS as geographic coverages and data files. Parameters were interpolated to the MODFLOW grid for the generation of model input files. Initial zonal estimates of horizontal hydraulic conductivity, vertical anisotropy, and storage properties were further adjusted and refined during model calibration, as described in Section 2.

4.2.6. Initial Conditions

Groundwater elevation measurements from KCWA and DWR sources were used to create layer specific initial conditions. To develop initial groundwater elevations representative of the first stress period of the model (January 1986), mapped groundwater elevations were evaluated along with discrete groundwater elevation data from wells. However, only 1980 and 1987 maps are available and the Spring 1987 map did not match January 1986 groundwater elevation values in target wells. Therefore, the starting head groundwater surfaces were developed using measured elevation data from calibration target wells during January and February 1986. The resulting groundwater elevation maps for the four model layers are shown on Figures 4-6 through 4-9, respectively. Starting heads in Layers 1 and 2 are identical; insufficient data were available to differentiate shallow groundwater levels at this time.

The starting head surfaces were then compared to various groundwater elevation contour maps from both KCWA and DWR, including spring 1980 and spring 1987. In general, the starting head surfaces resemble the flow directions and gradients on previously-developed contour maps. Starting head surfaces were imported to GMS as grid files and mapped to the MODFLOW grid for the appropriate layer.

4.2.7. Recharge

Groundwater recharge from several sources was simulated in the model from data collected for the water balance presented in Section 3. Recharge sources include:

- Agricultural irrigation return flow from applied water,
- Urban water use return flow,
- Infiltration from surface water sources (i.e. canals, ditches, streams, and the Kern River),
- Banking and managed recharge, and
- Wastewater disposal.

Recharge applied outside the model area was removed from the data used in generating model inputs. Subareas of recharge were created to address areas where multiple recharge types overlap and to account for recharge type changes over time. Recharge data for the entire model period were compiled on a monthly time step by type and subarea. All recharge is applied to the model spatially by zone as a daily rate to the top of the active model.

Agricultural and Municipal Return Flows

Return flows represent the component of irrigated water use that is applied in excess of actual demand, which results in infiltration to groundwater. The model accounts for irrigation return flows from both agricultural and municipal uses, and applies the amount as groundwater recharge.

Agricultural return flows were generated based on calculated irrigation demand and water supply application rates for various crops over the model area. Total monthly return flow volumes were calculated for 53 individual agricultural areas. These areas were primarily based on water district and service areas boundaries. In some cases, service areas were further subdivided to reflect land use changes over the study period. For example, some 1986 agricultural areas were urbanized by 2010. Such areas were delineated separately from the remaining service area where land use did not change. This facilitated the application of the appropriate recharge amount for each model stress period.

To simulate agricultural irrigation return flows in the model, various simplifying assumptions were made. First, a constant irrigation efficiency of 80 percent (20 percent return flows) was applied to all agricultural areas, even though these amounts likely vary spatially and over time. In addition, return flows were not corrected for vadose zone transport time and were applied as instantaneous recharge in the model. These assumptions were made in the absence of detailed historical data on irrigation types and practices over the model area. Further, developing a more detailed approach for the timing of return flows would be complicated by the varying saturated conditions and textures throughout Layer 1. Overlapping areas of recharge (e.g., a model cell that receives both canal loss and agricultural return flows) produce a complicated wetting front that would be difficult to simulate accurately in the model. Given the larger uncertainties associated with pumping locations and amounts, potential methods for time- and spatial-variation of return flows were determined to be unwarranted. To confirm that these assumptions did not introduce a significant error in the model, the timing of recharge was compared to the timing of observed peaks in the calibration target hydrographs. In general, the recharge and peaks correspond well, indicating that a lag in timing of recharge return flows is not needed. This comparison was also made in the banking areas to confirm that a lag in the timing of recharge was also unnecessary in those areas.

Agricultural return flow recharge rates were calculated for each agricultural subarea and for each stress period of the model. Monthly return flow volumes were converted to daily recharge rates by dividing the volume by the area and number of days per month. The agricultural return flow subareas included in the recharge package are shown on Figure 4-10.

Annual municipal return flow estimates were presented in Section 3. These annual values were summaries of data compiled from monthly time intervals. Monthly data were assumed to be uniformly distributed over each municipal area in the model; accordingly, these volumes were divided by surface area and the number of days per month to generate recharge rates in feet per day. Municipal service areas that extended outside of the model area were truncated at model boundaries and return flow volumes were prorated based on

the portion inside the model. The municipal return flow recharge areas are shown on Figure 4-11.

Canal and River Losses

Losses from unlined canals and the Kern River are a major source of recharge to the model. Annual summaries of these data were presented in Section 3 based on monthly data for all measured surface water bodies in the model area. These data were compiled from information provided by water districts, the City of Bakersfield, and annual Kern River Operations Reports. Varying widths commensurate with assumed recharge influence, location relative to original water source, and model cell dimensions were assigned to the canals and the River. Reported losses were distributed evenly along the entire length of each canal and loss volumes were converted to rates through division by the area of the water body and the number of days in each stress period. The canal and River recharge elements are shown in Figure 4-12.

Banking, Managed Recharge, and Wastewater Disposal

Monthly water volumes distributed to banking and recharge projects and to wastewater disposal were reported by water bank operators, water districts, and municipalities. These recharge elements were discussed in detail and summarized as annual datasets in Section 3. A total of 91 banking or managed recharge areas and 3 wastewater disposal sites represent recharge applied at the top of the model. Where known, the monthly recharge amounts were applied to specific recharge locations such as individual ponds in banking areas. Banking and managed recharge data were applied as provided by the operators of each reporting facility. Recharge amounts for the KWB had been adjusted by six percent to account for evaporative losses. Because recharge data for other banking areas were often not as detailed, it was difficult to determine when evaporative losses had already been assumed. For data that were provided as "recharged water," similar losses were not applied.

The locations of these recharge elements were mapped in GIS with assistance from the data provider to create a unified recharge coverage. Figure 4-13 shows the areas of managed recharge and wastewater disposal in the model. Areas of recharge and rates in acre-feet per month (AFM) are shown for January 1986, January 1999, August 2004, and December 2010 on Figures 4-14 through 4-17, respectively. These illustrative time periods represent the beginning of the model, wet conditions with high recharge rates in banking areas, drought conditions with low recharge rates in banking areas, and the end of the model, respectively.

Data Management

Individual coverages for each type of recharge were created and adjusted based on the model grid. These coverages were then combined into a single dataset with 373 unique zones representing the combination of the five different types of recharge throughout the model time period. For example, one zone may include a part of an agricultural return flow area, a canal reach, and managed recharge while another contains agricultural return flow during some time periods and urban return flow at others. The total area for each recharge type and subarea was calculated based on the zone map. Volumes were divided by the calculated areas to develop recharge rates for each model stress period and each recharge zone.

Recharge zones were not all contiguous, so the coverage actually included nearly 1,200 areas described by individual polygons. These polygons and the respective recharge rates were imported into GMS and simulated in the model.

4.2.8. Pumping

Production wells in the model were simulated using the revised multimode well package developed by the USGS (MNW2, Konikow 2009). This package simulates wells according to screened intervals and distributes pumping according to the length of screens in each layer. Wells and pumping were divided into three major types: municipal, recovery (banking), and agricultural. The reported and estimated monthly volumes of pumping for each of these types were presented in Section 3. Pumping was simulated on a monthly stress period and assigned only to wells within the model area.

A total of 1,431 wells are simulated in the model. The basis for the location of wells was dependent on well type and model region. Many well locations were based on location data from KCWA, DWR, and service providers. However, most agricultural well locations were approximated based on estimated distribution of groundwater demand. Reported well construction information was used in the multimode well package where well-specific information was available. Where well construction information was not available or well locations were synthesized, well construction information was also synthesized based on averages from available data. Information on the simulation of pumping wells is discussed in more detail below.

Municipal Pumping

Municipal pumping includes all groundwater production by purveyors in urban areas. Municipal pumpers within the model area include:

- City of Bakersfield,
- California Water Service Company (CalWater),
- Vaughn Mutual Water Company,
- Buttonwillow County Water District,
- Greenfield County Water District,
- Oildale Mutual Water Company,
- City of Shafter,
- Stockdale Mutual Water Company (and Stockdale Annex),
- West Kern Water District, and
- North of the River Municipal Water District (NORMWD)

Municipal well locations were either supplied by the purveyor or available from other sources. However, well construction information (including screened interval data) was not available for many of the municipal wells in the model area. Where municipal well construction information was available, the average depths to the top and bottom of screened interval(s) were calculated and applied to wells without construction data. The average depth to the top and bottom of screens in municipal wells was 260 feet below

ground surface (bgs), and 659 feet bgs, respectively. Well screen elevations for wells with actual screen depth information and those with synthesized depths were calculated based on ground surface elevation at each specific well location.

Municipal well locations are shown on Figure 4-18, which illustrates that most municipal wells are in the eastern portion of the model (areas associated with the City of Bakersfield and portions of the CalWater service area). The number of wells in the model by each municipal purveyor is listed in Table 4-3. As shown in the table, 80 percent of the total municipal wells in the model area are owned by CalWater and the City of Bakersfield.

Recovery Pumping

Recovery pumping refers to pumping at or near groundwater banking and managed recharge facilities to recover banked water. The locations and production volumes for recovery wells were provided by the operating parties, which include:

- City of Bakersfield 2800 Acres,
- Berrenda Mesa,
- Bolthouse Farms,
- City of Bakersfield,
- Improvement District 4 (ID4),
- Kern Water Bank,
- Pioneer Project, and
- Rosedale Rio Bravo Water Storage District (RRBWSD).

A total of 193 recovery wells are simulated in the model; all but 22 of these wells had construction information. For recovery wells without known construction information, the average top and bottom of known recovery well screens were used. Recovery well locations are shown on Figure 4-18; the number of recovery wells by recharge facility are included in Table 4-3. As shown on the figure and detailed in the table, the Kern Water Bank accounts for more than one-half of the recovery wells in the model. The number of recovery wells in Table 4-3 exceeds the total of 193 recovery wells reported above because 12 of the City of Bakersfield wells are reported as both recovery and municipal wells.

Agricultural Pumping

The volume of agricultural pumping was estimated based on crop demand and irrigation efficiency less surface water deliveries, as described in Section 3. Active groundwater well locations are not known with certainty, but are assumed to occur throughout the entire area of agriculture in the model. For RRBWSD, a recently completed survey of active irrigation wells was provided by KCWA with accurate location information; those locations were honored in the model. For the remainder of the model area, irrigation well locations were estimated based on property boundaries from County crop maps. Land ownership information (as reported in the 1999 crop map) was used to approximate the number and location of irrigation wells, as described below.

The 1999 crop map was the earliest complete data set that included ownership information. To estimate the density and location of irrigation wells, it was assumed that there would be at least one well per property owner and at least one well per section if a single owner had a large area of continuous land. A well location coverage dataset was developed based on these criteria; it was used to compare the well density and distribution known to occur in RRBWSD as a check for this methodology. The assumptions used to generate the synthesized dataset were found to produce similar numbers and general locations as actual well locations in RRBWSD.

Well-specific construction details were not available for any agricultural wells in the model area. Thousands of driller's logs were reviewed to develop reasonable construction data for wells in the model area. This review indicated that many wells had similar construction details, with the exception of the northern area of the model where wells are significantly deeper. This geographic difference is consistent with the conceptual model, so well construction details were developed separately for this area of the model. The well construction data generated from known construction information in two geographic areas were applied to agricultural wells in the multimode well package. Agricultural irrigation wells were assigned 215.5 feet below ground surface (ft bgs) and 377.5 ft bgs for the top and bottom of screens, respectively in the south and 281.5 ft bgs and 569 ft bgs for the top and bottom of screens, respectively in the north.

Agricultural wells are distributed on agricultural lands throughout the model area as shown on Figure 4-19. Wells on Figure 4-19 include some wells within current banking areas that were agricultural areas in the early portions of the model period. There are 953 agricultural wells simulated in the model. The total number of agricultural wells in specific water districts and/or service areas is listed in Table 4-4.

5. CALIBRATION PROCESS AND RESULTS

During the model development process, initial historical transient model simulations were performed and compared with observed groundwater elevations from a large set of monitoring and production wells. Input parameter adjustments were made until model-predicted groundwater elevations closely matched observed conditions.

5.1.1. Target Observations

To check model simulation of the groundwater system, simulated heads were compared to observed groundwater elevation data from target wells. For this comparison, 290 wells were selected as representative wells based on the following criteria:

- Layer specific – Wells with screens in one layer were the highest priority.
- Monitoring well – Wells used by the KFMC for reporting, and any wells identified as a monitoring well were the highest priority.
- Start date – Wells with groundwater elevation data from 1986 or earlier were placed at higher priority to help understand the starting heads for the model.
- Number of measurements – Wells with frequent monitoring and therefore more data points were selected for the target data set.
- Construction information – Wells with known construction information were higher priority.
- Length of record – Wells that have data spanning the entire model period were high priority.
- Geographic distribution – The above criteria were more often met in wells in and around the banking areas. Other wells in the north and southeast were needed to create a balanced target well distribution.

All 2,845 wells with groundwater elevation data from DWR or KCWA were assessed based on the above criteria. All wells selected for the target network were reviewed and anomalous data or wells were removed. The selected 159 wells were assigned to specific layers based on well construction. If construction was unknown, the well was assigned to all four layers. During calibration, the target set was revised to focus on the areas in and around the banking projects. There are 61, 89, 48, and 57 target wells in Layers 1, 2, 3, and 4 respectively. The targets for each of the four model layers are shown on Figures 5-1, 5-2, 5-3 and 5-4, respectively. The average well is associated with about 158 groundwater elevation measurements and is screened in two layers. A total of 41,659 groundwater elevation measurements were used in model calibration.

For more focused calibration, these targets were narrowed down to 85 wells. These selected targets:

- cover each hydraulic parameter zone (as much as possible),
- include the wells reported by the KFMC Annual Report, and
- represent the specific trends identified during early phases of calibration.

These selected targets for each model layer are included in Figures 5-1 through 5-4. Note that some wells are completed (screened) over depth intervals that span multiple model layers. These targets were assigned to multiple layers.

5.1.2. Calibration Process

Calibration was performed in a multiple step process including both manual calibration and automatic calibration. Each manual calibration step involved adjusting parameters and rerunning the model over twenty times.

- Manual calibration involved a trial and error testing of key model inputs including general head boundaries, initial conditions, time steps, and numerical solvers. The first phase of model calibration was deemed complete when the model converged on a reasonable solution with acceptable run times.
- Automatic calibration was conducted using PEST and the larger target set. PEST is a program used in conjunction with MODFLOW that performs nonlinear parameter estimation. PEST calibrates the model by changing the value of selected calibration parameters to determine values for each parameter that result in the best overall model fit. The parameters selected for the first PEST run were horizontal hydraulic conductivity, vertical anisotropy, specific yield and specific storage. Ranges (maximum and minimum allowed values) for each of these properties for each zone (discussed in the hydraulic property section) were provided to PEST. The resulting model and the fit to the target values were improved over phase 1 (Doherty 2010 and 2013).
- Manual calibration was repeated to test how the model could be improved in certain key areas (i.e., near recharge facilities). Storage parameter values were increased overall in order to better simulate the range of groundwater elevations in the banking locations. Boundary conditions were adjusted to better simulate groundwater elevations in targets around the boundaries.
- A second PEST run was conducted where the results of the second manual calibration helped identify storage parameters as critical to matching observed highs and lows in groundwater elevations near the banking locations.
- Manual calibration was performed after the recommendation from KFMC-TS to make the western boundary no flow.
- Manual calibration was performed following the recommendation from KFMC-TS to revise parameters to improve vertical gradients in simulated data.
- Manual calibration was conducted in response to the recommendation from KFMC-TS to add discretization in model layer and revise storage parameters to match generally understood values.

The final calibrated aquifer hydraulic parameters are listed in Table 5-1. Figures 5-5 through 5-16 are maps of the final calibrated distributions of horizontal hydraulic conductivity, vertical anisotropy, and storage coefficients for each model layer.

As shown on Figure 5-5, horizontal hydraulic conductivities in Layer 1 range from 32 to 85 feet/day. Higher hydraulic conductivities were simulated in eastern and western portions of the model area, with lower values in eastern, southern, and northern portions. In Layer 2, final calibrated horizontal hydraulic conductivities range from 32 to 85 feet/day. The values are slightly lower than hydraulic conductivities for Layer 1, and like Layer 1 are distributed with lower values in the western and northern portions of the model area (Figure 5-6). The spatial distributions of final calibrated horizontal hydraulic conductivity in Layers 1 and 2 are consistent with the site conceptual model and lithologies inferred from geophysical logs, which indicate the presence of several finer-grained zones at a depth corresponding to the upper portion of Model Layer 2 in the western and northern portions of the model area. Figure 5-7 shows the distribution of horizontal hydraulic conductivities in Model Layer 3, which range from 29 to 75 feet/day. Higher hydraulic conductivities were simulated in the eastern portion of Model Layer 3. Figure 5-8 shows the distribution of horizontal hydraulic conductivities in Model Layer 4, which range from 10 to 70 feet/day.

Figures 5-9 through 5-12 are final calibrated horizontal to vertical anisotropy ratios for Layers 1 through 4. In Model Layers 1 and 2 values range from 10 to 200 and in Layer 3 anisotropy values range from 50 to 500. Lower anisotropies were simulated in the eastern portions of the model and beneath and around the Kern River. This distribution is also consistent with the site conceptual model and lithologies inferred from geophysical logs, which indicate the presence of fewer finer-grained aquitard zones in these areas and more coarse-grained sediments associated with deposition from the paleo-Kern River. Anisotropies in Layer 4 were all set at 500.

The final calibrated distributions of specific yield in Layer 1 and Layer 2, and specific storage in Layers 2, 3, and 4 are illustrated on Figures 5-13 through 5-16. Specific yield in Layer 1 ranges from 0.15 to 0.25, and is distributed with higher values in the eastern and southern portions of the model than in the western and northern portions. Layer 2 is a convertible layer; when Layer 1 is wet, flow calculations in Layer 2 use specific storage, when Layer 1 is dry, flow calculations in Layer 2 use specific yield. Both values for specific storage and specific yield are shown on Figure 5-14 for Layer 2. Similarly, values for specific storage and specific yield are shown on Figure 5-15 for Layer 3.

Specific storage (storage coefficient divided by layer thickness) in Layers 3 and 4 ranges from 1.4×10^{-7} to 9.4×10^{-7}. Unlike the other final calibrated aquifer parameters, the distribution of specific storage in Layers 3 and 4 does not show an obvious geographic pattern because this parameter essentially represents confined storage coefficient, which is less a function of hydrostratigraphy.

The ranges and spatial distributions of the final calibrated hydraulic parameters are generally consistent with observed aquifer hydraulic properties and the hydrogeologic site conceptual model.

5.1.3. Calibration Results

Calibration is the process of matching model simulated conditions to observed conditions. For the model, the observed conditions are groundwater elevation measurements at the target locations. Multiple methods are available to evaluate the adequacy of calibration; discussed below, these include statistics, ASTM International (ASTM) standards, and the degree to which the simulated model remains true to the conceptual model.

Calibration Statistics

Several quantitative techniques are recommended by the ASTM Standard D5490 to compare model simulations to site specific information and to quantify error. These methods are consistent with those traditionally used in the model development (Anderson and Woessner 1992). These include the mean error, the mean absolute error, and the root mean square error. The mean error (ME) is the mean of the differences between measured heads (targets) and simulated heads. The mean absolute error (MAE) is the mean of the absolute value of the differences between measured heads and simulated heads. The root mean square (RMS) error is the square root of the average of the squared differences between measured heads and simulated heads. The difference between the measured hydraulic head and the simulated hydraulic head is termed a residual. Metrics based on these statistics are sometimes used to judge the adequacy of a numerical model. These metrics compare mean residual, absolute mean, root mean square, and residual standard deviation as a percent of the range in observations. The model calibration statistics for the selected targets and the calculated metrics are displayed in Table 5-2. The model meets all of these suggested metrics. Because the model is large, covering different areas as well as hydrologic conditions, these statistics alone may not demonstrate calibration. Other qualitative and qualitative methods developed by the ASTM Standards and the USGS can also inform calibration.

ASTM Standards

ASTM Standard D5490 (ASTM 2008) recommends using a combination of quantitative and qualitative measures. While the standard recommends the use of residuals and other statistics, it does not provide a threshold for adequate calibration. The standard proposes the calculation of residual statistics, presented above, and the evaluation of the correlations among residuals.

To identify correlation of all target points, scattergrams of observed and simulated groundwater elevations were prepared for each model layer. Ideally, if the simulated heads perfectly matched the observed heads, the target points would line up at a 45-degree angle. Usually, there is scatter around the line and the diagram can show thereby if the model is consistent in terms of over estimating or underestimating head. Figures 5-17 through 5-20 are scattergrams for Model Layers 1, 2, 3, and 4, respectively. As illustrated on the plots, the overall correlations of observed and simulated heads for the calibrated model are good for each layer. The correlation coefficients for Layers 1, 2, 3, and 4 are 79.1, 87.5, 83.3, and 83.0 percent respectively.

ASTM standards also recommend examination of residuals on a spatial and temporal basis. Hydrographs for all targets were reviewed after each phase of calibrations. Each target was reviewed for the goodness of fit between observed and simulated levels and possible spatial trends were identified. This comprehensive review was used to focus the later phases of calibration. A focused target set of 85 wells was reviewed with a similar method after the third and fourth phases of calibration. Selected hydrographs are presented and discussed later in this Section and the 255 hydrographs for each layer of each target are provided in Appendix D.

The mass balance (the difference between inflows and outflows) was checked to make sure that the sum of all inflows, outflows, and change in storage were minimal. ASTM D 5490 indicates that differences more than a few percent may indicate numerical problems. The maximum mass balance error was 0.002 percent, well within the ASTM standard (Table 5-2). The model's water balance was reviewed to ensure that the conceptual model was being simulated correctly. The volume of recharge and pumping were equal to estimated levels presented in Section 3.

Conceptual Model Representation

The USGS suggests that, in addition to quantitative measures, "the appropriateness of the conceptualization of the ground-water system and processes should always be evaluated during calibration" (Reilly 2004). The simulated model was reviewed to ensure that the final calibrated model reflects the conceptual model presented in Section 2 and Section 3. The volume of flow in/out of boundaries was within a reasonable range, and the overall groundwater flow paths were reasonable given the conceptual model. The model reacts well to the large fluxes of recharge and recovery and generally demonstrates the flow patterns.

5.1.4. Parameter Sensitivity

Through the PEST process, each parameter is adjusted and the sensitivity of the model solution to the parameter is recorded. A parameter is sensitive if a small change in the parameter results in a substantial change in the groundwater elevation residual. The first parameter estimate run indicated that the model is most sensitive to:

- Specific yield (all zones)
- Specific storage (select zones, generally north of banking areas)
- Hydraulic conductivity (all zones)

Through the manual calibration phase and review of hydrographs, it was found that the model fit (the match between simulated and observed head) was improved by adjustment of the storage parameters (specific yield and specific storage). The hydraulic conductivity, while sensitive, was simulated adequately in the model.

6. KERN FAN MODEL RESULTS

This section presents the model results, including simulated hydraulic heads and volumetric mass budgets for the model inflow and outflow components.

6.1.1. Simulated Heads

Model-simulated groundwater elevations were tabulated and mapped for selected periods. Figures 6-1 through 6-7 present contours of simulated groundwater elevation in map view for each model layer for four time periods: end of 1989, end of 1994, end of 1999, end of 2004, January 2007, March 2010, and end of 2010. The contour patterns reflect the boundary conditions, sources and sinks, and permeability zones, which cause changes in gradient magnitudes and directions. The final calibrated model simulates flow conditions, which are consistent with the conceptual model.

For most of the model period, simulated heads in each of four model layers are similar, with only a few feet of head difference simulated between the layers at most locations. Accordingly, overall horizontal hydraulic gradients in each of Layers 1, 2, 3, and 4 are similar.

During 1989, simulated heads indicate recharge from the Kern River near the eastern boundary of the model, with divergent flow away from the River toward the northwest and southwest (Figure 6-1). Groundwater elevations at the end of 1994 (a period with close to average rainfall early in local banking history) are shown on Figure 6-2. Simulated heads during 1999 (Figure 6-3) reflect the wet conditions and relatively high banking recharge that occurred during that period. A large recharge mound is simulated beneath the banking facilities, with divergent flow away from the recharge areas. During 2004, simulated heads reflect the dry conditions and limited banking recharge (Figure 6-4). The highest groundwater elevations on the example contour maps occur in 2004 where the Kern River enters the eastern model area, and groundwater elevations in the banking areas are lower than in 1999. Groundwater elevations in January 2007 (Figure 6-5) are simulated at or near their peak elevation, but have declined to low levels by March 2010 (Figure 6-6). At the end of the transient simulation In December 2010 (Figures 6-7), wet conditions create high groundwater elevations beneath the eastern Kern River, and localized groundwater mounds beneath most of the recharge facilities.

In general, the simulated contour maps are consistent with groundwater elevation maps based on observed measurements. Simulated groundwater elevations are particularly well-calibrated in the area of the banking facilities, as further discussed below. Hydrographs for the KFMC monitoring wells published in annual reports are shown on Figures 6-8 through 6-19. The hydrographs include simulated and observed groundwater elevations for each well screen. Hydrographs for the other selected targets are shown in Appendix D.

As illustrated on Figures 6-8 through 6-19, the simulated groundwater elevations increase and decrease in response to the inflow and outflow stresses, and are well calibrated with observed groundwater elevation fluctuations. Peak elevations observed in 1986, 2000, and

2007, and low elevations measured in 1995, 2005, and 2010 are accurately simulated. The simulated magnitudes of the overall trends and fluctuations throughout the model period are generally well correlated with observed groundwater elevations trends.

6.1.2. Water Budget

Volumetric flow data generated by MODFLOW and stored in the cell-by-cell flow budget file were mapped and evaluated to determine the relative and absolute magnitudes of inflow and outflow components and vertical flux conditions within the model domain. Table 6-1 presents the model water budget results for the 1986 through 2010 simulation. Inflows include recharge and subsurface inflow (referred to in the model as *Constant Head Flow In*). Outflows include pumping (represented in the model as *Well Flow Out*) and subsurface outflow along model boundaries (represented as *Constant Head Flow Out*). The difference between the total inflows and total outflows represents the change in groundwater in storage. Figure 6-20 summarizes the annual inflows and outflows from the model water budget; the average values over the model period are the far-right bar on the graph.

The overall water budget has very low net errors, and the relative magnitudes of inflows and outflows are consistent and in accordance with rates derived in the conceptual model (Section 3). As shown on Table 6-1, the model calculates total change in groundwater in storage as -3,126,311 AF over the model period. This compares to two pre-model estimates of change in storage (presented in Section 3) of -2 897,331 AF (estimated from annual groundwater elevation contour maps) and -2,715,704 AF (estimated from individual accounting of water budget components). The water budget from the model provides more rigorous representations of subsurface inflow and outflow than either of the previous methods. Further, the previous methods were limited by incomplete groundwater elevation contour maps, simplification of aquifer storage, and aggregated recharge data that was not distributed where it actually occurred. All estimates are within about 20 percent and indicate that the numerical model adequately captures the site conceptual model.

6.1.3. Model Predictive Capacity

The objective of the model is to predict differences to groundwater elevations with and without selected banking projects. Accordingly, the model was calibrated to ensure that simulated groundwater elevations in the Kern Fan banking areas are able to match the timing and range of observed values. Overall, the model accurately simulates conditions from 1986 through 2010. Because the model period includes a range of hydrological conditions through the model time, the resulting calibrated model is able to predict scenarios over a wide range of hydrological conditions. In addition, the with and without evaluation is designed to subtract results from the calibrated model (which includes the banking projects) for scenarios that remove the banking projects over the same time period. Therefore, any model errors outside of the banking areas will be minimized by being simulated similarly in both the calibrated model and the *without* scenarios. In this manner, the Kern Fan Model is capable of achieving project objectives, as discussed in the following section.

7. MODEL APPLICATION

The Kern Fan Model was used to perform multiple with and without banking project scenarios. These scenarios compared simulated conditions in the absence of any or all banking projects selected for analysis by the KFMC-TS (i.e., Kern Water Bank, Kern County Water Agency Projects -Pioneer and Berrenda Mesa, Buena Vista Water Storage District's banking programs, and Rosedale Rio Bravo Water Storage District projects). In total, six scenarios were simulated, five scenarios removing each of the five individual banking projects separately and one scenario with removing all of the selected banking projects.

All scenario simulations were compared to the with banking model scenario simulation (i.e., the calibrated model). This ensures that any uncertainty in the model remain constant over all scenarios and the resulting relative difference is as accurate as possible. Simulations are consistent with the design of the model and results fall within the range of model capabilities.

7.1. WITHOUT PROJECT SCENARIOS

To achieve the main objective of quantifying banking project impacts, the numerical model simulates the physical system as it would have been in the absence of banking (referred to herein as without project scenarios or no-project scenarios). Each banking agency provided information on the physical system in the absence of the banking project including land use, recovery pumping, additional water diversions to users, and reductions in managed recharge.

7.1.1. Kern Water Bank (KWB)

The Kern Water Bank provided a reasonable no-project scenario; this involved inclusion of 6,000 AFY of agricultural pumping, no managed recharge, and no recovery pumping. Prior to banking, the KWB area included over 17,000 acres of irrigated farmland; however, because of a combination of drought and property transfers to DWR, most of this farming had stopped by 1994.

In the KWB without project scenario, this 6,000 AFY was simulated as irrigation of 3,354 acres of dry beans (a crop grown in neighboring areas). Based on the crop characteristics, irrigation would occur annually from May to September over the irrigated acreage, which was identified to coincide with now-existing ponds in the central KWB. This pumping was assigned to existing pumping wells in the KWB area. Consistent with the larger model, 20 percent of applied irrigation was assumed to recharge the aquifer as return flow. No other adjustments were made to recharge (precipitation or stormwater runoff).

For this scenario, all managed recharge into the KWB ponds was removed as was recovery pumping. Table 7-1 summarizes the differences to the annual water balance volumes of pumping, return flow, managed recharge and recovery in the KWB without project scenario.

7.1.2. Kern County Water Agency (KCWA)

The two projects managed by KCWA, Berrenda Mesa and Pioneer, were simulated in one without project scenario. Replacement land use was provided by KCWA including irrigated agriculture and urban development from 1986-2003. The irrigated agriculture area for Berrenda Mesa and Pioneer was described to increase from 992 acres in the 1995 to 1,652 acres in 2010. Urban growth (mainly in Berrenda Mesa) was simulated to begin in 2003 and expand to about 600 acres by 2010.

For the KCWA without project scenario, crop types and crop acreage were detailed by KCWA, with the most common crops including carrots and beans. A large portion of the farmland is simulated as fallow in the 2010 drought. Agricultural pumping was adjusted monthly for crop demand and precipitation consistent with the overall evaluation of agricultural pumping. An 80 percent irrigation efficiency was assumed with 20 percent return flows. Urban density was assumed to be four homes per acre with 0.5 AFY water use per home, of which 50 percent is used for outdoor irrigation, with 20 percent of this outdoor irrigation simulated as return flows. This is consistent with previous evaluation for the model.

All managed recharge into the Pioneer and Berrenda Mesa ponds was removed, as was recovery pumping. Table 7-2 summarizes the annual differences to the water balance volumes of pumping, return flow, managed recharge and recovery in the KCWA without project scenario.

7.1.3. Rosedale Rio Bravo Water Storage District (RRBWSD)

The RRBWSD managed recharge project involves water banking and groundwater replenishment. For the no-project scenario, RRBWSD provided adjusted monthly recharge volumes at each pond to reflect replenishment operations only without groundwater banking; basin recharge capacities also were provided. A six percent evaporation loss was assumed and removed from the physical delivery volumes, consistent with other analyses of recharge pond losses. At times, the adjusted recharge volumes indicated water deliveries exceeding the recharge capacity for certain basins. To address this, water exceeding the pond capacity was carried over to the following months until all of it was accommodated.

RRBWSD also provided information on the volumes of additional surface water that would be provided to landowners for irrigation if no banking occurred. For modeling purposes, it was assumed that these diversions would be provided to landowners in the western portion of RRBWSD, which has the most agricultural acreage throughout the model period. Surface water diversions are used to offset pumping; accordingly, groundwater pumping was decreased by the diversion amounts.

All managed recharge into the Strand Ranch ponds was removed. Table 7-3 shows the differences to the annual water balance volumes of managed recharge, agricultural pumping, and agricultural return flow for the RRBWSD without project scenario.

7.1.4. Buena Vista Water Storage District (BVWSD)

For the without project scenario, BVWSD indicated that managed recharge should be removed and that all other factors (land use, diversions, and pumping) would remain the same. Accordingly, all managed recharge into any BVWSD facility was removed (including Elk Pen and Concrete Weir) and no adjustments were made to pumping or land use. The differences to the annual water balance volumes of managed recharge in BVWSD without project scenario are shown in Table 7-4.

7.1.5. Combination of All Projects (Combined)

The without project scenarios described above were simulated separately and compared to the with banking scenario. In addition, a fifth scenario simulated the combined KWB, KCWA, RRB, and BVWSD without project scenarios. The differences to the water balance volumes of managed recharge in the combined without project scenario are shown in Table 7-5.

7.2. MODEL SCENARIOS

The without banking scenarios were simulated individually and in combination using the Kern Fan Model. The without banking scenarios were simulated over the entire model period 1986-2010, with differences to the water balance occurring only when banking would have been operational. Total volume differences for each project from the with banking model water budget are shown in Table 7-6. Model output was compared to the with banking scenario to reduce potentially uncertainty within the numerical model. Variables not related to managed recharge (parameters, boundary conditions, ag pumping in surrounding areas etc.) remain constant in the with banking scenario as well as each without scenario.

The model period is 1986-2010. Accordingly, projects without recovery during the model period may appear to have contributed a greater net volume than those projects with recovery. For example, managed recharge in Strand Ranch began only in 2009 and it is unlikely the effects of removing that recharge (i.e., recovery) is fully simulated before the end of the model period.

7.3. MODEL RESULTS

7.4. SIMULATED GROUNDWATER ELEVATION HYDROGRAPHS

In order to compare water levels for the with and without scenarios, hydrographs are simulated for hypothetical wells located at the centroid of certain Township/Range Sections. The numerical model produces groundwater elevation data over the entire model area at each cell of the model. During calibration, simulated groundwater elevations were compared with observed groundwater elevations at wells with measured data. However, comparison of the with and without banking scenarios was not limited to locations with existing wells. For the with and without comparisons, Township Range centroids were used,

providing a more even distribution of project effects across the model area. These Township/Range centroids are shown in white on Figure 7-1 and hydrographs for each are in included in Appendix G. Additionally, eight of these centroids were selected as key locations (shown in red on Figure 7-1) and are discussed for each without project scenario below. Hydrographs showing the difference between the with and without project scenarios are included as Appendix H.

All six without project scenarios reduce managed recharge during the wettest periods of the model. For projects with substantial recovery pumping, significant groundwater declines are noticeable near the pumping wells during the driest portion of the model period.

7.4.1. Kern Water Bank (KWB)

Figures 7-2 and 7-3 show hydrographs for the with and without KWB project scenarios. Compared to the with banking scenario, fluctuations in groundwater elevations in the area are muted, lacking the peaks and troughs associated with the banking simulation. Areas close to the managed recharge at the bank show the most difference. On Figure 7-3, the hydrograph for 30S25E16 shows groundwater elevations in the without scenario over 120 feet below the with banking scenario in March 2007, a period immediately following intense recharge in the with banking scenario.

The groundwater elevations at the centroid 30S25E16 show the largest impact of project recovery wells (Figure 7-3). In March 2010, groundwater elevations were 40 feet lower in the with banking scenario than the without project scenario. This difference is due to the largest amount of recovery pumping in the model period, which was occurring at that time.

While the hydrograph of the centroid within the bank shows substantial differences, centroids further away show less variation in groundwater elevations between the with and without scenarios. The hydrographs for centroids 29S26E35 (Figure 7-2) and 30S26E04 (Figure 7-3) show a maximum difference of 80 feet and 40 feet respectively during peak recharge and no difference in peak recovery times. The groundwater elevation increase due to recharge extends to centroids farther away than the groundwater elevation decreases due to recovery pumping. The area of impact is discussed in more detail in Section 7.5.

7.4.2. Kern County Water Agency (KCWA)

Figures 7-4 and 7-5 show hydrographs for the KCWA with and without project scenario. Like the without KWB scenario, groundwater elevations without the project show less fluctuation than those with banking. Like KWB, areas close to the managed recharge at Pioneer and Berrenda Mesa show the most difference. However, the magnitude of the differences is smaller than the KWB, as it involves smaller volumes over a smaller area. The difference in groundwater elevations for recovery are about the same as KWB; in both, the project recovery wells are concentrated as points of removal rather than areally distributed like the managed recharge. On Figure 7-5, the hydrograph for 30S26E04 shows groundwater elevations in the without scenario over 40 feet below the with banking scenario in March 2007, a period immediately following intense recharge in the with banking scenario. The

groundwater elevations at the same centroid, 30S26E04, also show the impact of recovery wells. In March 2010, groundwater elevations were 35 feet lower in the with banking scenario than the without project scenario, as a result of recovery pumping.

As expected, areas farther from KCWA managed recharge and recovery show less difference. The hydrographs for centroid 30S24E13 (Figure 7-4) show very similar patterns in both the with and without banking scenarios. The maximum difference is only 15 feet during recharge and no difference during recovery times. This centroid 30S24E13 is located 9 miles feet away from the one showing the most impact, 30S26E04. The area of impact is discussed in more detail in section 7.5.

7.4.3. Rosedale Rio Bravo Water Storage District (RRBWSD)

Figures 7-6 and 7-7 show the hydrographs for the RRBWSD without project scenario. As noted before, RRBWSD project involves managed recharge for both groundwater banking and groundwater replenishment; the without banking scenarios involves reduction of managed recharge by only about 60 percent. Accordingly, the without banking scenario looks more similar to the with banking scenario than if all managed recharge had been removed. The landowner surface diversion, which decreased agricultural pumping in the west, contributes to relatively high groundwater elevations in the without banking project. The effects of no managed recharge in Strand Ranch begin to become apparent toward the end of the model period with slightly lower groundwater elevations. However, the full effect of reduced recharge is not simulated in the model time frame.

In addition, RRBWSD did not recover water for banking purposes during the model period. Consequently, there is little difference between the with and without banking scenarios during the dry periods. The differences are most evident during extremely wet periods. The hydrograph for the centroid 29S26E35 (Figure 7-6) indicates around 80 feet of difference in the lower model layers in January 2007. Centroids farther away, including 30S24E13, show only a 10-foot difference between scenarios in some layers.

7.4.4. Buena Vista Water Storage District (BVWSD)

Figures 7-8 and 7-9 show hydrographs for the BVWSD with and without project scenario. Because the BVWSD without scenario simply removes recharge, the result is lower groundwater elevations than the project scenario. The hydrograph for centroid 30S24E13 (Figure 7-8) shows a difference in groundwater elevations greater than 50 feet between the with and without project scenarios. However, hydrographs of centroids located farther away, like 29S26E35, show little difference (a maximum of 5 feet of difference).

7.4.5. Combined

Figures 7-10 and 7-11 show the hydrographs for the combined scenario (i.e., without the five banking projects). Effects of the KWB without project predominate due in part to the relatively large amount of managed recharge removed from the with banking scenario and

the absence of agriculture pumping or other water use in the area. The other projects contribute to the overall pattern of lower groundwater elevations.

The maximum difference occurs at the same centroid and time as the maximum difference in the KWB without scenario. Centroid 30S25E16 shows a difference exceeding 170-feet in February 2007 due to removal of managed recharge in the without projects scenario. However, the largest difference in groundwater elevation due to recovery pumping is located closer to KCWA; the hydrograph for centroid 30S26E04 shows a difference of 15 feet during recovery times. The combination of KWB and KCWA recovery pumping in the with banking scenario contributes to the groundwater elevation difference. It should be noted that the difference in the combined scenario during recovery is less than the difference in the individual without project scenarios, likely due to the decrease in pumping from RRBWSD landowner diversions and increased recharge in this period from the RRBWSD without project scenario.

7.5. SIMULATED GROUNDWATER ELEVATION DIFFERENCE MAPS

Groundwater elevation difference maps were prepared for the following seven time periods (as provided by the KFMC-TS), comparing each of the scenarios to the with banking simulation:

- End of 1989
- End of 1994
- End of 1999
- End of 2004
- January 2007
- March 2010
- End of 2010 (end of model)

These groundwater elevation difference maps were prepared by comparing the with banking simulated groundwater elevation surfaces for the relevant time periods above to the corresponding without project simulated groundwater elevation surface for each of the without project scenarios and the combined without project scenario. This comparison was completed using the Spatial Analyst tools in ESRI's ArcMap GIS software. The with banking simulated groundwater elevation surface for each model layer and time was subtracted from the simulated groundwater elevation surface for the same model layer and time for each of the without project scenarios. The resulting groundwater elevation difference surfaces show positive values when and where the without project simulation resulted in lower groundwater elevations, and negative values when and where the without project simulation resulted in higher groundwater elevations. The maps represent snapshots of then-current conditions, regardless of project operations. Depending on the timing of recharge or recovery of each project compared to the time of the map, project effects may be maximized or muted. For example, some projects were recharging a significant volume of water in the months immediately prior to and the time of the map, maximizing the impact of the project for certain model layers.

At early model time periods simulated groundwater elevations for some without projects were the same as the with banking simulation because banking and/or recovery associated with the project started later. No difference maps were produced for these time periods. Additionally, portions of model Layers 1, 2 and occasionally 3 are sometimes dry in both the with banking and the without project scenarios. The dry portions of all model layers were omitted from these analyses. Groundwater elevation differences for the without project scenarios for each model layer at the relevant time periods specified above are presented on Figures 7-12 through 7-41.

Some of the difference maps in these figures show closed contours representing groundwater elevation differences in areas of the model not associated with the specific banking project. These anomalies are related to the way pumping is simulated in the model using the multi-node well (MNW) package. The MNW package automatically assigns pumping to each model layer based on hydraulic conductivity. When a layer in which a well is located is dry, the MNW package reassigns pumping to deeper layers. The without banking projects often result in more model layer drying than was present in the with banking simulation. This causes more pumping in deeper layers in the without simulations, which leads to the presence of closed contours in the difference maps. This is a model anomaly and a product of the model discretization.

Groundwater elevation contour maps for the without project scenarios at each of the time periods specified above are presented in Appendix I.

7.5.1. Kern Water Bank (KWB)

Simulated groundwater elevation differences for the KWB without project simulation for the end of 1999, end of 2004, January 2007, March 2010, and end of 2010 are presented on Figures 7-12 through 7-16. These maps show that recharge associated with KWB has a significant positive effect of groundwater elevations in a large portion of the model area, illustrated by the large blue mound centered on KWB in Figures 7-12, 7-13, and 7-14. These beneficial effects are most significant during and following wet years when banked volumes are highest, with positive groundwater elevation effects of over 120 ft in model Layers 1 and 2 in January 2007 (Figure 7-14). However, the opposite occurs during recovery pumping periods, as shown by the areas of yellow and red showing deeper groundwater elevations in the with banking simulation of over 30 feet centered on KWB in March 2010 (Figure 7-15). These deeper groundwater elevation conditions persisted to a lesser extent through the end of the model period, as shown on Figure 7-16.

7.5.2. Kern County Water Agency (KCWA)

Simulated groundwater elevation differences for the KCWA without project simulation for the end of 1989, end of 1994, end of 1999, end of 2004, January 2007, March 2010, and end of 2010 are presented on Figures 7-17 through 7-23. These maps show that the KCWA project has a similar effect to KWB, but at a smaller magnitude. Figures 7-17 through 7-19 and 7-21 show KCWA recharge gradually increasing groundwater elevations until recovery pumping started in 2000 and then again through 2007. The magnitude of higher

groundwater elevations from KCWA banking peaks at over 70 feet in Layers 1 and 2 and over 40 feet in Layers 3 and 4 in January 2007 (Figure 7-21). The magnitude of these effects lessens following the start of recovery pumping in 2000, as shown on Figure 7-20. Further recovery pumping from 2007 through 2010 results in with banking groundwater elevations that are over 30 feet lower than those simulated in the without KCWA simulation, as shown on Figures 7-22 and 7-23.

7.5.3. Rosedale Rio Bravo Water Storage District(RRBWSD)

Simulated groundwater elevation differences for the RRBWSD without project simulation for the end of 2004, January 2007, March 2010, and end of 2010 are presented on Figures 7-24 through 7-27. These maps show that the RRBWSD banking has had a progressively positive effect on groundwater elevations since the project began. These positive effects increased throughout the model period, and by the end of 2010 had resulted in groundwater elevation increases approaching 100 feet in Layer 2, over 70 feet in Layer 3, and over 50 feet in Layer 4, as shown on Figure 7-27.

7.5.4. Buena Vista Water Storage District (BVWSD)

Simulated groundwater elevation differences for the BVWSD without project simulation for the end of 1989, end of 1994, end of 1999, end of 2004, January 2007, March 2010, and end of 2010 are presented on Figures 7-28 through 7-34. Similar to the RRBWSD without scenario, the BVWSD without simulation shows a progressively positive effect on groundwater elevations since the project began. These positive effects had a wide-ranging impact and peaked at around 30 feet in all layers directly beneath the BVWSD banking facilities

7.5.5. Combined

The simulated groundwater elevation differences for the combined without project scenario for all the selected time periods are shown on Figure 7-35 through 7-41. These figures show the combined without scenario to be similar to the conditions in the KWB and KCWA without simulations, but with much larger magnitudes difference. As with KWB and KCWA, the combined without simulation comparison to the with banking simulation shows the largest positive effects following periods when all the banking projects have been recharging and prior to periods of recovery, as shown in Figures 7-35 through 7-37 and Figure 7-39. These beneficial increases resulted in groundwater elevations over 150 feet higher in the with banking simulation, as shown on Figure 7-39. Then when recovery begins, groundwater elevations are lower around the recovery wells by approximately 30 feet (figure 7-40). The combined simulation difference analysis also shows that groundwater elevations rise more quickly again following recovery pumping in the with banking simulation than without all the banking projects (Figure 7-41).

8. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The Kern Fan Monitoring Committee (KFMC) has been working cooperatively to monitor groundwater conditions in the Kern Fan, which has been the locale of significant managed recharge for almost 50 years and large-scale groundwater banking for more than 20 years. Consistent with MOUs associated with groundwater banking projects, the KFMC has evaluated potential groundwater impacts from various banking projects over time. The basis of the evaluation is defined as the groundwater conditions that would have occurred in the *absence* of banking. The comparison of conditions with groundwater banking to conditions without groundwater banking is referred to as a *with and without* evaluation. To support this evaluation, the KFMC Technical Subcommittee retained Todd Groundwater to construct, calibrate, and apply a numerical groundwater flow model, termed the Kern Fan Model, which is documented in this report.

8.1. SUMMARY OF CONCLUSIONS

Construction of the model involved documentation of the Model Area (within the context of a broader study area) that encompasses 454 square miles over a model period of 25 years from 1986 – 2010. Documentation addressed the physical setting, groundwater management setting, hydrogeologic conceptual model, and water balance. While not presenting formal conclusions per se, the model construction provided a wealth of information, and where data were not complete, the model report provides clear documentation of the data gaps and the assumptions or analyses used to address them.

Calibration, the process of matching model simulated conditions to observed conditions, was performed in a multiple step process including manual and automatic techniques. The Kern Fan Model was developed to assess differences between the with banking scenarios and without project scenarios. Accordingly, the model was calibrated to ensure that simulated groundwater elevations in the banking area can match the timing and range of observed values. This calibration is thoroughly documented in this report with numerous hydrographs. Overall, the model accurately simulates conditions from 1986 through 2010. Because the model period includes a range of hydrological conditions through the model time, the resulting calibrated model is able to predict scenarios over a wide range of hydrological conditions.

Application of the Kern Fan Model involved simulation of the with banking scenario, six scenarios without each of the five individual banking projects, and one scenario with none of the projects in operation. The scenarios are fully documented with hydrographs and with maps representing selected years (including wet and dry years) through the model period. To summarize the model scenarios, groundwater elevations would have declined as much as 170 feet without groundwater recharge from banking during the wet years of the model period. However, groundwater elevations would have increased to over 30 feet without recovery pumping during dry times. While recharge has a net benefit to overall groundwater availability and elevations, there is also a localized negative impact associated with recovery pumping.

8.2. LIMITATIONS AND DATA GAPS

Any modelling project has limitations. Models are representations of reality and assumptions are made to support the given objective. Other models with small areas or more specific objectives have different assumptions regarding model boundary locations and flow conditions and the amount of managed recharge that percolates to the aquifer. Nonetheless, the Kern Fan Model and its documentation can be instructive about availability of data, data gaps, and how to address them.

Two overarching data gaps were identified in developing the Kern Fan Model: agricultural pumping and aquifer parameters. The first of these is location (areal and vertical), timing, and volume of agricultural pumping. Agricultural pumping represents 74 percent of the water balance. The numbers and locations of agricultural wells, and the timing and volumes of agricultural pumping, were estimated using available land use and other data. Future modeling in this area would be greatly improved if more data were available to assess agricultural pumping.

Aquifer parameters were also estimated for the purposes of the model. Sensitivity analyses showed that model layering and storage parameters have a significant effect on model calibration. Both specific storage and specific yield are largely unmeasured and application of these parameters to the model relied significantly on anecdotal information and professional judgement.

8.3. RECOMMENDATIONS

8.3.1. Continued Assessment of With and Without Banking Projects

The model was developed with the focused objective to evaluate adverse impacts from the banking projects consistent with MOUs associated with groundwater banking projects; including a “with and without” evaluation. The results in this report document the groundwater conditions with and without banking over the 25-year model period.

To continue the evaluation of with and without banking projects for future banking operations and groundwater conditions, the existing Kern Fan Model could be updated to simulate current conditions, allowing the with and without scenarios to be conducted on an annual basis. Additional data would be needed to update the model from 2010 to current conditions and then annually, as needed. Key data sets required for the updates would include climate, managed recharge deliveries, recovery pumping, municipal water use and pumping, agricultural water use and pumping, canal and river loss, and natural percolation. After updating, the model would be simulated through current conditions to verify model accuracy. Depending on the model performance for the verification scenario, a re-calibration of model parameters may be required. If re-calibrated, the model could also be revised to include any additional data on aquifer parameters.

8.3.2. Sustainable Groundwater Management Act (SGMA)

The Kern Fan Modeling effort was initiated with specific objectives relevant to groundwater banking impacts and was well underway when the Sustainable Groundwater Management Act (SGMA) became effective on January 2015. SGMA requires development of Groundwater Sustainability Plans (GSPs) on a groundwater-basin basis, and use of a surface water-groundwater flow model in preparing such GSPs is strongly encouraged by DWR.

Such a model would be regional, up-to-date to at least 2015, and developed with SGMA sustainability criteria and a variety of management actions in mind. DWR is currently updating their regional Central Valley model (C2V-Sim) and such a regional model would be well suited. With the concurrence of the KFMC Technical Subcommittee, Todd Groundwater has supplied databases and maps developed for this model to DWR to support the model update. Databases contain details on managed recharge, recovery pumping, municipal pumping, and canal and river losses compiled and confirmed by multiple sources. A legacy of this project will be to improve future modeling efforts.

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TABLES

Table 2-2: Model Layer Depths and Elevations from Geophysical Logs

					Model Layer 1				Model Layer 2				Model Layer 3				Model Layer 4			
Well Identification	Data Source	Ground Surface Elevation (feet MSL)	Date Drilled	Well Depth (feet)	Depth to Top of Layer 1 (feet)	Depth to Bottom of Layer 1 (feet)	Elevation of Top of Layer 1 (feet)	Elevation of Bottom of Layer 1 (feet)	Depth to Top of Layer 2 (feet)	Depth to Bottom of Layer 2 (feet)	Elevation of Top of Layer2 (feet)	Elevation of Bottom of Layer 2 (feet)	Depth to Top of Layer 3 (feet)	Depth to Bottom of Layer 3 (feet)	Elevation of Top of Layer 3 (feet)	Elevation of Bottom of Layer 3 (feet)	Depth to Top of Layer 4 (feet)	Depth to Bottom of Layer 4 (feet)	Elevation of Top of Layer 4 (feet)	Elevation of Bottom of Layer 4 (feet)
28S/22E-08B	Geophysical Log	252.4			0	135	252.411178	117.411178	135	270	117.411178	-17.588822	270	660	-17.588822	-407.588822				
28S/22E-12M	Geophysical Log	252.3			0	125	252.260605	127.260605	125	250	127.260605	2.260605	250	700	2.260605	-447.739395				
28S/23E-35A01	Geophysical Log	274.0			0	219	274.035192	55.035192	219	438	55.035192	-163.964808	438	700	-163.964808	-425.964808				
28S/24E-03N01	Geophysical Log	301.4			0	165	301.409727	136.409727	165	330	136.409727	-28.590273	330	610	-28.590273	-308.590273				
28S/24E-05K01	Geophysical Log	296.5											300	670	-3.458259	-373.458259				
28S/24E-06H	Geophysical Log	297.4			0	195	297.3523	102.3523	195	390	102.3523	-92.6477	390	520	-92.6477	-222.6477				
28S/24E-09	Geophysical Log	301.3			0	155	301.282334	146.282334	155	310	146.282334	-8.717666	310	520	-8.717666	-218.717666				
28S/24E-12R01	Geophysical Log	322.4			0	110	322.378694	212.378694	110	220	212.378694	102.378694	220	534	102.378694	-211.621306				
28S/24E-15H	Geophysical Log	309.0			0	125	309.026365	184.026365	125	250	184.026365	59.026365	250	610	59.026365	-300.973635				
28S/24E-16K	Geophysical Log	305.1			0	152	305.080375	153.080375	152	304	153.080375	1.080375	304	720	1.080375	-414.919625				
28S/24E-18	Geophysical Log	281.6			0	127.5	281.567735	154.067735	127.5	255	154.067735	26.567735	255	650	26.567735	-368.432265				
28S/24E-22R	Geophysical Log	312.4			0	110	312.447113	202.447113	110	220	202.447113	92.447113	220	520	92.447113	-207.552887				
28S/24E-24C01	Geophysical Log	316.3	2/10/2006	711	0	125	316.28951	191.28951	125	250	191.28951	66.28951	250	550	66.28951	-233.71049				
28S/24E-25A	Geophysical Log	317.9			0	153.5	317.883564	164.383564	153.5	307	164.383564	10.883564	307	680	10.883564	-362.116436				
28S/24E-27	Geophysical Log	307.8			0	119	307.75859	188.75859	119	238	188.75859	69.75859	238	650	69.75859	-342.24141				
28S/24E-30Q	Geophysical Log	268.1			0	142	268.13757	126.13757	142	284	126.13757	-15.86243	284	684	-15.86243	-415.86243				
28S/24E-31K01	Geophysical Log	272.6	8/18/2009	420	0	162.5	272.621942	110.121942	162.5	325	110.121942	-52.378058	325	700	-52.378058	-427.378058				
28S/25E-02J01	Geophysical Log	381.3			0	155	381.328155	226.328155	155	310	226.328155	71.328155	310	686	71.328155	-304.671845				
28S/25E-06M	Geophysical Log	332.6			0	142.5	332.579619	190.079619	142.5	285	190.079619	47.579619	285	530	47.579619	-197.420381				
28S/25E-07P	Geophysical Log	325.7											300	700	25.737633	-374.262367				
28S/25E-14F01	Geophysical Log	352.4			0	155	352.430176	197.430176	155	310	197.430176	42.430176	310	540	42.430176	-187.569824				
28S/25E-17E	Geophysical Log	327.7			0	138	327.723044	189.723044	138	276	189.723044	51.723044	276	570	51.723044	-242.276956				
28S/25E-22J	Geophysical Log	336.3			0	110	336.343753	226.343753	110	220	226.343753	116.343753								
28S/25E-26F01	Geophysical Log	334.0			0	145	333.996429	188.996429	145	290	188.996429	43.996429	290	655	43.996429	-321.003571				
28S/25E-27P01	Geophysical Log	329.1											300	680	29.144945	-350.855055				
28S/25E-31G01	Geophysical Log	318.4											300	750	18.374682	-431.625318				
28S/25E-33J01	Geophysical Log	327.7			0	130	327.702707	197.702707	130	260	197.702707	67.702707	260	690	67.702707	-362.297293				
28S/25E-35M	Geophysical Log	331.9			0	131	331.90865	200.90865	131	262	200.90865	69.90865	262	680	69.90865	-348.09135				
28S/26E-05F01	Geophysical Log	433.3			0	161	433.250424	272.250424	161	322	272.250424	111.250424	322	650	111.250424	-216.749576				
28S/26E-17A01	Geophysical Log	409.2			0	140	409.231383	269.231383	140	280	269.231383	129.231383	280	602	129.231383	-192.768617				
28S/26E-20J01	Geophysical Log	378.0			0	152.5	378.005976	225.505976	152.5	305	225.505976	73.005976	305	580	73.005976	-201.994024				
28S/26E-22L01	Geophysical Log	391.2			0	150	391.215433	241.215433	150	300	241.215433	91.215433	300	590	91.215433	-198.784567				
28S/26E-23K01	Geophysical Log	399.5			0	155	399.475017	244.475017	155	310	244.475017	89.475017	310	530	89.475017	-130.524983				
28S/26E-26P01	Geophysical Log	375.6			0	200	375.551724	175.551724	200	400	175.551724	-24.448276	400	710	-24.448276	-334.448276				
28S/26E-27F01	Geophysical Log	373.5			0	235	373.519966	138.519966	235	470	138.519966	-96.480034	470	720	-96.480034	-346.480034				
28S/26E-27H01	Geophysical Log	378.1			0	185	378.123007	193.123007	185	370	193.123007	8.123007	370	610	8.123007	-231.876993				
28S/26E-30F01	Geophysical Log	345.8		642	0	112.5	345.781876	233.281876	112.5	225	233.281876	120.781876	225	700	120.781876	-354.218124				
28S/26E-33L01	Geophysical Log	355.6		602	0	230	355.642428	125.642428	230	460	125.642428	-104.357572	460	630	-104.357572	-274.357572				
28S/26E-36P01	Geophysical Log	387.3											300	640	87.255022	-252.744978				
28S/27E-32Q01	Geophysical Log	454.9			0	195	454.921929	259.921929	195	390	259.921929	64.921929	390	622	64.921929	-167.078071				
29S/23E-11F01	Geophysical Log	272.4			0	130	272.367534	142.367534	130	260	142.367534	12.367534								
29S/23E-13P01	Geophysical Log	273.5			0	190	273.476456	83.476456	190	380	83.476456	-106.523544	380	680	-106.523544	-406.523544				
29S/23E-16R01	Geophysical Log	267.2		510	0	150	267.17118	117.17118	150	300	117.17118	-32.82882	300	490	-32.82882	-222.82882				
29S/23E-24F01	Geophysical Log	273.3			0	174	273.278935	99.278935	174	348	99.278935	-74.721065								
29S/23E-35K01	Geophysical Log	277.6			0	150	277.649631	127.649631	150	300	127.649631	-22.350369								
29S/24E-04F	Geophysical Log	277.9			0	170	277.869692	107.869692	170	340	107.869692	-62.130308	340	680	-62.130308	-402.130308				
29S/24E-08L01	Geophysical Log	296.3	1/1/1981	430	0	196	296.324145	100.324145	196	392	100.324145	-95.675855	392	550	-95.675855	-253.675855				
29S/24E-16F01	Geophysical Log	296.6			0	130	296.634008	166.634008	130	260	166.634008	36.634008								
29S/24E-20K01	Geophysical Log	288.5			0	140	288.501556	148.501556	140	280	148.501556	8.501556	280	650	8.501556	-361.498444				
29S/24E-27Q01	Geophysical Log	289.2			0	155	289.189135	134.189135	155	310	134.189135	-20.810865	310	590	-20.810865	-300.810865				
29S/24E-29C	Geophysical Log	280.5			0	160	280.501831	120.501831	160	320	120.501831	-39.498169	320	680	-39.498169	-399.498169				
29S/24E-34N01	Geophysical Log	285.1	1/1/1992	470	0	197.5	285.128617	87.628617	197.5	395	87.628617	-109.871383	395	560	-109.871383	-274.871383				
29S/25E-03F01	Geophysical Log	329.0	9/6/1956	300	0	145	328.955314	183.955314	145	290	183.955314	38.955314	290	575	38.955314	-246.044686				
29S/25E-12M01	Geophysical Log	329.3			0	110	329.294558	219.294558	110	220	219.294558	109.294558	220	640	109.294558	-310.705442				
29S/25E-13F01	Geophysical Log	332.7	6/6/1960	609	0	125	332.732652	207.732652	125	250	207.732652	82.732652								
29S/25E-23F01	Geophysical Log	326.5			0	137.5	326.455486	188.955486	137.5	275	188.955486	51.455486	275	725	51.455486	-398.544514				
29S/25E-25M01	Geophysical Log	327.7	1/1/1992	700	0	175	327.652296	152.652296	175	350	152.652296	-22.347704	350	600	-22.347704	-272.347704				
29S/25E-27L01	Geophysical Log	317.8			0	150	317.828142	167.828142	150	300	167.828142	17.828142	300	624	17.828142	-306.171858				
29S/25E-27N01	Geophysical Log	313.5	1/1/1992	700	0	156	313.457448	157.457448	156	312	157.457448	1.457448	312	610	1.457448	-296.542552				
29S/25E-30H	Geophysical Log	302.8			0	150	302.813026	152.813026	150	300	152.813026	2.813026	300	490	2.813026	-187.186974				
29S/25E-34H01	Geophysical Log	322.0			0	140	321.999152	181.999152	140	280	181.999152	41.999152	280	570	41.999152	-248.000848				
29S/25E-36	Geophysical Log	330.3	6/12/1977	400	0	115	330.335104	215.335104	115	230	215.335104	100.335104								
29S/26E-14H01	Geophysical Log	362.7			0	150	362.708021	212.708021	150	300	212.708021	62.708021	300	610	62.708021	-247.291979	610	790	-247.291979	-427.291979
29S/26E-14M02	Geophysical Log	357.3			0	130	357.250905	227.250905	130	260	227.250905	97.250905	260	625	97.250905	-267.749095				
29S/26E-15R01	Geophysical Log	356.7			0	155	356.667999	201.667999	155	310	201.667999	46.667999	310	490	46.667999	-133.332001	490	790	-133.332001	-433.332001
29S/26E-22A02	Geophysical Log	357.4	11/10/2003	450	0	170	357.373455	187.373455	170	340	187.373455	17.373455	340	715	17.373455	-357.626545				
29S/26E-23D01	Geophysical Log	358.7			0	155	358.734404	203.734404	155	310	203.734404	48.734404	310	770	48.734404	-411.265596				
29S/26E-25N01	Geophysical Log	365.9		1270	0	150	365.907121	215.907121	150	300	215.907121	65.907121	300	550	65.907121	-184.092879	550	800	-184.092879	-434.092879
29S/26E-28K	Geophysical Log	350.4		383	0	135	350.437985	215.437985	135	270	215.437985	80.437985								
29S/26E-29E02	Geophysical Log	340.1			0	135	340.147617	205.147617	135	270	205.147617	70.147617								
29S/26E-31H	Geophysical Log	341.3	10/9/1992	720	0	155	341.338298	186.338298	155	310	186.338298	31.338298	310	570	31.338298	-228.661702				
29S/26E-35A	Geophysical Log	363.4			0	115	363.420985	248.420985	115	230	248.420985	133.420985	230	580	133.420985	-216.579015				
29S/26E-35G	Geophysical Log	358.6			0	140	358.625295	218.625295	140	280	218.625295	78.625295	280	560	78.625295	-201.374705				
29S/26E-36Q02	Geophysical Log	367.5	7/16/2001	730	0	145	367.534783	222.534783	145	290	222.534783	77.534783	290	570	77.534783	-202.465217				
29S/27E-01A01	Geophysical Log	597.8			0	180	597.821208	417.821208	180	360	417.821208	237.821208	360	700	237.821208	-102.178792				
29S/27E-05M01	Geophysical Log	400.4			0	207.5	400.357639	192.857639	207.5	415	192.857639	-14.642361	415	630	-14.642361	-229.642361				
29S/27E-06	Geophysical Log	394.6			0	150	394.620979	244.620979	150	300	244.620979	94.620979	300	695	94.620979	-300.379021				
29S/27E-15F01	Geophysical Log	424.4			0	147.5	424.422842	276.922842	147.5	295	276.922842	129.422842	295	635	129.422842	-210.577158				

Table 2-2: Model Layer Depths and Elevations from Geophysical Logs

					Model Layer 1				Model Layer 2				Model Layer 3				Model Layer 4			
Well Identification	Data Source	Ground Surface Elevation (feet MSL)	Date Drilled	Well Depth (feet)	Depth to Top of Layer 1 (feet)	Depth to Bottom of Layer 1 (feet)	Elevation of Top of Layer 1 (feet)	Elevation of Bottom of Layer 1 (feet)	Depth to Top of Layer 2 (feet)	Depth to Bottom of Layer 2 (feet)	Elevation of Top of Layer2 (feet)	Elevation of Bottom of Layer 2 (feet)	Depth to Top of Layer 3 (feet)	Depth to Bottom of Layer 3 (feet)	Elevation of Top of Layer 3 (feet)	Elevation of Bottom of Layer 3 (feet)	Depth to Top of Layer 4 (feet)	Depth to Bottom of Layer 4 (feet)	Elevation of Top of Layer 4 (feet)	Elevation of Bottom of Layer 4 (feet)
29S/27E-16A01	Geophysical Log	417.8			0	150	417.823266	267.823266	150	300	267.823266	117.823266	300	640	117.823266	-222.176734				
29S/27E-20F01	Geophysical Log	392.4			0	150	392.369527	242.369527	150	300	242.369527	92.369527	300	690	92.369527	-297.630473				
29S/27E-21K01	Geophysical Log	397.2			0	125	397.17461	272.17461	125	250	272.17461	147.17461	250	700	147.17461	-302.82539				
29S/27E-23N01	Geophysical Log	402.5			0	162.5	402.533021	240.033021	162.5	325	240.033021	77.533021	325	680	77.533021	-277.466979				
29S/27E-24M01	Geophysical Log	406.4			0	120	406.356855	286.356855	120	240	286.356855	166.356855	240	670	166.356855	-263.643145				
29S/27E-26N01	Geophysical Log	397.2			0	165	397.17831	232.17831	165	330	232.17831	67.17831	330	610	67.17831	-212.82169				
29S/27E-27M01	Geophysical Log	396.4			0	185	396.409302	211.409302	185	370	211.409302	26.409302	370	690	26.409302	-293.590698				
29S/27E-28J01	Geophysical Log	390.3			0	135	390.302205	255.302205	135	270	255.302205	120.302205	270	670	120.302205	-279.697795				
29S/27E-31E01	Geophysical Log	369.4		750	0	117.5	369.442767	251.942767	117.5	235	251.942767	134.442767	235	670	134.442767	-300.557233				
29S/27E-31J	Geophysical Log	373.7			0	152.5	373.707188	221.207188	152.5	305	221.207188	68.707188	305	500	68.707188	-126.292812				
29S/27E-32H	Geophysical Log	382.6			0	125	382.551408	257.551408	125	250	257.551408	132.551408	250	670	132.551408	-287.448592				
29S/27E-34N01	Geophysical Log	387.4			0	145	387.441591	242.441591	145	290	242.441591	97.441591	290	710	97.441591	-322.558409				
29S/27E-36K02	Geophysical Log	394.0			0	130	394.048075	264.048075	130	260	264.048075	134.048075								
29S/28E-06G01	Geophysical Log	561.6			0	180	561.568586	381.568586	180	360	381.568586	201.568586	360	610	201.568586	-48.431414				
29S/28E-07D01	Geophysical Log	503.7			0	157.5	503.676869	346.176869	157.5	315	346.176869	188.676869	315	570	188.676869	-66.323131				
29S/28E-19F01	Geophysical Log	412.1			0	130	412.099858	282.099858	130	260	282.099858	152.099858	260	600	152.099858	-187.900142				
29S/28E-30A01	Geophysical Log	412.7											300	610	112.743537	-197.256463				
29S/28E-31B01	Geophysical Log	401.9			0	115	401.931754	286.931754	115	230	286.931754	171.931754	230	580	171.931754	-178.068246				
29S/28E-31F01	Geophysical Log	397.5			0	117.5	397.511204	280.011204	117.5	235	280.011204	162.511204	235	550	162.511204	-152.488796				
30S/24E-04C01	Geophysical Log	283.9			0	160	283.934812	123.934812	160	320	123.934812	-36.065188	320	530	-36.065188	-246.065188				
30S/24E-08D01	Geophysical Log	289.2			0	137.5	289.202287	151.702287	137.5	275	151.702287	14.202287								
30S/24E-12A	Geophysical Log	295.6			0	145	295.643911	150.643911	145	290	150.643911	5.643911	290	525	5.643911	-229.356089				
30S/24E-14M02	Geophysical Log	288.4	1/1/1992	700	0	142.5	288.444495	145.944495	142.5	285	145.944495	3.444495	285	580	3.444495	-291.555505				
30S/24E-22A	Geophysical Log	330.9			0	110	330.860534	220.860534	110	220	220.860534	110.860534								
30S/25E-01A01	Geophysical Log	332.1		50	0	142.5	332.109127	189.609127	142.5	285	189.609127	47.109127	285	480	47.109127	-147.890873				
30S/25E-07A01	Geophysical Log	301.1	4/27/1998	620	0	145	301.132385	156.132385	145	290	156.132385	11.132385	290	520	11.132385	-218.867615				
30S/25E-09C01	Geophysical Log	310.2	1/1/1991	716	0	150	310.197424	160.197424	150	300	160.197424	10.197424	300	490	10.197424	-179.802576				
30S/25E-11P	Geophysical Log	321.3			0	155	321.255188	166.255188	155	310	166.255188	11.255188	310	520	11.255188	-198.744812				
30S/25E-16B01	Geophysical Log	312.3	12/3/2000	730	0	180	312.344985	132.344985	180	360	132.344985	-47.655015	360	510	-47.655015	-197.655015				
30S/25E-19N	Geophysical Log	295.5			0	151	295.501312	144.501312	151	302	144.501312	-6.498688	302	475	-6.498688	-179.498688				
30S/25E-19R	Geophysical Log	297.9			0	155	297.8508	142.8508	155	310	142.8508	-12.1492	310	490	-12.1492	-192.1492				
30S/25E-21G01	Geophysical Log	308.4		700	0	132.5	308.433697	175.933697	132.5	265	175.933697	43.433697	265	590	43.433697	-281.566303				
30S/25E-22R01	Geophysical Log	316.0	1/1/1989	125	0	147.5	316.044361	168.544361	147.5	295	168.544361	21.044361	295	520	21.044361	-203.955639				
30S/25E-23N01	Geophysical Log	317.4			0	147.5	317.429657	169.929657	147.5	295	169.929657	22.429657	295	520	22.429657	-202.570343				
30S/25E-28K	Geophysical Log	306.8			0	160	306.751862	146.751862	160	320	146.751862	-13.248138	320	570	-13.248138	-263.248138				
30S/25E-34H	Geophysical Log	307.9			0	155	307.902863	152.902863	155	310	152.902863	-2.097137	310	540	-2.097137	-232.097137				
30S/25E-36R01	Geophysical Log	309.0	1/1/1992	640	0	137.5	308.985003	171.485003	137.5	275	171.485003	33.985003	275	530	33.985003	-221.014997				
30S/26E-02J03	Geophysical Log	357.9	6/8/1991	740	0	155	357.876385	202.876385	155	310	202.876385	47.876385	310	505	47.876385	-147.123615				
30S/26E-02R01	Geophysical Log	359.3	3/23/1991	730	0	165	359.284678	194.284678	165	330	194.284678	29.284678	330	555	29.284678	-195.715322				
30S/26E-04R01	Geophysical Log	350.9	4/28/1987	718	0	180	350.889964	170.889964	180	360	170.889964	-9.110036	360	595	-9.110036	-244.110036				
30S/26E-05E	Geophysical Log	338.7			0	130	338.653076	208.653076	130	260	208.653076	78.653076	260	560	78.653076	-221.346924				
30S/26E-05K01	Geophysical Log	342.5	1/17/2000	760	0	140	342.455088	202.455088	140	280	202.455088	62.455088	280	555	62.455088	-212.544912				
30S/26E-05L01	Geophysical Log	342.1			0	125	342.071503	217.071503	125	250	217.071503	92.071503	250	485	92.071503	-142.928497				
30S/26E-05N01	Geophysical Log	338.0	10/1/1998	770	0	155	337.954055	182.954055	155	310	182.954055	27.954055	310	480	27.954055	-142.045945				
30S/26E-05Q02	Geophysical Log	342.2	2/7/2000	750	0	175	342.209246	167.209246	175	350	167.209246	-7.790754	350	560	-7.790754	-217.790754				
30S/26E-05R01	Geophysical Log	344.1			0	175	344.089203	169.089203	175	350	169.089203	-5.910797	350	630	-5.910797	-285.910797				
30S/26E-06K	Geophysical Log	337.6			0	142.5	337.577942	195.077942	142.5	285	195.077942	52.577942	285	545	52.577942	-207.422058				
30S/26E-06K01	Geophysical Log	337.6	1/1/1998	750	0	145	337.578003	192.578003	145	290	192.578003	47.578003	290	460	47.578003	-122.421997				
30S/26E-06P01	Geophysical Log	333.3	6/14/2004	1033	0	170	333.263711	163.263711	170	340	163.263711	-6.736289	340	570	-6.736289	-236.736289				
30S/26E-08G01	Geophysical Log	342.5	2/28/2000	700	0	172.5	342.537861	170.037861	172.5	345	170.037861	-2.462139	345	660	-2.462139	-317.462139				
30S/26E-08H01	Geophysical Log	344.2	4/5/2000	710	0	185	344.236518	159.236518	185	370	159.236518	-25.763482	370	580	-25.763482	-235.763482				
30S/26E-09E01	Geophysical Log	345.0	3/23/2000	720	0	160	345.013713	185.013713	160	320	185.013713	25.013713	320	640	25.013713	-294.986287				
30S/26E-10A	Geophysical Log	357.3			0	155	357.33379	202.33379	155	310	202.33379	47.33379	310	630	47.33379	-272.66621				
30S/26E-10P01	Geophysical Log	346.3	1/1/1998	720	0	157.5	346.275306	188.775306	157.5	315	188.775306	31.275306	315	590	31.275306	-243.724694				
30S/26E-10Q01	Geophysical Log	350.4	1/1/1998	720	0	155	350.351405	195.351405	155	310	195.351405	40.351405	310	570	40.351405	-219.648595				
30S/26E-10Q02	Geophysical Log	353.3	4/24/2000	660	0	145	353.250851	208.250851	145	290	208.250851	63.250851	290	560	63.250851	-206.749149				
30S/26E-10R01	Geophysical Log	352.6	1/1/1999	770	0	170	352.587689	182.587689	170	340	182.587689	12.587689	340	540	12.587689	-187.412311				
30S/26E-11A01	Geophysical Log	357.8			0	130	357.815002	227.815002	130	260	227.815002	97.815002	260	640	97.815002	-282.184998				
30S/26E-11F01	Geophysical Log	354.9			0	125	354.853644	229.853644	125	250	229.853644	104.853644	250	610	104.853644	-255.146356				
30S/26E-11M01	Geophysical Log	353.7			0	145	353.699097	208.699097	145	290	208.699097	63.699097	290	580	63.699097	-226.300903				
30S/26E-15E01	Geophysical Log	347.7	6/19/2000	720	0	155	347.659357	192.659357	155	310	192.659357	37.659357	310	600	37.659357	-252.340643				
30S/26E-16L01	Geophysical Log	342.9	1/1/1998	720	0	165	342.895335	177.895335	165	330	177.895335	12.895335	330	510	12.895335	-167.104665				
30S/26E-16Q01	Geophysical Log	342.1	6/5/2000	690	0	160	342.129106	182.129106	160	320	182.129106	22.129106	320	600	22.129106	-257.870894				
30S/26E-16R01	Geophysical Log	342.6	5/15/2000	690	0	155	342.592013	187.592013	155	310	187.592013	32.592013	310	600	32.592013	-257.407987				
30S/26E-19B	Geophysical Log	327.7			0	137.5	327.70233	190.20233	137.5	275	190.20233	52.70233	275	550	52.70233	-222.29767				
30S/26E-22P	Geophysical Log	342.0	9/22/2006		0	200	341.966125	141.966125	200	400	141.966125	-58.033875	400	650	-58.033875	-308.033875				
30S/26E-24A01	Geophysical Log	356.4			0	122.5	356.437988	233.937988	122.5	245	233.937988	111.437988	245	560	111.437988	-203.562012				
30S/26E-25A04	Geophysical Log	350.3			0	137.5	350.34491	212.84491	137.5	275	212.84491	75.34491	275	590	75.34491	-239.65509				
30S/26E-28J	Geophysical Log	332.6			0	155	332.598836	177.598836	155	310	177.598836	22.598836	310	540	22.598836	-207.401164				
30S/26E-29B01	Geophysical Log	327.5			0	125	327.529019	202.529019	125	250	202.529019	77.529019	250	600	77.529019	-272.470981				
30S/26E-32N01	Geophysical Log	317.5	1/1/1989	330	0	150	317.537389	167.537389	150	300	167.537389	17.537389	300	575	17.537389	-257.462611				
30S/27E-01B01	Geophysical Log	392.5			0	120	392.497617	272.497617	120	240	272.497617	152.497617	240	570	152.497617	-177.502383				
30S/27E-01J01	Geophysical Log	388.7			0	145	388.660095	243.660095	145	290	243.660095	98.660095	290	570	98.660095	-181.339905				
30S/27E-02P01	Geophysical Log	388.3			0	135	388.318242	253.318242	135	270	253.318242	118.318242	270	590	118.318242	-201.681758				
30S/27E-02R01	Geophysical Log	384.4			0	122.5	384.438978	261.938978	122.5	245	261.938978	139.438978	245	560	139.438978	-175.561022				
30S/27E-03J02	Geophysical Log	382.7			0	170	382.719488	212.719488	170	340	212.719488	42.719488								
30S/27E-05A	Geophysical Log	381.0			0	145	381.016466	236.016466	145	290	236.016466	91.016466	290	545	91.016466	-163.983534				
30S/27E-07	Geophysical Log	366.6			0	147.5	366.578293	219.078293	147.5	295	219.078293	71.578293	295	500	71.578293	-133.421707				

Table 2-2: Model Layer Depths and Elevations from Geophysical Logs

					Model Layer 1				Model Layer 2				Model Layer 3				Model Layer 4			
Well Identification	Data Source	Ground Surface Elevation (feet MSL)	Date Drilled	Well Depth (feet)	Depth to Top of Layer 1 (feet)	Depth to Bottom of Layer 1 (feet)	Elevation of Top of Layer 1 (feet)	Elevation of Bottom of Layer 1 (feet)	Depth to Top of Layer 2 (feet)	Depth to Bottom of Layer 2 (feet)	Elevation of Top of Layer2 (feet)	Elevation of Bottom of Layer 2 (feet)	Depth to Top of Layer 3 (feet)	Depth to Bottom of Layer 3 (feet)	Elevation of Top of Layer 3 (feet)	Elevation of Bottom of Layer 3 (feet)	Depth to Top of Layer 4 (feet)	Depth to Bottom of Layer 4 (feet)	Elevation of Top of Layer 4 (feet)	Elevation of Bottom of Layer 4 (feet)
30S/27E-08J	Geophysical Log	371.5			0	154	371.453048	217.453048	154	308	217.453048	63.453048	308	514	63.453048	-142.546952				
30S/27E-09P01	Geophysical Log	371.3			0	150	371.263039	221.263039	150	300	221.263039	71.263039	300	505	71.263039	-133.736961				
30S/27E-12F01	Geophysical Log	383.2			0	117.5	383.227916	265.727916	117.5	235	265.727916	148.227916	235	550	148.227916	-166.772084				
30S/27E-13C01	Geophysical Log	378.4			0	155	378.378673	223.378673	155	310	223.378673	68.378673	310	460	68.378673	-81.621327				
30S/27E-14F01	Geophysical Log	373.1			0	160	373.118169	213.118169	160	320	213.118169	53.118169	320	564	53.118169	-190.881831				
30S/27E-18F01	Geophysical Log	362.0			0	118	361.994048	243.994048	118	236	243.994048	125.994048	236	530	125.994048	-168.005952				
30S/27E-19J	Geophysical Log	356.8		712	0	140	356.750112	216.750112	140	280	216.750112	76.750112	280	655	76.750112	-298.249888				
30S/27E-19N01	Geophysical Log	352.4			0	155	352.44339	197.44339	155	310	197.44339	42.44339	310	550	42.44339	-197.55661				
30S/27E-20D	Geophysical Log	361.3			0	130	361.340348	231.340348	130	260	231.340348	101.340348	260	700	101.340348	-338.659652				
30S/27E-21N01	Geophysical Log	360.0			0	125	360.015534	235.015534	125	250	235.015534	110.015534	250	630	110.015534	-269.984466				
30S/27E-23C01	Geophysical Log	370.6			0	110	370.633867	260.633867	110	220	260.633867	150.633867	220	580	150.633867	-209.366133				
30S/27E-26D	Geophysical Log	363.7	3/20/1959	222	0	145	363.72516	218.72516	145	290	218.72516	73.72516	290	650	73.72516	-286.27484				
30S/27E-30C	Geophysical Log	351.9	7/15/1963	172	0	155	351.852453	196.852453	155	310	196.852453	41.852453	310	530	41.852453	-178.147547				
30S/28E-05B01	Geophysical Log	393.0			0	160	393.025975	233.025975	160	320	233.025975	73.025975								
30S/28E-06C01	Geophysical Log	395.2			0	157.5	395.206013	237.706013	157.5	315	237.706013	80.206013	315	640	80.206013	-244.793987				
30S/28E-07C	Geophysical Log	387.5			0	125	387.470334	262.470334	125	250	262.470334	137.470334	250	520	137.470334	-132.529666				
30S/28E-16K01	Geophysical Log	372.6			0	180	372.571524	192.571524	180	360	192.571524	12.571524	360	590	12.571524	-217.428476				
30S/28E-18E01	Geophysical Log	376.8			0	137.5	376.753286	239.253286	137.5	275	239.253286	101.753286								
30S/28E-18K01	Geophysical Log	377.5			0	122.5	377.503756	255.003756	122.5	245	255.003756	132.503756	245	560	132.503756	-182.496244				
30S/28E-19A01	Geophysical Log	373.3			0	155	373.30886	218.30886	155	310	218.30886	63.30886	310	565	63.30886	-191.69114				
31S/25E-03E01	Geophysical Log	299.5			0	130	299.508246	169.508246	130	260	169.508246	39.508246	260	490	39.508246	-190.491754				
31S/25E-03E02	Geophysical Log	299.5			0	130	299.508246	169.508246	130	260	169.508246	39.508246	260	480	39.508246	-180.491754				
31S/25E-04Q	Geophysical Log	297.8			0	137.5	297.751313	160.251313	137.5	275	160.251313	22.751313	275	475	22.751313	-177.248687				
31S/25E-14L01	Geophysical Log	293.5			0	171	293.49054	122.49054	171	342	122.49054	-48.50946	342	495	-48.50946	-201.50946				
31S/25E-15F01	Geophysical Log	299.7			0	155	299.748205	144.748205	155	310	144.748205	-10.251795	310	520	-10.251795	-220.251795				
31S/25E-15M	Geophysical Log	297.5			0	155	297.483704	142.483704	155	310	142.483704	-12.516296	310	515	-12.516296	-217.516296				
31S/25E-25D	Geophysical Log	290.6			0	127.5	290.591538	163.091538	127.5	255	163.091538	35.591538	255	540	35.591538	-249.408462				
31S/26E-02	Geophysical Log	326.8			0	145	326.78162	181.78162	145	290	181.78162	36.78162	290	550	36.78162	-223.21838				
31S/26E-03A01	Geophysical Log	329.7			0	155	329.734986	174.734986	155	310	174.734986	19.734986	310	570	19.734986	-240.265014				
31S/26E-12N	Geophysical Log	321.1			0	155	321.05416	166.05416	155	310	166.05416	11.05416	310	575	11.05416	-253.94584				
31S/26E-27L01	Geophysical Log	298.5		515	0	130	298.454043	168.454043	130	260	168.454043	38.454043	260	505	38.454043	-206.545957				
31S/26E-34D	Geophysical Log	295.8			0	155	295.777591	140.777591	155	310	140.777591	-14.222409	310	480	-14.222409	-184.222409				
31S/27E-01H01	Geophysical Log	346.0		97	0	130	346.035025	216.035025	130	260	216.035025	86.035025								
31S/27E-07A	Geophysical Log	332.7	11/15/1990	685	0	155	332.742029	177.742029	155	310	177.742029	22.742029	310	590	22.742029	-257.257971				
31S/27E-12	Geophysical Log	336.3	6/29/1964	552	0	145	336.321302	191.321302	145	290	191.321302	46.321302	290	600	46.321302	-263.678698				
31S/27E-13G	Geophysical Log	331.3			0	147.5	331.305856	183.805856	147.5	295	183.805856	36.305856	295	555	36.305856	-223.694144				
31S/27E-15	Geophysical Log	328.4	3/29/1973	600	0	150	328.369916	178.369916	150	300	178.369916	28.369916	300	610	28.369916	-281.630084				
31S/27E-17K	Geophysical Log	326.4			0	132.5	326.439341	193.939341	132.5	265	193.939341	61.439341	265	650	61.439341	-323.560659				
31S/27E-18G	Geophysical Log	322.8			0	165	322.818986	157.818986	165	330	157.818986	-7.181014	330	570	-7.181014	-247.181014				
31S/27E-28B01	Geophysical Log	313.1	3/26/1990	620	0	167	313.072984	146.072984	167	334	146.072984	-20.927016	334	515	-20.927016	-201.927016				
31S/27E-29P	Geophysical Log	303.6	11/2/1990	805	0	177.5	303.630578	126.130578	177.5	355	126.130578	-51.369422	355	660	-51.369422	-356.369422				
31S/27E-32J	Geophysical Log	299.0			0	162.5	298.959001	136.459001	162.5	325	136.459001	-26.040999	315	570	-16.040999	-271.040999				
31S/28E-06C01	Geophysical Log	347.4			0	160	347.36721	187.36721	160	320	187.36721	27.36721	320	630	27.36721	-282.63279				
31S/28E-06M01	Geophysical Log	344.5		300	0	155	344.455434	189.455434	155	310	189.455434	34.455434	310	615	34.455434	-270.544566				
31S/28E-08A	Geophysical Log	338.7			0	155	338.699159	183.699159	155	310	183.699159	28.699159	310	600	28.699159	-261.300841				
31S/28E-12R01	Geophysical Log	385.2		403	0	167	385.199562	218.199562	167	334	218.199562	51.199562	334	610	51.199562	-224.800438				
31S/28E-20N01	Geophysical Log	316.3			0	162.5	316.318347	153.818347	162.5	325	153.818347	-8.681653	325	540	-8.681653	-223.681653				
31S/28E-24A	Geophysical Log	375.6			0	150	375.552114	225.552114	150	300	225.552114	75.552114	300	582	75.552114	-206.447886				
31S/28E-28A01	Geophysical Log	316.9	3/11/1955	516	0	150	316.927757	166.927757	150	300	166.927757	16.927757	300	600	16.927757	-283.072243				
31S/28E-30M01	Geophysical Log	313.7		815	0	162	313.74177	151.74177	162	324	151.74177	-10.25823	324	580	-10.25823	-266.25823				
31S/28E-31N01	Geophysical Log	301.8		815	0	150	301.793894	151.793894	150	300	151.793894	1.793894	300	550	1.793894	-248.206106				
31S/28E-31R01	Geophysical Log	306.9											300	550	6.913514	-243.086486				
31S/28E-33F01	Geophysical Log	303.4			0	160	303.445027	143.445027	160	320	143.445027	-16.554973	320	590	-16.554973	-286.554973				
32S/27E-03C	Geophysical Log	299.4			0	210	299.351131	89.351131	210	420	89.351131	-120.648869	420	560	-120.648869	-260.648869				
32S/27E-04F01	Geophysical Log	296.1			0	165	296.076444	131.076444	165	330	131.076444	-33.923556	330	590	-33.923556	-293.923556				
32S/27E-04J	Geophysical Log	295.8			0	175	295.805228	120.805228	175	350	120.805228	-54.194772	350	570	-54.194772	-274.194772				
32S/27E-09L	Geophysical Log	287.0			0	192.5	287.045139	94.545139	192.5	385	94.545139	-97.954861	385	605	-97.954861	-317.954861				
32S/27E-10L	Geophysical Log	286.3			0	165	286.326015	121.326015	165	330	121.326015	-43.673985	330	545	-43.673985	-258.673985				
32S/28E-06F01	Geophysical Log	298.4			0	185	298.407605	113.407605	185	370	113.407605	-71.592395	370	620	-71.592395	-321.592395				
32S/28E-06H	Geophysical Log	296.6			0	200	296.6216	96.6216	200	400	96.6216	-103.3784	400	600	-103.3784	-303.3784				
32S/28E-09B	Geophysical Log	301.6			0	150	301.552745	151.552745	150	300	151.552745	1.552745	300	570	1.552745	-268.447255				
Strand Ranch SREX-1	Geophysical Log	321.9	5/5/2010	670	0	200	321.861786	121.861786	200	400	121.861786	-78.138214	400	580	-78.138214	-258.138214	580	800	-258.138214	-478.138214
Strand Ranch SREX-2	Geophysical Log	319.5	3/23/2011	630	0	197.5	319.49408	121.99408	197.5	395	121.99408	-75.50592	395	564	-75.50592	-244.50592	564	800	-244.50592	-480.50592

Table 2-3: Aquifer Transmissivities and Storage Coefficients from Pumping Tests

Well Identification	Date Drilled	Perforated Interval (feet)	Well Depth (feet)	Total Length of Perforations (feet)	Tested By	Date of Test	Test Type	Data Analysis Method	Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Transmissivity (T - ft^2/day)	Hydraulic Conductivity (K - ft/day) (T/perf length)	Storage Coefficient (S - unit less)
28S/22E-08B		320-660		340	Kenneth D. Schmidt and Associates	3/1/2010	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,000	14.9	2,406	7.08	
28S/22E-08J		320-660		340	Kenneth D. Schmidt and Associates	3/1/2010	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,520	19.0	4,679	13.76	
28S/22E-11H		480-740		260	Kenneth D. Schmidt and Associates	10/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,950	10.7	3,743	14.40	
28S/22E-12M		410-700		290	Kenneth D. Schmidt and Associates	10/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,590	25.9	3,609	12.45	
28S/22E-17H		300-600		300	Kenneth D. Schmidt and Associates	10/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,520	20.7	5,481	18.27	
28S/22E-17R	10/1/2008	300-600	610	300	Kenneth D. Schmidt and Associates	10/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3,000	20.5	4,010	13.37	
28S/22E-30C		244-269		25	Kenneth D. Schmidt and Associates	8/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	70	10.0	6,016	240.62	
28S/23E-07N		200-500		300	Kenneth D. Schmidt and Associates	9/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,990	45.0	5,347	17.82	
28S/25E-16F		535-835		300	Kenneth D. Schmidt and Associates	5/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,010	33.0	34,489	114.96	
29S/22E-06L		126-146		20	Kenneth D. Schmidt and Associates	8/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	60	6.9	2,273	113.63	
29S/23E-09J		200-440		240	Kenneth D. Schmidt and Associates	2/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3,220	48.5	13,502	56.26	
29S/24E-19J01		195-455		60	Kenneth D. Schmidt and Associates	3/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,810	27.5	9,892	164.87	
29S/24E-24A01		210-455		245	Kenneth D. Schmidt and Associates	6/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3,030	31.6	7,352	30.01	
29S/25E-34A01	10/2/2009	185-455	475		RRBWSD/BW&P (Todd analysis)	10/19/2009	Constant Rate	Cooper-Jacob Straight Line (Recovery)	3,215	45.5	39,634	146.79	
29S/26E-14H		730-1171		441	Kenneth D. Schmidt and Associates	8/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,230	14.1	6,684	15.16	
29S/26E-15Q		840-1200		360	Kenneth D. Schmidt and Associates	4/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,500	25.0	4,545	12.63	
29S/26E-25N		970-1270		40	Kenneth D. Schmidt and Associates	6/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,300	18.8	4,946	16.49	
29S/26E-28D02	12/15/2005	780-1120	1165	340	Kenneth D. Schmidt and Associates	3/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,590	41.4	10,561	31.06	
29S/26E-32R		335-600		265	Kenneth D. Schmidt and Associates	8/1/2002	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,500	10.6	5,080	19.17	
29S/26E-35B01	12/1/2006	200-500, 560-700	740	440	Kenneth D. Schmidt and Associates	3/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,540	46.7	40,772	92.66	
29S/26E-35G02	5/1/2006	200-440, 500-640	680	380	Kenneth D. Schmidt and Associates	3/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,980	116.0	35,425	80.51	
29S/26E-35G02	5/1/2006	200-440, 500-640	660	380	KCWA / KWB	3/19/2007	Constant Rate	Cooper-Jacob Straight Line	3,000		30,000	78.95	
29S/26E-35H		190-650		460	Kenneth D. Schmidt and Associates	5/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3,000	179.4	58,685	127.58	
29S/26E-35H05	3/1/2007	210-450, 500-745	785	485	KCWA / KWB	5/21/2007	Constant Rate	Cooper-Jacob Straight Line	3,000		39,000	80.41	
29S/26E-35K01		205-665		460	Kenneth D. Schmidt and Associates	4/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3,000	148.3	41,441	90.09	
29S/26E-36K	12/15/2006	200-450, 500-680	720	480	Kenneth D. Schmidt and Associates	4/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	4,080	150.6	41,975	87.45	
29S/26E-36K01	12/15/2006	200-450, 500-680	720	430	KCWA / KWB	4/18/2007	Constant Rate	Cooper-Jacob Straight Line	4,976		46,000	106.98	
29S/26E-36L01	12/15/2006	200-550, 590-700	740	460	KCWA / KWB	5/10/2007	Constant Rate	Cooper-Jacob Straight Line	5,000		39,000	84.78	
29S/26E-36L01	12/15/2006	200-550, 590-700	740	460	Kenneth D. Schmidt and Associates	5/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	4,430	147.6	40,237	80.47	
30S/25E-21G		286-750		464	Kenneth D. Schmidt and Associates	9/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	4,480	69.6	16,844	36.30	

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Well Identification	Date Drilled	Perforated Interval (feet)	Well Depth (feet)	Total Length of Perforations (feet)	Tested By	Date of Test	Test Type	Data Analysis Method	Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Transmissivity (T - ft^2/day)	Hydraulic Conductivity (K - ft/day) (T/perf length)	Storage Coefficient (S - unit less)
30S/25E-21R04	10/7/2002	229-656	820	30	Kenneth D. Schmidt and Associates	5/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	4,430	46.3	16,576	38.82	
30S/25E-22M01	12/21/2002	225-360, 390-625	750	370	Kenneth D. Schmidt and Associates	2/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3,000	37.3	12,298	33.24	
30S/25E-25C01	12/15/2005	190-610	700	420	Kenneth D. Schmidt and Associates	2/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2,420	17.2	4,411	10.50	
30S/26E-02J03	6/8/1991	224-304, 384-724	740	420	KCWA / KWB	7/27/2001	Constant Rate	Cooper-Jacob Straight Line	2,737		27,000	64.29	
30S/26E-04E03	9/8/2009	280-480, 540-740	820	400	KCWA / KWB	11/12/2009	Constant Rate	Cooper-Jacob Straight Line	1,700		17,800	44.50	
30S/26E-05K01	1/17/2000	160-480, 560-740	760	500	KCWA / KWB	2/9/2000	Constant Rate	Cooper-Jacob Straight Line	3,005		24,000	48.00	
30S/26E-05L01				480	KCWA / KWB	2/22/2000	Constant Rate	Cooper-Jacob Straight Line	3,005		23,000		
30S/26E-05N01	10/1/1998	169.8-299.8, 340-420, 480-700	770	430	KCWA / KWB	2/22/1999	Constant Rate	Cooper-Jacob Straight Line	3,816		27,000	62.79	
30S/26E-05Q02	2/7/2000	190-350, 370-490, 570-730	750	440	KCWA / KWB	3/7/2000	Constant Rate	Cooper-Jacob Straight Line	3,005		28,000	63.64	
30S/26E-05R01				500	KCWA / KWB	1/26/2000	Constant Rate	Cooper-Jacob Straight Line	3,005		13,000		
30S/26E-06K01	1/1/1998	220-280, 340-700	750	420	KCWA / KWB	1/18/1999	Constant Rate	Cooper-Jacob Straight Line	3,977		33,000	78.57	
30S/26E-08G01	2/28/2000	160-340, 360-640, 660-680	700	480	KCWA / KWB	4/4/2000	Constant Rate	Cooper-Jacob Straight Line	3,005		34,000	70.83	
30S/26E-08H01	4/5/2000	110-370, 390-690	710	560	KCWA / KWB	5/4/2000	Constant Rate	Cooper-Jacob Straight Line	3,005		32,000	57.14	
30S/26E-09E01	3/23/2000	160-320, 340-580, 640-680	720	440	KCWA / KWB	4/17/2000	Constant Rate	Cooper-Jacob Straight Line	3,592		110,000	250.00	
30S/26E-10P01	1/1/1998	155-314.75, 355-635	720	439.75	KCWA / KWB	4/19/2000	Constant Rate	Cooper-Jacob Straight Line	3,799		20,000	45.48	
30S/26E-10Q01	1/1/1998	180-300, 340-650	720	430	KCWA / KWB	12/23/1998	Constant Rate	Cooper-Jacob Straight Line	3,841		15,000	34.88	
30S/26E-10Q02	4/24/2000	170-330, 380-500, 540-640	660	380	KCWA / KWB	5/26/2000	Constant Rate	Cooper-Jacob Straight Line	3,592		18,000	47.37	
30S/26E-10R01	1/1/1999	159.6-339.6, 379.8-479.8, 540-730	770	470	KCWA / KWB	2/3/1999	Constant Rate	Cooper-Jacob Straight Line	3,802		16,000	34.04	
30S/26E-11A		210-690		480	Kenneth D. Schmidt and Associates	12/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3,530	124.9	24,196	50.41	
30S/26E-11A01				440	KCWA / KWB	12/4/2007	Constant Rate	Cooper-Jacob Straight Line	3,010		22,000	50.00	
30S/26E-11G		200-780		580	Kenneth D. Schmidt and Associates	11/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3,560	125.8	29,543	50.94	
30S/26E-11G01					KCWA / KWB	11/16/2007	Constant Rate	Cooper-Jacob Straight Line	3,035		36,000	75.00	
30S/26E-11M		200-780		580	Kenneth D. Schmidt and Associates	12/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3,530	53.5	12,165	20.97	
30S/26E-11M01				200	KCWA / KWB	12/5/2007	Constant Rate	Cooper-Jacob Straight Line	3,003		9,400	47.00	
30S/26E-15E01	6/19/2000	180-380, 420-700	720	480	KCWA / KWB	7/25/2000	Constant Rate	Cooper-Jacob Straight Line	3,005		28,000	58.33	
30S/26E-16L01	1/1/1998	154.75-319.75, 360-390, 450-690	720	435	KCWA / KWB	12/21/1998	Constant Rate	Cooper-Jacob Straight Line	3,811		19,000	43.68	
30S/26E-16Q01	6/5/2000	150-330, 400-670	690	450	KCWA / KWB	7/12/2000	Constant Rate	Cooper-Jacob Straight Line	3,005		29,000	64.44	
30S/26E-16R01	5/15/2000	150-310, 370-670	690	460	KCWA / KWB	6/21/2000	Constant Rate	Cooper-Jacob Straight Line	3,005		23,000	50.00	
30S/26E-17B01	8/7/1999	170-290, 330-550, 590-690	710	440	KCWA / KWB	9/10/1999	Constant Rate	Cooper-Jacob Straight Line	3,511		19,000	43.18	
30S/26E-17C01	7/20/1999	168-248, 268-308, 328-628, 648-688	708	460	KCWA / KWB	8/23/1999	Constant Rate	Cooper-Jacob Straight Line	3,759		18,000	39.13	

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Well Identification	Date Drilled	Perforated Interval (feet)	Well Depth (feet)	Total Length of Perforations (feet)	Tested By	Date of Test	Test Type	Data Analysis Method	Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Transmissivity (T - ft^2/day)	Hydraulic Conductivity (K - ft/day) (T/perf length)	Storage Coefficient (S - unit less)
30S/26E-18R01	7/7/1999	160-260, 300-400, 420-620, 640-680	700	440	KCWA / KWB	9/27/1999	Step-Discharge	Step-Drawdown of Single Well	2,008		10,000	22.73	
30S/26E-22P03		280-390		184	Kenneth D. Schmidt and Associates	11/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,460	27.6	10,962	99.65	
30S/26E-23M		270-455		185	Kenneth D. Schmidt and Associates	11/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,230	66.1	31,014	167.64	
30S/26E-24J		630-730		100	Kenneth D. Schmidt and Associates	12/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,250	63.4	29,276	292.76	
30S/27E-19J01	12/7/1948	449-770	712	321	Kenneth D. Schmidt and Associates	4/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,560	82.1	28,607	89.12	
30S/27E-19R		550-710		160	Kenneth D. Schmidt and Associates	3/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,540	59.3	17,512	109.45	
30S/27E-20D		479-669		190	Kenneth D. Schmidt and Associates	4/1/2009	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,570	60.5	18,448	97.09	
30S/27E-20P	8/15/2006	475-730	750	30	Kenneth D. Schmidt and Associates	9/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,360	66.7	20,854	82.43	
30S/27E-22N		410-620		210	Kenneth D. Schmidt and Associates	1/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,250	30.6	32,217	153.41	
30S/27E-30C		545-670		50	Kenneth D. Schmidt and Associates	3/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,230	29.3	17,378	139.03	
30S/27E-33H	11/19/2002	135-185	190	50	Kenneth D. Schmidt and Associates	12/1/2002	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	44	14.2	10,293	205.87	
30S/27E-34B	6/1/2005	360-540	570	180	Kenneth D. Schmidt and Associates	9/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1,100	61.2	26,067	144.82	
31S/27E-16H		440-505		24	Kenneth D. Schmidt and Associates	5/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	485	17.9	9,892	152.19	
31S/27E-19A		420-510		190	Kenneth D. Schmidt and Associates	10/1/1991	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	230	21.3	6,818	35.88	
Strand Ranch SREX-1	5/5/2010	380-650	670	270	Wildermuth	5/4/2010	Constant Rate	Hantush-Jacob	2,496		7,680	28.44	0.01280
Strand Ranch SREX-2	10/8/2010	410-530, 570-650	670	200	Wildermuth	5/12/2010	Constant Rate	Hantush-Jacob	2,504		9,191	32.53	0.03420
Strand Ranch SREX-3	3/23/2011	410-610	630	200	Wildermuth	1/25/2011	Constant Rate	Hantush-Jacob	2,512		8,138	29.06	0.00440
Strand Ranch SREX-4	9/23/2010	410-540, 580-650	670	200	Wildermuth	1/30/2011	Constant Rate	Hantush-Jacob	2,513		6,048	22.12	0.00080
Strand Ranch SREX-5	11/4/2010	410-505, 545-650	670	200	Wildermuth	2/9/2011	Constant Rate	Hantush-Jacob	2,508		7,172	26.56	0.01860
Strand Ranch SREX-7	10/29/2010	410-480, 520-660	680	210	Wildermuth	1/19/2011	Constant Rate	Hantush-Jacob	2,507		5,460	19.71	0.00400
WKWD/NRRP - NW-1	4/13/2011	270-300, 310-395, 415-450, 470-515, 535-550, 560-570	590	220	WKWSD / Richard C. Slade & Associates	5/4/2011	Constant Rate	Recovery (Observation well NW-5)	2,995		35,343	160.65	0.00221
WKWD/NRRP - NW-1	4/13/2011	270-300, 310-395, 415-450, 470-515, 535-550, 560-570	590	220	WKWSD / Richard C. Slade & Associates	5/4/2011	Constant Rate	Recovery (Observation well NW-5)	2,995		20,332	92.42	0.00213
WKWD/NRRP - NW-1	4/13/2011	270-300, 310-395, 415-450, 470-515, 535-550, 560-570	590	220	WKWSD / Richard C. Slade & Associates	5/4/2011	Constant Rate	Theis Confined (DD & Recovery)	2,995	46.5	16,321	74.19	
WKWD/NRRP - NW-1	4/13/2011	270-300, 310-395, 415-450, 470-515, 535-550, 560-570	590	220	WKWSD / Richard C. Slade & Associates	5/4/2011	Constant Rate	Hantush-Jacob Leaky (DD & Recovery)	2,995	46.5	12,969	58.95	
WKWD/NRRP - NW-2	8/4/2011	650-675, 695-760, 790-810, 835-850, 860-880, 940-980	1000	185	WKWSD / Richard C. Slade & Associates	8/30/2011	Constant Rate	Theis Confined (DD & Recovery)	3,073	35.2	13,969	75.51	
WKWD/NRRP - NW-2	8/4/2011	650-675, 695-760, 790-810, 835-850, 860-880, 940-980	1000	185	WKWSD / Richard C. Slade & Associates	8/30/2011	Constant Rate	Hantush-Jacob Leaky (DD & Recovery)	3,073	35.2	13,969	75.51	
WKWD/NRRP - NW-3	5/6/2011	245-280, 290-335, 365-390, 405-435, 445-480, 505-520, 530-545	565	200	WKWSD / Richard C. Slade & Associates	6/1/2011	Constant Rate	Hantush-Jacob Leaky (DD & Recovery)	2,500	32.6	10,158	50.79	
WKWD/NRRP - NW-3	5/6/2011	245-280, 290-335, 365-390, 405-435, 445-480, 505-520, 530-545	565	200	WKWSD / Richard C. Slade & Associates	6/1/2011	Constant Rate	Recovery (Observation wells NW-1 & 5)	2,500		25,317	126.59	0.00120
WKWD/NRRP - NW-3	5/6/2011	245-280, 290-335, 365-390, 405-435, 445-480, 505-520, 530-545	565	200	WKWSD / Richard C. Slade & Associates	6/1/2011	Constant Rate	Recovery (Observation well NW-1 & 5)	2,500		26,414	132.07	0.00108
WKWD/NRRP - NW-3	5/6/2011	245-280, 290-335, 365-390, 405-435, 445-480, 505-520, 530-545	565	200	WKWSD / Richard C. Slade & Associates	6/1/2011	Constant Rate	Theis Confined (DD & Recovery)	2,500	32.6	13,982	69.91	

Table 2-3: Aquifer Transmissivities and Storage Coefficients from Pumping Tests

Well Identification	Date Drilled	Perforated Interval (feet)	Well Depth (feet)	Total Length of Perforations (feet)	Tested By	Date of Test	Test Type	Data Analysis Method	Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Transmissivity (T - ft^2/day)	Hydraulic Conductivity (K - ft/day) (T/perf length)	Storage Coefficient (S - unit less)
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	Recovery (Observation wells NW-1, 3, & 5)	2,536		20,078	143.41	0.00200
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	Recovery (Observation wells NW-1, 3, & 5)	2,536		15,934	113.81	0.00200
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	(Observation wells NW-1, 3, & 5)	2,536		17,444	124.60	0.00260
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	Hantush-Jacob Leaky (DD & Recovery)	2,536	26.0	8,030	57.35	
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	Theis Confined (DD & Recovery)	2,536	26.0	11,895	84.97	
WKWD/NRRP - NW-5	4/1/2011	220-285, 300-320, 330-390, 410-450, 510-540	560	215	WKWSD / Richard C. Slade & Associates	3/19/2011	Constant Rate	Theis Confined (Recovery only)	2,497		15,011	69.82	
WKWD/NRRP - NW-5	4/1/2011	220-285, 300-320, 330-390, 410-450, 510-540	560	215	WKWSD / Richard C. Slade & Associates	3/19/2011	Constant Rate	Theis Unconfined (DD only)	2,497	42.4	11,933	55.50	
WKWD/NRRP - NW-5	4/1/2011	220-285, 300-320, 330-390, 410-450, 510-540	560	215	WKWSD / Richard C. Slade & Associates	3/19/2011	Constant Rate	Theis Confined (DD only)	2,497	42.4	11,933	55.50	
WKWD/NRRP - Well 2	12/1/1980	250-602	602	352	WKWSD / Richard C. Slade & Associates	5/8/2009	Constant Rate	Cooper-Jacob Straight Line	2,000		30,080	119.37	

Table 2-4: Aquifer Specific Yields

Sediment Size	Number of Samples Measured	Range of Specific Yield (percent)
Sand	126	19 - 35
Clayey Sand	28	10 - 28
Sand-silt-clay	95	2 - 20
Sandy silt	49	1 - 12
Clayey silt	107	<1 - 7
Silt	79	1 - 7
Silty clay	86	<1 - 8

Table 3-1: Water Balance Summary

All Values in Acre Feet per Year (AFY)

Inflows	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Canal Loss	225,503	85,344	71,266	76,724	46,734	65,713	52,710	197,075	86,345	229,803	198,563	201,897	146,215	155,956	126,139	81,854	133,402	190,178	102,676	245,494	200,003	59,292	67,985	78,417	230,318	3,355,605	134,224
Managed Recharge	466,908	48,558	26,356	35,881	5,815	14,109	22,419	306,736	30,422	873,978	509,922	435,249	947,504	142,600	124,421	21,564	23,386	118,258	60,116	1,066,662	839,542	63,837	4,147	26,826	321,561	6,536,777	261,471
Agricultural Return Flows	166,791	184,293	175,150	162,716	161,884	179,668	180,737	175,062	172,533	189,923	165,232	158,039	190,997	152,207	164,128	169,852	160,238	142,031	138,183	141,747	149,264	140,139	158,718	160,583	164,572	4,104,686	164,187
Muni Return Flows	3,973	3,945	4,143	4,340	4,522	4,289	4,709	5,013	5,300	5,171	5,619	5,710	5,104	6,140	5,277	5,818	6,000	5,913	5,909	5,667	6,032	6,586	6,743	6,399	5,983	134,306	5,372
Wastewater Percolation	11,985	12,352	12,673	7,221	7,747	7,962	8,188	8,417	8,576	8,806	8,923	8,995	9,097	9,086	9,086	9,084	9,149	9,214	9,279	9,528	9,093	9,473	9,538	10,209	10,881	234,564	9,383
Recharge from Rainfall	-	-	-	-	-	-	-	-	-	64	-	-	884	-	-	-	-	-	-	-	-	-	-	-	717	1,665	67
Subsurface Inflow	2,249	2,249	4,722	4,722	4,722	15,556	14,858	14,160	10,772	7,383	9,006	9,006	10,629	12,797	-	10,819	15,549	6,970	5,738	5,325	6,100	3,831	6,151	23,442	18,911	225,667	9,027
TOTAL INFLOW	**877,409**	**336,740**	**294,310**	**291,605**	**231,424**	**287,297**	**283,623**	**706,464**	**313,947**	**1,315,127**	**897,265**	**818,896**	**1,310,430**	**478,786**	**429,051**	**298,991**	**347,724**	**472,563**	**321,900**	**1,474,422**	**1,210,034**	**283,158**	**253,281**	**305,876**	**752,944**	**14,593,269**	**583,731**
Outflows																											
Recovery Pumping	-	-	-	-	-	-	-	-	-	-	1,781	14	2,819	3,366	3,426	199,630	63,378	64,815	76,604	1,476	-	351,647	388,694	281,803	81,680	1,521,134	60,845
District Pumping for Agricultural	815	14,670	22,518	29,535	27,983	32,878	35,861	9,405	21,709	7,708	10,652	8,917	7,707	10,973	19,879	35,177	31,559	16,698	33,573	12,590	13,936	49,358	47,878	49,940	14,673	566,592	22,664
Other Pumping for Agricultural	422,958	606,385	610,900	563,393	602,808	605,312	616,369	481,865	579,385	499,796	449,968	432,426	425,108	463,867	459,661	511,597	499,604	397,822	479,849	388,711	358,888	503,340	521,901	524,823	405,548	12,412,284	496,491
Municipal Pumping	93,051	92,053	97,213	96,858	101,417	99,462	105,812	111,338	115,036	110,466	119,071	127,079	111,735	132,262	112,119	119,346	123,658	125,106	125,513	127,665	132,505	144,171	140,376	132,190	124,412	2,919,913	116,797
Subsurface Outflow	8,361	8,361	-	-	-	-	-	-	-	-	-	-	-	-	6,480	-	-	1,407	1,791	-	1,705	-	-	-	-	28,105	1,124
TOTAL OUTFLOW	**525,186**	**721,468**	**730,631**	**689,786**	**732,208**	**737,652**	**758,042**	**602,609**	**716,130**	**617,971**	**581,472**	**568,436**	**547,370**	**610,468**	**601,565**	**865,749**	**718,199**	**605,848**	**717,330**	**530,442**	**507,034**	**1,048,515**	**1,098,849**	**988,756**	**626,313**	**17,448,028**	**697,921**
Storage Changes																											
Inflow-Outflow Residual	352,224	(384,728)	(436,321)	(398,181)	(500,784)	(450,355)	(474,420)	103,855	(402,183)	697,157	315,793	250,460	763,061	(131,682)	(172,514)	(566,758)	(370,475)	(133,285)	(395,430)	943,980	703,000	(765,357)	(845,568)	(682,880)	126,631	(2,854,758)	(114,190)
From Groundwater Levels	247,086	247,086	(400,096)	(400,096)	(400,096)	(400,096)	(559,052)	(559,052)	143,627	143,627	374,080	374,080	374,080	423,722	30,351	205,960	(669,044)	(490,514)	(51,814)	(118,414)	537,820	552,382	(1,292,567)	(918,784)	(291,609)	(2,897,331)	(115,893)

Table 3-2: Agricultural Return Flows

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Bolthouse	2,221	2,550	2,337	1,860	1,852	2,086	2,160	2,062	1,987	2,254	1,988	1,931	2,254	1,768	1,443	1,933	1,894	1,760	1,854	1,809	1,820	1,454	1,523	1,881	1,642	48,323	1,933
BVWSD	11,349	12,411	11,879	10,645	10,661	11,208	11,190	11,171	11,237	11,610	11,688	11,328	12,532	10,546	9,890	11,155	11,222	9,979	10,213	12,381	10,953	11,100	13,607	14,509	14,338	288,801	11,552
Cawelo WD	544	604	573	306	308	321	324	312	345	334	533	520	636	363	495	447	335	299	273	317	254	213	206	211	230	9,304	372
JPID	20,819	23,319	21,955	15,813	15,761	17,573	17,968	17,330	16,865	18,754	5,788	5,319	6,967	5,944	9,493	9,548	8,017	6,613	5,089	5,018	5,208	5,351	6,543	6,246	6,396	283,697	11,348
KDWD no Service Area	3,384	3,816	3,544	3,076	3,071	3,416	3,513	3,385	3,298	3,683	3,253	3,152	3,838	2,882	3,036	2,937	3,024	2,832	2,842	2,694	2,781	2,588	3,337	2,989	3,501	79,870	3,195
KDWD Buena Vista	9,227	10,385	9,661	8,068	8,062	8,778	9,018	8,756	8,583	9,380	11,118	10,752	12,879	7,968	6,995	9,209	8,881	8,061	8,214	8,422	7,507	7,600	9,663	10,639	10,856	228,681	9,147
KDWD Farmers	6,692	7,454	7,021	6,602	6,575	7,292	7,485	7,226	6,983	7,808	7,117	6,885	8,199	7,282	7,658	8,764	7,943	6,556	7,022	7,156	6,588	6,242	6,995	6,331	6,926	178,805	7,152
KDWD Kern Island	16,096	18,002	16,874	17,281	17,185	19,243	19,788	18,998	18,317	20,678	18,861	18,203	21,943	18,135	19,624	20,093	19,490	17,788	15,562	16,669	16,584	17,230	19,257	19,150	20,936	461,987	18,479
KDWD Stine	14,882	16,690	15,592	13,230	13,180	14,475	14,782	14,311	14,033	15,435	16,637	16,132	19,356	13,235	13,598	14,798	13,800	12,475	12,820	13,680	14,867	13,217	15,653	15,439	16,556	368,872	14,755
KRCI	3,455	3,667	3,619	3,303	3,262	3,727	3,595	3,480	3,447	3,876	2,926	2,759	3,508	2,633	1,755	2,280	1,649	1,168	1,044	1,056	908	582	769	800	855	60,123	2,405
North Kern-Other	1,464	1,595	1,528	1,588	1,573	1,758	1,739	1,693	1,691	1,855	1,938	1,861	2,215	1,846	1,631	1,299	1,654	1,428	1,175	1,091	1,168	1,096	1,154	1,544	1,359	38,941	1,558
North Kern-Class1	3,477	3,855	3,672	4,104	4,084	4,489	4,389	4,270	4,330	4,627	4,137	3,901	4,763	4,195	4,996	4,250	4,283	3,840	3,809	3,748	4,441	3,869	3,975	4,050	3,866	103,423	4,137
North Kern-Class2	4,427	4,788	4,654	5,083	5,034	5,731	5,656	5,431	5,357	6,007	4,541	4,332	5,252	4,328	5,078	4,724	4,524	3,746	3,735	3,957	5,371	4,899	5,261	5,339	4,209	121,465	4,859
No Water District	15,303	16,729	16,060	15,796	15,728	17,434	17,527	16,974	16,814	18,395	14,421	13,626	16,849	12,994	16,140	14,636	12,785	11,058	11,774	11,480	12,142	11,515	12,570	12,835	14,023	365,608	14,624
RRBWSD	22,483	24,477	23,625	23,106	22,931	25,666	25,448	24,640	24,450	26,950	24,674	23,606	28,837	24,077	25,432	27,393	24,584	21,871	21,626	21,038	23,174	21,448	23,365	23,394	22,696	600,989	24,040
RRBWSD-BV Diversions	3,111	3,467	3,270	4,078	4,053	4,557	4,637	4,441	4,334	4,825	4,734	4,578	5,406	4,079	4,944	4,947	4,634	3,842	3,638	3,895	4,318	3,532	4,342	4,651	4,808	107,119	4,285
RRBWSD-Other Diversions	1,348	1,506	1,411	1,205	1,206	1,294	1,332	1,305	1,275	1,384	1,464	1,429	1,681	1,575	1,372	1,382	1,289	1,103	1,044	1,275	1,459	1,450	1,593	1,815	1,684	34,883	1,395
Rosedale Ranch	8,301	9,233	8,719	8,039	7,957	9,010	8,977	8,647	8,478	9,513	7,412	6,579	9,036	7,464	10,377	9,288	9,400	8,982	7,562	6,712	8,554	7,640	8,342	7,864	8,872	210,958	8,438
Semitropic-Other	4,401	4,938	4,631	4,639	4,630	5,068	5,159	4,993	5,017	5,399	5,386	5,230	6,076	4,670	4,355	4,972	4,818	4,151	5,005	4,297	4,881	4,954	5,079	5,180	6,170	124,101	4,964
Semitropic-Wegis	4,651	4,992	4,908	5,081	5,045	5,603	5,410	5,315	5,368	5,775	5,539	5,339	6,064	5,863	4,916	5,750	5,522	5,078	5,294	5,996	6,791	5,680	6,126	6,179	5,604	137,888	5,516
Shafter-Wasco ID	9,157	9,814	9,617	9,815	9,727	10,938	10,639	10,322	10,324	11,381	11,078	10,575	12,704	10,359	10,899	10,046	10,490	9,400	8,589	9,056	9,493	8,478	9,358	9,540	9,045	250,846	10,034
TOTAL	**166,791**	**184,293**	**175,150**	**162,716**	**161,884**	**179,668**	**180,737**	**175,062**	**172,533**	**189,923**	**165,232**	**158,039**	**190,997**	**152,207**	**164,128**	**169,852**	**160,238**	**142,031**	**138,183**	**141,747**	**149,264**	**140,139**	**158,718**	**160,583**	**164,572**	**4,104,686**	**164,187**

Table 3-3: Municipal Return Flows

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Buttonwillow	13	13	13	14	14	14	13	13	13	13	13	13	13	12	12	15	14	14	15	15	15	16	16	16	16	349	14
CalWater	2,263	2,228	2,271	2,338	2,412	2,276	2,489	2,584	2,727	2,594	2,802	2,869	2,370	2,772	2,086	2,147	2,272	2,014	1,742	1,721	1,832	1,882	1,754	1,709	1,754	55,907	2,236
COB	1,086	1,086	1,185	1,303	1,378	1,297	1,474	1,631	1,709	1,726	1,865	1,858	1,809	2,288	2,033	2,435	2,480	2,589	2,805	2,569	2,713	3,129	3,373	3,159	2,790	51,770	2,071
Greenfield	65	65	67	68	69	71	72	72	75	76	78	81	83	85	99	101	112	123	151	162	184	191	189	182	170	2,692	108
North of River MWD	0	0	0	0	0	11	0	-	-	-	-	-	-	2	9	47	3	9		4	21	23	18	22	21	190	8
Oildale	1	0	0	3	20		2	1	0	0	1	0	0	0	1	3	5	14	15	13	10	20	19	14	1	142	6
Shafter	233	240	246	253	259	239	245	250	256	262	267	273	279	315	335	339	347	364	353	350	364	354	390	339	348	7,499	300
Stockdale Annex	8	8	9	8	8	7	9	9	8	9	8	8	7	8	8	8	8	8	7	7	7	10	9	9	8	202	8
Stockdale MWC	16	17	17	16	16	14	18	17	17	18	15	16	13	15	15	16	16	16	14	15	15	20	18	19	16	405	16
Vaughn	287	287	334	336	346	360	388	435	494	473	569	591	529	644	681	709	744	763	807	811	871	942	957	930	858	15,149	606
West Kern WD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**3,973**	**3,945**	**4,143**	**4,340**	**4,522**	**4,289**	**4,709**	**5,013**	**5,300**	**5,171**	**5,619**	**5,710**	**5,104**	**6,140**	**5,277**	**5,818**	**6,000**	**5,913**	**5,909**	**5,667**	**6,032**	**6,586**	**6,743**	**6,399**	**5,983**	**134,306**	**5,373**

Table 3-4: Losses from Unlined Canals

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Alejandro Canal	10,291	31	-	57	-	(2)	27	1,288	2	91	-	-	(1)	-	-	-	-	-	-	-	2,962	77	79	33	10	14,947	598
Carrier Canal	6,935	5,562	4,818	4,271	3,855	5,868	4,473	6,971	5,308	6,685	6,358	5,401	5,144	5,359	4,682	8,548	6,016	3,753	5,100	6,137	5,208	3,766	4,092	5,880	4,989	135,179	5,407
Cross Valley Canal (unlined portion)	-	-	-	-	-	-	-	-	-	-	-	1,046	1,188	4	68	67	62	-		-	-	-	-	383	205	3,023	126
Eastside Canal	17,790	15,641	13,273	17,250	11,037	10,425	13,121	17,305	15,966	24,459	18,615	22,775	15,584	13,880	16,453	10,869	38,013	42,556	18,112	14,244	15,039	8,965	9,400	13,445	16,125	430,342	17,214
James Canal	7,464	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,464	299
KDWD Buena Vista Canal	8,029	1,767	1,605	2,396	1,800	7,834	3,647	6,500	3,663	7,080	9,251	7,384	5,858	6,416	5,514	4,374	4,459	8,533	5,505	8,460	5,964	2,235	3,869	6,060	13,570	141,775	5,671
KDWD Central Branch	6,765	6,849	6,112	8,115	5,913	5,640	5,565	5,833	7,309	6,253	6,721	7,402	1,976	7,078	7,236	7,215	7,188	7,397	6,518	6,467	6,105	6,218	5,657	5,189	8,284	161,009	6,440
KDWD Eastside Canal	50	52	49	40	25	39	49	59	37	38	31	33	191	30	26	31	41	48	33	36	22	26	51	46	93	1,177	47
KDWD Farmers Canal	4,043	2,001	258	2,180	-	2,391	1,068	4,887	1,459	7,194	5,691	7,292	-	3,283	2,526	1,817	2,390	5,882	3,371	6,537	3,912	680	2,565	2,068	6,887	80,382	3,215
KD Kern Island Canal	19,056	19,292	17,214	22,857	16,654	15,886	15,674	16,430	20,588	17,611	18,931	20,850	5,566	19,935	20,382	20,322	20,247	20,835	18,358	18,215	17,197	17,515	15,934	14,616	23,332	453,496	18,140
KDWD Stine Canal	27,120	7,918	2,028	6,612	-	7,412	2,858	19,682	5,212	26,710	24,934	23,528	-	11,050	9,068	4,346	6,098	23,226	14,206	34,474	24,276	4,462	11,770	18,640	35,742	351,372	14,055
KRCI Ditch	4,022	2,151	1,763	1,852	1,541	1,307	1,361	2,078	1,316	3,974	3,611	2,964	2,343	2,078	1,981	1,213	1,267	1,033	1,294	1,354	1,685	896	922	890	640	45,536	1,821
Main Canal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	87	-	95	-	-	-	35	34	415	210	876	35
Calloway Canal	26,718	3,092	5,188	1,897	1,638	1,557	1,088	21,753	1,772	33,503	19,839	17,746	20,862	17,247	3,560	2,987	3,178	785	1,365	27,432	22,592	642	2,166	2,163	23,739	264,509	10,580
Outlet Canal	7,692	2,205	2,757	3,358	2,274	3,059	1,710	2,705	4,247	6,625	5,430	8,907	8,912	3,118	3,578	2,628	1,945	2,124	5,033	6,291	8,207	4,309	5,650	2,073	6,734	111,570	4,463
Pioneer Canal	17,146	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17,146	686
Goose Lake Slough	-	-	-	-	-	-	-	-	-	-	-	-	1,268	-	-	-	-	-	-	-	-	-	-	-	-	1,268	51
River Loss	62,381	18,783	16,200	5,840	1,997	4,297	2,070	91,583	19,467	89,579	79,150	76,568	77,324	66,479	51,063	17,350	42,497	73,911	23,780	115,848	86,833	9,465	5,794	6,516	89,759	1,134,534	45,381
TOTAL	**225,503**	**85,344**	**71,266**	**76,724**	**46,734**	**65,713**	**52,710**	**197,075**	**86,345**	**229,803**	**198,563**	**201,897**	**146,215**	**155,956**	**126,139**	**81,854**	**133,402**	**190,178**	**102,676**	**245,494**	**200,003**	**59,292**	**67,985**	**78,417**	**230,318**	**3,355,605**	**134,224**

Table 3-5: Managed Recharge by Facility

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
COB 2800	132,584	7,488	-	-	-	-	-	129,055	16,692	148,332	61,477	32,375	95,676	10,473	30,918	2,539	1,480	1,447	6,956	155,977	81,521	4,495	-	-	7,039	926,524	37,061
Aera Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,392	1,619	-	-	-	1,569	5,580	223
Berrenda Mesa	18,403							20,737	2,204	34,486	9,966	6,555	20,349	633	1,027	-	-	719	2,872	34,896	26,229	2,098	-	-	-	181,174	9,535
BVWSD	35,622	-	-	865	-	-	-	13,847	-	22,468	668	22,252	91,539	592	-	-	357	-	-	7,678	23,487	-	-	-	5,056	224,431	8,977
KCWA-Kern River	-	-	-	-	-	-	-	-	-	3,258	18,325	6,471	872	2,043	4,073	2,214	1,038	24,441	1,863	29,997	825	-		-		95,420	4,149
Kern Delta WD	17,666	-	-	-	-	-	-	2,021	-	-	-	-	-	-	-	-	-	-	-	-	40,775		-	-	82,363	142,825	5,951
Kern Water Bank										208,924	163,443	105,526	284,901	34,548	25,924	9,428	12,633	37,952	16,981	364,304	266,239	15,724	-	-	31,143	1,577,670	98,604
North Kern WSD	149,865	23,000	4,784	398	-	4,038	12,759	34,059	3,478	202,621	76,128	106,187	240,833	30,645	2,438	-	2,099	897	13,683	104,884	159,813	30,151	2,487	13,083	19,141	1,237,471	49,499
Pioneer Project	-	-	-	-	-	-	-	-	-	79,513	45,676	30,085	68,744	13,732	15,296	1,253	1,434	8,372	6,811	111,199	61,228	4,813	-	-	-	448,156	17,926
RRID	-	-	-	-	-	-	-	-	702	21,461	9,892	-	-	782	-	-	-	-	-	6,057	5,127	-	-	1,073	8,474	53,568	2,143
RRBWSD	112,768	18,070	19,026	33,699	5,815	9,138	9,323	107,017	6,414	144,642	116,618	116,735	135,652	47,817	42,982	5,653	4,038	27,182	6,964	195,184	147,151	3,200	-	2,354	141,521	1,458,963	58,359
Semitropic WSD	-	-	-	-	-	-	-	-	-	1,690	1,734	2,016	1,150	615	213	10	-	412	-	978	1,019	211	-	-	625	10,675	427
The Park at River Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	127	964	3,555	1,736	611	663	1,019	8,675	347
Truxtun Lakes	-	-	2,546	919	-	933	337	-	932	6,583	5,995	7,047	7,788	719	1,550	467	307	476	346	1,006	-	727	1,002	1,434	1,018	42,132	1,685
West Kern WD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16,360	3,513	51,146	20,954	682	47	8,219	22,593	123,514	4,941
TOTAL	**466,908**	**48,558**	**26,356**	**35,881**	**5,815**	**14,109**	**22,419**	**306,736**	**30,422**	**873,978**	**509,922**	**435,249**	**947,504**	**142,600**	**124,421**	**21,564**	**23,386**	**118,258**	**60,116**	**1,066,662**	**839,542**	**63,837**	**4,147**	**26,826**	**321,561**	**6,536,777**	**261,471**

Table 3-6: Recovery Pumping by Area

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
2800 Acres	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16,708	6,906	1,371	4,531	1,098	-	16,770	21,410	12,985	3,793	85,573	3,423
Berrenda Mesa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22,918	-	-	589	-	-	23,245	36,604	29,594	6,291	119,241	4,770
Bolthouse	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6,464	-	-	-	-	-	-	-	-	-	6,464	259
COB	-	-	-	-	-	-	-	-	-	-	1,781	14	2,819	3,366	3,426	31,334	17,688	8,808	13,267	-	-	18,634	12,548	7,127	2,287	123,099	4,924
ID4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,892	3,345	-	-	-	8,052	9,717	4,536	861	28,403	1,136
KWB																88,695	26,974	48,377	49,288							213,334	53,333
KWB - James																						24,537	24,132	48,643	3,171	100,483	25,121
KWB - Main																						55,484	54,378	37,515	9,985	157,362	39,341
KWB - North																						3,134	5,067	2,839	1,322	12,362	3,091
KWB - River																						56,889	55,213		10,365	122,467	40,822
KWB - Strand																						52,752	53,003	35,838	10,825	152,418	38,105
KWB - West																						37,890	41,910	37,625	15,301	132,726	33,182
Pioneer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33,511	9,919	2,914	8,928	378	-	51,958	65,283	61,059	17,479	251,429	10,057
RRB-ID4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,302	9,429	4,042	-	15,773	631
TOTAL	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1,781**	**14**	**2,819**	**3,366**	**3,426**	**199,630**	**63,378**	**64,815**	**76,604**	**1,476**	**-**	**351,647**	**388,694**	**281,803**	**81,680**	**1,521,134**	**60,845**

Table 3-7: Groundwater for Agricultural Irrigation from Private Wells

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Bolthouse	8,984	9,553	9,479	8,275	8,246	8,198	8,243	8,006	8,072	6,905	7,799	7,893	7,235	7,619	6,332	7,386	7,618	7,046	8,440	7,636	7,286	6,786	6,700	7,766	5,660	193,164	7,727
BVWSD	9,305	16,385	19,900	19,451	18,874	20,976	26,037	11,808	16,930	11,101	13,804	11,261	5,667	14,451	14,756	17,655	18,685	16,655	25,159	16,435	11,056	20,385	26,020	27,573	16,090	426,421	17,057
Cawelo	1,568	1,710	1,654	694	937	1,044	1,032	712	929	756	1,248	1,247	1,799	908	1,343	1,674	956	594	774	726	534	755	756	730	651	25,731	1,029
JPID	32,264	95,902	94,784	65,472	64,824	64,511	64,779	62,566	63,148	61,382	15,069	14,846	11,501	14,101	22,470	23,488	19,562	14,240	10,813	10,860	5,864	10,685	13,471	12,117	8,387	877,106	35,084
KDWD no Service Area	14,011	15,039	14,828	13,812	13,769	13,731	13,829	13,438	13,564	13,358	12,960	12,899	10,978	12,663	11,973	11,134	11,816	11,381	12,721	11,438	11,102	11,983	14,371	12,646	12,006	321,451	12,858
KDWD Buena Vista	17,127	31,620	34,264	28,913	35,676	32,179	31,536	18,546	27,603	17,810	30,338	27,968	27,656	25,692	22,120	29,932	29,531	20,535	30,881	20,815	14,960	30,855	32,486	36,707	24,314	680,065	27,203
KDWD Farmers	16,066	26,123	27,366	25,457	29,626	25,238	27,599	17,971	26,010	18,522	17,521	17,617	20,963	25,189	22,751	29,751	27,237	18,936	25,168	19,685	16,510	27,299	21,137	20,314	15,602	565,659	22,626
KDWD Kern Island	15,998	25,039	21,953	23,941	26,257	29,686	33,332	16,953	26,917	17,453	15,503	13,412	49,085	25,140	21,842	24,046	28,081	12,593	21,043	12,248	6,321	24,813	22,105	25,600	12,371	551,730	22,069
KDWD Stine	44,795	60,301	60,451	52,314	60,045	57,077	58,241	41,416	55,208	47,778	54,404	53,972	48,052	48,199	42,210	52,327	50,708	41,723	48,345	43,984	37,567	58,260	59,701	57,870	40,479	1,275,430	51,017
KRCI	4,205	6,180	13,684	5,407	4,681	6,873	6,986	5,433	4,800	12,374	3,552	3,427	7,451	2,867	138	1,035	198	75	58	681	691	69	367	679	847	92,758	3,710
North Kern-Other	6,505	7,036	6,926	7,179	7,175	7,163	7,242	7,057	7,142	7,003	8,235	8,135	7,061	8,146	6,188	5,469	6,777	5,860	5,336	4,840	4,630	5,123	5,122	6,729	5,286	163,364	6,535
North Kern-Class1	1,469	2,202	1,420	3,192	3,467	5,984	5,029	5,327	5,124	6,761	5,286	6,047	7,506	8,059	7,256	5,376	4,763	4,491	6,242	3,299	6,533	7,032	6,199	7,335	6,768	132,170	5,287
North Kern-Class2	12,032	17,715	18,662	21,613	22,267	22,914	22,890	13,072	18,158	12,316	10,768	9,255	9,354	13,333	14,087	13,812	14,877	11,704	11,203	8,141	9,666	12,881	12,972	12,378	8,620	354,689	14,188
No Water District	66,460	71,553	70,424	72,098	72,057	72,138	72,725	70,799	71,669	70,896	59,851	59,327	50,890	56,124	63,458	56,309	51,812	45,013	54,048	50,783	48,492	54,065	56,008	55,692	53,103	1,525,794	61,032
Rosedale Rio Bravo	99,493	107,083	105,269	105,519	105,504	105,544	106,569	103,836	105,111	103,737	102,841	101,853	87,160	105,775	101,288	105,536	99,621	88,268	99,513	94,527	90,727	101,251	106,550	103,985	90,441	2,527,001	101,080
RRB-BV Diversions	8,424	10,636	11,365	14,845	16,698	18,342	16,702	12,902	16,311	12,770	14,017	14,827	12,186	13,589	16,190	19,732	19,006	14,782	15,208	14,492	17,460	16,327	20,080	20,449	17,198	384,539	15,382
RRB-Other Diversions	5,859	6,269	1,846	719	5,516	5,540	5,582	157	5,517	5,473	260	100	148	845	3,179	4,810	5,736	3,249	4,540	23	139	6,720	6,865	7,777	804	87,674	3,507
Rosedale Ranch	15,303	38,216	37,681	36,219	36,184	36,059	36,366	23,387	35,803	25,505	22,345	19,961	15,629	27,380	38,725	37,699	40,043	36,828	36,019	25,540	26,475	36,295	38,928	36,316	35,627	794,533	31,781
Semitropic-Other	19,225	20,624	20,408	21,145	21,143	21,165	21,313	20,742	21,000	20,836	22,379	22,093	19,470	20,470	17,432	19,215	19,537	16,773	22,562	18,563	19,535	23,027	22,131	21,669	21,423	513,878	20,555
Semitropic-Wegis	7,050	8,486	9,934	8,375	15,196	20,617	18,678	7,131	17,226	6,636	5,250	3,356	1,686	5,084	1,218	17,947	13,884	5,892	15,145	2,650	4,696	16,737	20,063	20,800	10,584	264,321	10,573
Shafter-Wasco ID	16,816	28,712	28,603	28,753	34,666	30,335	31,660	20,603	33,142	20,424	26,538	22,931	23,629	28,232	24,704	27,262	29,156	21,184	26,631	21,344	18,643	31,994	29,869	29,689	19,285	654,805	26,192
TOTAL	**422,958**	**606,385**	**610,900**	**563,393**	**602,808**	**605,312**	**616,369**	**481,865**	**579,385**	**499,796**	**449,968**	**432,426**	**425,108**	**463,867**	**459,661**	**511,597**	**499,604**	**397,822**	**479,849**	**388,711**	**358,888**	**503,340**	**521,901**	**524,823**	**405,548**	**12,412,284**	**496,491**

Table 3-8: Groundwater for Agricultural Irrigation from District Wells

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
BVWSD	815	3,455	6,024	12,042	8,802	10,347	12,930	9,112	9,513	7,695	10,635	8,770	7,564	10,973	13,410	14,712	12,413	10,016	11,322	12,590	13,492	15,558	13,427	12,318	10,708	258,644	10,346
NKWD	-	11,215	16,240	17,450	17,828	18,111	16,123	-	8,428	-	-	-	-	-	4,116	13,981	15,387	4,765	12,810	-	444	23,022	21,606	23,084	1,488	226,096	9,044
Semitropic WSD	-	-	254	43	1,353	4,420	6,808	293	3,768	13	16	147	143	-	2,352	6,485	3,759	1,918	9,442	-	-	10,777	12,845	14,538	2,477	81,852	3,274
TOTAL	**815**	**14,670**	**22,518**	**29,535**	**27,983**	**32,878**	**35,861**	**9,405**	**21,709**	**7,708**	**10,652**	**8,917**	**7,707**	**10,973**	**19,879**	**35,177**	**31,559**	**16,698**	**33,573**	**12,590**	**13,936**	**49,358**	**47,878**	**49,940**	**14,673**	**566,592**	**22,664**

Table 3-9: Municipal Pumping by Purveyor

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Buttonwillow	180	181	181	182	182	182	181	181	180	179	179	178	178	161	161	199	186	191	196	200	205	210	212	212	212	4,689	188
CalWater	54,522	53,322	55,579	58,681	61,486	57,856	63,263	65,992	68,782	63,678	67,757	74,707	61,497	72,111	52,021	53,872	58,348	51,953	45,566	45,590	49,249	50,417	46,783	44,781	45,747	1,423,560	56,942
COB	14,762	14,762	16,010	17,621	18,622	17,523	19,901	22,040	23,008	23,271	24,948	24,939	24,361	30,599	27,417	32,675	33,362	35,056	37,829	34,554	36,558	42,291	45,517	42,603	37,414	697,642	27,906
Greenfield	873	880	906	919	927	956	964	974	1,005	1,019	1,052	1,085	1,120	1,140	1,329	1,360	1,507	1,653	2,026	2,169	2,486	2,574	2,554	2,445	2,282	36,205	1,448
North of River MWD	6	6	6	6	6	226	3	-	-	-	-	-	-	30	178	939	52	181		82	416	443	364	434	414	3,792	158
Oildale	157	33	17	308	2,104		176	55	6	11	158	27	23	39	62	277	501	1,488	1,629	1,377	992	2,091	1,955	1,419	151	15,055	627
Shafter	3,122	3,211	3,299	3,388	3,476	3,204	3,280	3,356	3,432	3,507	3,583	3,659	3,743	4,219	4,488	4,539	4,653	4,881	4,727	4,688	4,887	4,770	5,258	4,578	4,663	100,612	4,024
Stockdale Annex	112	118	119	115	113	101	124	121	118	127	109	113	93	107	106	109	111	109	100	102	102	140	123	131	115	2,838	114
Stockdale MWC	224	236	239	230	226	203	247	243	236	254	217	226	187	214	212	218	221	218	199	204	204	280	246	263	230	5,676	227
Vaughn	3,800	3,800	4,420	4,468	4,633	4,805	5,178	5,804	6,574	6,270	7,544	7,844	7,021	8,600	9,095	9,433	9,929	10,194	10,776	10,812	11,668	12,666	12,825	12,481	11,447	202,089	8,084
West Kern WD	15,294	15,504	16,436	10,942	9,641	14,405	12,495	12,572	11,695	12,150	13,524	14,300	13,513	15,042	17,050	15,724	14,789	19,182	22,465	27,888	25,737	28,290	24,538	22,843	21,735	427,755	17,110
TOTAL	**93,051**	**92,053**	**97,213**	**96,858**	**101,417**	**99,462**	**105,812**	**111,338**	**115,036**	**110,466**	**119,071**	**127,079**	**111,735**	**132,262**	**112,119**	**119,346**	**123,658**	**125,106**	**125,513**	**127,665**	**132,505**	**144,171**	**140,376**	**132,190**	**124,412**	**2,919,913**	**116,797**

Table 4-1: Coarse Grained Thickness and Percentages by Model Layer

Well ID	Layer 1&2 Thickness[1] (feet)	Layer 3 Thickness (feet)	Layer 4 Thickness (feet)	Layer 1&2 Coarse Grained Thickness[1] (feet)	Layer 3 Coarse Grained Thickness (feet)	Layer 4 Coarse Grained Thickness (feet)	Layer 1 & 2 Percent Coarse	Layer 3 Percent Coarse	Layer 4 Percent Coarse
29S/24E-34N01	100	270	155	90	120	60	90%	44%	39%
29S/25E-25M01	100	260	150	60	105	95	60%	40%	63%
29S/25E-27N01	100	265	160	60	70	65	60%	26%	41%
30S/26E-22P03	100	350	150	85	140	65	85%	40%	43%
WKWD/NRRP - NW-5	100	280	260	65	90	70	65%	32%	27%
WKWD/NRRP - NW-2	100	320	220	65	140	100	65%	44%	45%
WKWD/NRRP - NW-4	100	320	250	70	85	80	70%	27%	32%
WKWD/NRRP - NW-3	100	240	110	65	115	45	65%	48%	41%
WKWD/NRRP - NW-1	100	270	30	55	110		55%	41%	
29S/26E-36L01	100	312	168	50	205	95	50%	66%	57%
29S/26E-35H05	100	280	220	85	150	120	85%	54%	55%
29S/26E-35G02	100	422	75	75	185	50	75%	44%	67%
29S/26E-35B01	100	310	180	80	180	115	80%	58%	64%
29S/23E-16R01	100	218		60	110		60%	50%	
29S/25E-13F01	100	315	25	60	145	5	60%	46%	20%
28S/26E-33L01	100	330	170	85	260	60	85%	79%	35%
29S/26E-35K01	100	308	177	35	115	85	35%	37%	48%
30S/27E-19J01	100	345	175	70	195	55	70%	57%	31%
31S/28E-28A01	100	280	220	55	188	154	55%	67%	70%
30S/25E-09C01	100	190	200	42	115	64	42%	61%	32%
30S/26E-06K01	100	210	200	50	95	165	50%	45%	83%
30S/26E-05N01	100	190	250	75	55	125	75%	29%	50%
30S/26E-10P01	100	275	110	45	40	45	45%	15%	41%
30S/26E-10Q01	100	260	150	60	65	60	60%	25%	40%
30S/26E-10R01	100	200	190	60	65	60	60%	33%	32%
30S/26E-02R01	100	250	205	65	146	90	65%	58%	44%
30S/26E-02J03	100	200	215	35	90	95	35%	45%	44%
30S/26E-17B01	100	405	90	50	140	40	50%	35%	44%
30S/26E-17C01	100	337	95	60	170	25	60%	50%	26%
30S/26E-18R01	100	380	95	75	130	30	75%	34%	32%
30S/26E-16L01	100	200	210	35	75	115	35%	38%	55%
30S/25E-11N01	100	230	260	50	160	110	50%	70%	42%
30S/25E-11E01	100	240	250	40	110	150	40%	46%	60%
30S/26E-20C01	100	265	225	55	105	130	55%	40%	58%
30S/25E-24K01	100	255	235	45	95	100	45%	37%	43%
30S/25E-14J01	100	265	230	65	155	90	65%	58%	39%
30S/25E-14E01	100	220	165	75	110	75	75%	50%	45%
30S/25E-23H01	100	245	255	35	105	150	35%	43%	59%
30S/25E-16M01	100	255	255	60	140	115	60%	55%	45%
30S/25E-10K01	100	245	240	35	135	125	35%	55%	52%
30S/25E-13J01	100	245	245	30	85	120	30%	35%	49%
30S/25E-16D01	100	240	240	65	185	120	65%	77%	50%
30S/25E-17H01	100	230	275	60	130	155	60%	57%	56%
30S/25E-14R01	100	250	255	80	125	110	80%	50%	43%
30S/26E-19G01	100	250	240	55	125	100	55%	50%	42%
30S/26E-05K01	100	275	180	50	95	95	50%	35%	53%
30S/26E-05Q02	100	215	165	50	70	130	50%	33%	79%
30S/26E-08H01	100	260	150	65	105	100	65%	40%	67%
30S/26E-08G01	100	315	100	90	70	55	90%	22%	55%
30S/26E-09E01	100	320	90	45	70	30	45%	22%	33%
30S/26E-10Q02	100	180	260	55	35	70	55%	19%	27%
30S/26E-15E01	100	290	100	60	45	60	60%	16%	60%
30S/26E-16R01	100	290	120	45	75	75	45%	26%	63%
30S/26E-16Q01	100	320	120	60	55	45	60%	17%	38%
30S/25E-36R01	100	255	120	83	85	41	83%	33%	34%
30S/25E-21D01	100	240	270	70	100	135	70%	42%	50%
30S/25E-15N01	100	240	255	75	55	100	75%	23%	39%
30S/26E-32N01	100	255	135	80	70	22	80%	27%	16%
30S/26E-16B01	100	275	180	35	145	55	35%	53%	31%
30S/25E-17J01	100	230	265	20	105	170	20%	46%	64%
30S/25E-16B01	100	150	240	32	92	54	32%	61%	23%
30S/25E-16J01	100	235	265	30	110	95	30%	47%	36%
30S/24E-14M02	100	250	160	80	155	51	80%	62%	32%
30S/25E-14K01	100	230	270	45	95	130	45%	41%	48%
30S/25E-22M01	100	220	105	35	60	40	35%	27%	38%
30S/25E-21R04	100	295	125	50	110	45	50%	37%	36%
30S/26E-06P01	100	260	220	70	58	193	70%	22%	88%
30S/26E-08M01	100	265	230	35	95	135	35%	36%	59%
30S/26E-07Q01	100	260	230	40	135	95	40%	52%	41%
30S/25E-17M04	100	185	300	65	95	120	65%	51%	40%
30S/25E-17M03	100	185	300	65	95	120	65%	51%	40%
30S/25E-17M02	100	185	300	65	95	120	65%	51%	40%
30S/25E-11Q01	100	235	250	25	120	115	25%	51%	46%
29S/25E-34A01	100	290	230	75	80	120	75%	28%	52%
29S/27E-31E01	100	315	140	59	172	52	59%	55%	37%
29S/24E-08L01	100	295	105	40	130	65	40%	44%	62%
31S/27E-19A	100	240	200	80	180	40	80%	75%	20%
28S/22E-08B	100	200	180	45	90	60	45%	45%	33%
28S/22E-12M	100	200	300	50	130	100	50%	65%	33%
29S/26E-32R	100	260	130	73	104	84	73%	40%	65%

Table 4-1: Coarse Grained Thickness and Percentages by Model Layer

Well ID	Layer 1&2 Thickness[1] (feet)	Layer 3 Thickness (feet)	Layer 4 Thickness (feet)	Layer 1&2 Coarse Grained Thickness[1] (feet)	Layer 3 Coarse Grained Thickness (feet)	Layer 4 Coarse Grained Thickness (feet)	Layer 1 & 2 Percent Coarse	Layer 3 Percent Coarse	Layer 4 Percent Coarse
29S/26E-35H	100	360	143	55	185	95	55%	51%	66%
29S/26E-36K	100	285	130	55	160	110	55%	56%	85%
30S/26E-11A	100	350	160	50	105	40	50%	30%	25%
30S/26E-11G	100	360	190	70	150	55	70%	42%	29%
30S/26E-11M	100	290	200	50	95	75	50%	33%	38%
30S/27E-20D	100	240	300	50	90	130	50%	38%	43%
30S/27E-22N	100	380	100	55	160	80	55%	42%	80%
30S/27E-30C	100	230	470	45	160	170	45%	70%	36%
28S/24E-24C01	100	330	102	45	170	55	45%	52%	54%
28S/24E-31K01	100	340	110	40	110	50	40%	32%	45%
28S/26E-30F01	100	395	145	45	210	35	45%	53%	24%
30S/25E-01A01	100	195	120	28	68	27	28%	35%	23%
29S/25E-03F01	100	320		95	160	0	95%	50%	
29S/26E-22A02	100	325	170	90	245	70	90%	75%	41%
29S/26E-28K	100	280	95	80	110	30	80%	39%	32%
29S/26E-31H	100	250	150	40	95	60	40%	38%	40%
30S/27E-26D	100	210	210	79	154	60	79%	73%	29%
31S/26E-27L01	100	240		51	168		51%	70%	
31S/27E-01H01	100		31	73	22		73%		
31S/27E-07A	100	285	120	63	180	99	63%	63%	83%
31S/27E-28B01	100	285		72	163		72%	57%	
31S/27E-29P	100	270	215	94	194	134	94%	72%	62%
31S/28E-06M01	100	295	205	60	180	98	60%	61%	48%
31S/28E-12R01	100	280	215	70	167	157	70%	60%	73%
31S/28E-30M01	100	270	160	62	100	85	62%	37%	53%
31S/28E-31N01	100	270	215	40	119	85	40%	44%	40%
Strand Ranch SREX-1	100	280	170	80	110	80	80%	39%	47%
Strand Ranch SREX-2	100	270	180	80	120	90	80%	44%	50%
Strand Ranch SREX-3	100	300	175	65	110	60	65%	37%	34%
Strand Ranch SREX-4	100	315	105	50	75	65	50%	24%	62%
Strand Ranch SREX-5	100	245	150	75	85	75	75%	35%	50%
Strand Ranch SREX-7	100	280	170	70	85	70	70%	30%	41%
30S/26E-05L01	100	230	450	60	65	120	60%	28%	27%
30S/26E-05R01	100	280	70	70	45	40	70%	16%	57%
30S/26E-11A01	100	350	160	50	105	40	50%	30%	25%
30S/26E-11M01	100	290	220	50	95	75	50%	33%	34%
28S/25E-14F01	100	300	190	84	269	100	84%	90%	53%
30S/26E-05E	100	290	180	54	72	166	54%	25%	92%
30S/25E-07A01	100	240	175	53	76	66	53%	32%	38%
30S/25E-11P	100	215	180	33	105	36	33%	49%	20%
30S/25E-19N	100	175	195	42	78	33	42%	45%	17%
30S/25E-19R	100	180	230	44	76	68	44%	42%	30%
30S/25E-23N01	100	215	240	40	50	40	40%	23%	17%
30S/27E-19N01	100	220	86	66	101	16	66%	46%	19%
30S/25E-28K	100	250	230	54	45	99	54%	18%	43%
30S/25E-34H	100	230	260	60	88	93	60%	38%	36%
30S/26E-11G01	100	360	190	70	150	55	70%	42%	29%
29S/26E-14H	100	310	180	40	150	70	40%	48%	39%
30S/25E-21G	100	295	125	50	110	45	50%	37%	36%
29S/24E-16F01	100	245		30	130		30%	53%	
29S/27E-36K02	100	325		77	135		77%	42%	
30S/27E-01J01	100	305	110	80	189	44	80%	62%	40%
30S/27E-02P01	100	300	100	89	223	20	89%	74%	20%
30S/27E-02R01	100	400	175	76	236	110	76%	59%	63%
30S/27E-13C01	100	310	210	80	160	139	80%	52%	66%
30S/28E-05B01	100	300	100	72	137	62	72%	46%	62%
30S/28E-18E01	100	250		90	192		90%	77%	
30S/28E-18K01	100	315	70	50	150	30	50%	48%	43%
29S/23E-11F01	100	325	45	45	120	30	45%	37%	67%
29S/23E-13P01	100	315	100	50	150	60	50%	48%	60%
29S/23E-24F01	100	170		90	140		90%	82%	
29S/23E-35K01	100	285		75	95		75%	33%	
29S/24E-04F	100	320	95	45	135	60	45%	42%	63%
29S/25E-36	100	265	40	55	115	20	55%	43%	50%
31S/27E-12	100	298	150	76	206	127	76%	69%	85%
31S/27E-15	100	290	120	58	177	76	58%	61%	63%
31S/27E-13G	100	280	130	46	199	91	46%	71%	70%
31S/28E-24A	100	280	215	70	211	122	70%	75%	57%
31S/28E-20N01	100	305	130	90	171	73	90%	56%	56%
28S/24E-03N01	100	320	185	40	120	100	40%	38%	54%
28S/24E-12R01	100	325		65	150		65%	46%	
28S/24E-16K	100	327	186	65	110	80	65%	34%	43%
28S/24E-15H	100	330	120	30	150	65	30%	45%	54%
28S/24E-22R	100	325	145	70	145	80	70%	45%	55%
28S/24E-25A	100	355	157	45	155	75	45%	44%	48%
29S/24E-27Q01	100	320	35	50	130	25	50%	41%	71%
29S/24E-29C	100	315	190	40	160	95	40%	51%	50%
30S/24E-04C01	100	260	240	74	184	113	74%	71%	47%
30S/24E-08D01	100	165		69	58		69%	35%	
30S/24E-12A	100	230	120	82	105	41	82%	46%	34%

Table 4-1: Coarse Grained Thickness and Percentages by Model Layer

Well ID	Layer 1&2 Thickness[1] (feet)	Layer 3 Thickness (feet)	Layer 4 Thickness (feet)	Layer 1&2 Coarse Grained Thickness[1] (feet)	Layer 3 Coarse Grained Thickness (feet)	Layer 4 Coarse Grained Thickness (feet)	Layer 1 & 2 Percent Coarse	Layer 3 Percent Coarse	Layer 4 Percent Coarse
30S/24E-22A	100	95		65	55		65%	58%	
28S/24E-06H	100	270	90	50	215	15	50%	80%	17%
28S/24E-30Q	100	350	90	75	155	45	75%	44%	50%
28S/23E-35A01	100	347	80	35	185	55	35%	53%	69%
29S/23E-35K01	100	285		75	95		75%	33%	
28S/26E-05F01	100	330	115	40	250	115	40%	76%	100%
28S/26E-17A01	100	330	172	80	225	60	80%	68%	35%
28S/26E-20J01	100	330	180	100	165	90	100%	50%	50%
28S/26E-22L01	100	320	175	80	120	90	80%	38%	51%
28S/25E-02J01	100	360	160	30	300	90	30%	83%	56%
28S/25E-06M	100	315	200	60	205	130	60%	65%	65%
28S/25E-07P	100	130	180	0	70	70		54%	39%
28S/25E-17E	100	325		60	170		60%	52%	
28S/25E-22J	100	275		70	175		70%	64%	
28S/25E-26F01	100	340	170	65	230	70	65%	68%	41%
28S/26E-23K01	100	305	180	85	150	65	85%	49%	36%
28S/25E-27P01	100	130	170	0	35	70		27%	41%
28S/26E-27H01	100	315	225	75	140	70	75%	44%	31%
28S/26E-27F01	100	335	155	75	185	90	75%	55%	58%
28S/26E-26P01	100	325	150	95	160	70	95%	49%	47%
28S/25E-31G01	100	120	180	0	60	75		50%	42%
29S/26E-35A	100	300	130	70	180	80	70%	60%	62%
29S/27E-31J	100	300	90	45	220	40	45%	73%	44%
29S/27E-34N01	100	320	190	85	131	105	85%	41%	55%
29S/27E-32H	100	335	125	77	187	72	77%	56%	58%
29S/28E-31B01	100	315	70	25	174	50	25%	55%	71%
29S/28E-31F01	100	315	160	71	155	125	71%	49%	78%
28S/25E-33J01	100	337	188	50	165	100	50%	49%	53%
28S/25E-35M	100	357	166	50	185	70	50%	52%	42%
28S/26E-36P01	100	140	160	0	60	40		43%	25%
28S/27E-32Q01	100	300	160	70	120	115	70%	40%	72%
29S/28E-06G01	100	300	178	64	102	62	64%	34%	35%
29S/27E-01A01	100	420	150	90	380	88	90%	90%	59%
29S/25E-12M01	100	350	190	60	185	30	60%	53%	16%
29S/28E-07D01	100	250		83	184		83%	74%	
29S/26E-14M02	100	320	175	80	210	85	80%	66%	49%
29S/27E-16A01	100	315	175	71	107	117	71%	34%	67%
29S/27E-15F01	100	330	160	72	232	138	72%	70%	86%
29S/25E-23F01	100	255	195	65	120	85	65%	47%	44%
29S/27E-20F01	100	330	110	88	176	55	88%	53%	50%
29S/26E-23D01	100	310	185	70	235	120	70%	76%	65%
29S/27E-21K01	100	345	165	82	218	71	82%	63%	43%
29S/27E-23N01	100	320	180	87	212	128	87%	66%	71%
29S/27E-24M01	100	355	140	68	209	98	68%	59%	70%
29S/28E-19F01	100	330	50	75	294	20	75%	89%	40%
29S/25E-30H	100	250	60	40	165	50	40%	66%	83%
29S/25E-27L01	100	280	105	70	165	50	70%	59%	48%
29S/26E-29E02	100	280	30	60	120	20	60%	43%	67%
29S/27E-28J01	100	345	165	82	159	90	82%	46%	55%
29S/27E-27M01	100	330	175	55	90	88	55%	27%	50%
29S/27E-26N01	100	310	90	72	214	77	72%	69%	86%
30S/26E-06K	100	240	185	72	135	106	72%	56%	57%
30S/27E-05A	100	300	180	72	214	86	72%	71%	48%
30S/27E-03J02	100	225		85	196		85%	87%	
30S/27E-01B01	100	318	90	88	184	47	88%	58%	52%
30S/28E-06C01	100	350	60	65	199	35	65%	57%	58%
30S/27E-08J	100	290	125	64	207	95	64%	71%	76%
30S/27E-09P01	100	285	215	48	224	166	48%	79%	77%
30S/28E-07C	100	305	40	88	125	4	88%	41%	10%
30S/27E-12F01	100	300	85	88	265	75	88%	88%	88%
30S/27E-18F01	100	285	185	72	177	135	72%	62%	73%
30S/27E-14F01	100	285	225	92	156	184	92%	55%	82%
30S/28E-16K01	100	295	205	73	155	89	73%	53%	43%
30S/27E-23C01	100	280	70	81	236	41	81%	84%	59%
30S/28E-19A01	100	300	190	65	108	108	65%	36%	57%
30S/26E-28J	100	265	125	72	54	60	72%	20%	48%
30S/26E-29B01	100	270	235	70	120	70	70%	44%	30%
31S/25E-04Q	100	220	280	72	51	100	72%	23%	36%
31S/25E-03E01	100	218	250	80	89	112	80%	41%	45%
31S/25E-15F01	100	225	270	64	84	94	64%	37%	35%
31S/25E-15M	100	228	205	35	90	50	35%	39%	24%
31S/25E-14L01	100	210	240	38	103	102	38%	49%	43%
31S/25E-25D	100	250	265	60	143	95	60%	57%	36%
31S/26E-03A01	100	275	30	68	173	22	68%	63%	73%
31S/28E-06C01	100	290	75	50	223	47	50%	77%	63%
31S/26E-12N	100	270	230	80	181	160	80%	67%	70%
31S/28E-08A	100	290	215	73	182	126	73%	63%	59%
31S/27E-18G	100	240	200	80	180	40	80%	75%	20%
31S/27E-17K	100	385	50	45	160	40	45%	42%	80%
31S/26E-34D	100	240	45	45	184	18	45%	77%	40%

Table 4-1: Coarse Grained Thickness and Percentages by Model Layer

Well ID	Layer 1&2 Thickness[1] (feet)	Layer 3 Thickness (feet)	Layer 4 Thickness (feet)	Layer 1&2 Coarse Grained Thickness[1] (feet)	Layer 3 Coarse Grained Thickness (feet)	Layer 4 Coarse Grained Thickness (feet)	Layer 1 & 2 Percent Coarse	Layer 3 Percent Coarse	Layer 4 Percent Coarse
31S/27E-32J	100	250	150	56	198	129	56%	79%	86%
31S/28E-31R01	100	195		72	140		72%	72%	
31S/28E-33F01	100	270	220	50	104	53	50%	39%	24%
32S/27E-04F01	100	260	220	86	154	137	86%	59%	62%
32S/27E-04J	100	255		50	125		50%	49%	
32S/27E-03C	100	255	160	76	217	75	76%	85%	47%
32S/28E-06H	100	280	210	83	130	102	83%	46%	49%
32S/28E-06F01	100	260	215	70	120	117	70%	46%	54%
32S/27E-09L	100	245	215	55	110	84	55%	45%	39%
32S/27E-10L	100	360	120	60	85	90	60%	24%	75%
32S/28E-09B	100	270	215	75	172	106	75%	64%	49%
28S/24E-09	100	300	200	40	90	110	40%	30%	55%
28S/24E-27	100	355	105	45	190	90	45%	54%	86%
28S/24E-18	100	345	175	40	160	50	40%	46%	29%
29S/27E-06	100	335	150	74	188	84	74%	56%	56%
30S/27E-07	100	270	170	44	182	74	44%	67%	44%
31S/26E-02	100	260	90	50	202	46	50%	78%	51%
31S/25E-03E02	100	230	290	80	77	105	80%	33%	36%
30S/25E-21N01	100	240	260	60	100	135	60%	42%	52%

Notes:

1 : Only the bottom 100 feet of model layer 2 was evaluated for coarse grained content. The result was applied to both layers 1 & 2.

Table 2-2: Aquifer Transmissivities from Pumping Tests, Coarse Grained Thickness, and Hydraulic Conductivity

Well ID	Groundwater Depth when Drilled	Perforated Interval(s) (feet bgs)	Perforated Model Layer(s)	Tested By	Pumping Rate (gpm)	Transmissivity (T - ft²/day)	Geophysical Log Notes	Layer 1 Saturated Thickness (feet)	Layer 1 Total Thickness (feet)	Layer 2 Saturated Thickness (feet)	Layer 2 Total Thickness (feet)	Layer 3 Total Thickness (feet)	Layer 4 Total Thickness (feet)	Layer 1 and 2 Combined Coarse Grained Fraction Thickness (feet)	Layer 3 Coarse Grained Fraction Thickness (feet)	Layer 4 Coarse Grained Fraction Thickness (feet)	Layer 1 and 2 Combined Percent Coarse Grained (coarse thickness / saturated thickness)	Layer 3 Percent Coarse Grained (coarse thickness / total thickness)	Layer 4 Percent Coarse Grained (coarse thickness / total thickness)	Sum of Coarse Grained Thickness in Perforated Layer(s) (feet)	Sum of Fine Grained Thickness in Perforated Layer(s) (feet)	Hydraulic Conductivity Normalized by Coarse Thickness in Perforated Layer(s) (Kcoarse - ft/day)
29S/22E-06L	36.9	126-146	1	Kenneth D. Schmidt and Associates	60	2,273	Used 29S/23E-16R01	113.1	150	150	150	190	310	195	125		74.1%	65.8%		195	68.1	11.7
30S/26E-22P03	120.51	280-390	1	Kenneth D. Schmidt and Associates	1460	10,962	Used 30S/26E-22P	79.49	200	200	200	250	150	85	140	65	30.4%	56.0%	22.4%	85	194.49	129.0
28S/22E-08B	14.1	320-660	2	Kenneth D. Schmidt and Associates	2000	2,406		120.9	135	135	135	390	140	45	90	60	17.6%	23.1%	30.8%	90	300	26.7
28S/22E-08J	14.1	320-660	2	Kenneth D. Schmidt and Associates	2520	4,679	Used 28S/22E-08B	120.9	135	135	135	390	140	145	90	60	56.7%	23.1%	20.3%	90	300	52.0
28S/22E-12M	17	410-700	2	Kenneth D. Schmidt and Associates	2590	3,609		108	125	125	125	450	100	50	130	100	21.5%	28.9%	35.7%	130	320	27.8
30S/27E-19K	143.19	550-710	2	Kenneth D. Schmidt and Associates	1540	17,512	Used 30S/27E-20D	0	130	116.81	130	440	100	65	90	130	55.6%	20.5%	45.6%	90	350	194.6
30S/27E-20D	196.55	479-669	2	Kenneth D. Schmidt and Associates	1570	18,448		0	130	63.45	130	440	100	50	90	130	78.8%	20.5%	48.1%	90	350	205.0
30S/27E-20P	196.55	475-730	2	Kenneth D. Schmidt and Associates	1360	20.854	Used 30S/27E-20D	0	130	63.45	130	440	100	50	90	130	78.8%	20.5%	48.1%	90	350	231.7
30S/27E-22N	189.05	410-620	2	Kenneth D. Schmidt and Associates	1250	32,217	Used 30S/27E-21N01	0	125	60.95	125	380	170	45	160	80	73.8%	42.1%	28.1%	160	220	201.4
30S/27E-30C	174.35	545-670	2	Kenneth D. Schmidt and Associates	1230	17,378		0	155	135.65	155	220	270	80	160	170	59.0%	72.7%	41.5%	160	60	108.6
31S/27E-16H	146.27	440-505	2	Kenneth D. Schmidt and Associates	485	9,892	Used 31S/27E-17K	0	132.5	118.73	132.5	385	150	45	300		37.9%	77.9%		300	85	33.0
31S/27E-19A	145	420-510	2	Kenneth D. Schmidt and Associates	230	6,818	Used 31S/27E-18G	20	165	165	165	240	230	110	180	40	59.5%	75.0%	12.1%	180	60	37.9
WKWD/NR8P - NW-1	175.1	270-300, 310-395, 415-450, 470-515, 535-550, 560-570	2	WKWSD / Richard C. Slade & Associates		20.893		0	150	124.9	150	300	200	55	110		44.0%	36.7%		110	190	189.9
29S/26E-14H	146.5	730-1171	3	Kenneth D. Schmidt and Associates	1230	6,684	Used 29S/26E-14H01	3.5	150	150	150	310	180	40	150	70	26.1%	48.4%	26.9%	70	110	95.5
WKWD/NR8P - NW-2	177.9	650-675, 695-760, 790-810, 835-850, 860-880, 940-980	3	WKWSD / Richard C. Slade & Associates	3073	13,969		0	125	72.1	125	320	220	65	140	100	90.2%	43.8%	32.8%	100	120	139.7
29S/23E-09J	70.57	200-440	1-2	Kenneth D. Schmidt and Associates	3220	13,502	Used 29S/23E-16R01	79.43	150	150	150	190	310	165	125		71.9%	65.8%		290	129.43	46.6
29S/24E-19J01	188	195-455	1-2	Kenneth D. Schmidt and Associates	2810	9,892	Used 29S/24E-20K01	0	140	92	140	370	150	90	95	65	97.8%	25.7%	26.0%	185	277	53.5
29S/24E-24A01	163	210-455	1-2	Kenneth D. Schmidt and Associates	3030	7,352	Used 29S/24E-20K01	0	140	117	140	370	150	80	95	65	68.4%	25.7%	27.1%	175	312	42.0
29S/25E-24A01	202.15	185-455	1-2	RWWSD/BWAP (Todd analysis)	3215	39,634		0	125	47.85	125	360	180	75	80	120	156.7%	22.2%	43.6%	155	252.85	255.7
30S/26E-23M	137.97	270-455	1-2	Kenneth D. Schmidt and Associates	1230	31,014	Used 30S/26E-22P	62.03	200	200	200	250	150	125	140	65	47.7%	56.0%	19.7%	265	247.03	117.0
WKWD/NR8P - NW-3	172.4	245-280, 290-335, 365-390, 405-435, 445-480, 505-520, 530-54	1-2	WKWSD / Richard C. Slade & Associates	2536	15,934		0	130	87.6	130	240	300	65	115	45	74.2%	47.9%	20.0%	180	147.6	88.5
WKWD/NR9P - NW-5	167.4	220-285, 300-320, 330-390, 410-450, 510-540	1-2	WKWSD / Richard C. Slade & Associates		21,174		0	145	122.6	145	280	260	65	90	70	53.0%	32.1%	31.1%	155	247.6	136.6
29S/26E-35B01	140.28	200-500, 560-700	1-3	Kenneth D. Schmidt and Associates	2540	40.772		0	115	89.72	115	350	220	80	180	115	89.2%	51.4%	30.7%	375	64.72	108.7
29S/26E-35G02	169.38	200-440, 500-640	1-3	KCWA / KWB	3000	30,000		0	140	110.62	140	280	240	75	185	50	67.8%	66.1%	16.1%	310	320.62	96.8
29S/26E-35H	128.27	190-650	1-3	Kenneth D. Schmidt and Associates	3000	58,685	Used 29S/26E-35H01	11.73	140	140	140	280	240	80	185	95	52.7%	66.1%	26.4%	360	311.73	163.0
29S/26E-35H05	127.54	210-450, 500-745	1-3	KCWA / KWB	3000	39,000	Used 29S/26E-35G	12.46	140	140	140	280	240	85	150	120	55.8%	53.6%	33.8%	355	317.46	109.9
29S/26E-35K01	160.68	205-665	1-3	Kenneth D. Schmidt and Associates	3000	41,441	Used 29S/26E-35K03	0	140	119.32	140	280	240	55	115	85	46.1%	41.1%	33.3%	255	384.32	162.5
29S/26E-36K	147.2	200-450, 500-680	1-3	Kenneth D. Schmidt and Associates	4080	41.975	Used 29S/26E-36K01	0	145	142.8	145	280	230	55	160	110	38.5%	57.1%	33.8%	325	327.8	129.2
29S/26E-36K01	150.49	200-450, 500-680	1-3	KCWA / KWB	4976	46,000		0	145	139.51	145	280	230	115	130	80	82.4%	46.4%	24.6%	325	324.51	141.5
29S/26E-36L01	150.77	200-550, 590-700	1-3	KCWA / KWB	5000	39,000		0	145	139.23	145	280	230	90	205	95	64.6%	73.2%	24.4%	390	259.23	100.0
30S/25E-22M01	144.81	225-360, 390-625	1-3	Kenneth D. Schmidt and Associates	3000	12,298	Used 30S/25E-22R01	2.69	147.5	147.5	147.5	225	280	35	60	40	23.3%	26.7%	29.6%	135	520.19	91.1
30S/25E-25C01	131.48	190-610	1-3	Kenneth D. Schmidt and Associates	2420	4,411	Used 30S/25E-23N01	16.02	147.5	147.5	147.5	225	280	75	50	40	45.9%	22.2%	24.2%	165	503.52	26.7
30S/26E-02J03	163.31	224-304, 384-724	1-3	KCWA / KWB	2737	27.000		0	155	146.69	155	195	295	100	90	95	68.2%	46.2%	33.3%	285	351.69	94.7
30S/26E-04E03	207.17	280-480, 540-740	1-3	KCWA / KWB	1700	17,800	Used 30S/26E-04R01	0	180	152.83	180	235	205	90	40	65	58.9%	17.0%	33.3%	195	397.83	91.3
30S/26E-05K01	209.86	160-480, 560-740	1-3	KCWA / KWB	3005	24,000		0	140	70.14	140	275	245	50	95	95	71.3%	34.5%	39.6%	240	350.14	100.0
30S/26E-05L01	188.8		1-3	KCWA / KWB	3005	23,000		0	125	61.2	125	235	315	30	65	120	49.0%	27.7%	55.8%	215	396.2	107.0
30S/26E-05N01	181.68	169.8-299.8, 340-420, 480-700	1-3	KCWA / KWB	3816	27,000		0	155	128.32	155	170	320	90	55	125	70.1%	32.4%	46.3%	270	348.32	100.0
30S/26E-05O02	175.02	190-350, 370-490, 570-730	1-3	KCWA / KWB	3005	28,000		0	175	174.98	175	210	240	110	70	130	62.9%	33.3%	41.9%	310	314.98	90.3
30S/26E-05R01	189.2		1-3	KCWA / KWB	3005	13,000		0	175	160.8	175	280	170	100	45	40	62.2%	16.1%	21.6%	185	425.8	70.3
30S/26E-06K01	115.12	220-280, 340-700	1-3	KCWA / KWB	3977	33,000		29.88	145	145	145	170	340	105	95	165	60.0%	55.9%	45.2%	365	319.88	90.4
30S/26E-08G01	178.08	160-340, 360-640, 660-680	1-3	KCWA / KWB	3005	34,000		0	172.5	166.92	172.5	315	140	130	70	55	77.9%	22.2%	21.6%	255	366.92	133.3
30S/26E-08H01	171.29	110-370, 390-690	1-3	KCWA / KWB	3005	32,000		13.71	185	185	185	210	220	95	105	100	47.8%	50.0%	33.3%	300	328.71	106.7
30S/26E-09E01	185.07	160-320, 340-580, 640-680	1-3	KCWA / KWB - Re-Analyzed by Todd Eneineers	3592	41.760		0	160	134.93	160	320	160	65	70	30	48.2%	21.9%	18.2%	165	449.93	253.1
30S/26E-10P01	147.29	155-314.75, 355-635	1-3	KCWA / KWB	3799	20,000		10.21	157.5	157.5	157.5	275	210	120	40	45	71.6%	14.5%	22.0%	205	447.71	97.6
30S/26E-10Q03	197.76	180-300, 340-650	1-3	KCWA / KWB	3841	15,000		0	155	112.24	155	260	230	55	65	60	49.0%	25.0%	33.3%	180	422.24	83.3
30S/26E-10Q02	134.28	170-330, 380-500, 540-640	1-3	KCWA / KWB	3592	18,000		10.72	145	145	145	270	240	85	35	70	54.6%	13.0%	36.8%	190	475.72	94.7
30S/26E-10R01	195.9	159.6-339.6, 379.8-479.8, 540-730	1-3	KCWA / KWB	3802	16,000		0	170	144.1	170	200	260	85	65	60	59.0%	32.5%	28.6%	210	394.1	76.2
30S/26E-11A	155.97	210-690	1-3	Kenneth D. Schmidt and Associates	3530	24,196	Used 30S/26E-11A01	0	130	104.03	130	380	160	50	105	40	48.1%	27.6%	20.5%	195	449.03	124.1
30S/26E-11A01	231.54		1-3	KCWA / KWB	3010	22,000		0	130	28.46	130	380	160	50	105	40	175.7%	27.6%	20.5%	195	373.46	112.8
30S/26E-11G	146.8	200-780	1-3	Kenneth D. Schmidt and Associates	3560	29,543	Used 30S/26E-11F01	0	125	103.2	125	360	190	70	150	55	67.8%	41.7%	20.0%	275	378.2	107.4
30S/26E-11G01	217.27		1-3	KCWA / KWB	3035	36,000	Used 30S/26E-11F01	0	125	32.73	125	360	190	70	150	55	213.9%	41.7%	20.0%	275	307.73	130.9
30S/26E-11M	146.8	200-780	1-3	Kenneth D. Schmidt and Associates	3530	12,165	Used 30S/26E-11M03	0	145	143.2	145	290	220	65	95	75	45.4%	32.8%	31.9%	235	418.2	51.8
30S/26E-11M01	250.56		1-3	KCWA / KWB	3003	9.400		0	145	39.44	145	290	220	10	95	75	25.4%	32.8%	41.7%	180	369.44	52.2
30S/26E-15E01	188.26	180-380, 420-700	1-3	KCWA / KWB	3005	28,000		0	155	121.74	155	290	200	60	45	60	49.3%	15.5%	36.4%	165	446.74	169.7
30S/26E-16L01	163.17	154.75-319.75, 360-390, 450-690	1-3	KCWA / KWB	3811	19,000		1.83	165	165	165	180	290	35	75	115	21.0%	41.7%	51.1%	225	411.83	84.4
30S/26E-16Q01	171.34	150-330, 400-670	1-3	KCWA / KWB	3005	29,000		0	160	148.66	160	280	200	60	55	45	40.4%	19.6%	28.1%	160	468.66	181.3
30S/26E-16R01	107.28	150-310, 370-670	1-3	KCWA / KWB	3005	23,000		47.72	155	155	155	290	200	45	75	75	22.2%	25.9%	38.5%	195	497.72	117.9
30S/26E-17B01	248.92	170-290, 330-550, 590-690	1-3	KCWA / KWB	3511	19.000		0	165	81.08	165	180	290	25	140	40	30.8%	77.8%	19.5%	205	346.08	92.7
30S/26E-17C01	171.22	168-248, 268-308, 328-628, 648-688	1-3	KCWA / KWB	3759	18,000		0	165	158.78	165	180	290	60	170	25	37.8%	94.4%	9.8%	255	373.78	70.6
30S/26E-18R01	172.32	160-260, 300-400, 420-620, 640-680	1-3	KCWA / KWB	2008	10,000		0	137.5	102.68	137.5	275	250	70	130	30	68.2%	47.3%	13.0%	230	397.68	43.5
28S/22E-11H	9.4	480-740	2-3	Kenneth D. Schmidt and Associates	1950	3,743	Used 28S/22E-12M	115.6	125	125	125	450	100	135	130	100	56.1%	28.9%	27.4%	230	320	16.3
28S/25E-16F	245.51	535-835	2-3	Kenneth D. Schmidt and Associates	2010	34,489	Used 28S/25E-17E	0	138	10.49	138	294	230	30	170	100	98.4%	57.8%	33.3%	270	254	127.7
29S/26E-32R	145.57	335-600	2-3	Kenneth D. Schmidt and Associates	1500	5.080	Used 29S/26E-31H	9.43	155	155	155	260	230	73	104	84	44.4%	40.0%	32.2%	188	302	27.0
30S/25E-21G	147.84	286-750	2-3	Kenneth D. Schmidt and Associates	4480	16,844	Used 30S/25E-21G01	0	132.5	117.16	132.5	325	210	85	110	45	72.6%	33.8%	18.8%	155	380	108.7
30S/25E-21R04	134.29	229-656	2-3	Kenneth D. Schmidt and Associates	4430	16,576	Used 30S/25E-21G01	0	132.5	130.71	132.5	325	210	85	110	45	65.0%	33.8%	18.8%	155	380	106.9
30S/27E-19J01	151.24	449-770	2-3	Kenneth D. Schmidt and Associates	1560	28,607	Used 30S/27E-19J	0	140	128.76	140	375	145	85	195	55	66.0%	52.0%	16.4%	250	270	114.4
Strand Ranch SREK-1	187.85	380-650	2-3	Wilderruth	2508.8	11,100		0	140	92.15	140	280	240	80	110	80	86.8%	39.3%	29.6%	190	330	58.4
Strand Ranch SREK-2	190.32	410-530, 570-650	2-3	Wilderruth	2504	9.191		0	145	99.68	145	270	240	80	120	90	80.3%	44.4%	31.0%	210	300	43.8
Strand Ranch SREK-3	212.03	410-610	2-3	Wilderruth	2508	8,071		0	125	37.97	125	300	250	65	110	60	171.2%	36.7%	25.5%	170	380	47.5
Strand Ranch SREK-4	207.83	410-540, 580-650	2-3	Wilderruth	2509	12,206		0	125	42.17	125	320	230	50	75	65	118.6%	23.4%	34.2%	140	410	87.2
Strand Ranch SREK-5	210.83	410-505, 545-650	2-3	Wilderruth	2509	11,759		0	162.5	114.17	162.5	245	230	75	85	75	65.7%	34.7%	31.9%	160	315	73.5
Strand Ranch SREK-7	212.72	410-480, 520-660	2-3	Wilderruth	2510.66667	11,860		0	135	57.28	135	280	250	70	85	70	122.2%	30.4%	31.1%	155	375	76.5
WKWD/NR8P - NW-4	149.2	285-330, 440-535	2-3	WKWSD / Richard C. Slade & Associates	2536	8,030		0	115	80.8	115	320	250	70	85	80	86.6%	26.6%	34.0%	165	405	48.7
							Averages:	**13.55**	**146**	**118**	**146**	**293**	**216**	**75**	**111**	**77**	**66.2%**	**39.5%**	**29.9%**	**207**	**322**	**101.6**

Table 4-3: Municipal and Recovery Pumping Wells

Municipal / Recovery Area	Number of Wells	Well Type
City of Bakersfield 2800 Acres	15	Recovery
Berenda Mesa	14	Recovery
Bolthouse	7	Recovery
City of Bakersfield	8	Recovery
Improvement District 4 (ID4)	11	Recovery
Kern Water Bank	118	Recovery
Pioneer	25	Recovery
Rosedale Rio Bravo Water Storage District	7	Recovery
Subtotal	205	
Buttonwillow	2	Muni
CalWater	167	Muni
City of Bakersfield	63	Muni
Greenfield	1	Muni
North of the River Mutual Water District (NORMWD)	4	Muni
Oildale	10	Muni
Shafter	6	Muni
Stockdale	2	Muni
Stockdale Annex	1	Muni
Vaughn Mutual Water Company	19	Muni
West Kern Water District	9	Muni
Subtotal	284	
TOTAL	**489**	

Table 4-4: Agricultural Wells

Agricultural Area	Number of Wells
Bolthouse	12
Buena Vista Water Storage District	87
Cawelo	6
James Pioneer Irrigation District	38
Kern Delta-Buena Vista	30
Kern Delta-Farmers	37
Kern Delta-Kern Island	90
Kern Delta-Stine	77
Kern Delta General (no designated service area)	19
Kern River Canal and Irrigation Company	16
North Kern	39
Rosedale Rio Bravo	198
Rosedale Ranch	38
Semitropic	43
Shafter	126
Areas outside of water districts	97
Total	**953**

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
1	Horizontal Hydraulic Conductivity (Kh)	01	32	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	02	65	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	03	35	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	04	81	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	05	60	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	06	64	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	07	60	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	08	50	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	09	35	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	10	85	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	11	57	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	12	70	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	13	63	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	14	59	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	15	59	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	16	61	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	17	52	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	18	55	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	19	45	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	20	65	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	21	45	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	22	48	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	23	48	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	24	59	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	25	45	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	26	45	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	27	35	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	28	35	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	29	61	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	30	51	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	31	67	ft/day
1	Horizontal Hydraulic Conductivity (Kh)	32	50	ft/day

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
1	Vertical Anisotropy (Kh/Kz)	01	50	Unitless
1	Vertical Anisotropy (Kh/Kz)	02	50	Unitless
1	Vertical Anisotropy (Kh/Kz)	03	25	Unitless
1	Vertical Anisotropy (Kh/Kz)	04	10	Unitless
1	Vertical Anisotropy (Kh/Kz)	05	50	Unitless
1	Vertical Anisotropy (Kh/Kz)	06	200	Unitless
1	Vertical Anisotropy (Kh/Kz)	07	200	Unitless
1	Vertical Anisotropy (Kh/Kz)	08	200	Unitless
1	Vertical Anisotropy (Kh/Kz)	09	200	Unitless
1	Vertical Anisotropy (Kh/Kz)	10	50	Unitless
1	Vertical Anisotropy (Kh/Kz)	11	10	Unitless
1	Vertical Anisotropy (Kh/Kz)	12	50	Unitless
1	Vertical Anisotropy (Kh/Kz)	13	50	Unitless
1	Vertical Anisotropy (Kh/Kz)	14	50	Unitless
1	Vertical Anisotropy (Kh/Kz)	15	50	Unitless
1	Vertical Anisotropy (Kh/Kz)	16	10	Unitless
1	Vertical Anisotropy (Kh/Kz)	17	10	Unitless
1	Vertical Anisotropy (Kh/Kz)	18	10	Unitless
1	Vertical Anisotropy (Kh/Kz)	19	200	Unitless
1	Vertical Anisotropy (Kh/Kz)	20	100	Unitless
1	Vertical Anisotropy (Kh/Kz)	21	25	Unitless
1	Vertical Anisotropy (Kh/Kz)	22	10	Unitless
1	Vertical Anisotropy (Kh/Kz)	23	25	Unitless
1	Vertical Anisotropy (Kh/Kz)	24	10	Unitless
1	Vertical Anisotropy (Kh/Kz)	25	50	Unitless
1	Vertical Anisotropy (Kh/Kz)	26	200	Unitless
1	Vertical Anisotropy (Kh/Kz)	27	25	Unitless
1	Vertical Anisotropy (Kh/Kz)	28	25	Unitless
1	Vertical Anisotropy (Kh/Kz)	29	25	Unitless
1	Vertical Anisotropy (Kh/Kz)	30	10	Unitless
1	Vertical Anisotropy (Kh/Kz)	31	10	Unitless
1	Vertical Anisotropy (Kh/Kz)	32	50	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
1	Specific Yield (Sy)	01	0.20	Unitless
1	Specific Yield (Sy)	02	0.23	Unitless
1	Specific Yield (Sy)	03	0.22	Unitless
1	Specific Yield (Sy)	04	0.23	Unitless
1	Specific Yield (Sy)	05	0.23	Unitless
1	Specific Yield (Sy)	06	0.18	Unitless
1	Specific Yield (Sy)	07	0.16	Unitless
1	Specific Yield (Sy)	08	0.16	Unitless
1	Specific Yield (Sy)	09	0.16	Unitless
1	Specific Yield (Sy)	10	0.25	Unitless
1	Specific Yield (Sy)	11	0.16	Unitless
1	Specific Yield (Sy)	12	0.16	Unitless
1	Specific Yield (Sy)	13	0.20	Unitless
1	Specific Yield (Sy)	14	0.18	Unitless
1	Specific Yield (Sy)	15	0.18	Unitless
1	Specific Yield (Sy)	16	0.17	Unitless
1	Specific Yield (Sy)	17	0.15	Unitless
1	Specific Yield (Sy)	18	0.16	Unitless
1	Specific Yield (Sy)	19	0.16	Unitless
1	Specific Yield (Sy)	20	0.16	Unitless
1	Specific Yield (Sy)	21	0.20	Unitless
1	Specific Yield (Sy)	22	0.16	Unitless
1	Specific Yield (Sy)	23	0.16	Unitless
1	Specific Yield (Sy)	24	0.17	Unitless
1	Specific Yield (Sy)	25	0.23	Unitless
1	Specific Yield (Sy)	26	0.18	Unitless
1	Specific Yield (Sy)	27	0.21	Unitless
1	Specific Yield (Sy)	28	0.21	Unitless
1	Specific Yield (Sy)	29	0.18	Unitless
1	Specific Yield (Sy)	30	0.15	Unitless
1	Specific Yield (Sy)	31	0.20	Unitless
1	Specific Yield (Sy)	32	0.19	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
1	Specific Storage (Ss)	01	6.7E-04	Unitless
1	Specific Storage (Ss)	02	7.7E-04	Unitless
1	Specific Storage (Ss)	03	7.3E-04	Unitless
1	Specific Storage (Ss)	04	7.7E-04	Unitless
1	Specific Storage (Ss)	05	7.7E-04	Unitless
1	Specific Storage (Ss)	06	6.0E-04	Unitless
1	Specific Storage (Ss)	07	5.3E-04	Unitless
1	Specific Storage (Ss)	08	5.3E-04	Unitless
1	Specific Storage (Ss)	09	5.3E-04	Unitless
1	Specific Storage (Ss)	10	8.3E-04	Unitless
1	Specific Storage (Ss)	11	5.3E-04	Unitless
1	Specific Storage (Ss)	12	5.3E-04	Unitless
1	Specific Storage (Ss)	13	6.7E-04	Unitless
1	Specific Storage (Ss)	14	6.0E-04	Unitless
1	Specific Storage (Ss)	15	6.0E-04	Unitless
1	Specific Storage (Ss)	16	5.7E-04	Unitless
1	Specific Storage (Ss)	17	5.0E-04	Unitless
1	Specific Storage (Ss)	18	5.3E-04	Unitless
1	Specific Storage (Ss)	19	5.3E-04	Unitless
1	Specific Storage (Ss)	20	5.3E-04	Unitless
1	Specific Storage (Ss)	21	6.7E-04	Unitless
1	Specific Storage (Ss)	22	5.3E-04	Unitless
1	Specific Storage (Ss)	23	5.3E-04	Unitless
1	Specific Storage (Ss)	24	5.7E-04	Unitless
1	Specific Storage (Ss)	25	7.7E-04	Unitless
1	Specific Storage (Ss)	26	6.0E-04	Unitless
1	Specific Storage (Ss)	27	7.0E-04	Unitless
1	Specific Storage (Ss)	28	7.0E-04	Unitless
1	Specific Storage (Ss)	29	6.0E-04	Unitless
1	Specific Storage (Ss)	30	5.0E-04	Unitless
1	Specific Storage (Ss)	31	6.7E-04	Unitless
1	Specific Storage (Ss)	32	6.3E-04	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
2	Horizontal Hydraulic Conductivity (Kh)	01	32	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	02	65	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	03	35	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	04	81	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	05	60	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	06	64	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	07	60	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	08	50	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	09	35	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	10	85	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	11	57	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	12	35	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	13	63	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	14	59	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	15	59	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	16	61	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	17	52	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	18	55	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	19	45	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	20	45	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	21	45	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	22	48	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	23	48	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	24	59	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	25	45	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	26	45	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	27	35	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	28	35	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	29	61	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	30	51	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	31	67	ft/day
2	Horizontal Hydraulic Conductivity (Kh)	32	50	ft/day

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
2	Vertical Anisotropy (Kh/Kz)	01	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	02	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	03	25	Unitless
2	Vertical Anisotropy (Kh/Kz)	04	10	Unitless
2	Vertical Anisotropy (Kh/Kz)	05	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	06	200	Unitless
2	Vertical Anisotropy (Kh/Kz)	07	200	Unitless
2	Vertical Anisotropy (Kh/Kz)	08	200	Unitless
2	Vertical Anisotropy (Kh/Kz)	09	200	Unitless
2	Vertical Anisotropy (Kh/Kz)	10	200	Unitless
2	Vertical Anisotropy (Kh/Kz)	11	10	Unitless
2	Vertical Anisotropy (Kh/Kz)	12	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	13	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	14	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	15	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	16	10	Unitless
2	Vertical Anisotropy (Kh/Kz)	17	10	Unitless
2	Vertical Anisotropy (Kh/Kz)	18	10	Unitless
2	Vertical Anisotropy (Kh/Kz)	19	200	Unitless
2	Vertical Anisotropy (Kh/Kz)	20	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	21	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	22	10	Unitless
2	Vertical Anisotropy (Kh/Kz)	23	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	24	10	Unitless
2	Vertical Anisotropy (Kh/Kz)	25	50	Unitless
2	Vertical Anisotropy (Kh/Kz)	26	200	Unitless
2	Vertical Anisotropy (Kh/Kz)	27	25	Unitless
2	Vertical Anisotropy (Kh/Kz)	28	25	Unitless
2	Vertical Anisotropy (Kh/Kz)	29	25	Unitless
2	Vertical Anisotropy (Kh/Kz)	30	10	Unitless
2	Vertical Anisotropy (Kh/Kz)	31	10	Unitless
2	Vertical Anisotropy (Kh/Kz)	32	50	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
2	Specific Yield (Sy)	01	0.10	Unitless
2	Specific Yield (Sy)	02	0.05	Unitless
2	Specific Yield (Sy)	03	0.03	Unitless
2	Specific Yield (Sy)	04	0.18	Unitless
2	Specific Yield (Sy)	05	0.10	Unitless
2	Specific Yield (Sy)	06	0.07	Unitless
2	Specific Yield (Sy)	07	0.10	Unitless
2	Specific Yield (Sy)	08	0.03	Unitless
2	Specific Yield (Sy)	09	0.04	Unitless
2	Specific Yield (Sy)	10	0.08	Unitless
2	Specific Yield (Sy)	11	0.14	Unitless
2	Specific Yield (Sy)	12	0.02	Unitless
2	Specific Yield (Sy)	13	0.06	Unitless
2	Specific Yield (Sy)	14	0.03	Unitless
2	Specific Yield (Sy)	15	0.03	Unitless
2	Specific Yield (Sy)	16	0.21	Unitless
2	Specific Yield (Sy)	17	0.15	Unitless
2	Specific Yield (Sy)	18	0.06	Unitless
2	Specific Yield (Sy)	19	0.03	Unitless
2	Specific Yield (Sy)	20	0.03	Unitless
2	Specific Yield (Sy)	21	0.03	Unitless
2	Specific Yield (Sy)	22	0.03	Unitless
2	Specific Yield (Sy)	23	0.03	Unitless
2	Specific Yield (Sy)	24	0.05	Unitless
2	Specific Yield (Sy)	25	0.06	Unitless
2	Specific Yield (Sy)	26	0.03	Unitless
2	Specific Yield (Sy)	27	0.12	Unitless
2	Specific Yield (Sy)	28	0.12	Unitless
2	Specific Yield (Sy)	29	0.05	Unitless
2	Specific Yield (Sy)	30	0.04	Unitless
2	Specific Yield (Sy)	31	0.05	Unitless
2	Specific Yield (Sy)	32	0.05	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
2	Specific Storage (Ss)	01	3.3E-04	Unitless
2	Specific Storage (Ss)	02	1.7E-04	Unitless
2	Specific Storage (Ss)	03	1.0E-04	Unitless
2	Specific Storage (Ss)	04	6.0E-04	Unitless
2	Specific Storage (Ss)	05	3.3E-04	Unitless
2	Specific Storage (Ss)	06	2.4E-04	Unitless
2	Specific Storage (Ss)	07	3.4E-04	Unitless
2	Specific Storage (Ss)	08	8.7E-05	Unitless
2	Specific Storage (Ss)	09	1.2E-04	Unitless
2	Specific Storage (Ss)	10	2.7E-04	Unitless
2	Specific Storage (Ss)	11	4.7E-04	Unitless
2	Specific Storage (Ss)	12	6.7E-05	Unitless
2	Specific Storage (Ss)	13	2.0E-04	Unitless
2	Specific Storage (Ss)	14	1.0E-04	Unitless
2	Specific Storage (Ss)	15	1.0E-04	Unitless
2	Specific Storage (Ss)	16	6.9E-04	Unitless
2	Specific Storage (Ss)	17	5.0E-04	Unitless
2	Specific Storage (Ss)	18	1.9E-04	Unitless
2	Specific Storage (Ss)	19	1.0E-04	Unitless
2	Specific Storage (Ss)	20	1.0E-04	Unitless
2	Specific Storage (Ss)	21	1.0E-04	Unitless
2	Specific Storage (Ss)	22	1.0E-04	Unitless
2	Specific Storage (Ss)	23	1.0E-04	Unitless
2	Specific Storage (Ss)	24	1.5E-04	Unitless
2	Specific Storage (Ss)	25	2.0E-04	Unitless
2	Specific Storage (Ss)	26	1.0E-04	Unitless
2	Specific Storage (Ss)	27	4.0E-04	Unitless
2	Specific Storage (Ss)	28	4.0E-04	Unitless
2	Specific Storage (Ss)	29	1.7E-04	Unitless
2	Specific Storage (Ss)	30	1.3E-04	Unitless
2	Specific Storage (Ss)	31	1.7E-04	Unitless
2	Specific Storage (Ss)	32	1.7E-04	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
3	Horizontal Hydraulic Conductivity (Kh)	01	60	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	02	75	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	03	50	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	04	51	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	05	68	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	06	50	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	07	64	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	08	70	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	09	30	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	10	50	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	11	51	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	12	29	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	13	69	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	14	48	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	15	52	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	16	52	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	17	42	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	18	40	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	19	59	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	20	45	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	21	31	ft/day
3	Horizontal Hydraulic Conductivity (Kh)	22	56	ft/day

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
3	Vertical Anisotropy (Kh/Kz)	01	500	Unitless
3	Vertical Anisotropy (Kh/Kz)	02	50	Unitless
3	Vertical Anisotropy (Kh/Kz)	03	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	04	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	05	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	06	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	07	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	08	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	09	50	Unitless
3	Vertical Anisotropy (Kh/Kz)	10	50	Unitless
3	Vertical Anisotropy (Kh/Kz)	11	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	12	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	13	500	Unitless
3	Vertical Anisotropy (Kh/Kz)	14	500	Unitless
3	Vertical Anisotropy (Kh/Kz)	15	50	Unitless
3	Vertical Anisotropy (Kh/Kz)	16	500	Unitless
3	Vertical Anisotropy (Kh/Kz)	17	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	18	500	Unitless
3	Vertical Anisotropy (Kh/Kz)	19	50	Unitless
3	Vertical Anisotropy (Kh/Kz)	20	100	Unitless
3	Vertical Anisotropy (Kh/Kz)	21	50	Unitless
3	Vertical Anisotropy (Kh/Kz)	22	500	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
3	Specific Yield (Sy)	01	7.5E-05	Unitless
3	Specific Yield (Sy)	02	8.4E-05	Unitless
3	Specific Yield (Sy)	03	6.5E-05	Unitless
3	Specific Yield (Sy)	04	1.7E-04	Unitless
3	Specific Yield (Sy)	05	2.2E-04	Unitless
3	Specific Yield (Sy)	06	7.6E-05	Unitless
3	Specific Yield (Sy)	07	1.5E-04	Unitless
3	Specific Yield (Sy)	08	5.4E-05	Unitless
3	Specific Yield (Sy)	09	4.3E-05	Unitless
3	Specific Yield (Sy)	10	4.1E-05	Unitless
3	Specific Yield (Sy)	11	7.9E-05	Unitless
3	Specific Yield (Sy)	12	1.7E-04	Unitless
3	Specific Yield (Sy)	13	1.5E-04	Unitless
3	Specific Yield (Sy)	14	1.3E-04	Unitless
3	Specific Yield (Sy)	15	1.5E-04	Unitless
3	Specific Yield (Sy)	16	9.9E-05	Unitless
3	Specific Yield (Sy)	17	1.5E-04	Unitless
3	Specific Yield (Sy)	18	6.8E-05	Unitless
3	Specific Yield (Sy)	19	1.7E-04	Unitless
3	Specific Yield (Sy)	20	1.4E-04	Unitless
3	Specific Yield (Sy)	21	1.0E-04	Unitless
3	Specific Yield (Sy)	22	4.5E-05	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
3	Specific Storage (Ss)	01	2.5E-07	Unitless
3	Specific Storage (Ss)	02	2.8E-07	Unitless
3	Specific Storage (Ss)	03	2.2E-07	Unitless
3	Specific Storage (Ss)	04	5.8E-07	Unitless
3	Specific Storage (Ss)	05	7.3E-07	Unitless
3	Specific Storage (Ss)	06	2.5E-07	Unitless
3	Specific Storage (Ss)	07	5.0E-07	Unitless
3	Specific Storage (Ss)	08	1.8E-07	Unitless
3	Specific Storage (Ss)	09	1.4E-07	Unitless
3	Specific Storage (Ss)	10	1.4E-07	Unitless
3	Specific Storage (Ss)	11	2.6E-07	Unitless
3	Specific Storage (Ss)	12	5.6E-07	Unitless
3	Specific Storage (Ss)	13	4.9E-07	Unitless
3	Specific Storage (Ss)	14	4.3E-07	Unitless
3	Specific Storage (Ss)	15	5.0E-07	Unitless
3	Specific Storage (Ss)	16	3.3E-07	Unitless
3	Specific Storage (Ss)	17	5.0E-07	Unitless
3	Specific Storage (Ss)	18	2.3E-07	Unitless
3	Specific Storage (Ss)	19	5.8E-07	Unitless
3	Specific Storage (Ss)	20	4.7E-07	Unitless
3	Specific Storage (Ss)	21	3.4E-07	Unitless
3	Specific Storage (Ss)	22	1.5E-07	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
4	Horizontal Hydraulic Conductivity (Kh)	01	10	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	02	30	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	03	25	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	04	50	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	05	58	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	06	20	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	07	57	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	08	51	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	09	70	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	10	25	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	11	40	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	12	45	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	13	52	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	14	59	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	15	35	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	16	35	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	17	48	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	18	43	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	19	24	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	20	30	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	21	43	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	22	43	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	23	57	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	24	55	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	25	37	ft/day
4	Horizontal Hydraulic Conductivity (Kh)	26	43	ft/day

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
4	Vertical Anisotropy (Kh/Kz)	01	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	02	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	03	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	04	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	05	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	06	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	07	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	08	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	09	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	10	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	11	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	12	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	13	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	14	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	15	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	16	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	17	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	18	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	19	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	20	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	21	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	22	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	23	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	24	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	25	500	Unitless
4	Vertical Anisotropy (Kh/Kz)	26	500	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
4	Specific Yield (Sy)	01	1.7E-03	Unitless
4	Specific Yield (Sy)	02	1.1E-03	Unitless
4	Specific Yield (Sy)	03	1.1E-03	Unitless
4	Specific Yield (Sy)	04	1.5E-03	Unitless
4	Specific Yield (Sy)	05	1.7E-03	Unitless
4	Specific Yield (Sy)	06	1.5E-03	Unitless
4	Specific Yield (Sy)	07	1.7E-03	Unitless
4	Specific Yield (Sy)	08	1.5E-03	Unitless
4	Specific Yield (Sy)	09	1.8E-03	Unitless
4	Specific Yield (Sy)	10	1.9E-03	Unitless
4	Specific Yield (Sy)	11	1.8E-03	Unitless
4	Specific Yield (Sy)	12	1.3E-03	Unitless
4	Specific Yield (Sy)	13	1.5E-03	Unitless
4	Specific Yield (Sy)	14	1.7E-03	Unitless
4	Specific Yield (Sy)	15	1.1E-03	Unitless
4	Specific Yield (Sy)	16	1.7E-03	Unitless
4	Specific Yield (Sy)	17	1.4E-03	Unitless
4	Specific Yield (Sy)	18	1.3E-03	Unitless
4	Specific Yield (Sy)	19	1.5E-03	Unitless
4	Specific Yield (Sy)	20	1.3E-03	Unitless
4	Specific Yield (Sy)	21	1.3E-03	Unitless
4	Specific Yield (Sy)	22	1.3E-03	Unitless
4	Specific Yield (Sy)	23	1.7E-03	Unitless
4	Specific Yield (Sy)	24	1.6E-03	Unitless
4	Specific Yield (Sy)	25	1.1E-03	Unitless
4	Specific Yield (Sy)	26	1.3E-03	Unitless

Table 5-1: Post Calibration Model Parameters

Layer	Parameter	Zone	Parameter Value	
4	Specific Storage (Ss)	01	4.1E-07	Unitless
4	Specific Storage (Ss)	02	4.5E-07	Unitless
4	Specific Storage (Ss)	03	4.3E-07	Unitless
4	Specific Storage (Ss)	04	6.5E-07	Unitless
4	Specific Storage (Ss)	05	7.9E-07	Unitless
4	Specific Storage (Ss)	06	7.0E-07	Unitless
4	Specific Storage (Ss)	07	8.1E-07	Unitless
4	Specific Storage (Ss)	08	7.0E-07	Unitless
4	Specific Storage (Ss)	09	8.3E-07	Unitless
4	Specific Storage (Ss)	10	5.1E-07	Unitless
4	Specific Storage (Ss)	11	5.4E-07	Unitless
4	Specific Storage (Ss)	12	7.9E-07	Unitless
4	Specific Storage (Ss)	13	8.4E-07	Unitless
4	Specific Storage (Ss)	14	9.4E-07	Unitless
4	Specific Storage (Ss)	15	6.0E-07	Unitless
4	Specific Storage (Ss)	16	8.4E-07	Unitless
4	Specific Storage (Ss)	17	2.3E-07	Unitless
4	Specific Storage (Ss)	18	5.9E-07	Unitless
4	Specific Storage (Ss)	19	7.5E-07	Unitless
4	Specific Storage (Ss)	20	3.7E-07	Unitless
4	Specific Storage (Ss)	21	5.4E-07	Unitless
4	Specific Storage (Ss)	22	5.0E-07	Unitless
4	Specific Storage (Ss)	23	3.6E-07	Unitless
4	Specific Storage (Ss)	24	4.1E-07	Unitless
4	Specific Storage (Ss)	25	4.9E-07	Unitless
4	Specific Storage (Ss)	26	2.8E-07	Unitless

Table 5-2: Model Calibration Statistics

Statistic		Description	Value
Basic Residual Statistics	Residual Mean	Average difference between simulated and observed	4.62 feet
	Residual Standard Deviation	Standard deviation of the residuals	31.85 feet
	Absolute Residual Mean	Average difference between absolute values for simulated and observed	23.30 feet
	Residual Sum of Squares	Total of all residuals squared	46,483,758 square feet
	Root Mean Squared Error	The square root of the square of mean residual	32.17888385 feet
	Minimum Residual	Minimum difference between simulated and observed	-160.90 feet
	Maximum Residual	Maximum difference between simulated and observed	209.21 feet
	Range of Observations	The difference between the highest and lowest observation	370.11 feet
	Number of Observations	Total observations	44,891 --
Calculated Metrics	Residual Mean as a Percent of Range of Observations	Recommended to be below 5 percent	1.25%
	Absolute Residual Mean as a Percent of Range of Observations	Recommended to be below 10 percent	8.60%
	Root Mean Square Error as a Percent of Range of Observations	Recommended to be below 10 percent	8.69%
	Residual Standard Deviation as a Percent of Range of Observations	Recommended to be below 10 percent	8.60%
	Correlation Coefficient Layer 1	Pearson product-moment correlation coefficient for Layer 1	79.12%
	Correlation Coefficient Layer 2	Pearson product-moment correlation coefficient for Layer 2	87.53%
	Correlation Coefficient Layer 3	Pearson product-moment correlation coefficient for Layer 3	83.34%
	Correlation Coefficient Layer 4	Pearson product-moment correlation coefficient for Layer 4	82.99%
	Correlation Coefficient All Selected Targets	Pearson product-moment correlation coefficient for all selected targets	86.25%
	Maximum Mass Balance Error	Comparison of all mass balance inflows to outflows	0.0017%

Table 6-1: Model Water Budget Annual Summary

All Values in Acre Feet per Year (AFY)

	Water Budget Element[1]	Year																									Average:	Total
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010		
Inflows	Recharge In	790,996	316,246	278,318	274,469	219,911	259,346	255,343	642,211	287,487	1,179,518	822,032	742,212	1,207,147	424,623	404,381	275,346	313,198	434,225	292,123	1,376,139	1,057,871	246,592	239,790	264,733	704,314	532,343	13,308,570
	Constant Head Flow In	61,582	73,822	71,726	71,906	63,468	68,899	94,223	86,950	104,638	88,584	89,631	93,557	99,792	109,304	113,579	103,822	96,217	98,120	106,583	95,046	107,012	99,054	86,991	97,957	93,570	91,041	2,276,033
Outflows	Well Flow Out	-490,644	-675,619	-685,374	-639,493	-685,093	-686,730	-699,295	-566,132	-668,301	-582,653	-544,110	-534,358	-487,609	-572,704	-564,145	-799,592	-674,774	-575,610	-677,107	-507,589	-481,597	-986,328	-1,037,506	-925,881	-591,998	-653,610	-16,340,240
	Constant Head Flow Out	-147,104	-133,239	-120,763	-123,437	-124,616	-108,288	-80,341	-77,698	-65,034	-103,525	-106,465	-99,120	-131,659	-92,153	-62,598	-68,905	-80,936	-83,076	-65,008	-88,239	-96,795	-81,013	-86,528	-64,313	-79,834	-94,827	-2,370,686
	Change in Storage	-214,831	418,789	456,094	416,556	526,330	466,772	430,069	-85,332	341,211	-581,925	-261,089	-202,292	-687,670	130,930	108,782	489,328	346,295	126,341	343,409	-875,359	-586,492	721,694	797,253	627,503	-126,055	125,052	3,126,311
Mass Balance	Total Flow In to Model	1,166,490	977,047	916,223	857,489	879,295	882,937	872,259	975,460	868,708	1,444,076	1,175,867	1,134,671	1,453,297	948,382	889,323	1,014,039	914,194	899,864	912,995	1,667,581	1,369,543	1,262,688	1,225,602	1,090,026	1,131,295	1,077,174	26,929,350
	Total Flow Out of Model	-1,166,491	-977,048	-916,223	-857,489	-879,295	-882,937	-872,259	-975,460	-868,708	-1,444,077	-1,175,867	-1,134,672	-1,453,298	-948,382	-889,323	-1,014,039	-914,195	-899,864	-912,995	-1,667,581	-1,369,542	-1,262,688	-1,225,603	-1,090,028	-1,131,297	-1,077,174	-26,929,361
	Difference	-1	0	0	0	0	0	0	-1	0	-1	-1	-1	0	0	0	-1	0	0	-1	0	0	-1	-1	-1	-1	0	-11

Notes:

1: Values shown exported from model cell centered flow (.ccf) file. Rounding during data export has resulted in minor differences between change in storage and total flow terms and the sum of individual flow budget components.

Table 7-1. Differences to the model in the KWB Without Scenario

All values in Acre-Feet

Year	Managed Recharge	Agricultural Pumping	Agricultural Return Flow	Recovery Pumping
1986	-	-	-	-
1987	-	-	-	-
1988	-	-	-	-
1989	-	-	-	-
1990	-	-	-	-
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	(222,236)	6,000	1,200	-
1996	(173,851)	6,000	1,200	-
1997	(112,238)	6,000	1,200	-
1998	(303,063)	6,000	1,200	-
1999	(36,730)	6,000	1,200	-
2000	(27,555)	6,000	1,200	-
2001	(10,006)	6,000	1,200	(88,695)
2002	(13,416)	6,000	1,200	(27,597)
2003	(40,351)	6,000	1,200	(48,367)
2004	(18,041)	6,000	1,200	(49,289)
2005	(387,533)	6,000	1,200	-
2006	(283,210)	6,000	1,200	-
2007	(16,704)	6,000	1,200	(230,686)
2008	-	6,000	1,200	(233,703)
2009	-	6,000	1,200	(162,461)
2010	(33,107)	6,000	1,200	(50,969)
TOTAL	(1,678,043)	96,000	19,200	(891,767)
AVG	(67,122)	3,840	768	(35,671)

Table 7-2. Differences to the model in the KCWA Without Scenario

All values in Acre-Feet

Year	Managed Recharge	Agricultural Pumping	Agricultural Return Flow	Recovery Pumping	Urban Pumping	Urban Return Flow
1986	(18,224)	-	-	-	-	-
1987	-	-	-	-	-	-
1988	-	-	-	-	-	-
1989	-	-	-	-	-	-
1990	-	-	-	-	-	-
1991	-	-	-	-	-	-
1992	-	-	-	-	-	-
1993	(20,559)	-	-	-	-	-
1994	(2,025)	-	-	-	-	-
1995	(114,009)	2,622	433	-	-	-
1996	(55,653)	3,019	550	-	-	-
1997	(36,651)	3,068	597	-	-	-
1998	(89,101)	1,657	226	-	-	-
1999	(14,368)	1,682	295	-	-	-
2000	(16,325)	2,963	485	-	-	-
2001	(1,256)	2,707	467	(62,893)	-	-
2002	(1,444)	3,765	683	(11,811)	-	-
2003	(9,093)	3,316	542	(6,259)	420	42
2004	(9,685)	4,271	802	(9,517)	426	43
2005	(146,097)	2,680	531	(378)	1,170	117
2006	(87,459)	3,654	616	-	1,162	116
2007	(6,913)	3,835	723	(83,255)	1,164	116
2008	-	3,638	678	(111,935)	1,170	117
2009	-	4,010	757	(94,100)	1,230	123
2010	(10,058)	2,874	519	(24,441)	1,164	116
TOTAL	(638,919)	49,761	8,902	(404,589)	7,906	791
AVG	(25,557)	1,990	356	(16,184)	316	32

Table 7-3. Differences to the model in the RRBWSD Without Scenario

All values in Acre-Feet

Year	Managed Recharge	Agricultural Pumping	Agricultural Return Flow
1986	-	-	-
1987	-	-	-
1988	-	-	-
1989	-	-	-
1990	-	-	-
1991	-	-	-
1992	-	-	-
1993	-	-	-
1994	-	-	-
1995	-	-	-
1996	-	-	-
1997	-	-	-
1998	-	-	-
1999	-	-	-
2000	-	-	-
2001	-	-	-
2002	-	-	-
2003	-	-	-
2004	10,901	(2,554)	-
2005	(87,199)	(8,142)	-
2006	(80,918)	(5,096)	-
2007	16,506	(1,022)	-
2008	9,081	(1,062)	-
2009	9,012	-	-
2010	(117,205)	(2,797)	-
TOTAL	(239,822)	(20,674)	-
AVG	(9,593)	(827)	-

Table 7-4. Differences to the model in the BVWSD Without Scenario

All values in Acre-Feet

Year	Managed Recharge
1986	(35,622)
1987	-
1988	-
1989	(865)
1990	-
1991	-
1992	-
1993	(13,847)
1994	-
1995	(22,468)
1996	(668)
1997	(22,252)
1998	(91,539)
1999	(592)
2000	-
2001	-
2002	(357)
2003	-
2004	-
2005	(7,678)
2006	(23,487)
2007	-
2008	-
2009	-
2010	(5,056)
TOTAL	(224,431)
AVG	(8,977)

Table 7-5. Differences to the model in the Combined Projects Without Scenario

All values in Acre-Feet

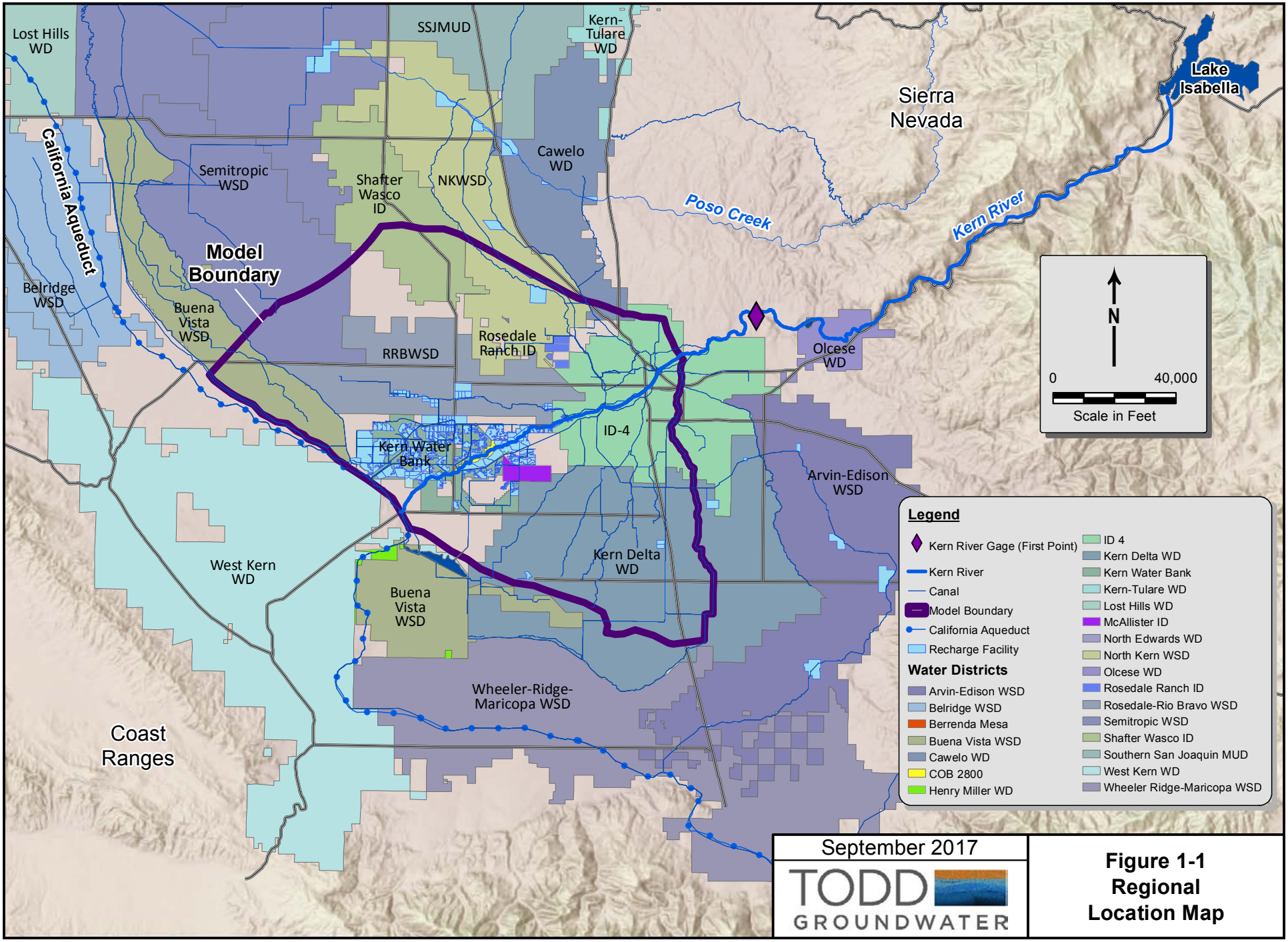
Year	Managed Recharge	Agricultural Pumping	Agricultural Return Flow	Recovery Pumping	Urban Pumping	Urban Return Flow
1986	(53,846)	-	-	-	-	-
1987	-	-	-	-	-	-
1988	-	-	-	-	-	-
1989	(865)	-	-	-	-	-
1990	-	-	-	-	-	-
1991	-	-	-	-	-	-
1992	-	-	-	-	-	-
1993	(34,406)	-	-	-	-	-
1994	(2,025)	-	-	-	-	-
1995	(358,713)	8,622	1,633	-	-	-
1996	(230,173)	9,019	1,750	-	-	-
1997	(171,141)	9,068	1,797	-	-	-
1998	(483,703)	7,657	1,426	-	-	-
1999	(51,690)	7,682	1,495	-	-	-
2000	(43,880)	8,963	1,685	-	-	-
2001	(11,262)	8,707	1,667	(151,588)	-	-
2002	(15,217)	9,765	1,883	(39,408)	-	-
2003	(49,444)	9,316	1,742	(54,626)	420	42
2004	(16,825)	7,716	2,002	(58,806)	426	43
2005	(628,508)	538	1,731	(378)	1,170	117
2006	(475,074)	4,557	1,816	-	1,162	116
2007	(7,112)	8,813	1,923	(313,941)	1,164	116
2008	9,081	8,576	1,878	(345,638)	1,170	117
2009	9,012	10,010	1,957	(256,561)	1,230	123
2010	(165,427)	6,077	1,719	(75,410)	1,164	116
TOTAL	(2,781,215)	125,087	28,102	(1,296,356)	7,906	791
AVG	(111,249)	5,003	1,124	(51,854)	316	32

Table 7-6. Total Differences to the Model in the Without Scenario for Each Project

All values in Acre-Feet

	KWB	KCWA	RRB	BV	Combined
Managed Recharge	(1,678,043)	(638,919)	(239,822)	(224,431)	(2,781,215)
Agricultural Pumping	(96,000)	(49,761)	20,674	-	(125,087)
Agricultural Return flow	19,200	8,902	-	-	28,102
Recovery Pumping	891,767	404,589	-	-	1,296,356
Urban Pumping	-	7,906	-	-	7,906
Urban Return Flow	-	791	-	-	791

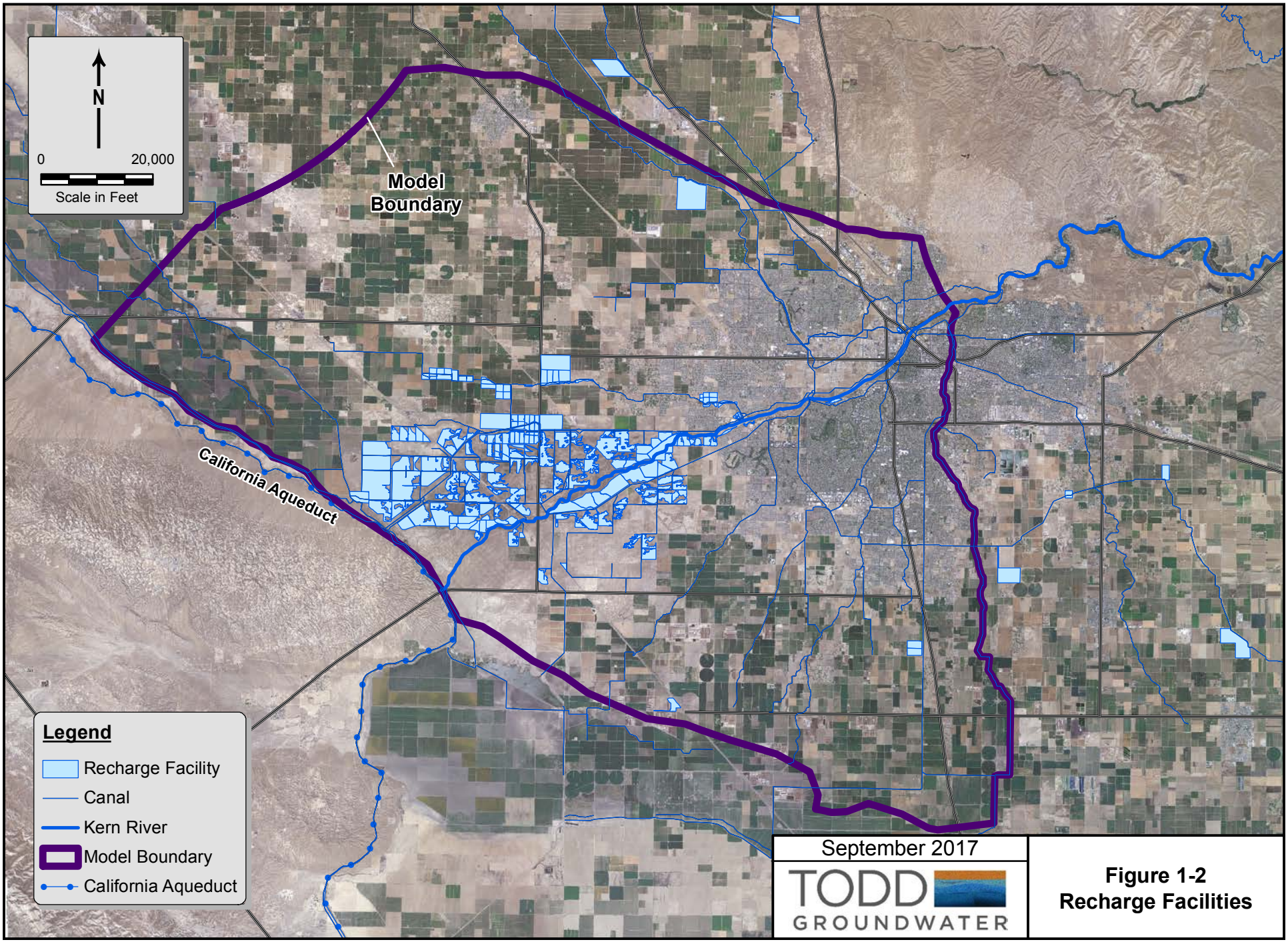
FIGURES



September 2017

TODD GROUNDWATER

Figure 1-1
Regional Location Map


N
0
20,000
Scale in Feet
Model Boundary
California Aqueduct
Legend
Recharge Facility
Canal
Kern River
Model Boundary
California Aqueduct
September 2017
TODD GROUNDWATER
Figure 1-2
Recharge Facilities

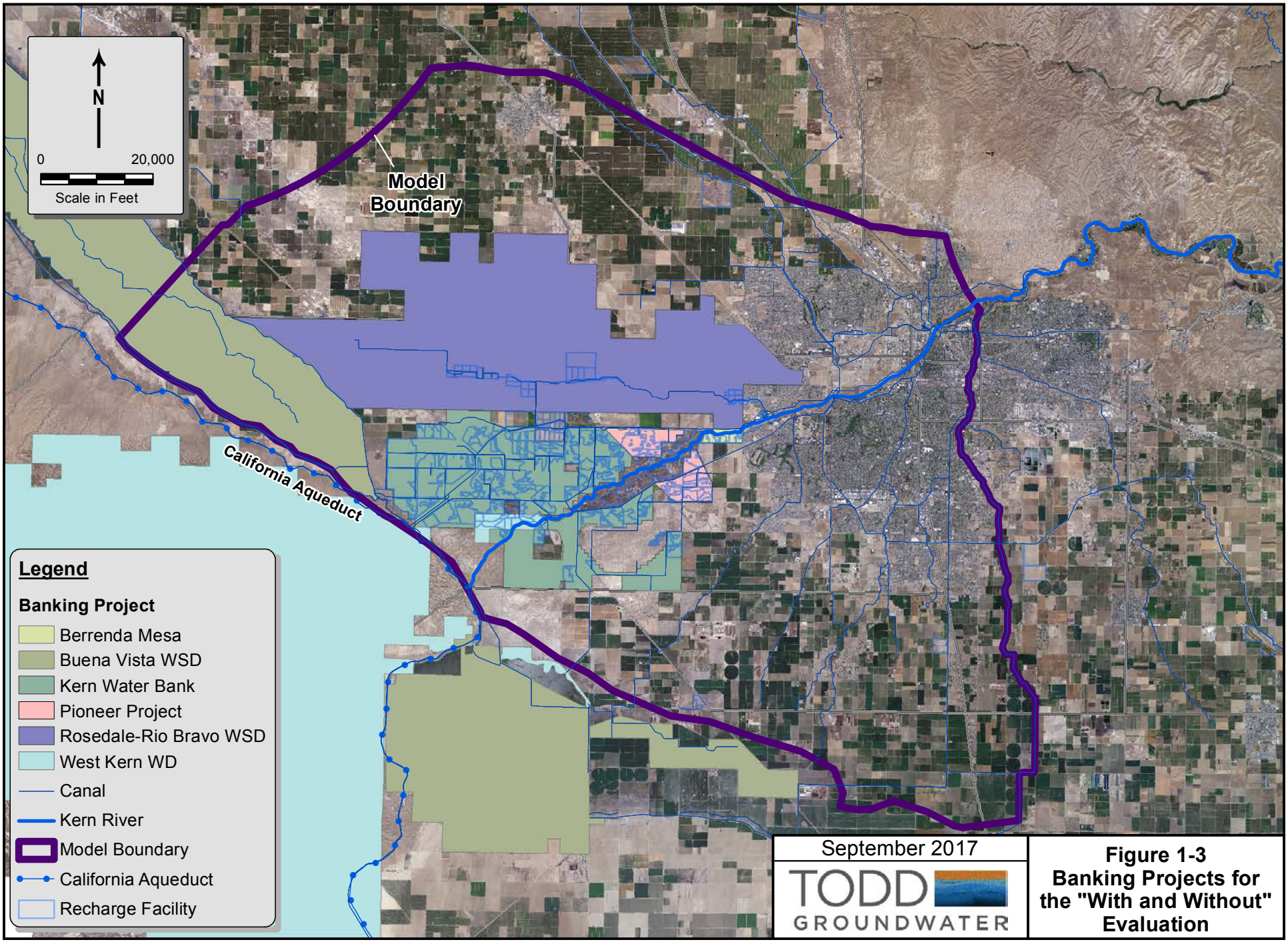
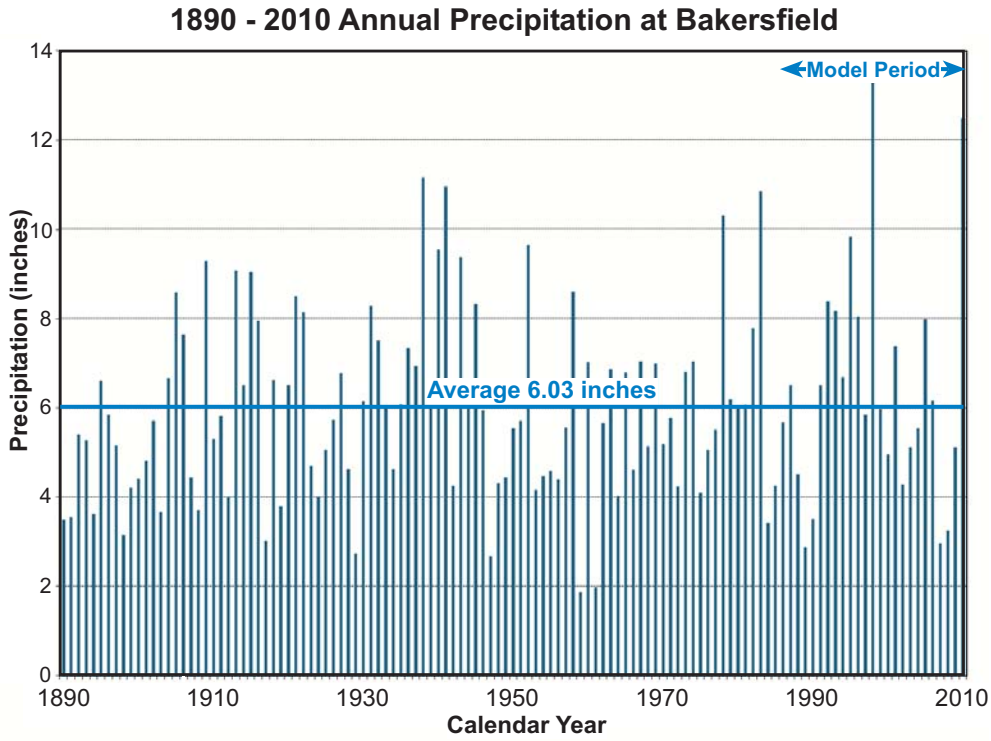
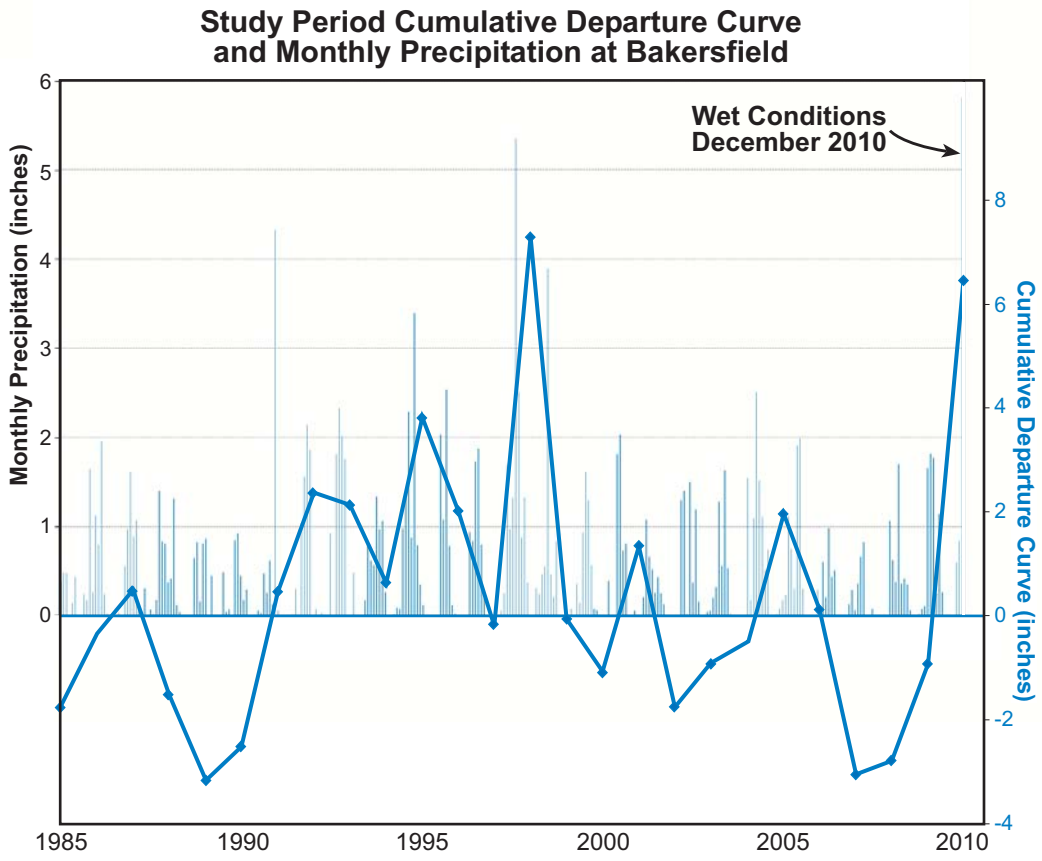


Figure 1-3
Banking Projects for the "With and Without" Evaluation

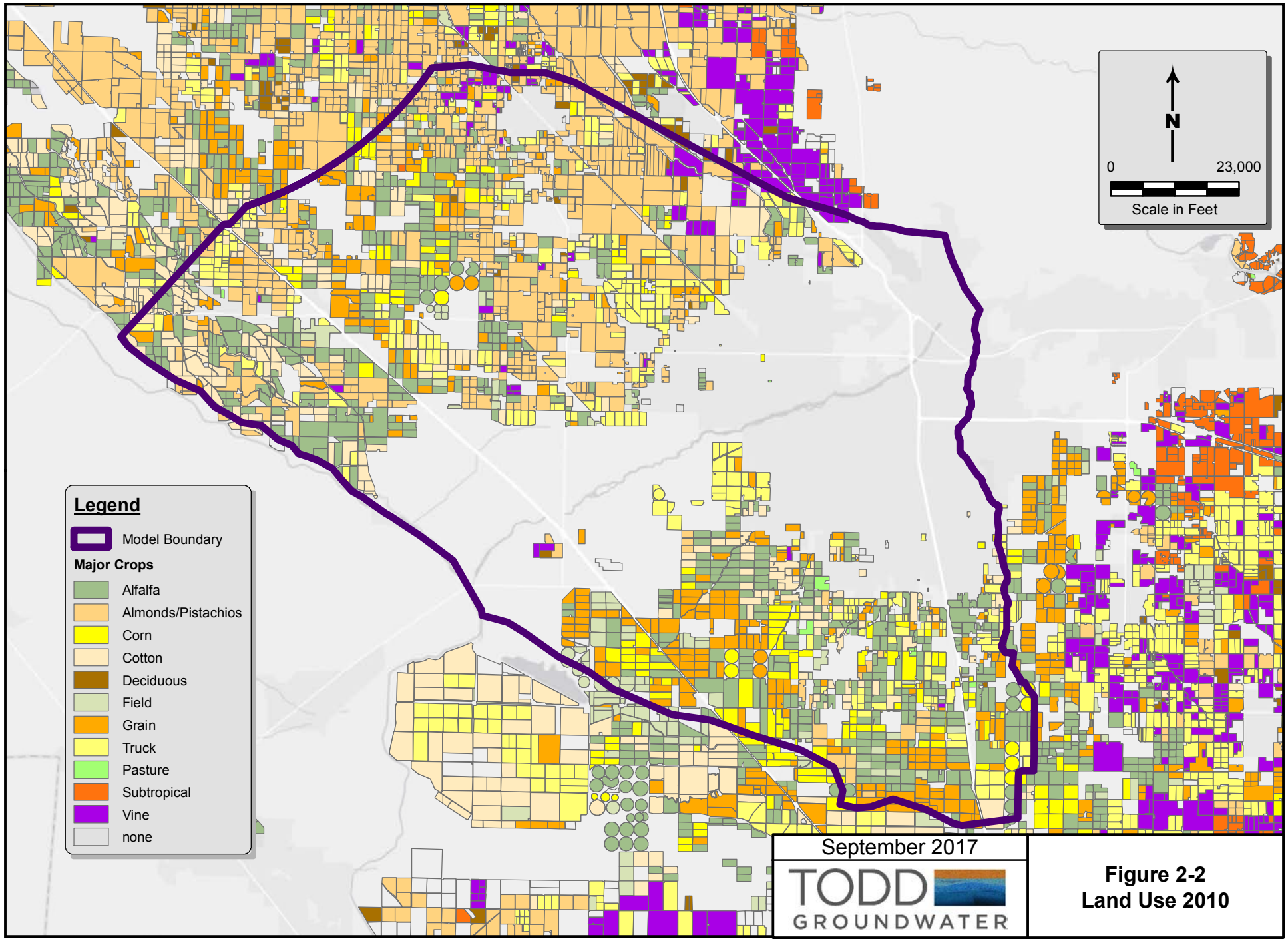


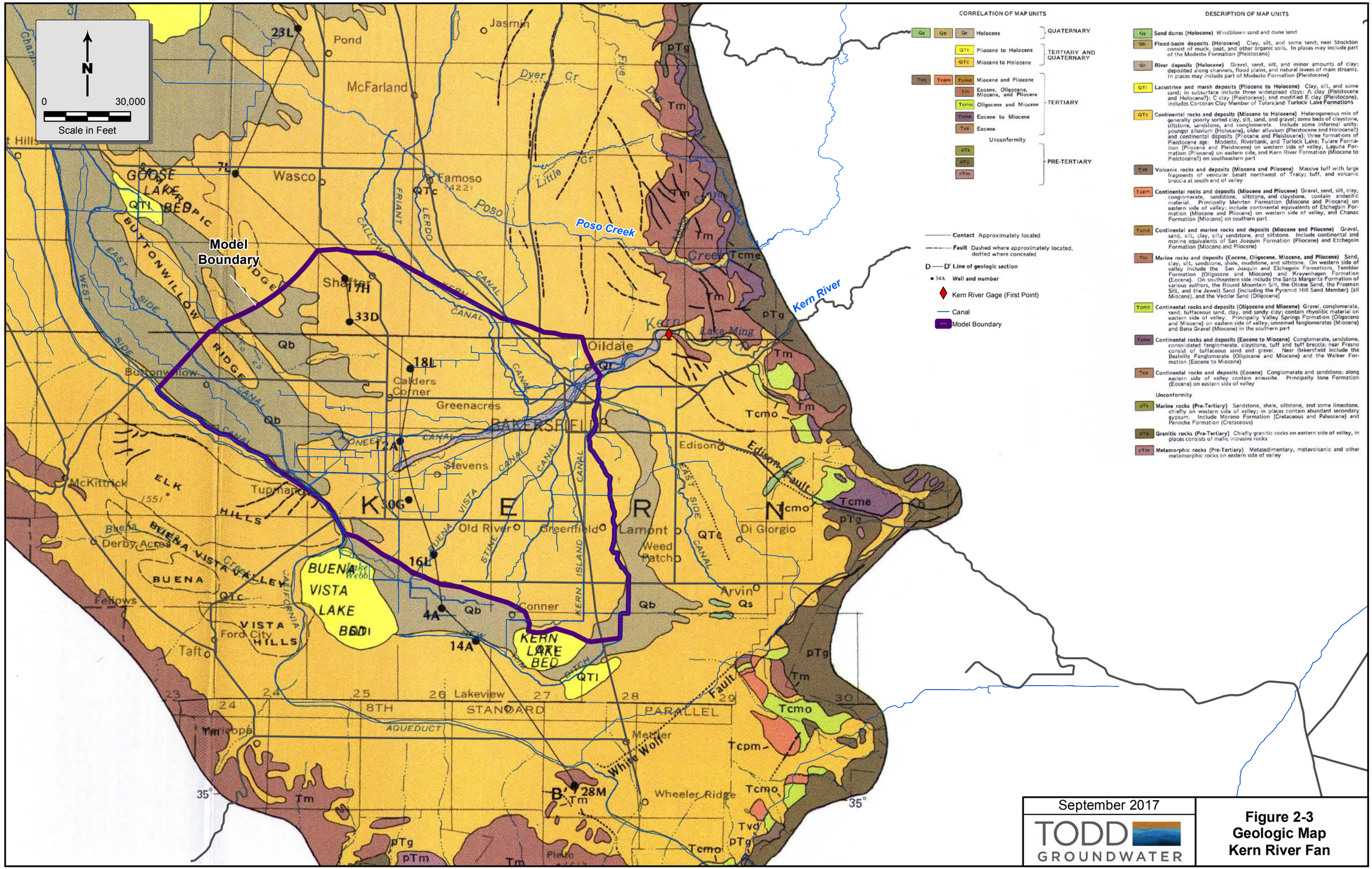


September 2017

TODD GROUNDWATER

Figure 2-1
Precipitation and Cumulative Departure Curve


N
0
23,000
Scale in Feet
Legend
Model Boundary
Major Crops
Alfalfa
Almonds/Pistachios
Corn
Cotton
Deciduous
Field
Grain
Truck
Pasture
Subtropical
Vine
none
September 2017
TODD GROUNDWATER
Figure 2-2
Land Use 2010

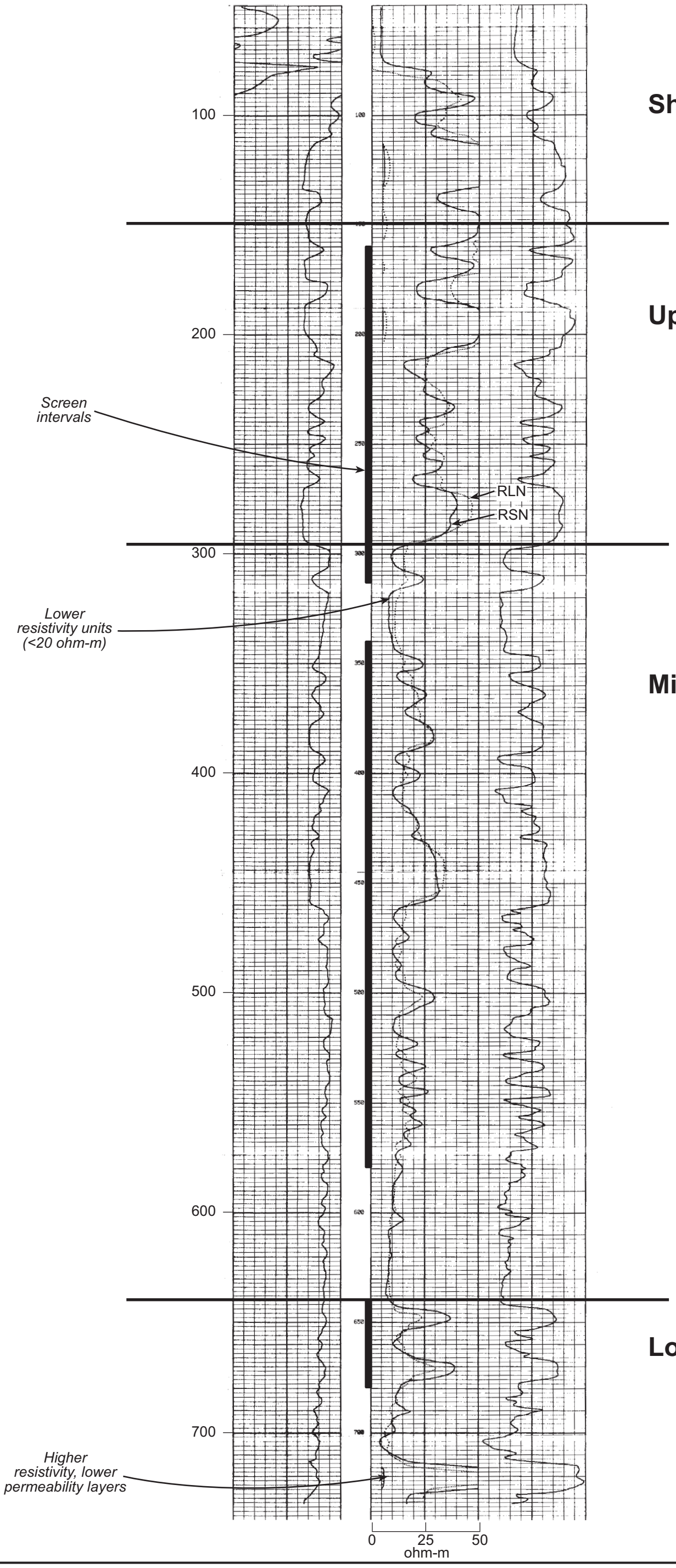


September 2017

TODD GROUNDWATER

Figure 2-3
Geologic Map
Kern River Fan

Example Electric Log
Pioneer Project
30S/26E-9E01



Shallowest Unit

Upper Unit

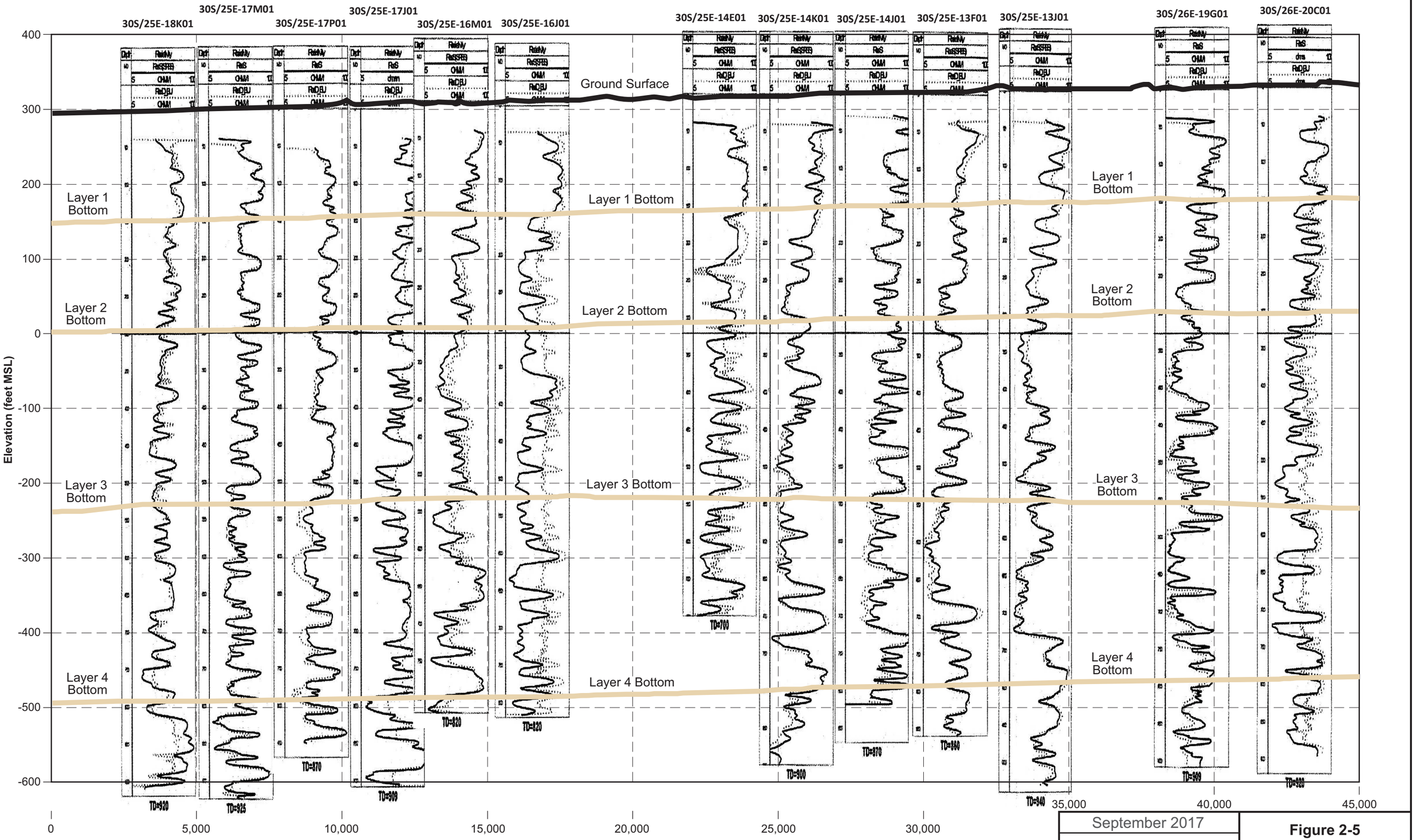
Middle Unit

Lower Unit

Figure 2-4
Hydrostratigraphic Units

September 2017

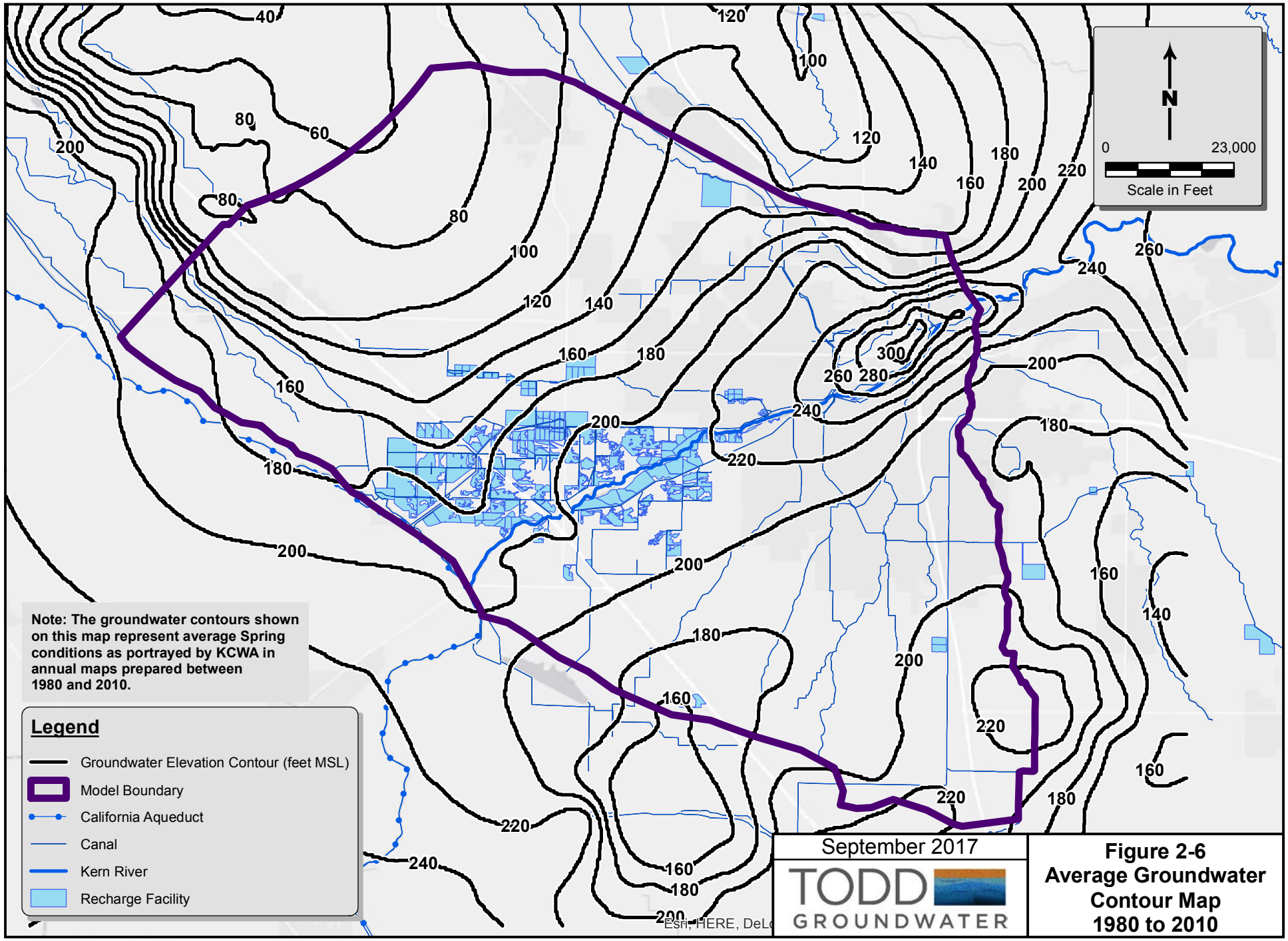
TODD GROUNDWATER



September 2017

TODD GROUNDWATER

Figure 2-5
Schematic Section with Geophysical Logs and Model Layers


N
0
23,000
Scale in Feet
Note: The groundwater contours shown on this map represent average Spring conditions as portrayed by KCWA in annual maps prepared between 1980 and 2010.
Legend
Groundwater Elevation Contour (feet MSL)
Model Boundary
California Aqueduct
Canal
Kern River
Recharge Facility
September 2017
TODD GROUNDWATER
Figure 2-6
Average Groundwater Contour Map
1980 to 2010

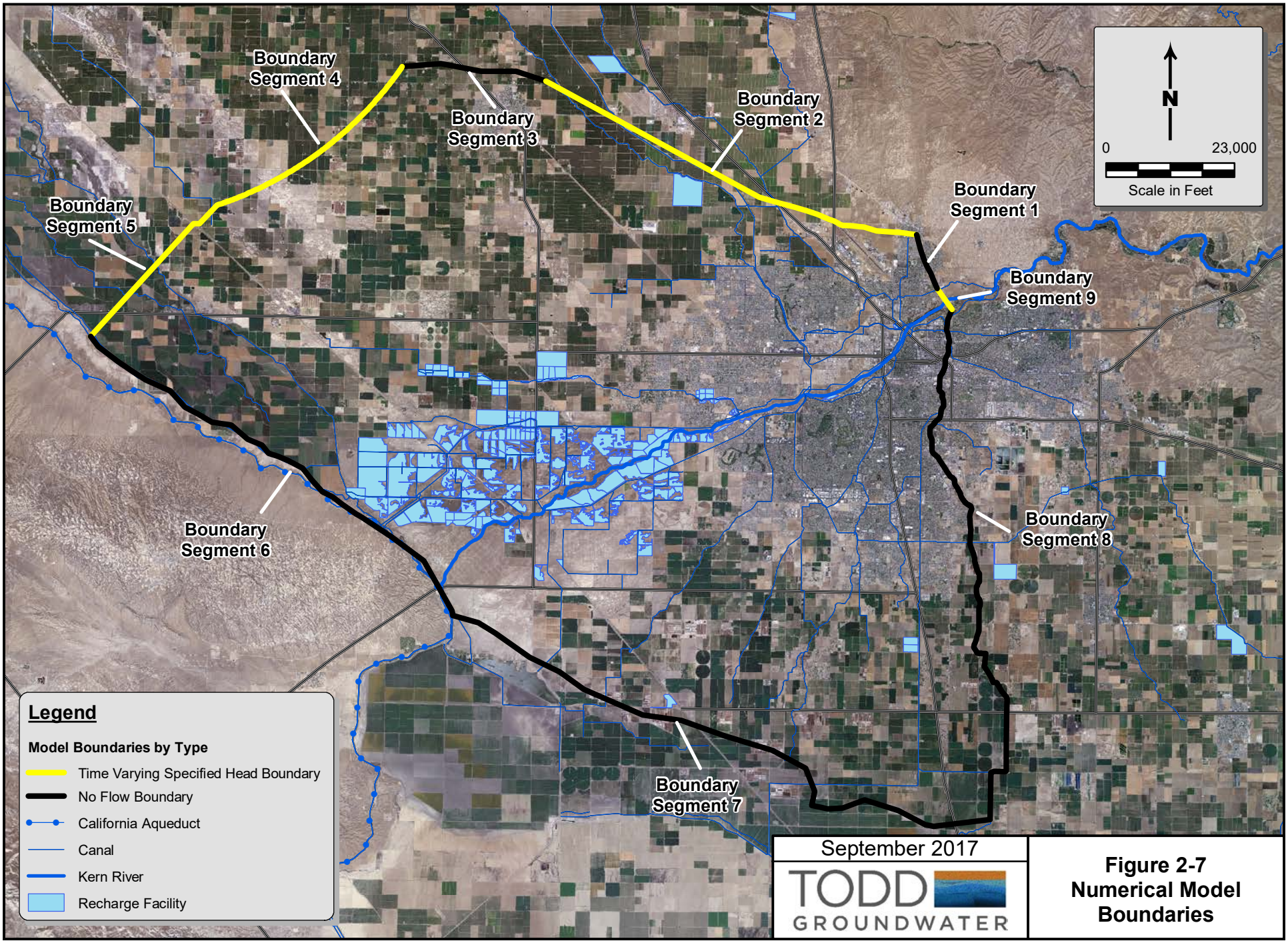
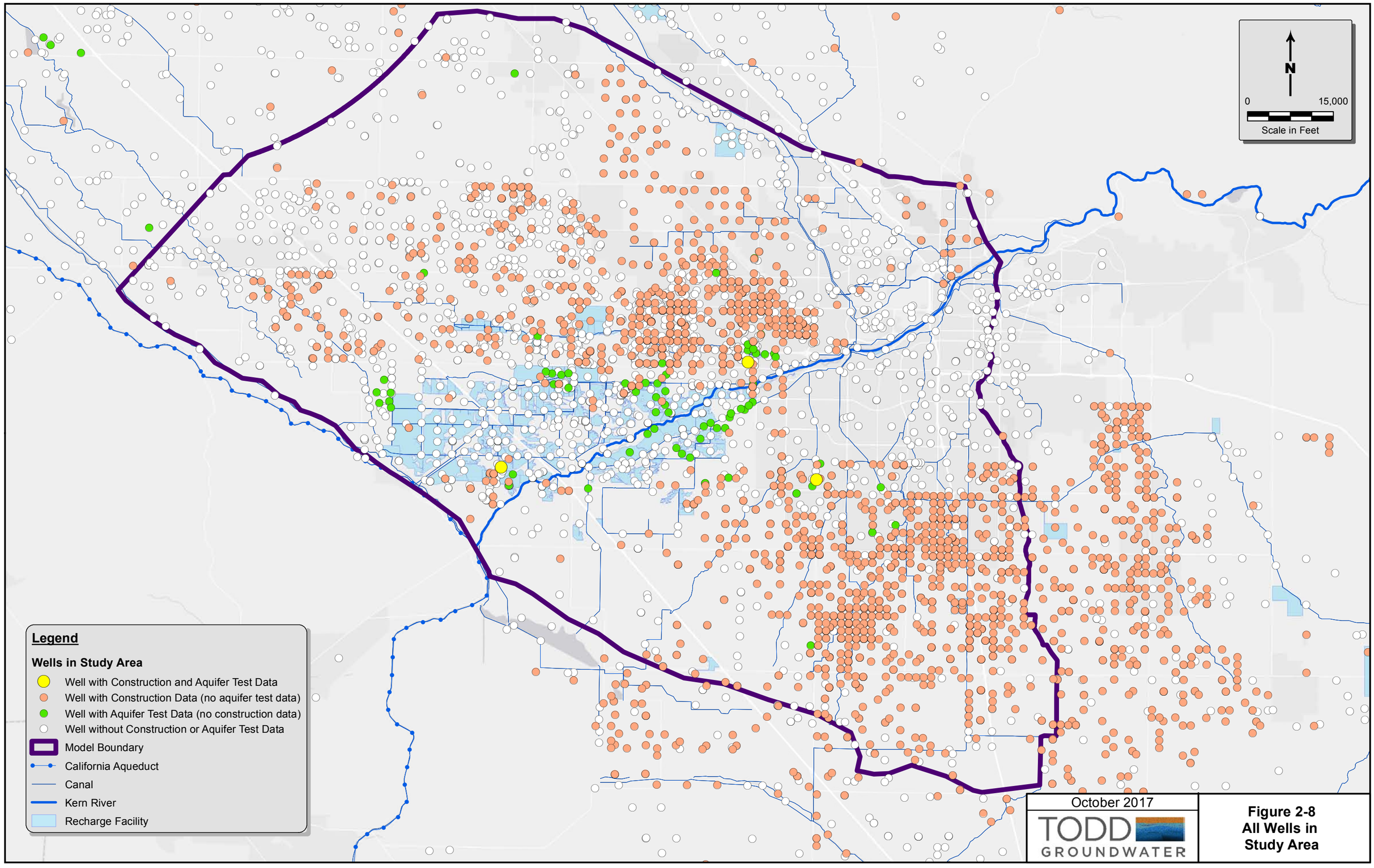
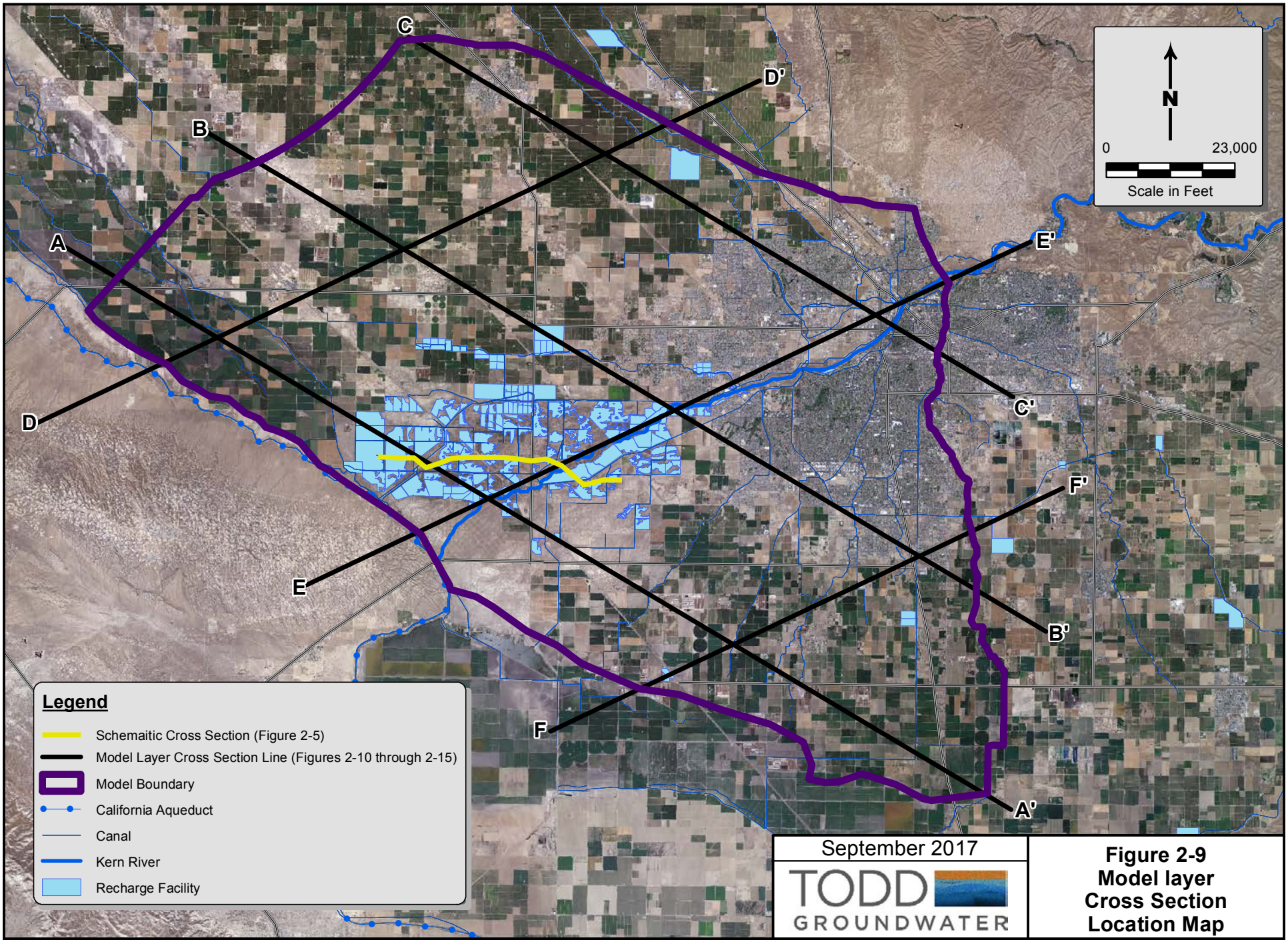


Figure 2-7
Numerical Model Boundaries

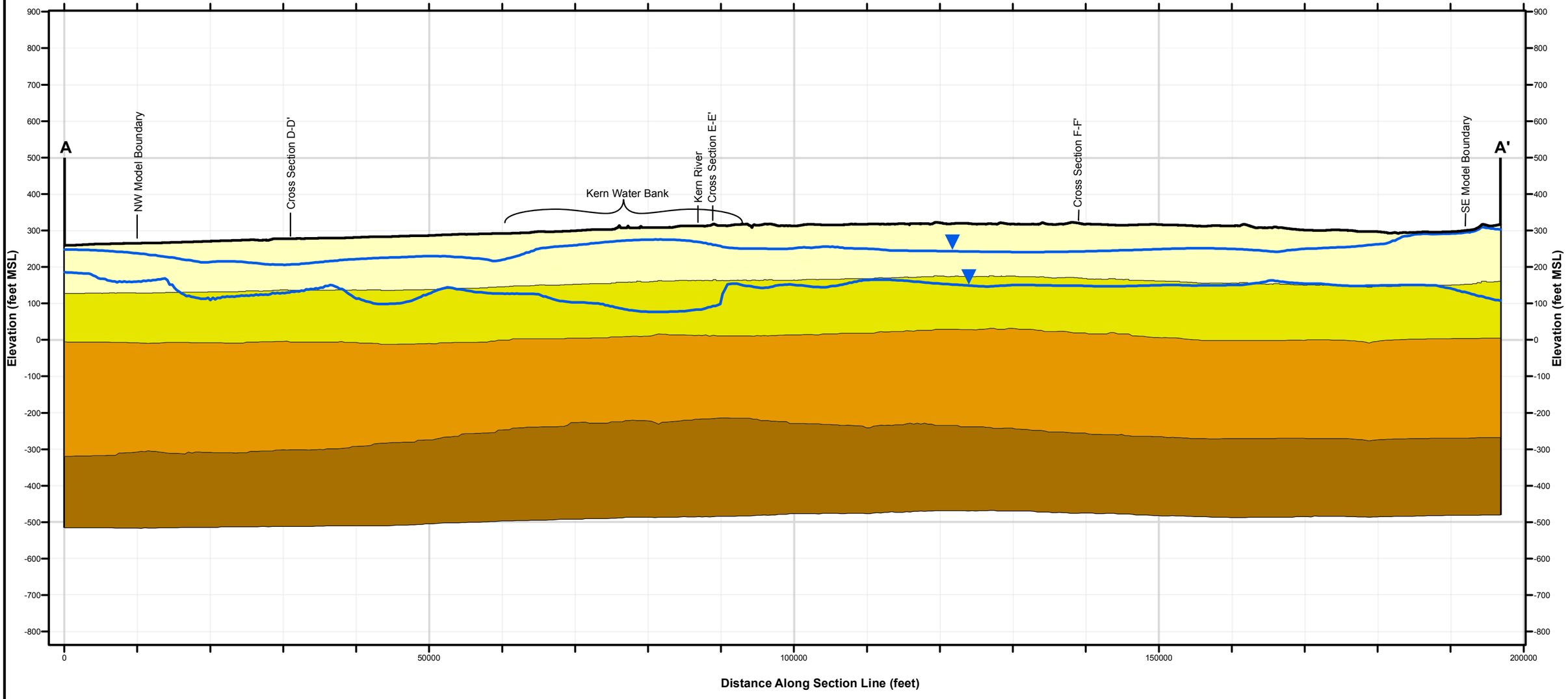

N
0
15,000
Scale in Feet
Legend
Wells in Study Area
Well with Construction and Aquifer Test Data
Well with Construction Data (no aquifer test data)
Well with Aquifer Test Data (no construction data)
Well without Construction or Aquifer Test Data
Model Boundary
California Aqueduct
Canal
Kern River
Recharge Facility
October 2017
TODD GROUNDWATER
Figure 2-8
All Wells in
Study Area



September 2017

TODD GROUNDWATER

Figure 2-9
Model layer Cross Section Location Map



Legend

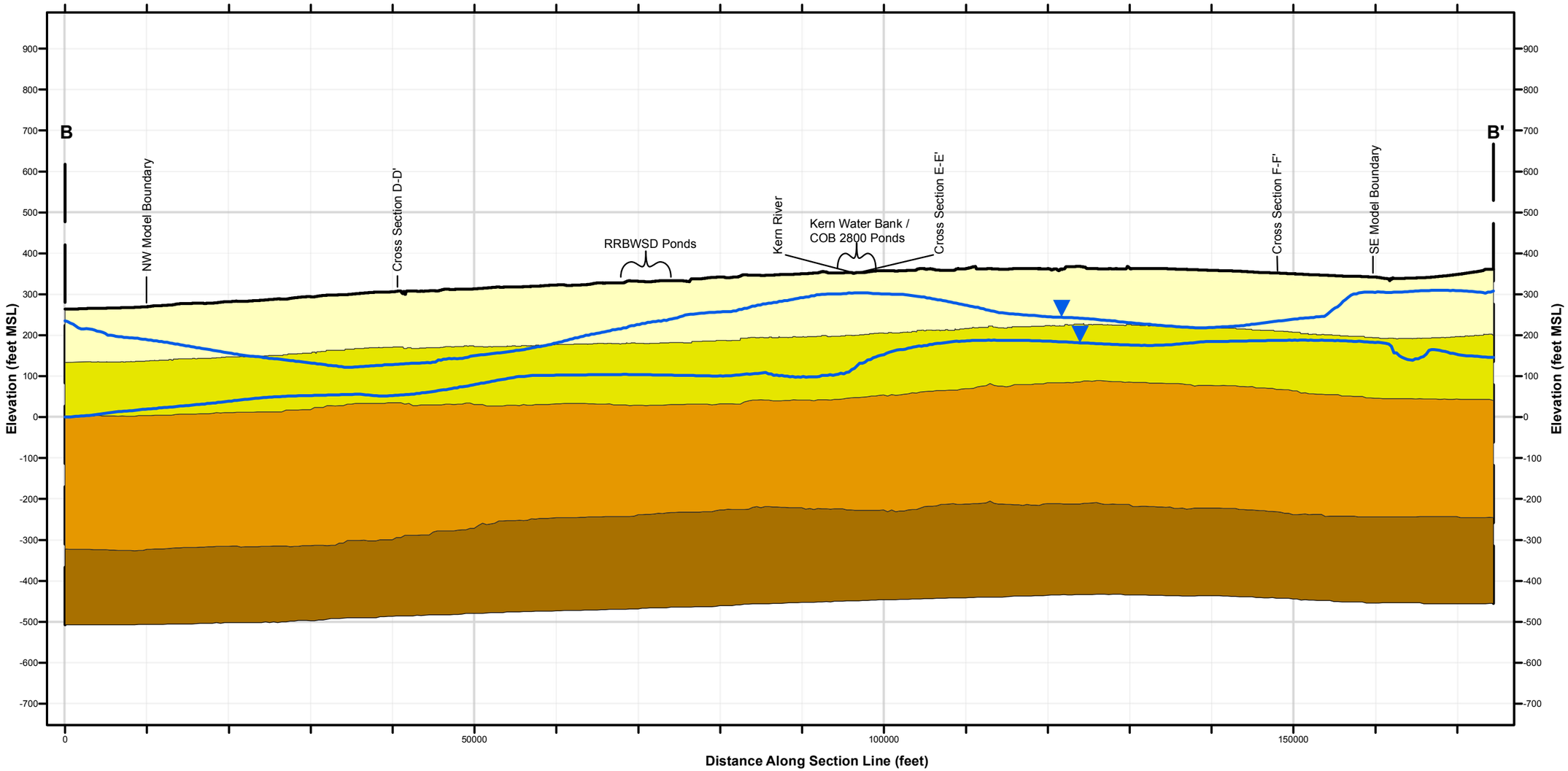
- Range of Historical Groundwater Elevations (from KCWA)
- Model Layer 1
- Model Layer 2
- Model Layer 3
- Model Layer 4

50 x Vertical Exaggeration

September 2017

TODD GROUNDWATER

Figure 2-10
Hydrogeologic Cross Section A - A'



Legend

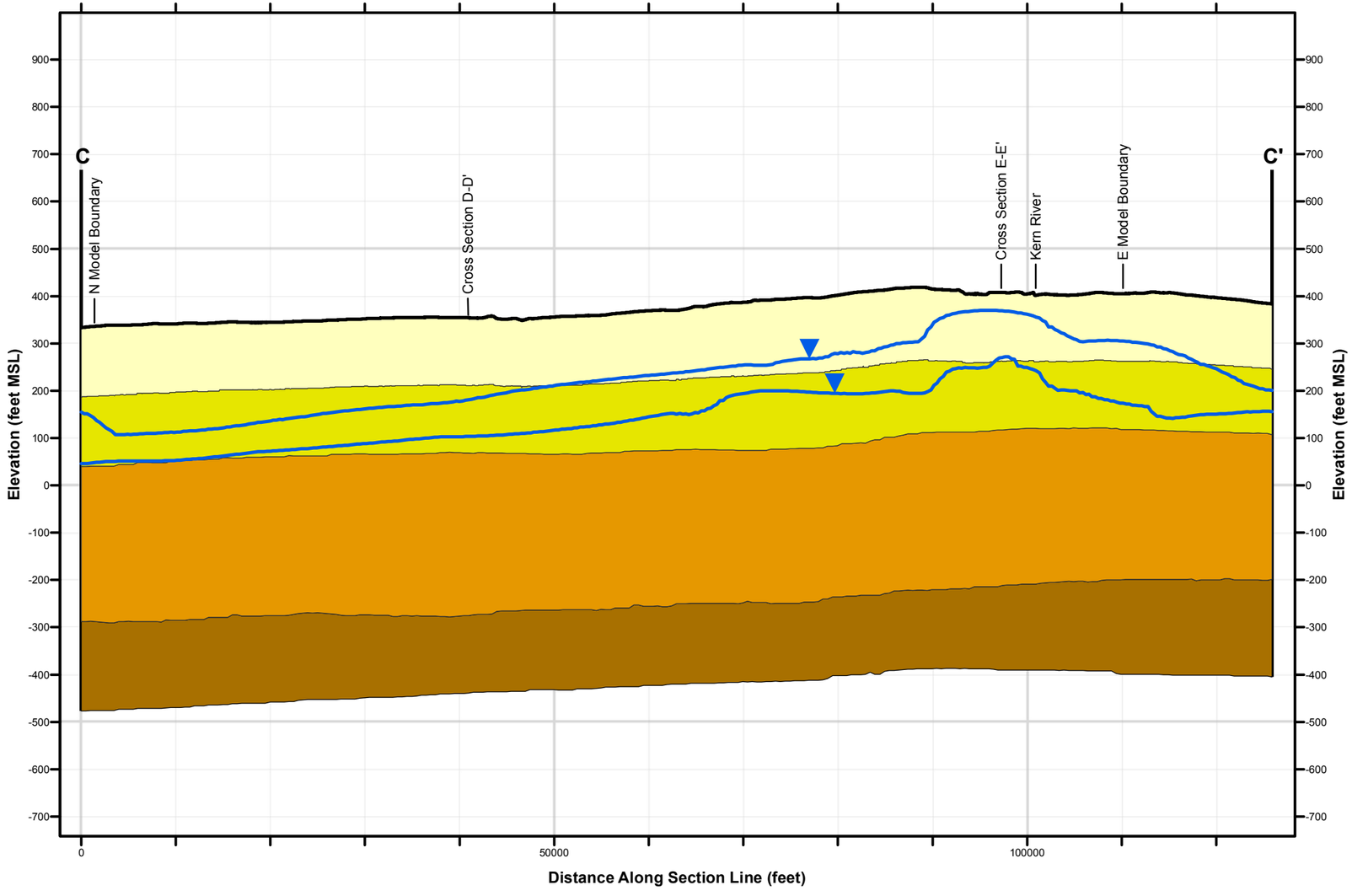
- Range of Historical Groundwater Elevations (from KCWA)
- Model Layer 1
- Model Layer 2
- Model Layer 3
- Model Layer 4

50 x Vertical Exaggeration

September 2017

TODD GROUNDWATER

Figure 2-11
Hydrogeologic Cross Section B - B'



Legend

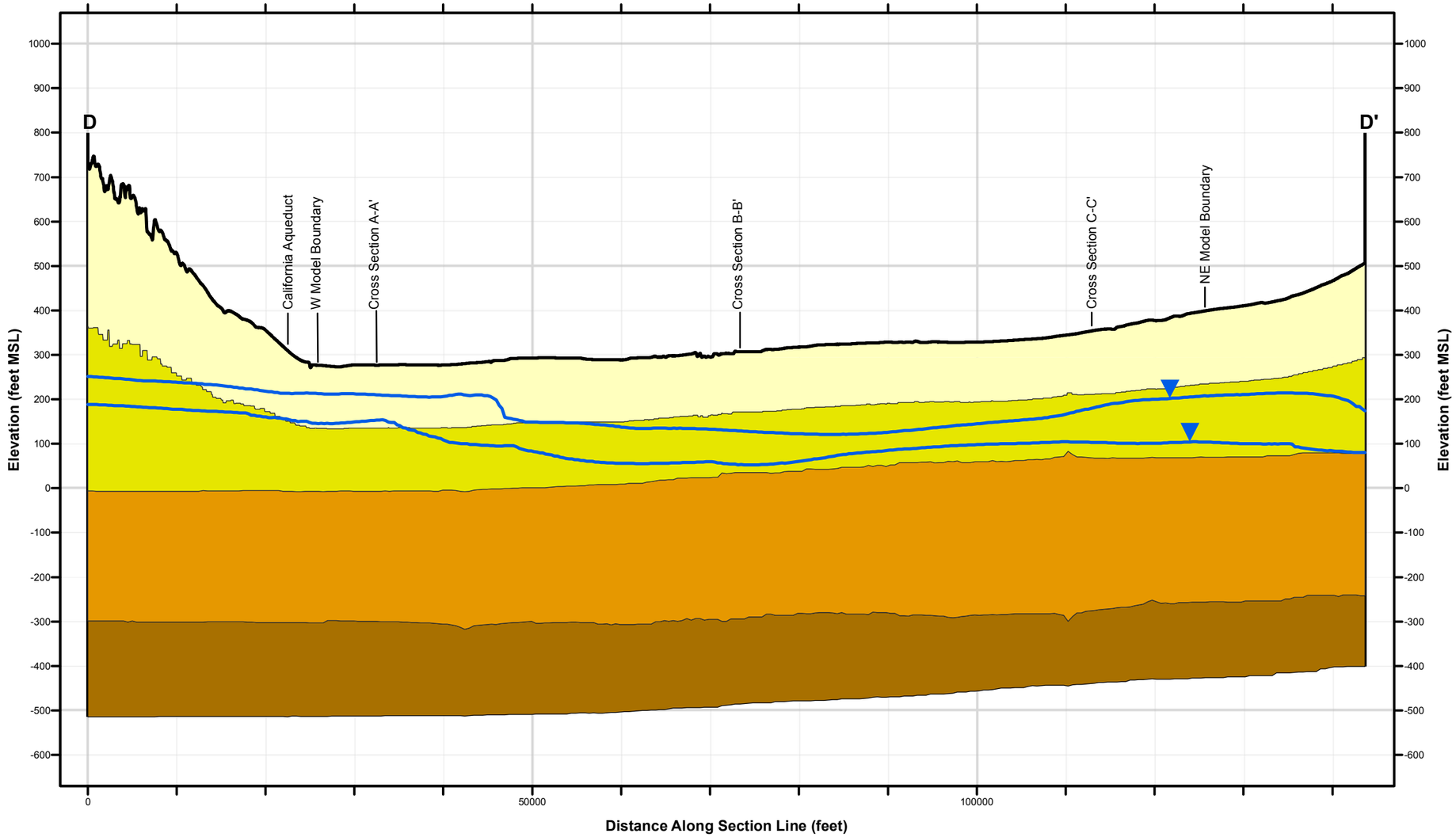
- Range of Historical Groundwater Elevations (from KCWA)
- Model Layer 1
- Model Layer 2
- Model Layer 3
- Model Layer 4

50 x Vertical Exaggeration

September 2017

TODD GROUNDWATER

Figure 2-12
Hydrogeologic Cross Section C - C'



Legend

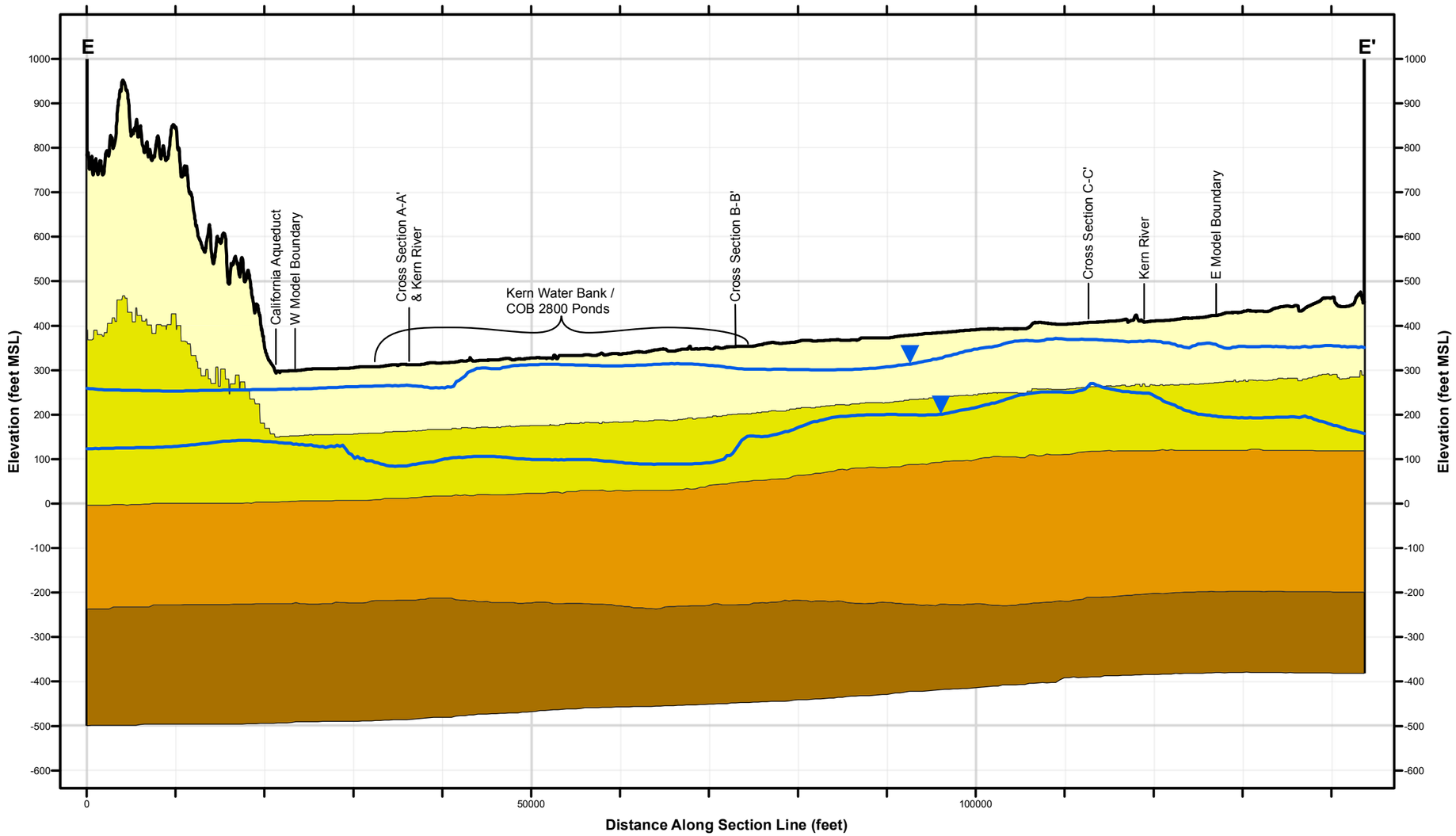
- Range of Historical Groundwater Elevations (from KCWA)
- Model Layer 1
- Model Layer 2
- Model Layer 3
- Model Layer 4

50 x Vertical Exaggeration

September 2017

TODD GROUNDWATER

Figure 2-13
Hydrogeologic Cross Section D - D'



Legend

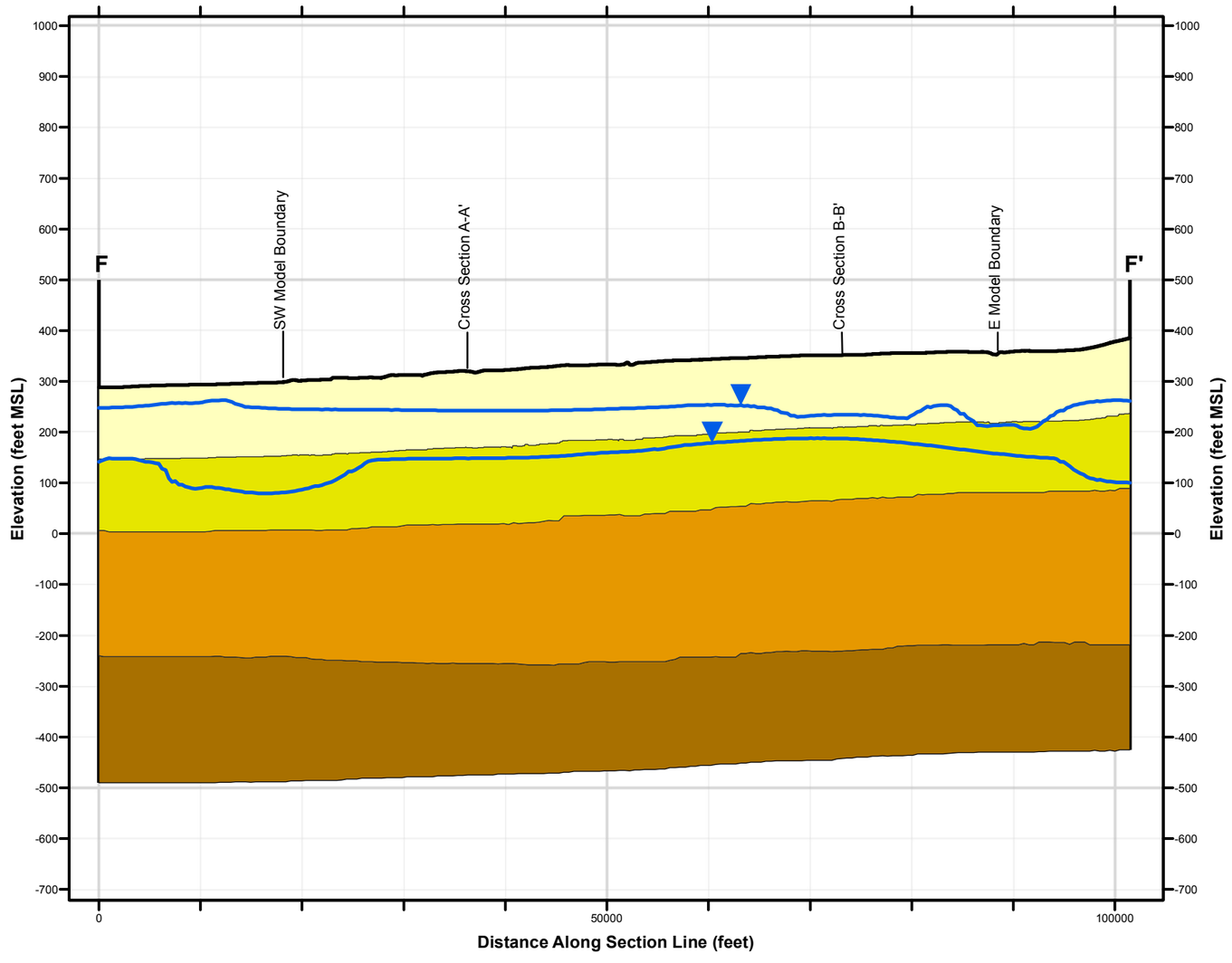
- Range of Historical Groundwater Elevations (from KCWA)
- Model Layer 1
- Model Layer 2
- Model Layer 3
- Model Layer 4

50 x Vertical Exaggeration

September 2017

TODD GROUNDWATER

Figure 2-14
Hydrogeologic Cross Section E - E'



Legend

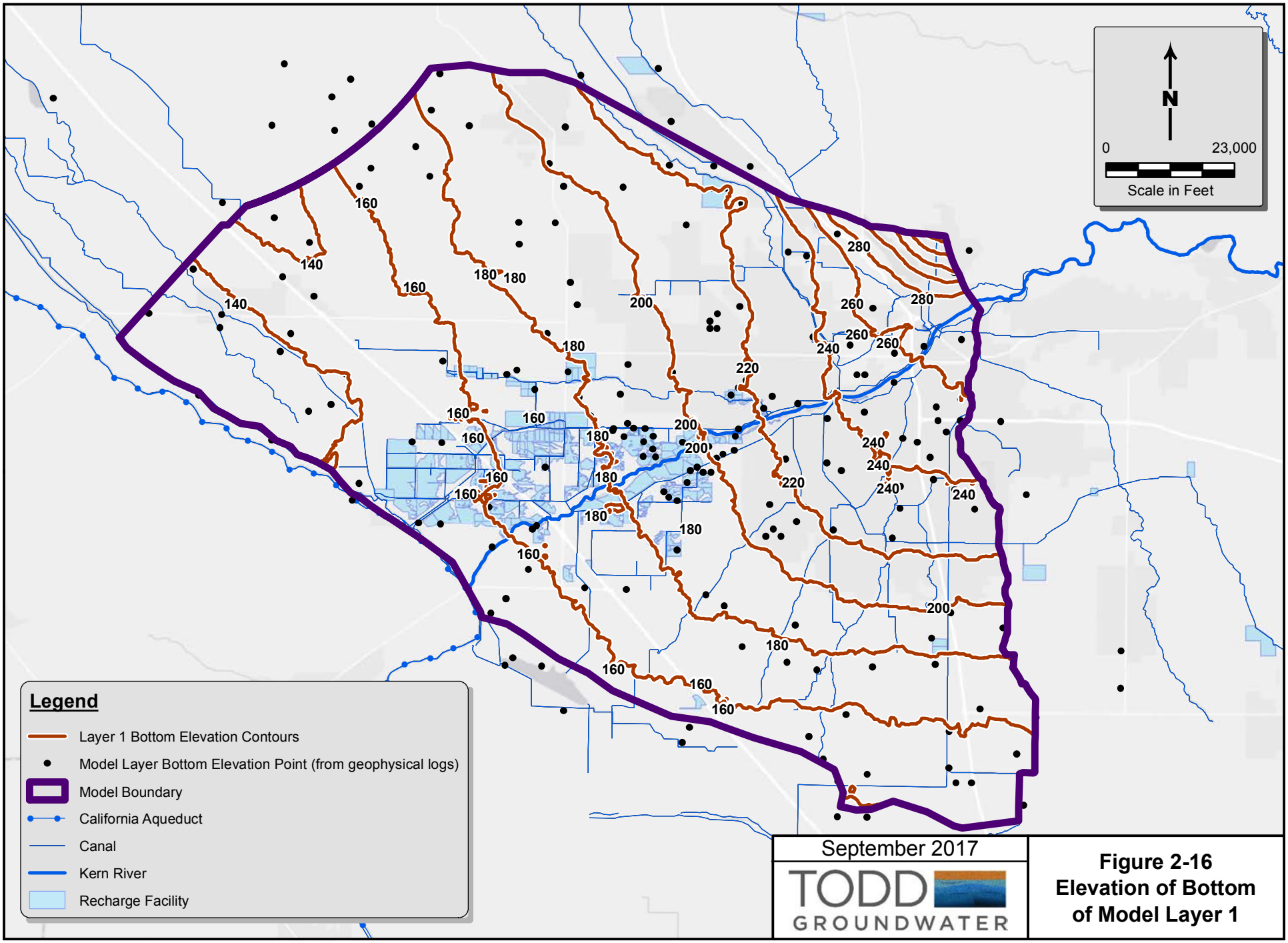
- Range of Historical Groundwater Elevations (from KCWA)
- Model Layer 1
- Model Layer 2
- Model Layer 3
- Model Layer 4

50 x Vertical Exaggeration

September 2017

TODD GROUNDWATER

Figure 2-15
Hydrogeologic Cross Section F - F'


N
0
23,000
Scale in Feet
Legend
Layer 1 Bottom Elevation Contours
Model Layer Bottom Elevation Point (from geophysical logs)
Model Boundary
California Aqueduct
Canal
Kern River
Recharge Facility
140
160
180
200
220
240
260
280
September 2017
TODD GROUNDWATER
Figure 2-16
Elevation of Bottom
of Model Layer 1

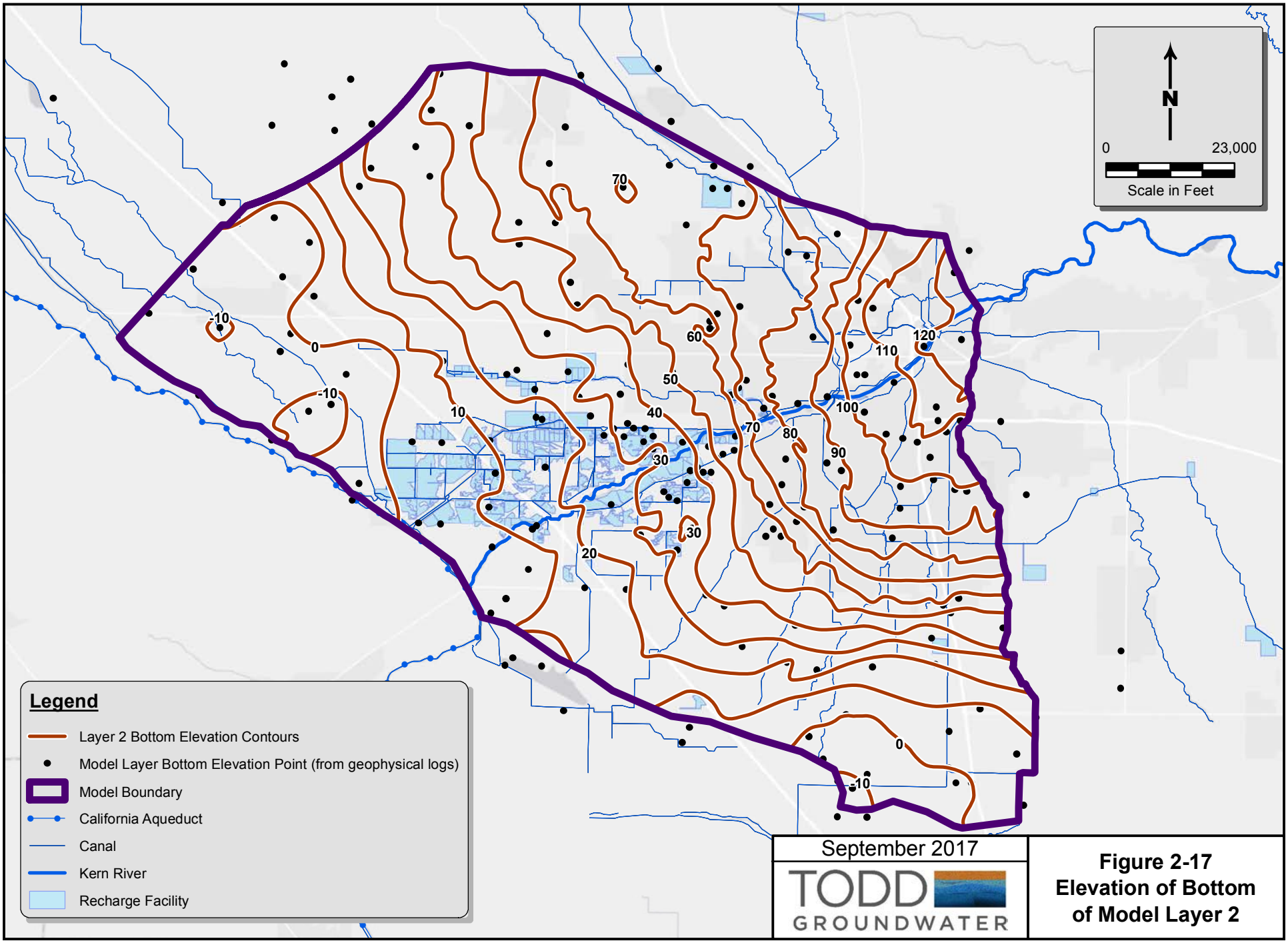


Figure 2-17
Elevation of Bottom of Model Layer 2

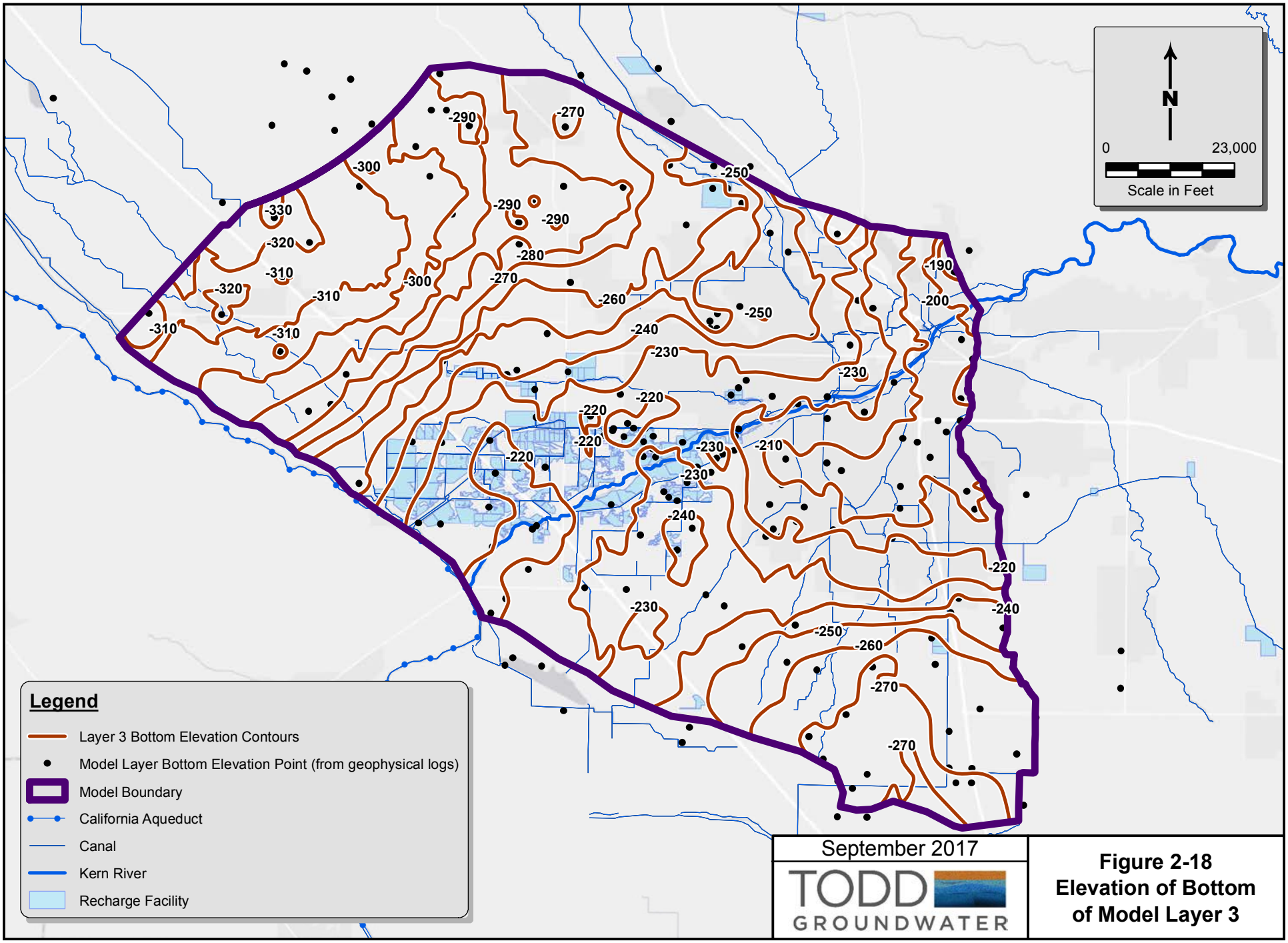


Figure 2-18
Elevation of Bottom of Model Layer 3

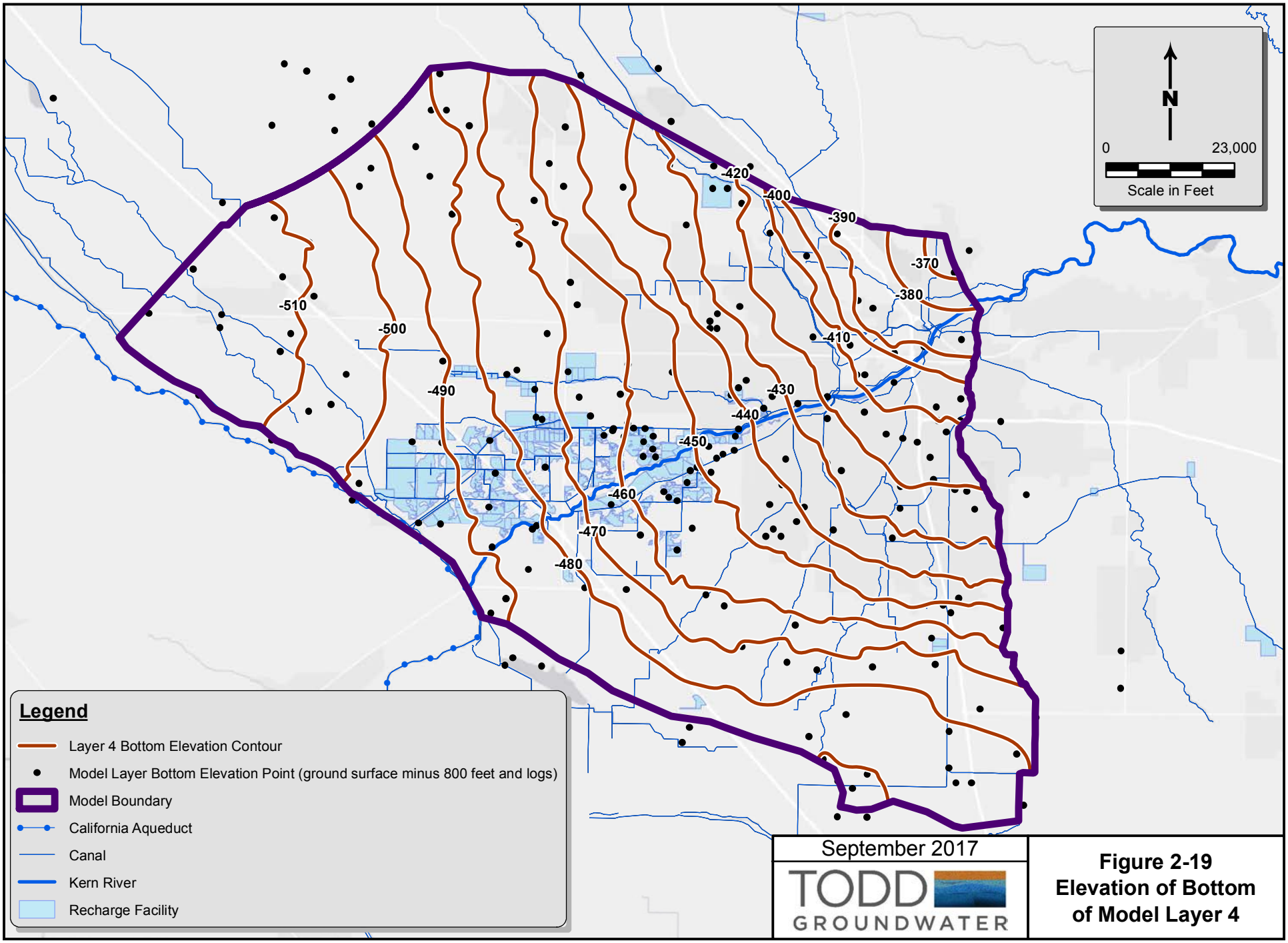


Figure 2-19
Elevation of Bottom of Model Layer 4

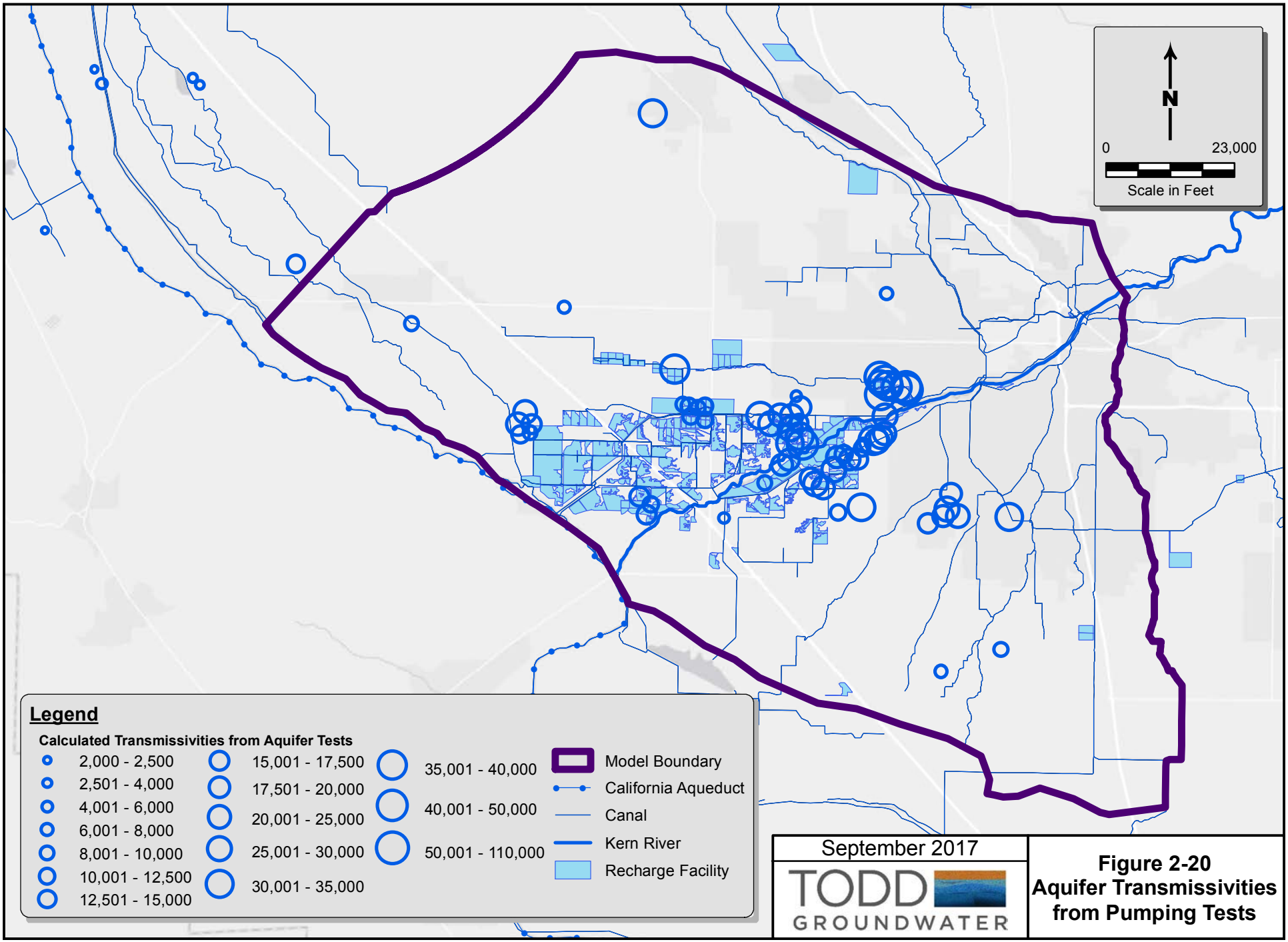
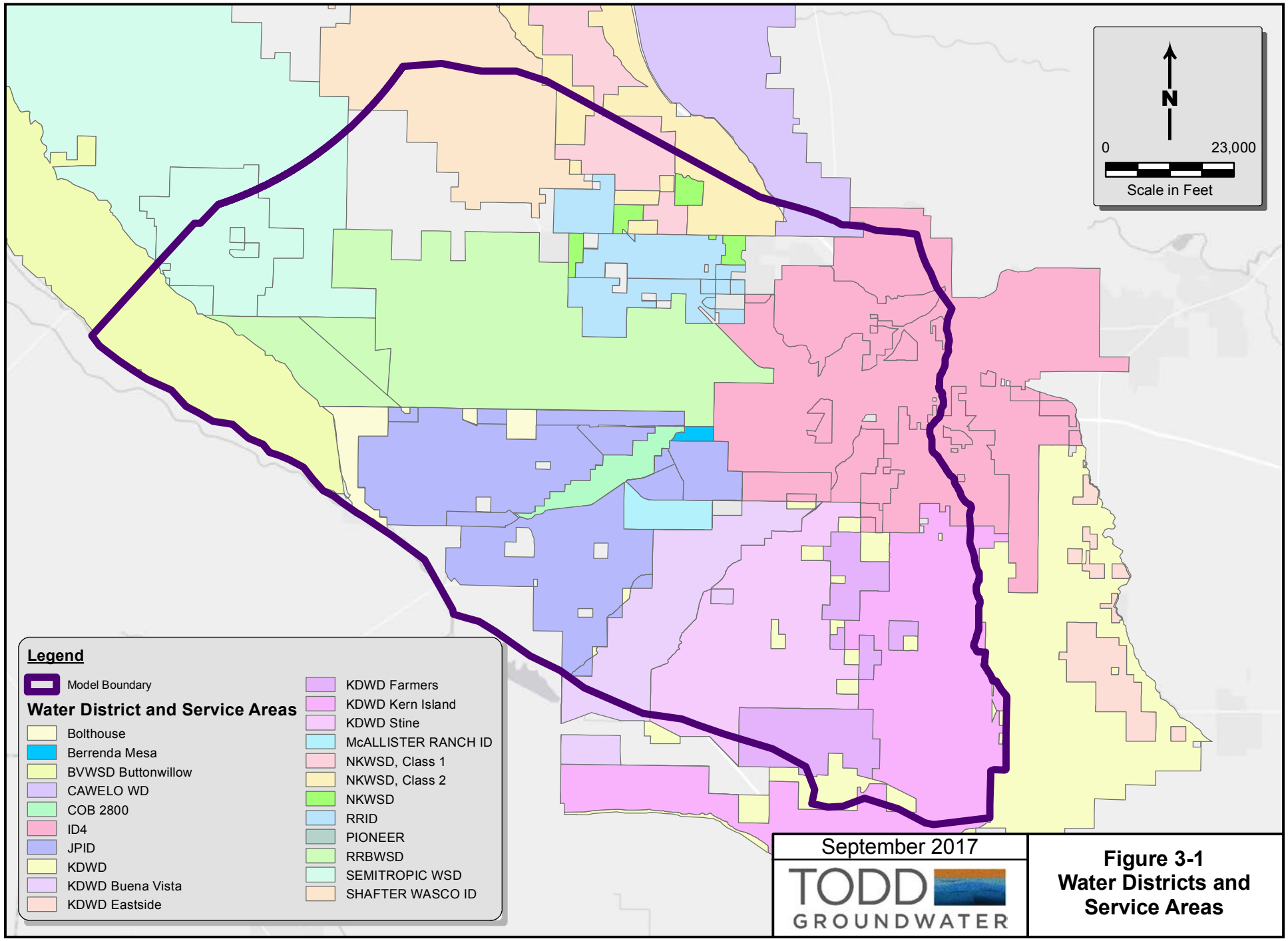


Figure 2-20
Aquifer Transmissivities from Pumping Tests


N
0
23,000
Scale in Feet
Legend
Model Boundary
Water District and Service Areas
Bolthouse
Berrenda Mesa
BVWSD Buttonwillow
CAWELO WD
COB 2800
ID4
JPID
KDWD
KDWD Buena Vista
KDWD Eastside
KDWD Farmers
KDWD Kern Island
KDWD Stine
McALLISTER RANCH ID
NKWSD, Class 1
NKWSD, Class 2
NKWSD
RRID
PIONEER
RRBWSD
SEMITROPIC WSD
SHAFTER WASCO ID
September 2017
TODD GROUNDWATER
Figure 3-1
Water Districts and
Service Areas

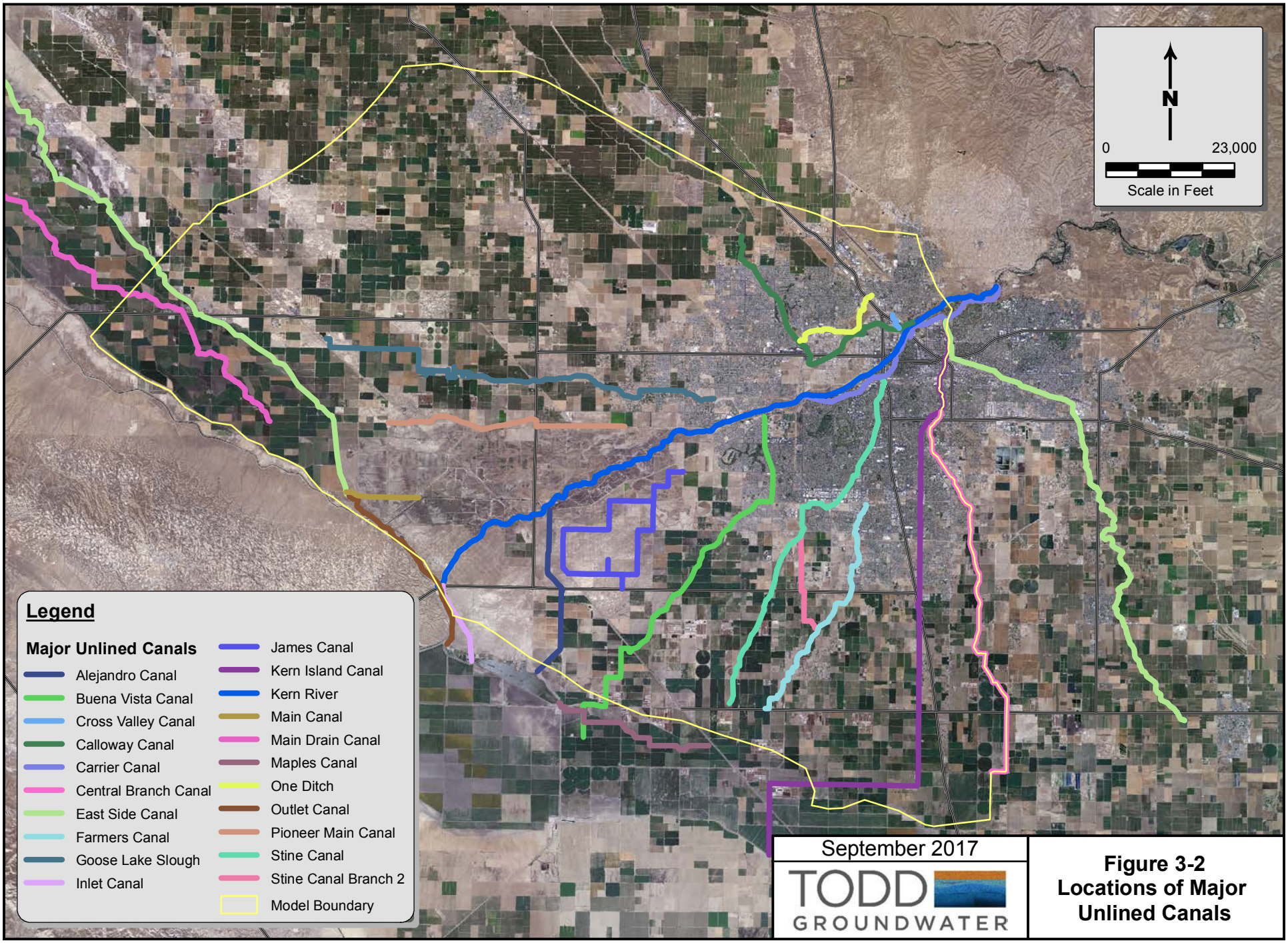
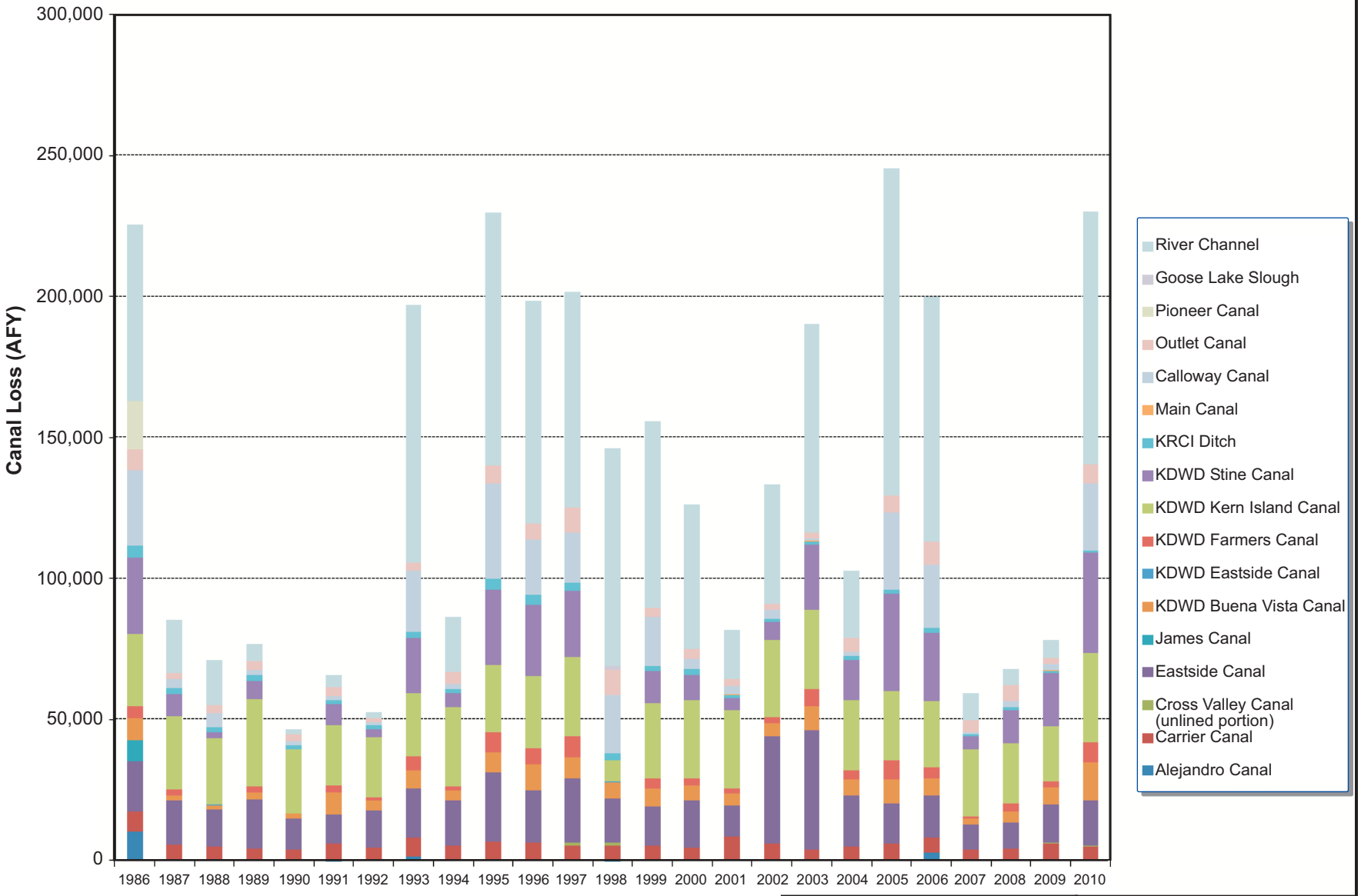


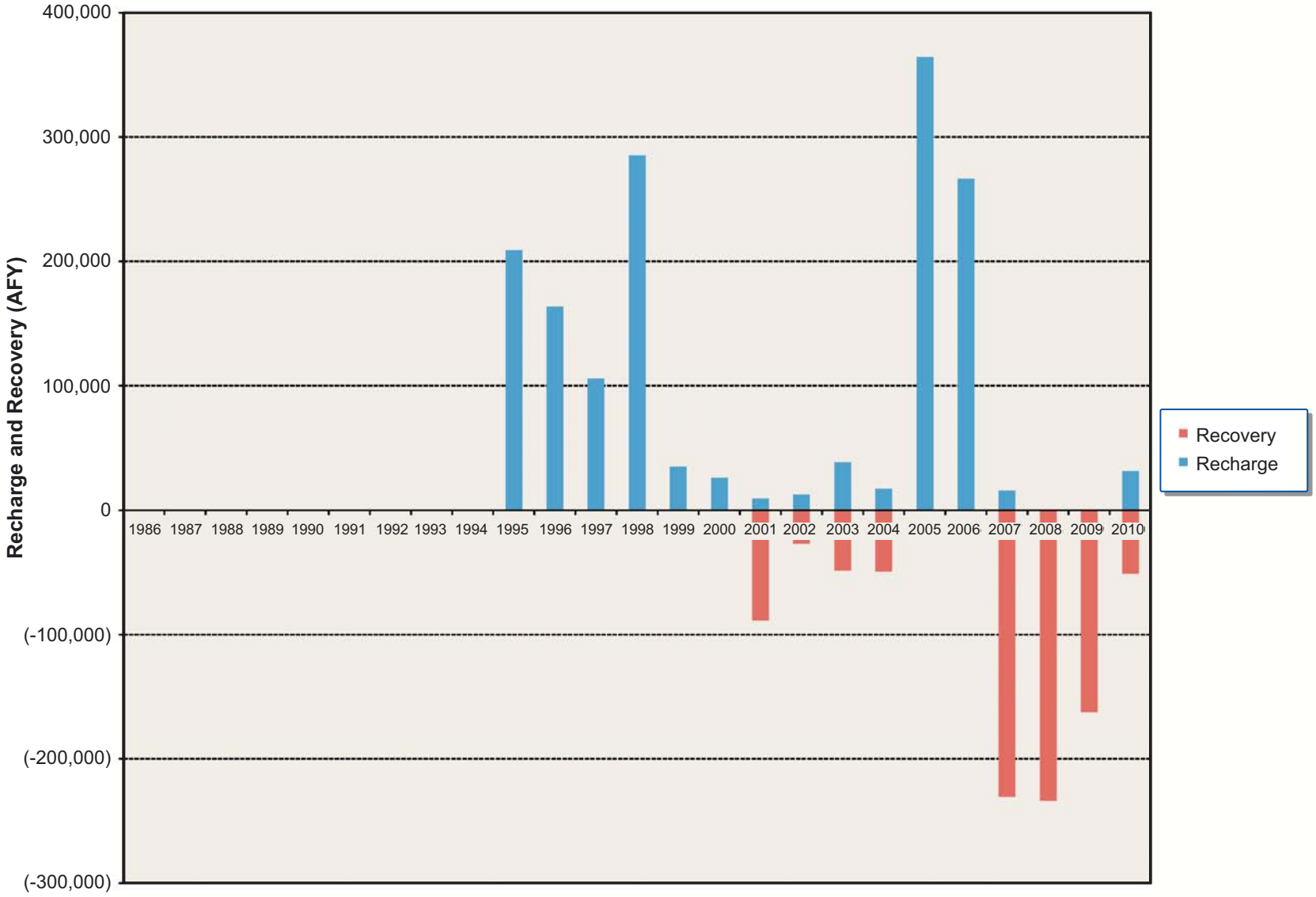
Figure 3-2
Locations of Major Unlined Canals



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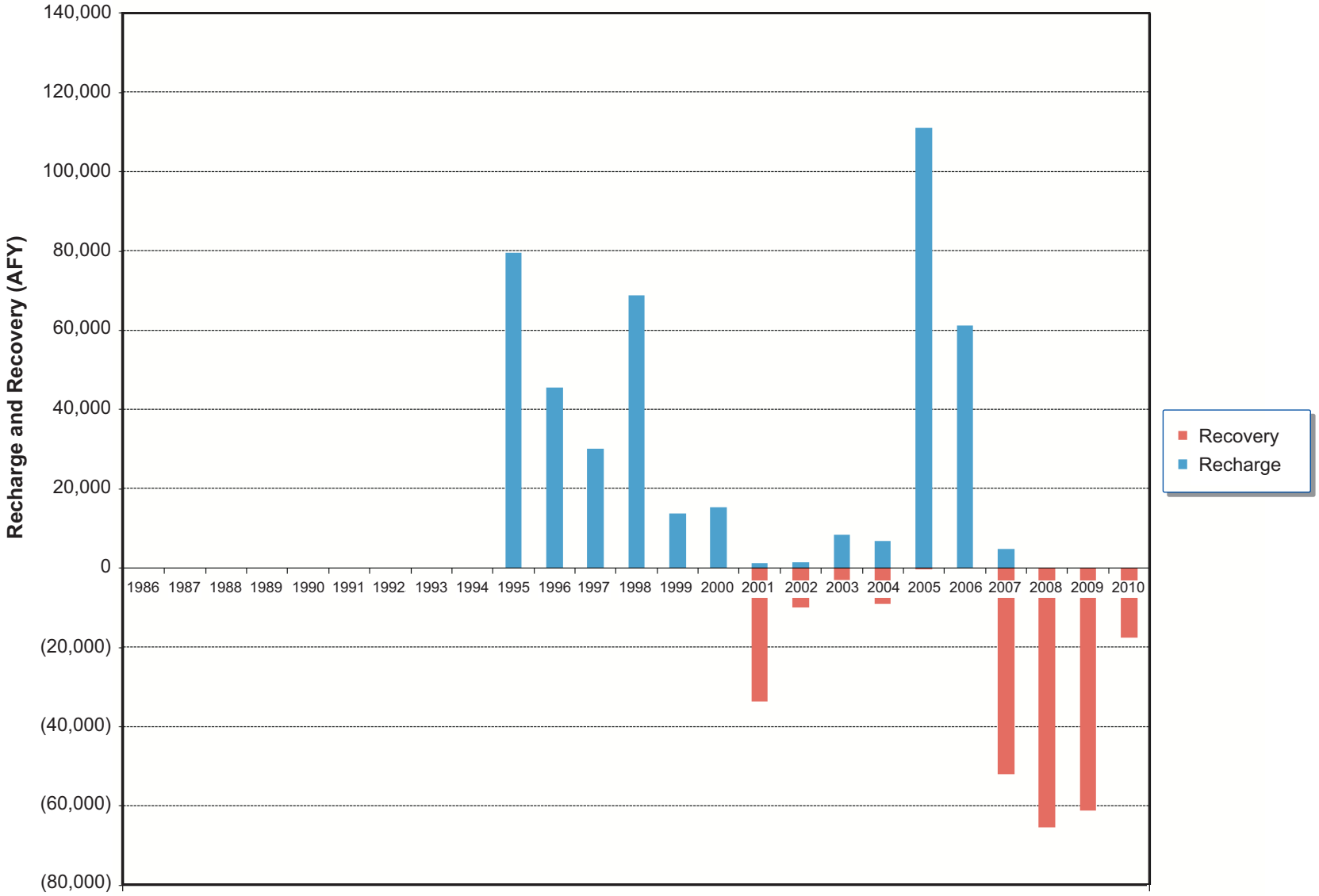
Figure 3-3
Estimated Losses along Canals and Kern River Channel



September 2017

TODD GROUNDWATER

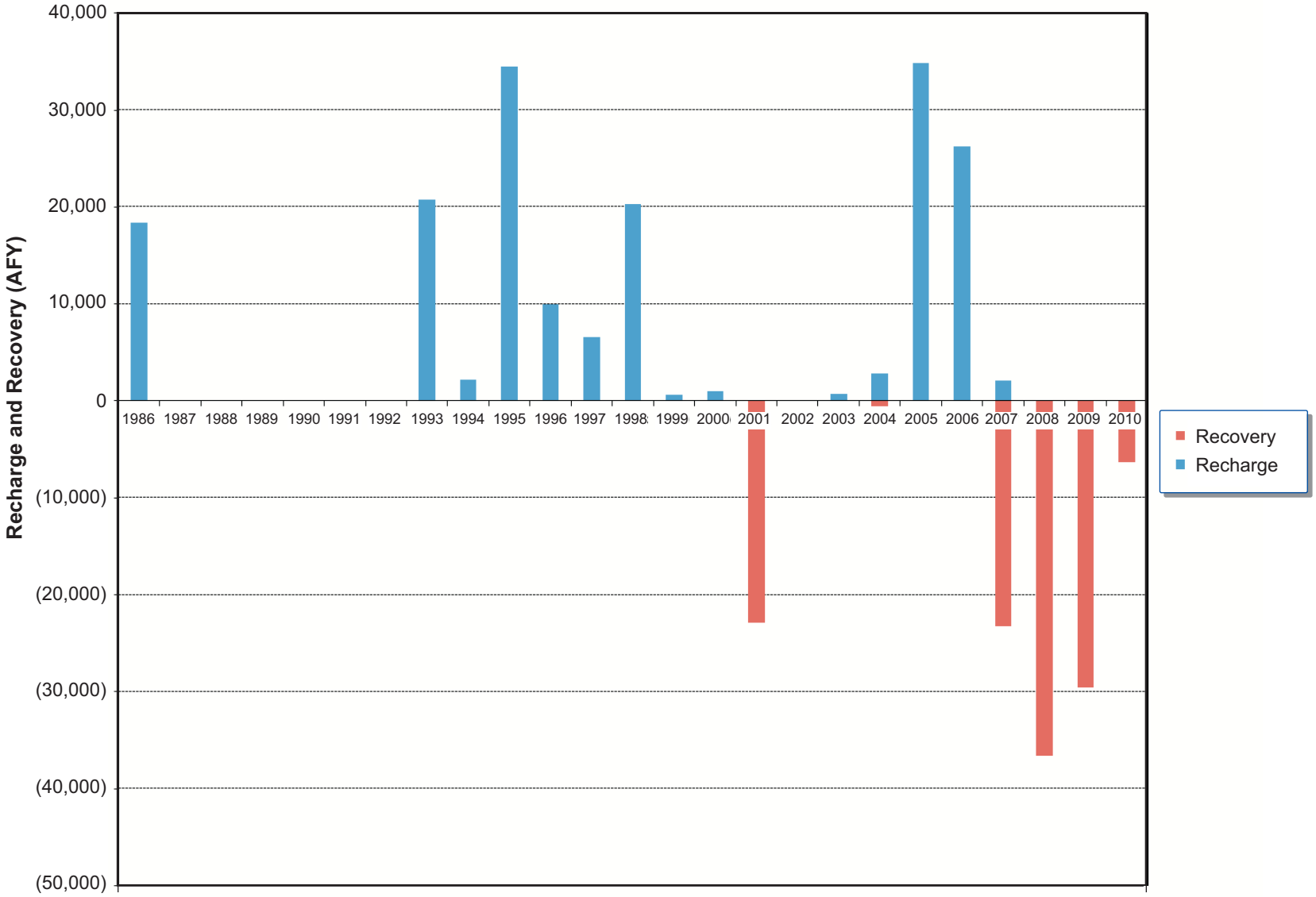
Figure 3-4
Groundwater Banking
Kern Water Bank



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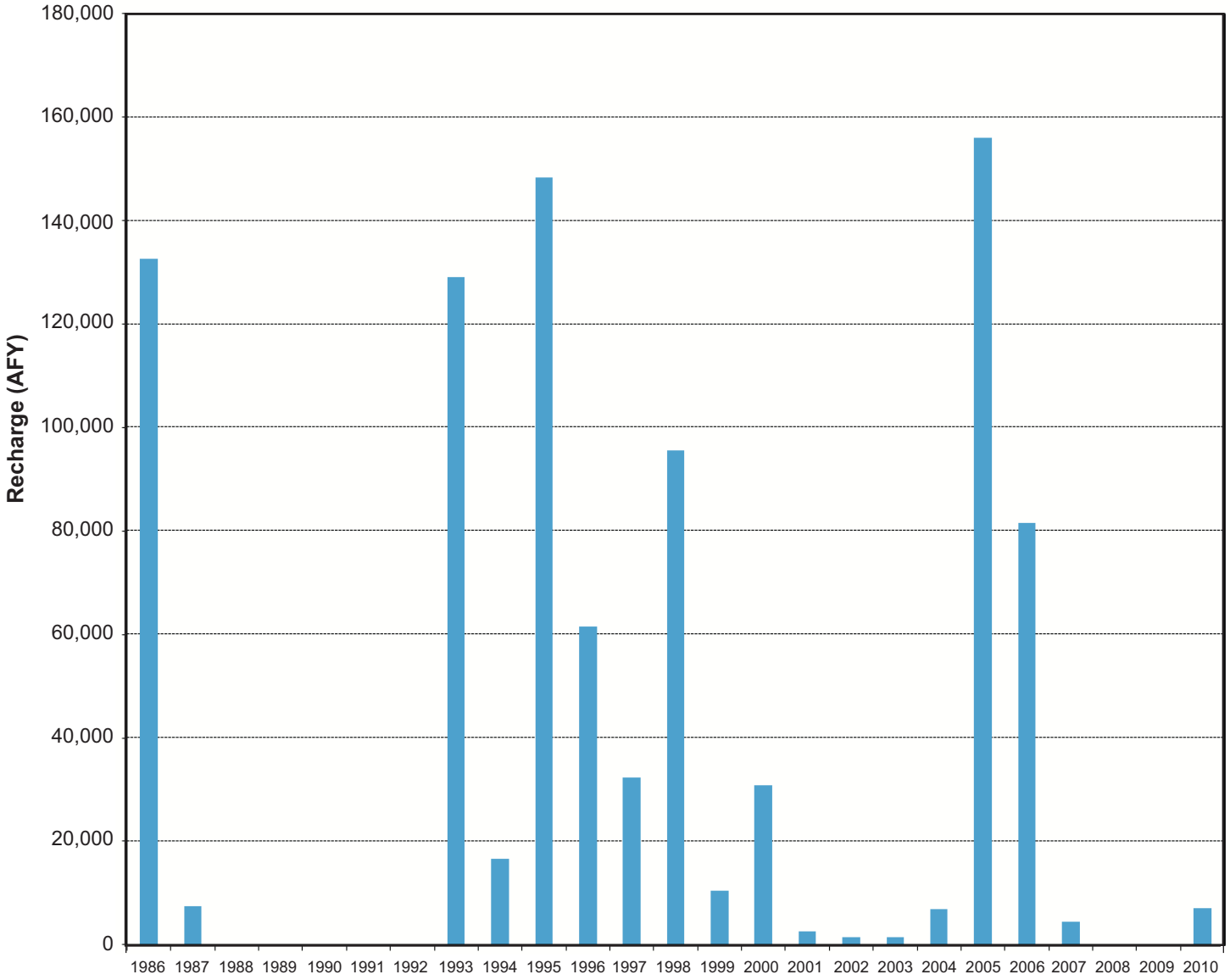
Figure 3-5
Groundwater Banking
Pioneer Project



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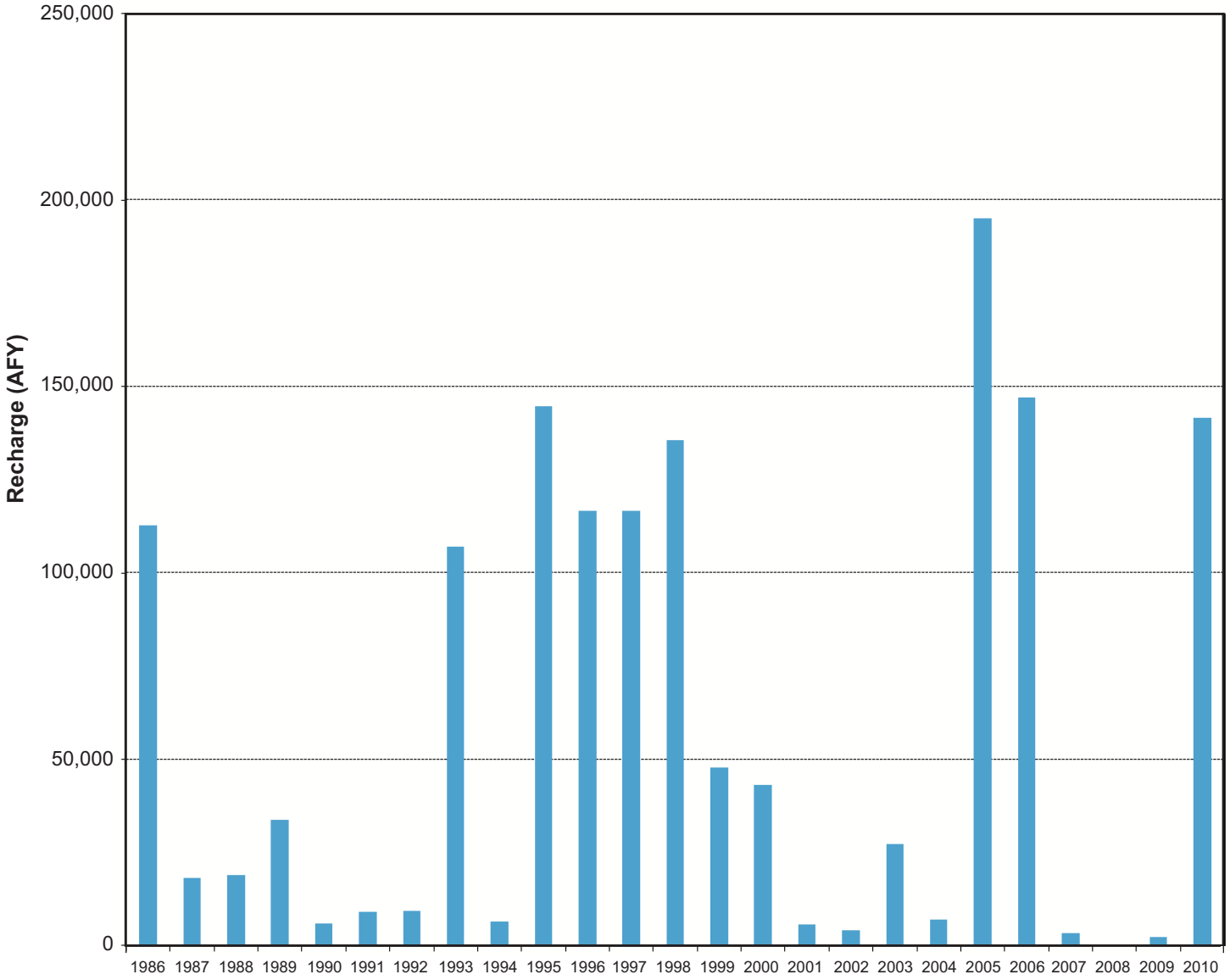
Figure 3-6
Groundwater Banking
Berrenda Mesa Project



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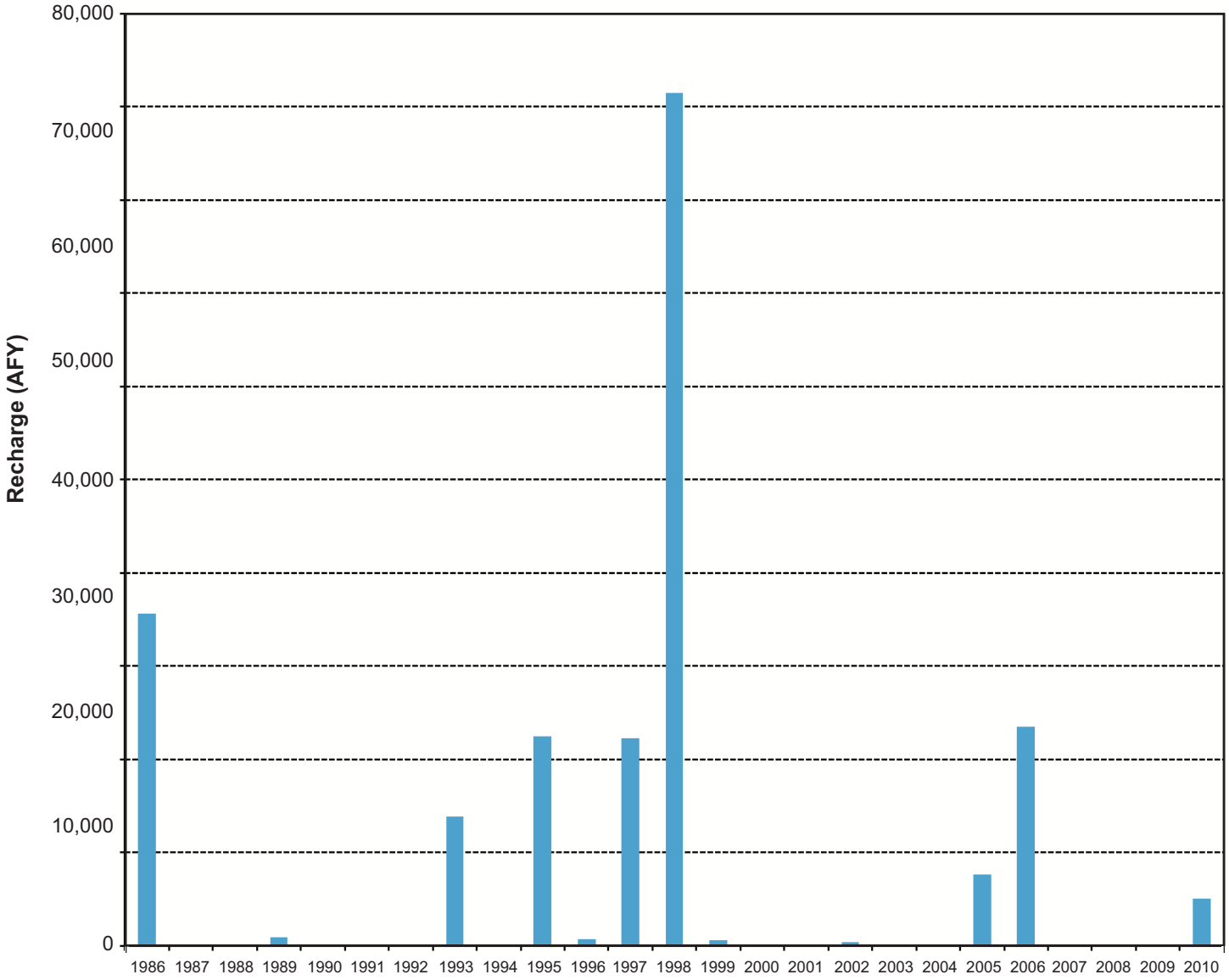
Figure 3-7
Groundwater Banking
COB 2800 Facility



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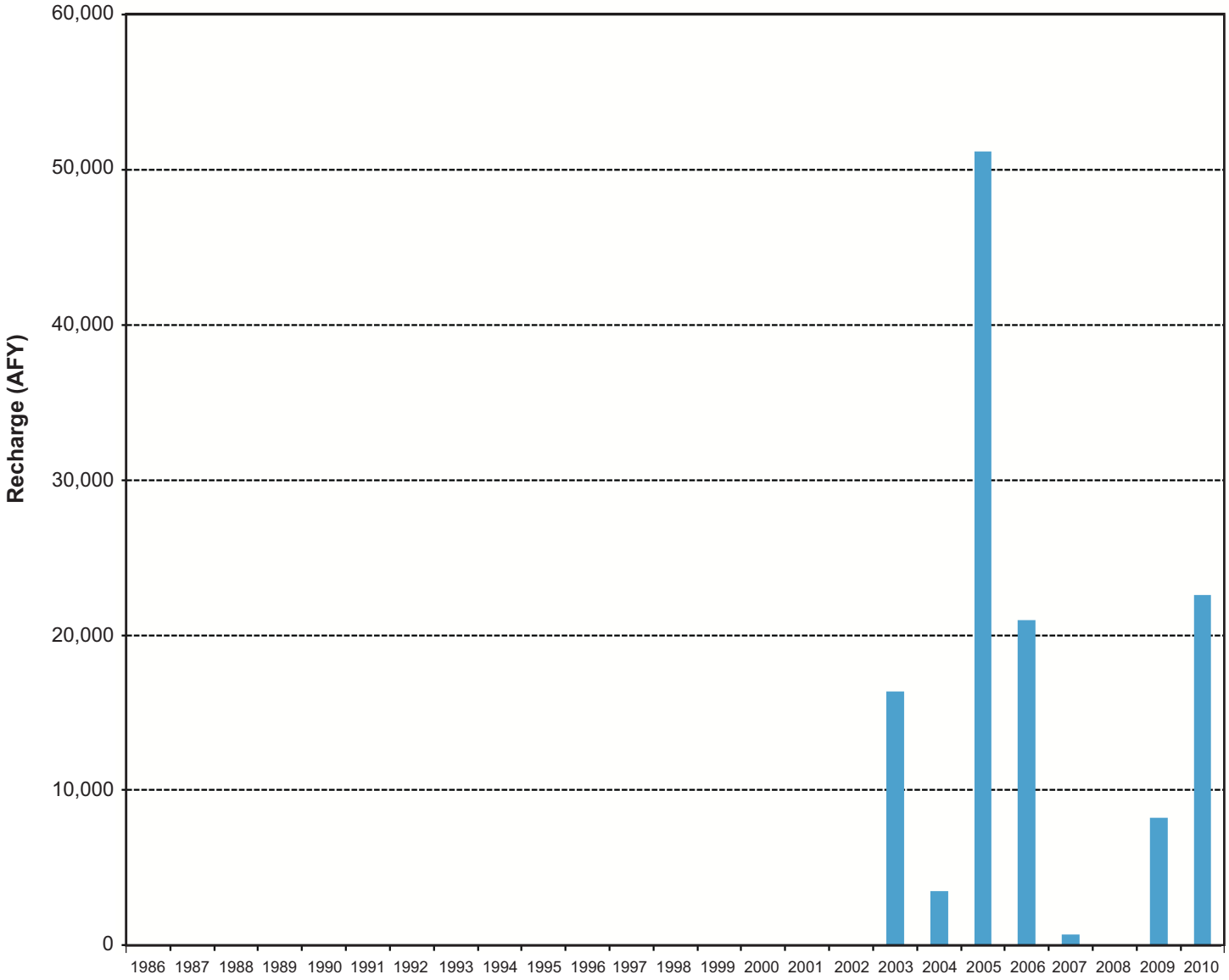
Figure 3-8
Groundwater Recharge
Rosedale
Rio Bravo WSD



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TODD GROUNDWATER

Figure 3-9
Groundwater Recharge
Buena Vista WSD



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Figure 3-10
Groundwater Recharge
West Kern
Water District

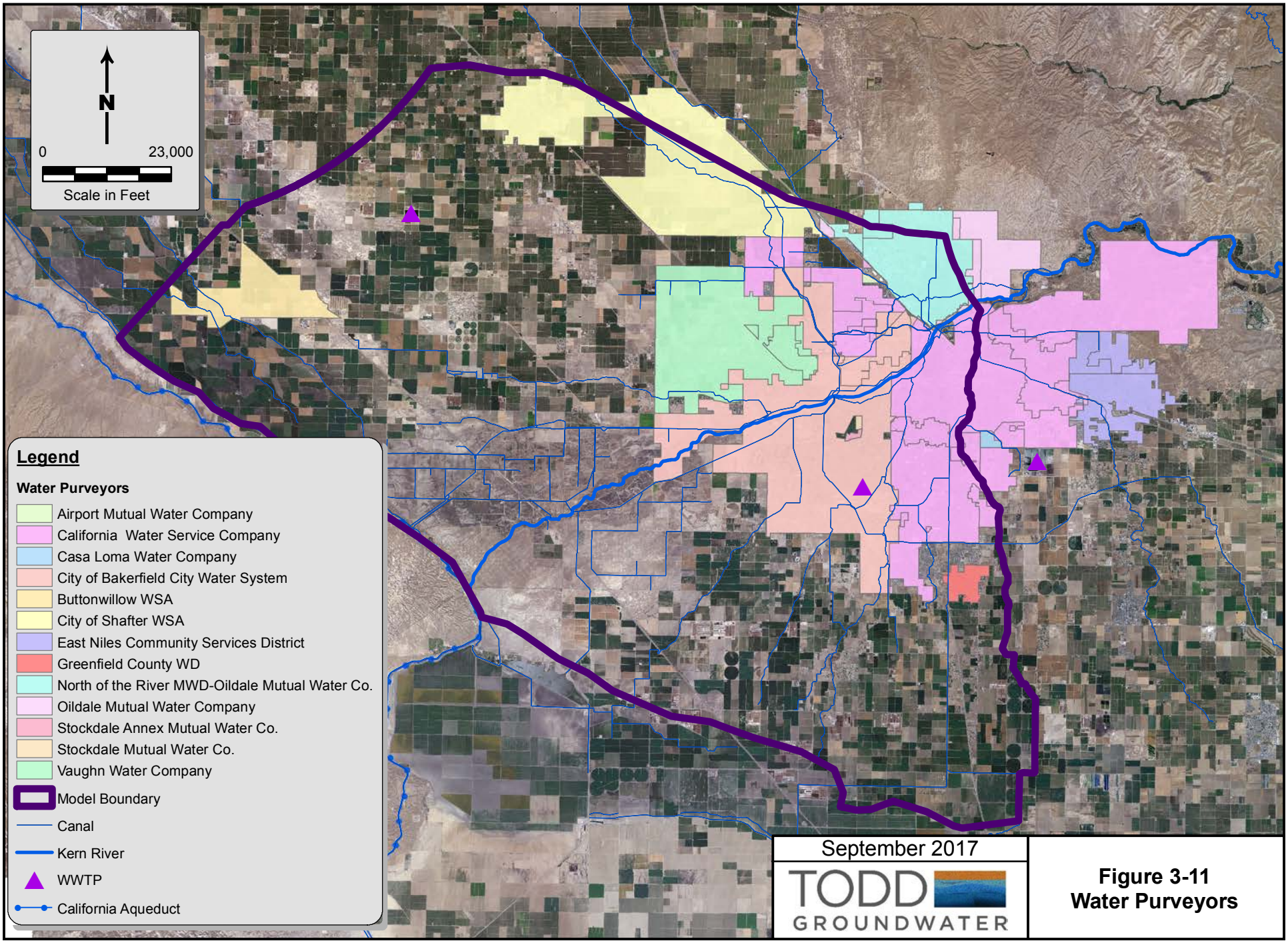
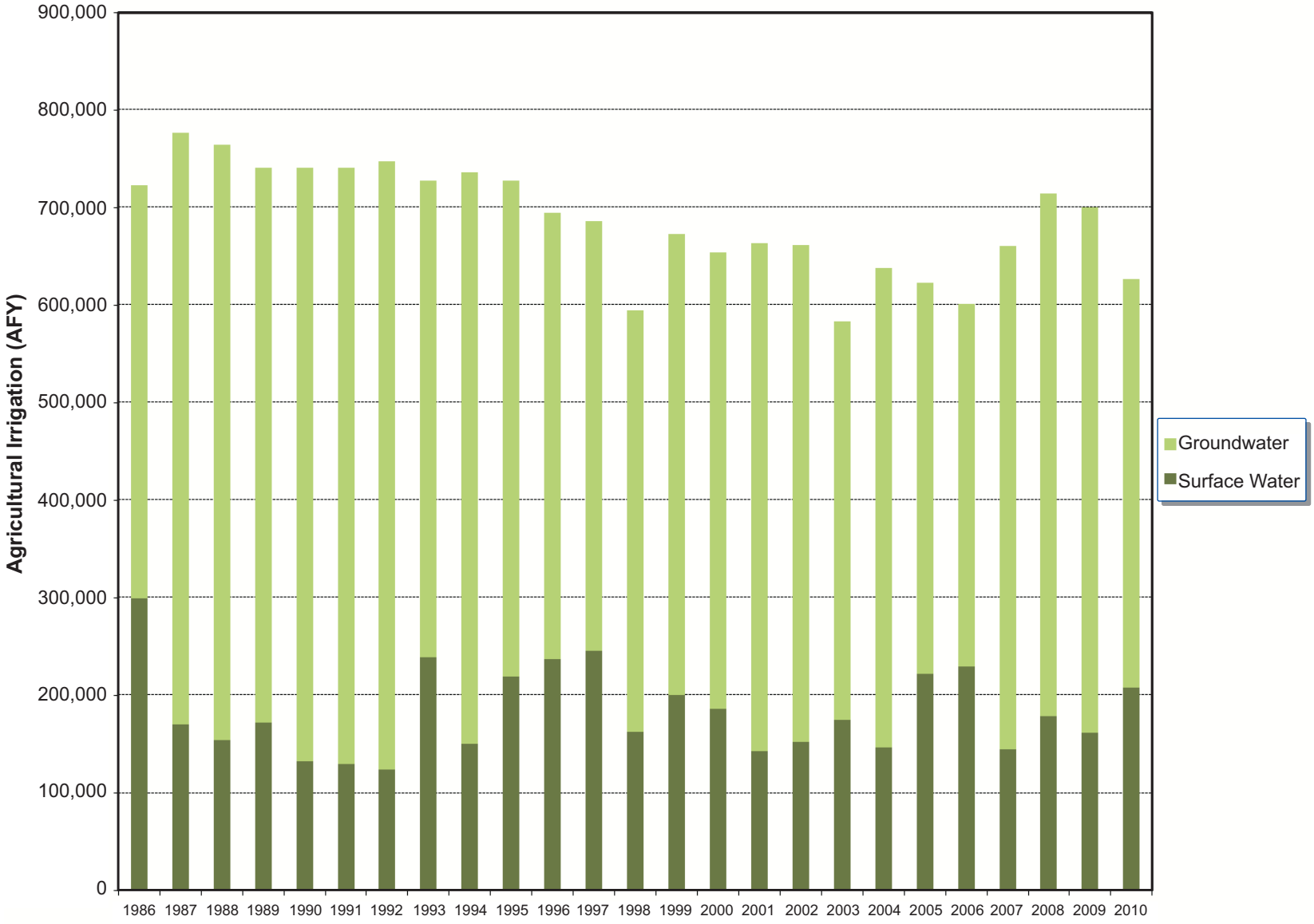


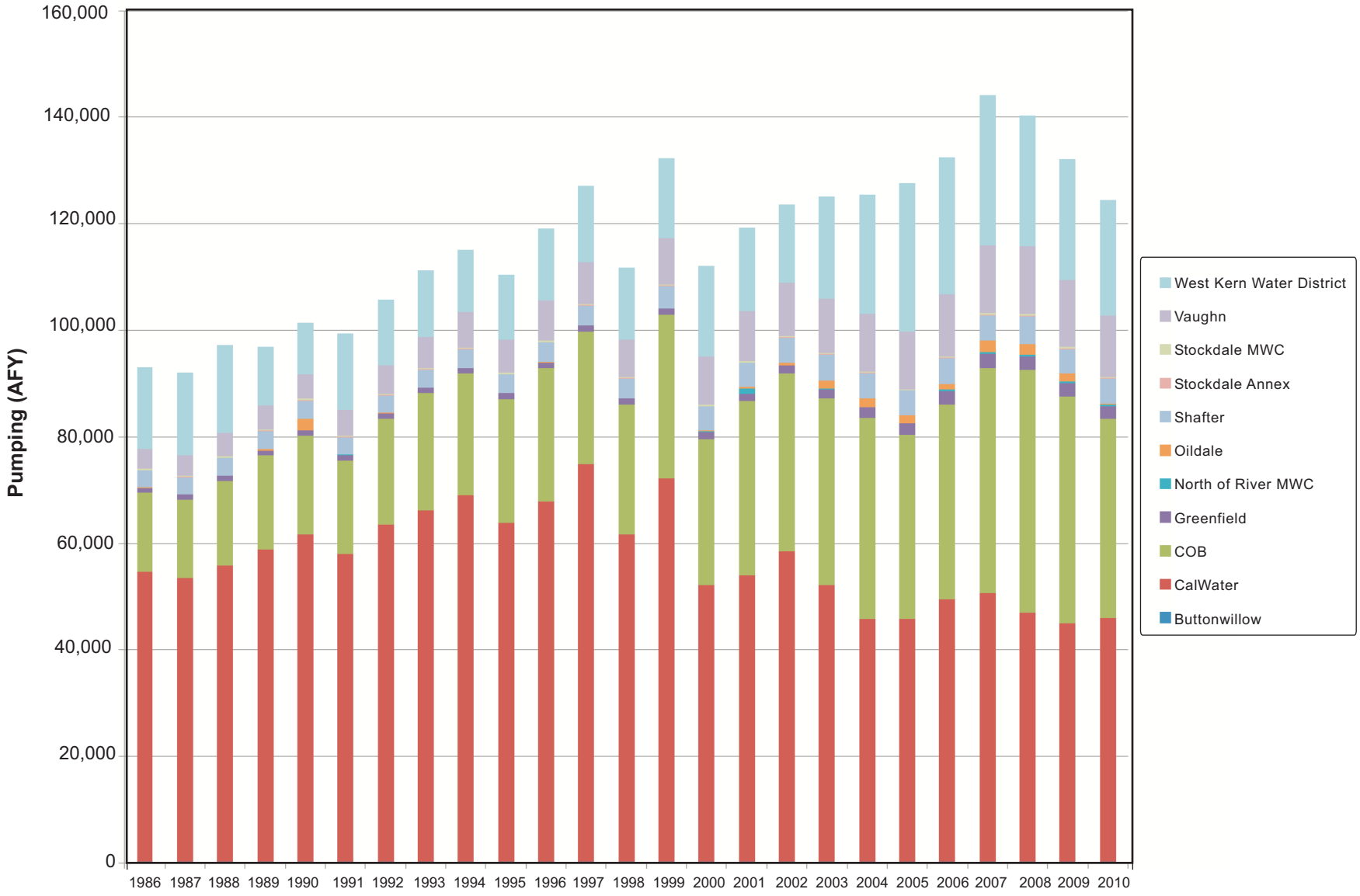
Figure 3-11
Water Purveyors



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TODD GROUNDWATER

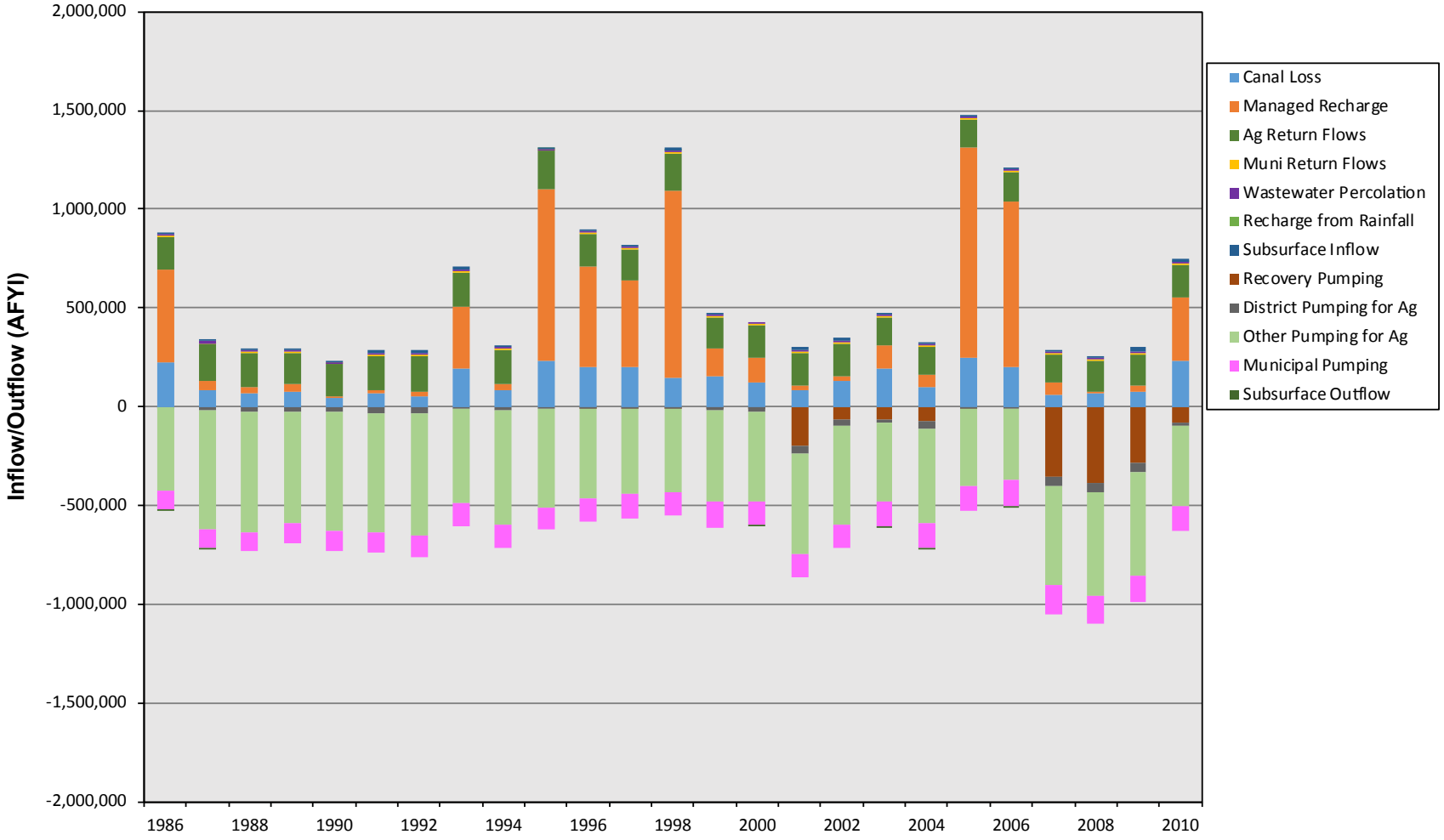
Figure 3-12
Agricultural Irrigation by Source



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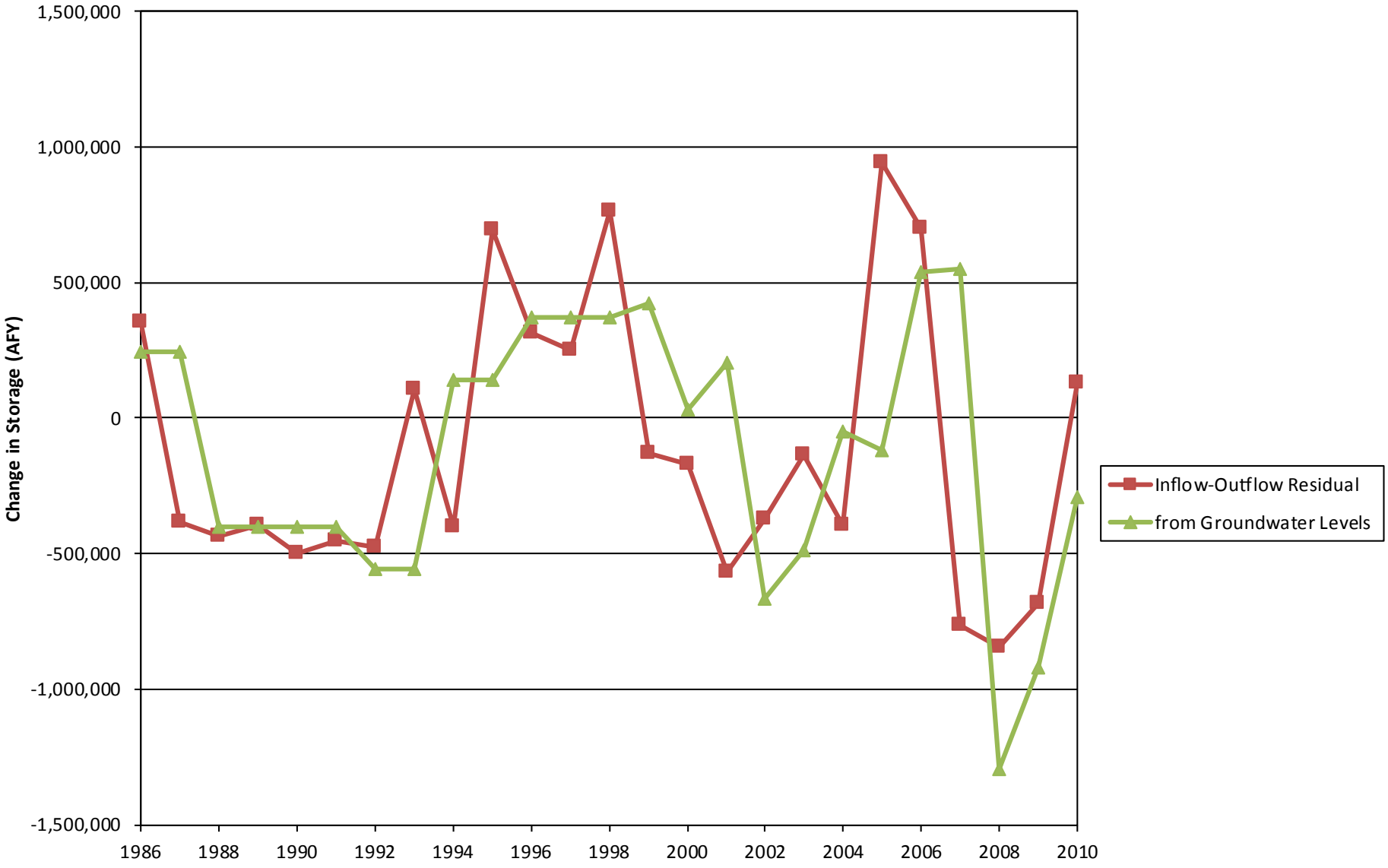
Figure 3-13
Municipal Pumping by Purveyer Model Area



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TODD GROUNDWATER

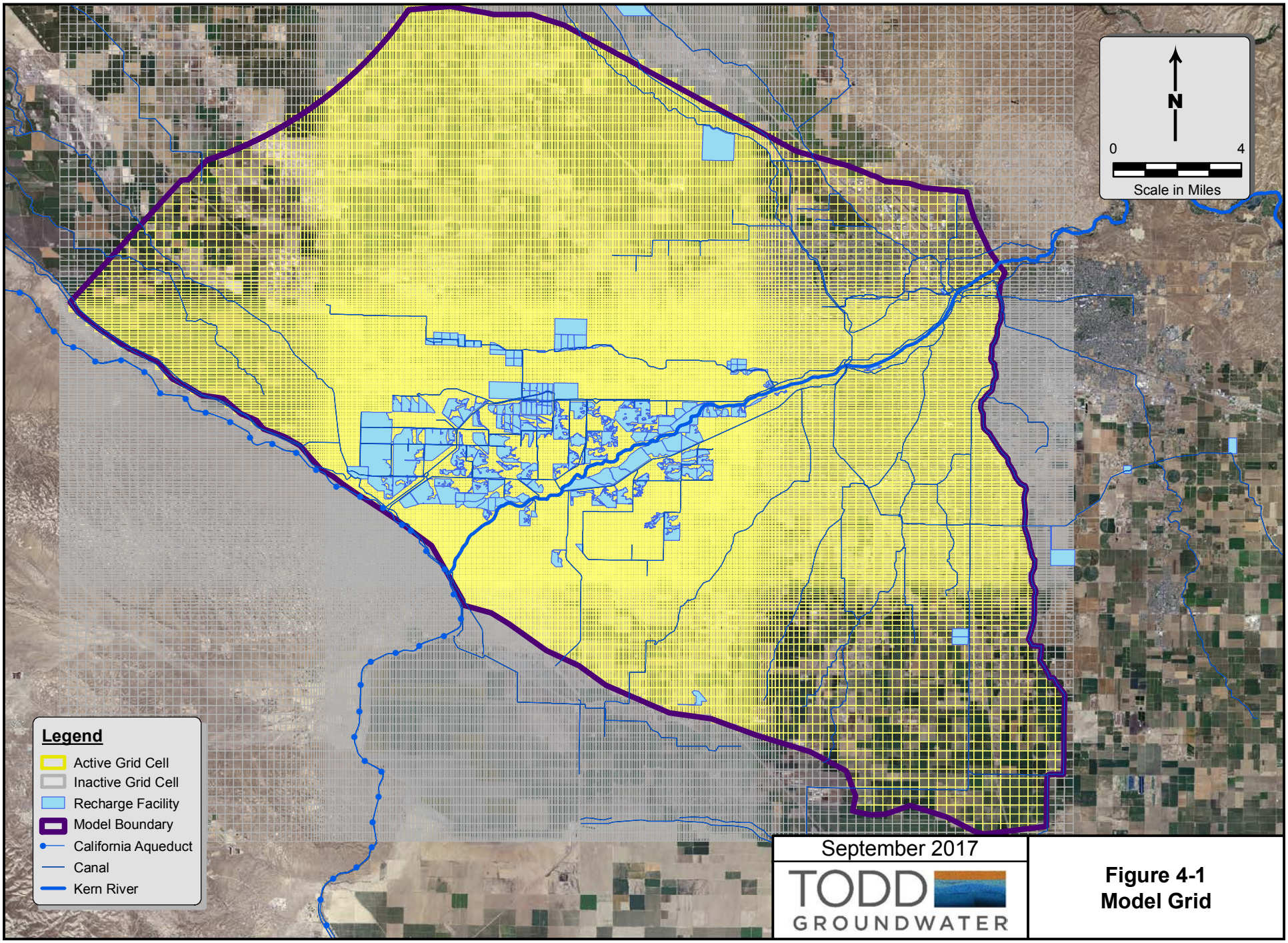
Figure 3-14
Water Balance
Inflows and Outflows



September 2017

TODD GROUNDWATER

Figure 3-15
Change in Groundwater in Storage


N
0
4
Scale in Miles
Legend
Active Grid Cell
Inactive Grid Cell
Recharge Facility
Model Boundary
California Aqueduct
Canal
Kern River
September 2017
TODD GROUNDWATER
Figure 4-1
Model Grid

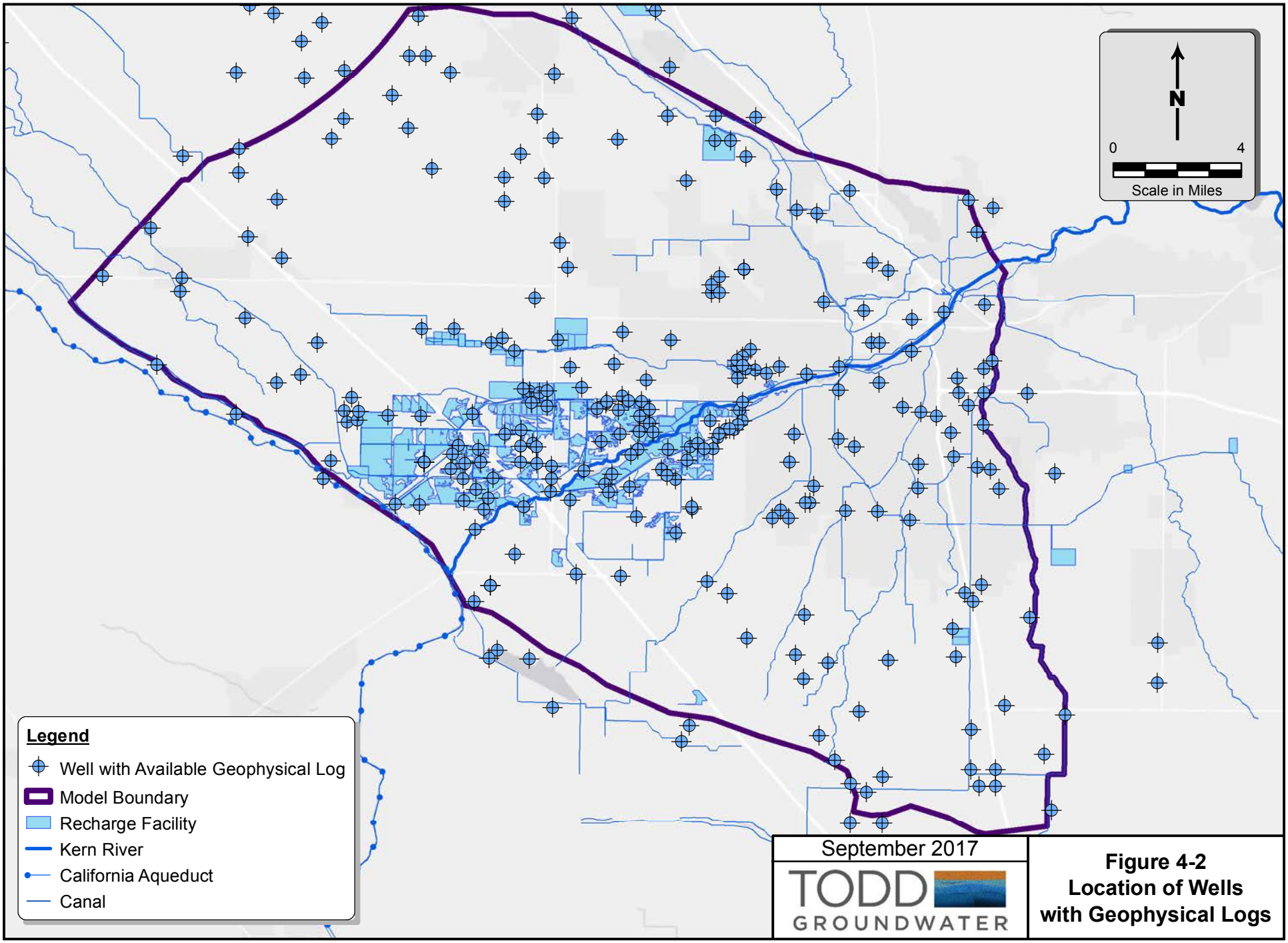


Figure 4-2
Location of Wells with Geophysical Logs

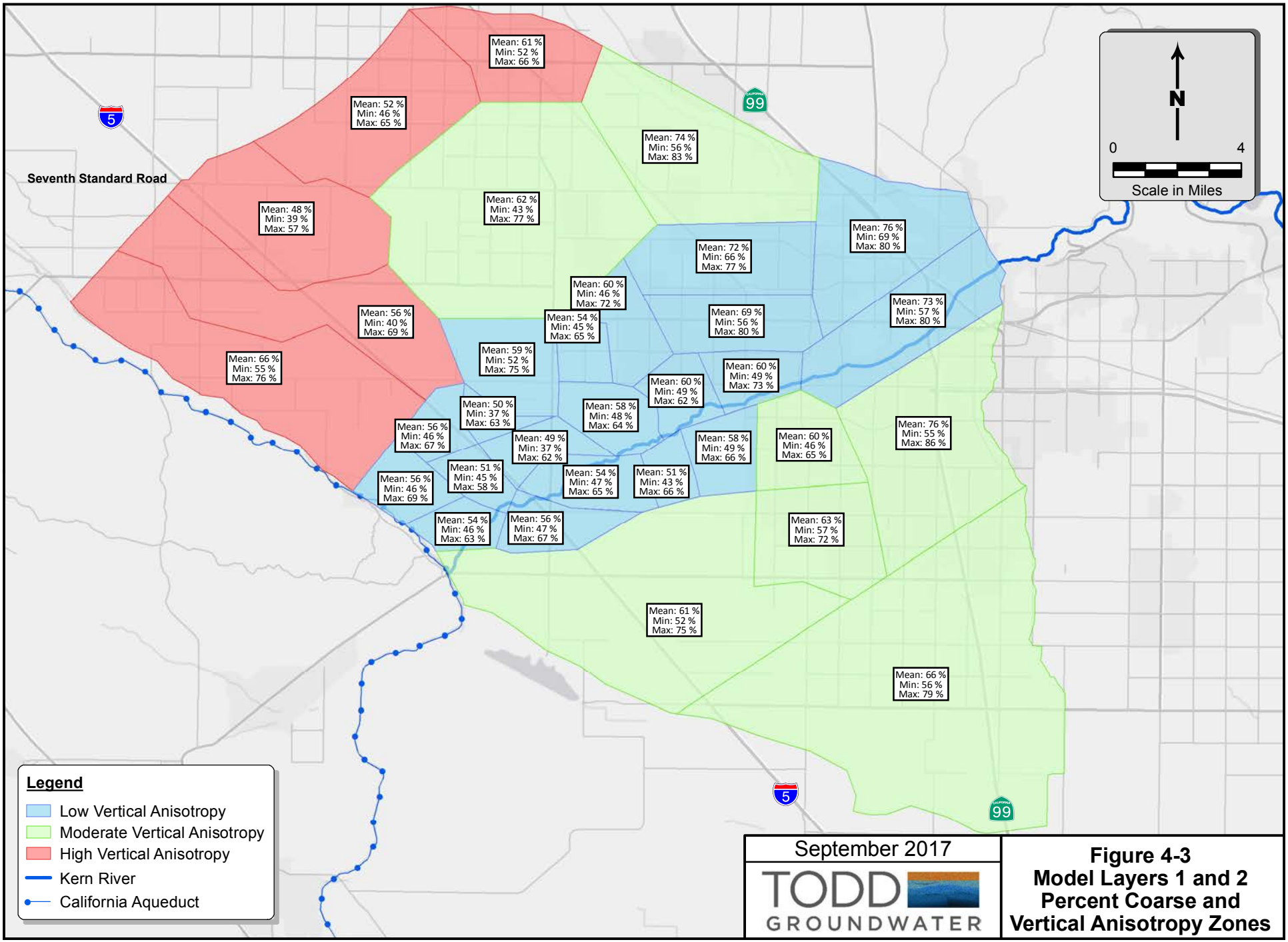
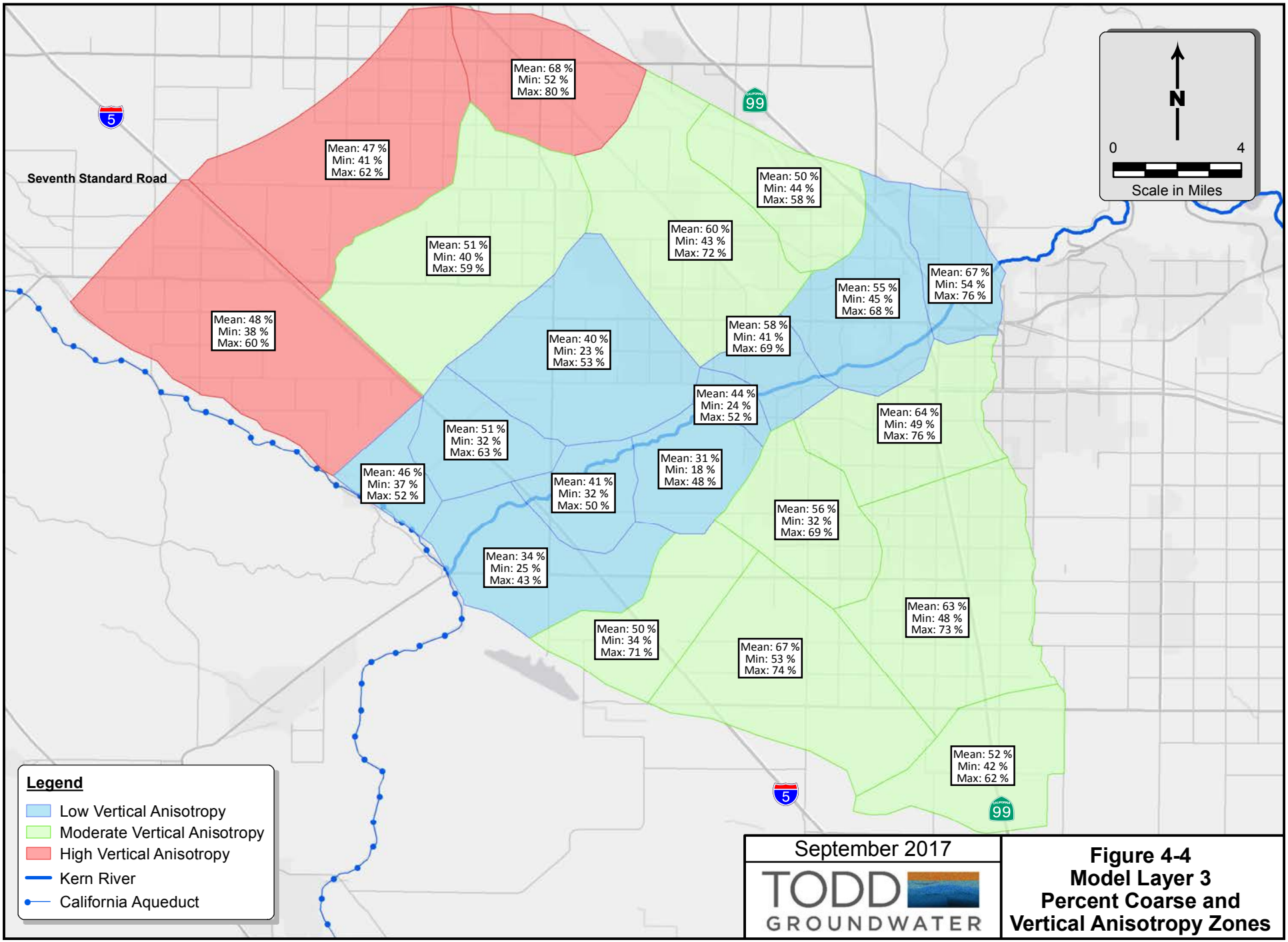
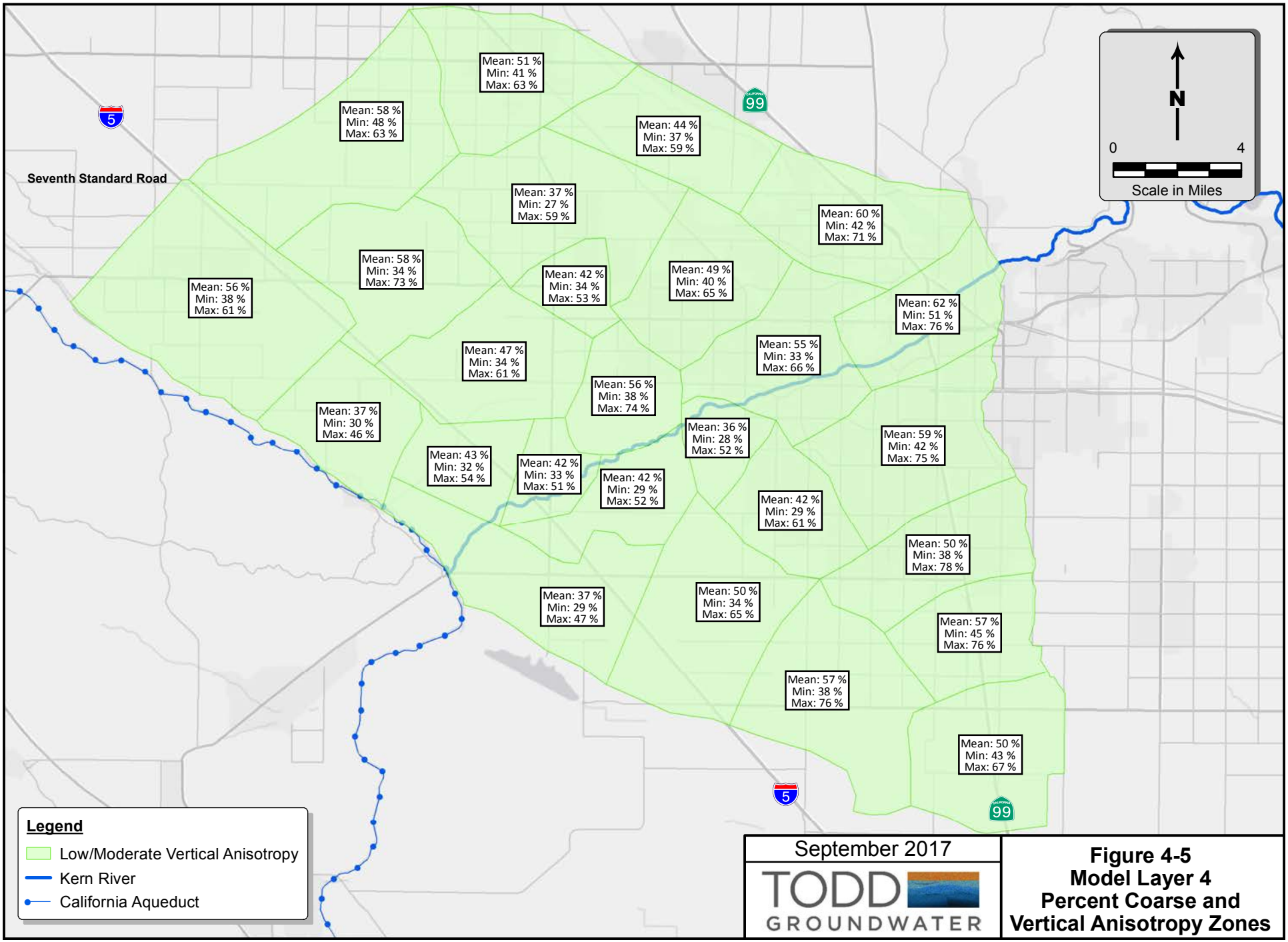
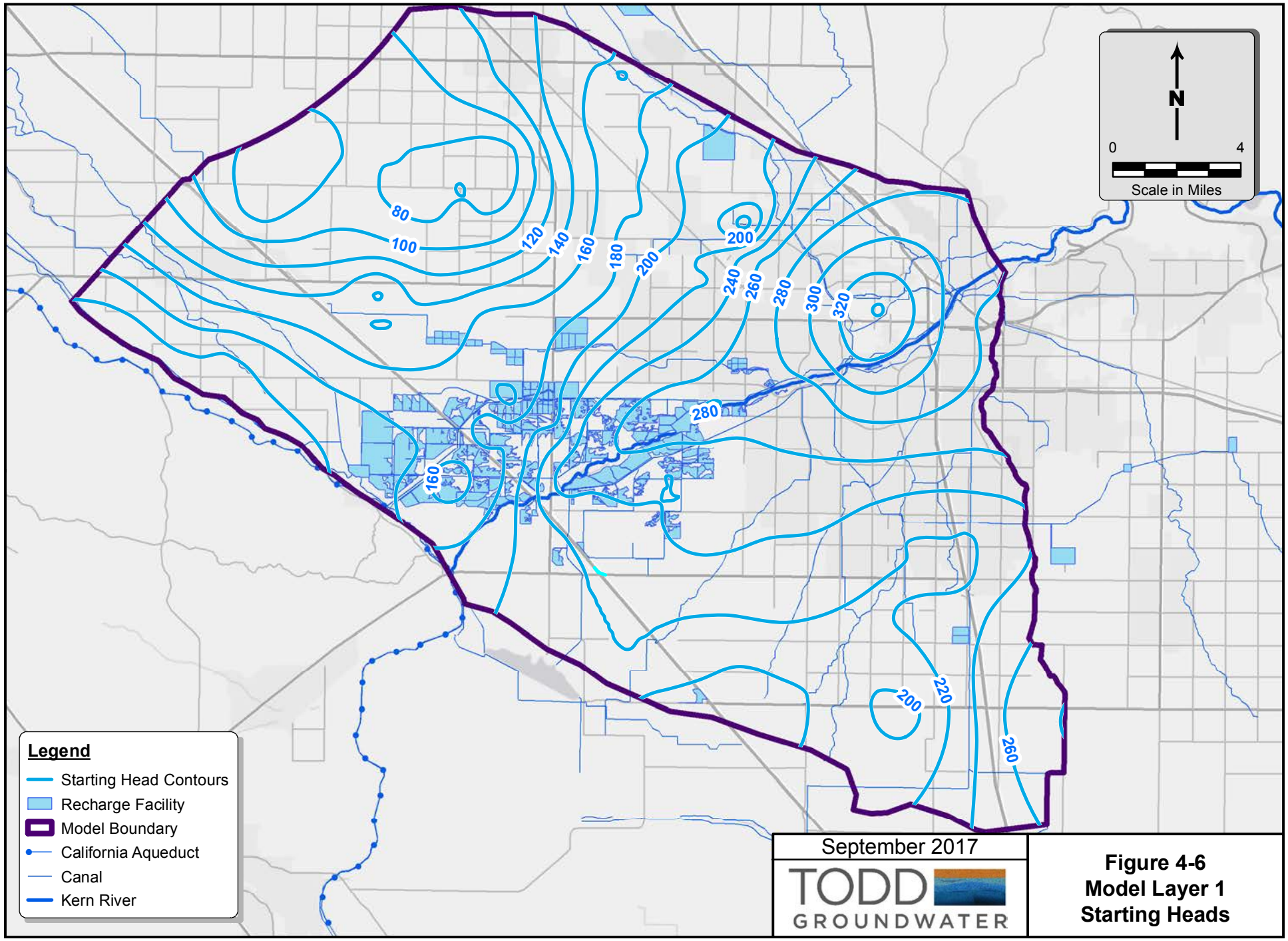
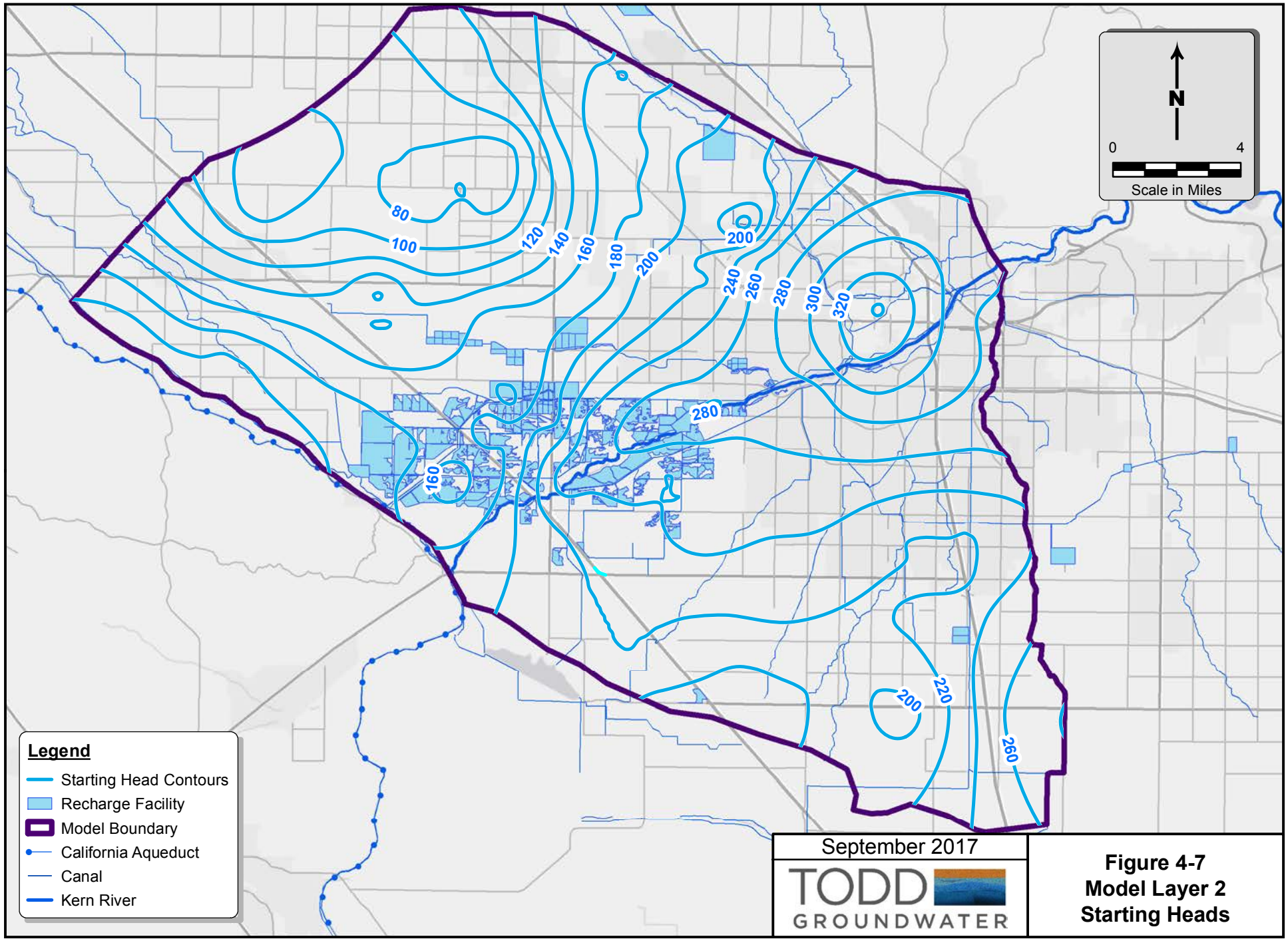


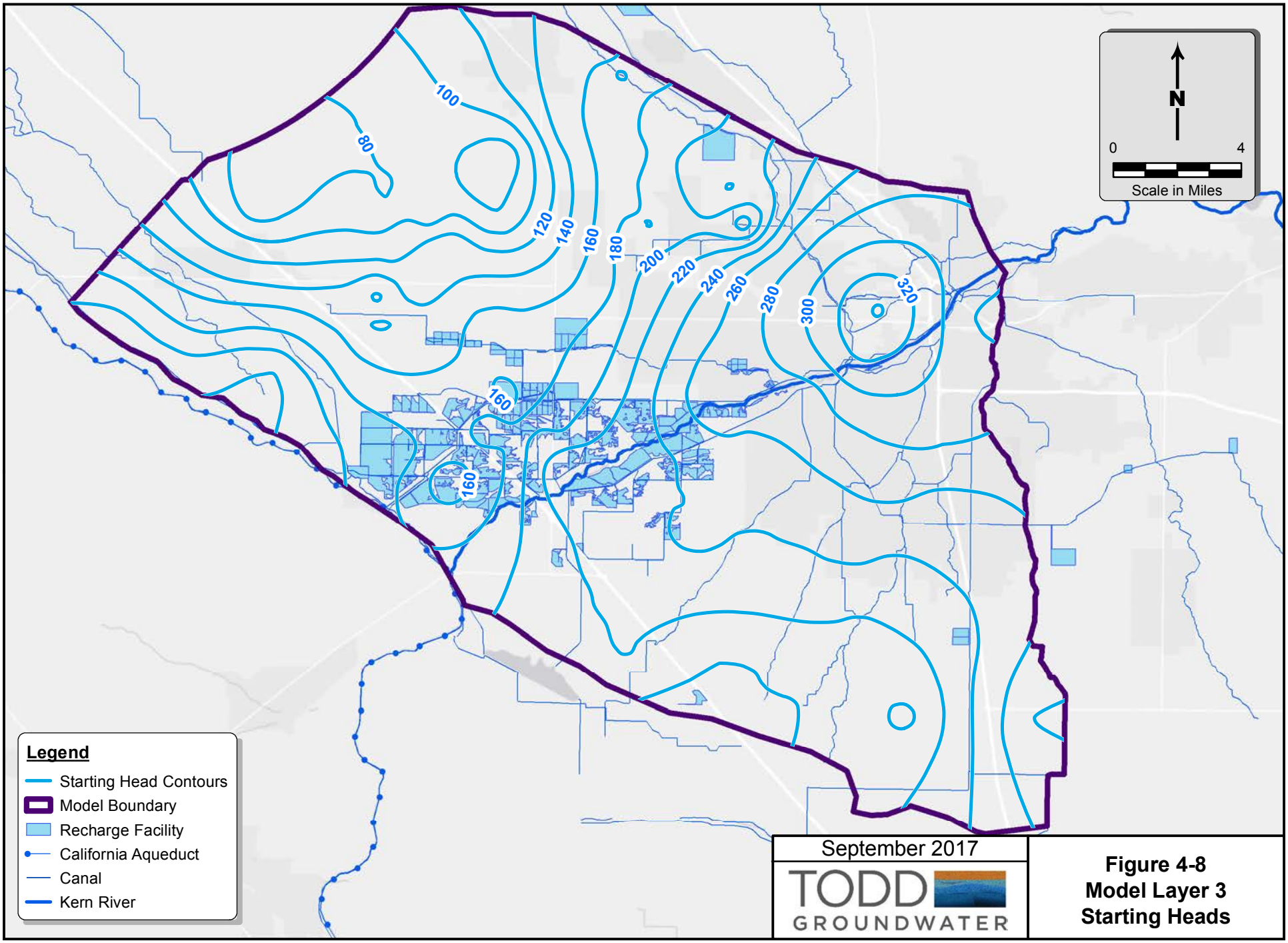
Figure 4-3
Model Layers 1 and 2
Percent Coarse and
Vertical Anisotropy Zones

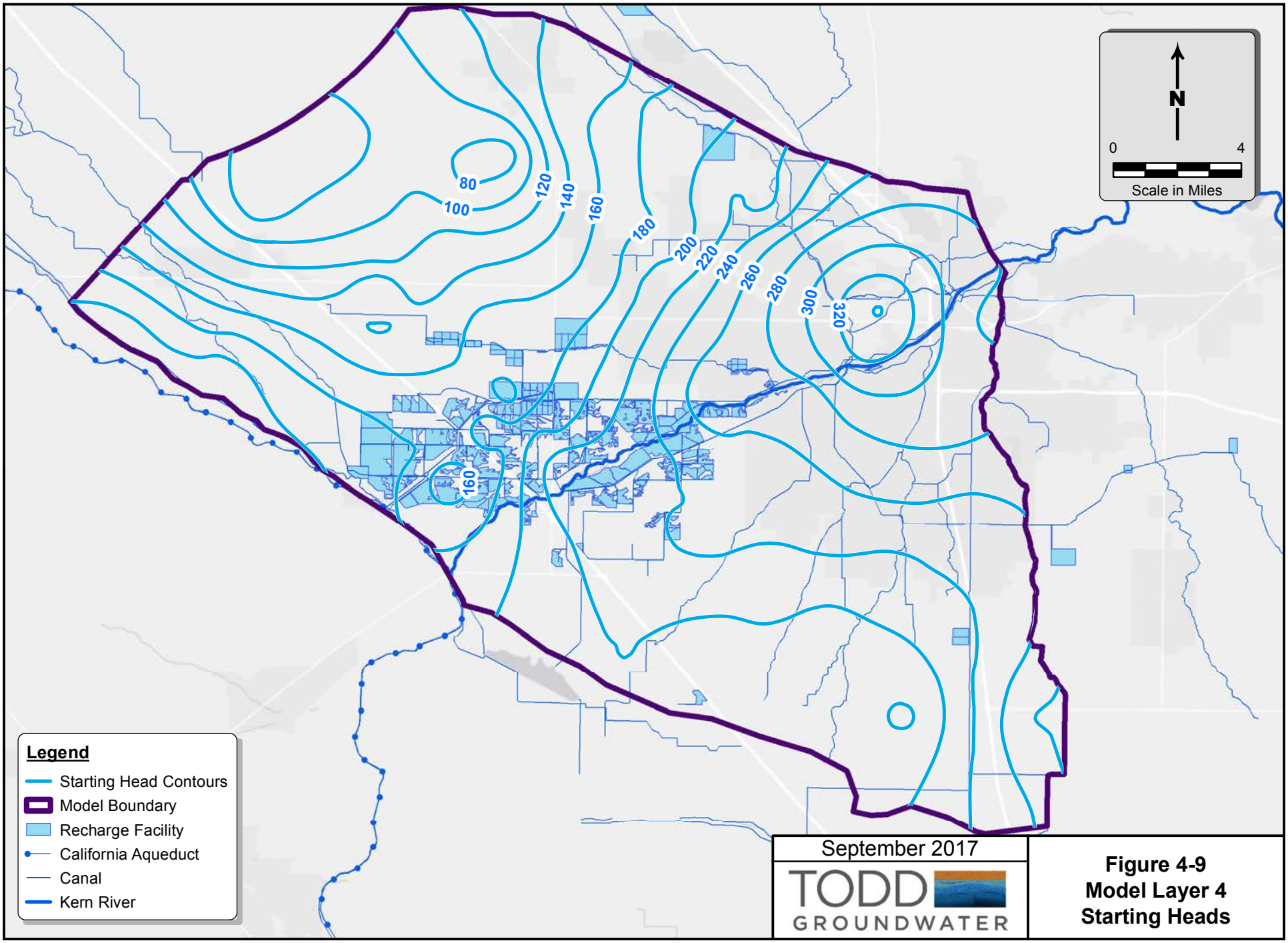

Mean: 68 %
Min: 52 %
Max: 80 %
Mean: 47 %
Min: 41 %
Max: 62 %
Seventh Standard Road
Mean: 50 %
Min: 44 %
Max: 58 %
Mean: 60 %
Min: 43 %
Max: 72 %
Mean: 51 %
Min: 40 %
Max: 59 %
Mean: 67 %
Min: 54 %
Max: 76 %
Mean: 55 %
Min: 45 %
Max: 68 %
Mean: 48 %
Min: 38 %
Max: 60 %
Mean: 58 %
Min: 41 %
Max: 69 %
Mean: 40 %
Min: 23 %
Max: 53 %
Mean: 44 %
Min: 24 %
Max: 52 %
Mean: 64 %
Min: 49 %
Max: 76 %
Mean: 51 %
Min: 32 %
Max: 63 %
Mean: 31 %
Min: 18 %
Max: 48 %
Mean: 46 %
Min: 37 %
Max: 52 %
Mean: 41 %
Min: 32 %
Max: 50 %
Mean: 56 %
Min: 32 %
Max: 69 %
Mean: 34 %
Min: 25 %
Max: 43 %
Mean: 63 %
Min: 48 %
Max: 73 %
Mean: 50 %
Min: 34 %
Max: 71 %
Mean: 67 %
Min: 53 %
Max: 74 %
Mean: 52 %
Min: 42 %
Max: 62 %
N
0
4
Scale in Miles
Legend
Low Vertical Anisotropy
Moderate Vertical Anisotropy
High Vertical Anisotropy
Kern River
California Aqueduct
September 2017
TODD GROUNDWATER
Figure 4-4
Model Layer 3
Percent Coarse and
Vertical Anisotropy Zones


Mean: 51 %
Min: 41 %
Max: 63 %
Mean: 58 %
Min: 48 %
Max: 63 %
Mean: 44 %
Min: 37 %
Max: 59 %
Seventh Standard Road
Mean: 37 %
Min: 27 %
Max: 59 %
Mean: 60 %
Min: 42 %
Max: 71 %
Mean: 58 %
Min: 34 %
Max: 73 %
Mean: 42 %
Min: 34 %
Max: 53 %
Mean: 49 %
Min: 40 %
Max: 65 %
Mean: 56 %
Min: 38 %
Max: 61 %
Mean: 62 %
Min: 51 %
Max: 76 %
Mean: 47 %
Min: 34 %
Max: 61 %
Mean: 55 %
Min: 33 %
Max: 66 %
Mean: 56 %
Min: 38 %
Max: 74 %
Mean: 37 %
Min: 30 %
Max: 46 %
Mean: 36 %
Min: 28 %
Max: 52 %
Mean: 59 %
Min: 42 %
Max: 75 %
Mean: 43 %
Min: 32 %
Max: 54 %
Mean: 42 %
Min: 33 %
Max: 51 %
Mean: 42 %
Min: 29 %
Max: 52 %
Mean: 42 %
Min: 29 %
Max: 61 %
Mean: 50 %
Min: 38 %
Max: 78 %
Mean: 37 %
Min: 29 %
Max: 47 %
Mean: 50 %
Min: 34 %
Max: 65 %
Mean: 57 %
Min: 45 %
Max: 76 %
Mean: 57 %
Min: 38 %
Max: 76 %
Mean: 50 %
Min: 43 %
Max: 67 %
N
0
4
Scale in Miles
Legend
Low/Moderate Vertical Anisotropy
Kern River
California Aqueduct
September 2017
TODD GROUNDWATER
Figure 4-5
Model Layer 4
Percent Coarse and
Vertical Anisotropy Zones


N
0
4
Scale in Miles
80
100
120
140
160
180
200
200
240
260
280
300
320
280
160
200
220
260
Legend
Starting Head Contours
Recharge Facility
Model Boundary
California Aqueduct
Canal
Kern River
September 2017
TODD GROUNDWATER
Figure 4-6
Model Layer 1
Starting Heads


N
0
4
Scale in Miles
80
100
120
140
160
180
200
200
240
260
280
300
320
280
160
200
220
260
Legend
Starting Head Contours
Recharge Facility
Model Boundary
California Aqueduct
Canal
Kern River
September 2017
TODD GROUNDWATER
Figure 4-7
Model Layer 2
Starting Heads


N
0
4
Scale in Miles
100
80
120
140
160
180
200
220
240
260
280
300
320
160
160
Legend
Starting Head Contours
Model Boundary
Recharge Facility
California Aqueduct
Canal
Kern River
September 2017
TODD GROUNDWATER
Figure 4-8
Model Layer 3
Starting Heads


N
0
4
Scale in Miles
80
100
120
140
160
180
200
220
240
260
280
300
320
160
Legend
Starting Head Contours
Model Boundary
Recharge Facility
California Aqueduct
Canal
Kern River
September 2017
TODD GROUNDWATER
Figure 4-9
Model Layer 4
Starting Heads

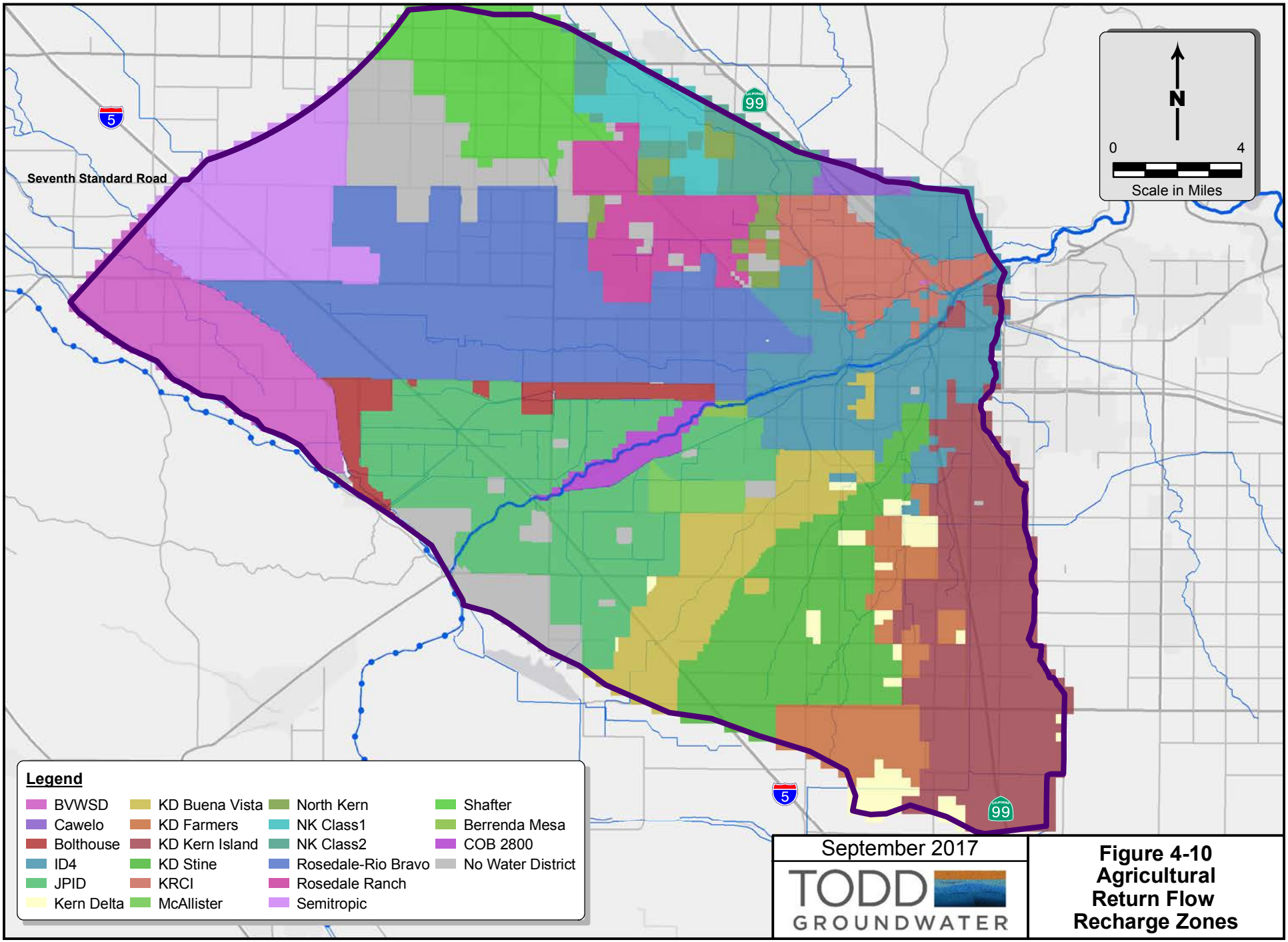


Figure 4-10
Agricultural Return Flow Recharge Zones

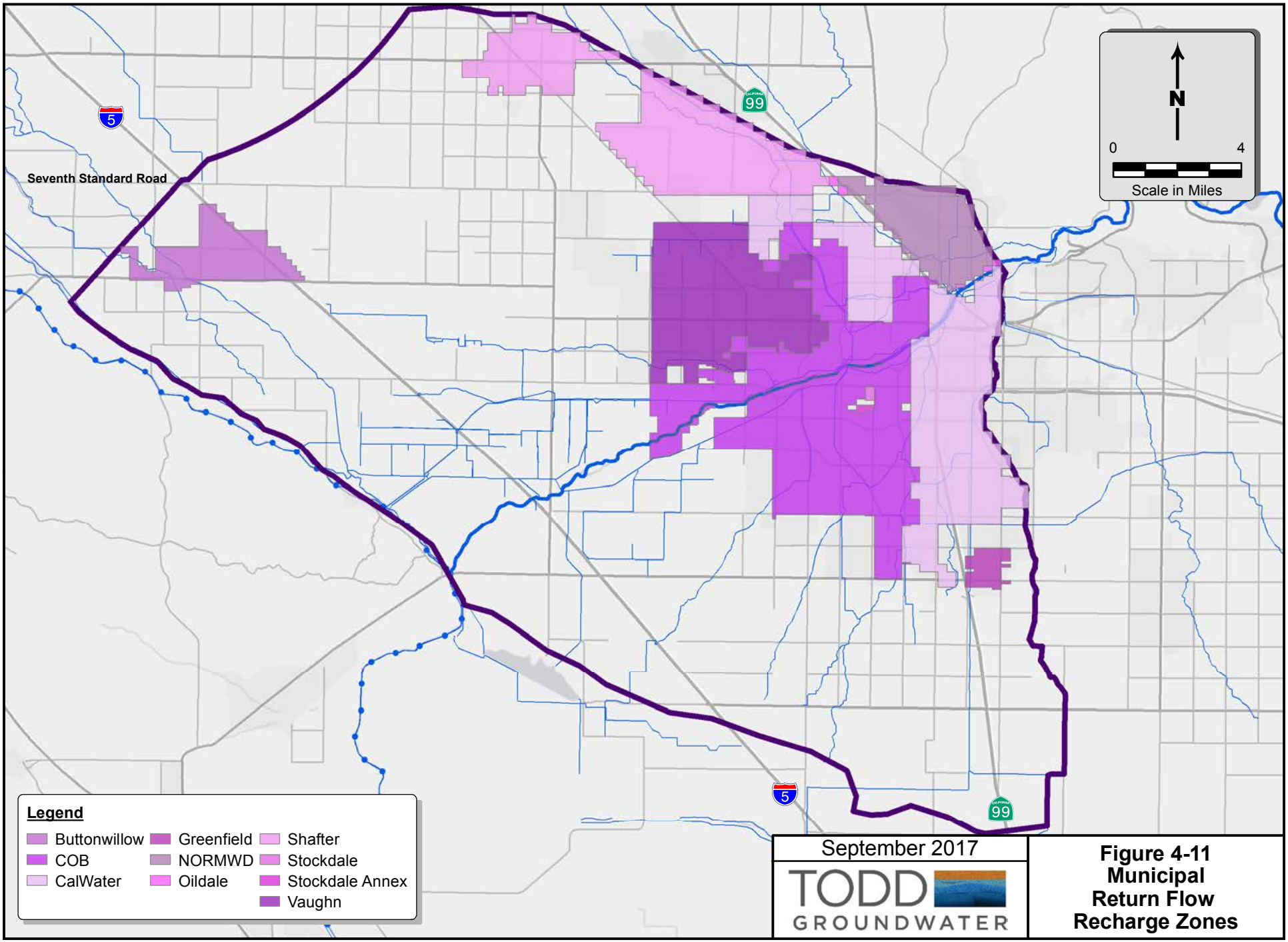


Figure 4-11
Municipal Return Flow Recharge Zones

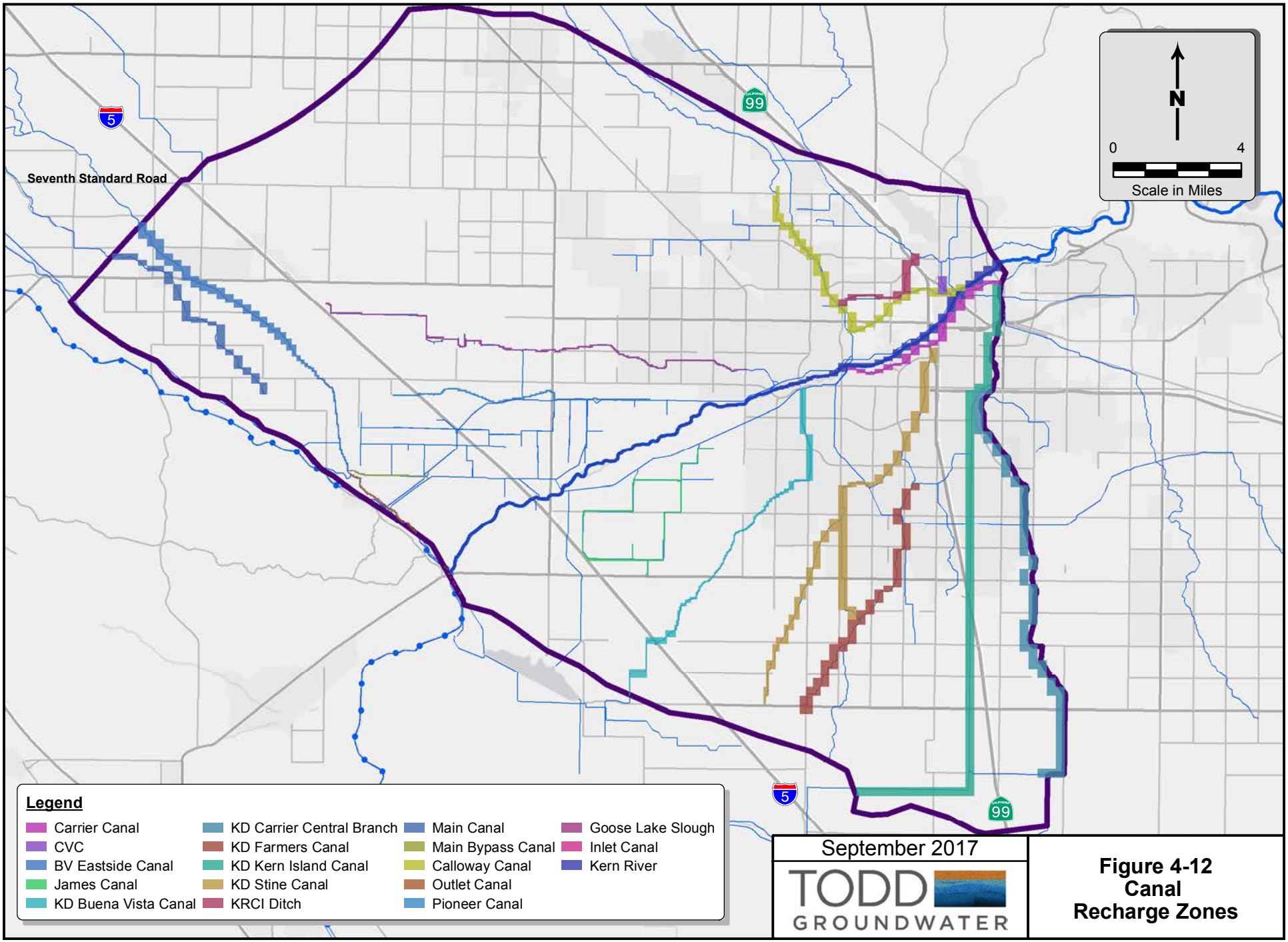


Figure 4-12
Canal
Recharge Zones

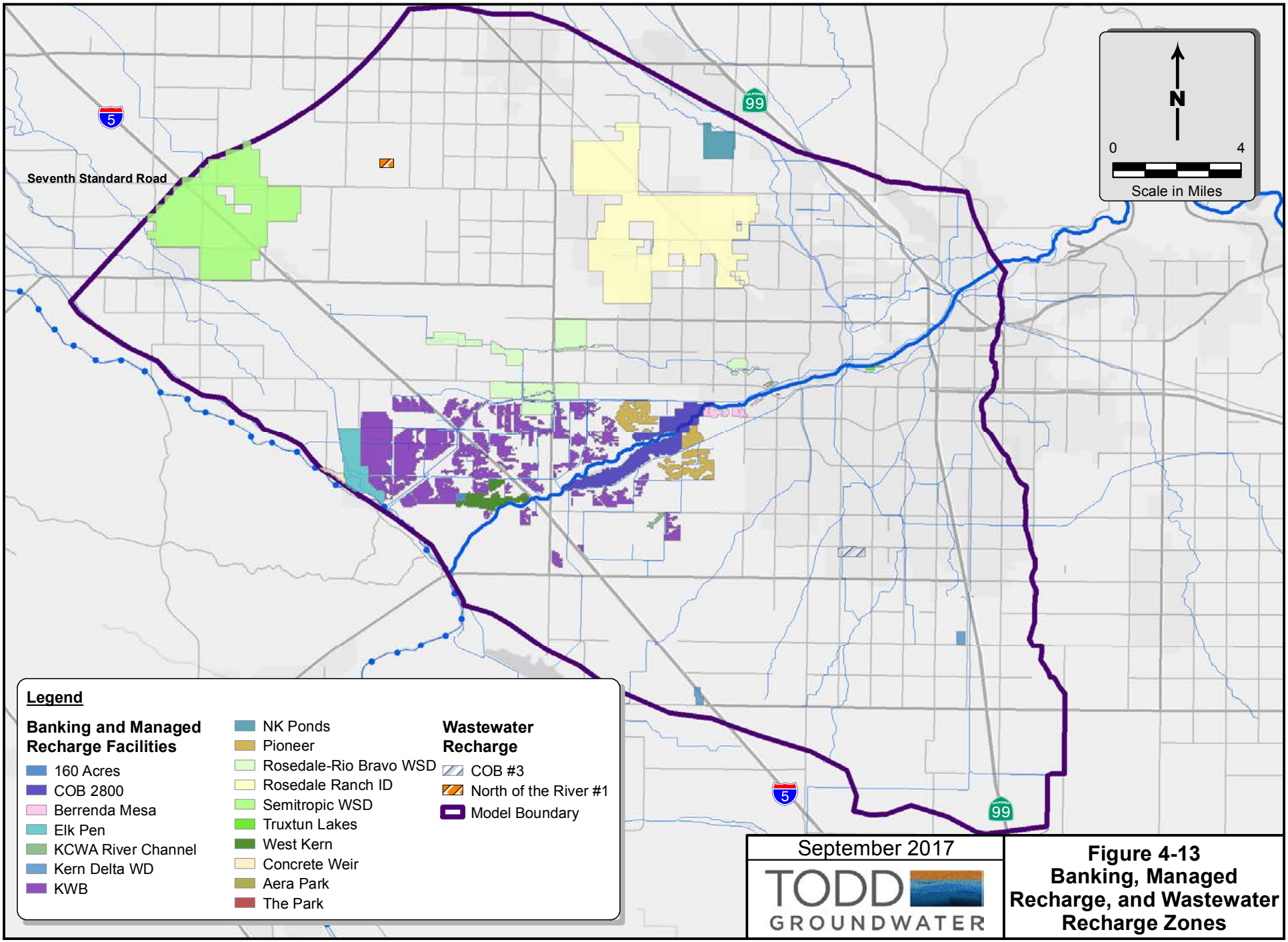


Figure 4-13
Banking, Managed Recharge, and Wastewater Recharge Zones

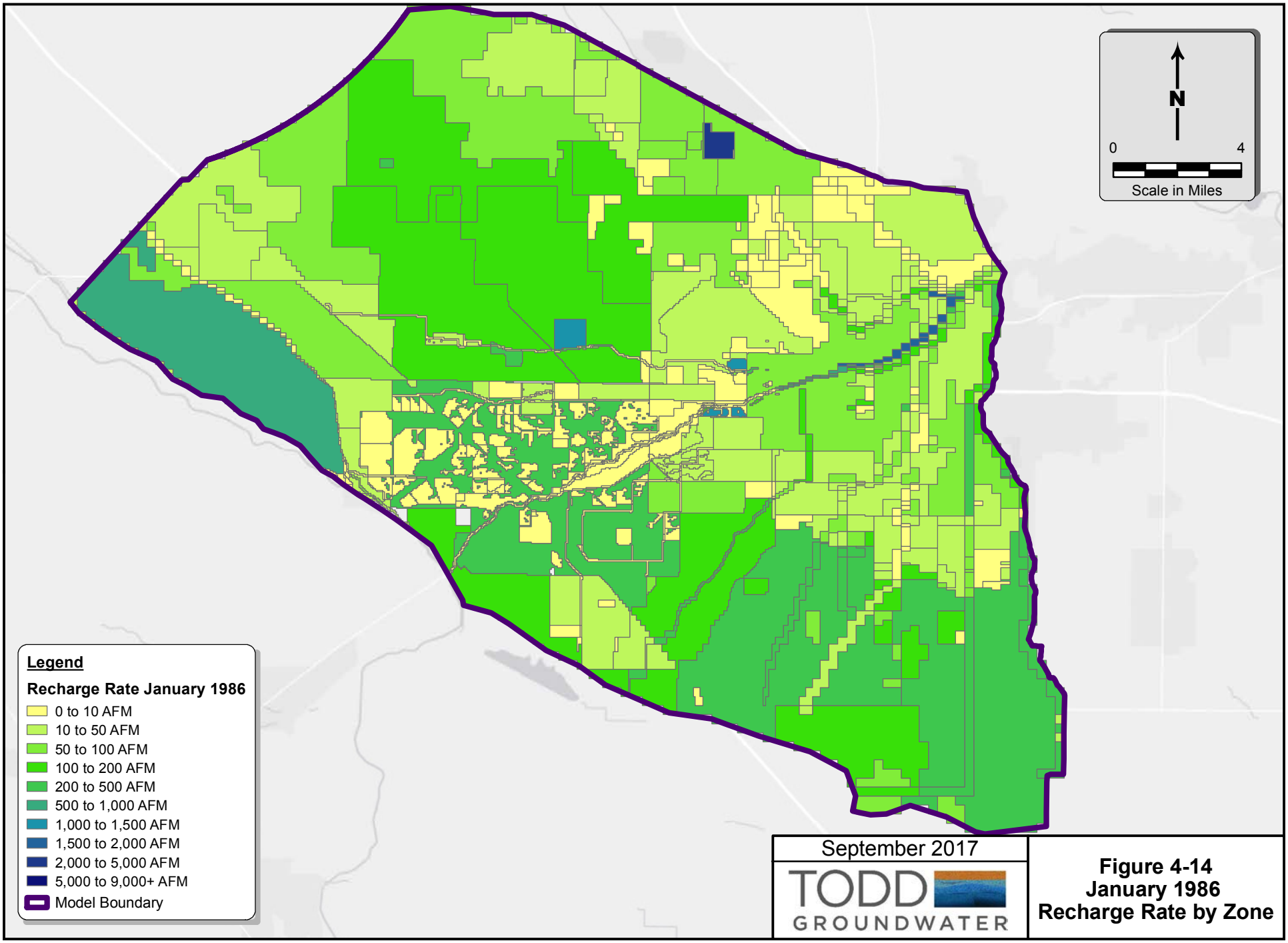


Figure 4-14
January 1986
Recharge Rate by Zone

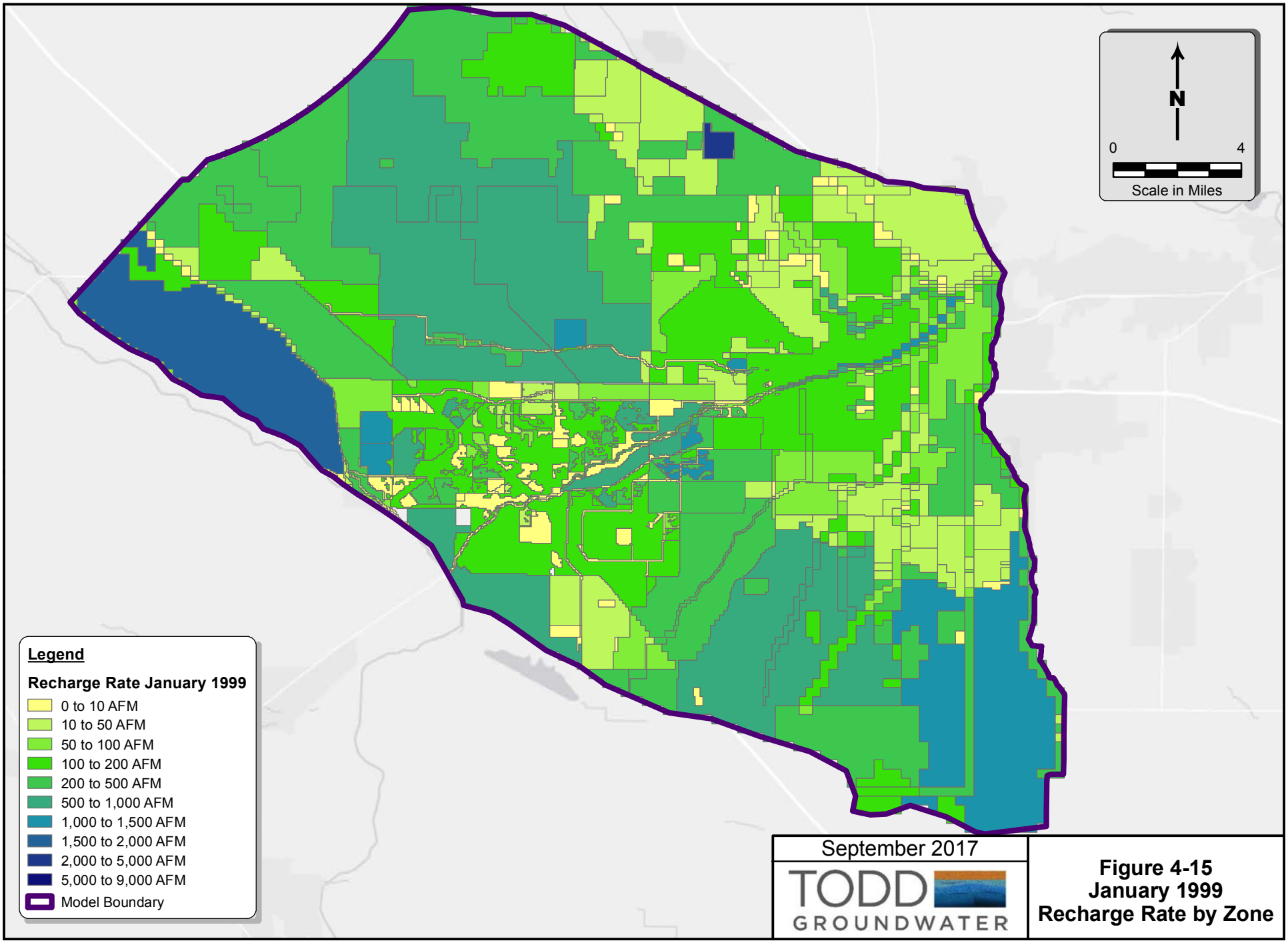


Figure 4-15
January 1999
Recharge Rate by Zone

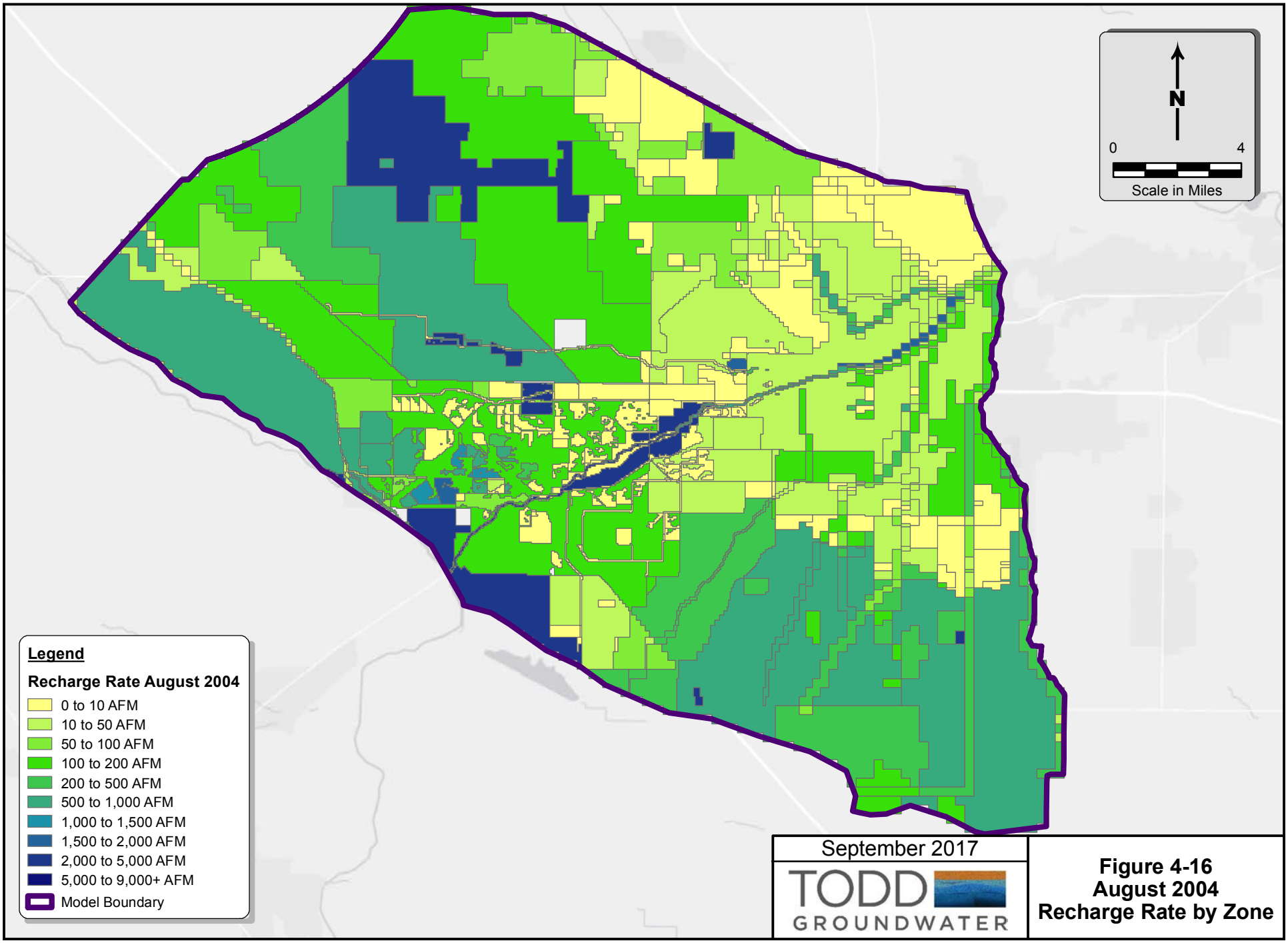


Figure 4-16
August 2004
Recharge Rate by Zone

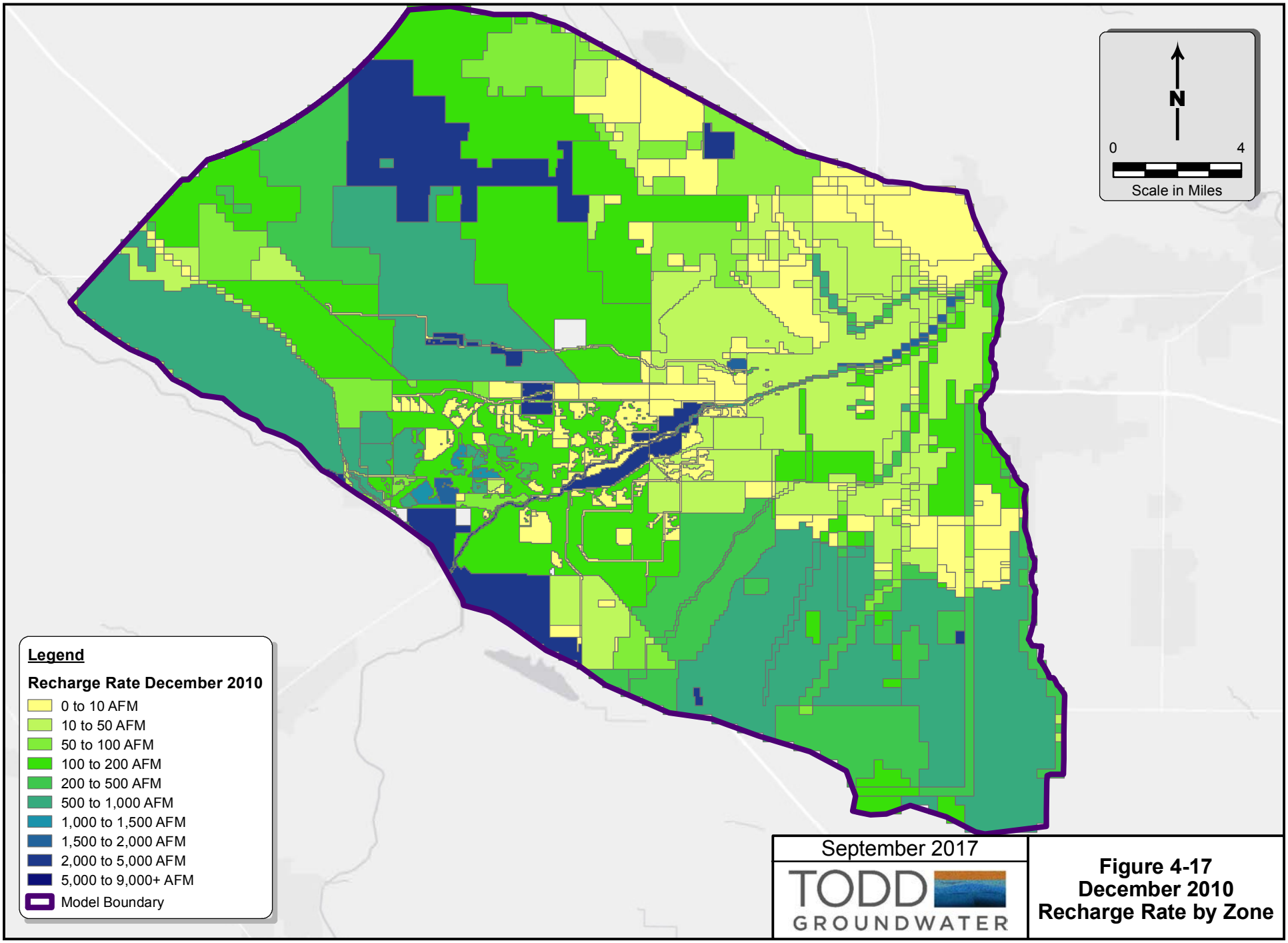


Figure 4-17
December 2010
Recharge Rate by Zone

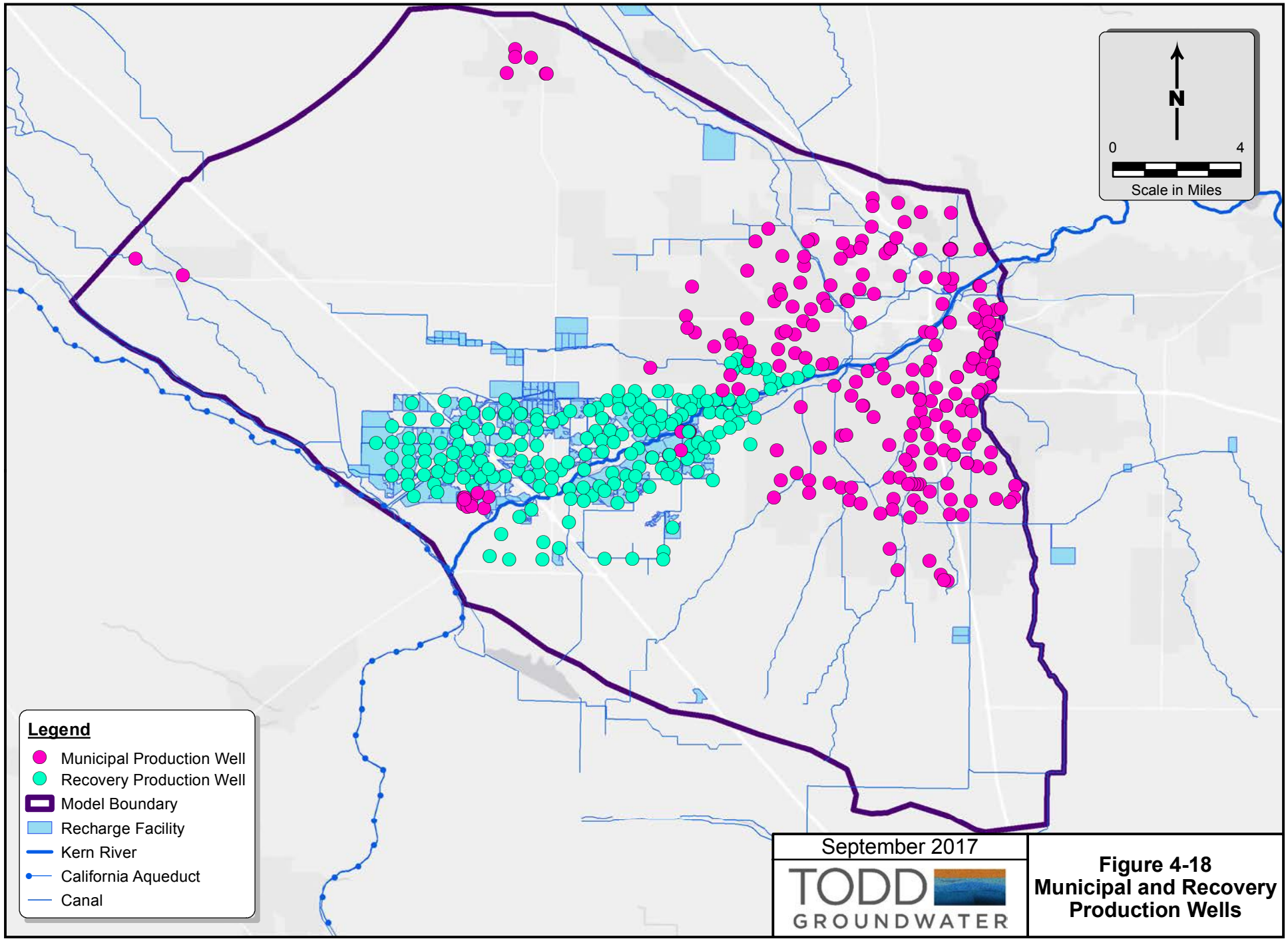


Figure 4-18
Municipal and Recovery Production Wells

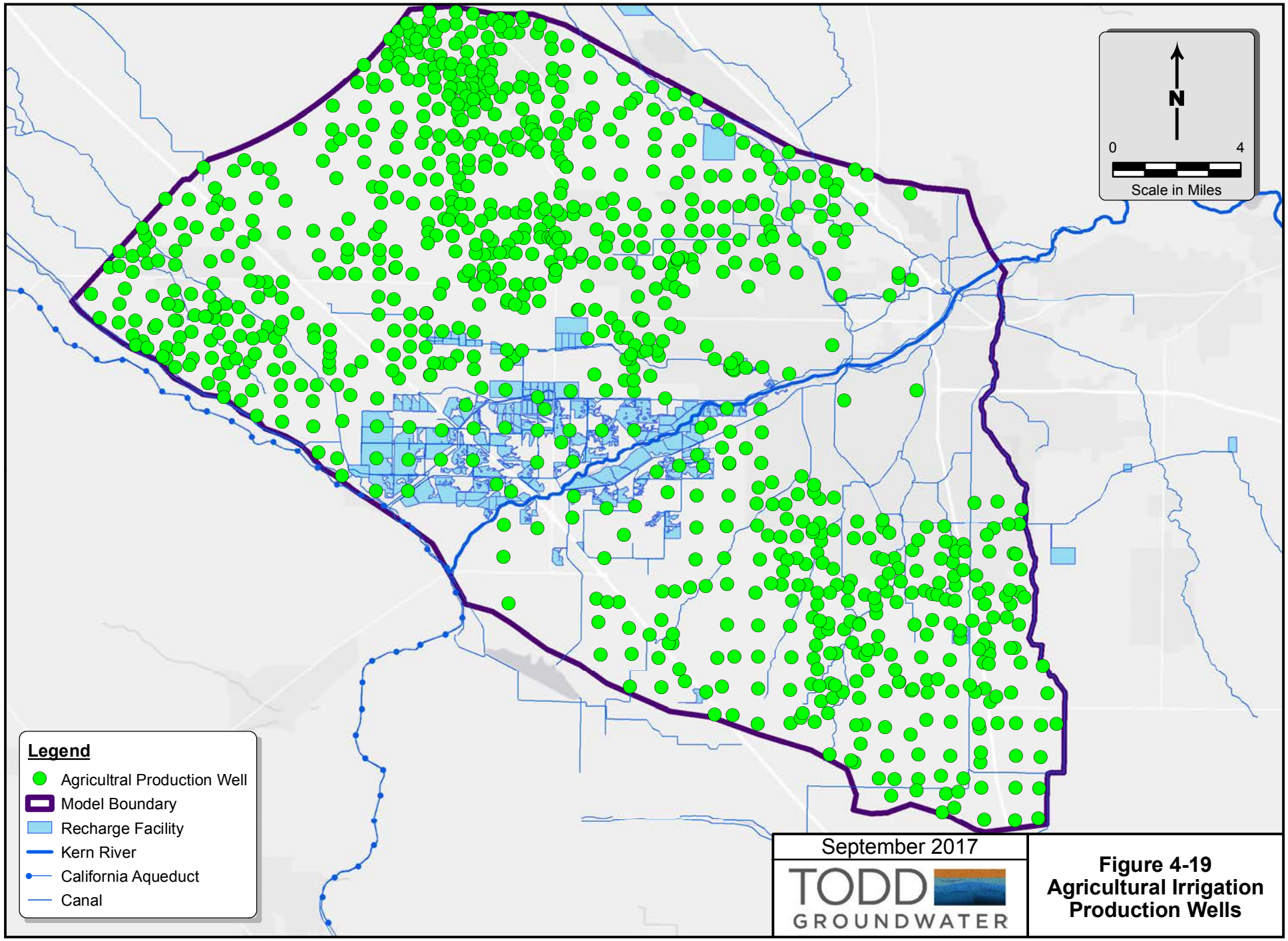
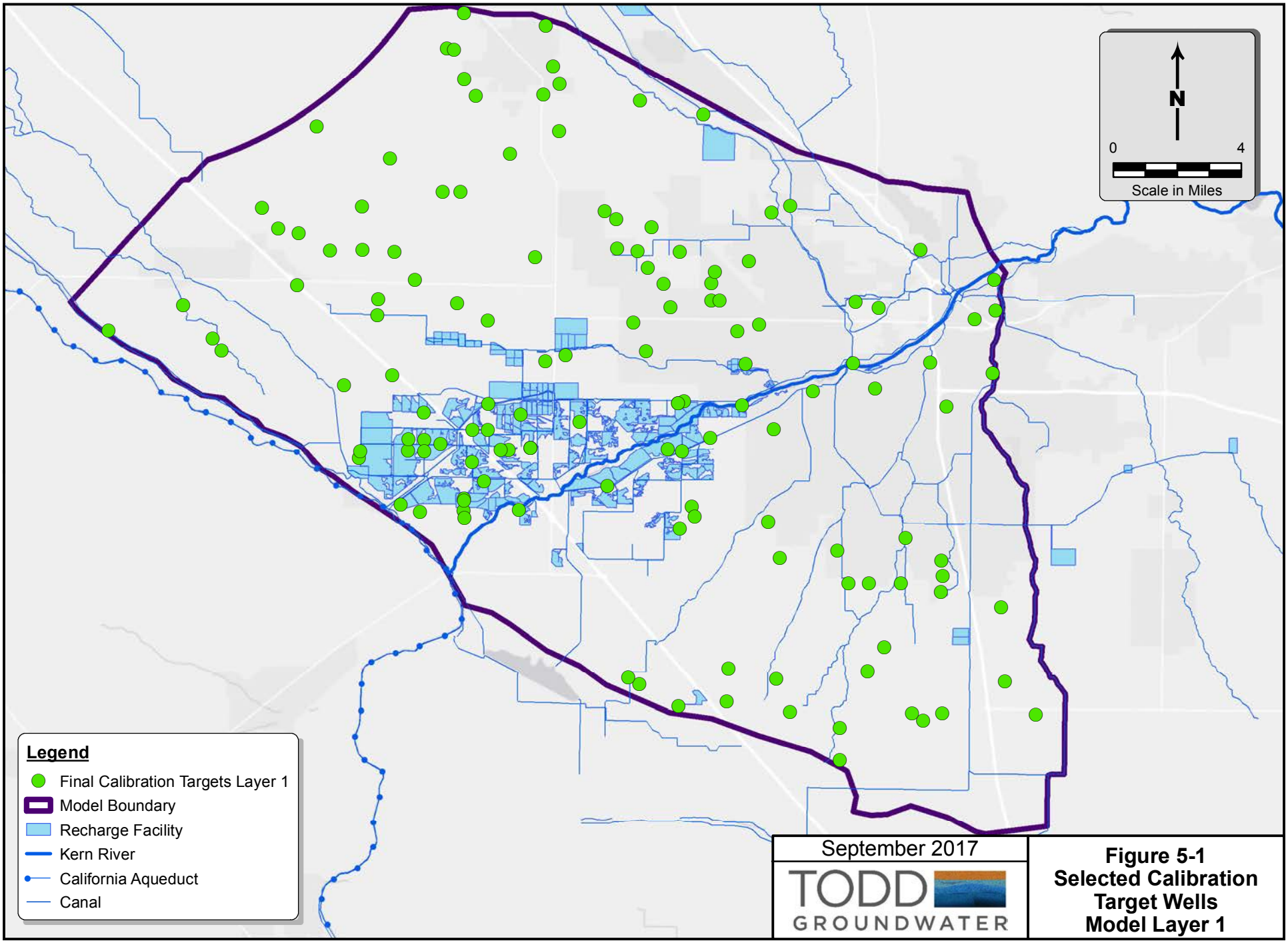
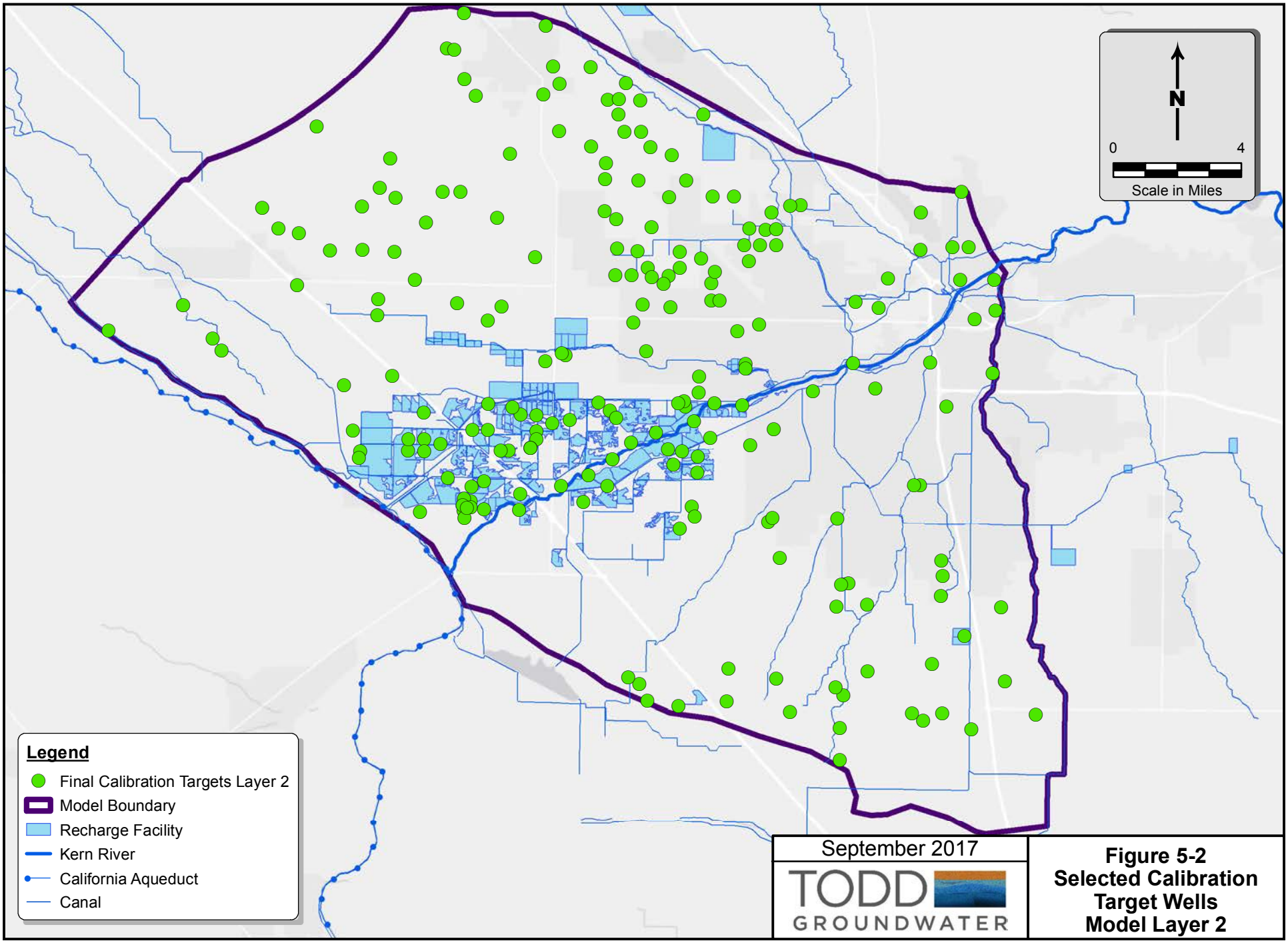


Figure 4-19
Agricultural Irrigation Production Wells


N
0
4
Scale in Miles
Legend
Final Calibration Targets Layer 1
Model Boundary
Recharge Facility
Kern River
California Aqueduct
Canal
September 2017
TODD GROUNDWATER
Figure 5-1
Selected Calibration Target Wells
Model Layer 1


N
0
4
Scale in Miles
Legend
Final Calibration Targets Layer 2
Model Boundary
Recharge Facility
Kern River
California Aqueduct
Canal
September 2017
TODD GROUNDWATER
Figure 5-2
Selected Calibration Target Wells
Model Layer 2

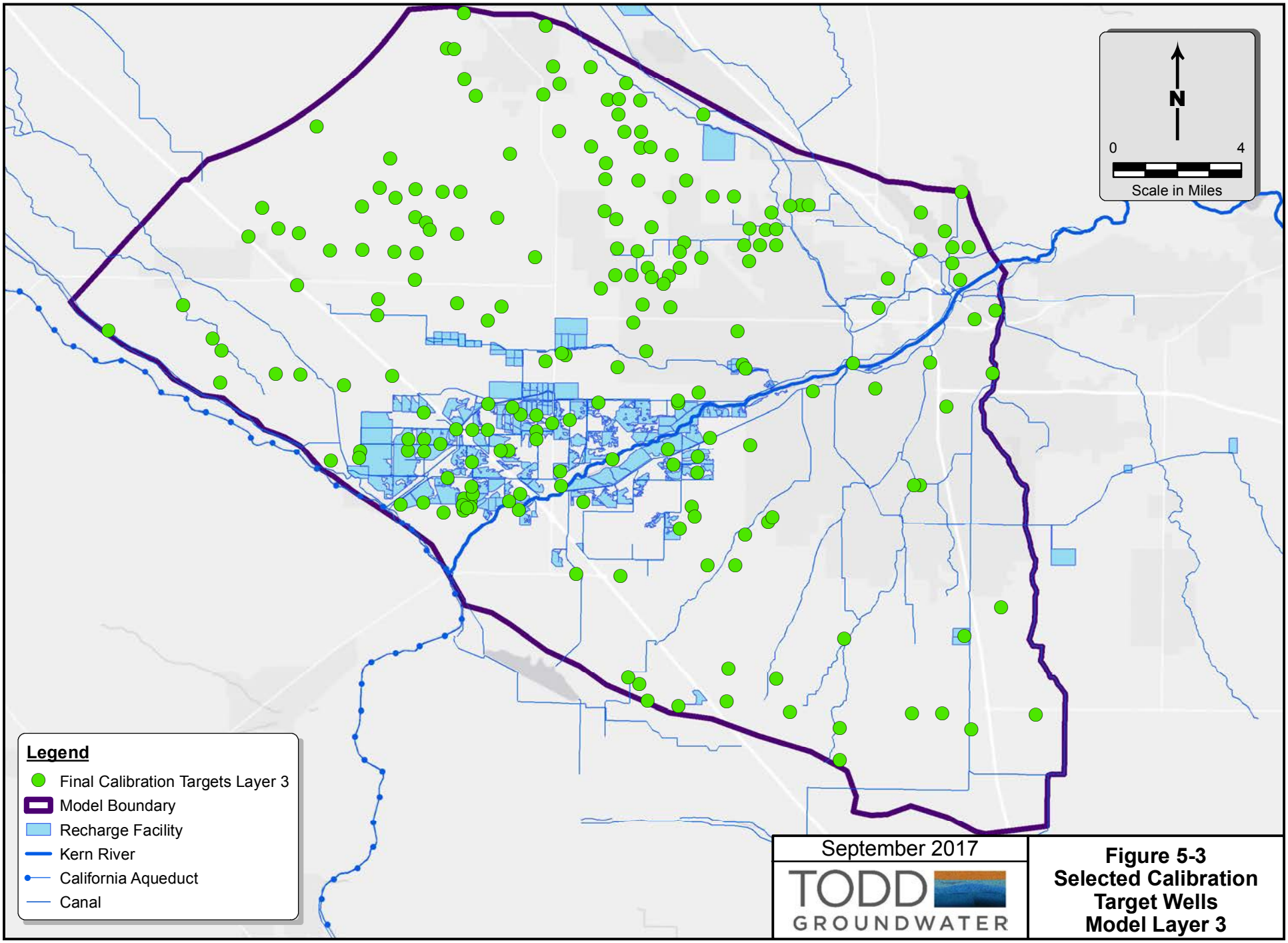
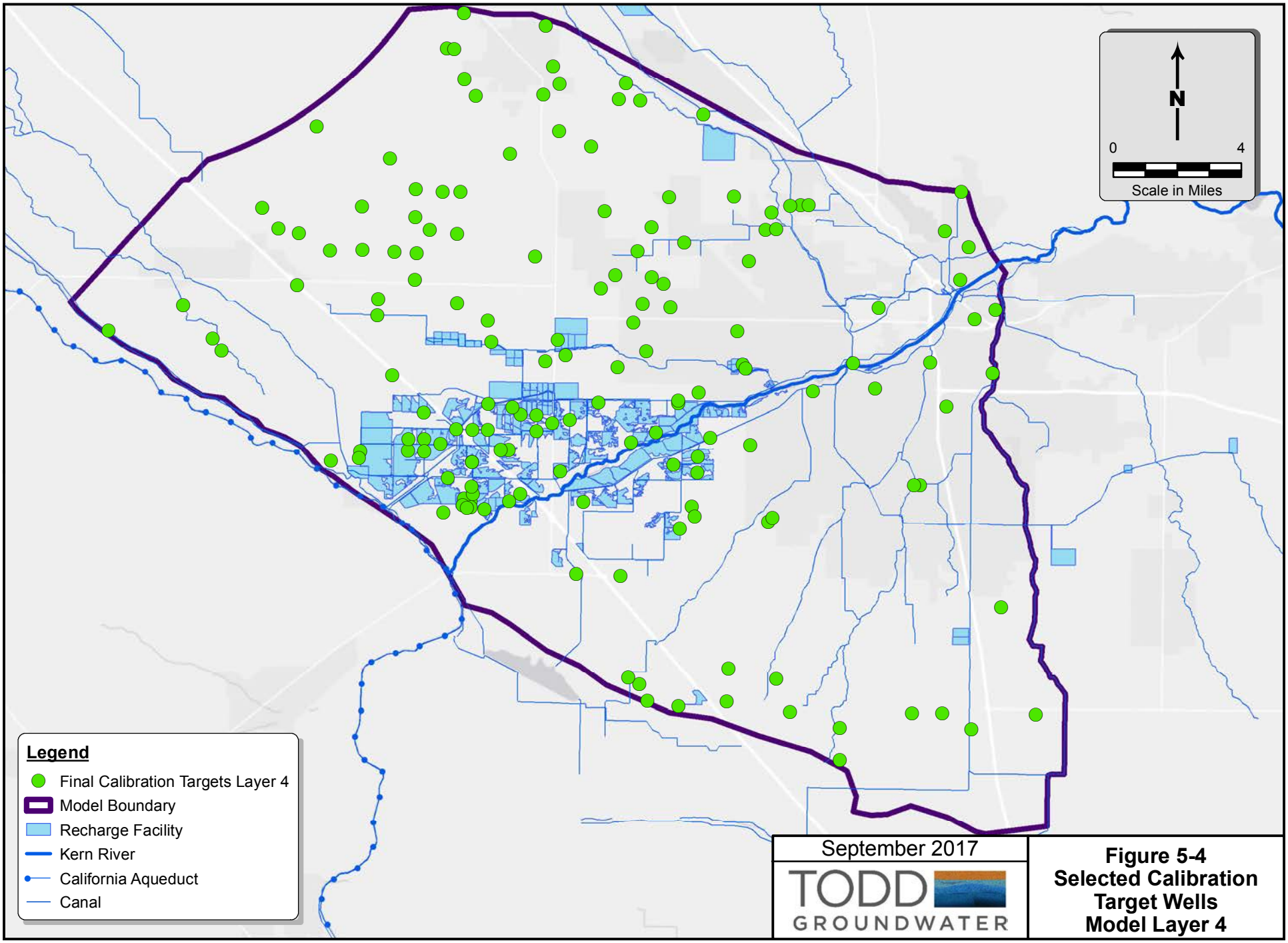


Figure 5-3
Selected Calibration Target Wells
Model Layer 3


N
0
4
Scale in Miles
Legend
Final Calibration Targets Layer 4
Model Boundary
Recharge Facility
Kern River
California Aqueduct
Canal
September 2017
TODD GROUNDWATER
Figure 5-4
Selected Calibration Target Wells
Model Layer 4

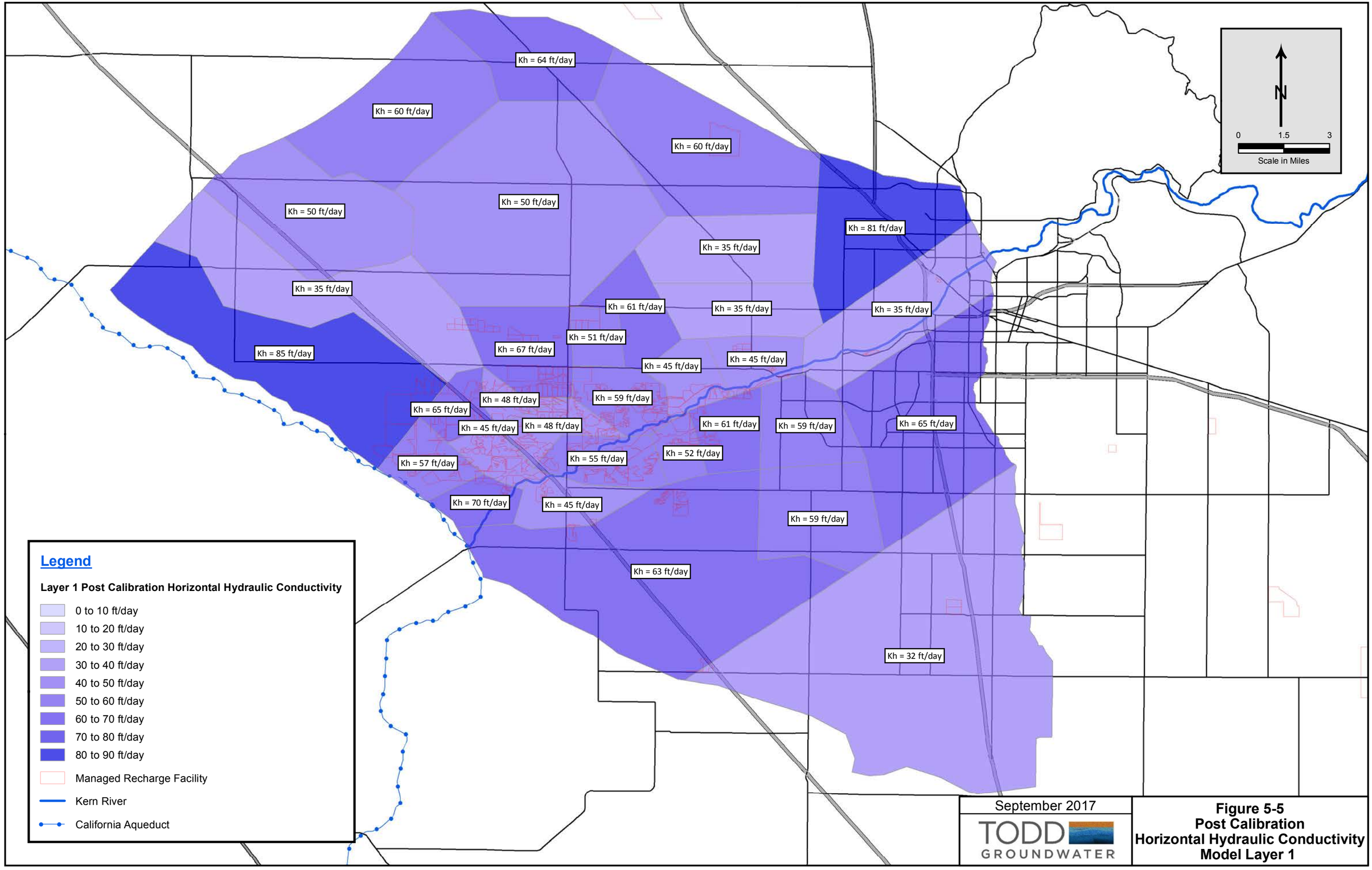


Figure 5-5
Post Calibration
Horizontal Hydraulic Conductivity
Model Layer 1

Kh = 64 ft/day
Kh = 60 ft/day
Kh = 60 ft/day
Kh = 50 ft/day
Kh = 50 ft/day
Kh = 81 ft/day
Kh = 35 ft/day
Kh = 35 ft/day
Kh = 61 ft/day
Kh = 35 ft/day
Kh = 35 ft/day
Kh = 51 ft/day
Kh = 67 ft/day
Kh = 45 ft/day
Kh = 85 ft/day
Kh = 48 ft/day
Kh = 45 ft/day
Kh = 59 ft/day
Kh = 45 ft/day
Kh = 61 ft/day
Kh = 59 ft/day
Kh = 65 ft/day
Kh = 48 ft/day
Kh = 52 ft/day
Kh = 57 ft/day
Kh = 45 ft/day
Kh = 55 ft/day
Kh = 35 ft/day
Kh = 45 ft/day
Kh = 59 ft/day
Kh = 63 ft/day
Kh = 32 ft/day

N

0 1.5 3

Scale in Miles

Legend

Layer 2 Post Calibration Horizontal Hydraulic Conductivity

- 0 to 10 ft/day
- 10 to 20 ft/day
- 20 to 30 ft/day
- 30 to 40 ft/day
- 40 to 50 ft/day
- 50 to 60 ft/day
- 60 to 70 ft/day
- 70 to 80 ft/day
- 80 to 90 ft/day
- Managed Recharge Facility
- Kern River
- California Aqueduct

Path: T:\Projects\Kern Fan Model\167x\GIS\Maps\Figures\Final Report Figures\Section 5\Figure 5-6 Model Layer 2 Post Calibration Horizontal Hydraulic Conductivity.mxd

September 2017

TODD GROUNDWATER

Figure 5-6
Post Calibration
Horizontal Hydraulic Conductivity
Model Layer 2

Kh = 69 ft/day
Kh = 48 ft/day
Kh = 51 ft/day
Kh = 29 ft/day
Kh = 52 ft/day
Kh = 30 ft/day
Kh = 60 ft/day
Kh = 50 ft/day
Kh = 40 ft/day
Kh = 59 ft/day
Kh = 45 ft/day
Kh = 70 ft/day
Kh = 52 ft/day
Kh = 75 ft/day
Kh = 31 ft/day
Kh = 42 ft/day
Kh = 56 ft/day
Kh = 50 ft/day
Kh = 64 ft/day
Kh = 51 ft/day
Kh = 68 ft/day
Kh = 50 ft/day

N

0 1.5 3

Scale in Miles

Legend

Layer 3 Post Calibration Horizontal Hydraulic Conductivity

- 0 to 10 ft/day
- 10 to 20 ft/day
- 20 to 30 ft/day
- 30 to 40 ft/day
- 40 to 50 ft/day
- 50 to 60 ft/day
- 60 to 70 ft/day
- 70 to 80 ft/day
- 80 to 90 ft/day
- Managed Recharge Facility
- Kern River
- California Aqueduct

Path: T:\Projects\Kern Fan Model\671\16\GIS\Maps\Figures\Final Report Figures\Section 5\Figure 5-7 Model Layer 3 Post Calibration Horizontal Hydraulic Conductivity.mxd

September 2017

TODD GROUNDWATER

Figure 5-7
Post Calibration
Horizontal Hydraulic Conductivity
Model Layer 3

Kh = 52 ft/day
Kh = 45 ft/day
Kh = 59 ft/day
Kh = 35 ft/day
Kh = 40 ft/day
Kh = 35 ft/day
Kh = 24 ft/day
Kh = 43 ft/day
Kh = 10 ft/day
Kh = 25 ft/day
Kh = 48 ft/day
Kh = 55 ft/day
Kh = 57 ft/day
Kh = 30 ft/day
Kh = 37 ft/day
Kh = 70 ft/day
Kh = 30 ft/day
Kh = 43 ft/day
Kh = 43 ft/day
Kh = 43 ft/day
Kh = 51 ft/day
Kh = 25 ft/day
Kh = 50 ft/day
Kh = 57 ft/day
Kh = 58 ft/day
Kh = 20 ft/day

N

0 1.5 3

Scale in Miles

Legend

Layer 4 Post Calibration Horizontal Hydraulic Conductivity

- 0 to 10 ft/day
- 10 to 20 ft/day
- 20 to 30 ft/day
- 30 to 40 ft/day
- 40 to 50 ft/day
- 50 to 60 ft/day
- 60 to 70 ft/day
- 70 to 80 ft/day
- 80 to 90 ft/day
- Managed Recharge Facility
- Kern River
- California Aqueduct

Path: T:\Projects\Kern Fan Model (407)\GIS\Maps\Figures\Final Report Figures\Section 5\Figure 5-8 Model Layer 4 Post Calibration Horizontal Hydraulic Conductivity.mxd

September 2017

TODD GROUNDWATER

Figure 5-8
Post Calibration
Horizontal Hydraulic Conductivity
Model Layer 4

Kh/Kz = 200
Kh/Kz = 200
Kh/Kz = 50
Kh/Kz = 50
Kh/Kz = 200
Kh/Kz = 10
Kh/Kz = 25
Kh/Kz = 200
Kh/Kz = 25
Kh/Kz = 25
Kh/Kz = 25
Kh/Kz = 10
Kh/Kz = 10
Kh/Kz = 50
Kh/Kz = 50
Kh/Kz = 25
Kh/Kz = 200
Kh/Kz = 10
Kh/Kz = 100
Kh/Kz = 10
Kh/Kz = 10
Kh/Kz = 50
Kh/Kz = 50
Kh/Kz = 10
Kh/Kz = 25
Kh/Kz = 10
Kh/Kz = 10
Kh/Kz = 50
Kh/Kz = 200
Kh/Kz = 50
Kh/Kz = 50
Kh/Kz = 50

N

0 1.5 3

Scale in Miles

Legend

Layer 1 Post Calibration Vertical Anisotropy

- 10
- 25
- 50
- 100
- 200
- 500
- Managed Recharge Facility
- Kern River
- California Aqueduct

September 2017

TODD GROUNDWATER

Figure 5-9
Post Calibration Vertical Anisotropy Model Layer 1

Path: N:\Projects\Kern Fan Model (607\GIS\Maps\Figures\Final Report Figures\Section 5\Figure 5-9 Model Layer 1 Post Calibration Vertical Anisotropy.mxd

Kh/Kz = 200
Kh/Kz = 200
Kh/Kz = 50
Kh/Kz = 50
Kh/Kz = 200
Kh/Kz = 10
Kh/Kz = 25
Kh/Kz = 200
Kh/Kz = 25
Kh/Kz = 25
Kh/Kz = 25
Kh/Kz = 10
Kh/Kz = 10
Kh/Kz = 50
Kh/Kz = 200
Kh/Kz = 200
Kh/Kz = 10
Kh/Kz = 50
Kh/Kz = 50
Kh/Kz = 10
Kh/Kz = 10
Kh/Kz = 50
Kh/Kz = 50
Kh/Kz = 10
Kh/Kz = 10
Kh/Kz = 50
Kh/Kz = 200
Kh/Kz = 50
Kh/Kz = 50
Kh/Kz = 50

N

0 1.5 3

Scale in Miles

Legend

Layer 2 Post Calibration Vertical Anisotropy

- 10
- 25
- 50
- 100
- 200
- 500
- Managed Recharge Facility
- Kern River
- California Aqueduct

Path: H:\Projects\Kern Fan Model II\07\GIS\Maps\Figures\Final Report Figures\Section 5\Figure 5-10 Model Layer 2 Post Calibration Vertical Anisotropy.mxd

September 2017

TODD GROUNDWATER

Figure 5-10
Post Calibration
Vertical Anisotropy
Model Layer 2

Kh/Kz = 500
Kh/Kz = 500
Kh/Kz = 100
Kh/Kz = 100
Kh/Kz = 50
Kh/Kz = 500
Kh/Kz = 50
Kh/Kz = 50
Kh/Kz = 500
Kh/Kz = 100
Kh/Kz = 50
Kh/Kz = 100
Kh/Kz = 500
Kh/Kz = 50
Kh/Kz = 100
Kh/Kz = 100
Kh/Kz = 100
Kh/Kz = 100
Kh/Kz = 100

N

0 1.5 3

Scale in Miles

Legend

Layer 3 Post Calibration Vertical Anisotropy

- 10
- 25
- 50
- 100
- 200
- 500
- Managed Recharge Facility
- Kern River
- California Aqueduct

Path: H:\Projects\Kern Fan Model (407.01\GIS\Maps\Figures\Final Report Figures\Section 5\Figure 5-11 Model Layer 3 Post Calibration Vertical Anisotropy.mxd

September 2017

TODD GROUNDWATER

Figure 5-11
Post Calibration Vertical Anisotropy Model Layer 3

Vani = 500

N

0 1.5 3

Scale in Miles

Legend

Layer 4 Post Calibration Vertical Anisotropy

- 10
- 25
- 50
- 100
- 200
- 500
- Managed Recharge Facility
- Kern River
- California Aqueduct

Path: H:\Projects\Kern Fan Model (407)\GIS\Maps\Figures\Final Report Figures\Section 5\Figure 5-12 Model Layer 4 Post Calibration Vertical Anisotropy.mxd

September 2017

TODD GROUNDWATER

Figure 5-12
Post Calibration Vertical Anisotropy Model Layer 4

Sy = 0.18
Sy = 0.16
Sy = 0.23
Sy = 0.16
Sy = 0.19
Sy = 0.23
Sy = 0.21
Sy = 0.16
Sy = 0.18
Sy = 0.21
Sy = 0.22
Sy = 0.15
Sy = 0.25
Sy = 0.2
Sy = 0.23
Sy = 0.16
Sy = 0.18
Sy = 0.17
Sy = 0.16
Sy = 0.18
Sy = 0.23
Sy = 0.16
Sy = 0.17
Sy = 0.15
Sy = 0.2
Sy = 0.16
Sy = 0.16
Sy = 0.16
Sy = 0.16
Sy = 0.18
Sy = 0.2
Sy = 0.2
N
0
1.5
3
Scale in Miles

Legend

Layer 1 Post Calibration Specific Yield

- 0 to 0.02
- 0.02 to 0.04
- 0.04 to 0.06
- 0.06 to 0.08
- 0.08 to 0.10
- 0.10 to 0.12
- 0.12 to 0.14
- 0.14 to 0.16
- 0.16 to 0.18
- 0.18 to 0.20
- 0.20 to 0.22
- 0.22 to 0.24
- 0.25 to 0.25
- Managed Recharge Facility
- Kern River
- California Aqueduct

Path: T:\Projects\Kern Fan Model\GIS\MXD\Figures\Final Report Figures\Section 5\Figure 5-13 Model Layer1 Post Calibration Specific Yield.mxd

September 2017

TODD GROUNDWATER

Figure 5-13
Post Calibration Specific Yield Model Layer 1

Sy = 0.07
Ss = 0.0002

Sy = 0.1
Ss = 0.0003

Sy = 0.1
Ss = 0.0003

Sy = 0.03
Ss = 0.0001

Sy = 0.05
Ss = 0.0002

Sy = 0.18
Ss = 0.0006

Sy = 0.12
Ss = 0.0004

Sy = 0.04
Ss = 0.0001

Sy = 0.12
Ss = 0.0004

Sy = 0.03
Ss = 0.0001

Sy = 0.04
Ss = 0.0001

Sy = 0.05
Ss = 0.0002

Sy = 0.05
Ss = 0.0002

Sy = 0.06
Ss = 0.0002

Sy = 0.08
Ss = 0.0003

Sy = 0.03
Ss = 0.0001

Sy = 0.03
Ss = 0.0001

Sy = 0.04
Ss = 0.0001

Sy = 0.03
Ss = 0.0001

Sy = 0.21
Ss = 0.0007

Sy = 0.03
Ss = 0.0001

Sy = 0.05
Ss = 0.0002

Sy = 0.03
Ss = 0.0001

Sy = 0.14
Ss = 0.0005

Sy = 0.03
Ss = 0.0001

Sy = 0.06
Ss = 0.0002

Sy = 0.15
Ss = 0.0005

Sy = 0.02
Ss = 0.0001

Sy = 0.03
Ss = 0.0001

Sy = 0.03
Ss = 0.0001

Sy = 0.06
Ss = 0.0002

Sy = 0.1
Ss = 0.0003

N

0 1.5 3

Scale in Miles

Legend

Layer 2 Post Calibration Specific Yield

- 0 to 0.02
- 0.02 to 0.04
- 0.04 to 0.06
- 0.06 to 0.08
- 0.08 to 0.10
- 0.10 to 0.12
- 0.12 to 0.14
- 0.14 to 0.16
- 0.16 to 0.18
- 0.18 to 0.20
- 0.20 to 0.22
- 0.22 to 0.24
- 0.25 to 0.25
- Managed Recharge Facility
- Kern River
- California Aqueduct

Path: H:\Projects\Kern Fan Model 667.01\GIS\Maps\Figures\Final Report Figures\Section 6\Figure 5-14 Model Layer 2 Post Calibration Specific Yield and Specific Storage.mxd

September 2017

TODD GROUNDWATER

Figure 5-14
Post Calibration
Specific Yield and Specific Storage
Model Layer 2

Sy = 0.00015
Ss = 0.00000049

Sy = 0.00013
Ss = 0.00000043

Sy = 0.00008
Ss = 0.00000026

Sy = 0.00017
Ss = 0.00000056

Sy = 0.00015
Ss = 0.0000005

Sy = 0.00004
Ss = 0.00000014

Sy = 0.00007
Ss = 0.00000025

Sy = 0.00004
Ss = 0.00000014

Sy = 0.00017 Ss = 0.00000058

Sy = 0.00007
Ss = 0.00000022

Sy = 0.00008 Ss = 0.00000028

Sy = 0.00014
Ss = 0.00000047

Sy = 0.0001
Ss = 0.00000033

Sy = 0.00005
Ss = 0.00000018

Sy = 0.0001
Ss = 0.00000034

Sy = 0.00015
Ss = 0.0000005

Sy = 0.00004
Ss = 0.00000015

Sy = 0.00006
Ss = 0.00000022

Sy = 0.00015
Ss = 0.0000005

Sy = 0.00017
Ss = 0.00000058

Sy = 0.00022
Ss = 0.00000073

Sy = 0.00008
Ss = 0.00000025

N

0 1.5 3

Scale in Miles

Legend

Layer 3 Post Calibration Specific Yield

- 0.00004
- 0.00004 to 0.00006
- 0.00006 to 0.00008
- 0.00008 to 0.00010
- 0.00010 to 0.00012
- 0.00012 to 0.00014
- 0.00014 to 0.00016
- 0.00016 to 0.00018
- 0.00018 to 0.00020
- 0.00020 to 0.00022
- Managed Recharge Facility
- Kern River
- California Aqueduct

Path: T:\Projects\Kern Fan Model\GIS\Maps\Figures\Final Report Figures\Section 5\Figure 5-15 Model Layer 3 Post Calibration Specific Yield and Specific Storage.mxd

September 2017

TODD GROUNDWATER

Figure 5-15
Post Calibration
Specific Yield and Specific Storage
Model Layer 3

Ss = 0.00000084
Ss = 0.00000094
Ss = 0.00000054
Ss = 0.00000079
Ss = 0.0000006
Ss = 0.00000083
Ss = 0.0000004
Ss = 0.00000051
Ss = 0.00000059
Ss = 0.00000075
Ss = 0.00000037
Ss = 0.00000084
Ss = 0.0000007
Ss = 0.00000045
Ss = 0.00000054
Ss = 0.00000023
Ss = 0.0000005
Ss = 0.00000043
Ss = 0.00000081
Ss = 0.00000065
Ss = 0.00000079
Ss = 0.0000007

N

0 1.5 3

Scale in Miles

Legend

Layer 4 Post Calibration Specific Yield

- 0 to 0.00000025
- 0.00000025 to 0.00000030
- 0.00000030 to 0.00000040
- 0.00000040 to 0.00000050
- 0.00000050 to 0.00000060
- 0.00000060 to 0.00000070
- 0.00000070 to 0.00000080
- 0.00000080 to 0.00000090
- 0.00000090 to 0.00000095
- Managed Recharge Facility
- Kern River
- California Aqueduct

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September 2017

TODD GROUNDWATER

Figure 5-16
Post Calibration Specific Storage Model Layer 4

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2.5.1.1.2 Geology

2.5.1.1.2.1 General

California is a region of sharply contrasting geologic features resulting from the juxtaposition of blocks, commonly separated by faults, which are comprised of dissimilar rock types and structures, and which have different geologic histories (Hill, 1954). These geologic features are controlled by two major structural trends. The most prominent structural grain trends north to northwest and is dominated by the San Andreas fault zone and sub-parallel faults. The second major structural pattern trends east-west to northeast-southwest. The structural patterns and other fundamental geologic and physiographic elements combine to characterize the natural provinces (Fig. 2.5.1-1).

The Site is situated in the southern part of the Great Valley Province known as the San Joaquin basin. Geologic aspects of the San Joaquin basin as well as other areas within a 200-mile radius of the Site are discussed below by natural province.

Regional geologic setting is discussed as an integral part of this subsection.

The regional geology within a 200-mile radius of the Site is shown in Figure 2.5.1-3. The regional tectonic map is shown in Figure 2.5.1-4.

Structural evolution of the Site Region relates directly to the Region Surrounding the Site (20 mile radius) and is discussed in Subsection 2.5.1.1.6 and Appendix 2.5E. A generalized geologic time scale is presented in Table 2.5.1-2.

2.5.1.1.2.2 Great Valley Province

2.5.1.1.2.2.1 Stratigraphy

A thick sequence of sediments has filled the Great Valley structural trough which ranges from Jurassic to Holocene age. As much as 40,000 feet of Cenozoic sediments have accumulated beneath the San Joaquin basin which forms the southern two thirds of the trough. This sedimentary sequence rests on basement rocks which consist of metasediments, volcanics and granitics along the eastern margin of the basin and probably basaltic or ultramafics beneath the western edge (Hackel, 1966).

The generalized stratigraphy of the southern San Joaquin basin is presented in Figure 2.5.1-5. The San Joaquin basin contains Upper Cretaceous marine strata overlain by Tertiary and Quaternary marine and non-marine beds. The section is thickest along the western edge of the southern portion of the valley. The depth to basement rocks below the land surface increases from 0 feet in the Sierran foothills to about 20,000 feet at the Site. Test holes on the west side of the valley do not reach basement rocks. The full

thickness of sedimentary fill is not known from drilling, however, it is estimated by geophysicists that at least 40,000 feet of sediments overlie crystalline basement rock (Manning, 1973).

The sediments that form this thick stratigraphic section in the San Joaquin basin were derived by erosion from land areas now occupied by the Sierra Nevada, Tehachapi Mountains, San Emigdio Mountains, and eastern Coast Ranges. Most of these sediments are composed of consolidated marine deposits laid down in seaways that once occupied the valley trough. The marine beds are overlain by brackish to fresh water lacustrine and fluvial continental deposits.

The continental deposits in the San Joaquin Valley range from Pliocene to Holocene in age. Alluvial deposits along the west side of the valley, which are derived from the Coast Ranges, are assigned to the Tulare Formation as described by Anderson (1905), and Woodring and others (1940). Continental deposits along the east side of the valley in Kern County were derived from the Sierra Nevada, and are assigned to the Kern River Formation. (Diepenbrock, 1933). Farther north, in the Modesto area and beyond, the sediments derived from the Sierra Nevada have been differentiated into several units. The Tulare and Kern River Formations are described in Subsection 2.5.1.1.5.

A mid-Pleistocene lacustrine clay has been identified and correlated beneath an area of about 5000 square miles in portions of the central and southern San Joaquin Valley (Figure 2.5.1-6). This clay has been variously designated the Corcoran Clay by Frink and Kues (1954), the Diatomaceous Clay by Davis and others (1959) and the E-Clay by Croft and Gordon (1968). The clay is interbedded with alluvial fan deposits of the Tulare and Kern River Formations.

5

Holocene sediments in the San Joaquin basin overlie the Tulare and Kern River Formations, but can only be differentiated from them along the margins of the basin where small unconformities and paleosols occur. Holocene deposits in the central portion of the basin have not been readily differentiated from the underlying Pleistocene deposits due to their similar lithologies and gradational contact.

A discussion of the stratigraphy of the Region Surrounding the Site is presented in Subsection 2.5.1.1.5.

2.5.1.1.2.2.2 Structure

The Great Valley structural trough is asymmetrical, the axis of which lies close to the western border. The trough has a

long stable eastern shelf, formed by the westward dipping slope of the basement surface beneath the sedimentary rocks in the Sacramento and San Joaquin Valleys. Structure contours on top of the basement complex (Smith, 1964) diverge from the surface contours with an apparent westward dip of 400 to 800 feet per mile. The dip steepens toward the west and south, suggesting tectonic warping of the valley trough accompanied tectonic uplift of the Sierra Nevada block. The short western flank is formed by the steep up-turned edge of the basin sediments (Hackel, 1966).

The regional southward tilt of the Great Valley trough is interrupted by two transverse, subsurface, structural highs known as the Stockton Arch and the Bakersfield Arch (Figures 2.5.1-4 and 2.5.1-7). The Stockton Arch extends from the Sierra Nevada southwesterly across the central portion of the Great Valley, separating the San Joaquin basin on the south from the northern Sacramento basin. The Bakersfield Arch, located in the southern San Joaquin Valley, plunges westerly from Bakersfield across the basin and forms the dominant portion of a continuous structural uplift which divides the San Joaquin basin into two subbasins: the elongate Tulare basin to the northwest and the oval Maricopa basin to the southeast (Hoots and others, 1954).

The dominant structural features of the southern San Joaquin Valley are shown in Figures 2.5.1-7 and 2.5.1-7A. A geologic profile of the structural features is presented in Figure 2.5.1-8.

Dibblee (1955) has summarized the structural setting of the southeastern San Joaquin Valley region:

> "The pivotal area of the continuously westward tilted Sierra Nevada-Great Valley block follows the present margin between the Sierra Nevada and the Great Valley, as topographic and stratigraphic evidence indicates this marginal area to have been neither elevated nor depressed to any great extent during Cretaceous or Cenozoic time. During that long interval of time, this 600-mile long pivotal area has been remarkably stable and free from tectonic movements. Only in the extreme southeastern portion of Bakersfield have tectonic disturbances occurred and these have been in the form of faulting. The largest of these faults is the White Wolf fault trending northeast directly across the pivotal margin between the Sierra Nevada and the San Joaquin Valley."

The dominant structural feature of the southeastern San Joaquin Valley is a faulted, northwesterly striking, regional homocline formed by the westward tilting of the Sierra Nevada block (Richardson, 1966). The homocline is

broken by many closely to moderately spaced, parallel, north to northwest trending faults, predominantly displaying normal tensional movement, which displaced Tertiary and Plio-Pleistocene deposits.

Faults within this area include the Mount Poso, Round Mountain, Kern Front and Premier faults (Figure 2.5.1-7A). These features generally trend north to northwesterly and have cumulative vertical displacement of less than about 500 feet. Faults which exhibit larger displacements are the Kern Gorge (Kern River), Edison, Poso Creek and White Wolf faults (Figure 2.5.1-7A). Vertical offset on the Kern Gorge and Edison faults is 2,000 feet (Park and others, 1963) and 5,000 feet (Dibblee and Chesterman, 1953), respectively.

The Kern Gorge fault, also known as the Kern River fault, is a northwest trending normal fault which forms a prominent scrap between upthrown Sierran quartz diorite on the northeast and downthrown Tertiary strata on the southwest (Figures 2.5.1-7, 2.5.1-7A and 2.5.1-10A). The fault is traceable for about 15 miles and dips from 55° to 30° to the southwest and south (Dibblee and Chesterman, 1953). Vertical displacement on the Kern Gorge fault has been described as at least 2,000 feet by Nugent (1942), Dibblee and Chesterman (1953) and Addicott (1972) and as 5,000 feet (A.A.P.G., 1965). The fault appears to have developed along a plane of foliation in quartz diorite and vertical fault grooves have been identified on the fault plane (Dibblee and Chesterman, 1953).

The relationship of the Kern Gorge fault to other faults is variously illustrated in Figure 2.5.1-10B. The most recent interpretation, by Kern COG (in preparation), is shown enlarged for clarity. The southwest dipping Kern Gorge fault, combined with the northeast dipping Mount Poso-Round Mountain fault systems, forms a northwest trending graben-like structure on the east margin of the valley. Several west trending normal faults, including the Poso Creek fault, are downthrown to the south and cross the graben feature. Both the Kern Gorge fault and Round Mountain-Mount Poso fault systems are shown intersecting with the Poso Creek fault (Kern COG, in preparation). The Kern Gorge fault is most likely a separate fault unassociated with the Poso Creek fault because: 1) the Kern Gorge fault forms the eastern boundary of the graben south of the Poso Creek fault, 2) the northwest trending graben and southwest dipping normal faults continue north of the Poso Creek fault along the same general trend as the Kern Gorge fault, and 3) the presence of other westerly trending faults transverse to the graben suggest that the Poso Creek fault is probably associated with the system of cross faults.

No demonstrable evidence is known which might suggest that the Kern Gorge fault is capable. Although the Kern Gorge fault has been described as being active during the Pleistocene (Dibblee, 1955), there are no known Pleistocene deposits overlying the fault to indicate offset. Buwalda and St. Amand (1955) indicate that a strong shock apparently occurred on the Kern Gorge fault seven days after the Arvin-Tehachapi earthquake, but no evidence of surface displacement was found. However, because of the uncertainty in location of events, assigning a particular event to a specific fault is not justified.

The Edison fault (Figures 2.5.1-7 and 2.5.1-9) has a maximum vertical displacement of more than 5,000 feet (Dibblee and Chesterman, 1953) between crystalline basement and Tertiary deposits near the edge of the valley and 1,500 feet in upper Miocene and older sediments (Wood and Dale, 1964) in the valley. Water-level measurements adjacent to the fault indicate that water-bearing deposits have been displaced along a line coinciding with the fault (Wood and Dale, 1964). The Edison fault is described as being inactive since Pliocene time (Dibblee and Chesterman, 1953).

The westerly trending Poso Creek fault veers northward towards the Pond fault and for conservatism has been considered one continuous fault system in this report. This fault is discussed in Subsection 2.5.1.1.5.

The White Wolf fault, responsible for the 1952 Arvin-Tehachapi earthquake, is discussed in detail later in this subsection.

The amount of faulting decreases toward the center of the valley basin, and northwesterly trending anticlinal folds become the dominant structural features modifying the regional homocline (Richardson, 1966). The thick overburden makes fault detection more difficult. However, faults are detected by seismic studies beneath ten to twenty thousand feet of sediments, or more, throughout the valley basin. Faults interpreted at these depths may be as numerous as those mapped along portions of the valley margin. These deep features decrease in amount of displacement in overlying strata, and, except as noted in Subsection 2.5.1.1.5.3.2, can be demonstrated by seismic profile interpretations not to offset Pliocene or younger sediments (Appendix 2.5E). Folds, therefore, become the principal structural element in the valley basin in younger strata.

Folding throughout the San Joaquin basin is believed to be pronounced at great depth, with the amount of folding decreasing upwards into the overlying younger deposits. Folding is reflected at the present ground surface by the

gentle topographic uplift of the Buena Vista Hills, Elk Hills, Lost Hills and others. Although folds of the central and western parts of the valley attained most of their present form during the mid-Pleistocene deformation, several folds were initiated in late Miocene or early Pliocene, and experienced additional growth during late Pliocene and early Pleistocene time (Hoots and others, 1954).

The widespread mid-Pleistocene lacustrine clay previously mentioned forms a broad, south-southeast plunging open syncline, its steep flank on the west, generally conformable with the regional structure of the basin. A series of low saddles and depressions occur in the southern portion of the structure which deepens, north to south (Davis and others, 1959). The structure of the clay indicates that moderate regional downwarping of the basin has occurred since mid-Pleistocene deposition of the unit. Although no evidence of faulting has been recognized throughout the extent of the "diatomaceous" clay (Davis and others, 1959) prior to this study,an apparent vertical offset has been demonstrated in a clay zone about eleven miles northeasterly of the Site (Subsection 2.5.1.1.5).

White Wolf Fault - The White Wolf fault is located 52 miles southeast of the Site (Figure 2.5.1-7 and Figure 2.5.1-9). Various investigations note its known length as about 32 miles following the 1952 earthquake. However, Warne (1965) indicates the fault to have a length of about 45 miles.

The White Wolf fault is a left lateral reverse (oblique-slip) fault, with the predominant movement being reverse (Hill, 1955). Total vertical displacement is approximately 10,000 feet, and the total overall left-lateral displacement is probably not more than 2,000 feet (Dibblee, 1955).

During the 1952 Arvin-Tehachapi earthquake, surface ruptures formed along 17 miles of the surface length of the fault. The U. S. Coast and Geodetic surveys (now NGS) indicated that the Bear Mountain block moved northwest, was elevated two feet and was tilted toward the southeast. Depression of the northwest side of the fault was about 1-1/2 feet near Arvin (Whitten, 1955, p. 80). Oakeshott (1955) suggests that the pattern of faulting in the earthquake area appeared to be genetically related to joints, shear zones, and planes of weakness in ancient crystalline rocks underlying the region and exposed in the mountains.

The White Wolf fault is believed to have developed in Miocene time, and has been most active during Pleistocene and Holocene time (Dibblee, 1955). Left-lateral creep is occurring along the surface trace of the fault at a rate of

about .51 inches per year (Calif. Div. of Mines and Geol., Map 72-1, 1972).

Displacements on the White Wolf fault apparently set off movements on minor subsurface faults south and east of Bakersfield. One such event probably occurred on a minor fault southeast of Bakersfield that caused the Bakersfield earthquake on August 22, 1952 (Dibblee, 1955) of magnitude 5.8.

Many cracks appeared in the San Joaquin Valley floor in the vicinity of the fault. Most of these features were lurch cracks and were not actual displacements along faults (Buwalda and St. Amand, 1955). An additional discussion of these cracks is presented in Appendix 2.50, Section VI.

Other Faults with Historic Ground Displacement

Creep has occurred on the Kern Front, Buena Vista thrust, and New Hope faults in the southern San Joaquin Valley (Figure 2.5.1-9). The Kern Front fault, located in the Kern Front oil field, is a normal fault, down-thrown to the west, and approximately 6-1/2 miles in length. The fault has had a measured creep rate of about one-half inch per year since 1968 (Manning, 1973). Movement along the fault has previously been described in terms of tectonic faulting unaccompanied by seismic activity (Hill, 1954). Yerkes and Castle (1969), however, suggest that movement along the fault is attributable to the effects of subsurface compaction resulting from oil withdrawal. Their interpretation is based on the observation that movement along the fault:

a) is associated with measured differential subsidence;

b) continues with continuing fluid extraction;

c) occurs along a pre-existing fault which dips toward the differential subsidence over the Kern Front field; and

d) is unaccompanied by seismic activity.

The Buena Vista thrust fault, located in the Buena Vista oil field, is approximately 1-1/2 miles in length. Movement on the fault appears to include both underthrusting and overthrusting, although the major part of the movement appears to be underthrusting (Howard, 1967). Movement along the fault has previously been interpreted as tectonic (Koch, 1933; Wilt, 1958), even though the fault cannot be traced to depth in numerous wells (Yerkes and Castle, 1969). Whitten (1961) has attributed movement along the fault to subsidence

caused by the withdrawal of oil; the fault provides a simple mechanism at the ground surface to accommodate the horizontal movement which generally accompanies subsidence. The occurrence of different rates of movement on different parts of the fault, with apparently less movement at depth (0.9 to 1.1 inches per year) than at the surface (1.5 inches per year), has been interpreted as resulting from ground subsidence due to oil withdrawal (Nason and others, 1968). No seismic events have been recorded on the Buena Vista thrust fault (Manning, 1973).

Creep along two short faults, the New Hope faults (Kern COG, in preparation), ruptured the ground surface and cracked a highway about 15 miles north of Bakersfield. Movement along the cracks is normal, down-thrown to the west. These features are not associated with an oil field; therefore, movement along them may be tectonic rather than a result of fluid withdrawal. There are no estimates as to the amount of creep that is occurring.

2.5.1.1.2.3 Coast Ranges Province

2.5.1.1.2.3.1 General Geology

The Coast Ranges, located west of the San Joaquin Valley, comprise several distinct ranges and intervening valleys which trend northwesterly parallel to the axis of the Great Central Valley. The strata of the Coast Ranges are sharply deformed into many folds and are crossed by numerous faults. A thick section of upper Mesozoic and Cenozoic rocks, composed chiefly of clastic marine sediments, are exposed throughout the southerly part of this province. These strata overlie or are in fault contact with two fundamental types of core complexes, one the Jurassic-Cretaceous Franciscan series and the other consisting of a Cretaceous granitic - metamorphic complex.

The Diablo and Temblor Ranges form distinct structural units within the province adjacent to the San Joaquin Valley. In a general sense, the Diablo Range consists of a series of folds, the core of which is composed of the Franciscan series. In many places the Franciscan rocks have been intruded by masses of serpentine. Marine and non-marine strata of Tertiary through Holocene age locally overlie the Franciscan series. The northwest-southeast trending Temblor Range borders the San Joaquin Valley on the southwest. Miocene marine rocks comprise the strata of the range, although some Lower Cretaceous and Eocene marine rocks are exposed in the northern part.

Structural deformation within the Temblor Range occurred mostly during the Plio-Pleistocene Coast Range orogeny

2.5.1.1.4 Geologic History of the Region

A discussion of the Tectonic Structures Underlying the Region Surrounding the Site including the structural evolution of the southern San Joaquin Valley is presented in Subsection 2.5.1.1.6. A generalized geologic time scale is presented in Table 2.5.1-2. | 12

2.5.1.1.4.1 Pre-Tertiary

During the Paleozoic era, the region now occupied by the Coast Ranges, the San Joaquin Valley and the Sierra Nevada, was an area of marine deposition. However, it is difficult to reconstruct the history of the Paleozoic era because there are few outcrops to study. A few remnants of marine deposition that occurred during late Jurassic and early Cretaceous time are preserved as scattered roof pendants in the Sierra Nevada pluton. A more complete record of marine deposition during Triassic, Jurassic and early Cretaceous time is exposed in the Coast Ranges.

Uplift of the Sierra Nevada region occurred after the emplacement of plutonic rocks during the Mesozoic era. Subsequent erosion of the uplifted area resulted in deposition of thick accumulations of detritus in the Cretaceous seas lying to the west. Flysch type sediments were deposited to form the Great Valley sequence between an ancient magmatic arc formed by the ancestral Sierra Nevada and an ancient trench system represented by the Franciscan complex (Dickinson, 1971; Mansfield, 1972). The eastern half of California has been positive continuously since the mid-Cretaceous orogeny but the western half has been alternately emergent and submergent.

2.5.1.1.4.2 Tertiary and Quaternary

During early Cenozoic time tectonic processes elevated the Coast Ranges, and concomitantly, the ancestral San Joaquin basin was formed. The basin consisted of a structural trough lying between the Coast Ranges on the southwest and the older Sierra Nevada land mass on the northeast. The Diablo uplift caused regression of marine waters that had filled the basin through early Eocene time. Regional subsidence during late Eocene caused an extensive marine transgression and deposition of marine sediments on top of the formerly exposed early Eocene soils. The Oligocene epoch represents a time of regional uplift, marine regression, and deposition of predominantly continental sediments which continued into early Miocene time. During the later part of the early Miocene, extensive marine seas covered the entire southern San Joaquin Valley and remained until late Miocene time. | 6

The Miocene marine transgression was terminated by orogenic activity with regional effects. Sediments along the southern and southwestern borders of the valley were tilted basinward and covered by poorly-sorted, non-marine beds (Hoots and others, 1954).

Alluvial and lacustrine environments prevailed in the central portion of the valley during early Pliocene time. Continued elevation of land masses combined with valley subsidence

2.5.1.1.5 Geology of the Region Surrounding the Site (20-mile radius)

2.5.1.1.5.1 General

This subsection describes the general geologic conditions within about a 20-mile radius of the Site; encompassing a portion of the relatively flat San Joaquin Valley floor. Geologic descriptions are, necessarily, based upon subsurface well data.

Figure 2.5.1-8 is a geologic profile which shows the relationship of the regional geology to the Site. The geology of the Region Surrounding the Site is included on the Regional Geologic Map, Figure 2.5.1-3, and a detailed geologic map of the Site area, Figure 2.5.1-12.

2.5.1.1.5.2 Stratigraphy and Lithology

A general description of the thick section of sediments which have accumulated beneath the Region Surrounding the Site is included in Subsection 2.5.1.1.2. This subsection presents a more detailed description of the following sequences:

a) Tertiary deposits,
b) Plio-Pleistocene continental deposits,
c) Lacustrine deposits - E-Clay, and
d) Pleistocene and Holocene alluvium.

2.5.1.1.5.2.1 Tertiary Deposits

The uplift of ranges in regions adjoining the Site area during late Cretaceous time resulted in deposition of clastic marine sediments in a basin larger than the present Great Valley. During early and middle Tertiary time, recurring periods of basin subsidence were accompanied by marine deposition of thick sand and shale units. Marine deposition alternated with lesser intervals of sea withdrawal and deposition of continental sediments. An exploratory well drilled 6 miles southwest of the Site indicates 21,500 feet of sedimentary rocks overlying Cretaceous strata.

2.5.1.1.5.2.2 Plio-Pleistocene Continental Deposits

Sea withdrawal during the Pliocene resulted in widespread deposition of continental sediments derived from the Coast Ranges and Sierra Nevada. Plio-Pleistocene sediments derived from the Sierra Nevada, designated the Kern River Formation (Diepenbrock, 1933), underlie most of the Region Surrounding the Site. These sediments, laid down chiefly as alluvial fan deposits, consist of poorly consolidated,

indistinctly-bedded lenticular sand and sandy clay beds with minor gravelly sand and clay.

The Tulare Formation, similar to the Kern River Formation, consists mainly of poorly sorted, poorly consolidated alluvial fan deposits. These sediments, however, were derived from the Coast Ranges. This unit reaches a maximum thickness of about 3,000 feet near the basin axis several miles west of the Site.

2.5.1.1.5.2.3 Lacustrine Deposits, E-Clay

Lacustrine deposits, which range from clay to sandy clay, are interbedded with the alluvial fan deposits of the Kern River and Tulare Formations. The most widespread of these clayey beds occurs beneath about 5,000 square miles of the valley (Figure 2.5.1-6). This extensive single unit, variously designated the Corcoran Clay (Frink and Kues, 1954), the Diatomaceous Clay (Davis and others, 1959) and the E-Clay (Croft, 1972), is present in the Region Surrounding the Site and beneath the Site (Figure 2.5.1-10). The distinct characteristics of this clayey unit form the basis of significant interpretations of geologic conditions at the Site.

Geologic correlations at the Site are based primarily on persistent, distinctive geophysical log signatures of the clayey zone, similar to the correlations of electric log signatures used by Croft (1972). Consequently, Croft's E-Clay designation is considered the most appropriate name for the clay encountered at the Site and is used instead of previous names.

The E-Clay unit consists of blue-gray clay and silt mixtures of high porosity and low permeability. Diatoms are usually abundant. The clay varies in thickness from less than 10 feet near its edges at a depth of about 200 feet below ground surface to a maximum of about 160 feet thick, about 800 to 900 feet in depth beneath the present bed of Tulare Lake (Davis and others, 1959). A detailed description of the E-Clay beneath the Site is included in Subsection 2.5.1.2.2.

The clayey unit forms a broad structural synclinal trough. Several minor structures which consist of low saddles and depressions have been superimposed on the structural trough. Prior to this investigation, no evidence of faulting had been recognized. Detailed down-hole geophysical correlations performed across the Pond fault eleven miles northeasterly of the Site identified about 80 feet of cumulativ apparent vertical offset in a clayey zone. This clayey zone has a stratigraphic position, geophysical response and

lithology very similar to that of the E-clay (See Appendix 2.5F, Section V).

The age of the E-Clay (Corcoran Clay) is based primarily on Potassium-Argon age determinations performed by the U.S. Geological Survey on volcanic material associated with the clay about 95 miles northerly of the Site at Friant. Results of these determinations indicate the age of the clay is at least 600,000 years, b.p. (Janda, 1965). Subsequently, additional age dating measurements made by the U.S.G.S. have substantiated the former dates (Dalrymple, 1973).

Other dating techniques include fossil evidence. Identification of diatom assemblages indicates the clay is Pleistocene in age (Croft, 1972). Vertebrate fossils from excavations about 90 miles northerly from the Site show that the E-Clay is of middle or late Pleistocene age (Frink and Kues, 1954, and Hall, 1965). The fossil diatom assemblages of the clay represent a dominantly fresh to somewhat brackish water fauna, and, consequently, probably accumulated as deposits on the bottom of a large fresh-water lake.

Dark colors of the clay suggest a reducing environment of deposition. Deposits laid down in lakes or swampy areas are not subject to subaerial weathering; they are not likely to reach a high degree of oxidation. Moreover, where appreciable organic matter is present in deposits below the water table, anaerobic bacteria may remove oxygen from the sediments, thus reducing iron compounds to a still lower degree of oxidation. The lake in which the clay was deposited was probably somewhat larger than the extent of the clay because coarser grained material equivalent in age to the clay would normally be deposited near the margins and be subjected to a higher degree of oxidation.

2.5.1.1.5.2.4 Pleistocene and Holocene Alluvium

Pleistocene and Holocene age continental alluvial deposits consist mainly of fan, floodplain and basin sedimentary units. These surficial units are distinguished primarily by interpretations of relative soil profile development, minor changes in elevation normally indicative of different land forms, and degree of topographic dissection. The contact between the Holocene and Pleistocene deposits is not readily recognizable.

Figure 2.5.1-12 presents a geologic map of the Site and Site Vicinity which shows the distribution of surficial deposits in relationship to the Site. The Site is situated directly on Holocene flood plain deposits and basin-fill sediments

deposited primarily along the margins of Tulare Lake basin. These deposits include overbank and distributary deposits that overlie distal segments of the Poso Creek alluvial fan. The Poso Creek fan is composed of upper Pleistocene granitic-rock alluvium derived from the Sierra Nevada and delivered into the Site Vicinity by Poso Creek and its distributaries. Although these deposits are generally assigned to the Kern River Formation in the subsurface in this part of the San Joaquin Valley, the surficial deposits appear to be equivalent to the upper part of the Modesto Formation after the usage of Davis and Hall (1954) and Janda and Croft (1967) (see Table 2.5.1-1).

In the Site Vicinity, two Pleistocene units are recognized. These units are generally alluvial fan deposits characterized by undeveloped to moderately developed soil profiles.

Pleistocene alluvial fan deposits east of Lost Hills are composed of sedimentary-rock alluvium and probably represent surficial deposits of the Tulare Formation.

Plio-Pleistocene sediments underlying Buttonwillow and Semitropic Ridges are composed of granitic-rock sediments while deposits of the same age underlying Lost Hills were derived from a sedimentary rock source presumably in the Coast Ranges.

2.5.1.1.5.3 Structure

The subsurface geologic structure within the Region Surrounding the Site is characterized by a series of northwesterly-trending folds, parallel with the axis of the San Joaquin basin. Several of these folds were apparently initiated during a mild mid-Eocene uplift (Callaway, 1971) and others were initiated in late Miocene or early Pliocene time (Hoots and others, 1954). The pronounced mid-Pleistocene regional uplift, however, was primarily responsible for the existing structural configuration. The folds generally contain relatively few, short, pre-Quaternary faults (Subsection 2.5.1.1.5.3.2).

A discussion of the structural evolution of the Southern San Joaquin Valley is presented in Subsection 2.5.1.1.6.

The northwesterly-trending anticlinal structures in the Region Surrounding the Site are indicated in Figure 2.5.1-7. A geologic profile of the structural features is presented in Figure 2.5.1-8.

2.5.1.1.5.3.1 Folds

The prominent anticlinal trends, named in order from Southwest to Northeast, consist of the Belridge, Lost Hills, Buttonwillow-Bowerbank, Semitropic and Trico structures as

shown in Figure 2.5.1-7. These structural highs produce oil and/or gas from various zones ranging in depth from 200 to over 11,000 feet.

The northwesterly trending structures consist of gently-folded, elongate, somewhat asymmetric anticlines and domes. These features range from about 3 to 20 miles in length and one or two miles in width. The relationship of these features to the Site is discussed in Subsection 2.5.1.2.3.

2.5.1.1.5.3.2 Faults

Several relatively short faults occur within the Region Surrounding the Site (Figure 2.5.1-10A). These faults, generally less than about three miles in length, show evidence of vertical displacement on the order of hundreds of feet in Tertiary strata. Faults in the Belridge and Bowerbank oil fields are shown in Pleistocene sediments (California Division of Oil and Gas, 1973; and Crowder, 1955, respectively). These fields are more than 15 miles from the Site and, except for the Pond fault, represent the nearest approach of known Quaternary faulting to the Site.

Three relatively long faults are present within the 20-mile radius of the Region Surrounding the Site: the Semitropic Anticline fault, the Greeley fault and the Pond -Poso Creek fault. These faults are discussed below.

Semitropic Anticline Fault

Interpretations of seismic reflection lines (Appendix 2.5E) indicate that a northwest trending fault, about 28 miles long, is located at the southwestern flank of the Semitropic anticline. The closest approach of the surface projection of the fault to the Site is about 6.5 miles. As much as 1,380 feet of vertical displacement at a depth of 15,900 feet is demonstrated on this structure. The displacement decreases rapidly upward in younger strata, however, and terminates in sediments at a depth of approximately 10,000 feet.

Greeley Fault System

Interpretations of seismic reflection profiles (Appendix 2.5E) indicate the northwest trending Greeley fault system extends, at depth, from the Greeley oil field to and beyond the Site, for a distance of approximately 32 miles (Figure 2.5.1-10A). The fault system is downthrown to the northeast, and its sense of movement is normal. The Greeley fault system is comprised of a set of echelon faults and can be separated into three distinct segments. The north segment passes beneath the eastern boundary of the Site and terminates southeasterly at a point about 2.5 miles west of the City of Wasco. The central segment consists of two parallel faults, lying west of the Cities of Wasco and Shafter. The south segment, herein called the Greeley oil field fault, parallels the axes of the Rio Bravo and Greeley anticlines (Figure 2.5.1-7 and 2.5.1-7A) along the northeastern boundary of oil production.

Petroleum investigations in the Greeley and Rio Bravo oil fields have indicated that middle Miocene and Pliocene strata respectively, overlying the Greeley oil field fault show no evidence of displacement (Welge, 1970; Sullivan and Weddle, 1960). The fault is reported to have a large lateral component of displacement which gives an apparent vertical displacement of 175 to 250 feet in lower Miocene strata (Welge, 1970; Sullivan and Weddle, 1960). Seismic profile interpretations and electric log correlations, however, indicate the fault system is downthrown to the northeast, and its sense of movement is normal. The Greeley oil field fault has offsets which range from 180 to 640 feet and 380 to 850 feet at the V-Horizon and Acoustic Basement Horizon, respectively (Appendix 2.5E).

Seismic reflection profiles and electric well logs demonstrate that the Greeley oil field fault terminates at a location about 25 miles southeast of the Site (Figure 2.5.1-10A). Displacement decreases rapidly to the southeast between Profiles ST-852 and T-850, with offsets of 840 feet and 180 feet, respectively, at the lower Miocene V-Horizon (Appendix 2.5E). The southern extent of the Greeley oil field fault appears to terminate less than a mile southeast of Profile T-850 (Figure 2.5.1-10A) at the V-Horizon (Plate 2, Appendix 2.5E). In addition, two northeasterly trending faults, "A" and "B", extend uninterrupted across the projection of the Greeley oil field fault. No evidence is present to suggest that the Greeley structural trend extends beyond these crosscutting faults, located at a distance of about 22 miles from the White Wolf fault (Figures 2.5.1-7A, 2.5.2-2, 2.5.2-3 and 2.5.2-4). There is no apparent relationship between northeasterly trending faults and the White Wolf fault.

The Greeley fault system is overlain by a progressively thicker and older section of sediments to the northwest. The subsurface fault trace extends no shallower than a depth of about 8,000 feet below sea level, about 22 miles southeast of the Site, and no shallower than at least 13,800 feet on the north segment of the fault system beneath the Site Vicinity (Appendix 2.5E). A middle Pleistocene deposit, the E-Clay, can be correlated, unfaulted, across the near-surface projection of the fault beneath the Site (Subsection 2.5.1.2.3.3).

In order to determine whether the Greeley fault system offsets Quaternary strata, three subsurface, downhole geophysical logging investigations were performed across the fault trace. Two investigations were performed within the Site Vicinity across the north segment of the fault system, adjacent to and southeast of the Site (Section II and Subappendix 2 in Appendix 2.5F). The third investigation was conducted across the fault system in the Shafter gas field, approximately 15 miles southeast of the Site (Section II and Subappendix 1 in Appendix 2.5F). Results of the geophysical logging investigations indicated that correlatable deposits, approximately 600,000 to 700,000 years old, extend continuously, unfaulted, over the deeply buried Greeley fault system. Exploratory trenches exposing unfaulted horizons were excavated adjacent to the Site (Section II and Subappendix 2 in Appendix 2.5F). In addition, 12.5 miles of an irrigation canal located south and southeast of the Site were logged in detail. There is no evidence for faulting in the sedimentary units overlying the upward projection of the Greeley fault system (Appendix 2.5Q).

The comprehensive investigation, which included literature review, interpretation of seismic reflection profiles (Appendix 2.5E), high resolution downhole geophysical logging, and exploratory trenching, demonstrates that the Greeley fault system is a deeply-buried feature no younger than Miocene in age (Section II in Appendix 2.5F). 12 Q1b

No macro-seismicity has been instrumentally determined to be directly associated with the fault system. Seismic profiles and deep well logs demonstrate that the Greeley fault system is not associated with another structural feature or capable fault. Accordingly, the Greeley fault system is not capable.

Pond-Poso Creek Fault

The surface or near-surface trace of the Pond fault trends northwesterly about 11 miles east of Unit 1 at its closest approach. The fault has been previously recognized only from subsurface exploratory investigations by oil companies and is believed to be the basinward extension of the Poso Creek fault. Jennings (1973) shows the two faults as forming one continuous structure extending from the eastern limb of the Trico anticline, southeasterly, through the Poso Creek oil field to the base of the Sierra Nevada, for a total length of about 48 miles. Figure 2.5.1-10A and Appendix 2.5E show that the length of the Pond-Poso Creek fault, based primarily on seismic profile interpretations, is about 37 miles and that it approaches to within 3.5 miles of the Tulare County line. Faulting is present in the Acoustic Basement northwest of this area, but the position of this faulting is such that it does not appear to connect with the Pond-Poso Creek fault to the southwest. 7 Q16 6 10 10 7 Q11 Q1

The largest amount of apparent offset which occurs along the fault is at the Acoustic Basement (profile W-67-T, Figure 2.5.1-10A) southeasterly of the Pond area. Farther southeast, in the Poso Creek oil field, the fault has an apparent maximum vertical displacement of about 300 feet within lower Pliocene strata (Weddle, 1959).

Interpretations of seismic reflection lines (Figure 2.5.1-10A and Appendix 2.5E) indicate that the Pond fault is a zone of northwesterly trending normal faults, downthrown to the southwest, and dipping approximately 50 degrees to 70 degrees. Displacement along the fault decreases northwesterly as shown on the Etch-Horizon, within the Etchegoin Formation (Figure 2.5F-2). This reduction of displacement, horizontally, is also reflected in the M-Horizon map (Figure 2.5F-3) which was prepared at the preliminary stage of interpretation and subsequently replaced with more detailed data on the O-Horizon in Figures 2.5E-2A and 2.5E-2B. 7 5 7 10 7 Q1b Q16

Interpretation of vibratory seismic profile GSC-1 (Figure 2.5F-1) conducted across the fault in the Pond Area (Figures 2.5.1-10A and 2.5.1-10C) indicates the fault zone consists of four subparallel breaks, forming a zone approximately 2/3 mile in width. The westernmost fault break has the largest amount of apparent vertical offset, which decreases as the fracture approaches the ground surface. The amounts of apparent vertical displacement at depths of 3,600 feet, 1,760 feet, and 875 feet, as interpreted on the profile, are approximately 250 feet, 100 feet, and 50 feet, respectively. Seismic profile interpretations of the three easternmost breaks indicate disturbed strata with offsets too small to be measured at a depth of about 1,500 feet. These easterly breaks apparently do not continue upward into the younger strata. 5 Q1b Q16 7

Stratigraphic correlation of a distinct clayey zone most likely equivalent to the E-clay at the Site, and interpretations of borehole geophysical logs, suggest an apparent vertical displacement across a ground crack of about 35 feet at a depth of approximately 250 feet in the Pond area (Figures 2.5.1-10A and 2.5.1-10C). Total cumulative offset of this horizon is approximately 80 feet across the Pond fault zone. Two exploratory trenches near the surface projection of the ground crack (Figure 2.5.1-10C) indicate a vertical displacement of nine inches at a depth of 10 feet (Figure 2.5F-4). The down-hole geophysical investigation is discussed in Section V and Sub-appendix 5 in Appendix 2.5F. The exploratory trenches are discussed in Section V in Appendix 2.5F. Detailed logging of a surface exposure of the Poso Creek fault zone is discussed in Appendix 2.5F. Orientations of slickensides measured on the fault planes (Figure 2.5F-6) indicate near vertical, oblique slip movement. This evidence precludes significant strike slip movement in the Pond-Poso Creek fault zone.

prevents

A review of published literature and interpretations of seismic lines has determined the capable length of the Pond-Poso Creek fault to be about 37 miles. The capable portion of the fault extends from near the base of the Sierra Nevada to just south of the Kern County-Tulare County line (Figure 2.5.1-9), where there is no evidence for fault offset of lower Pliocene or younger strata (Plate 6, Appendix 2.5E). The fault probably extends farther to the northwest, but only in deeper, older horizons.

Figure 2.5.2-5 shows the positions of seismic events according to their relocated epicenters. The grouping of epicenters labeled A coincides with the Pond-Poso Creek fault zone. Epicentral uncertainties could conceivably distribute these locations more widely, but it is more likely that they represent activity on the Pond-Poso Creek fault. This conclusion is reinforced by two pairs of events, each of which occurred within a few hours or a few days of each other.

2.5.1.2.2 Geologic Conditions of the Site

2.5.1.2.2.1 Lithology

2.5.1.2.2.1.1 General

The Site is underlain by Pleistocene to Holocene alluvial fan, alluvial plain and lacustrine deposits. The alluvial deposits consist of alternating beds of sand, silt and clay. The main lithologic units thicken and thin laterally, but are continuous beneath the Site. However, lithologic changes within the main units are common.

The Site stratigraphic column presented in Figure 2.5.1-14 describes the general lithologic characteristics of units encountered in borings within the Site. Although small-scale lithologic variations occur from location to location, the section described is grossly typical for all borings. The upper 500 feet of sediments are divided for descriptive convenience into three zones:

a) Upper Oxidized Zone
b) Middle Reduced Zone
c) Lower Oxidized Zone

The sand and silt-sized grains of the Oxidized and Reduced Zones are composed almost entirely of quartz and feldspar. Common accessory minerals are biotite and hornblende. A few igneous and metamorphic rock fragments are present as particles of sand and gravel. Sorting is generally poor and rounding is angular to sub-angular with rare, rounded coarse sand and gravel-sized particles. The deposits encountered throughout the upper 500 feet are consolidated to various degrees. Only in rare, one-half to two-inch thick layers was there any significant cementation.

2.5.1.2.2.1.2 Upper Oxidized Zone

The Upper Oxidized Zone extends from the ground surface to a depth of about 240 feet. Brown to yellow-brown sand, silty sand, and sandy silt comprise about 80 percent of the total thickness. Oxidation is ubiquitous throughout this zone. Locally, pockets and streaks of highly oxidized material are abundant. Beds of brown clay and clay-silt mixtures occur in abundance, generally between depths of 78 to 108 feet. The brown sediment grades into the grayish, fine-grained material of the Middle Reduced Zone at about 240 feet depth.

The interlensing bedding, poor sorting, color, and size of the particles of the Upper Oxidized Zone indicate deposition in a distal alluvial fan environment. The clay and clayey silt at the 78 to 108 foot depths probably represents one of the following situations: (1) the streams became dammed and small ponds were formed allowing fine-grained material to

settle out, or (2) the clays may represent overbank and flood plain deposits. When rivers flood and overflow their levees in areas of low relief, large shallow water areas are formed. The quiet water of these overflow basins allows clay and silt-sized particles to settle out. The composition of the grains indicates an acid igneous source rock similar to those exposed in the Sierra Nevada east of the Site. The angularity of the grains suggests short to moderate distances of transport.

2.5.1.2.2.1.3 Middle Reduced Zone

The Middle Reduced Zone occupies the interval between about 240 to 290 feet below the ground surface. This Reduced Zone is characterized by its grayish-blue, grayish-green, and dark brown sediments, which generally can be divided into three lithologic subdivisions. These subdivisions in most borings consist of two sequences of sand, silty sand, and clayey sand separated by a distinct clayey unit (see Figure 2.5.1-14). The upper subdivision contains the coarsest material encountered in the Middle Reduced Zone; a sandy unit that grades downward into the middle unit of clay and silty clay.

The clay comprising the middle unit within the Middle Reduced Zone is commonly of two types: a dark greenish-brown organic clay, and a bluish-gray clay with scattered organic material. The organic material of this bluish-gray clay is not as homogeneous or as widely disseminated as in other clays of this unit, but occurs in randomly oriented discontinuous pockets.

The high percentage of fine-grained blue, gray, green, and dark brown materials in the Middle Reduced Zone suggests that they were deposited in a lake or marshy swamp environment. Sediment deposited in this type of environment is not subject to significant subaerial weathering, and is unlikely to reach a high degree of oxidation.

The abundance of organic matter encountered throughout the clay further suggests conditions typified by a reducing environment. The organic mottling suggests features created by burrowing organisms or roots, such as are found in modern-day swamps and marsh environments. The abundance of sand and silt interbeds indicates that deposition occurred near the margins of a lake which was subject to increased influxes of water and sediment. The influx of sediments probably occurred during periods of heavy runoff and may be associated with glacial melting in the Sierra Nevada (see Subsection 2.5.1.1.5).

2.5.1.2.2.1.4 Lower Oxidized Zone

The Lower Oxidized Zone was encountered from a depth of about 290 feet to about 500 to 540 feet in boreholes at the Site. This lower sequence is generally similar in color and lithology to the Upper Oxidized Zone. Preliminary studies, however, indicate that a higher degree of oxidation may have occurred in this lower zone. The particles are somewhat coarser in this zone, consisting mostly of alternating beds of sand and sandy silt. The upper contact shows an intercalation of brown oxidized layers with the grayish sediments of the Middle Reduced Zone.

The depositional environment of the Lower Oxidized Zone is also typical of an alluvial fan environment. The coarse grain size indicates competent stream flow. The lack of clay indicates that no periods of quiescence occurred as during the period of deposition within the Upper Oxidized Zone. The provenance was one of acid igneous rock and distance of transport was not great.

2.5.1.2.2.1.5 Geophysical Logging Response

The relationship between lithology and geophysical response is presented in Figures 2.5.1-15 through 2.5.1-18. Appendix 2.5A presents interpretations of downhole geophysical responses. Geophysical logging capabilities and procedures are given in Appendix 2.5C.

The most diagnostic geophysical responses are associated with the Middle Reduced Zone. These responses are designated as Geophysical Zones IV and V in Figure 2.5.1-15. Geophysical Zone V gives an unusually diagnostic high gamma-gamma response which correlates well with the organic clay layer at a depth of 268-282 feet in most boreholes. The high gamma-gamma response is due to the high porosity of the zone and the reduction in gamma attenuation caused by the high-carbon content of the zone. Bottom and top contacts of Geophysical Zone V are very sharp and lend themselves well to correlation among all boreholes.

Geophysical response has been used to subdivide the Upper Oxidized Zone into Geophysical Zones I, II, III in Appendix 2.5A and Figure 2.5.1-14. Zone I, the uppermost zone, is generally a sequence of clayey and sandy strata. Zone II consists mostly of silty sand, silt and fine to medium sand. Zone III contains interlensing beds of sand and silt of variable thicknesses, and displays abundant lateral changes.

There are no distinctive geophysical responses within the Lower Oxidized Zone (Zone VI). The signatures indicate alternating lenses of sand and silty sand which correlate with the borehole lithologic descriptions.
This lower unit is designated Geophysical Zone VI in Figure 2.5.1-14 and Appendix 2.5A.

2.5.1.2.2.2 Stratigraphy

2.5.1.2.2.2.1 General

A Site stratigraphic column is presented in Figure 2.5.1-14. The stratigraphic section is described from 36 exploratory borings drilled within the Site. Four geologic profiles, constructed southwest-northeast, northwest-southeast, north-south and east-west through the Site, are shown in Figure 2.5.1-15 through Figure 2.5.1-18, respectively. The exploratory program is described in Appendix 2.5G. Locations of the geologic profiles and the borings drilled at the Site are presented in Figure 2.5.1-13.

The Site is underlain by a thick sequence of marine and non-marine sedimentary rocks that range in age from Eocene to Holocene. The deep stratigraphy is described in Subsection 2.5.1.1.5.

Detailed stratigraphic descriptions of the Site are confined to the upper 500 feet of unlithified continental deposits explored in borings for the Site Investigation (Appendix 2.5G). These deposits are generally assigned to the Plio-Pleistocene Tulare or Kern River Formations which are overlain by Holocene alluvium. The continental surficial deposits of Holocene age are fan and basin deposits. These deposits were laid down during flood stages in the basins that developed between the low natural levees flanking the Poso Creek distributary system. The contact between the Holocene and Pleistocene deposits is not clearly recognizable.

Boring logs, methods of investigation and discussion of downhole geophysical logging procedures are presented in Appendices 2.5G, 2.5H and 2.5C, respectively.

2.5.1.2.2.2.2 E-Clay Correlations

Correlation of units underlying the Site is based primarily on the distinct lithologic and geophysical response characteristics of Geophysical Zones IV and V. These characteristics correlate with the widespread bluish-gray diatomaceous clay described and designated by Croft (1972) as the E-Clay. Croft based his correlations primarily on distinctive electric log signature correlations. The regional extent and characteristics of the E-Clay are described in Subsection 2.5.1.1.5.

Sediments within the Middle Reduced Zone (Geophysical Zones IV and V) bear a close resemblance in color and lithology to the E-Clay of Croft (1972), and the Corcoran Clay of Frink and Kues (1954). The fine-grained materials in this zone are greenish-gray, bluish-gray, and very dark brown to black. They are composed of clay, silty clay, clayey sand

and very fine to medium sand. Mica is abundant throughout the sequence. Thin, ash-rich strata are rare and discontinuous.

The most valuable correlation tool for subsurface studies within the San Joaquin Valley has been downhole geophysical logs (Crosby, 1973). The E-Clay has been recognized and correlated by its distinctive electric-log signatures in thousands of wells throughout the valley. Widespread correlation of the Corcoran Clay, as presented by Gardner (1961) and amended by subsurface data from the Site is presented in Figure 2.5.1-6. A structure contour map drawn on the base of the E-Clay in the Site Vicinity is presented in Figure 2.5.1-10. The electric-log signatures of the Middle Reduced Zone at the Site correlate with those presented beyond the Site boundary in Figures 2.5.1-6 and 2.5.1-10.

Lithologic and stratigraphic evidence obtained from Site borehole data indicates the clayey sequence designated as the Middle Reduced Zone is correlative regionally with the clay described by Croft (1972), Frink and Kues (1954), and Davis and others (1959).

2.5.1.2.2.2.3 Age Dating

Regionally, the E-Clay, or diatomaceous clay of Davis and others (1959), has been dated by several methods which include: 1) fossil diatom species cored in the clay, 2) vertebrate fossils excavated from the clay and associated strata, and 3) radiometric (K-Ar) dating of volcanic material which is correlated with ash overlying the clay. These dating methods are described more fully in Subsection 2.5.1.1.5.

At the Site, diatoms were studied and age determinations were made from the E-Clay zone (Lipps, 1974). Diatoms from Borehole H-35 at depths of 276.5 feet to 279 feet and 280 feet indicate freshwater conditions of deposition, whereas those from Borehole H-24 suggest a somewhat brackish environment. The diatom assemblages in the E-Clay, as a whole, are indicative of an age range from the Middle Pliocene to the Pleistocene. The presence of two extinct species suggest an age not younger than the Late Pleistocene. The age of the microfossils is compatible with results of other age dating techniques presented herein.

2.5.1.2.3 Geologic Structure in the Site Vicinity (5 mile radius)

2.5.1.2.3.1 General

Maps showing structural contours drawn on various horizons beneath the Site and Site Vicinity are presented in Figures 2.5.1-19, 2.5.1-21, and 2.5.1-22. In addition, Figure 2.5.1-22A presents various horizons shown as block diagrams which illustrate the relationship of structures beneath the Site Vicinity. The relationship of the various horizons to geologic time is presented in Table 2.5.1-2. Figure 2.5.1-7 shows the location of oil and gas fields in relation to the Site.

The northwesterly-trending folds and faults in the Region Surrounding the Site (20-mile radius) are discussed in Subsection 2.5.1.1.5.

2.5.1.2.3.2 Folds

The Site Vicinity is situated between the Trico anticline on the north and the Semitropic anticline on the south (Figure 2.5.1-10). The Semitropic structure forms a low topographic ridge, whereas the Trico structure has no surface expression (Figure 2.5.1.-12).

Structure beneath the Site Vicinity is known principally from scattered exploratory oil and gas wells and projection of interpreted data from oil and gas fields within the Region Surrounding the Site (Figure 2.5.1-7). The following discussion of structures beneath the Site Vicinity is integrated with the block diagrams of six horizons presented in Figure 2.5.1-22A which graphically show the structural configurations.

Subsurface structure contours drawn on the First Mya Sand horizon, at a depth of about 3,000 feet, (Figure 2.5.1-21) show the Site Vicinity lies within a broad synclinal trough relative to the Trico and Semitropic anticlines. The crest-to-trough relief on this horizon is between 600 and 800 feet. This synclinal structure persists beneath the First Mya Sand. Contours constructed on top of the Pliocene Etchegoin Formation, at a depth of about 4,900 feet below the Site Vicinity, demonstrate this structure (Figure 2.5.1-22). The relief of the structure at the 4,900 foot depth, however, has decreased to between 500 and 600 feet.

Structural contours drawn on the Wilhelm Sand, at a depth of about 5,800 feet beneath the Site Vicinity, are represented by one of the block diagrams in Figure 2.5.1-22A. At this horizon, the Site Vicinity is still in an essentially low relative position. Within this trough, a low relief flexure, or nosing, appears to have developed. This subtle anticlinal fold trends northwesterly, in line with the Rio Bravo-Greeley anticline 18 miles to the southeast (Figure 2.5.1-7). The low-relief fold is distinct from and parallel with the

Semitropic anticlinal structure which, at this depth, has lost much of its relief and northwesterly projection (Figure 2.5.1-22A).

The low-relief nosing shown in the Wilhelm Sand beneath the Site Vicinity becomes more pronounced in deeper horizons. At a depth of about 7,300 feet, contours on the top of the Randolph Zone show the low Rio Bravo-Greeley structural trend with possible slight closure beneath the Site Vicinity. The Semitropic anticlinal trend becomes less pronounced at this depth.

The Antelope Shale "N" Marker contours, at a depth of about 10,000 feet, show a more pronounced northwesterly trending anticlinal structure beneath the Site Vicinity (Figures 2.5.1-22 and 2.5.1-22A). The Semitropic structure dissipated above this depth and is absent on this horizon.

The deepest horizon shown diagrammatically in Figure 2.5.1-22A is the top of the Vedder Sand, about 13,500 feet below ground surface. Structure contours indicate the Rio Bravo-Greeley structure is well-defined on this horizon, with a steep regional southwesterly dip along the flank of the fold.

Interpretation of seismic profiles beneath the Site (Appendix 2.5E) also indicates slight synclinal folding (downwarping) of strata to a depth of about 7,000 feet. The folding is in the form of a broad trough. Beneath this structure, the anticlinal fold is identified in strata overlying basement, approximately 19,000 to 22,000 feet below the ground surface.

2.5.1.2.3.3 Faults

The northwesterly trending anticlinal folds in the Region Surrounding the Site are relatively free from faulting (Subsection 2.5.1.1.5). There is no demonstrable evidence of faulting in the Trico field and none in the upper portion of the Pliocene San Joaquin Formation in the Semitropic field, although a small north-south trending fault has been postulated in the Semitropic oil and gas field (Section VIII, Appendix 2.5O). Church (1965) also postulates a fault, at depth, in the Semitropic anticlinal structure (Figures 2.5.1-7A and 2.5.1-22). Church states that:

> "Evidence for this fault is not conclusive, as vertical displacement is relatively minor; however, production characteristics and contouring are more easily explained by such a fault than otherwise, and it is suggested that this may be a relatively deep seated (basement?) fault having lateral movement along which there has been recurrent activity at least to the end of Etchegoin time...It is possible to contour the field without this fault, but contouring of a number of horizons above the Randolph, as well as isopachs of various intervals, while not conclusive, is regarded as highly suggestive of such a structure."

Church suggests that the fault shows an apparent vertical displacement of about 500 feet in Miocene Strata at a depth of about 11,000 feet to 13,000 feet. Church indicates a decrease of the relative amount of displacement to less than 100 feet in Pliocene Strata.

The anomalous production characteristics and contouring on which the fault interpretation is based, are absent in the overlying younger sediments (Figure 2.5.1-21). Production characteristics and contouring indicate the absence of fault offset of upper Pliocene and Pleistocene age sediments in the Trico and Semitropic structures. Clearly, the minimum age of the postulated fault is Pliocene, younger than the "Scalez" Sand, and older than the first Mya Zone of the San Joaquin Formation, between 3,000 and 4,000 feet deep.

Interpretations of deep seismic reflection profiles in the Site Vicinity (Figure 2.5.1-10A) indicate the absence of faulting to a depth of at least 13,800 feet. The profiles crossing the fault postulated by Church (1965) show no evidence of this feature (Appendix 2.5E). The Greeley fault system is interpreted as continuing northwesterly beneath the Site at a depth of at least 16,500 feet, i.e. below the Vedder Sand. The apparent vertical displacement in basement at a depth of about 19,000 to 21,000 feet is approximately 1,200 to 2000 feet. A reflector that approximates the lower Miocene Vedder Sand (beneath the O-Horizon) is not offset, but a reflector (probably within the Eocene) approximately midway between the Vedder reflector and the Acoustic Basement appears to have less than 140 feet of vertical offset (Appendix 2.5E).

To demonstrate that the middle Pleistocene E-clay is unfaulted, a down-hole geophysical investigation was conducted across the near-surface projection of the fault in and adjacent to the southeastern area of the Site (Section II and Subappendix 2 in Appendix 2.5F). Results of the investigation indicate that relative points on the geophysical zones are connected with one another in adjacent boring logs by smooth curves, indicative of primary, nearly horizontal sedimentation features. The absence of through-going planar disruptions of the gentle northerly-sloping strata beneath the Site strongly precludes the presence of horizontal or vertical component displacements within the limits of contouring of field data (3 to 5 feet).

Direct observation of near-surface strata was made in exploratory trenches and canal exposures. These trenches and canal exposures are located across the trace of the deeply-buried northern segment of the Greeley fault system projected to the ground surface and above the areas of maximum elevation change on the top of the E-Clay as determined from the geophysical logs (Section II and Subappendix 2 in Appendix 2.5F). Results of the trenching investigation demonstrated near horizontal stratigraphic units with no evidence of any linear, vertical features which might be indicative of vertical or horizontal component offsets

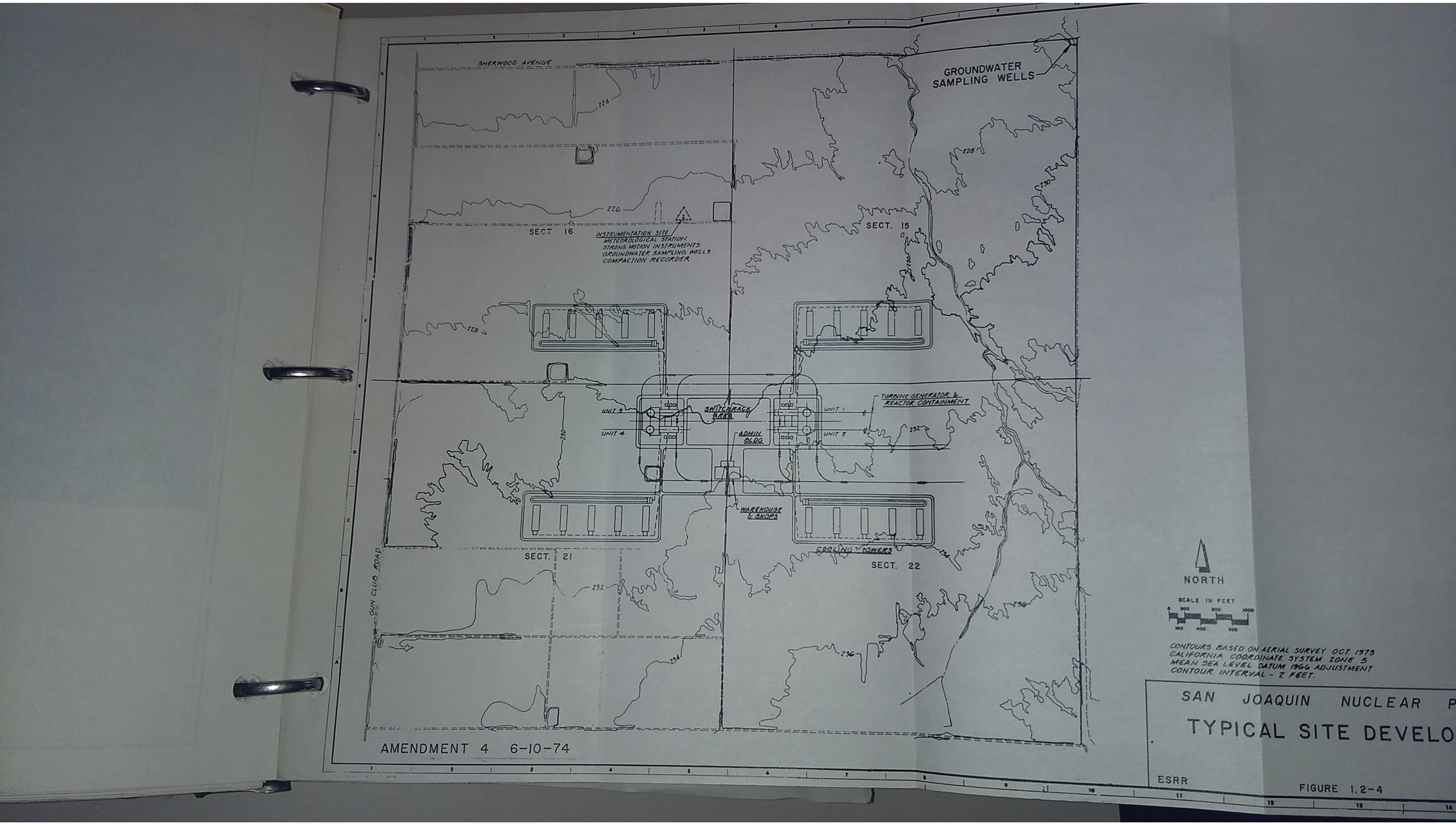
(Figures 2.5F-1, -1A, and -1B). The canal excavation was approximately 3 miles southeast of the Site across the projection of the northern segment of the Greeley fault system. The results of the canal logging indicate continuous, overlapping sedimentary contacts with no offsets or disruptions across the upward projection of the deeply-buried Greeley fault (Appendix 2.5Q).

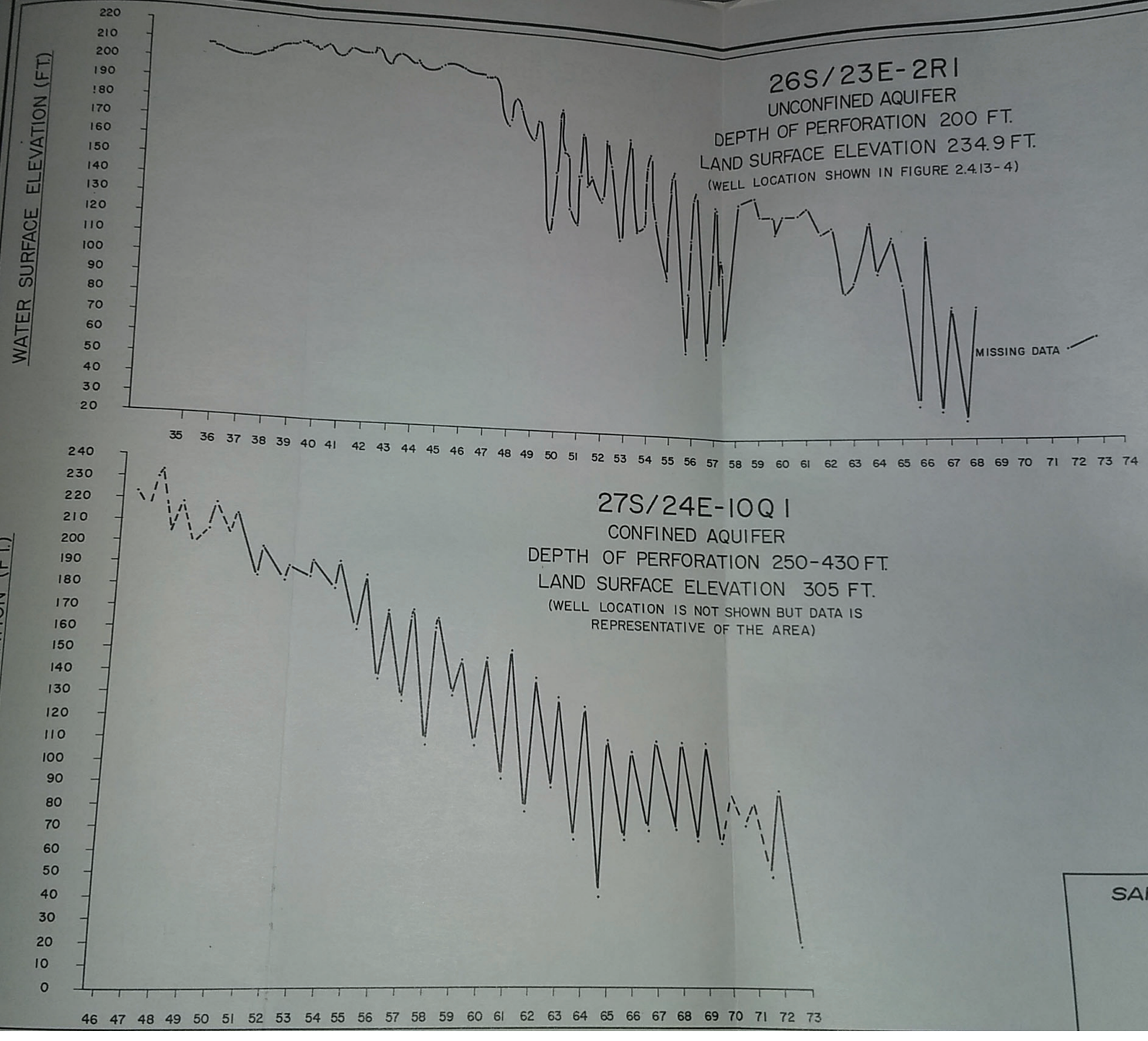
The near-surface geologic structure in the Site Vicinity is reflected in the structure of the middle Pleistocene E-Clay (Figure 2.5.1-10). The structure of the E-Clay is characterized by a series of elongate, northwesterly trending folds (Buttonwillow, Semitropic, and Trico anticlines), parallel with the axis of the San Joaquin basin. Most of the folds within the Region Surrounding the Site were formed during the middle Pleistocene uplift (Subsection 2.5.1.1.4) which was followed by relatively slight tectonic warping and differential compaction (Subsection 2.5.1.2.5).

The location of the Pond-Poso Creek, Greeley (northern and central segments), and Semitropic Anticline faults at various reflective horizons are plotted on Figure 2.5.1-10 for comparison to the structure of the E-Clay. The E-Clay structure contour map indicates that the Pond-Poso Creek fault and the Greeley fault system (northern and central segments) are not associated with folding. Interpretation of 37 seismic profiles crossing the Pond-Poso Creek fault and Greeley fault system (northern and central segments) within the Region Surrounding the Site, indicates no associated shallow folding along these features. Folding occurs only at greater depths along the Greeley structural trend (Subsection 2.5.1.2.3.2).

A coincidental relationship of E-Clay structure to faulting occurs along the upward projection of the Semitropic Anticline fault. However, approximately 170 wells drilled for petroleum exploration along the Semitropic and Buttonwillow anticlines indicate no evidence for shallow faulting; and no sharp dip changes or other anomalous features occur in shallow horizons that might be indicative of faulting. The Semitropic anticline is expressed only in shallow, unfaulted horizons above 10,000 feet (Appendix 2.5E), which indicates that the Semitropic Anticline fault is not genetically related with the formation of the overlying fold. Interpretation of an overlapping network of 12 seismic profiles within the Region Surrounding the Site indicate that the Semitropic Anticline fault decreases rapidly upwards from the acoustic basement and terminates in strata at a depth no shallower than approximately 10,000 feet.

In summary, based on logs of enumerable deep exploratory wells and interpretation of intersecting seismic profiles, no relationship whatsoever exists between shallow E-Clay folding and subsurface faults.


SHERWOOD AVENUE
GROUNDWATER SAMPLING WELLS
224
226
228
230
232
234
236
SECT 16
SECT. 15
SECT. 21
SECT. 22
INSTRUMENTATION SITE
METEOROLOGICAL STATION
STRONG MOTION INSTRUMENTS
GROUNDWATER SAMPLING WELLS
COMPACTION RECORDER
UNIT 5
UNIT 4
UNIT 1
UNIT 2
SWITCHRACK AREA
ADMIN. BLDG.
TURBINE GENERATOR & REACTOR CONTAINMENT
WAREHOUSE & SHOPS
COOLING TOWERS
GUN CLUB ROAD
NORTH
SCALE IN FEET
0 300 600 1000
100 400 800
CONTOURS BASED ON AERIAL SURVEY OCT. 1973
CALIFORNIA COORDINATE SYSTEM ZONE 5
MEAN SEA LEVEL DATUM 1966 ADJUSTMENT
CONTOUR INTERVAL - 2 FEET.
SAN JOAQUIN NUCLEAR P
TYPICAL SITE DEVELO
ESRR
FIGURE 1.2-4
AMENDMENT 4 6-10-74



EXPLANATION

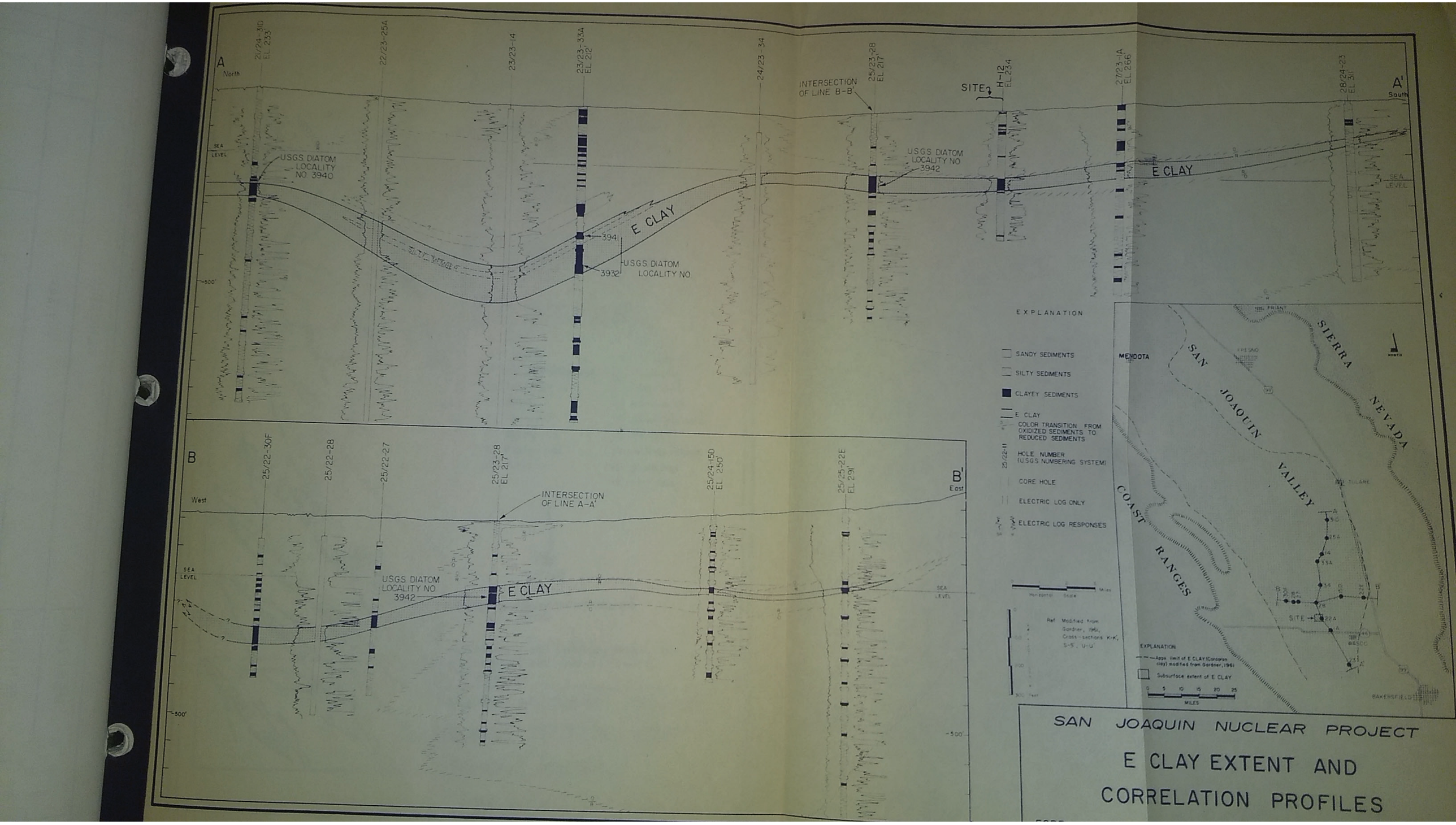
DATA POINTS INDICATE GROUND-WATER ELEVATIONS, GENERALLY IN SUMMER AND WINTER.

DASHED WHERE FLUCTUATION IS INFERRED

SAN JOAQUIN NUCLEAR PROJECT

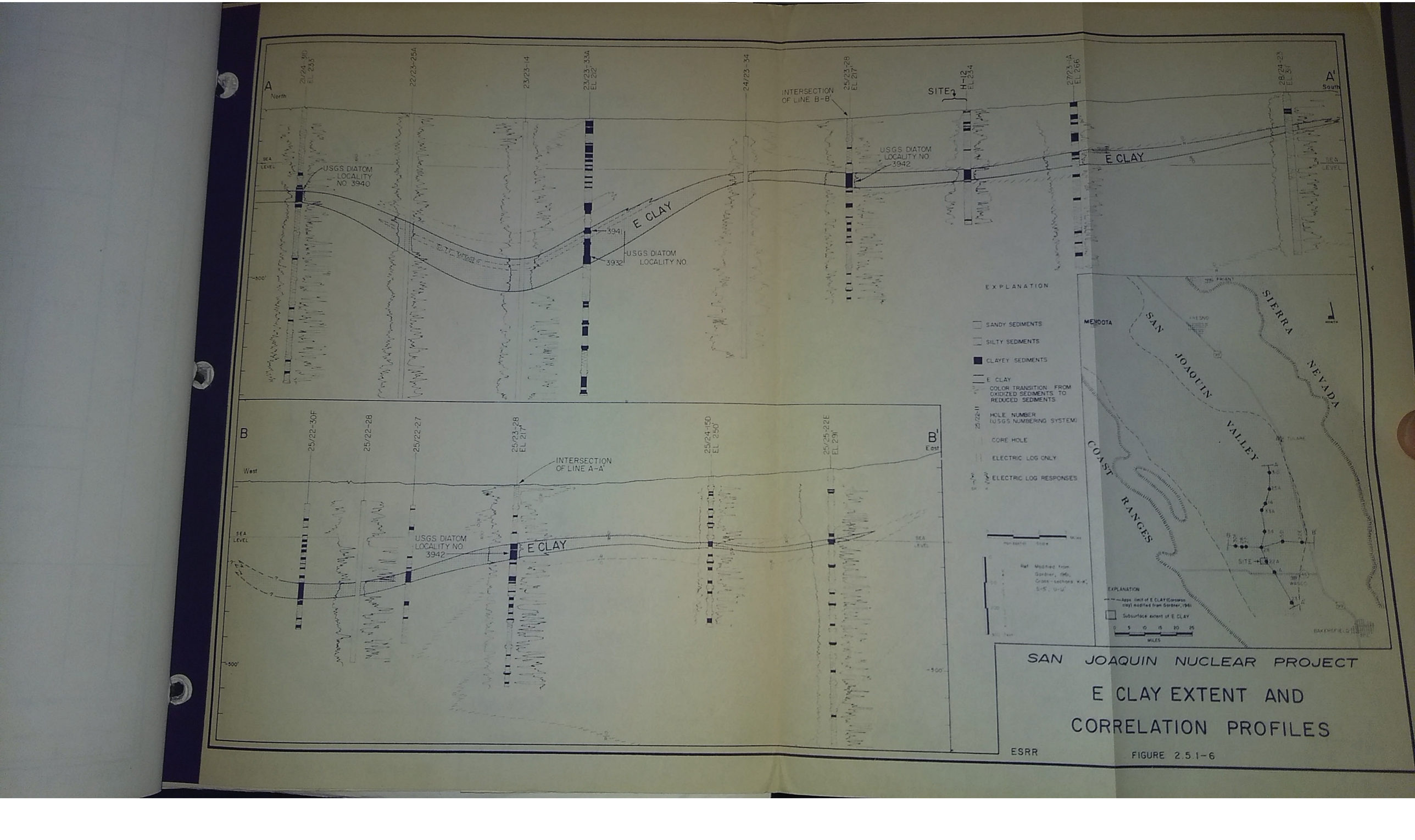
WELL HYDROGRAPHS

SHOWING GROUNDWATER LEVEL FLUCTUATIONS IN A CONFINED AND UNCONFINED AQUIFER

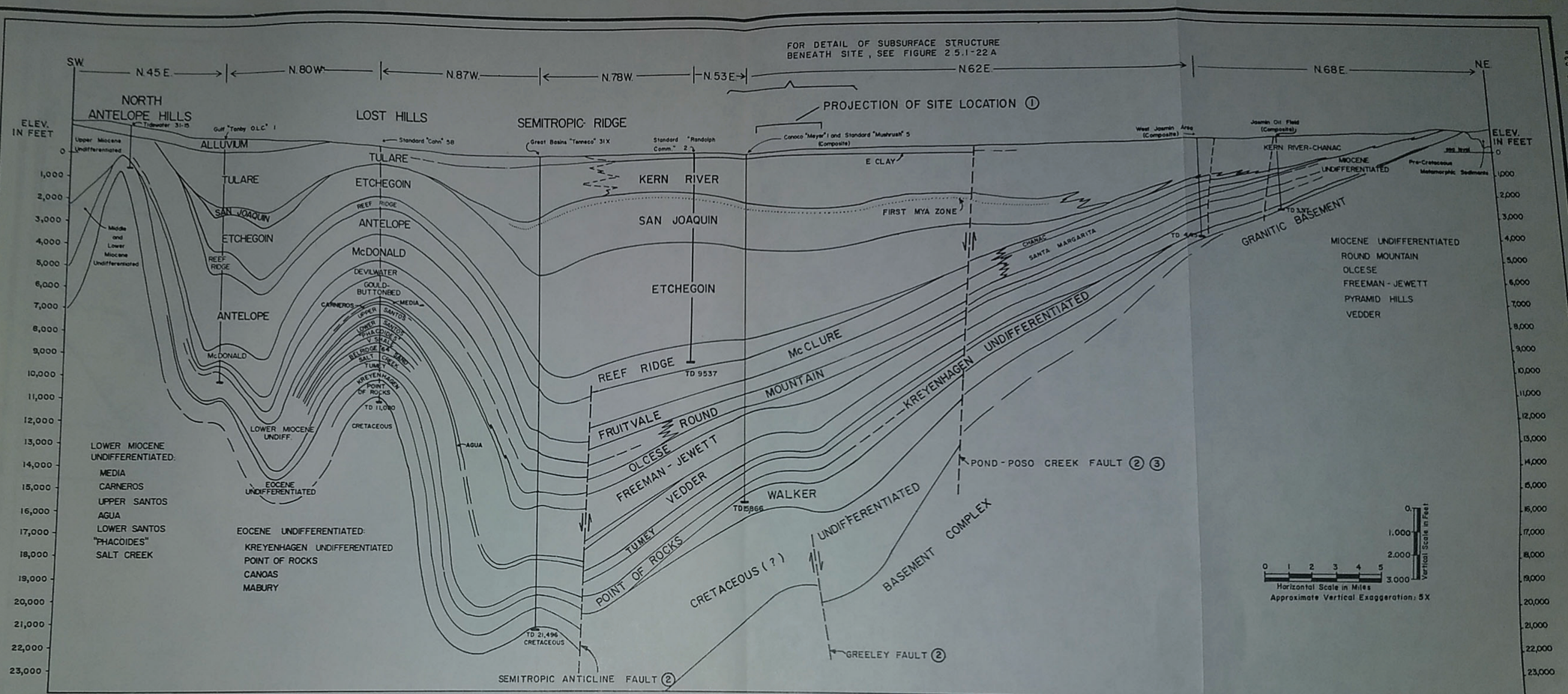


SAN JOAQUIN NUCLEAR PROJECT

E CLAY EXTENT AND CORRELATION PROFILES


A
North
A'
South
21/24-30
EL 233
22/23-25A
23/23-14
23/23-33A
EL 212
24/23-34
25/23-28
EL 217
INTERSECTION
OF LINE B-B'
SITE
H-12
EL 234
27/23-1A
EL 266
28/24-23
EL 30
SEA
LEVEL
USGS DIATOM
LOCALITY
NO 3940
E CLAY
394
3932
USGS DIATOM
LOCALITY NO
USGS DIATOM
LOCALITY NO
3942
E CLAY
-500'
B
West
B'
East
25/22-30F
25/22-28
25/22-27
25/23-28
EL 217
INTERSECTION
OF LINE A-A'
25/24-15D
EL 250'
25/25-22E
EL 291'
USGS DIATOM
LOCALITY NO
3942
E CLAY
-500'
EXPLANATION
SANDY SEDIMENTS
SILTY SEDIMENTS
CLAYEY SEDIMENTS
E CLAY
COLOR TRANSITION FROM
OXIDIZED SEDIMENTS TO
REDUCED SEDIMENTS
HOLE NUMBER
(USGS NUMBERING SYSTEM)
25/22-11
CORE HOLE
ELECTRIC LOG ONLY
ELECTRIC LOG RESPONSES
Horizontal Scale
Ref Modified from
Gardner, 1961,
Cross-sections K-K',
S-S', U-U'
MENDOTA
FRESNO
TULARE
BAKERSFIELD
SIERRA
NEVADA
SAN
JOAQUIN
VALLEY
COAST
RANGES
SITE
H-12
EXPLANATION
Approx. limit of E CLAY (Corcoran
clay) modified from Gardner, 1961
Subsurface extent of E CLAY
0 5 10 15 20 25
MILES
SAN JOAQUIN NUCLEAR PROJECT
E CLAY EXTENT AND
CORRELATION PROFILES
ESRR
FIGURE 2.5.1-6

FOR DETAIL OF SUBSURFACE STRUCTURE BENEATH SITE, SEE FIGURE 2.5.1-22A

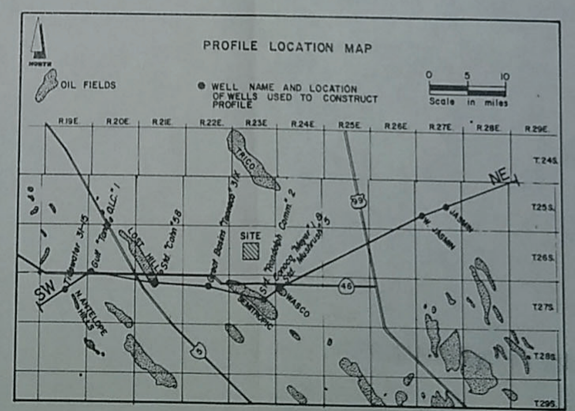


(1) NOTE: THE SITE LOCATION HAS BEEN PROJECTED PARALLEL TO NORTHWESTERLY TRENDING STRUCTURES IN THE SITE VICINITY.

(2) NOTE: UPWARD EXTENT OF SEMITROPIC ANTICLINE FAULT, GREELEY FAULT, AND POND-POSO CREEK FAULT BASED ON SEISMIC PROFILE INTERPRETATIONS (APPENDIX 2.5E).

(3) NOTE: REFER TO FIGURE 2.5F-IC FOR DETAILS OF POND-POSO CREEK FAULT.

REF: THE PORTION OF THIS PROFILE WEST OF LOST HILLS IS FROM CROSS-SECTION A-A' OF GEOLOGIC MAP OF TEMBLOR RANGE IN GUIDEBOOK TO GEOLOGY AND OILFIELDS, WESTSIDE SOUTHERN SAN JOAQUIN VALLEY, 1968: PACIFIC SECTIONS A.A.P.G., S.E.G., AND S.E.P.M.



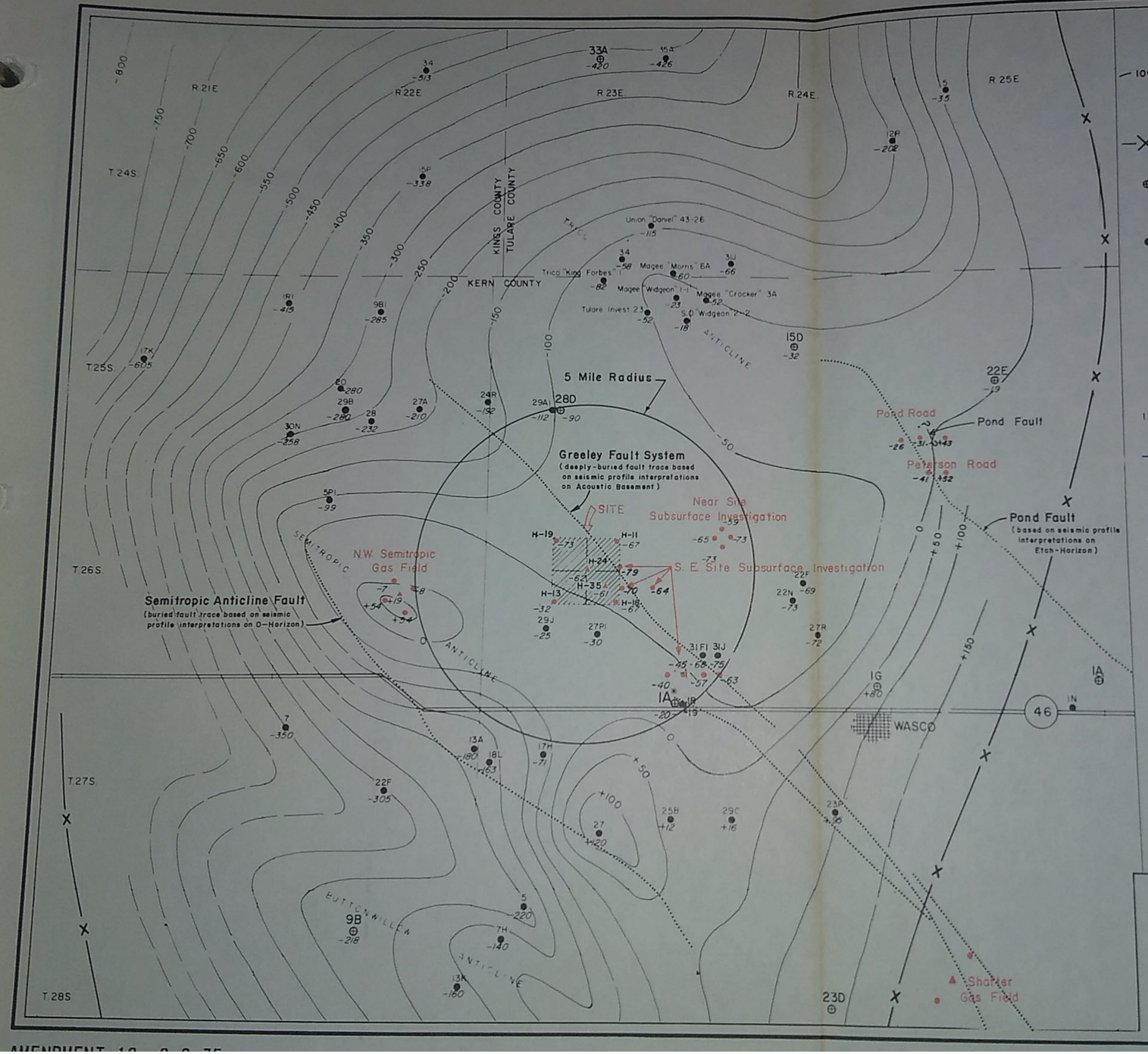
SAN JOAQUIN NUCLEAR PROJECT

GENERALIZED REGIONAL GEOLOGIC PROFILE

FIGURE 2.5.1-8

AMENDMENT 17 11-18-75

SJNP-15-3336-C3e



EXPLANATION

- 100 — CONTOUR LINES. DASHED WHERE APPROXIMATE. DRAWN ON THE BASE OF THE E CLAY. CONTOUR INTERVAL IS 50 FEET. DATUM IS MEAN SEA LEVEL.
- —X— APPROXIMATE BOUNDARY OF THE E CLAY (MODIFIED FROM GARDNER, 1961)
- ⊕ CORE HOLE LOCATION. LITHOLOGIC LOG AND ELECTRIC LOG USED TO DETERMINE THE BASE OF THE E CLAY. (U.S. BUREAU OF RECLAMATION)
- ● WELL LOCATION. BASE OF CLAY DETERMINED FROM ELECTRIC LOG SIGNATURE.
- ▲ LOCATION OF HOLES DRILLED FOR THIS STUDY. LITHOLOGICAL LOGS, ELECTRIC LOGS, AND RADIATION LOGS USED TO DETERMINE THE BASE OF THE E CLAY.
- ● LOCATION OF HOLES DRILLED FOR THIS STUDY. ELECTRIC LOGS AND RADIATION LOGS USED TO DETERMINE THE BASE OF THE E CLAY.
- 1R1 WELL NUMBER U.S. GEOLOGICAL SURVEY NUMBERING SYSTEM.
- −32 ELEVATION OF THE BASE OF THE E CLAY.

NOTE: THE WELLS SHOWN ARE EXAMPLES OF A FEW OF THE HOLES DRILLED AT EACH LOCATION. REFER TO THE FOLLOWING FIGURES FOR LOCATION OF ALL HOLES DRILLED:

LOCATION	FIGURE NUMBER
SITE	2.5.1 - 13
S.E. SITE SUBSURFACE INVESTIGATION	2.5.F - 26H
NEAR SITE SUBSUBSURFACE INVESTIGATION	2.5F - 42B
N.W. SEMITROPIC GAS FIELD	2.5F - 30B
SHAFTER GAS FIELD	2.5F - 11D
POND ROAD AND PETERSON ROAD	2.5F - 58

SCALE
0 1 2 3 4 5 Miles

NORTH

* PROBABLE LOCATION OF COREHOLE (SEE SECTION II, APPENDIX 2.5F)

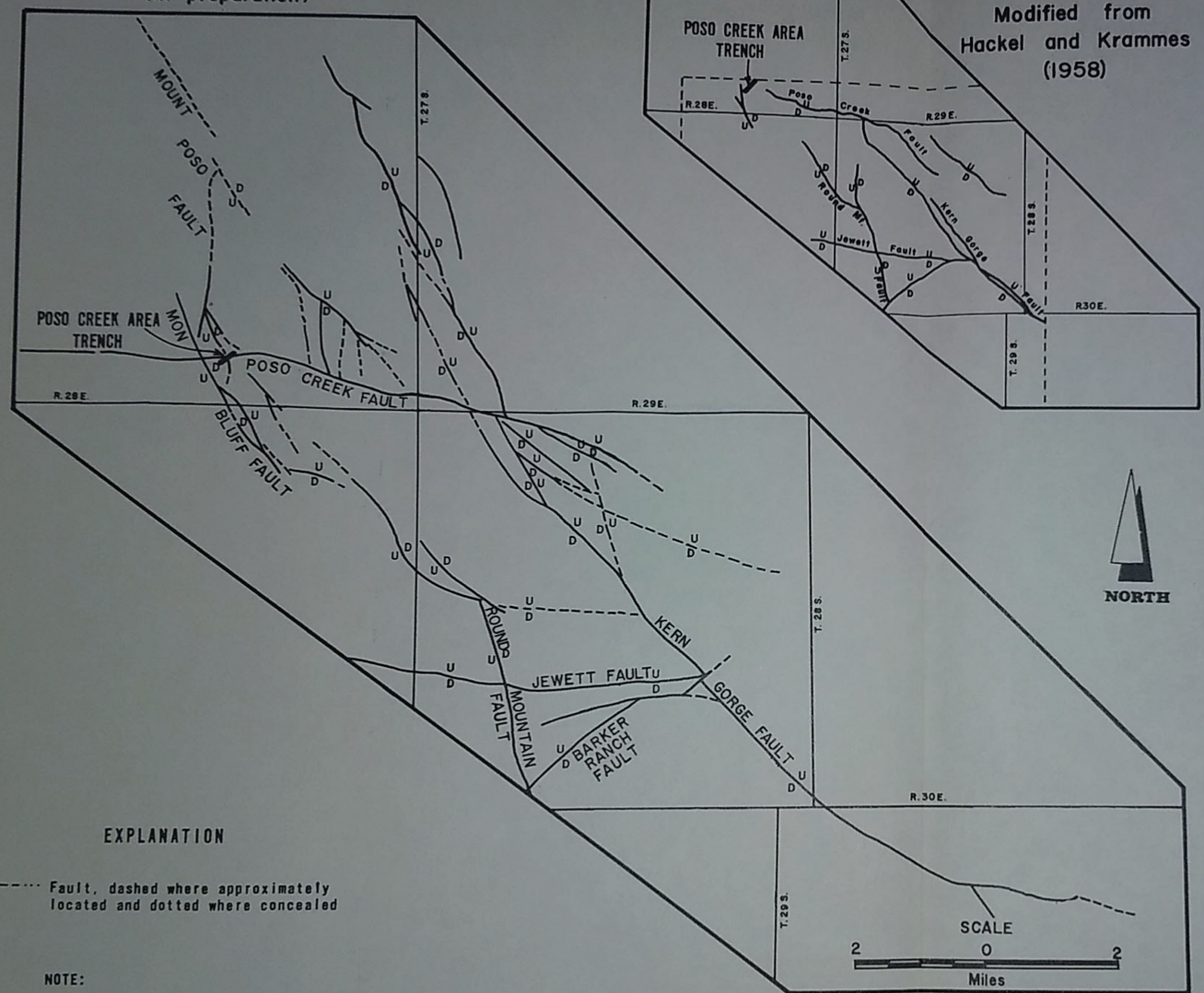
SAN JOAQUIN NUCLEAR PROJECT

STRUCTURE CONTOUR MAP, E CLAY

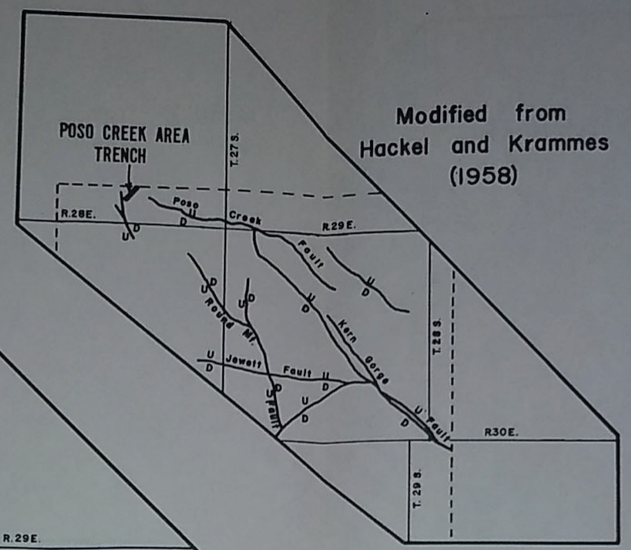
FIGURE 2.5.1 - 10

AMENDMENT 10 - 2-2-75

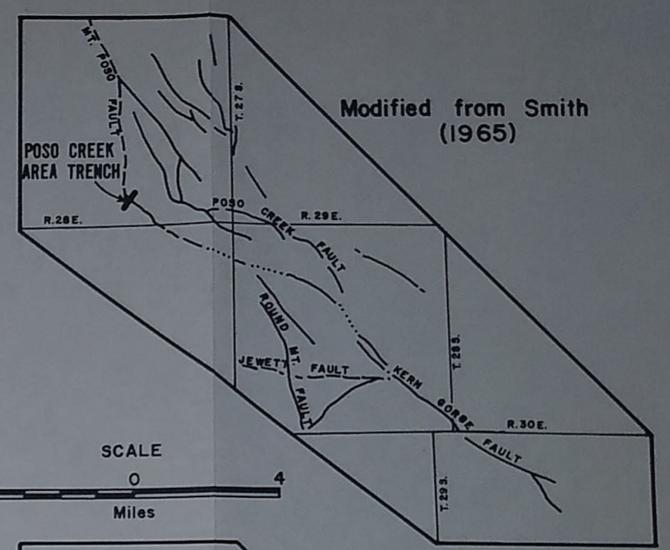
Modified from Kern COG
(In preparation)



Modified from
Hackel and Krammes
(1958)

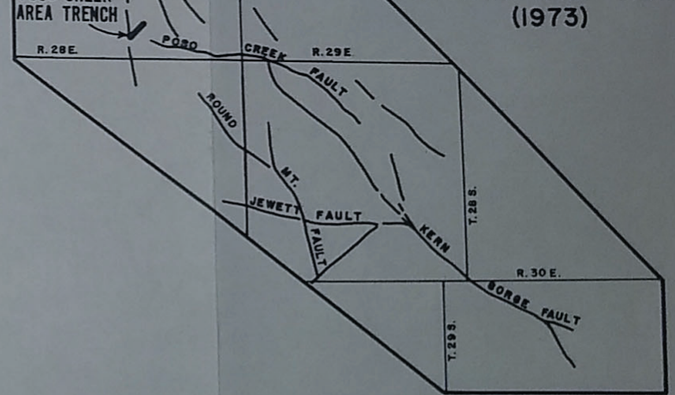


Modified from Smith
(1965)



SCALE
4 0 4
Miles

Modified from Jennings
(1973)



EXPLANATION

U/D ------ Fault, dashed where approximately located and dotted where concealed

NOTE:

1) Refer to Figure 2.5.1-10A for regional location

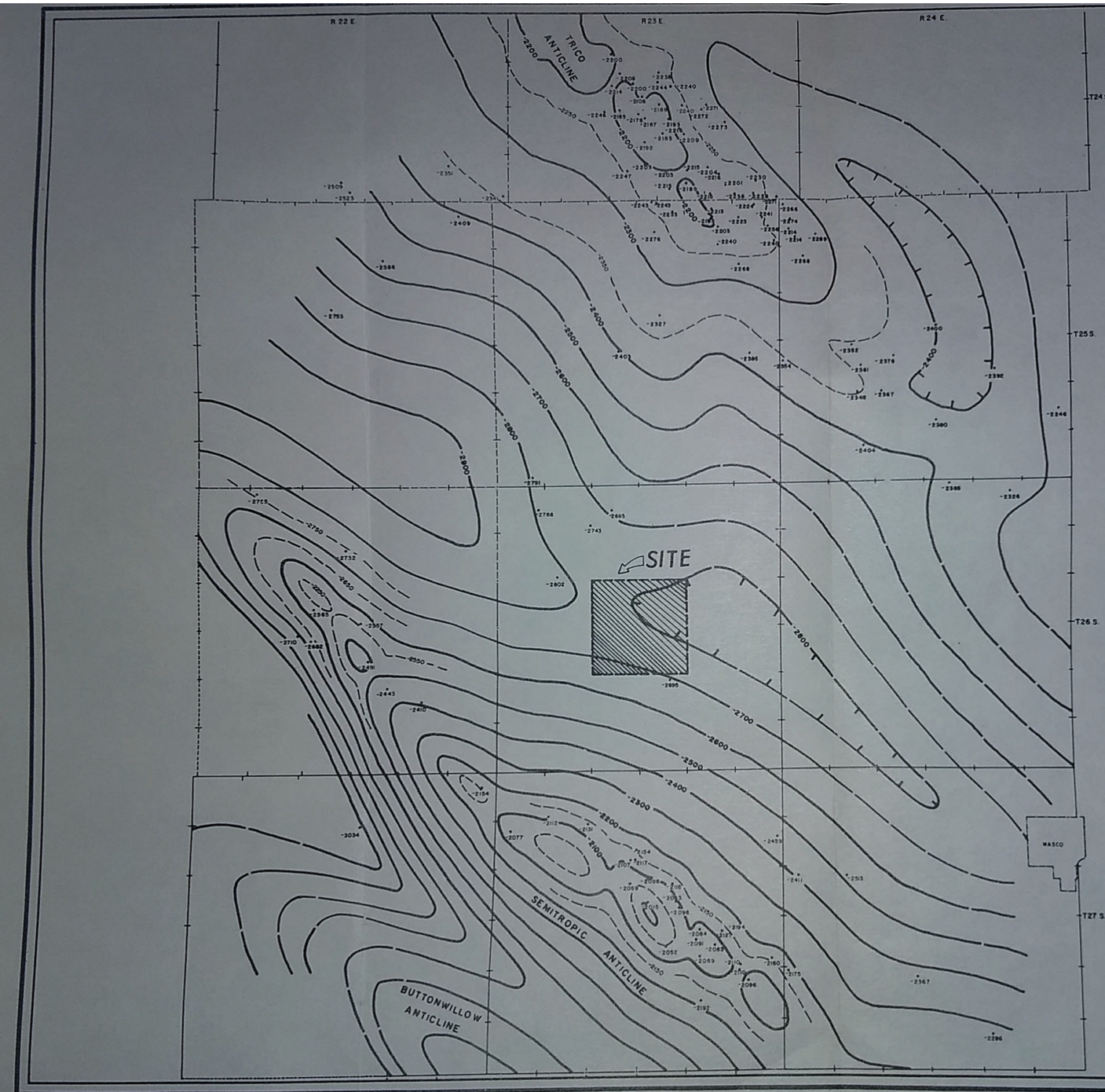
2) Refer to Figure 2.5F-5 for Poso Creek Area trench log

SAN JOAQUIN NUCLEAR PROJECT

INTERSECTION OF POSO CREEK
AND
KERN GORGE FAULTS

FIGURE 2.5.1-10B

AMENDMENT 16 10-31-75



EXPLANATION

2700 — Well location number indicates elevation on top of First *MYA* Sand. Datum is mean sea level.

—2400— Contour interval 100 feet, Dashed where approximate.

Contour interval 50 feet.

Depression

0 4000 8000 12000 16000 20000
(Feet)

NORTH

SAN JOAQUIN NUCLEAR PROJECT

STRUCTURE CONTOUR MAP, FIRST *MYA* SAND

FIGURE 2.5 1-21

AMENDMENT 5 6-12-74

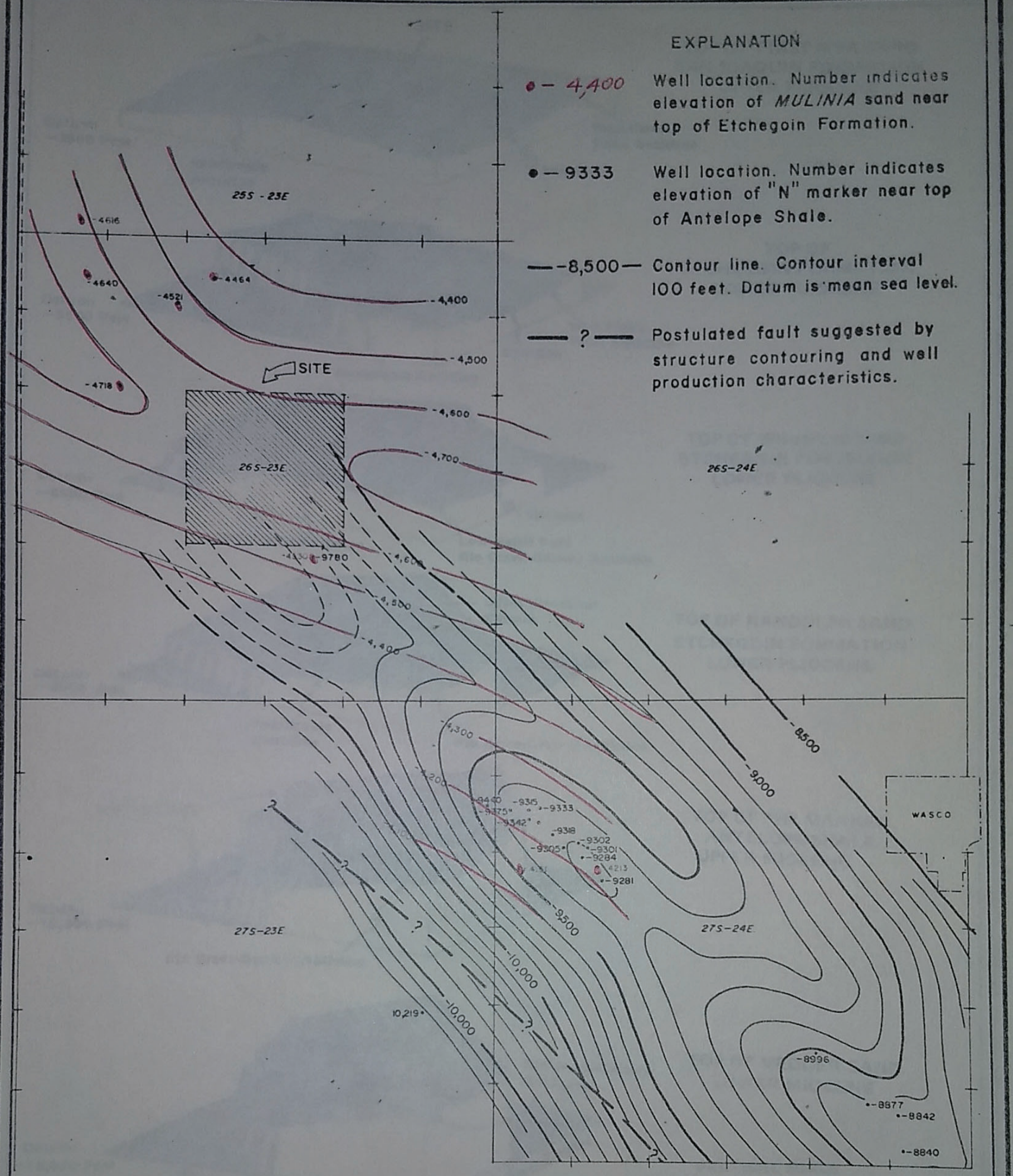
EXPLANATION

- 4,400 — Well location. Number indicates elevation of *MULINIA* sand near top of Etchegoin Formation.

• — 9333 — Well location. Number indicates elevation of "N" marker near top of Antelope Shale.

—8,500— Contour line. Contour interval 100 feet. Datum is mean sea level.

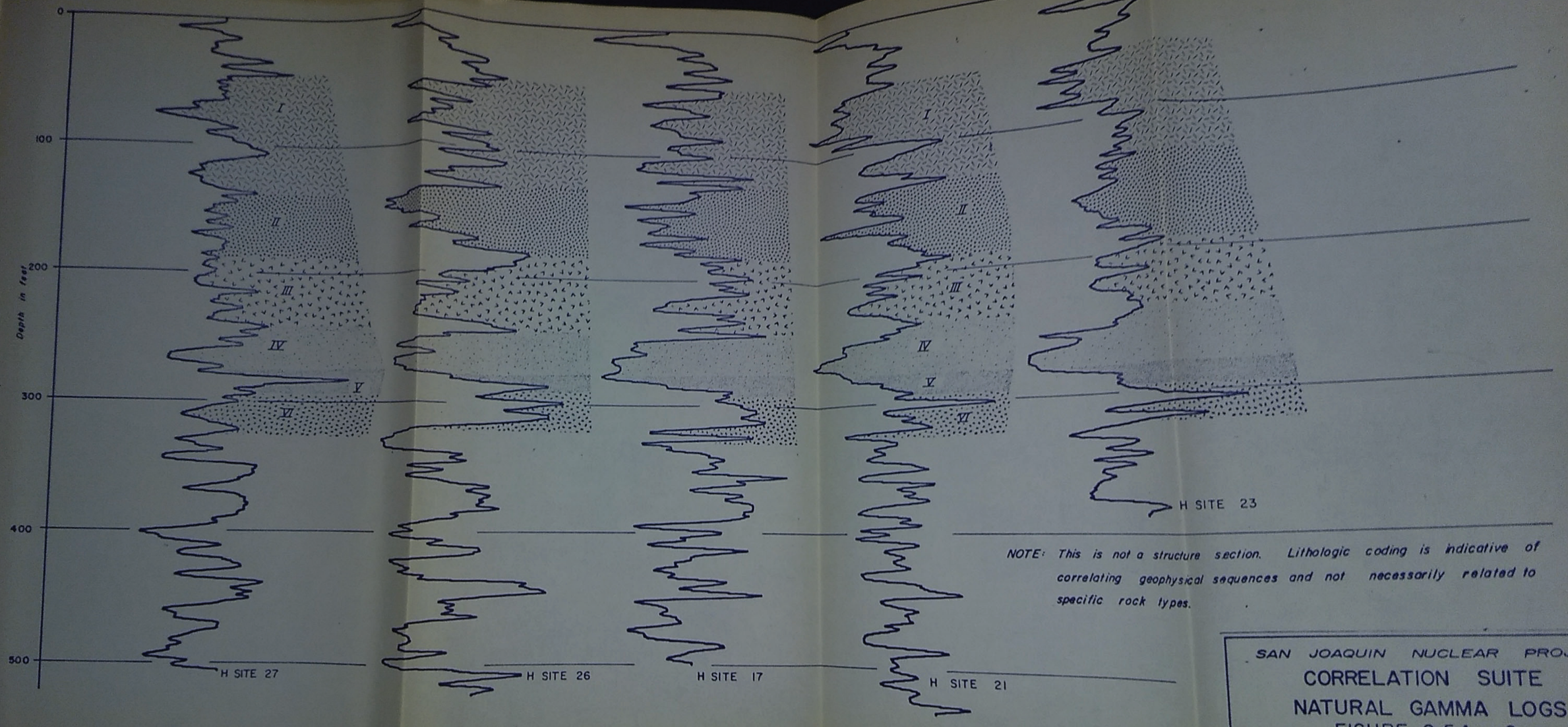
— ? — Postulated fault suggested by structure contouring and well production characteristics.



SAN JOAQUIN NUCLEAR PROJECT

STRUCTURE CONTOUR MAP ETCHEGOIN FORMATION AND ANTELOPE SHALE

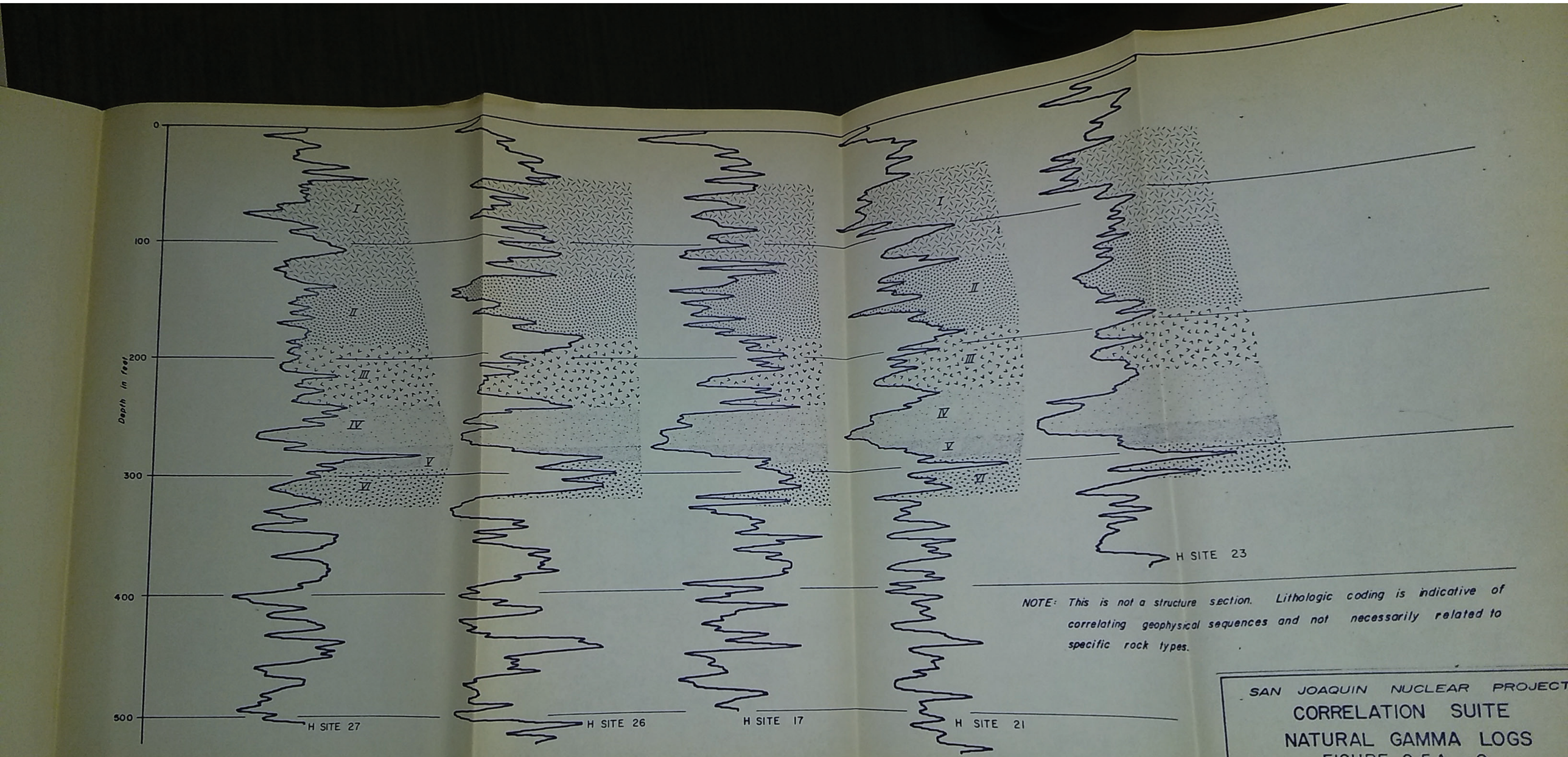
ESRR FIGURE 2.5.1-22



NOTE: This is not a structure section. Lithologic coding is indicative of correlating geophysical sequences and not necessarily related to specific rock types.

SAN JOAQUIN NUCLEAR PROJ

CORRELATION SUITE
NATURAL GAMMA LOGS
FIGURE 2.5A - 9



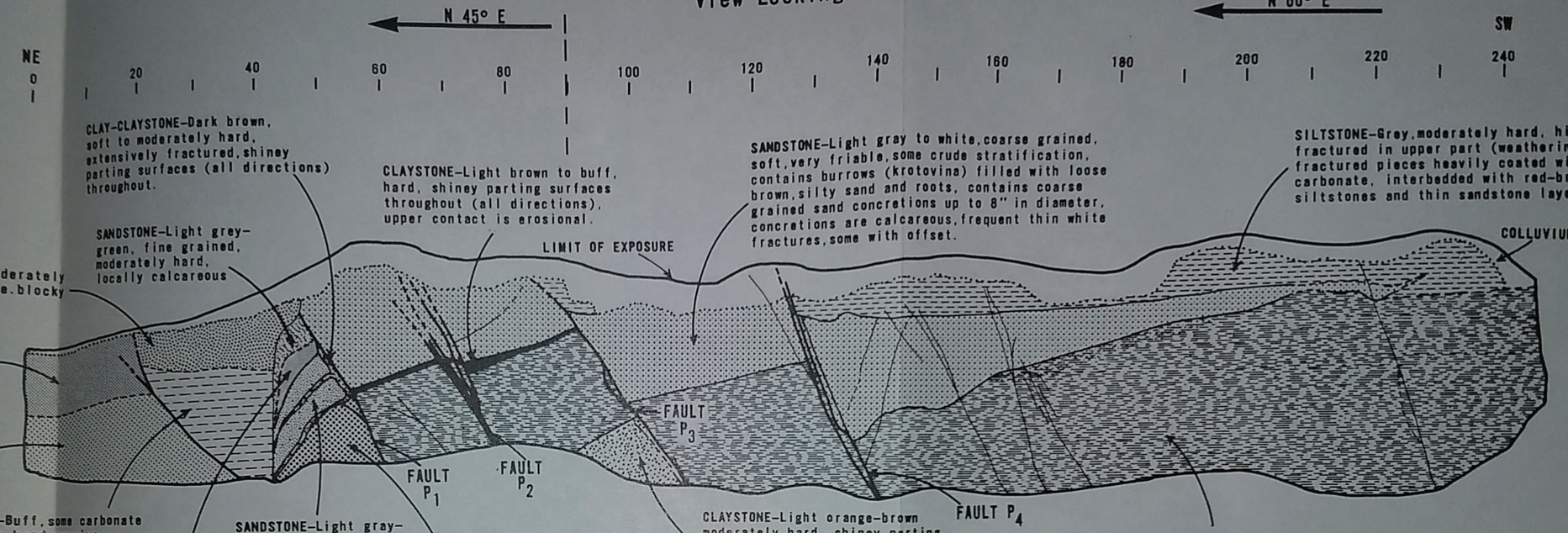
NOTE: This is not a structure section. Lithologic coding is indicative of correlating geophysical sequences and not necessarily related to specific rock types.

SAN JOAQUIN NUCLEAR PROJECT

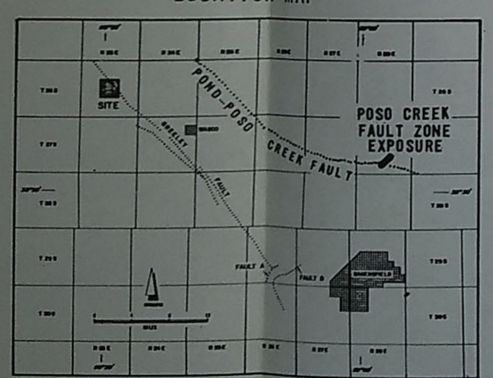
CORRELATION SUITE
NATURAL GAMMA LOGS
FIGURE 2.5A - 9

POSO CREEK FAULT ZONE EXPOSURE

View Looking Southeast



LOCATION MAP



NOTE: TRENCH SIZE EXAGGERATED

EXPLANATION

Fault with mappable displacements

Fracture (no displacement)

NOTES:

1) The highly fractured nature of the uppermost areas is probably related to mass–wasting processes.
2) Noticeable carbonate coating underlying colluvial contact from Station 45 to western end of exposure.
3) Refer to figure 2 5F–6 for Slickenslide Orientations of the Poso Creek Fault Zone Exposure

SAN JOAQUIN NUCLEAR PROJECT

LOG OF POSO CREEK FAULT ZONE EXPOSURE

FIGURE 2.5F–5

KERN COUNTY WATER AGENCY
STUDY OF THE REGIONAL GEOLOGIC STRUCTURE RELATED TO GROUND WATER AQUIFERS IN THE SOUTHERN SAN JOAQUIN VALLEY GROUND WATER BASIN, KERN COUNTY, CALIFORNIA

September 20, 1991

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Plate XI Proposed Subbasin Structural Boundary Map

APPENDIX

Data Base of Wells Available for Study

Project Authorization

The Agency Board of Directors on January 25, 1990, authorized a clay map study of the San Joaquin Valley portion of Kern County.

Kern County Water Agency Act 9098 Section 4.6 Surveys and Investigations

"The Agency shall have the power to make surveys and investigations for works and projects and of the water supply and resources of the Agency, and to carry on and perform technical and other investigations of all kinds, make measurements, collect data and make analyses, studies and inspections pertaining to water supply, water, water rights, control of flood and storm water and use of water both within and without the Agency, and for these purposes the Agency shall have the right to access through its authorized representative, to all properties within the Agency; provided, that the existence of such right of access shall not relieve the Agency from liability for damage sustained by any property owner by reason of the exercise of said right."

1.0 CONCLUSIONS

1.1 The shallow structure (less than 2,000 feet below surface) in the study area is more complex than previously mapped, as established by the following:

a. Extensive subsurface deformation exists, and shallow structural highs can be used to subdivide the valley into ten structural subbasins.
b. Some of the subsurface structures have little or no surface expression (e.g. Paloma anticline, Bakersfield Arch).
c. There are several regional and many local unconformities.
d. Faulting is observed which extends into the near surface sediments.

1.2 The "E" Equivalent Clay as identified in well 23S/24E-16B can be mapped as far south as T.30S.-R.24E., MDB&M, within the Buttonwillow trough. The clay can be correlated with confidence from the deepest part of the basin eastward to a line that extends roughly from Delano through McFarland and west of Shafter. The clay reaches depths of -900 feet subsea (1,100± feet subsurface) in T.25S.-R.20E., MDB&M, at the Kern County line.

1.3 A widespread clay informally named the "Paloma" Clay is mappable south of the Bakersfield arch. It is identified in wells 31S/25E -15R, 31S/25E -36A, and 32S/25E-1H in the Buena Vista lake bed area. This clay is eroded to the north (including the Kern Water Bank area) and is deeper than 4,400 feet below sea level in the depocenter at the southern end of the valley near Mettler (Plate X). Stratigraphic correlations indicate the "Paloma" Clay is older than the the "E" Equivalent Clay as mapped in this study.

1.4 There are other shallow correlatable units in the southern San Joaquin Valley. None of these clays appear to be as areally extensive as the "E" Equivalent and "Paloma" clays mapped in this study. However, some of these clays may have significant hydrogeologic importance to local ground water conditions.

1.5 Seismic surveys can be an effective (and sometimes essential) tool for mapping the shallow subsurface.

2.0 PURPOSE AND SCOPE OF STUDY

2.1 PURPOSE

As ground water management pressures have increased, a need has developed within the Kern County Water Agency for a geologic evaluation of the regional clay layer which separates the confined and unconfined aquifers in the San Joaquin Valley portion of Kern County south of Township 24 South, MDB&M. The previous maps of the clay were made using electric log correlations, and due to the subjective nature of the correlations, they have been the subject of much controversy. The current clay map most widely used was prepared by the Department of Water Resources and is more regional in nature. A more detailed evaluation of the clay layer would benefit the Agency, County, State and public for general planning and development of ground water resource projects. Primary use would be for water well, recharge development and development of a general ground water management plan for the valley.

The first phase of the clay study was to make a structure map on the clay itself. Subsurface structure mapping provides basic information for hydrogeologic analysis. This is especially true in the young sediments of the San Joaquin Valley. Two passages from the widely used text, Groundwater (Freeze & Cherry, 1979) support this concept,

> "In unconsolidated deposits, the lithology and stratigraphy constitute the most important controls. In most regions knowledge of the lithology, stratigraphy, and structure leads directly to an understanding of the distribution of aquifers and aquitards." (page 145)
>
> "In terrain that has been deformed by folding and faulting, aquifers can be difficult to discern because of the geologic complexity. In these situations the main ingredient in groundwater investigations is often large-scale structural analysis of the geologic setting." (page 147)

The "confining clay" was generally called the Corcoran or "E" clay by the ground water community because it had been loosely correlated with the

formation known as the Corcoran Clay (Frink and Kues, 1954) north of Kern County.

This study was not intended to identify or name specific clays in the southern San Joaquin Valley, nor to confirm or disprove the existence or competency of individual clays as confining barriers. This study concentrated on subsurface structural and stratigraphic relationships.

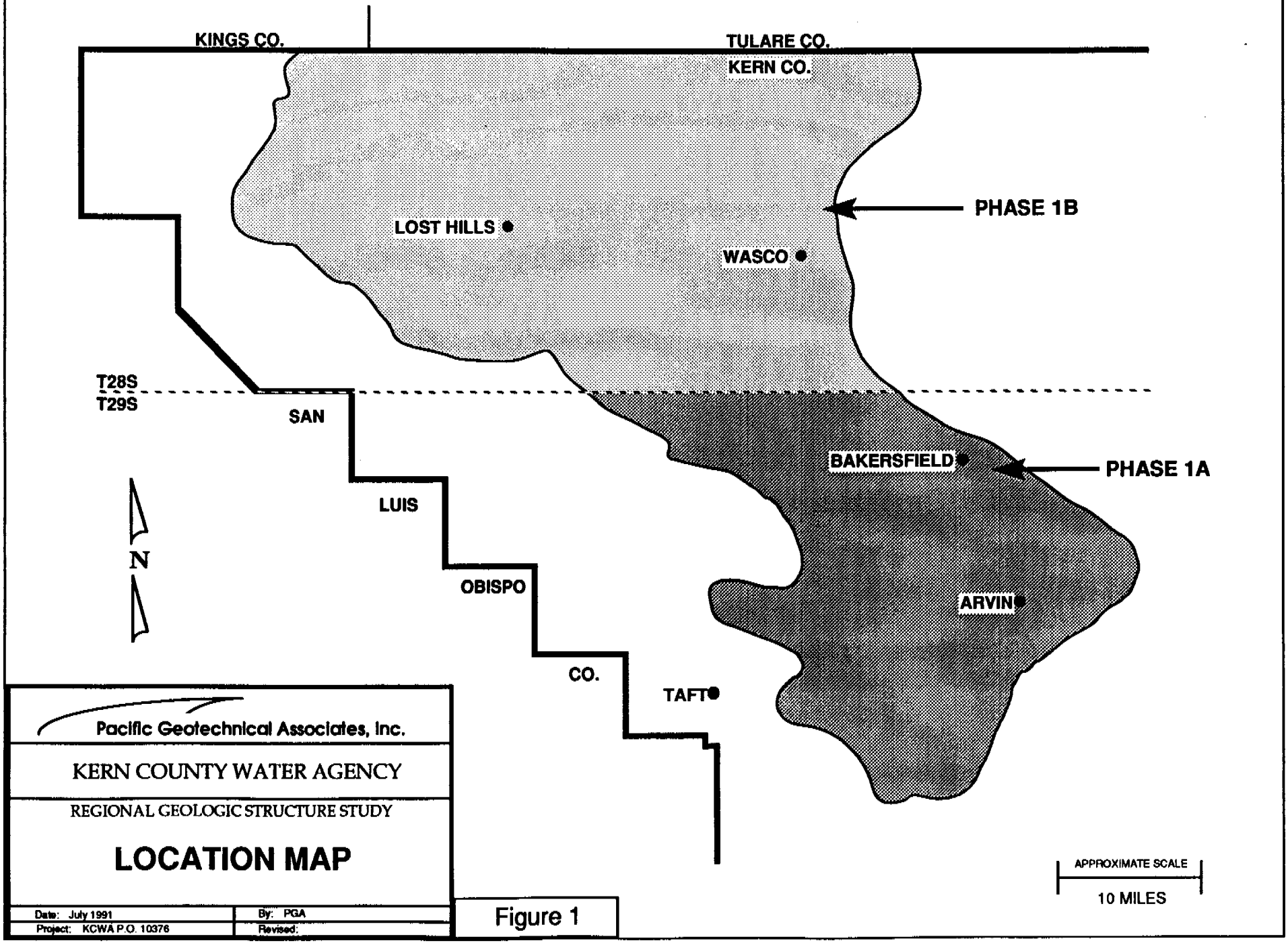
All formation and member names used herein have been adopted from work by previous authors (Page, 1986, Rector, 1982, Croft, 1972 and Brown, 1969) with the exception of the term "Paloma" which has been informally adopted to distinguish it from the "E" Equivalent and Corcoran clays. The horizons found on this report have been identified through correlation with existing reports, well logs and seismic data. No other means such as paleontology or age dating have been employed to independently establish the identity of the mapped clays.

2.2 SCOPE OF PHASE 1A

Pacific Geotechnical Associates, Inc., was contracted by the Kern County Water Agency to construct a geologic structure map and an isopach map of a regional "confining clay" in the San Joaquin Valley within Kern County. Phase 1A of the study covered the valley south of Township 28 South, MDB&M, while Phase 1B covered the area northward to the Kern County line (Figure 1).

2.3 EARLY DISCOVERIES OF PHASE 1A WORK

Phase 1A of the project began with a data base of 870± well logs and the construction of five geologic cross sections. Approximately 800 well logs were provided by the Kern County Water Agency with the remainder from other sources including ARCO Oil & Gas Company and the authors' files. Initial well correlations were made using depositional sequence analysis (i.e. fining upward and coarsening upward sequences). Due to the interbedded sand/clay deposition of alluvial, lacustrine, and fluvial environments as identified on wireline and drillers logs, numerous correlation choices existed for every well (see Figure 2). Poor log quality was also a problem in many of the water well



Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

LOCATION MAP

Date: July 1991	By: PGA
Project: KCWA P.O. 10376	Revised:

Figure 1

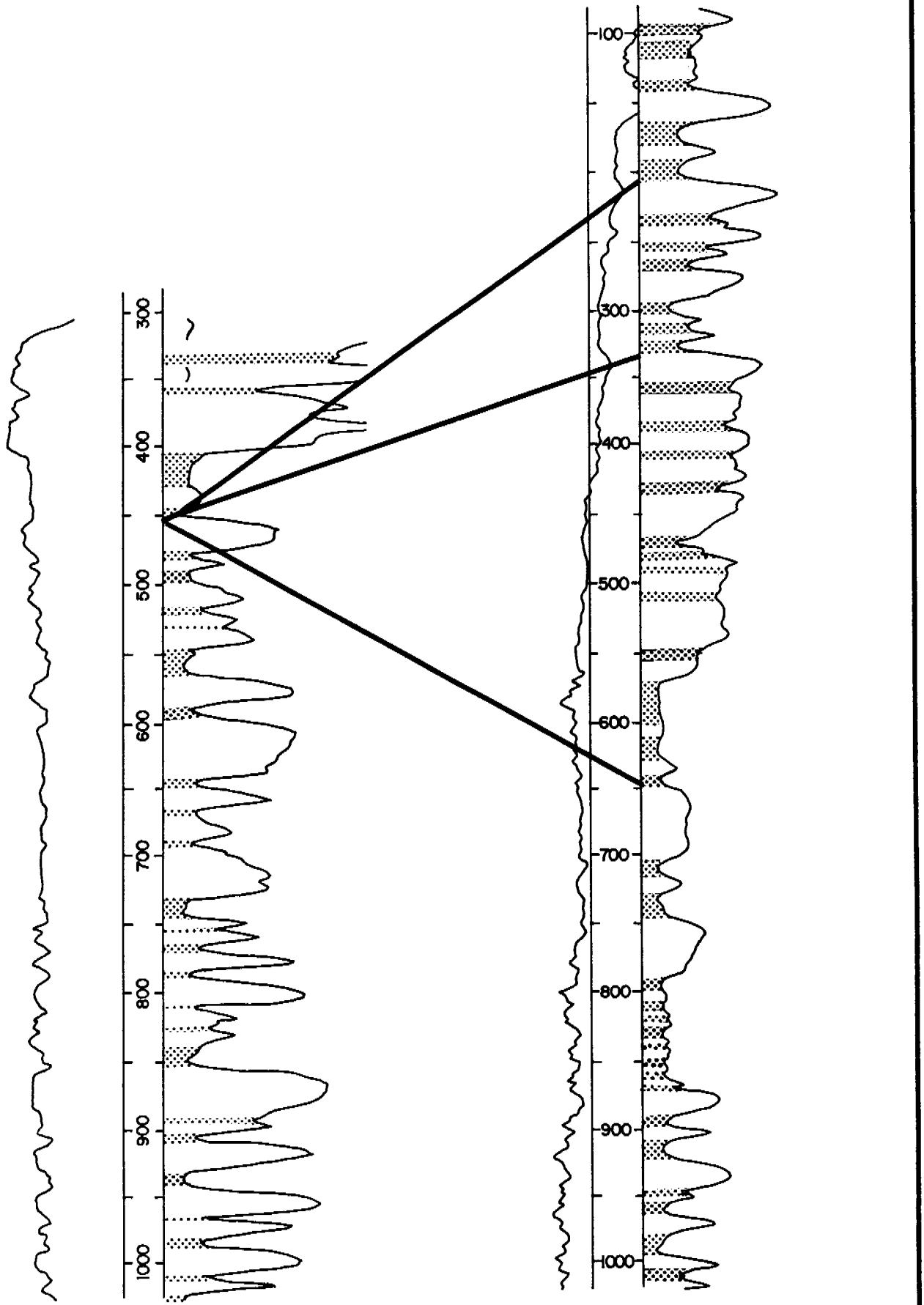


Figure 2. Example of possible correlation options.

logs. Because of the heterogeneous geologic environment and questionable log validity, little confidence could be put in many electric log correlations.

In order to make confident correlations and produce a defendable "confining clay" map, the Kern County Water Agency secured permission for the authors to utilize ARCO Oil & Gas Company's proprietary seismic data base. This data base was integrated with well logs to map the base of the "Paloma" Clay (originally thought to be the "E" Equivalent Clay) and later used to con-struct a regional "structural form map" on the shallowest mappable seismic horizons.

The seismically integrated structure map on the base of the "Paloma" Clay (included in this report as Plate X) led to a new understanding of the subsurface: 1) the "Paloma" Clay which was consistently correlated as "E" Equivalent Clay by previous authors in the area around the Buena Vista lake bed is not present on the Bakersfield Arch due to erosion, and 2) the clay is not relatively flat-lying but displays as much as 4,000 feet of structural relief between the Paloma and Mettler areas.

From these discoveries it was concluded that there is more than one significant clay in the study area, and that there is much more relief in the subsurface structure than had been previously mapped.

2.4 FINAL PHASE 1A WORK

Due to this new perspective on the nature of the subsurface, two new maps were constructed so that a better understanding of the subsurface structure and stratigraphy could be obtained:

a. An integrated seismic/well log structure map on the base of the "E" Equivalent Clay (herein informally called the "Paloma" Clay, Plate X).

b. A Structural Form Map on shallow seismic horizons (Plate I).

2.5 SCOPE OF PHASE 1B

Phase 1B tasks included extending the Structural Form Map northward to the Kern County line, constructing two east-west (dip) and one north-south (strike) structure cross sections, correlate at least one of the sections northward to tie into the "E" Equivalent or Corcoran Clay in the type or typical area, construct a structure map on the base of the "E" Equivalent Clay, and compose a report of techniques, findings, conclusions and recommendations for further work.

2.6 STUDY PERSONNEL

The geological analyses and well log correlations were performed by E. Kevin Beacom, Brian M. Hirst (Calif. Reg. Geol. #4583), Michael R. McGrath and Patricia J. Bell. Geophysical analyses were performed by Robert D. Dennis (Calif. Reg. Geop. #911) and Tom D. Fassio. The project was under the supervision of Randall T. Metz (Calif. Reg. Geol. #3995).

3.0 PURPOSE AND SCOPE OF REPORT

The purpose of this report is to document the methods and procedures used to make the maps and cross sections presented herein and to describe their uses and significance.

This report incorporates the findings and conclusions of both Phase 1A and Phase 1B work. The interpretation and integration of more than 1,250 miles of seismic data, hundreds of well logs and numerous check shot surveys has produced the Structural Form Map, Base "E" Equivalent Clay structure contour map, Base "Paloma" Clay structure contour map and correlations presented on the geologic cross sections.

4.0 STRUCTURAL FORM MAP

The Structural Form Map is a structure contour map on the shallowest mappable seismic horizons (Plate I). It presents a regional structural picture of the shallow sediments in the valley. This map is an aid to

1) understanding structural influences on regional ground water conditions,
2) making well log correlations and
3) developing ground water models.

Based on this map and other information, ten structural subbasins can be inferred for the southern San Joaquin Valley.

4.1 BACKGROUND

Ambiguous well log correlations in the early phase of this study lead the authors to seek other types of analyses to aid in the mapping of subsurface structures. Seismic reflection surveys are one of the most widely used geophysical methods employed by geoscientists to probe the structure and stratigraphy of sedimentary basins. Oil companies operating in the San Joaquin Valley have many miles of seismic data lines in the area of study. An arrangement was made with ARCO Oil & Gas Company to use their seismic data base. These data were used to generate a map which is made on a number of shallow reflection horizons. This map has been given the title Structural Form Map (Plate I).

The Structural Form Map was constructed from a large data base of structural information related to the shallow sediments which is independent of well information. Early attempts at correlating well logs over large distances failed to provide unique and defendable solutions even when depositional sequences were correlated. This is largely a result of the alluvial, lacustrine, and fluvial environments of deposition of the sediments being studied. Seismic data is more suited to reliably and unambiguously indicating the structural nature of these sediments.

4.2 DESCRIPTION OF SEISMIC DATA SET

Approximately 1,250 miles of ARCO Oil & Gas Company proprietary seismic data were used to generate the Structural Form Map. These data were generously provided by ARCO Oil & Gas Company through an agreement established with the Kern County Water Agency. Due to its proprietary and confidential nature, the seismic data set was interpreted in ARCO's office, and the locations of the lines have not been posted on the interpreted maps.

The density of coverage varied locally from a two mile grid to a six mile grid of seismic profiles (a two mile grid meaning two miles distance between parallel lines). The average grid was approximately two miles by three miles. This density of data is sufficient to [redacted] It is not sufficient to map local structural features covering less than a square mile or resolving the trends of small shallow faults.

[redacted] With the exception of those faults shown on the map near Buena Vista Hills, Elk Hills and McFarland these faults were unmappable because they were seen on only one profile or could not be confidently correlated with fault breaks on adjacent lines. These faults may or may not appear on Kern County seismic hazards maps, and the potential hazard they represent is not known by the authors.

These seismic lines are part of a large data base collected for the exploration of oil and gas. This data set has been acquired over a number of years, by different contractors with different objectives, techniques and vintages of equipment. These data are typically designed, collected, and processed for information on the deeper stratigraphic section (2500 feet below sea level and deeper). However, the newer, high frequency data does record and show the structural configuration of the relatively shallow sediments (300 feet to 1,500 feet below sea level).

The data set is not uniform in data quality, frequency content or processing techniques. In spite of this caveat, the data base as a whole shows from good to excellent quality in most areas, with the area proximal to the Bakersfield City limits showing only fair to good quality.

Typical acquisition parameters include a vibroseis source with medium frequency sweeps (10 to 60 Hertz), 110 foot group intervals, and 12 to 30 fold (although the very shallow data in the mute zone is only two to six fold). Near offsets on the seismic cable range from 300 to 700 feet, and the far offsets range from 3,600 to 12,000 feet.

Various programs have been used in the computer processing of the data to attain higher frequency resolution. These include spiking deconvolution, statics, residual statics, predictive deconvolution, and increased stacking velocity control.

4.3 SEISMIC METHODOLOGY

The Structural Form Map was made by beginning in a subsurface depression and mapping the shallowest seismic reflector as far up structure as the data allowed, then dropping down to the next suitable reflector and mapping it in a similar fashion, and continuing this technique until the entire study area was mapped (see Figure 3).

The sequence of steps used to generate the Structural Form Map (Plate I) was as follows:

a. Beginning with the synclinal axes of the study area, the shallowest continuous reflective horizon was chosen to tie and correlate from seismic profile to profile.

b. When the horizon became too shallow to follow with confidence, the interpretation was shifted down to the next horizon that showed continuous reflections. This procedure was repeated as often as necessary throughout the mapped area (Figure 3).

c. Several of these horizons were chosen because seismic stratigraphic analysis indicated they were significant sedimentary sequence boundaries (ie. angular unconformities, previously mapped clays, etc.).

d. Seismic times of the interpreted horizons were annotated and contoured on a regional base map.

e. The interpreted time map was converted back to depth using available velocity information.

The structure contours over the top of Elk Hills, Buena Vista Hills, and northwest of Bakersfield are on the approximate top of the [redacted] formation as generally accepted by petroleum geologists. This correlation was made by comparing the mapped seismic horizons with electric logs which had been converted from drill depth to two-way seismic travel time. The structure contours over the Bakersfield Arch in the vicinity of the Kern Water Bank are on the approximate [redacted]n based on seismic ties to wells at South Belridge oil field. At the north end of the map northeast of Lost Hills the contours are on the approximate [redacted] The seismic tie to this formation is discussed in Section 5.2.3.

Structure contours on these various horizons have been combined onto one map with no overlap, giving the appearance of a single contoured horizon. Horizon changes are noted by a heavy broken line on Plate I.

4.4 GEOLOGIC SIGNIFICANCE

4.4.1 Basic Structural Uses

The Structural Form Map (Plate I), although changing contour horizons many times, is useful for characterizing the structure of the shallow sedimentary deposits (less than 2,000 feet below surface). The con-tours range from -200 to -1,800 feet subsea or approximately 400 to 2,100 feet below the surface with most contours being between -600 and -1,000 feet subsea or approximately 800 to 1,200 feet below the surface.

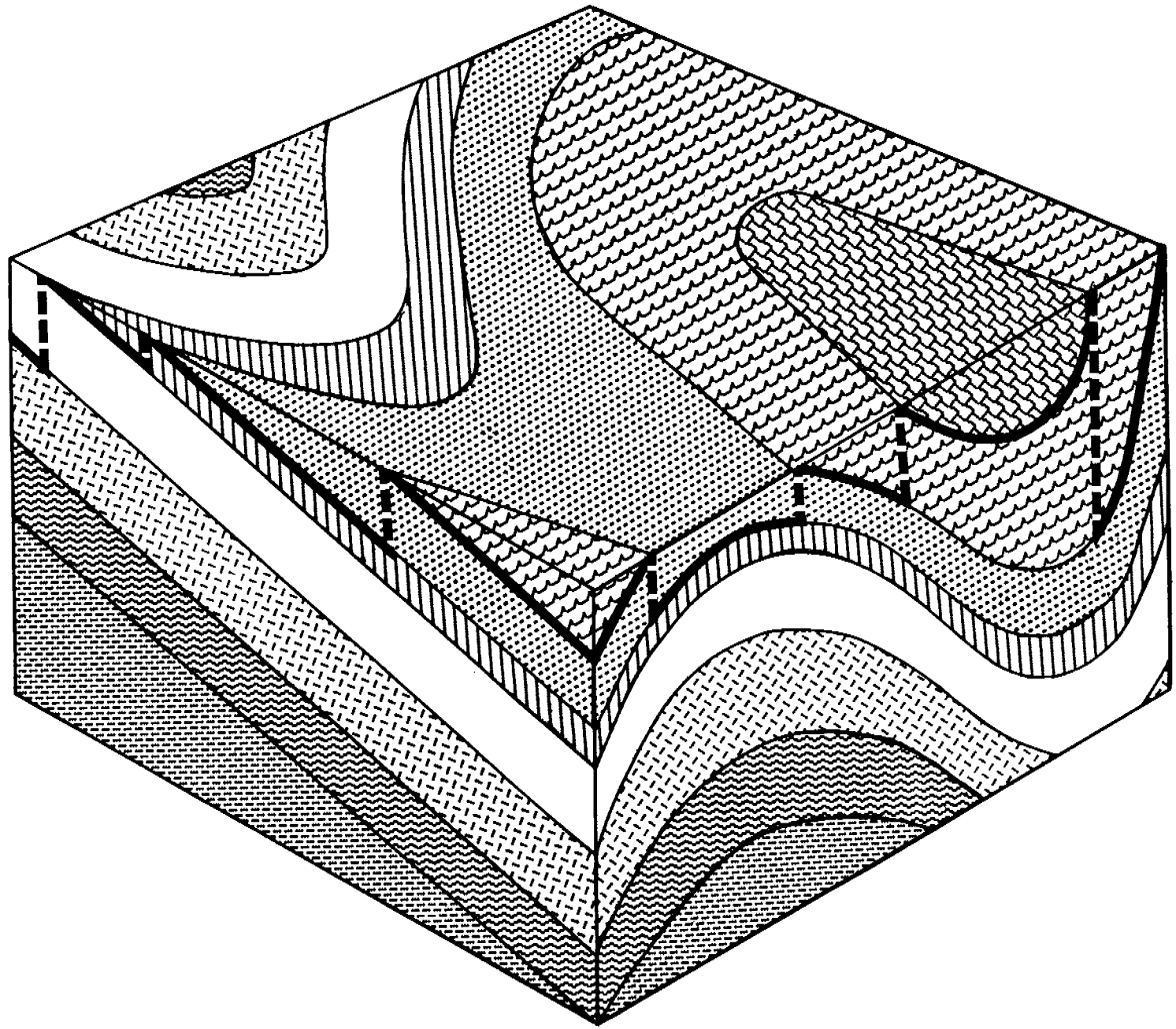


FIGURE 3 Conceptual view of method used in constructing structural form map. Top of block represents limit of seismic data resolution. Heavy lines represent contoured horizon. Dashed lines indicate where contour horizon changes.

It is important to note that structural dip in the subsurface generally increases with depth. This was observed consistently in the seismic profiles used in this study. [redacted] deeper than indicated by a given structural form contour horizon may be expected to have a greater magnitude of structural dip. However, the direction of dip should not deviate greatly in either case.

In general, the map is most accurate when used to judge the structural attitude of sediments at the depth indicated by the structural form contour lines. [redacted]

4.4.2 Regional Implications

One of the most significant aspects of the Structural Form Map is the regional picture it presents for the shallow sediments of the southern San Joaquin Valley. These include:

a. There are long prominent structural highs (anticlines) and lows (synclines) which may subdivide the southern San Joaquin Valley into hydrogeologic subbasins (see Section 8.0).

b. The east-west trending Bakersfield Arch structurally divides the southern San Joaquin Valley into two large structural subbasins.

c. There is an increasing intensity of structuring westward across the valley.

d. The synclines or troughs contain a significantly thicker sequence of young sediments than do the anticlines or broad highs. This is dramatically evidenced by the [redacted]

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KERN COUNTY WATER AGENCY
REGIONAL GEOLOGIC STRUCTURE STUDY

PROPOSED SUBBASINS STRUCTURAL BOUNDARY MAP

Kern County, California

TULARE SUBBASIN

LOST HILLS SUBBASIN

WASCO SUBBASIN

JERRY SLOUGH SUBBASIN

BUTTONWILLOW SUBBASIN

BUENA VISTA SUBBASIN

MAICOPA SUBBASIN

METTLER SUBBASIN

TEJON SUBBASIN

EDISON SUBBASIN

SAN LUIS OBISPO COUNTY

DELANO

MCFARLAND

WASCO

SHAFTER

BUTTONWILLOW

BUENA VISTA LAKE BED

TAFT

MARICOPA

FOOTHILL LINE
BEDROCK LINE
GROUND WATER BARRIER
CALIFORNIA AQUEDUCT AND TURNOUTS

KCWA BASE MAP LEGEND

EXPLANATION

This map shows the boundaries of subbasins within the southern San Joaquin Valley. The indicated subbasins are bounded by distinct structural highs due to folding and faulting. The structural interpretation is based upon analyses of subsurface well and seismic data presented in the report: KERN COUNTY WATER AGENCY STUDY OF THE REGIONAL GEOLOGIC STRUCTURE RELATED TO GROUND WATER AQUIFERS IN THE SOUTHERN SAN JOAQUIN VALLEY GROUND WATER BASIN, SOUTHERN KERN COUNTY, CALIFORNIA.

These subbasins may contain isolated or partially isolated hydrogeologic systems. Solid lines represent prominent, continuous bounding highs. Dashed lines represent low areas along these boundaries where communication between subbasins is more likely.

NOTE - This map is derived solely from a structural interpretation. Other sources of hydrogeologic data such as gradients, geochemical analyses, etc. will help determine the role of these individual subbasins in the hydrogeology of the southern San Joaquin Valley.

FIGURE 4

e. Many of the structural highs do not have a surficial expression such as the Paloma structure.

4.4.3 Stratigraphic Correlations

By knowing the approximate direction and rate of dip between two wells it is possible to project approximate stratigraphic correlations between them. This is a great advantage in areas of the valley where well correlations are ambiguous. The Structural Form Map was effectively used for this purpose in correlating the geologic cross sections and well picks for the "E" Equivalent Clay Map as discussed in Sections 5.0 and 6.0.

4.4.4 Hydrogeologic Models

The Structural Form Map can provide valuable structural information in areas where hydrogeologic models are being developed. Structural information in conjunction with a stratigraphic interpretation provides the basis for modeling natural and man made effects on the hydrogeologic system.

5.0 REGIONAL STRATIGRAPHIC CORRELATIONS

5.1 INTRODUCTION

The stratigraphy of the shallow sediments (less than 2,000 feet) is typical of clastic dominated alluvial, fluvial, and lacustrine environments. Generally, the section is composed of sands and silts with a lesser percentage of clay. Typically, sandy and silty layers are many tens to hundreds of feet thick whereas, clay layers are seldom more than a few tens of feet thick (Plates IV - VIII). Depositionally, the clays are associated with fluvial systems such as abandoned channels (oxbow lakes) or small lakes in basin lows which migrated with continued tectonic shifting of the basin.

Integration of

structural information derived from seismic data with regional geologic cross sections verified the regional extent of these units. The stratigraphic and historical significance of these clays is discussed in the following Subsections.

5.2 "E" EQUIVALENT CLAY

5.2.1 Historical Significance

The Corcoran Clay was identified as a distinctive mappable unit in water wells and core holes as early as the 1920's. The first comprehensive discussion of the clay was by Frink and Kues (1954). Their paper summarized previous investigations (which were of limited scope) and presented regional maps of the clay which extended from southern San Joaquin County to northern Kern County.

Croft (1972) presented expanded studies of late Tertiary and Quaternary lacustrine and marsh deposits in the Tulare lake bed area. He defined six clays of Quaternary age which were designated "A" (youngest) through "E"(oldest). The "E" clay is equivalent to the Corcoran Clay and was mapped further south by Croft (1972) to the Buena Vista and Kern Lake beds. Page (1986) presented updated maps on the "E" clay which differed most notably from those of Croft (1972) in the Buena Vista and Kern Lake beds area. In recognition of these differences Page (1986) introduced the name "modified E clay" to describe the mapped clay unit.

Historically the "E" clay has attained much attention in the literature. This is primarily due to the fact that it is the most regionally mappable Quaternary unit in the San Joaquin Valley, and it was perceived as a significant aquitard early in the history of the basin's ground water development. As a mappable unit it provides information about the structure and stratigraphy of sediments above and below it. As an aquitard it has significant importance to hydrogeologic dynamics of the basin.

5.2.2 Type Well Documentation

Well 23S/24E-16B was selected as a type well for correlating the "E" clay into the study area. This well located approximately four miles southwest of

Pixley was drilled to a depth of 1,400 feet by the U.S. Bureau of Reclamation in 1951. The well was included in the cross section D-D' of Frink and Kues (1954). It was selected as a type log for the present study because:

a. It provided a tie with the Corcoran Clay mapping of Frink and Kues (1954);

b. Subsequent work by Croft (1972) and Page (1986) correlated "E" clay at the same depth as the Corcoran of Frink and Kues (1954) in this well;

c. It is in an area with the best well density north of the study area, thus providing the highest quality and confidence in correlating the wells to the south into the study area.

Type well 23S/24E-16B is presented in Geologic Cross Section B'-B" (Plate VII). The well correlations southward from this well into the study area are excellent and demonstrate the quality of mapping possible where the "E" clay is well developed.

5.2.3 Geologic Cross Section Correlations

Geologic cross section B'-B" (Plate VII) has been extended north of the study area to tie the Type Well (well 23S/24E -16B). Correlation of the "E" Equivalent Clay southward in the cross section towards the study area is facilitated by the relatively thick nature (60 to 90 feet) of the clay in this area. The contoured horizons from the Structural Form Map have been placed on all the cross sections for correlation purposes.

"E" Clay

The "Paloma" Clay thins southwestward towards B' and comes within 100 feet of the surface over the Trico and Semitropic anticlinal structures. At B' the cross section ties with geologic cross section A-A' and B-B' (Plates IV and VI). As seen in section B-B', the clay is believed to outcrop or subcrop beneath surface alluvium along the east flank of the Lost Hills anticline.

Cross section A-A' was laid out to follow the structurally lowest portion of the basin as indicated on the Structural Form Map. The "E" Equivalent Clay can be correlated to the north end of section A-A'. Here the clay has thickened to approximately 140 feet. These clay correlations match the structure suggested by the Structural Form Map well. [redacted]. As described in Subsection 5.2.4, this should be anticipated because this seismic horizon was selected by tying the seismic data to previous "E" Equivalent Clay studies north of the Kern County line. Two different methods to tie into two different areas of the previous studies of the "E" Equivalent Clay north of the Kern County gave consistent results.

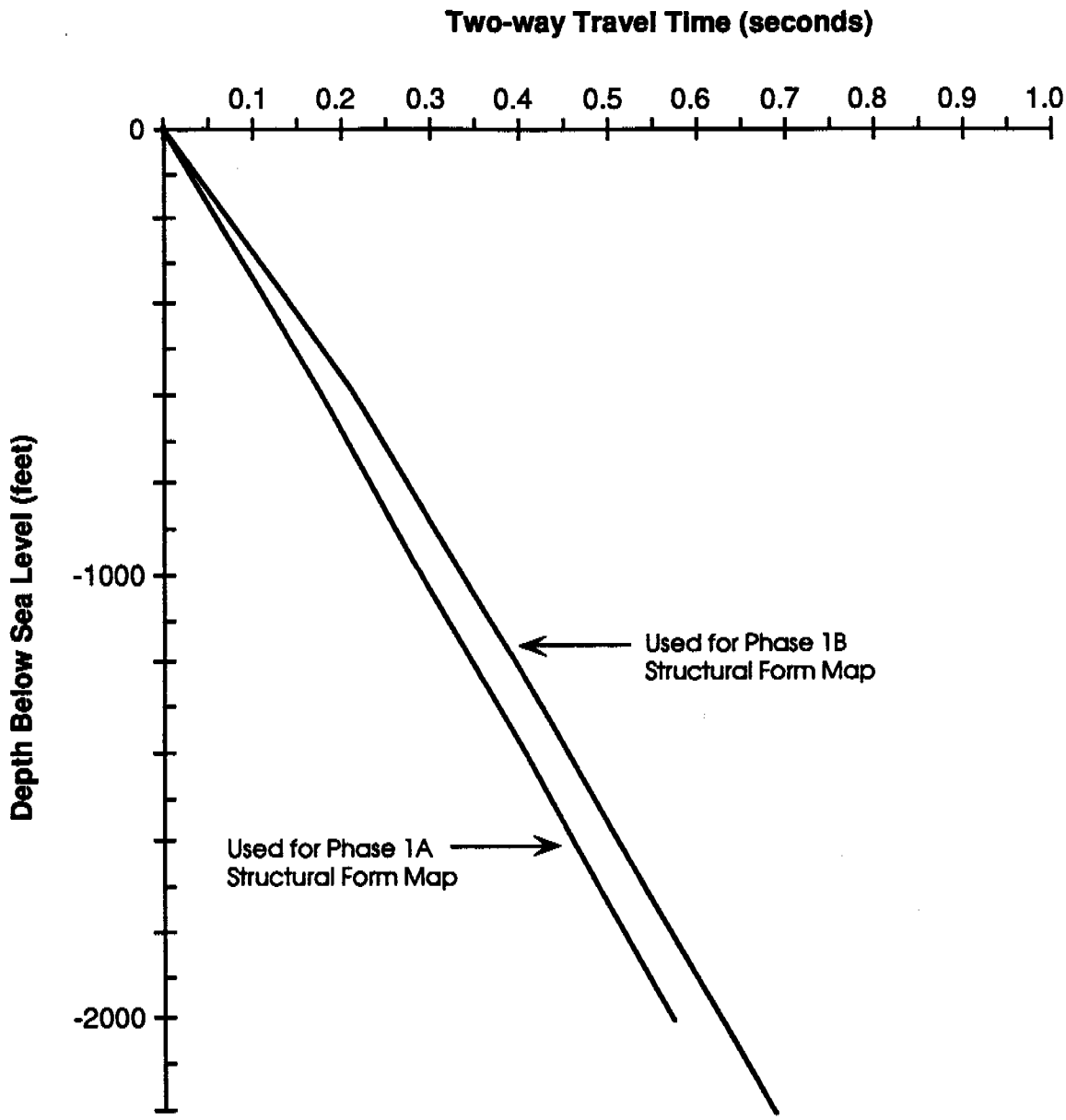
[redacted] correlated to dip into the Buttonwillow Trough where it is seer[redacted]t. It then rises out of the trough and outcrops or subcrops on the north flank of the Bakersfield Arch.

Cross section C-C' shows several "E" Equivalent Clay correlations. These are based on correlation work performed in making the Base "E" Equivalent Clay Structure Map (Plate IX).

5.2.4 Seismic Correlation to Previous Studies

Regional north-south seismic lines were used to tie into well defined [redacted]ty. The "Best Fit" velocity function shown in Figure 5 was used to convert the depths and isopachs of [redacted]. These times were then transferred to the corresponding seismic profiles to select the seismic horizon [redacted] This horizon was mapped as the [redacted] (Plate I).

In addition, the type well (23S/24E-16B), shown on Geologic Section B'-B" was also posted in the same manner on a regional seismic line. This pick was tied seismically into the seismic data grid and confirms the continuity of this particular unit in a limited northern portion of the study area.



Generalized graph showing the relationship between depth below sea level and two-way seismic travel time in shallow sediments in the southern San Joaquin Valley.

Figure 5

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

TIME vs DEPTH GRAPH

Date: July 1991	By: PGA
Project: KCWA P.O. 10376	Revised:

5.3 "PALOMA" CLAY

5.3.1 Background

Previous studies consistently agree that a thick clay found in wells near the Buena Vista lake bed area is the Corcoran or "E" Equivalent Clay. Because of this agreement, three key wells were selected as type wells and a structure map was constructed on the base of this clay during phase 1A of this study. These wells and the measured depth to the base of the clay is as follows: 31S/25E-15R at 840 feet; 31S/25E-36A at 810 feet; 32S/25E-1H at 960 feet.

Subsequent work during phase 1B of the study has led to the conclusion that this is an older clay and not related to the "Corcoran" or "E" Equivalent Clay. The name "Paloma" Clay has been informally assigned to this unit for purposes of this study.

5.3.2 Stratigraphic Relationship To "E" Equivalent Clay

The "Paloma" Clay appears to be significantly older than the "E" Equivalent Clay as defined in this report. This conclusion is based on the correlations presented in geologic cross sections A-A' and A'-A" (Plates IV and V).

As shown in these cross sections and the structure map on the base of the "Paloma" Clay (Plate X) the "Paloma" Clay rises northward out of the Maricopa basin and is truncated along the southern flank of the Bakersfield Arch and Elk Hills This . Similarly, the younger "Buena Vista" unconformity was recognized in seismic data and later in well correlations. These unconformities have been named for well developed expressions in seismic lines in the vicinities of the Paloma and Buena Vista structures respectively.

An unnamed clay is found 300 to 400 feet above the "Buena Vista" unconformity as seen in Geologic Cross Section A'-A" (lightly shaded on Plate V). This clay is correlated approximately 350 feet below the "E" Equivalent Clay on Geologic Cross Section A-A', Well T30S/R24E/4C (Plate IV). Based on the intervening position of the unidentified clay to the "E" Equivalent and "Paloma" clays, the "Paloma" Clay is stratigraphically below and older than the "E" Equivalent Clay. It is not known if this clay has hydrogeologic significance. These regional correlations would be difficult to make and to justify were it not for the seismic data base.

6.0 "E" EQUIVALENT CLAY STRUCTURE MAP

6.1 INTRODUCTION

Section 5.0 provides the stratigraphic documentation for the "E" Equivalent Clay. The base of the clay was selected for constructing a structure contour map based on stratigraphic reasons such as its consistency as a marker and its relationship to the units above and below the clay. The resulting Structure Contour Map on Base "E" Equivalent Clay is presented as Plate IX.

6.2 WELL LOG CORRELATIONS

As seen in Geologic Cross Section A-A' and B-B' (Plates IV and VI), well log correlation of the "E" Equivalent Clay can be relatively straight forward when the clay is more than 30 feet thick. More than 100 well logs were correlated. In general, the best correlations with the highest degree of confidence were in the northern most regions of the study area (within 10 miles of the Kern County line between Lost Hills oil field and the town of Delano).

Correlations were guided by two principle criteria; overall correlation of the lithologic units above and below the clay and basic structural conformity with the Structural Form Map . The electric log "signature" of the

thick enough to display it. Attempts to expand the correlated limits of the clay were stopped when the clay was indicated to be within approximately 50 feet of ground level and/or the thin (less than ten feet) nature of the clay and nondistinctive encompassing lithologies made further correlation indefensible.

6.3 INTEGRATION WITH STRUCTURAL FORM MAP

The subsea depths for the base of the "E" Equivalent Clay were posted on a base map and contoured. Where well control was sparse or multiple contouring options existed, contouring was guided by the Structural Form Map. [illegible]

6.4 GEOLOGICAL SIGNIFICANCE

Historically, the "E" Equivalent Clay has significance to ground water issues in the San Joaquin Valley. There has been debate as to the areal extent of the clay and its' importance as an aquitard in Kern County. The areal extent and structure of the clay presented here differ to varying degrees with previous studies. This map is unique in that it incorporates a regional seismic data base to guide well correlation and structural interpretation. As such it is possibly the most accurate in depicting the structure of the clay and hopefully will be useful in understanding the role of the "E" Equivalent Clay in the ground water hydrology of the southern San Joaquin Valley.

7.0 " PALOMA" CLAY STRUCTURE MAP

7.1 INTRODUCTION

The "Paloma" Clay was selected for mapping early in the project based on previous studies (see Section 5.0). The base of the clay was chosen because it tied well with the seismic data, it was easier to correlate in well logs compared to the top of the clay and it could be correlated over a wider area on the seismic data. The "Paloma" Clay is located south of Township 29 South, MDB&M (see Plate X).

7.2 DESCRIPTION OF SEISMIC DATA SET

Approximately 425 miles of the seismic data used in making the Structural Form Map were used to construct the Structure Contour Map on Base "Paloma" Clay (Plate X).

7.3 SEISMIC METHODOLOGY

The base of the clay in the key wells (31S/25E-15R, 31S/25E-36A and 32S/25E-1H) surveys in nearby wells. This graphical and numerical depth conversion changes the measured depths to seismic two-way travel time. At these depths, it is normally accurate to within ten percent (plus or minus 85 feet). However, in conjunction with the numerical conversion, the stratigraphic interpretation of the seismic profile reflection coefficients reduces the possible mis-tie to less than 25 feet. Once this seismic horizon was identified, it, as well as other seismic horizons were correlated and tied around on the seismic database.

The sequence of steps used to make the Structure Contour Map on Base "Paloma" Clay (Plate X) was as follows:

a. Interpret the "top" and "base" of the base "Paloma" Clay in wells that contain generally accepted correlations (31S/25E-15R, 31S/25E-36A, and 32S/25E-1H).

b. Convert the depths to seismic two-way travel time by compiling and plotting velocity survey information from petroleum wells in the general vicinity.

c. Post the converted horizon times of the base "Paloma" Clay onto the nearest seismic profile and select the most appropriate reflector for interpretation.

d. Interpret the seismic reflector over the study area.

e. Annotate and contour the interpreted horizon times on a regional base map.

[redacted]

7.4 GEOLOGIC SIGNIFICANCE

The Base "Paloma" Clay map shows that the base of the clay varies in depth from very shallow to over 4,400 feet below sea level in the southern end of the valley near the town of Mettler. This horizon has been eroded and underlies one or more unconformity as it approaches the Bakersfield Arch to the north (Subsection 5.3.2.)

This map is an excellent example of how units encountered at relatively shallow depths on the west side of the San Joaquin Valley may be related to significantly deeper sediments in the structural lows or troughs. The more intense structural development found on the west side of the valley is not always apparent at the surface as shown by the Paloma anticline. [redacted]

The Base "Paloma" Clay map also illustrates the importance of local and semi-regional unconformities in the shallow sediments particularly along the west side of the valley. These unconformities require that a number of structural/stratigraphic maps be made in order to adequately describe critical relationships governing the hydrogeology of the area.

A summary of the geologic observations made while constructing this map includes:

a. The Base "Paloma" Clay Structure Map shows that the clay exists in only a portion of the study area.

b. At least two significant unconformities can be mapped in the shallow sediments in the southwest portion of the study area.

c. The Elk Hills, Buena Vista Hills, and Paloma structures are still active, and have had a major influence on Pliocene to Recent deposition and shallow faulting.

8.0 PROPOSED STRUCTURAL SUBBASINS

8.1 INTRODUCTION

The shallow sediments of the southern San Joaquin Valley constitute a large ground water basin which has been heavily utilized for agricultural, industrial and domestic uses for decades. These uses in conjunction with natural and planned recharge of the aquifers has created dynamic ground water conditions. There is ample evidence showing this basin is more complex than a simple isotropically homogeneous aquifer. Many analytical disciplines can be called upon to measure and study the anisotrophy and inhomogeneity of a ground water basin (ie., stratigraphy, sedimentology, geochemistry, structural geology, aquifer analysis etc.). This section will discuss how the regional structure of the shallow sediments, as mapped in this study, can be used to characterize and divide the basin into structurally defined subbasins.

8.2 PROPOSED SUBBASINS

The Structural Form Map (Plate I) presents a seismic interpretation of the shallow regional structure (less than 2,000 feet subsurface) of the basin. Structural highs seen in this map along with other well known structural [illegible] (such as major faults) have [illegible] the basin into ten subbasins as presented in Figure 4 and Plate XI.

These ten subbasins have been named informally as follows:

Buena Vista Subbasin	Buttonwillow Subbasin
Edison Subbasin	Jerry Slough Subbasin
Lost Hills Subbasin	Mettler Subbasin
Maricopa Subbasin	Tejon Subbasin
Tulare Subbasin	Wasco Subbasin

Solid lines between the subbasins on Plate XI indicate the areas with prominent structural highs and represent the greatest structural potential for hydrologic barrier development. The dashed lines are the lowest areas along the structural highs and represent areas with the greatest potential for hydrologic migration between subbasins.

8.3 IMPLICATIONS TO FUTURE STUDIES

The importance of structural attitude on hydraulic gradients and flow within an aquifer system is dependent on the degree to which horizontal conductivity exceeds vertical conductivity. The exact dependence of hydraulic gradients and flow on structure in the southern San Joaquin Valley is not known, however some level of dependence surely exists. To this extent a structural high (such as Paloma anticline) should act as a partial or total barrier to ground water migration across the high.

While these structurally defined subbasins address only one aspect of control on the hydrologic system, they do provide a basis for areal division of the valley. The hydrologic characterization of these smaller units will provide a more focused investigation which can address the anomalies and questions associated with a particular subbasin.

9.0 RECOMMENDED FUTURE WORK

This report represents a first step toward attaining an understanding of the hydrogeology of the southern San Joaquin Valley and the development of a meaningful ground water management plan. The next steps involve gathering other types of data and integrating them with the structural and stratigraphic data. The final steps will be to interpret the data and to create maps and illustrations useful for preparation and implementation of a plan.

9.1 DELINEATE SUBBASINS USING SEISMIC, WELL AND WATER DATA

The limits of the subbasins defined by the Structural Form Map should be refined by integrating additional seismic data with well log correlations, water quality values from electric log calculations, ground water chemistry,

pressure, and other ground water data. This will allow researchers to better determine the extent to which structural subbasins act as hydrologic subbasins. If current data bases (such as the water quality data base) are inadequate or incomplete, they should be upgraded.

9.2 MAP THE CONFINING CLAY(S) IN INDIVIDUAL SUBBASINS

[redacted]

9.3 CONSTRUCT A REGIONAL "CONFINING CLAY" MAP WHICH SHOWS ALL SUBBASINS (BOTH STRUCTURAL AND DEPTH-TO MAPS)

Combine the Confining Clay(s) maps described in Section 9.2 to create one map showing all of the subbasins. The map will be a convenient resource to those who must enforce and those who must adhere to water well ordinances. The increasing emphasis or ground water recharge and withdrawal in the San Joaquin Valley will necessitate an improved understanding at hydrologic controls on groundwater movements.

10.0 CLOSING

This investigation was conducted for the Kern County Water Agency in accordance with generally recognized geological and geophysical procedures. The conclusions of this preliminary study are based solely on the work described herein and should not be used as a basis for final decisions.

Robert D. Dennis, R.GP.

Randall T. Metz, R.G.

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GLOSSARY

alluvial, lacustrine and fluvial environments	Valley floor, lake and stream and river depositional settings respectively.
anticline	A fold that is convex upward.
checkshot	Measurement taken in a well bore of the travel time required to transmit energy from the ground surface to a measured depth. This information is necessary to convert seismic travel time to depth.
confining clay	Sedimentary clay deposit which has the ability to greatly retard the transmission of fluid, even when a pressure gradient is applied.
"E" Equivalent Clay	Name adopted by Page for a widespread shallow clay in the San Joaquin Valley. It is identified in well 23S/24E-16B.
Etchegoin	Pliocene age formation in the San Joaquin Valley which is generally thought to represent the transition from marine or brackish conditions to a nonmarine lake and fluvial environment of deposition.
fold, seismic	Redundancy in the data. High fold is desirable for most applications as it eliminates ambient "noise" and has the effect of strengthening the returning seismic signal.
frequency	Characteristic of energy waves measured in cycles per second (Hertz). Generally speaking the higher the frequency the thinner the bed which can be resolved on seismic data.
group interval	Spacing between seismic recording stations on the ground surface. Generally speaking the larger group intervals are used to image deeper data.
isopach map	A map showing points of equal thickness of a particular unit.

mute zone	Area of a seismic record which represents the time between imparting the energy into the earth and the return energy from the nearest reflector.
offsets	Distance between the source of the energy being imparted into the ground and the various geophones (energy sensor).
"Paloma" Clay	Informal name coined for a mappable clay south of the Bakersfield Arch. It is identified in wells 31S/25E-15R, 31S.25E - 36A and 32S/25E-1H
Pleistocene	The earlier of the two epochs which comprise the Quaternary period. It covers a period approximately 1.6 to 0.01 million years before present (Geol. Soc. America).
Pliocene	The latest of the epochs comprising the Tertiary period. It covers a period approximately 5.3 to 1.6 million years before present (Geol. Soc. America).
reflection horizon	Plane beneath the surface (usually the contact between two parallel strata) which has the ability to reflect seismic energy back to the surface when a surface seismic energy source is employed.
seismic data base	Collection of seismic lines and checkshot surveys of different vintage, collection parameters and acquisition companies.
seismic travel time	Time it takes for seismic energy to go from the source into the subsurface and reflect back to the surface at a recording device. It is commonly measured in milliseconds.
spiking deconvolution, statics, residual statics, predictive deconvolution, increased stacking velocity control	Mathematical manipulations of the raw data applied during processing to make seismic cross sections more useable.

structural subbasin	A feature which is a depression that is defined by its structural shape. It can be elongate or equant or irregular.
syncline	A fold that is concave upward.
Tulare	Pleistocene age formation in the San Joaquin Valley which is composed of nonmarine deposits. The Corcoran Clay of Frink and Kues (1954) is believed to have been deposited near the middle of Tulare formation.
unconformity	A surface or erosion of nondeposition which separates younger strata from older strata.
vibroseis	Energy source which involves one or more truck mounted vibrating pads which act in concert to impart energy of desired frequency and strength into the earth.

APPENDIX A

Data Base of wells available for Kern County Water Agency Regional Structure Study
Note: Log depth listed is either, total depth from the log header, or greatest depth of the log copy on file.

Township 10N

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
RICHFIELD OIL CORP	TEJON	TEJON# 61-6	6	A	10N	19W	2729
BRITISH AMERICAN OIL CO.	TEJON	#81-6	6	Z	10N	19W	2751
CALIFORNIA DEPT OF WATER	GRAPEVINE CREEK	#A1	8	A1	10N	19W	1775
B.K.S. OIL COMPANY	TEJON RANCH	PILGRIM #11A-12	12	Z	10N	19W	2796
N.H.K. OIL COMPANY	S.E. TEJON	TEJON# 84-14	14	H	10N	19W	3875
CALIFORNIA DEPT OF WATER	WHEELER RIDGE AREA	#H1	1	H1	10N	20W	1770

Number of wells in this Township 6

Township 11N

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
EWAN OIL COMPANY	TEJON HILLS	COREHOLE #.3	2		11N	18W	591
FRED A MILLER	TEJON HILLS	MILLER#2	2	Z	11N	18W	574
JOHN C. JOHNSTON FARMS	SOUTH ARVIN		6	Z	11N	18W	1200
JERGINS OIL COMPANY	TEJON HILLS	TEJON # 1	10	Z	11N	18W	1255
RAINBOW OIL CO.	TEJON HILLS	RAINBOW #5	11	Z	11N	18W	615
RAINBOW OIL CO.	TEJON HILLS	RAINBOW #15	11	Z	11N	18W	637
TEJON RANCH CO.	TEJON RANCH	TEST HOLE# D	12	L1	11N	18W	751
TEJON RANCH CO.	TEJON RANCH	TEST HOLE-A	14	N1	11N	18W	1175
SUNSET OIL CO.	TEJON HILLS	WATER WELL #1	14	Z	11N	18W	1313
STEELE PETROLEUM CO.	TEJON HILLS	TEJON# 1	14	Z	11N	18W	1080
STEELE PETROLEUM	TEJON HILLS	ROCO# 54	15	Z	11N	18W	508
VAN GLAHN OIL CO., INC.	COMANCHE PT.	TEJON # 1	18	Z	11N	18W	1485
	TEJON HILLS	#46	19	Z	11N	18W	457
D.K. PARTNERSHIP	TEJON HILLS	#67-20	20	Z	11N	18W	3791
O.M. SLOSSON OIL COMPANY	TEJON HILLS	#37	21	G	11N	18W	2554
TEJON RANCH CO.	TEJON RANCH	TEST HOLE C	22	Z	11N	18W	1035
TEJON RANCH CO.	TEJON RANCH	TEST HOLE "E"	28	G1	11N	18W	911
D.K. PARTNERSHIP NO.2	TEJON HILLS	CORRAL# 273-29	29	Z	11N	18W	2000

Data Base of wells available for Kern County Water Agency Regional Structure Study

D.K. PARTNERSHIP-2	SPRINGS FAULT	D.K. PARTNERSHIP-2	29	Z	11N	18W	1680
PURCELL FARMS	METTLER	#1	7		11N	19W	1310
U.S. BUREAU OF	TEJON	11-19-7E	7	R	11N	19W	1100
RESERVE OIL AND GAS CO.	TEJON FLATS	BUTLER 44-17	17	E	11N	19W	8550
FRED KRAFT	WHEELER RIDGE	W.W. #1	20	H1	11N	19W	940
RESERVE OIL & GAS CO.	TEJON	21A	21	Z	11N	19W	3400
RESERVE OIL AND GAS	TEJON RESERVE	BUCHHOLZ WATER WELL	23	H1	11N	19W	942
			23	Z	11N	19W	1000
MOORS, PERMEATER &	E WHEELER RIDGE	WATER WELL #1	24	H1	11N	19W	926
RESERVE OIL AND GAS CO.	TEJON RANCH	TEJON POTATO CO. (WATER	25	D	11N	19W	984
MOODY & JONES	TEJON	WATER WELL TEJON NO. 1	25	F1	11N	19W	966
RESERVE OIL & GAS CO.	TEJON RESERVE	BOLLER & NEUFELD WATER	26	F1	11N	19W	1007
ROY SANDERS	TEJON	WATER WELL	26	R1	11N	19W	990
RESERVE OIL & GAS CO.	TEJON	KOUCKY WATER WELL	28	G1	11N	19W	1094
RESERVE OIL AND GAS CO.	TEJON	HIGHLAND FARMS INC	28	K1	11N	19W	1084
BAUMEL AND KURTZ	TEJON	WATER WELL #1	29	G1	11N	19W	930
STOLLER BROTHERS	WHEELER RIDGE	TEJON LEASE #3	29	Z	11N	19W	1324
RICHFIELD OIL CORP	TEJON	TEJON 11-19-31	31	R	11N	19W	2705
PETROL CORP.	TEJON	RES. PETROL 32-2	32	Z	11N	19W	6022
RESERVE OIL & GAS	TEJON	TEJON 33-14	33	Z	11N	19W	2685
RIDGE HILL OIL CO	TEJON	34-4	34	Z	11N	19W	2693
ENTERPRISE OIL COMPANY	TEJON HILLS	R.E. 57-34	34	Z	11N	19W	4631
RESERVE OIL AND GAS	TEJON RANCH	#45-34	34	Z	11N	19W	2838
KERN CO. LAND COMPANY	WHEELER RIDGE	K.C.L. 10-G-5-3	5	J	11N	20W	2020
RENALD M. METTLER	WHEELER RIDGE	W. W. #10	10	C2	11N	20W	2129
KERN COUNTY LAND CO.	WHEELER RIDGE	10 G-13-3	13	M1	11N	20W	1301
DEPT OF WATER RESOURCES		G. W. OBSERV WELL	15	D1	11N	20W	242
ARCO OIL & GAS CO.	TEJON	KCL SWS 86-24	24	Z	11N	20W	5400
KERN ROCK	WHEELER RIDGE	W.W. C-83	25	K1	11N	20W	1202
RICHFIELD OIL CORP.	WHEELER RIDGE	W. W. #1	34	J	11N	20W	1202
EASTON AND SHUMAN	SAN EMIGDIO	WATER WELL# 2	2	G1	11N	21W	1200
U.S. GEOLOGICAL SURVEY	SAN EMIGDIO AREA	LAKEVIEW TEST #1	3	B1	11N	21W	1500
		KCL 87-3	3	R	11N	21W	3570

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SAM ANDREWS & SONS	LAKEVIEW	ANDREWS RANCH	3	Z	11N	21W	1823
STATE OF CALIFORNIA D.W.R.	OLD RIVER	SITE NO. 16	4	P2	11N	21W	642
W.P. ROMERO	SAN EMIGDIO	KCL W. W. #1	6	K1	11N	21W	1190
SWEET BROS. DRILLING CO	SAN EMIGDIO AREA	K.C.L -#1 10 F7-2	7	D1	11N	21W	2215
RICHFIELD OIL CORPORATION	SAN EMIGDIO	K.C.L.-H-81-8	8	A	11N	21W	1200
KERN COUNTY LAND CO	SAN EMIGDIO AREA	KCL 10F8-3	8	H1	11N	21W	2408
KERN COUNTY LAND CO.	SAN EMIGDIO NOSE	10 F 9-1	9	F	11N	21W	2200
REYNOLD METTLER	SAN EMIGDIO	WATER WELL	11	G1	11N	21W	2000
KERN COUNTY LAND CO.	SAN EMIGDIO NOSE	10F 11-	11	NP	11N	21W	2509
RICHFIELD OIL CORPORATION	PLEITO HILLS	SAN EMIDIO D-3	32	Q	11N	21W	6397
HUMBLE OIL AND REFINING	PLEITO CREEK	KCL B-1	35	Z	11N	21W	4342
HUMBLE OIL AND REFINING	PLEITO CREEK	KCL B-13	36	Z	11N	21W	4505
ROBERT PELLETIER	SAN EMIGDIO	WATER WELL #20	1	F1	11N	22W	2570
ROBERT PELLETIER	SAN EMIGDIO	W.W. #16	1	L2	11N	22W	1250
ROBERT PELLETIER	SAN EMIGDIO	WATER WELL #3	1	Z	11N	22W	1007
TENNECO OIL CO	YOWLUMNE LEASE	WW #45-4B	4	Z	11N	22W	2005
THE OHIO OIL CO.	EAST MARICOPA	KCL-O #15-5	5	M	11N	22W	10533
CONTINENTAL OIL CO.	SAN EMIGDIO	SANTIAGO #1	8	E	11N	22W	2600
TENNECO OIL CO.	YOWLUMNE LEASE	W.W. 83-17	9	A	11N	22W	1665
TENNECO	"YOWLUMNE"	88-10	10	R	11N	22W	12100
RICHFIELD OIL CORP.	KCL "M"	#21-16	16	D	11N	22W	11715
RICHFIELD OIL CORPORATION	LOS LOBOS	SAN EMIDIO A 25-19	19	M1	11N	22W	6780
TENNECO WEST		ARCO #48	21	P	11N	22W	8500
CONTINENTAL OIL CO	SAN EMIGDO	KCL M-1	27	G	11N	22W	8341
RICHFIELD OIL CORPORATION	LOS LOBOS -SAN EMIGDIO	A-25-28	28	M	11N	22W	3311
STANDARD OIL CO OF	PIONEER	KCL 44-32	32	C	11N	22W	4760
STANDAR OIL CO OF	PIONEER	KCL 44-12	32 ?	D	11N	22W	750
STANDARD OIL CO. OF CAL.	PIONEER	KCL 44-23	32	E	11N	22W	896
STANDARD OIL COMPANY	PIONEER ANTICLINE	KCL 44-34	32	F	11N	22W	10017
STANDARD OIL CO. OF	PIONEER	KCL 44-43	32	F	11N	22W	5850
STANDARD OIL CO OF	PIONEER	KCL 44-45	32	L	11N	22W	4325
STANDARD OIL CO. OF	PIONEER	KCL 44-25	32	M	11N	22W	4330
UNION OIL CO	SUNSET	INTST. 22-A-4	4	D	11N	23W	4300

Data Base of wells available for Kern County Water Agency Regional Structure Study

TRACY DEV CORP.	MIDWAY SUNSET	INTST.#22-T	4	Z	11N	23W	3019
STANDARD OIL COMPANY OF	SUNSET	129	5	K	11N	23W	2740
STANDARD OIL COMPANY	SUNSET	125	5	K	11N	23W	2452
STANDARD OIL CO	SUNSET	131	5	K	11N	23W	3400
STANDARD OIL CO.	MIDWAY-SUNSET	9A	5	K	11N	23W	4319
STANDARD OIL CO	SUNSET	119	5	K	11N	23W	2112
UNION OIL CO.	MIDWAY	SLOAN FLACK	7	A	11N	23W	2396
UNION OIL CO.	SUNSET	SLOAN FLACK #3	7	H	11N	23W	2580
COAST EXPLORATION CO.	MARICOPA	BRONCO # 1	8	Z	11N	23W	2572
RICHFIELD OIL CORPORATION	SANTIAGO	LEUTHOLTZ A-20	22	Z	11N	23W	3330
BANKLINE OIL COMPANY	MARICOPA	57-23	23	Q	11N	23W	1104
BANKLINE OIL COMPANY	MARICOPA	24-24	24	E	11N	23W	4325

Number of wells in this Township 96

Township 12N

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
LEE AULT & ASSOCIATES	COMANCHE POINT	AULT # 2	29	Z	12N	18W	873
MCFARLAND ENERGY	COMANCHE POINT	"BROWN" 4	32	Z	12N	18W	1565
SIERRA OIL CO.	COMANCHE POINT	SIERRA # 1	25	Z	12N	19W	1594
R.A. HILDEBRAND	HILDEBRAND RANCH	#4	29	J1	12N	19W	1010
WILLIAM MOORE	TEJON	MOORE #1	34	H	12N	19W	1204
JOE FANUCCHI & SONS	ADOBE & DAVID RDS		25	Q	12N	20W	1041
WESTERN GULF OIL CO.	SAND HILLS	S.P. #1	25	Z	12N	20W	3500
PUREGRO	BAKERSFIELD	#1	28	Z	12N	20W	1050
PARKS BROS. & GARLOW	LAKEVIEW AREA	STANDARD #2	29	R1	12N	20W	1408
			30	N1	12N	20W	1195
R.L. SANDERS	SAN EMIGDIO	WATER WELL #2	27	N2	12N	21W	1440
TENNECO-CHEVRON		TENNECO #77X	28	R	12N	21W	14775
STANDARD OIL CO OF	LAKEVIEW AREA	W.W. #10	31	F1	12N	21W	1400
PARKS BROTHERS	LAKEVIEW	W.W. #10	31	P2	12N	21W	2504
PARKS BROTHERS	LAKEVIEW	WATER WELL #1	33	P1	12N	21W	1516
ART SANDERS	SAN EMIGDIO	WATER WELL #2	35	P1	12N	21W	1493
STANDARD OIL CO.	SAN EMIGDIO	FRICK # 4	25	Z	12N	22W	1407

Data Base of wells available for Kern County Water Agency Regional Structure Study

DEPT OF WATER RESOURCES		G. W. OBSERV. WELL	32	D1	12N	22W	242
PACIFIC COAST DRILLING CO.	SAN EMIGDIO	WATER WELL#11	33	R	12N	22W	985
ROBERT PELLETIER	PELLETIER RANCH	TEST HOLE #1	34	K	12N	22W	800
ROBERT PELLETIER	PELLETIER RANCH	WATER WELL	34	M1	12N	22W	1266
	SAN EMIGDIO	WHARTON #2	35	R1	12N	22W	1736
DEPT OF WATER RESOURCES		G. W. OBSERV. WELL	26	N3	12N	23W	242
	MARICOPA	2A SEC 31-E	31	E	12N	23W	785
	GARDNER FIELD		33	H1	12N	23W	1000

Number of wells in this Township 25

Township 25S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
WHEELABRATOR	DELANO	#1	25	L	25S	25E	775
CALIFORNIA VINEYARD	DELANO	#22-A-2	4	A2	25S	26E	1450
PINKHAM PROPERTIES, INC.	DELANO	WATER WELL #4	4	F	25S	26E	1346
M. CARATAN	DELANO	WATER WELL #6	8	C1	25S	26E	1304
PACIFIC OIL AND GAS CO.	JASMINE	SALCO-BOONE # 44	1	Z	25S	27E	2100
A.K. DAWSON	RICHGROVE AREA	#1	3	G	25S	27E	1950
HILTON DRLG. CO.	RICHGROVE-BENNETT	#4 W.W. #2	4	C1	25S	27E	1903
JEFFERY HERRICK	RICHGROVE	WELL #1	4	P	25S	27E	632
			4	Q	25S	27E	
HYLTON DRLG.	RICHGROVE	BENNETT RANCH # 4 ,	4	Z	25S	27E	1905
			5	A	25S	27E	1830
B.M. NEILSEN FARMS	RICHGROVE AREA	WATER WELL	6	A1	25S	27E	1202
H.M. HOLLOWAY, JR.	JASMINE	HOLLOWAY # 2	8	H1	25S	27E	2003
H.M. HOLLOWAY RANCH	RICHGROVE AREA	#4	8	P	25S	27E	2198
WHITTEN BROTHERS	RICHGROVE	H.M. ROLLOWAY # 3	8	R1	25S	27E	2140
TIDEWATER ASSOCIATED OIL	RICHGROVE	QUINN #46	8	Z	25S	27E	3786
			10	F	25S	27E	1750
HARP & BROWN	JASMINE AREA	QUINN # 1	11	A	25S	27E	2347
PACIFIC OIL & GAS DEV.	JASMINE	QUINN # 1	13	D	25S	27E	2170
AMERADA	RICHGROVE	JASMINE F	13	D	25S	27E	1906
PACIFIC OIL & GAS CO.	JASMINE	QUINN # 3	14	Z	25S	27E	2266

Data Base of wells available for Kern County Water Agency Regional Structure Study

PACIFIC OIL AND GAS	JASMINE	QUINN # 2	14	Z	25S	27E	2286
L.C. GOULD OPERATOR	JASMINE	RICHARDSON # 16-1	16	Z	25S	27E	2300
RUBY OIL CO.	QUINN AREA	QUINN # 17	17	P	25S	27E	2500
			18	A	25S	27E	2320
WHITTEN PUMPS INC.	JASMINE	GRIGGS & HARDEN #2	18	Z	25S	27E	2104
PACIFIC OIL & GAS	JASMINE	CANTLEBERRY # 74	22	Z	25S	27E	2320
PACIFIC OIL & GAS DEV.	JASMINE	JOL # 1-23	23	Z	25S	27E	2200
ROTHSCHILD OIL CO.	JASMINE AREA	McDEVITT # 1	24	N	25S	27E	2060
S.A. CAMP PUMP CO.	RAFTER "F" RANCH	WATER WELL	28	Z	25S	27E	2039
WARREN CARTER FARMS	JASMINE		31	Z	25S	27E	
HANCOCK OIL CO.	JASMINE	MARQUIS # 1	31	Z	25S	27E	4500
BRITISH AMERICAN OIL PROD.	JASMINE	DAVIS # 36	32	Z	25S	27E	3180
BANDINI PET. CO.	JASMINE AREA	JASMIN # 1	35	B	25S	27E	2010
COUNTY OF KERN	KERN VALLEY LAND FIELD	TEST WELL # 2	35	Z	25S	33E	153

Number of wells in this Township 35

Township 26S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
RICHARD S. RHEEM	RAVENS PASS	AMBROSE # 1	25	Z	26S	17E	1453
YELLOWSTONE OIL CO.	DEVIL'S DEN	STILL MABURY 0-12-1	1	J	26S	18E	457
			9	E1	26S	18E	
WOODWARD & REYNOLDS	BLACKWELLS CORNER	MABURY # 4	25	N	26S	18E	1400
HANCOCK OIL CO.	SHALE POINT	MABURY # 1	36	Z	26S	18E	1376
HAMILTON & SHERMAN	BLACKWELLS CORNER	BEER AREA B # 6	7	B	26S	19E	815
BRITISH AMERICAN	BLACKWELLS CORNER	BEER B # 58	8	Z	26S	19E	3175
HAMILTON & SHERMAN	BLACKWELLS CORNER	BEER B # 2	17	Z	26S	19E	1043
SEABOARD OIL CO.	DEVIL'S DEN AREA	BEER # 66	17	Z	26A	19E	8821
HAMILTON & SHERMAN	BLACKWELLS CORNER	BEER # 7	19	Z	26S	19E	1218
BRITISH AMERICAN OIL CO.	BLACKWELLS CORNER	BEER B # 85	21	Z	26S	19E	3542
PATRICK A. DOHENY	BLACKWELLS CORNER	CROSBY-BEER # 1	21	Z	26S	19E	5881
BRITISH AMERICAN OIL CO.	BLACKWELLS CORNER	BEER # 11	22	Z	26S	19E	8351
BERRENDA MESA WATER	NA	TEST WELL	28	A	26S	19E	1332
ARCHIE MYERS	BLACKWELLS CORNER	WATER RESOURCES	36	Q	26S	19E	655

Data Base of wells available for Kern County Water Agency Regional Structure Study

TIDE WATER OIL CO.	LOST HILLS	?-#2	2	L1	26S	20E	300
MARYLYN COMPANY	LOST HILLS	WEST COAST #5-L	2	L2	26S	20E	1686
ENERGY DEV. OF CA INC.	LOST HILLS	WEST COAST 5M3	2	L4	26S	20E	1372
ENERGY DEV. OF CA INC.	LOST HILLS	WEST COAST #1-3	2	L5	26S	20E	1629
TEXACO INC.	LOST HILLS	"THETA NCT-1" #2-20	2	M1	26S	20E	1423
TEXACO INC.	LOST HILLS	"THETA NCT-1" #2-27	2	M2	26S	20E	1129
TEXACO INC.	LOST HILLS	"THETA NCT-1" #2-23	2	M2	26S	20E	1255
MARYLYN CO.	LOST HILLS	"THETA NCT-1" #2-33	2	M4	26S	20E	1122
CHEVRON U.S.A. INC.	LOST HILLS	UNITED#1	2	N2	26S	20E	810
STANDARD OIL CO.	LOST HILLS	UNITED #6	2	N3	26S	20E	1166
CHEVRON U.S.A. INC.	LOST HILLS	UNITED #?	2	P1	26S	20E	1293
CHEVRON U.S.A. INC.	LOST HILLS	UNITED #1-50	2	P2	26S	20E	1570
CHEVRON U.S.A. INC.	LOST HILLS	UNITED # 2	2	P3	26S	20E	1585
CHEVRON U.S.A. INC.	LOST HILLS	UNITED #3	2	P4	26S	20E	1401
CHEVRON USA INC.	LOST HILLS	UNITED # 7	2	P5	26S	20E	1296
	LOST HILLS	UNITED #6	2	Q1	26S	20E	1582
ENERGY DEV. OF CA INC.	LOST HILLS	WILLIAMSON #4	2	Q3	26S	20E	1016
PETRO LEWIS CORP.	LOST HILLS	WILLIAMSON #1	2	Q4	26S	20E	697
	LOST HILLS	WILLIAMSON #10-R	2	Q8	26S	20E	1440
	LOST HILLS	WILLIAMSON #11	2	Q9	26S	20E	1500
RANDAN PETROLEUM CORP.	LOST HILLS	THETA #3	3	H	26S	20E	1731
TEXAS CORP.	LOST HILLS	THETA #3 11-9	11	A	26S	20E	2048
TEXAS CORP.	LOST HILLS	THETA #8 1113	11	A	26S	20E	1149
ENERGY DEV. OF CA INC.	LOST HILLS	B-11	11	B	26S	20E	1098
GENERAL PETRO. CO	LOST HILLS	WILLIAMSON # 33-11	11	F	26S	20E	1800
MOBILE OIL CORP.	LOST HILLS	WILLIAMSON # 3-11	11	F	26S	20E	1634
MOBILE OIL CORP.	LOST HILLS	WILLIAMSON # 1-11	11	G	26S	20E	1650
CHEVRON USA INCROP.	LOST HILLS	CHEVRON WILLIAMSON	11	G	26S	20E	1430
CHEVRON U.S.A.	LOST HILLS	UNITED #4	11	H	26S	20E	1293
MARYLN CO.	LOST HILLS	THETA # 11-20	11	J	26S	20E	1717
ARCO OIL & GAS CO.	LOST HILLS	LOST HILLS FEE "E" # 301	11	L	26S	20E	2200
RICHFIELD OIL CORP.	LOST HILLS	FEE "E" # 1	11	L	26S	20E	2600
THE TEXAS CO.	LOST HILLS	THETA # 12-16	12	E	26S	20E	2000

Data Base of wells available for Kern County Water Agency Regional Structure Study

MARLYN AO.	LOST HILLS	THETA NCT 3-12-5	12	E	26S	20E	2435
MOBILE OIL CO.	LOST HILLS	WILLIAMSON # 1-12	12	F	26S	20E	1550
ATLANTIC CO.	LOST HILLS	FEE D-2	12	M	26S	20E	1920
CHEVRON U.S.A. INC.	LOST HILLS	UNITED #23	12	P	26S	20E	1899
STANDARD OIL CO.	LOST HILLS	UNITED 2-29	12	P	26S	20E	2495
SUPERIOR OIL CO.	LOST HILLS	TOL #3	12	Q	26S	20E	1450
MOBIL OIL CORP.	LOST HILLS	THETA #34	13	A	26S	20E	1550
MOBILE OIL CO.	LOST HILLS	THETA THREE # 17	13	B	26S	20E	1500
MOBIL OIL CORP.	LOST HILLS	LOST HILLS THREE #5	13	C	26S	20E	2500
MOBIL OIL CORP.	LOST HILLS	LOST HILLS THREE #3	13	D	26S	20E	1598
ARCO	LOST HILLS	LOST HILLS C-21	13	E	26S	20E	655
GETTY OIL CO	LOST HILLS	# 14A	13	E	26S	20E	947
GETTY OIL CO.	LOST HILLS	# 2-5	13	G	26S	20E	536
GETTY OIL CO.	LOST HILLS	GETT-1 # 502	13	G	26S	20E	508
GETTY OIL CO.	LOST HILLS	# 307	13	H	26S	20E	402
TEXACO PRODUCING INC.	LOST HILLS	# 525	13	J	26S	20E	586
GETTY OIL CO.	LOST HILLS	# 506	13	K	26S	20E	458
GETTY OIL CO.	LOST HILLS	# 108	13	L	26S	20E	689
FERGUSEN AND BOSWORTH	LOST HILLS	FEE # 1	14	J	26S	20E	1900
MOBILE OIL CO.	LOST HILLS	#170	19	E	26S	20E	1324
GENERAL PETROLEUM	LOST HILLS	LOST HILLS TWO # 40	19	K	26S	20E	1950
M.M. WHITTIER	LOST HILLS	STAR # 102	24	A	26S	20E	1250
M.M. WHITTIER	LOST HILLS	STAR # 105?	24	A	26S	20E	1300
M.M. WHITTIER	LOST HILLS	STAR # 114	24	H	26S	20E	1433
M.M. WHITTIER	LOST HILLS	STAR # 112	24	H	26S	20E	1324
CA LANDS INC.	LOST HILLS	C.L.C. # 1	24	L	26S	20E	1400
	LOST HILLS		24	L	26S	20E	1600
			24	M	26S	20E	1330
MOBILE OIL CORP.	LOST HILLS	BLACKWELL # 1	25	B	26S	20E	5075
WM. M. THORNBURY	KERN COUNTY	SUPERIOR-OCCIDENTAL # 1	27	R	26S	20E	1650
GETTY OIL CO.	BEER NOSE AREA	5 & 6 #1	30	N	26S	20E	1640
GETTY OIL CO.			31	D	26S	20E	1380
GULF OIL CORP.	BLACKWELLS CORNER	TENBY OLC # 1	31	K	26S	20E	11100

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WEST FARMERS	LOST HILLS	#3	5	K	26S	21E	1794
TEJON HILLS OIL CO.	LOST HILLS	#1	12	C	26S	21E	3592
ARTHUR C. FISHER			14	G	26S	21E	3000
JOHN J. FRANTZ	LOST HILLS	WATER WELL # 1	14	Z	26S	21E	316
		26S/21E-17D	17	D	26S	21E	237
SUPERIOR OIL CO.	LOST HILLS	LOST HILLS # 3	18	E	26S	21E	1500
MOBILE OIL CO.	LOST HILLS	LOST HILLS TWO # 126	19	C	26S	21E	1450
MOBILE OIL CORP.	LOST HILLS	LOST HILLS TWO # 125	19	D	26S	21E	1669
MOTOR OIL CO.	LOST HILLS	LOST HILLS TWO # 108	19	F	26S	21E	1900
	LOST HILLS	LOST HILLS TWO # 94	19	F	26S	21E	1750
	LOST HILLS		19	G	26S	21E	1650
MOBILE OIL CO.	LOST HILLS	#1	19	G	26S	21E	1750
	LOST HILLS	LOST HILLS TWO	19	J	26S	21E	2300
GENERAL PET. CORP.	LOST HILLS	LOST HILLS TWO # 69	19	K	26S	21E	1900
GENERAL PETROLEUM CORP.	LOST HILLS	LOST HILLS TWO #67	19	L	26S	21E	1800
MOBIL OIL CO.	LOST HILLS	LOST HILLS TWO #47	19	M	26S	21E	1683
MOBILE OIL CO.	LOST HILLS	LOST HILLS TWO # 22	19	N	26S	21E	1664
MOBIL CO.	LOST HILLS	LOST HILLS TWO #21A	19	P	26S	21E	1740
MOBIL OIL CORP.	LOST HILLS	LOST HILLS TWO #182	19	Q	26S	21E	1804
GENERAL PETROLEUM CORP.	LOST HILLS	LOST HILLS TWO #34	19	R	26S	21E	1718
STANDARD OIL	LOST HILLS	GALBREATH #14	20	E	26S	21E	1800
	LOST HILLS	GALBREATH #3	20	N	26S	21E	1470
			28	N	26S	21E	700
CHEVRON USA INC.	LOST HILLS	# 4-3A	29	C-F	26S	21E	1400
CHEVRON U.S.A. INC.	LOST HILLS	#1-1	29	D	26S	21E	1400
CHEVRON U.S.A. INC.	LOST HILLS	#2-2	29	D	26S	21E	2150
	LOST HILLS		29	E	26S	21E	1930
CHEVRON U.S.A. INC.	LOST HILLS	#3-49?	29	E	26S	21E	1500
CHEVRON U.S.A. INC.	LOST HILLS		29	F	26S	21E	2080
STANDARD OIL CO.	LOST HILLS	#7-6A	29	K	26S	21E	1700
CHEVRON U.S.A. INC.	LOST HILLS	#4-7	29	L	26S	21E	1740
CHEVRON U.S.A. INC.	LOST HILLS	#4-8	29	L	26S	21E	1837
			29	M	26S	21E	1750

Data Base of wells available for Kern County Water Agency Regional Structure Study

CHEVRON U.S.A. IN	LOST HILLS	#2-8	29	M	26S	21E	1700
			29	N	26S	21E	1700
CHEVRON U.S.A. INC.	LOST HILLS	#1-?	29	N	26S	21E	1750
CHEVRON U.S.A. INC.	LOST HILLS	#3-10	29	P	26S	21E	1700
CHEVRON USA INC.	LOST HILLS	# 6-8A	29	P-Q	26S	21E	1500
CHEVRON U.S.A. INC.	LOST HILLS		29	Q	26S	21E	1900
GULF OIL CORP.	LOST HILLS	#11-3	30	A	26S	21E	1722
GULF OIL CORP.	LOST HILLS	#10-1	30	A	26S	21E	1778
GULF OIL CORP.	LOST HILLS	#7-1	30	B	26S	21E	1653
GULF OIL CO.	LOST HILLS	#8-1X	30	B	26S	21E	1620
GULF OIL CORP.	LOST HILLS		30	C	26S	21E	1600
GULF OIL CORP.	LOST HILLS	#4-2	30	C	26S	21E	1900
GLF OIL CORP.	LOST HILLS	# 5-1-30	30	C	26S	21E	1700
GULF OIL CO.	LOST HILLS		30	C-D	26S	21E	1900
GULF OIL CORP.	LOST HILLS		30	D	26S	21E	1700
CHEVRON USA INC.	LOST HILLS	# 3-5-30	30	E	26S	21E	1500
GULF OIL CORP.	LOST HILLS	#5-4?	30	F	26S	21E	1550
GULF OIL CORP.	LOST HILLS	#6-5A	30	F	26S	21E	1600
GULF OIL CORP.	LOST HILLS	#7-4	30	G	26S	21E	1400
GULF OIL CORP.	LOST HILLS	#7-6	30	G	26S	21E	1875
GULF OIL CORP.	LOST HILLS	#110-4	30	H	26S	21E	826
GULF OIL CORP.	LOST HILLS	#11-6	30	H	26S	21E	1754
GULF OIL CORP.	LOST HILLS	#11-10X	30	J	26S	21E	1865
GULF OIL CORP.	LOST HILLS	#10-7	30	J	26S	21E	1780
GULF OIL CORP.	LOST HILLS	#8-8	30	K	26S	21E	1500
GULF OIL CO.	LOST HILLS	# 5-7	30	K	26S	21E	1850
FERRELL G. NIXON	LOST HILLS	USL #1-30	30	L	26S	21E	1650
GULF OIL CORP.	LOST HILLS	# 12A	30	Q	26S	21E	1500
GULF OIL CORP.	LOST HILLS	# ?-10	30	Q	26S	21E	1800
GULF OIL CO.	LOST HILLS	# 32-12	30	R	26S	21E	1921
GULF OIL CO.	LOST HILLS	# 11-11B	30	R	26S	21E	1550
GULF OIL CORP.	LOST HILLS	# 5-1-30	30	Z	26S	21E	1707
CHEVRON USA	LOST HILLS	# 10-2C	31	A	26S	21E	1500

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GULF OIL CORP.	LOST HILLS	# 10-1	32	A	26S	21E	1400
GULF OIL CORP.	LOST HLLS	# 11-3	32	A	26S	21E	1460
GULF OIL CORP.	LOST HILLS	# 7-14	32	B	26S	21E	1850
GULF OIL CORP.	LOST HILLS		32	B	26S	21E	1840
GULF OIL CORP.	LOST HILLS	# 5-1	32	C	26S	21E	1812
GULF OIL CORP.	LOST HILLS	# 5-3	32	C	26S	21E	1800
GULF OIL CORP.	LOST HILLS	# 3-2	32	D	26S	21E	1800
GULF OIL EXPLORATION	LOST HILLS	# 2-6	32	E	26S	21E	1150
GULF OIL CO.	LOST HILLS	# 1-4	32	E	26S	21E	1080
GULF OIL CORP.	LOST HILLS	# 4-4	32	F	26S	21E	1500
GULF OIL CORP.	LOST HILLS	# 5-5	32	F	26S	21E	1890
GULF OIL CORP.	LOST HILLS	# 7-5	32	G	26S	21E	1834
GULF OIL CORP.	LOST HILLS		32	G	26S	21E	1800
GULF OIL CORP.	LOST HILLS	# 11-4	32	H	26S	21E	1550
UNIVERSAL CONS. OIL CO.	LOST HILLS	# 71-32	32	J	26S	21E	1800
GULF OIL CORP.	LOST HILLS	# 11-8	32	J	26S	21E	1895
GULF OIL CORP.	LOST HILLS		32	J	26S	21E	1860
GULF OIL CORP.	LOST HILLS		32	K	26S	21E	1830
GULF OIL CORP.	LOST HILLS		32	K	26S	21E	1940
GULF OIL CORP.	LOST HILLS	# ? 5-7	32	L	26S	21E	1460
GULF OIL CORP.	LOST HILLS		32	M	26S	21E	1720
GULF OIL CORP.	LOST HILLS		32	M	26S	21E	1560
GULF OIL CORP.	LOST HILLS	# 5-10	32	P	26S	21E	1480
GULF ENERGY & MINERAL OIL	LOST HILLS	# 6-11	32	P	26S	21E	1130
GULF OIL CORP.	LOST HILLS	# 2-1	32	Q	26S	21E	1810
GULF OIL CORP.	LOST HILLS		32	Q	26S	21E	1340
GULF OIL CORP.	LOST HILLS	# 12-11	32	R	26S	21E	1940
GULF OIL CORP.	LOST HILLS	# 11-104	32	R	26S	21E	1070
STANDARD OIL CO.	LOST HILLS	# 1-3	33	D	26S	21E	1900
CHEVRON USA INC.	LOST HILLS	# 1-5	33	E	26S	21E	2190
CHEVRON USA INC.	LOST HILLS	# 1-4	33	E	26S	21E	2350
CHEVRON USA INC.	LOST HILLS		33	L	26S	21E	1560
CHEVRON USA INC.	LOST HILLS	# 2-8	33	M	26S	21E	1650

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CHEVRON USA INC	LOST HILLS	# 1-6A	33	M	26S	21E	1500
CHEVRON USA INC.	LOST HILLS	# 2-10A	33	N	26S	21E	2325
CHEVRON USA INC.	LOST HILLS	# 1-9A	33	N	26S	21E	1550
CHEVRON USA INC.	LOST HILLS	# 4-11	33	P	26S	21E	1580
CHEVRON USA INC.	LOST HILLS	# 3-9A	33	P	26S	21E	1680
			5	P	26S	22E	500
	LOST HILLS AREA	WATER WELL # 1	5	Z	26S	22E	547
KERN GAS ASSOC.	NW SEMITROPIC	# TW-SP 1-9	9	Q	26S	22E	2500
GENERAL PERTOLEUM CORP.	N. SEMITROPIC	K.P.C. # 1	16	Z	26S	22E	6025
CHEVRON USA	SEMITROPIC	#3	25	H	26S	22E	720
D.D. AND DORTHY DUNLAP	SEMITROPIC	# 45-26	26	Z	26S	22E	8500
			27	Q2	26S	22E	
ANDERSON	WEST END ELMO HWY	#3	1	Z	26S	23E	740
POND HEIFER RANCH	WASCO SHERWOOD RANCH	#5	11	R	26S	23E	842.2
JACOBSEN FARMS INC.	WASCO		13	H	26S	23E	845
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING H-11	15	A	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING H-11	15	D	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-21	15	E	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-23	15	F,G,L	26S	23E	520
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING H-9	15	K-J	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-8	15	M	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-1	15	N	26S	23E	501
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-14	15	N	26S	23E	470
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-19	16	D	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-26	16	G-H	26S	23E	522
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-27	16	G-K	26S	23E	515
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-17	16	H	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-7	16	J	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-33	16	J-K	26S	23E	518
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-32	16	K	26S	23E	520
ALVERUS JANSSEN	WASCO	#1	18	Z	26S	23E	504
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-15	21	B	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-31	21	B,A,	26S	23E	520

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CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-22	21	B-A	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-30	21	C-B	26S	23E	520
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-20	21	D	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-29	21	G	26S	23E	518
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-28	21	G-H	26S	23E	524
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-12	22	A	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-6	22	C-B	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-2	22	C-B	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-5	22	C-D	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-3	22	D	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-25	22	F-G	26S	23E	540
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-18	22	R	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-34	27	D	26S	23E	520
		FANNIN WW # 1	27	P	26S	23E	700
			27	P1	26S	23E	700
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-13	28	D	26S	23E	500
			29	J	26S	23E	700
NATIONAL ROYALTIES	SEMITROPIC	WATER WELL # 1	29	Z	26S	23E	680
			32	F	26S	23E	
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	M.W.#H-16	21/22	21 HJ	26S	23E	500
CITY OF LOS ANGELES	SAN JOAQUIN NUCLEAR	SOIL BORING #H-4	21/22	21A	26S	23E	500
LAYNE-WESTERN	POND	# 2C10-4	10	F	26S	24E	1010
BAKERSFIELD WELL & PUMP	POND	# 2C11-5	11	F	26S	24E	993
DENNIS & MARY ALLEN	WASCO	DENNIS & MARY ALLEN	13	K	26S	24E	401
S.A. CAMP PUMP CO.	POND	# 2C 12-4	14	H	26S	24E	989
			15	F	26S	24E	1000
GRUNDT BROTHERS	WASCO	WATER WELL # 1	15	Z	26S	24E	1000
TENNECO WEST	WASCO	# 2C 27-4	27	F	26S	24E	1005
			27	R	26S	24E	
KERN COUNTY LAND	WASCO AREA	# 2C 31-4	31	F1	26S	24E	761
			31	P	26S	24E	700
KERN COUNTY LAND CO.	WASCO AREA	# 2C 31-3	31J	Z	26S	24E	731
KERN COUNTY LAND CO.	SEMITROPIC AREA	# 2C 31-2	31	Z	26S	24E	724

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	MCFARLAND	#1	2	A	26S	25E	1300
ATHA SARIS	McFARLAND	NELLA # 1	2	A	26S	25E	3776
ALINA FARMS	MCFARLAND	DOMESTIC	2	Z	26S	25E	653
ALINA FARMS	McFARLAND	DOMESTIC	2	Z	26S	25E	653
JERRY DAVIS	McFARLAND	88-05	3	R	26S	25E	820
ALINA FARMS	McFARLAND	DOMESTIC	7	Z	26S	25E	653
LARRY MUNGIA	McFARLAND	#1	8	Z	26S	25E	530
BAKERSFIELD WELL & PUMP	CITY OF MCFARLAND WEST	#6	11	B	26S	25E	1400
BAKERSFIELD WELL & PUMP	McFARLAND	McFARLAND # 6	11	B	26S	25E	1380
BAKERSFIELD	McFARLAND	CITY OF McFARLAND # 6	12	D	26S	25E	1380
BAKERSFIELD WELL & PUMP	McFARLAND	CITY OF McFARLAND # 5	12	Z	26S	25E	1376
J.B. WALDRIP	POND	WALDRIP # 2	18	PON	26S	25E	1008
NORTH KERN WATER	McFARLAND	#9	27	C	26S	25E	998
H & G OPERATING CO.		EAST SLOPE #3	30	Q	26S	25E	3515
S.A. CAMP PUMP CO.		WATERWELL	2	Z	26S	26E	1897
PETROLEUM CORP.		#1	11	E	26S	26E	2250
TESORO PETROLEUM CORP.	STRINE NOSE	# 74-11	11	H	26S	26E	3200
			11	H	26S	26E	2100
			11	Z	26S	26E	
SHELL OIL CO.	WOODY ROAD AREA	GUTH McCALES COMM. # 1	12	Z	26S	26E	5280
	MCFARLAND AREA	BORGEN #26-26	15	C	26S	26E	1600
TIDE WATER ASSOC. OIL CO.	McFARLAND AREA	#32	15	C	26S	26E	
SUPERIOR FARMING CO.	FOMOSA AREA	# 12-3D	17	Z	26S	26E	1196
SUPERIOR FARMING CO.	FAMOSA AREA	# 12-4	17	Z	26S	26E	2007
SUPERIOR FARMING CO.	FAMOSA AREA	# 12	17	Z	26S	26E	2300
ATLANTIC OIL CO.	McFARLAND	DEL FORTUNA # 1	21	P	26S	26E	6850
SUPERIOR FARMING	FAMOSA AREA	W. W. #13-3	22	E	26S	26E	2030
SUPERIOR FARMS		SUPERIOR ALMONDS	23	A	26S	26E	800
GEORGE D. BROWN		ROBERTS - COX # 1	23	Z	26S	26E	2000
SUPERIOR FARMING	FAMOSA AREA	#14-6	24	Z	26S	26E	2030
COX - FERGUSON		#1	24	Z	26S	26E	5960
MARIE FARR	FAMOSA	#2	25	L	26S	26E	990
SUPERIOR FARMING	FAMOSA AREA	WATER WELL 14-7	27	Z	26S	26E	2030

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TRICO OIL & GAS	FAMOSA	KCL # 16 M	30	M	26S	26E	3500
SUPERIOR FARMING	FAMOSA FIELD	# 14-6	34	Z	26S	26E	2028
SUPERIOR OIL CO.	FAMOSA AREA	WATER WELL # 20-2	35	F	26S	26E	2032
SUPERIOR OIL CO.	FAMOSA AREA	WATER WELL # 20-3	35	N	26S	26E	2042
			36	C	26S	26E	2200
S.A. CAMP PUMP CO.	FAMOSA AREA	WATERWELL	36	Z	26S	26E	1923
SUPERIOR FARMING CO.	FAMOSA AREA	# 24-1	36	Z	26S	26E	2338
SUPERIOR FARMING	FAMOSA AREA	# 24-2	36	Z	26S	26E	2013
H.M. HOLLOWAY	JASMINE	#2	8	H1	26S	27E	2003
MARIE FARR	FAMOSA	#1	21	P	26S	27E	456
		#5	24	B	26S	27E	
GETTY OIL		# 27-1	27	F	26S	27E	1245
MARIE FARR	FAMOSA	#1	28	E	26S	27E	456
SEMI - TROPIC	SEMITROPIC	#5	32	F	26S	27E	619
GETTY OIL CO.	NORTH POSO CREEK	WATER PROBE# 33-1	33	L	26S	27E	1003
TRICO OIL & GAS	N. MT. POSO	VILLARD # 1	17	Z	26S	28E	1778
INTEX OIL CO.	MT. POSO	GLIDE # 1	19	Z	26S	28E	1820
GLEN H. MITCHELL	MT. POSO AREA	S.P. # 2	33	Z	26S	28E	2055

Number of wells in this Township 297

Township 27S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
MACSON OIL CO.	SHALES HILLS	TWISSELMAN COMMUNITY	16	Z	27S	18E	1887
THE TEXAS CO.	SHALE HILLS	McLENNAN # 1	19	A	27S	19E	1750
BRITISH AMERICA	ANTELOPE PLAIN	US GOVT. 66-20	20	N	27S	19E	2731
INDEPENDENT EXPLORATION	WILLEAMS AREA	GRABE # 85X	20	R	27S	19E	1731
SHELL OIL CO.	ANTELOPE HILLS	CORE HOLE # 66-21	21	Q	27S	19E	3567
INDEPENDENT EXPLORATION	ANTELOPE PLAINS 27	WILLIAMSON # 1	27	Z	27S	19E	3066
JACOBSON OIL CO.	SHALE HILLS	STEWART # 1	32	Z	27S	19E	2066
ATLAS PRODUCTION	McDONALD ANTICLINE	US # 1	33	A	27S	19E	1500
		# 44	33	F	27S	19E	
ASSSOCIATED OIL CO.	NORTH BELRIDGE	#5	34	Z	27S	19E	7975
YIRSAL OIL CO.	NORTH BELRIDGE	REYNOLDS & KNUDSEN # 5	36	Z	27S	20E	660

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VIRSAL OIL CO.	NORTH BELRIDGE	REYNOLDS & KNUDSEN # 9	36	Z	27S	20E	830
CHEVRON USA INC.	LOST HILLS	"CAHN" # 7-2	4	B	27S	21E	1620
CHEVRON USA INC.	LOST HILLS	" CAHN " # I47	4	C	27S	21E	1600
	LOST HILLS	LOST HILLS ONE # 101	4	D	27S	21E	1800
MOBILE OIL CORP.	LOST HILLS	LOST HILLS ONE # 102	4	E	27S	21E	2215
CHEVRON USA INC.	LOST HILLS	" CAHN " # 136	4	F	27S	21E	1535
STANDARD OIL CO.	LOST HILLS	" CAHN " # 7-3A	4	G	Q27S	21E	1320
CHEVRON USA INC.	LOST HILLS	" CAHN" # 9-7	4	J	27S	21E	1370
CHEVRON USA INC.	LOST HILLS	"CAHN" # 7-7A	4	K	27S	21E	1540
CHEVRON USA INC.	LOST HILLS	"CAHN" # ? - 7A	4	L	27S	21E	1490
CHEVRON USA INC.	LOST HILLS	"CAHN " # I-38	4	N	27S	21E	1660
	LOST HILLS		4	P	27S	21E	1490
CHEVRON USA INC.	LOST HILLS	"CAHN" # 4-?	4	P	27S	21E	1760
CHEVRON USA INC.	LOST HILLS	"CAHN" # 7-9	4	Q	27S	21E	1640
CHEVRON USA INC.	LOST HILLS	"CAHN" # 8-10	4	Q	27S	21E	1530
CHEVRON USA INC.	LOST HILLS	"CAHN" # 10-10	4	R	27S	21E	1460
ARCO OIL & GAS CO.	LOST HILLS		5	A	27S	21E	2300
GULF OIL CO.	LOST HILLS	# 1-C-5	5	A	27S	21E	1600
GULF OIL CO.	LOST HILLS		5	B	27S	21E	1530
GULF OIL CO.	LOST HILLS	# 25-1	5	C	27S	21E	1750
GULF OIL EPL. & PROD.	LOST HILLS	# 3-6 (FEE)	5	E	27S	21E	1440
CHEVRON USA INC.	LOST HILLS	VULCAN # 11-B	5	G	27S	21E	1550
	LOST HILLS	VULCAN # 1-A	5	H	27S	21E	1680
MOBILE OIL CO.	LOST HILLS	LOST HILLS ONE # 100B	5	J	27S	21E	2490
ATLANTIC CO.	LOST HILLS	"BUCK" # 1	6	R	27S	21E	1770
GETTY OIL CO.	LOST HILLS	# A-231	8	C	27S	21E	1700
DWR SAN JOAQUIN DISTRICT		# 11C1	11	C	27S	21E	240
DWR			20	H	27S	21E	1500
			25	D	27S	21E	
DWR			25	D	27S	21E	1300
BELLRIDGE OIL CO.	NORTH BELRIDGE	# 85A-34	34	J	27S	21E	1620
TORIGIANI FARMS	LOST HILLS	#4	5	Z	27S	22E	613
	LOST HILLS	BROOKS-WALKER WW#1	7	D?	27S	22E	603

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C.A. SPICER	SEMI-TROPIC	W.W.	11	K	27S	22E	611
	SEMI-TROPIC	#2	12	K	27S	22E	535
	SEMI-TROPIC	MCLAIN #1	13	A	27S	22E	605
B.B. BALDWIN FARMS	BUTTOWILLOW		20	Z	27S	22E	382
			22	F	27S	22E	1220
NICKEL ENTERPRISES	CARMEL RANCH	#36	22	Z	27S	22E	526
DWR			23	D	27S	22E	510
TEXACO INC.	BUTTOWILLOW	MITCHEL #1	26	D	27S	22E	1500
DWR	LOST HILLS		31	N?	27S	22E	603
DWR			31	N	27S	22E	580
BLOEMHOF AG	BUTTONWILLOW	DELFINO #3	33	H	27S	22E	557.8
CARR & WRATH	BUTTOWILLOW	"PERDIDO #1	36	B	27S	22E	1650
CARR & WRATH	BUTTOWILLOW	MOBIL #1	36	R	27S	22E	1550
U.S. BUREAU OF	WASCO		1	A	27S	23E	1164
			2	Z	27S	23E	700
SEMI TROPIC SCHOOL	SEMI TROPIC	#2	4	P	27S	23E	505
CHEVRON	SEMITROPIC	#1	5	N?	27S	23E	2000
			6	G2	27S	23E	430
			6	Q	27S	23E	1190
CHEVRON	SEMITROPIC	TOWLE ESTATE # 32	7	C	27S	23E	1500
HARVESTER CO.	SEMITROPIC	TOWLE ESTATE # 3-7	7	C	27S	23E	1400
	SEMITROPIC	TOWLE TRUST # 01	7	J	27S	23E	1700
FALCON PETROLEUM CO.	SEMITROPIC	HILL # 55	8	K	27S	23E	1800
			8	P1	27S	23E	540
HUMBLE OIL	SEMITROPIC		9	J	27S	23E	1500
FALCON PETROLEUM CO.	SEMITROPIC		9	N	27S	23E	1800
T & T OIL CO.	SEMITROPIC	CONN # 1	9	R	27S	23E	1850
ARGOSY OIL CO.	SEMITROPIC	S.A.M. UNIT # 1	10	C	27S	23E	1750
			14	Q	27S	23E	1500
	SEMITROPIC		15	Q	27S	23E	1500
	SEMITROPIC		16	H	27S	23E	1600
			17	F	27S	23E	540
			17	H1	27S	23E	780

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			18	H2	27S	23E	620
			18	L	27S	23E	1000
			18	L3	27S	23E	1000
VISTA PETROLEUM CO.	SEMITROPIC	GOVT. # 3 ?	22	A	27S	23E	1700
	SEMITROPIC		22	G	27S	23E	
VISTA PETRO. CO.	SEMITROPIC	BRADFORD # 24	23	A	27S	23E	2000
VISTA PETRO. CO.	SEMITROPIC	BRADFORD #66 ?	23	K	27S	23E	1650
MITCHELL CO.	SEMITROPIC	MITCHELL- BRADFORD # 24-	23	N	27S	23E	1850
MITCHELL CO.	SEMITROPIC	MITCHELL - BRADFORD #	23	P	27S	23E	1650
BOOKLAND FARMS	SEMITROPIC	# 18	23	Z	27S	23E	785
	SEMITROPIC	WILLIAMS # 1	24	R	27S	23E	1800
McCULLOCH OIL CORP. OF CA	SEMITROPIC	# 1 W	25	A	27S	23E	1850
STANDARD OIL CO.	SEMITROPIC	FULERTON # 2	25	C	27S	23E	2000
	SEMITROPIC		25	D	27S	23E	1380
			25	E	27S	23E	1200
NEUFELD	SHAFTER	#4	25	P1	27S	23E	480
			26	F1	27S	23E	400
RICHARD S. PRATHER CO.	SEMITROPIC	GULF # 1	26	L	27S	23E	1950
ROBERT NUEMAN & SONS	SEMITROPIC	WATERWELL # 1	27	J1	27S	23E	502
RUSS BARLING	SEMITROPIC	#2	27	Z	27S	23E	927
			34	A1	27S	23E	740
U.S. BUREAU OF	WASCO QUAD	# 1G	1	G	27S	24E	1125
	DUCOR	JOSEPHSEN & CARATANN	3	M	27S	24E	1219
CITY OF WASCO PUBLIC	WASCO	WASCO GOLF COURSE	4	Z	27S	24E	829
KCL	SEMITROPIC AREA	# 3C 6-4	6	P1	27S	24E	730
CONTINENTAL OIL CO.	WASCO	MEYER # 1	7	L	27S	24E	2830
	WASCO	" KCL LEASE # 40 " 32-17	17	C	27S	24E	1960
STANDARD OIL CO. OF CA	WASCO	KCL # 41- ?	18	C	27S	24E	2130
BEAR CREEK PROD.	BEAR CREEK	# 89-20	23	L	27S	24E	625
KCL	SEMITROPIC	# 2 C	27	Z	27S	24E	707
KERN COUNTY LAND CO.	SEMITROPIC	# 2C 27-2	27	Z	27S	24E	700
PATRICK A. DONERY	SOUTH WASCO	UNIT # 28-1	28	A	27S	24E	1730
SUPERIOR OIL CO.	WASCO	C.F. #75 WATER WELL	29	C1	27S	24E	800

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McCULLOCH OIL EXP. CO. OF	SEMITROPIC	McCULLOCH ARROWHEAD #	30	A	27S	24E	1880
CARR & WRATH		MITCHELL # F3-32	32	L	27S	24E	2000
MILLER & YORK		SUPERIOR - CALDWELL # F-3	33	N	27S	24E	2000
GEOCHEMICAL SURVEYS INC.		KCL - # 23-35	35	E	27S	24E	1750
MOBIL PAN PETROLEUM	SHAFTER AREA	KCL 86-35	35	J	27S	24E	2020
U.S. BUREAU OF	FAMOSO AREA	27-25-1	1	A	27S	25E	1460
N. KERN WATER STORAGE	WASCO	#3D1-4	1	Z	27S	25E	1040
SUPERIOR FARMING CO.		73-8R	5	R	27S	25E	910
MOBIL PAN AMERICAN	WASCO	KCL #31-15	15	C	27S	25E	13373
S.A. CAMP PUMP CO	WASCO	NKWSD#3D 15-5	15	C	27S	25E	996
	WASCO	BEAR CREEK NURSERY	17	H	27S	25E	1005
S.A. CAMP	SUN WORLD WASCO	SUN WORLD INC.	17	L	27S	25E	1028
PETERS FARMS	WASCO	#1 MAPLE LEAF	19	C	27S	25E	805
SUPERIOR FARMING CO.	SHAFTER	#88-8R	22	J	27S	25E	1040
JACKSON & PERKIN CO.	WASCO		30	D	27S	25E	1020
SUPERIOR FARMING	SHAFTER	70-2R	32	A	27S	25E	1031
McCARTHY OIL & GAS CORP.		BERGMAN TRUST #1	2	Z	27S	26E	1560
STEELE PETROLEUM CO.	FAMOSO AREA	#4-1	4	R	27S	26E	7488
SUPERIOR FARMING CO.	FAMOSA	#09A-6	9	P	27S	26E	1335
RILEY BARNES		"BARNES-HARNER" #1	13	P	27S	26E	4066
SUPERIOR FARMING CO.	FAMOSA	#25-3	14	F	27S	26E	2050
SUPERIOR FARMING CO.	FAMOSA AREA	WATER WELL 25-4	14	P	27S	26E	2040
SUPERIOR FARMING CO.	FAMOSA AREA	RANCH 25-4	14	R	27S	26E	1768
TESORO PETROLEUM CORP.	PREMIER AREA	15A	15	A	27S	26E	6930
TEXACO INC.		? #1	16	A	27S	26E	1540
SUPERIOR FARMING CO.	FAMOSA AREA	#27-5	17	Z	27S	26E	2030
N. KERN WATER STORAGE	PAMONA	#3E18-7	18	C	27S	26E	995
N. KERN WATER STORAGE	FOMOSA	#3E18-6	18	N	27S	26E	990
MORTON & SONS		BENDER WEST #1	20	N	27S	26E	1650
			20	N	27S	26E	6001600
LANE FARMS	FAMOSO	WATER WELL #1	21	A	27S	26E	1159
STANDARD OIL COMPANY	SLATER AREA	CWOD #87	22	R	27S	26E	1820
GARNER-LANCE OIL CO.	(WEST POSO CREEK)	NEWHOUSE #1	24	E	27S	26E	1640

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McCOLLUCH OIL & GAS CORP.	POSO CREEK WEST	"McCULLOCH #105 ?	26	C-B	27S	26E	1680
		"MOBIL FLORIDA #1-23"	27	R	27S	26E	1580
JOHN & IKA PETERS FARMS	KIMBERLINA	TEST HOLE #1	28	Z	27S	26E	1015
JOHN & IKE PETERS FARMS	KIMBERLINA AREA	TEST HOLE #1	28	Z	27S	26E	970
SECURITY PACIFIC BANK	FAMOSA	#1	29	C	27S	26E	817
SUPERIOR FARMING CO.	WASCO	#61-9R	30	C	27S	26E	920
SECURITY PACIFIC NAT. BANK	FAMOSO-CAWELO		30	H	27S	26E	875
N. KERN WATER STORAGE		#3E31-5 (?9A)	31	R	27S	26E	1020
SUPERIOR FARMING CO.	FAMOSA AREA	WATER WELL #51-3	34		27S	26E	2000
SHEPARD & ROBERTSON	POSO CREEK	CARTER #1	7	Z	27S	27E	3050
GETTY OIL CO.	NORTH POSO CREEK	WATER PROBE #9-1	9	K	27S	27E	1400
TIDEWATER OIL CO.	MT. POSO	WATER PROBE 11-1	11	G	27S	27E	1100
GETTY OIL CO.	NORTH POSO CREEK	WATER PROBE 15-1	15	E	27S	27E	1250
	POSO CREEK	SALLY #1	20	Z	27S	27E	1948
GETTY OIL CO.	NORTH POSO CREEK	WATER PROBE #21-1	21	L	27S	27E	1400
CHEVRON U.S.A.	POSO CREEK	2-4	25	D	27S	27E	1500
GOLDEN BEAR OIL CO.	NORTH POSO CREEK AREA	AGEY #3	28	C	27S	27E	2046

Number of wells in this Township 160

Township 28S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
LAYMAC CORPORATION	MC DONALD ANTICLINE	SAN JAUQUIN #11	12	Q	28S	19E	2000
GOLDEN BEAR OIL COMPANY	ANTELOPE HILLS	VOIGT # 1	5	Z	28S	20E	3359
PALOMAR OIL AND REFINING	ANTELOPE HILLS	VOIGHT # 2	6	B	28S	20E	2540
BELRIDGE OIL COMPANY	SOUTH BELRIDGE	# 46	7	F	28S	20E	1175
BELRIDGE OIL CO.	SOUTH BELRIDGE	# 57	12	Z	28S	20E	1555
GENERAL PETROLEUM	BELRIDGE	ST. HELENS # 1	12	Z	28S	20E	
FERGUSON AND BOSWORTH	McDONALD ANT.	LAYMAN # 16	18	Z	28S	20E	2190
WILRICH DEVELOPMENT	BACON HILLS	THETA # 1	20	Z	28S	20E	1540
SEABOARD OIL CO.	BACON HILLS	BANDINI 58-21	21	Z	28S	20E	8754
MITCHELL REALITY	BACON HILLS	G.H. MITCHELL 77-22	22	Z	28S	20E	878
BELRIDGE OIL CO.	N. BELRIDGE	BELRIDGE # 24-1	1	E	28S	21E	1603
BELRIDGE OIL CO.	N. BELRIDGE	# 45-2	2	Z	28S	21E	2000

Data Base of wells available for Kern County Water Agency Regional Structure Study

BELRIDGE OIL CO.	S. BELRIDGE	# 71 N 9	9	Z	28S	21E	2500
BELRIDGE OIL CO.	S. BELRIDGE	# 15 M 9	9	Z	28S	21E	2503
			11	Z	28S	21E	
SHELL CA PROD. INC.	LOST HILLS	# 12P	12	P1	28S	21E	250
SCPI PROD.	BELRIDGE	MONITOR E-SHALLOW-2	13	E	28S	21E	260
SCPI PROD.	BELRIDGE	E-SHALLOW-2	13	E	28S	21E	260
SHELL CA PROD.	BELRIDGE	# 13F-SHALLOW	13	F1	28S	21E	175
SHELL CA PROD. INC.	BELRIDGE	# 13F-DEEP	13	P2	28S	21E	265
SHELL CA PROD. INC.	BELRIDGE	# 13H	13	H1	28S	21E	235
SCPI	BELRIDGE	BELRIDGE MONITOR E	13	Z	28S	21E	500
SHELL CA PROD. INC.	BELRIDGE	# 14D	14	D1	28S	21E	258
SHELL CA PROD. INC.	BELRIDGE	# 14M	14	M	28S	21E	252
SHELL CA PROD. INC.	BELRIDGE		14	N	28S	21E	245
SHELL CA PROD. INC.	BELRIDGE	# 14P	14	P1	28S	21E	270
SHELL CA PROD. INC.	BELRIDGE	# 15P	15	P	28S	21E	260
SAN JOAQUIN VALLEY OR H20			17	B1	28S	21E	251.5
STANDARD OIL CO.	S. BELRIDGE	HILL # 73	19	Z	28S	21E	1155
STANDARD OIL CO.	S. BELRIDGE	HILL # 48	19	Z	28S	21E	650
B & L PROD.	S. BELRIDGE	KING # 58A-19	19	Z	28S	21E	950
B & L PROD. CO.	S. BELRIDGE	ELLIS # 76A-19	19	Z	28S	21E	1500
SCPI	BELRIDGE FARMS	MONITER-A	21	C	28S	21E	500
SCPI PROD.	BELRIDGE	A-SHALLOW	21	C	28S	21E	285
SHELL CA PROD. INC.	BELRIDGE AREA	# 21 C2 NORTH	21	C2	28S	21E	360
BELRIDGE OIL CO.	S. BELRIDGE	WATER WELL # 46-22	22	K	28S	21E	655
SCPI PROD.	BELRIDGE	MONITOR B	22	K	28S	21E	220
SHELL CA PROD. INC.	BELRIDGE AREA	# 22 K2	22	K2	28S	21E	624
SHELL CA PROD. INC	BELRIDGE	# 22M	22	M1	28S	21E	260
SHELL CA PROD. INC.	BELRIDGE	# 22P	22	P1	28S	21E	270
SHELL CA PROD. INC.	BELRIDGE	# 23B	23	B1	28S	21E	258
SHELL CA PROD. INC.	BELRIDGE	# 23J	23	J1	28S	21E	265
SCPI BELRIDGE	SPICER CITYQ24	MONITOR C	24	P	28S	21E	496
SCPI PROD.	BELRIDGE	C-SHALLOW	24	P	28S	21E	265
SHELL CA PROD. INC.	BELRIDGE AREA	# 24 P2 NORTH	24	P2	28S	21E	404

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SHELL CA PROD. INC.	BELRIDGE	# 25G	25	G1	28S	21E	145
SHELL CA PROD. INC.	BELRIDGE	# 25G-DEEP	25	G2	28S	21E	275
SHELL CA PROD. INC.	BELRIDGE	# 25J-SHALLOW	25	J1	28S	21E	179
SHELL CA PROD. INC.	BELRIDGE	# 25J-DEEP	25	J2	28S	21E	315
SCPI PROD.	BELRIDGE	MONITOR D	28	J	28S	21E	380
B & L PROD.	S. BELRIDGE	KING # 51A-30	30	Z	28S	21E	875
B & L PROD.	S. BELRIDGE	KING # 71A-30	30	Z	28S	21E	770
SCPI PROD.	BELRIDGE	MONITOR F	32	N	28S	21E	320
SCPI PROD.	BELRIDGE	MONITOR F	32	P	28S	21E	320
MOBILE OIL CORP.	BELRIDGE AREA	28/21- 36K2	36	K2	28S	21E	249
MOBILE OIL CORP.	BELRIDGE	# 36Q-SHALLOW	36	Q1	28S	21E	282
MOBILE OIL CORP.	BELRIDGE	# 36Q	36	Q2	28S	21E	312
BALL& GGRANITE	WEST LERDO	LERDO WELL	7	N	28S	22E	619
SHELL CA PROD. INC.	BELRIDGE AREA	MONITOR G	7	N	28S	22E	300
SHELL CA PROD. INC.	BELRIDGE AREA	MONITOR G	7	N2	28S	22E	300
BALL & GRANITE	W. LERDO HIGHWAY	LERDO WELL	7	Z	28S	22E	619
SHELL CA PROD. INC.	BELRIDGE AREA	MONITOR G	7	Z	28S	22E	300
U.S. BUREAU OF	SPICER CITY	# 28-22-9B	9	B	28S	22E	1300
BUTTONWILLOW GINING CO.	SPICER CITY	WATERWELL	9	R	28S	22E	704
			10	P4	28S	22E	420
			10	Z	28S	22E	
GOOSE LAKE FARMS	GOOSE LAKE	# 12-1	12	Z	28S	22E	390
			13	K	28S	22E	
HOUCHIN BROS.	BUTTONWILLOW	T.H. RANCH # 11	15	M?	28S	22E	650
ELMO BELLUOMINI	BUTTONWILLOW	W.W. # 3	22	D	28S	22E	700
			22	D1	28S	22E	
ELMO BELLUOMINI	BUTTONWILLOW	WATER WELL	22	E1	28S	22E	600
ELMO BELLUOMINI	BUTTONWILLOW	WATER WELL	22	Z	28S	22E	600
HOUCHIN BROS.	BUTTONWILLOW	DOMESTIC	26	Z	28S	22E	425
MOBILE OIL CORP.	BELRIDGE AREA	28/22/31G2	31	G2	28S	22E	268
MOBILE OIL CORP.	BELRIDGE AREA	28/22/31Q2	31	Q2	28S	22E	259
CALIF. DEPT. OF WATER	AQUADUCT "OUTSIDE"	28/22-33N1	33	N1	28S	22E	227
MOBILE OIL CORP.	BELRIDGE AREA		33	N1	28S	22E	259

Data Base of wells available for Kern County Water Agency Regional Structure Study

			35	G1	28S	22E	
JOHN ROMANINI FARMS	WASCO - BUTTONWILLOW	#2	1	A	28S	23E	648
S.A. CAMP	BUTTONWILLOW - SHAFTER	#2	2	J	28S	23E	620
	BUTTONWILLOW		5	E	28S	23E	1570
	BUTTONWILLOW		5	M	28S	23E	1770
	BUTTONWILLOW		5	Q	28S	23E	1550
SEABOARD OIL CO.	BUTTONWILLOW	KERN # 7	5	Q	28S	23E	3517
			6	D	28S	23E	1800
TEXACO INC.	BUTTONWILLOW		6	E	28S	23E	1750
CARR & WRATH	BUTTONWILLOW		6	G	28S	23E	1950
	BUTTONWILLOW		6	J	28S	23E	2000
CARR & WRATH	BUTTONWILLOW	DAVIS # 14-6	6	K	28S	23E	1780
	BUTTONWILLOW	DERN # 3	6	Z	28S	23E	3800
	BUTTONWILLOW		7	A	28S	23E	
KENNETH A. ROSS JR.	BUTTONWILLOW	"SP" # 13-A7	7	B	28S	23E	1820
MILHAM FARMS	BUTTONWILLOW RIDGE	WATER WELL # 3	7	C2	28S	23E	612
MILHAM FARMS	BUTTONWILLOW RIDGE	WATER WELL # 9	7	H1	28S	23E	612
MILHAM FARMS	BUTTONWILLOW RIDGE	WATER WELL # 9	7	Z	28S	23E	612
DUAL PETROLEUM	BUTTONWILLOW	KCL # 1	8	G	28S	23E	2500
CARR & WRATH	BUTTONWILLOW	? UNIT # 1	8	L	28S	23E	2320
MOBILE OIL CORPORATION	BUTTONWILLOW	MOBILE-GULF-TUPMAN-USL	10	N	28S	23E	1750
THE TEXAS CO.	BUTTONWILLOW	BREEN # 1	14	P	28S	23E	13733
JACK WOOD OPR.	BUTTONWILLOW	JACK WOOD, HYDE KIM #	16	J	28S	23E	2270
JACK WOOD OPR.	BUTTONWILLOW	JACK WOOD, HYDE-KIM #	16	J	28S	23E	3997
JACK WOOD OPR.	BUTTONWILLOW	JACK WOOD, HYDE KIM #	16	Z	28S	23E	4005
MOBILE OIL CORP.	WEST ELM HILLS	BRAVO # 1	17	Q	28S	23E	2200
B & B BALDWIN	BEL RIDGE	#5	29	N	28S	23E	514
	BUTTONWILLOW	ELMER SUOREY	31	R	28S	23E	475
	BUTTONWILLOW	ELMER SUOREY	32	N	28S	23E	475
DAVID BLOEMHOF	BUTTONWILLOW	#4	33	G	28S	23E	840
GOLDEN BEAR OIL	W. SHAFTER	KCL # 55 X-2	2	K	28S	24E	1980
			4	N	28S	24E	
			4	R	28S	24E	

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CARR & WRATH	GARRISON CITY 5-28S	MITHCELL # F-2-5	5	A	28S	24E	2320
			7	P1	28S	24E	600
GOLDEN BEAR OIL CO.	SHAFTER	GARRISON CITY UNIT # 1	9	F	28S	24E	1500
RICHFIELD OIL CORP.	GARRISON CITY	ROCO MITCHELL ? # 1	9	H	28S	24E	1960
GOLDEN BEAR OIL	GARRISON CITY	OHIO-MITCHELL # 66X-9	9	J	28S	24E	1920
GOLDEN BEAR OIL CO.	GARRSION CITY	KCL# 66X-10	10	K-J	28S	24E	2100
GOLDEN BEAR OIL CO.	GARRISON CITY	KCL # 26X-10	10	M	28S	24E	2050
TED BLOEMHOFF	SHAFTER	REPLACEMENT #1	13	C	28S	24E	720
		WATER WELL	13	C	28S	24E	
TEXACO, INC.	GARRISON CITY	SEMITROPIC RIDGE # 1	15	H	28S	24E	1990
LAYNE WESTERN CO.	SHAFTER	WOOD STONE RANCHES #	17	A	28S	24E	726
U.S. BURAEU OF	W. OF SHAFTER		23	D	28S	24E	702
			23	D1	28E	24S	
U.S. BUREAU OF	W. OF SHAFTER		23	P	28S	24E	702
GOLDEN BEAR OIL CO.	GARRISON CITY	GARRISON CITY UNIT	5	K-J	28S	25E	2300
PUBLIC PETROLEUM CO.	SHAFTER	# 63	7	G	28S	25E	1950
McFARLAND ENERGY INC.	SHAFTER	JONES # 1	7	K	28S	25E	2000
TIDEWATER ASSOCIATED OIL	SHAFTER FIELD	PENNER # 37-7	7	P	28S	25E	2000
GEOCHEMICAL SURVEY &	SHAFTER	SHAFTER GAS UNIT # 67-7	7	Q	28S	25E	1850
GEOCHEMICAL SURVEYS &	SHAFTER	SHAFTER GAS UNIT # 67-7	7	Z	28S	25E	4320
RAPP OIL CO.	SHAFTER	KIRSCHENMAN # 32 X-8	8	C	28S	25E	1680
WASCO DRILLING CO.	SHAFTER	JAMES W. BRYANT WELL	14	E	28S	25E	626
TEEN CHALLENGE	SHAFTER	#1	16	P	28S	25E	718
HUMBLE OIL & REFINING CO.	SHAFTER	GEO. W. WATSON ET UX 1	17	E	28S	25E	1800
GEOCHEMICAL SURVEYS	SHAFTER	NEUMAN # 26X-17	17	P	28S	25E	1900
TIDEWATER ASSOC. OIL CO.	SHAFTER	STONE # 1-18-1	18	D-E	28S	25E	2200
TIDEWATER OIL CO. &	SHAFTER AREA	LOEPP # 63-18	18	G	28S	25E	2600
TIDEWATER ASSOC. OIL CO.	SHAFTER	CLARK # 67-18	18	Q	28S	25E	1550
S.A. CAMP	SHAFTER	KERMETH ANDERSON	20	D	28S	25E	713
UNION OIL CO.	RIO BRAVO	KERNCO # 25X	26	M	28S	25E	1680
SUPERIOR OIL CO.	RIO BRAVO	BURNER # 6G	27	P	28S	25E	1800
SUPERIOR OIL CO.	RIO BRAVO	FINK # 5-K	27	Q	28S	25E	1740
RICHARD S. RHEEM ,	PARALLEL AREA	PARALLEL UNIT B # 1	31	G	28S	25E	1830

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SUPERIOR OIL CO.	RIO BRAVO	PASADENA REALITY # 8	33	J	28S	25E	1500
UNION OIL	RIO BRAVO	KERNCO # 6IX - 34	34	A	28S	25E	1850
SUPERIOR OIL CO.	RIO BRAVO	KERNCO # 41X - 34	34	C	28S	25E	1860
SUPERIOR OIL	RIO BRAVO	WATERWELL # 2	35	M	28S	25E	800
S.A. CAMP PUMP CO.	CAWELO AREA	W.W. R 74 F9	2	Z	28S	26E	1301
	CAWELO AREA	W.W. # R7F9	2	Z	28S	26E	1300
	COWELO AREA	WATERWELL	4	H	28S	26E	2510
N. KERN WATER STROAGE	MINTER FIELD	# 4E-56	5	L	28S	26E	1095
SUPERIOR FARMS	SHAFTER	# 65-5R	7	D	28S	26E	1000
UNION OIL CO.			13	G	28S	26E	3923
UNION OIL CO. OF CA		MATTEL FEE	13	G	28S	26E	1920
KCL	BEARDSLEY	KCL OXIDENTAL # 18X-13	13	N	28S	26E	2010
J.G. DYER	LERDO	LERDO # 1	15	P	28S	26E	1850
CHEVRON USA INC.		KCL # 38-22-16	16	D	28S	26E	1600
E.A. BENDER	LERDO	KCL # 47-20	20	P	28S	26E	1650
N. KERN WATER STORAGE	ROSEDALE	# 4E20-1 (7)	20	Z	28S	26E	958
U.S. BUREAU OF REC.	SOUTH SHAFTER	# 21	21	H	28S	26E	900
MORTON & SONS	LERDO AREA	LERDO COMM. 1-5	25	D	28S	26E	1600
MORTON & SONS	LERDO AREA	LERDO COMM. # 1-5	25	D	28S	26E	2020
N. KERN WATER STORAGE	ROSEDALE	# 4E26-4 (6)	26	G	28S	26E	888
WESTERN GULF OIL CO.	N. ROSEDALE RANCH	KCL LERDO # 1	26	J	28S	26E	1580
PROFESSIONAL OIL		" BUTTES AVEDIAN " # 25X	26	M	28S	26E	1950
STANDARD OIL CO.	N. LERDO	KCL 37-33-27	27	F	28S	26E	1820
N. KERN WATER STORAGE		# 4E 27-3	27	H	28S	26E	938
STANDARD OIL CO.	7TH STANDARD AREA	KCL 68 # 28	28	Q	28S	26E	1760
ROY & GEORGE FANUCCHI	PANAMA	#4	30	Z	28S	26E	825
EUGENE FANUCCHI	PANAMA	# 1	30	Z	28S	26E	825
TESORO PET CORP	ROSEDALE	KCL 46-33	33	L	28S	26E	7724
INTEX OIL CO.	RODEDALE	INTEX-HANCOCK KCL #	33	L	28S	26E	1700
CHEVRON USA INC.	ROSEDALE RANCH	KCL 64 # 167-35	35	Q	28S	26E	1820
STANDARD OIL CO.	ROSEDALE RANCH	KCL 50 # 17-36	36	N	28S	26E	1380
NE- TEX OIL CO.	ROSEDALE	NE- TEX LERDO LAND # 1-36	36	P	28S	26E	1900
M.H. WHITTIER CORP.	KERN FRONT	"STAR ROBINSON" #3		Z	28S	27E	1190

Data Base of wells available for Kern County Water Agency Regional Structure Study

C.D. DRAUCKER	KERN FRONT	"CARIBOU" 2	2	P	28S	27E	1050
CAWELO WATER DIST.		#1 ?(EHA40-90)	6	C	28S	27E	1211
POWER SYSTEM	OILDALE	DOUBLE "C"	11	Z	28S	27E	1228
OXY USA , INC.	KERN FRONT	WATER WELL # 3	11	Z	28S	27E	1508
FENIAN OIL CORP.	KERN RIVER	"LATIMER" 9	13	C	28S	27E	730
ANGUS PETROTECH CORP.	KERN RIVER	#5	13	R	28S	27E	1197
CHEVRON U.S.A. INC.	KERN FRONT	WATER WELL #2	15	G	28S	27E	1460
NOEL WILSON	LERDO	#1	18	E	28S	27E	605
PAN AMERICAN PET. CO.	KERN RIVER	#24	22	S	28S	27E	2019
OILFIELD TRANSPORTATION &	BAKERSFIELD	#2	32	Z	28S	27E	620
EMCON ASSOC.		# WS-1	2	Z	28S	28E	802
SHELL CA PROD. INC.	KERN RIVER	RAMBLER # 71W	19	R	28S	28E	1250
SHELL CA PROD. INC.	KERN RIVER	RAMBLER # 102W	19	R	28S	28E	1120
SHELL OIL CO.	KERN RIVER	WATER PROBE # 6	20	H	28S	28E	940
SHELL CA. PROD. INC.	KERN RIVER	MARCO # 30W W.W.	20	N	28S	28E	1250
SHELL OIL CO.	KERN RIVER	WATER PROBE # 5	20	Z	28S	28E	950
A.M. VAN FLICK	SHARKTOOTH AREA	USL VAN RAY # 1	22	H	28S	28E	2670
E.A. BENDER	ROUND MTN.	BENDER BARLOW # 1	24	Z	28S	28E	2397
TENNECO OIL CO.	KERN RIVER	"COMET" # 24	28	D	28S	28E	890
GETTY OIL CO.	KERN RIVER	# 601	33	M	28S	28E	972
TIDEWATER OIL CO.	KERN RIVER	GREEN & WHITTIER # 104	34	N	28S	28E	805

Number of wells in this Township 198

Township 29S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
MOBILE OIL CORP.	BELRIDGE		1	M1	29S	21E	395
MOBILE OIL CORP.	BELRIDGE	# 12R	12	R1	29S	21E	304
MOBILE OIL CORP.	BELRIDGE	# 12R-DEEP	12	R2	29S	21E	498
STATE OF CALIFORNIA, DWR	SOUTH BUTTONWILLOW	#35K1	35	K1	29S	23E	603
KERN COUNTY LAND CO.	RIO BRAVO	5C 25-1	25	Z	29S	24E	610
JOHN BLAIR WELL			32	K	29S	24E	575
FRANCESCHI & SON	BUTTONWILLOW	#88-39 #2 PERMIT	32	Z	29S	24E	490
EDWARD KOSAREFF	BUTTONWILLOW	DOMESTIC	33	Z	29S	24E	410

Data Base of wells available for Kern County Water Agency Regional Structure Study

			29	Z	29S	25E	
KERN COUNTY LAND CO.	WATER WELL	JD 30-2	30	H	29S	25E	600
KERN COUNTY WATER AGENCY		L.S. DWR #1 TASK ORD	36	H	29S	25E	605
	ROSEDALE	KCL C-6	14	R	29S	26E	6804
LAYNE WESTERN CO.	ROSEDALE	HAHER MUTUAL WATER CO.	24	M/N	29S	26E	684
BROCK WATER CO.	ROSEDALE	#3	25	Z	29S	26E	639
CARR & WRATH	BELLEVUE	BRANDT #1	27	P	29S	26E	7400
JIM GARSIDE	ROSEDALE	TW 2	28	D	29S	26E	607
WEGIS WATER CO. -WASCO	ROSEDALE	#1	28	K	29S	26E	670
MIKE'S FENCE CO.	ROSEDALE	#1	29	E	29S	26E	600
VEROS ENTERPRISE	SOUTH OREFLEY	#86	29	H	29S	26E	1200
JOHN ROMANINI & SONS	BAKERSFIELD	88-40	31	J	29S	26E	830
DRILLING EXPLORATION &	BAKERSFIELD	WATER 1	33	F	29S	26E	488
CHEVRON U.S.A. INC.	BELLEVUE	KARPE #2-53	34	G	29S	26E	8420
BOYLE ENGINEERING CORP.	FRUITVALE	MNTR. WELL #B	15	L	29S	27E	204
J.A. WATERS	FRUITVALE	WATERS #7	15	P1	29S	27E	3993
J.A. WATERS CO.	FRUITVALE	J.A. WATERS #2	22	D1	29S	27E	4005
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 120-01	25	B2	29S	27E	601
CALIFORNIA WATER SERVICE	BAKERSFIELD	W. W. #126-01	25	G	29S	27E	605
DUMM BROTHERS PETROLEUM	FRUITVALE	#1 HARDING-DOUGLAS	26	D1	29S	27E	3717
CALIF WATER SERVICE CO.		STATION 152-01	26	N-50	29S	27E	288
SIERRA BAG CO.	FRUITVALE	STRIP #1	27	M	29S	27E	4015
MOHAWK PETROLEUM CORP.	REFINERY YARD	W. W. #2	27	Z	29S	27E	790
GOLDEN BEAR OIL CO.	FRUITVALE	ARMSTRONG #1	28	D	29S	27E	4361
	FRUITVALE	KCL 83A-28	28	H	29S	27E	4060
SIGNAL OIL & GAS CO.	FRUITVALE	W.W. #114	28	J52	29S	27E	1260
TOSCO PETRO REFINERY	BAKERSFIELD	#5	28	J53	29S	27E	800
TOSCO PETRO CORP.	FRUITVALE	INJECTION WELL #2	28	K	29S	27E	3710
AJAN OIL CO.	FRUITVALE	SCHULZ #1 (BLACKENED)	28	P	29S	27E	4473
BANKLINE OIL CO.	GREENACRES	PLANK COM#28	29	N1	29S	27E	7397
SHELL OIL CO.	JASTRO AREA	"K.C.L."#1	31	Z	29S	27E	3510
S.A. CAMP PUMP CO.	BAKERSFIELD	#25	32	C	29S	27E	750
GOLDEN BEAR OIL CO.	STOCKDALE	KCL 87-33	33	R	29S	27E	4675

Data Base of wells available for Kern County Water Agency Regional Structure Study

LEBOW AND MCNEE	FRUITVALE	KCL 78-4A	34	H1	29S	27E	4016
U.S. BUREAU OF	FRUITVALE	29-27-34	34	N1	29S	27E	799
CITY OF BAKERSFIELD	ASHE	#13	34	Z	29S	27E	710
CALIFORNIA WATER SERVICE	SW BAKERSFIELD	W. W. #81-2	36	K2	29S	27E	612
HANCOCK OIL CO.	N.E. BAKERSFIELD	KAAR #1	26	Z	29S	28E	6503
HANCOCK OIL CO.	NILES RIDGE	KAAR #1	26	Z	29S	28E	8500
KERN GENERAL HOSPITAL	BAKERSFIELD	WATER WELL	28	Z	29S	28E	1220
CALIFORNIA WATER SERVICE	BAKERSFIELD	WATERWELL 40-02	31	B1	29S	28E	658
H.H. MAGEE OPER & MOHAWK	EDISON	OSBORN #1	36	P	29S	28E	5196
RICHARD S. RHEEM OPERATOR	RACETRACK HILL	HAGOOD #44A-26	26	F	29S	29E	4718
W.K. GILLETT	RACETRACK-EDISON	U.S.L. FIELD #11	26	F	29S	29E	776
	EDISON	S.-C.#J8-26	26	Z	29S	29E	4987
RICHARD S. RHEEM	RACETRACK HILLS	J.-W.#35-26	26	Z	29S	29E	4730
STANDARD OIL CO. OF CALIF.	RACETRACK	#48-27	27	Z	29S	29E	4735
STANDARD OIL CO. OF CALIF.	RACETRACK	#45-27	27	Z	29S	29E	4625
STANDARD OIL CO. OF CALIF	RACE TRACK	#65-27	27	Z	29S	29E	4680
KERN OIL CO. LTD	EDISON GROVES	COHN #6D	28	B	29S	29E	1079
KERN OIL CO LTD.	EDISON GROVES	COHN #3-A	28	G	29S	29E	1211
KERN OIL CO. LTD	EDISON GROVES	COHN 3-E	28	H	29S	29E	1087
KERN OIL CO LTD.	EDISON GROVES	ROSS #2-B	28	P	29S	29E	1334
CALIFORNIA WATER SERVICE	BAKERSFIELD AREA	STATION 140-01	30	A	29S	29E	822
TRICO OIL & GAS	EDISON GROVES	HOTCHKISS #1	30	Z	29S	29E	5278
TEXACO OIL CORP	EDISON	G.-D.#1	30	Z	29S	29E	4103
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 43-02	31	F1	29S	29E	800
KERN OIL CO. LTD.	RACE TRACK HILLS	#1-Z	33	A	29S	29E	960
KERN OIL CO LTD.	RACE TRACK HILL	PORTALS 82	33	Z	29S	29E	4968
CALIFORNIA WATER SERVICE	E. BAKERSFIELD	514 BATES AVE.	33	Z	29S	29E	700
CALIF WATER SERVICE CO.	EDISON	#155-01	34	J	29S	29E	660
VACA DRILLING CO.	N.E. EDISON	CORE HOLE#1	36	D	29S	29E	730
HADDAD BROTHERS	EDISON	WATER WELL #5	36	M	29S	29E	1881

Number of wells in this Township 71

Data Base of wells available for Kern County Water Agency Regional Structure Study

Township 30S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
	ELK HILLS NORTH	BRIGHT #1	1		30S	23E	2210
STANDARD OIL CO OF CALIF	ELK HILLS	62-23R	23	B	30S	23E	2727
STANDARD OIL CO OF CALIF	ELK HILLS	88-24R	24	R	30S	23E	2838
STANDARD OIL CO. OF CALIF	ELK HILLS	46-29R	29	L	30S	23E	2745
STANDARD OIL CO OF CALIF	ELK HILLS	44-34R	34	F	30S	23E	2672
STANDARD OIL CO OF CALIF	ELK HILLS	44-36R	36	F	30S	23E	2860
U.S. BUREAU OF	BUTTONWILLOW	30-24-4C	4	C	30S	24E	800
			5	Z	30S	24E	
GENERAL PET. CORP.	SO. BUTTONWILLOW	DOYLE-MCKEON 1	6	B	30S	24E	6149
JOHN ROMANINI & SONS	BUTTONWILLOW	#2	8	Z	30S	24E	302
PALM FARMS	BUTTONWILLOW	DOMESTIC	10	Z	30S	24E	366
TENNECO WEST	ELK RESERVE		12	H	30S	24E	640
JOHNSON	TUPMAN	SUSIE #1	14	L	30S	24E	505
STANDARD OIL CO.	ELK HILLS	3-45-19S	19	L	30S	24E	11161
			22	A	30S	24E	430
			22	H	30S	24E	
DEPT OF WATER RESOURCES		30-24-23D1 GRND WATER	23	D1	30S	24E	200
UO-NPR NO.1	ELK HILLS	51-36S	36	B	30S	24W	3360
WEST KERN WATER CO	WEST KERN WATER	#6-02	?	Z	30S	25E	840
WEST KERN WATER DISTRICT	NORTH COLES LEVEE	2-01 N. COLES LEVEE	?	Z	30S	25E	1008
ARTHUR & ORUM	BUENA VISTA RANCH	KWB DRILL HOLE 1	4	J	30S	25E	690
THE TEXAS CO.	GOOSLOO AREA	KCL #1 GOOSLOO SO.	8	B	30S	25E	9504
UNIVERSAL CONSOLIDATED	N. CANAL	KCL #13-10	10	E	30S	25E	10204
KERN COUNTY WATER AGENCY	K.W.B.	30/25-11 L1	11	L1	30S	25E	626
			11	Z	30S	25E	600
KERN COUNTY WATER AGENCY	STRAND OIL FIELD	12AE (DWR 8253)	12	A1	30S	25E	143
S.A. CAMP PUMP CO	BUENA VISTA	TENNECO 6D 16-2	16	B	30S	25E	646
S.A. CAMP PUMP CO.	PALM RANCH	W. W. A2461 PALM FARMS	18	P	30S	25E	600
ARTHUR & ORUM WELL	TULE ELK RESERVE	KWB DRILL HOLE 2	19	N	30S	25E	675
STANDARD OIL CO.	TUPMAN	KCL 21-1	19	P	30S	25E	9900

Data Base of wells available for Kern County Water Agency Regional Structure Study

WEST KERN COUNTY WATER		#7-01	21	Z	30S	25E	920
WEST KERN WATER DISTRICT	NORTH COLES LEVEE	2.01 NORTH COLES LEVEE	21	Z	30S	25E	1008
WEST KERN WATER CO.	WEST KERN WATER	#6-02	21	Z	30S	25E	840
SHELL	NORTHWEST TEN SECTION	"KCL" 74 WS-23	23	H	30S	25E	2800
STATE OF CALIFORNIA	2800 ACRES	30-25-24C4	24	C	30S	25E	708
CTIY OF BAKERSFIELD	2800 ACRES	30-25-24C1	24	C1	30S	25E	250
DEPT WATER RESOURCES		DESTAFANI	26	J	30S	25E	406
RICHFIELD OIL CO	COLES LEVEE	CL-A 56-27	27	K	30S	25E	9351
ARCO OIL & GAS	NORTH COLES LEVEE	CL-A-555-27	27	L	30S	25E	2204
WESTERN WATER WORKS	COLES LEVEE	WATER WELL #7	28	C3	30S	25E	675
RICHFIELD OIL CORP.	N. COLES LEVEE	"KCL" A 14-28	28	E	30S	25E	1400
RICHFIELD OIL CORPORATION	N. COLES LEVEE	KCL B 74-28	28	H	30S	25E	9491
RICHFIELD OIL CORP	COLES LEVEE	KCL A 56-28	28	K	30S	25E	9502
RICHFIELD OIL CORP	N. COLES LEVEE	A 36-28	28	L	30S	25E	9200
ATLANTIC RICHFIELD	NORTH COLES LEVEE	C. L. A. 577-28	28	R	30S	25E	2310
WEST KERN COUNTY WATER	COLES LEVEE	#6-01 REPLACEMENT WELL	28	Z	30S	25E	825
RICHFIELD OIL CORP	COLES LEVEE	KCL A-56-29	29	K	30S	25E	9150
DEPT OF WATER RESOURCES		30S/25E-30A1	30	A1	30S	25E	200
RICHFIELD OIL CORP	N. COLES LEVEE	KCL 21-30	30	D	30S	25E	9790
			30	Z	30S	25E	1300
RICHFIELD OIL CORP	COLES LEVEE	KCL B-85-31	31	J	30S	25E	9000
RICHFIELD OIL CORP.	N. COLES LEVEE	WATER WELL #5	32	B	30S	25E	506
			32	C	30S	25E	1000
RICHFIELD OIL CORP	NORTH COLES LEVEE	CLA-27-32	32	N	30S	25E	9260
RICHFIELD OIL CORP.	COLE'S LEVEE	KCL A-72-33	33	A	30S	25E	9480
RICHFIELD OIL CORP.	N. COLES LEVEE	A-12-33	33	D	30S	25E	8148
ATLANTIC RICHFIELD CO.	NORTH COLES LEVEE	CLA-543-33	33	F	30S	25E	1562
RICHFIELD OIL CORP.	COLES LEVEE	KCL A 54-33	33	G	30S	25E	9350
ATLANTIC RICHFIELD CO.	NORTH COLES LEVEE	CLA #12-33 RD#3	33	Z	30S	25E	9197
ARCO OIL & GAS CO	N. COLES LEVEE	584-34	34	H	30S	25E	3700
RICHFIELD OIL CORP.	COLES LEVEE	C.L.A. 54-34	34	K	30S	25E	9349
KERN COUNTY LAND CO	NORTH COLES LEVEE	WATER WELL #6D-35-1	35	B	30S	25E	1400
RICHFIELD OIL CORP	COLES LEVEE	K.C.L. 54-35	35	Z	30S	25E	9818

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KCWA/DWR	SOUTH COLES LEVEE/KWB	ARCO #74X-36	36	G	30S	25E	1423
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 145-01	1	B	30S	26E	675
KERN COUNTY LAND CO.	BELLEVUE	6 E U-4	1	J	30S	26E	706
ZUBLIN WELL LOGGING		KCL GE 1-4	1	J	30S	26E	600
JACOBASON, JOHN F. LIVING		#12 ASH WATER	2	A	30S	26E	
CALIFORNIA WATER	BAKERSFIELD	STATION 1701	2	F	30S	26E	678
CITY OF BAKERSFIELD	2800 ACRES	30-26-3J1	3	J1	30S	26E	268
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	#4	3	L1	30S	26E	678
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	#5	3	L2	30S	26E	738
KERN COUNTY WATER AGENCY	BAKERSFIELD	TW 1	3	M1	30S	26E	690
KERN COUNTY WATER AGENCY	BAKERSFIELD	8601 EAST OBS WELL	3	M2	30S	26E	710
KERN COUNTY WATER AGENCY	BAKERSFIELD	8601 #2 S OBS WELL	3	M3	30S	26E	730
KERN COUNTY WATER AGENCY	BAKERSFIELD	#8601 N PROD. WELL	3	M4	30S	26E	688
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	8701-2	3	P	30S	26E	715
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	#8701-OBS. WELL	4	J	30S	26E	670
KERN COUNTY WATER AGENCY	KERN RIVER SPREADING	#1	4	R	30S	26E	718
ARTHUR & DRUM WELL	CROSS VALLEY CANAL RR	KWB D. H.#3	6	Z	30S	26E	695
CITY OF BAKERSFIELD	2800 ACRES	30-26-8P1	8	P1	30S	26E	260
STATE OF CALIFORNIA	2800 ACRES	30-26-8P4	8	P4	30S	26E	710
STATE OF CALIFORNIA	2800 ACRES	30-26-9M4	9	M4	30S	26E	710
CONTINENTAL OIL CO.	GREELEY-ROSEDALE	KCL-D-1	10	G	30S	26E	7199
CITY OF BAKERSFIELD	2800 ACRES	30-26-10C1	10	Q	30S	26E	260
HANCOCK OIL CO.	GOSFORD	KCL 28-11	11	N	30S	26E	8200
	BELLEVUE AREA	KCL ?	12	H?	30S	26E	600
SIGNAL OIL & GAS CO.	GOSFORD	KCL 28X-12	12	N	30S	26E	7948
CITY OF BAKERSFIELD	STOCKDALE	#20	13	J	30S	26E	760
S.A. CAMP PUMP CO	BAKERSFIELD	STATION #195-01	14	Z	30S	26E	815
DEPT. WATER		CBK-22	16	A	30S	26E	710
CITY OF BAKERSFIELD	KERN RIVER SPREADING	OBS WELL #2	16	B	30S	26E	700
OLCESE WATER DISTRICT	BAKERSFIELD FLOOD	#1	16	E	30S	26E	730
CONTINENTAL OIL CO.	STRAND	E-1	17	H	30S	26E	7742
OLCESE WATER DIST	BAKERSFIELD	#2	17	K	30S	26E	636
OLCESE WATER DISTRICT	BAKERSFIELD	#3	17	M	30S	26E	720

Data Base of wells available for Kern County Water Agency Regional Structure Study

OLCESE WATER DISTRICT	BAKERSFIELD	#3	17	PN	30S	26E	720
CONTINENTAL OIL CO.	SOUTH STRAND	KCL H-1	18	G	30S	26E	7995
CITY OF BAKERSFIELD	2800 ACRES	30-26 18 H 1	18	H1	30S	26E	265
STATE OF CAL DWR	2800 ACRES	30-26-18H4	18	H4	30S	26E	710
CITY OF BAKERSFIELD	2800 ACRES	30 26 18 N1	18	N1	30S	26E	260
BOLSA CHICA OIL	STRAND	KCL 82-18	18	Z	30S	26E	8350
OLCESE WATER DISTRICT	BAKERSFIELD	#4	19	A	30S	26E	640
CITY OF BAKERSFIELD	KERN RIVER SPREADING	OBS WELL #1	19	B	30S	26E	703
OLCESE WATER DISTRICT	BAKERSFIELD	#5	19	C1	30S	26E	660
TENNECO WEST	STRAND	WATER WELL #4	21	G	30S	26E	728
BUREAU OF RECLAMATION	TEN SECTION	WATER WELL 30-26-22	22	P	30	26E	794
HANCOCK OIL CO.	CANFIELD RANCH FIELD	63-23	23	G	30S	26E	9540
LAYNE-WESTERN CO		TOM BRIGGS #1	24	C	30S	26E	685
			25	G	30S	26E	1262
			25	L	30S	26E	700
THE TEXAS CO.	OLD RIVER	COULTER #1	25	Q	30S	26E	8314
HANCOCK OIL CO	GOSFORD	KCL 44-26	26	Z	30S	26E	8500
SHELL OIL CO.	TEN SECTIION	KCL A-52-29	29	B	30S	26E	8235
ARTHUR & ORUM WELL	KERN WATER BANK	KWB-DH-5 32N-1,2,3	32	N	30S	26E	700
KERN COUNTY LAND CO.	TEN SECTION	KCY 44-33	33		30S	26E	8665
RICHARD S. RHEEM,	CANFIELD RANCH	KCL 32X-34 NORRIS	34	C	30S	26E	10687
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 145-01	1	C	30S	27E	675
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 139-01	1	J50	30S	27E	710
CALIFORNIA WATER SERVICE	S.W. BAKERSFIELD	STATION 144-01	1	J51	30S	27E	650
CALIFORNIA WATER SERVICE	W. BRUNDAGE	STATION 106-01	2	D1	30S	27E	602
CALIFORNIA WATER SERVICE	S. STINE ROAD	STATION 130-01	2	P1	30S	27E	675
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION 134-01	2	R50	30S	27E	750
ROBERTSON DRILLING CO.	WEST HIGH SCHOOL	TEST HOLE #1	3	J2	30S	27E	526
S.A. CAMP PUMP CO.	BAKERSFIELD	CBK #19-01	5	A	30S	27E	770
			5	H	30S	27E	1185
WESTERN GULF	STOCKDALE AREA	KCL "STOCKDALE "	5	H	30S	27E	5992
CEMCO-EDISON NO.1 (F.R.)	EDISON	PORTALS	5	N	30S	27E	4220
KCWA/DWR	OCEANIC PACIFIC GOLF	30/27/7E	7	E	30S	27E	723

Data Base of wells available for Kern County Water Agency Regional Structure Study

BANKLINE OIL CO	GOSFORD NORTH	KCL 35-7	7	Z	30S	27E	8008
S.A. CAMP PUMP CO.	BAKERSFIELD	ASHE W. W.#10	8	J	30S	27E	701
KERN COUNTY LAND CO.	BELLVUE AREA	6F94	9	JP	30S	27E	763
CALIFORNIA WATER SERVICE	HUGHES LANE & WILSON RD	W. W.#112-01	12	L2	30S	27E	617
CALIF. WATER SERVICE CO.	BAKERSFIELD (CITY	STATION #137-01	12	Z	30S	27E	668
CALIF WATER SERVICE CO.	SO. H. NO. OF WHITE LANE	W.W. #123-02	13	C	30S	27E	790
CALIF WATER SERVICE CO.	SO.H. NO. OF WHITE LANE	W. W. #123-01	13	H51	30S	27E	750
KLEINFELDER & ASSOC	NALCO CHEMICAL,	M.W.#2	15	R	30S	27E	160
UNIVERSAL CONSOLIDATED	GOSFORD	STATEX KCL DW #1 19	19	E	30S	27E	4460
CALIF WATER SERVICE CO.	BAKERSFIELD	#89	19	N	30S	27E	663
S.A. CAMP PUMP CO.	BAKERSFIELD	STATION #16	20	D	30S	27E	746
SIGNAL OIL & GAS CO	GOSFORD	E.C.L.A.-1	21	M	30S	27E	1600
S.A. CAMP PUMP CO.	BAKERSFIELD	TWI#4167	21	N	30S	27E	730
CALIF WATER SERVICE CO.	S.W. BAKERSFIELD AREA	WW 146-03	23	C-50	30S	27E	650
SLOCUM WW DRILLING CO	BAKERSFIELD	WW 146-02	23	C51	30S	27E	650
CALIF WATER SERVICE CO.	BAKERSFIELD	146-01	23	C52	30S	27E	642
CALIF WATER SERVICE CO.	BAKERSFIELD	STATION 146-05	23	D50	30S	27E	660
CALIF WATER SERVICE CO.	BAKERSFIELD	STATION 146-04	23	D51	30S	27E	710
CALIF WATER SERVICE CO.	BAKERSFIELD	#189	24	RL	30S	27E	663
CITY OF BAKERSFIELD	BAKERSFIELD	1801	26	D	30S	27E	680
UNIVERSAL CONSOLIDATED	GOSFORD	KCY-O'HARE 1X-30	30	D	30S	27E	10765
CALIFORNIA WATER SERVICE	BAKERSFIELD	145-01	1	B	30S	28E	675
CALIFORNIA WATER SERVICE	4 NO OF WHITE LANE	W. W. 123-01	1	B	30S	28E	750
MORTON AND DOLLEY	EDISON	PORTER #1	1	H	30S	28E	4735
I.E. TYNER BX 3831 E.	BRUNDAGE & STERLING	#1 BAKERSFIELD	2	C2	30S	28E	1250
STANDARD OIL CO.	MCGUNDEN	ROUTZONG #1	2	J	30S	28E	5787
SIGNAL OIL & GAS	EDISON	#1 SIGNAL-DEL PAPA	2	Q	30S	28E	6037
KERN HIGH SCHOOL	MT. VERNON & 58	#1	3	D	30S	28E	800
WESTERN GULF	BRUNDAGE AREA	BLOEMER #1	3	J	30S	28E	6026
WESTERN GULF	MAGUNDEN AREA	COHN EST.#1	3	R	30S	28E	6278
LAYNE WESTERN DRILLING	MOUNT		3	Z	30S	28E	420
GENERAL PETROLEUM CORP.	EAST UNION AVE	BANKHAM 56X-4	4	K	30S	28E	4927
CALIFORNIA WATER SERVICE	COTTONWOOD AREA	W.W. #132-01	5	B1	30S	28E	690

Data Base of wells available for Kern County Water Agency Regional Structure Study

CALIFORNIA WATER SERVICE	BAKERSFIELD	#102-01	5	C	30S	28E	603
CALIFORNIA WATER SERVICE	BAKERSFIELD	STATION #138-01	5	N1	30S	28E	1000
HANCOCK OIL CO.	UNION AVENUE AREA	JEWETT COMM #1	5	Z	30S	28E	7874
CALIF. WATER SERVICE	EDISON	#153-01	6	C50	30S	28E	710
THE HANCOCK OIL CO.	UNION AVENUE AREA	ROBERTS #3	6	H	30S	28E	4243
THE HANCOCK OIL CO.	UNION AVENUE	ROBERTS #4	6	J	30S	28E	5056
C.R. JAMES	BAKERSFIELD	W.W. # A5	7	C1	30S	28E	670
CALIFORNIA WATER SERVICE		125-01	8	B50	30S	28E	604
CALIFORNIA WATER SERVICES	BAKERSFIELD	#187-01	8	E	30S	28E	745
U.S. BUREAU OF	MT. VIEW	30-28-10	10	N	30S	28E	1199
DEBBIE TASK	BAKERSFIELD	#1	11	Z	30S	28E	465
THE HANCOCK OIL CO.	EDISON	MULLER #1	12	B	30S	28E	6100
ROTHCHILD OIL CO.	EDISON	MCCLEAN #1	12	L	30S	28E	4010
J. PAUL GETTY	MT. VIEW	FAURE #44	13	F	30S	28E	4706
J. PAUL GETTY	MT. VIEW	FAURE #33	13	F	30S	28E	4697
J. PAUL GETTY	MT. VIEW	COREY 74	13	H	30S	28E	4550
PARAMJTT DOSANJH	EDISON	#1	13	Z	30S	28E	513
OMAR CARMONA	BAKERSFIELD	#1	13	Z	30S	28E	400
HORACE STEELE GOLDEN	MT. VIEW	NUNAZ #1 YOUNG KWON	14	C	30S	28E	5000
			14	P	30S	28E	1600
CALIFORNIA WATER SERVICES	BAKERSFIELD	#187	16	E	30S	28E	745
			16	J	30S	28E	1400
RICHFIELD OIL CO.	MT. VIEW	M.V. #1	16	K	30S	28E	4800
			18	E	30S	28E	
CALIFORNIA WATER WELL		STATION 143-01	18	K50	30S	28E	655
KERN COUNTY UNION HIGH	SOUTH HIGH SCHOOL	WATERWELL	18	L	30S	28E	535
S.A. CAMP PUMP CO	BAKERSFIELD	CAL WATER STATION	19	A	30S	28E	770
GENERAL PETR CORP	WEST MT. VIEW	KERN SUMNER 27	22	N	30S	28E	6800
MR. SOTO	HILLTOP	# 1	24	A	30	28	503
MORTON & DOLLEY	MT. VIEW	MOHAWK-VINEYARD	24	Z	30S	28E	4967
HOGAN PETROLEUM	MT. VIEW	WIBLE #1	26	N	30S	28E	6619
MT. VERNON -PANORAMA	HILL TOP	27-1	27	A	30S	28E	820
GENERAL PET CORP.	EDISON AREA	K.SUMNER 8-27	27	N	30S	28E	7178

Data Base of wells available for Kern County Water Agency Regional Structure Study

CALIFORNIA WATER WELL	S.E. BAKERSFIELD	M.SANCHEZ W.W. #1	28	A	30S	28E	300
KIRSCHENMAN RANCH	EDISON	W.W. #1	3	A1	30S	29E	1688
BOLSA CHICA OIL CO.	RACETRACK HILL	HADDAD-BUTLER#1	3	B	30S	29E	4900
BRITISH-AMERICAN OIL CO.	RACE TRACK HILLS	PORTALS#34-3	3	F	30S	29E	4787
BRITISH AMERICAN OIL CORP	RACE TRACK HILLS	PORTALS#26-A-3	3	M	30S	29E	4765
DUMM BROS. AND MACRATE	EDISON	G.-W.#1	3	Z	30S	29E	4928
RICHARD S. RHEEM	RACE TRACK HILL		4	C	30S	29E	5475
THE OIL CO.	EDISON	EDISON 4	4	G	30S	29E	2490
FRED R. WILLIAMS	EDISON	4-30-29	4	J	30S	29E	2100
BRITISH AMERICAN OIL CO.	EDISON	P. BERRY 9A-4	4	J	30S	29E	1600
A.F.C. INC	EDISON	W.W.#2	4	LM	30S	29E	711
GOLDEN BEAR OIL CO.	EDISON	SEALE #1	5	D	30S	29E	4117
REPUBLIC PET. CO. (SHELL)	EDISON	PORTALS #2	5	K	30S	29E	3855
OHIO OIL CO.	EDISON	PORTAL COMM#2	5	Z	30S	29E	3972
PETREX INC.	EDISON	#2	6	A	30S	29E	2592
MRS. SYNDICATE	EDISON	REUTER #1	6	G	30S	29E	2000
MORTON AND DOLLEY CO.	EDISON	EDISON COMM#1	6	L	30S	29E	4500
LAYNE-WESTERN CO. INC.	KERRNITA FIELD	W-A T. H. #1 WESTERN	6	Q	30S	29E	700
LAYNE WESTERN CO.	EDISON	W.-A.#1 WESTERN	6	Z	30S	29E	716
WILSON ROAD WATER ASSOC.	WEEDPATCH & WILSON	#1	7	Z	30S	29E	602
PAUL GETTY	EDISON	ROAGLAND#2	8	C	30S	29E	
GENERAL PETROLEUM	EDISON	SPEED 10-8	10	Z	30S	29E	1855
GOLDEN BEAR OIL CO.	EDISON	GRAYSON 45-10	10	Z	30S	29E	4985
AL HADDAD	EDISON	W.W. #1	11	H1	30S	29E	2296
GENERAL PETROLEUM	EDISON	SPEED 28-11	11	N	30S	29E	3013
GENERAL PETROLEUM	EDISON	SPEED 38-11	11	P	30S	29E	2970
GENERAL PETROLEUM	EDISON	SPEED 58-11	11	Q	30S	29E	2050
F.G. WALKER	EDISON AREA	EDI-RITA #1	12	D	30S	29E	1708
UNION OIL CO.	EDISON	BROCKMAN 2A	13	E	30S	29E	3810
JERGINS OIL CO.	EDISON	MCCOWAN 13B-3	13	K	30S	29E	1830
AT JERGINS TRUST	EDISON	MCCOWAN 13-A-8	13	L	30S	29E	1502
JERGINS OIL CO.	EDISON	MCCOWAN 13A-1	13	L	30S	29E	1781
JERGINS OIL CO.	EDISON	MCCOWAN 13A-7	13	L	30S	29E	1786

Data Base of wells available for Kern County Water Agency Regional Structure Study

JERGINS OIL CO.	EDISON	MCCOWAN A5	13	M	30S	29E	1587
JERGINS OIL CO.	EDISON	MCCOWAN 13 A S-5	13	M	30S	29E	1545
JERGINS OIL CO.	EDISON	"FEE 13" S-1	13	N	30S	29E	2901
JERGINS OIL CO.	EDISON	CORP.FEE S-2	13	N	30S	29E	2150
A.T. JERGINS TRUST	EDISON	FEE 13-8	13	P	30S	29E	1291
JERGINS OIL CO.	EDISON	CORP.FEE 13 S-3	13	P	30S	29E	1662
JERGINS OIL CO.	EDISON	MCCOWAN 13-B-5	13	Q	30S	29E	1626
JERGINS OIL CO.	EDISON	MCCOWAN 13B-7A	13	Q	30S	29E	1345
HARRY H. MAGEE	EDISON	DOUGHERTY #6	14	A	30S	29E	2000
H.H. MAGEE	EDISON	DOUGHERTY #8	14	A	30S	29E	2100
H.H. MAGEE	EDISON	DOUGHERTY #1	14	A1	30S	29E	2847
H.H. MAGEE	EDISON	DOUGHERTY #9	14	B	30S	29E	2600
H.H. MAGEE OPER	EDISON	BROWN#4	14	C	30S	29E	2593
JERGINS OIL CO.	EDISON	HERSHEY #7	14	J	30S	29E	1511
JERGINS OIL CO.	EDISON	HERSHEY# S-5	14	J	30S	29E	2031
JERGINS OIL CO.	EDISON	HERSHEY #8	14	J	30S	29E	1399
			14	K	30S	29E	1300
GENERAL PET. CORP	EDISON	L-N.#3	14	L	30S	29E	2770
GENERAL PETROLEUM CO.	EDISON	LEDDY #1	14	M	30S	29E	2108
JERGINS OIL CO.	EDISON	HERSHEY #S-2	14	Q	30S	29E	2623
JERGINS OIL CO.	EDISON	HERSHEY #14	14	Q	30S	29E	2427
JERGINS OIL CO.	EDISON	HERSHEY #9	14	R	30S	29E	1673
NORTH AMERICAN	EDISON	BROWN # 8	14	Z	30S	29E	2934
JEKINS OIL COLGATE	EDISON	CLIFTON	15	K	30S	29E	2058
GENERAL PET CORP	EDISON 1	JED 1	15	R	30S	29E	2806
GENERAL PETROLEUM CORP.	EDISON	C. FEE 42-16B	CAULEY	B	30S	29E	6029
RICHFIELD OIL CORP	EDISON	CAULEY 43-16	16	F	30S	29E	
GENERAL PETROLEUM	EDISON	CAULEY 53-16	16	G	30S	29E	4901
DES MOINES OIL CO.	EDISON	CAULEY #8	16	P	30S	29E	2200
J. PAUL GETTY	EDISON	ALEXIS# 2	17	B	30S	29E	2800
J. PAUL GETTY	WEST EDISON	ALEXIS #1	17	B	30S	29E	2200
FIRST NATIONAL FINANCE	EDISON	DEMILLE FIRST	17	C1	30S	29E	3598
FIRST NATIONAL FINANCE	EDISON AREA	DEMILLE BIGGAR#1	17	D	30S	29E	3629

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PACIFIC WESTERN	EDISON	PORTER # 2	17	E	30S	29E	3909
PACIFIC WESTERN	EDISON	PORTER#1	17	E	30S	29E	2300
WASCO DRILLING CO	EDISON	PORTER FARMS	17	H	30S	29E	900
DES MOINES CO	EDISON	PORTER	17	R	30S	29E	1954
J. PAUL GETTY	EDISON	PORTER#17-6	17	Z	30S	29E	3935
J. PAUL GETTY	EDISON	PORTER#17-4	17	Z	30S	29E	4078
MAREX OIL CO	MT. VIEW	MCDONALD#18	18	N	30S	29E	1700
A.1. CORPORATION	MT VIEW	A.1 #1	18	Z	30S	29E	4144
GILMOUR	MT. VIEW	NICHOLS #1	19	P	30S	29E	3000
STANDARD OIL CO OF CALIF	MT. VIEW	NICHOLS COMM #3	19	Z	30S	29E	5120
			20	A	30S	29E	1950
SHELL OIL CO. INC.	MT. VIEW	VOARHOSE#1	20	E	30S	29E	4958
WOOD-CALLAHAN	EDISON	21 COMMUNITY 6	21	B	30S	29E	3664
WOOD-CALLAHAN	WEST EDISON	21 COMMUNITY 8	21	B	30S	29E	4460
ROTHSCHILD-BENDER	EDISON	HEYDEN#4	21	BD	30S	29E	2100
ROTHSCHILD BENDER	EDISON	HEYDEN#2	21	C	30S	29E	2000
ROTHSCHILD-BENDER	EDISON	HEYDEN#1	21	C	30S	29E	3390
ROTHSCHILD OIL CO.	EDISON	BOYCE#1	21	D	30S	29E	
ROTHCHILD OIL CO.	EDISON	OMAHA# 3	21	F	30S	29E	3896
WOOD-CALLAHAN	EDISON	KRANZ #1	21	H	30S	29E	3650
WOOD-CALLAHAN OIL CO.	EDISON	HEYDEN #1	21	H	30S	29E	4369
WOOD CALLAHAN	EDISON	FEE# 3	21	H	30S	29E	2200
WOOD CALLAHAN OIL CO. LTD	EDISON	MAGOFFIN#1	21	J	30S	29E	3200
RING OIL CO.	EDISON	WILKIE #1	21	L	30S	29E	1600
ROTHSCHILD-BENDER	EDISON	HEYDEN# 3	21	Z	30S	29E	1500
RING OIL CO.	EDISON	PORTER# 1	21	Z	30S	29E	4175
MORRIS	EDISON	BRANDT #1	22	E	30S	29E	3375
MARK MORRIS	EDISON	BRANDT #. 2	22	E	30S	29E	3379
JERGINS OIL CO.	EDISON	TEXAS FEE 23#13	23	B	30S	29E	2408
			23	E	30S	29E	
JERGINS OIL CO.	EDISON	TEXAS FEE 23#20	23	G	30S	29E	2183
THE TEXAS CO.	EDISON	HINTZ #2	23	J	30S	29E	2586
THE TEXAS CO.	EDISON	HINTZ# 3	23	J	30S	29E	1600

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JERGINS A.T.	EDISON	ANDREWS #7	23	N	30S	29E	3287
THE TEXAS CO.	EDISON	HINTZ #1	23	R	30S	29E	1600
GEN PET CORP	EDISON	KNAPP#5	24	C	30S	29E	1428
GENERAL PETR	EDISON	KNAPP #9	24	F	30S	29E	1458
	EDISON	JOHNSON #1	24	Z	30S	29E	1525
THE TEXAS CO.	EDISON	METTLER # 1	24	Z	30S	29E	2200
THE TEXAS CO.	EDISON	METTLER # 2	25	D	30S	29E	2813
EM H. METTLER & SONS	EDISON	METTLER#1	25	K	30S	29E	1501.77
THE CAPITAL CO.	EDISON	L.-B. 3-38	26	P	30S	29E	3250
CAPITAL COMPANY	EDISON	L.-B. 36-26-2 LAWSON	26	Z	30S	29E	3280
KUNDERT BROS FRM.	LAMONT	BA-2538	27	K	30S	29E	800
SEABOARD OIL CO	EDISON	PORTER # 1	28	G	30S	29E	5166
UNION OIL CO	MT. VIEW	PORTER 74-28	28	H	30S	29E	4240
STULL & STULL	HILLTOP	#501	29	D	30S	29E	804
PACIFIC WESTERN	MT. VIEW	KOEHLER #2	29	R	30S	29E	5563
BENDER OIL OPERATIONS	MT. VIEW	B.A. CO # 1	29	Z	30S	29E	5400
MOHAWK PETROLEUM CORP	MT. VIEW	CLENDENEN #10	30	F	30S	29E	6012
HOGAN PET CO.	MT. VIEW	WHARTON #10	32	B	30S	29E	5100
SHELL OIL CO.	MT. VIEW	PORTER# 2-2	32	J	30S	29E	5868
SHELL OIL CO.	MT. VIEW	PORTER TWO-7	32	J	30S	29E	5200
L.F. GILMOUR	MOUNTAIN VIEW	DERBY#22	33	D	30S	29E	8833
GETTY	MT VIEW AREA	DERBY #23	33	E	30S	29E	
J. PAUL GETTY	MT. VIEW	DERBY #53	33	G	30S	29E	8963
MORTON & DOLLEY	MT. VIEW	DERBY#1	33	L	30S	29E	5421
RING OIL CO.	EDISON	#3	33	Z	30S	29E	4600
BARNHART-MORROW	MT VIEW	KOVACEVICH #1	34	Q	30S	29E	4812
DIGIORGIO FRUIT CORP	ARVIN	W.W.#36-H	36	B	30S	29E	830
DI GIORGIO FRUIT CORP.	SO. EDISON	W.W.#36-G	36	E1	30S	29E	1052
WESTERN GULF OIL CO.	CALIENTE CREEK	DI GIORGIO #44-36	36	F	30S	29E	2108
DI GIORGIO FRUIT CORP.	DI GIORGIO FARMS	W.W.#36-F	36	J2	30S	29E	1029
SOUTHERN CALIF PETROLEUM	RACE TRACK HILLS	#44-5 BROWN PALLETTE	5	Z	30S	30E	4768
GIUMARRA VINEYARDS	EDISON	W.W. (DEEPENING)	6	J1	30S	30E	2389
DAVIS INVESTMENT CO.	EDISON AREA	BADMAN 1101	8	R	30S	30E	2456

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HARLEY BARLING	EDISON AREA	W.W.#1	17	A1	30S	30E	1591
T.H. METTLER	EDISON	W.W.#1	18	G2	30S	30E	2770
			19	M	30S	30E	1125
			20	C	30S	30E	1400
BRYAN SMITH FARMS	EDISON	W.W. #3	20	D1	30S	30E	2191
GROSHEN OIL CO.	CALIENTE CREEK AREA	GROSHEN #1	22	Z	30S	30E	3830
			23	Z	30S	30E	1800
R.H.L. OIL CO.	EDISON AREA	R.H.L. 2	27	B	30S	30E	1720
ATLANTIC OIL CO.	MT. VIEW	MOHAWK #1	29	Z	30S	30E	5146
BRYAN SMITH	EDISON	LAUGHLIN#1	30	B	30S	30E	790
DIGIORGIO	EDISON	W.W,# 31A	31	B1	30S	30E	909
SAN JOAQUIN DRILLING CO.	EDISON	DI GIORGIO #5	32	N	30S	30E	682
KERN COUNTY WATER AGENCY	HECK FARM	DWR 8366	8	D	30S	32E	460

Number of wells in this Township 340

Township 31S

Company	Field	Well No.	Sec.	Loc. Ltr.	T	R	Log Depth
UO-NPR No 1	ELK HILLS	#18-14B	14	B	31S	22E	3760
CALIFORNIA SOUTHERN OIL	NORTH MIDWAY	#2	16	Z	31S	22E	1030
SANTA FE ENERGY CO.	MIDWAY SUNSET	AMBER# 99 (WATER WELL)	26	F	31S	22E	1981
UO-NPR #1 (SOCO OF CALIF	ELK HILLS	#84-2B	2	H	31S	23E	2100
WILLIAMS BROTHERS	NPR #1	#84W - 13B	13	B	31S	23E	1900
WILLIAMS BROTHERS	NPR #1	#82W-14B	14	A	31S	23E	2000
CHEVRON U.S.A. INC	FAIRWEATHER	18-16B	16	B	31S	23E	3166
EMCON ASSOCIATES	TAFT SANITARY LANDFILL	B-1/MW-1	25	H	31S	23E	439
S.A. CAMP PUMP CO	BV GOLF COURSE	B.V.G.C. #1	12	E	31S	24E	822
JACK WOOD	NO. TAFT	W.W.# 1	20	K1	31S	24E	410
JACK WOOD	NORTH TAFT	W.W.#2	21	Z	31S	24E	393
W.W. HOLMES	ELK HILLS	W.P.53-22	22	G	31S	24E	5725
ARCHIE MYERS DRILLING CO	BUENA VISTA LAKE WEST	WATER WELL	25	E	31S	24E	560
NORTH AMERICAN OIL CONS	BUENA VISTA HILLS	#35-32	32	B	31S	24E	5600
STANDARD OIL	MIDWAY	# 4106	33	G	31S	24E	4529
TEXACO INC		THOURNBER #A-10	34	N	31S	24E	4500

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KERN COUNTY LAND COMPANY	S. COLES LEVEE	KCL #38X-1	1	Z	31S	25E	10143
MJM&M OIL CO	S. COLES LEVEE	KCL #54-2	2	G	31S	25E	10050
UNION OIL COMPAMY	S. COLES LEVEE	KERNCO # 56-2	2	K	31S	25E	10096
RICHFIELD OIL CO	S. COLES LEVEE	SLC #32-3	3	C	31S	25E	10005
			3	D	31S	25E	1050
MARATHON		SCLU #12	3	D	31S	25E	9790
RICHFIELD OIL CORP	COLES LEVEE	2ND-B-14-3	3	E	31S	25E	9695
MARATHON		SCLU #67-4	4	Q	31S	25E	9881
OHIO OIL CO	S. COLES LEVEE	SCLU #74-5	5	Z	31S	25E	5998
ATLANTIC OIL COMPANY	S. COLES LEVEE	KCL #11	9	D	31S	25E	4200
CARR & WRATH		KCL #101	10	B	31S	25E	2200
HYLTON WATER WELL	BUENA VISTA PARK	#12A	14	L	31S	25E	749
J. G. BOSWELL	S. COLES LEVEE	ML #7	15	R1	31S	25E	965
THE OHIO OIL CO.	SOUTH COLES LEVEE	K.C.L.-F. U-15	15	Z	31S	25E	9748
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.# ML-2	16	A	31S	25E	1253
CROCKETT AND GAMBOGY	BUENA VISTA LAKE	31/25/16D	16	D	31S	25E	1375
CROCKETT AND GAMBOGY	BUENA VISTA LAKE	W.W.# ML-3	16	H	31S	25E	900
CROCKETT AND GAMBOGY	BUENA VISTA LAKE	M.L.#4	16	J?	31S	25E	1140
RICHFIELD OIL CO.	PALOMA	#78	24	R	31S	25E	11337
RICHFIELD OIL CO.	PALOMA	#72	25	A	31S	25E	11115
RICHFIELD OIL CO.	PALOMA	BVA#52	25	B	31S	25E	11178
RICHFIELD OIL CO.		BVA #61	25	B	31S	25E	11280
RICHFIELD OIL CO.	PALOMA	#41	25	C	31S	25E	13103
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.#16	26	A	31S	25E	1474
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.#7	26	C	31S	25E	1474
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.#10	26	D1	31S	25E	1476
TEXACO	PALOMA	BVA#1	26	E	31S	25E	11501
CROCKETT AND GAMBOGY	BUENA VISTA LAKE	WATER WELL	26	Z	31S	25E	1066
CROCKET AND GAMBOGY	BUENA VISTA LAKE	W.W.# 19	27	D	31S	25E	1476
U.S. BUREAU OF	PALOMA	31-25-27F1	27	F1	31S	25E	1000
E.A. BENDER	PALOMA	BVA#88	31	R	31S	25E	9510
BUTTES GAS & OIL CO.		BVF#1	35	A	31S	25E	10887
			36	A	31S	25E	1010

Data Base of wells available for Kern County Water Agency Regional Structure Study

RICHFIELD OIL CO.	BUENA VISTA LAKE	BVA #81		36	A	31S	25E	11329
STANDARD	N.W. PALOMA	BVA#52		36	B	31S	25E	5785
S.A. CAMP	OLD RIVER	W.W.# 7E2-1		2	J1	31S	26E	634
TENNECO	LAKESIDE	KCL#15		2	M	31S	26E	8893
S.A. CAMP	OLD RIVER	#7E-2-2		2	Z	31S	26E	644
JOHN MOLATORE	OLD RIVER AREA	WATER WELL	NE	3	A1	31S	26E	600
RICHFIELD OIL CORP	TEN SECTION AREA	OLD RIVER KCL 1		3	D	31S	26E	3815
TIDEWATER	OLD RIVER	KCL#86		3	J	31S	26E	10809
RICHARAD S. RHEEM	JAMES SLOUGH	KCL#31		4	C	31S	26E	8724
RICHFIELD OIL CO.	JAMES SLOUGH	KCL#1		6	M	31S	26E	10250
				9	B	31S	26E	1100
				13	Z	31S	26E	672
RICHFIELD	PALOMA	KCL "O"#18		14	N	31S	26E	12033
WESTERN GULF OIL COMPANY	PALOMA	KCL-NW#18-19		19	N	31S	26E	11288
KERN COUNTY LAND CO	PALOMA	#7E 20-1		20	C	31S	26E	624
HAMILTON DOME OIL CO.	PALOMA	KCL 'A'#23		20	F	31S	26E	10896
RICHFIELD OIL CO.	PALOMA	KCL-N#54		23	G	31S	26E	13252
				27	L	31S	26E	510
THE SUPERIOR OIL CO.	PALOMA AREA	W.W.#I-27		27	L1	31S	26E	515
WESTERN GULF OIL	PALOMA	#52		29	B	31S	26E	11576
WESTERN GULF OIL	PALOMA	#12		29	D	31S	26E	11244
WESTERN GULF OIL CO	PALOMA			29	Q	31S	26E	10990
OHIO OIL CO	PALOMA	MILLER& LUX #3		29	Z	31S	26E	10861
MARATHON	PALOMA	KCL-B#81		30	A	31S	26E	11408
MARATHON	PALOMA	KCL-B#41		30	C	31S	26E	11167
MARATHON	PALOMA	KCL-B#12		30	D	31S	26E	11376
MARATHON	PALOMA	KCL-B#23		30	E	31S	26E	10958
TENNECO	PALOMA	TOC 73X31		31	C	31S	26E	5800
OHIO OIL CO	PALOMA	KCL "N" 53-31		31	G	31S	26E	5620
TENNECO	PALOMA	MITCHELL KCL#201		31	J	31S	26E	5608
GENERAL PET CORP.	TUPMAN	#18		36	N	31S	26E	11549
COUNTY OF KERN	PUMPKIN CENTER	CURNOW YARD #1			H	31S	27E	320
BEATRICE FOOD CO.	PANAMA	#38-2		2	P	31S	27E	9529

Data Base of wells available for Kern County Water Agency Regional Structure Study

MEADOW GOLD FARMS	OLD RIVER AREA	K.C.L. 7 F 7-4	7	Z	31S	27E	722
ROCKY MOUNTIAN DRILLING	PANAMA SLOUGH	#78	9	R	31S	27E	13215
	OLD RIVER AREA	KCL 7F 19-2	19	DI	31S	27E	704
RIO COLORADO SEED LTD	OLD RIVER	#1	24	Z	31S	27E	616
SUNDANCE CATTLE		#1146	28	F	31S	27E	662
FREITAS FARMS	GREENFIELD	PERMIT 8823	6	C	31S	28E	680
THE TERMO OIL CO	LAMONT	TRM.-S.RAY#53X	12	G	31S	28E	13000
JAMES MATHIS	LAMONT	NEW WELL	13	Z	31S	28E	400
COSTERISAN FARMS	BEAR MOUNTAIN	PERMIT 8826	20	N	31S	28E	760
PORTER LAND CO`	WEEDPATCH	WATER WELL #1	23	A	31S	28E	1321
F AND K FRICK	WEEDPATCH	#3	26	Z	31S	28E	1355
FRANCES BAILEY	BAKERSFIELD	#1	28	A	31S	28E	800
EDMOND BESHARA	GREENFIELD	KARPE #1	29	D	31S	28E	5000
VALWOOD KARPE			29	Z	31S	28E	5000
HANK ROZENBERG	BAKERSFIELD		30	R	31S	28E	410
KERN COUNTY LAND COMPANY	KERN LAKE	7 G 31-4	31	E	31S	28E	702
DR. BURGER	WEST ARVIN	#1	31	R	31S	28E	500
EL RANCHO DE LOS PATOS		WATER WELL	33	Z	31S	28E	1106
DI GIORGIO	ARVIN AREA	WATER WELL 1-E	1	A1	31S	29E	1070
JERGINS OIL CO	EDISON AREA	BIGELOW #17	1	D	31S	29E	3030
V & C OIL CO.	ARVIN AREA	#1	1	Q	31S	29E	2091
DI GIORGIO FRUIT CORP	ARVIN	WATER WELL 2-E	2	M1	31S	29E	810
DI GIORGIO FRUIT CORP	ARVIN AREA	WATER WELL #3D	3	A2	31S	29E	780
DI GIORGIO FRUIT	SOUTH EDISON	WATER WELL 3C	3	C1	31S	29E	700
PATRICK A. DONENY	MT. VIEW	DI GIORGIO #1	3	G	31S	29E	4922
TERMINAL OIL CO	MT. VIEW	DI GIORGIO 1-3	3	P	31S	29E	500
DI GIORGIO FARMS		WATER WELL #4-A	4	J1	31S	29E	760
HOGAN PETROLEUM CO.	MT. VIEW	S.-B.#1 SYMONS	4	P	31S	29E	6967
MORTON N D'EVELYN OPR.	MT. VIEW	EARL FRUIT #5	4	Q	31S	29E	5981
MOHAWK PET. CORP	MT. VIEW	EARL FRUIT #4	4	Z	31S	29E	5446
	MT. VIEW	PETERS #4	5	H	31S	29E	5588
FLORENE PLEDGER	LAMONT	#1	5	R	31S	29E	484
HAZEL MOORE	LAMONT	#1	5	Z	31S	29E	517

Data Base of wells available for Kern County Water Agency Regional Structure Study

SECTION 6 OIL CO	MT. VIEW	JOHNSTON #1	6	D	31S	29E	6002
MT. VIEW SCHOOL DISTRICT	LAMONT	HALL&MRYTLE	6	F1	31S	29E	500
P. H. GREER	MT. VIEW	PERREL #2	9	B	31S	29E	5697
TIDE WATER ASSOC	ARVIN POOL AREA	TUPMAN#43-9	9	F	31S	29E	8704
DIGIORGIO FRUIT CORP		W.W.#10 A-3	10	A1	31S	29E	800
WESTERN GULF OIL CO.	MT. VIEW	DI GIORGIO #1	10	Z	31S	29E	6677
DIGIORGIO FRUIT CORP	EDISON	W.W.#11-AA	11	B1	31S	29E	1143
DI GIORGIO FRUIT CORP	ARVIN	# 11-A-3	11	D1	31S	29E	927
THE TEXAS COMPANY	ARVIN	DI GIORGIO "A" 2	11	E	31S	29E	4661
DI GIORGIO FARMS		W.W. 12-11-2	12	B1	31S	29E	930
DI GIORGIO FRUIT CORP	EDISON	DI GIORGIO 12-B	12	L1	31S	29E	1039
SUPERIOR ALMOND	ARVIN	BUENA VISTA RD	13	C	31S	29E	900
THE TEXAS COMPANY	KRAUTER	#2	14	M	31S	29E	6139
DEREY FARMS	EDISON	W.W.# 15-11	15	C3	31S	29E	804
APEX PETROLEUM CORP LTD.	MT. VIEW	CATTANI #5	15	N	31S	29E	6723
UNIVERSAL CONSOLIDATED	ARVIN	DERBY #1	15	Z	31S	29E	6173
STANDARD OIL CO	ARVIN	JEWETT COMM 2-4	16	A	31S	29E	4247
THE TEXAS COMPANY	ARVIN	JEWETT 2	16	B	31S	29E	3100
TIDEWATER	LAMONT	FRICK 22	16	D	31S	29E	9259
S.A. CAMP PUMP CO	WEED PATCH	FRICK WELL	16	F	31S	29E	816
STANDARD OIL CO	ARVIN	JEWETT COMM 2#8	16	J	31S	29E	6700
DIGIORGIO FRUIT	ARVIN AREA	W.W.#17A	17	Z	31S	29E	760
S.A. CAMP PUMP CO	WEEDPATCH	#2	19	D	31S	29E	326
STANDARD OIL CO	MT. VIEW ARVIN AREA	TUPMAN# 2	22	C	31S	29E	7567
GUIMARRA FARMS	ARVIN	PETERS#1	22	J	31S	29E	1025
HUGH S. JEWETT	ARVIN	W.W.#3	23	L2	31S	29E	1196
THE TEXAS COMPANY	NORTH ARVIN	GEORGE#19	23	Z	31S	29E	5650
LINDLEY C. MORTON	MT. VIEW	BARLOW #1	25	G	31S	29E	5942
GRIMMWAY FARMS	ARVIN	#1	25	Z	31S	29E	840
THE TEXAS COMPANY	ARVIN	ARVIN UNIT 3#4	26	A	31S	29E	6250
BRITISH AMERICAN OIL	MT. VIEW	ARVIN 8-14 26	26	D	31S	29E	7717
ARVIN HIGH SCHOOL	ARVIN	WATER WELL	26	E1	31S	29E	1202
BRITISH AMERICAN CAPITAL	MT. VIEW	ARVIN 47A-28	26	P	31S	29E	7944

Data Base of wells available for Kern County Water Agency Regional Structure Study

WOOD-CALLAHAN	ARVIN MT. VIEW	HOUCHIN #1	27	A	31S	29E	7354
			28	Z	31S	29E	
KERN COUNTY	ARVIN LANDFILL	ARVIN #1	31	C	31S	29E	137
KERN COUNTY	ARVIN	ARVIN# 1	31	D	31S	29E	125
KERN COUNTY	ARVIN	AR-1-03-9/87-W	31	E	31S	29E	122
KERN COUNTY	ARVIN	ARVIN # 2	31	Z	31S	29E	125
BRITISH AMERICAN OIL PROD	ARVIN	KOVACEVICH	35	B	31S	29E	7551
DI GIORGIO FRUIT CORP		W.W. #36-S-5	36	B2	31S	29E	820
CHARLES MALOVICH	ARVIN	#1	36	D	31S	29E	905

Number of wells in this Township 157

Township 32S

Company	Field	Well No.		Sec.	Loc. Ltr.	T	R	Log Depth
STANDARD OIL CO. OF	BUENA VISTA HILLS	1C-2-8A		1	M	32S	23E	3265
NORTH AMERICAN CONS OIL	BUENA VISTA HILLS	#41-2		2	Z	32S	23E	4086
OCEANIC OIL CO	MIDWAY	D-1-7		7	Z	32S	23E	3556
OCEANIC OIL COMPANY	MIDWAY	GEN.AMER.#76-X		16	Z	32S	23E	4336
MILLERFRAX	BUENA VISTA	H.M.#1	HAROLD	24	R	32S	23E	914
NATIONAL OIL CO.	MIDWAY	GOVT # 41		25	Z	32S	23E	1710
GENERAL PETROLEUM CORP.	BUENA VISTA AREA	B.V.A. #1		1	N	32S	24E	11686
NORTH AMERICAN OIL CO.	BUENA VISTA HILLS	#6-2		2	E	32S	24E	3862
STANDARD OIL CO OF CALIF	BUENA VISTA HILLS	#429 - 7D		7	D	32S	24E	2473
HONOLULU OIL COMPANY	MIDWAY-SUNSET	10-25-P		10	M	32S	24E	12825
STATE OF CALIFORNIA, DWR	BUENA VISTA HILLS	BV-1106		12	B1	32S	24E	135
STATE OF CALIFORNIA, DWR	BUENA VISTA	BV-1107		12	G1	32S	24E	190
STATE OF CALIFORNIA, DWR	BUENA VISTA HILLS	BV-1108		12	G3	32S	24E	228
MURVALE OIL CO	MIDWAY-SUNSET	#46		20	D	32S	24E	2100
MURVALE OIL CO.	MIDWAY SUNSET	#56-20		20	Z	32S	24E	2300
CHEVRON U.S.A. INC.	MIDWAY SUNSET	#6		21	D	32S	24E	3342
CHAS. JACOBSON VISTA	B.V. HILLS	G.P.-V. G. #1		22	A	32S	24E	8153
STATE OF CALIFORNIA	SANDY CREEK	32S-24E-26A		26	A1	32S	24E	625
EXETER OIL COMPANY	MIDWAY SUNSET	MURPHY FEE 13 J		28	N	32S	24E	6000
CHEVRON U.S.A., INC.	MARICOPA	#1-35D		35	N	32S	24E	850

Data Base of wells available for Kern County Water Agency Regional Structure Study

DEPT OF WATER RESOURCES		OBS. W.#36L1	36	L1	32S	24E	242
			1	H1	32s	25E	
ROBERTSON DRILLING	GARDNER FIELD AREA	WATER WELL	2	Z	32s	25E	675
WESTERN GULF OIL CO	BUENA VISTA	BVA#18-3	3	N	32S	25E	12464
MONTEREY OIL CO	BUENA VISTA	INDIAN OIL	7	L	32S	25E	6050
SHELL OIL CO.	BUENA VISTA LAKE	B.V. A. #1	9	M	32S	25E	6112
GETTY OIL COMPANY	BUENA VISTA	BVA#22	11	D	32S	25E	11374
BUENA VISTA FARMS	BUENA VISTA	# 27	13	R	32S	25E	1215
SEABOARD OIL CO	B.V. LAKE BED	#73-14	14	H	32S	25E	12558
FERGUSON AND BOSWORTH	BUENA VISTA HILLS	BVA#1	15	A	32S	25E	10493
FERGUSON AND BOSWORTH	BUENA VISTA	BVA#142	16	H	32S	25E	8086
DEPT OF WATER RESOURCES	BUENA VISTA LAKE	#P1	16	P1	32S	25E	745
			25	Q	32S	25E	1010
SINCLAIR OIL & GAS	BUENA VISTA	E. JOHNSON #1	28	C	32S	25E	12548
			29	N2	32S	25E	1000
GENE REID DRILLING CO.	BUENA VISTA HILLS	DOUGHERTY #1	30	M	32S	25E	5947
			31	B	32S	25E	960
J. T. HERROD	GARDNER FIELD	W.W.#1	32	Z	32S	25E	1010
STANDARD OIL LAND CO.	GARDNER FIELD	FRICK # 2	35	N2	32S	25E	1650
KERN COUNTY LAND CO	SAN JOAQUIN VALLEY	#882-4	2	Z	32S	26E	875
OHIO OIL COMPANY	PALOMA	KCL #B 3	3	Z	32S	26E	10288
			4	Q	32S	26E	1180
STANDARD OIL CO.	PALOMA	KCL#43-57	4	Q	32S	26E	10336
TEXACO, INC.	PALOMA	KCL#1	6	K	32S	26E	12701
HUMBLE OIL & REFINING CO.	PALOMA	KCL #54-9	9	G	32S	26E	11467
SUPERIOR	PALOMA	ST. SURE# 27X-11	11	N	32S	26E	10372
WESTERN GULF OIL	PALOMA UNIT	#32	12	C	32S	26E	11104
WESTERN GULF OIL CO.	PALOMA	P.U.# 54-12	12	G	32S	26E	11304
UNION OIL CO	PALOMA	MORGAN# 81-14	14	A	32S	26E	11456
BONANZA FARMS	BUENA VISTA LAKE	# 3 REPLACEMENT	16	E	32S	26E	1020
	PALOMA	#3	16	G	32S	26E	1573
CHEVRON			17	Z	32S	26E	1050
4 H FARMS	BUENA VISTA	8908	18	K	32	26E	943

Data Base of wells available for Kern County Water Agency Regional Structure Study

4 H FARMS	BUENA VISTA	#89-19	18	K Q	32S	26E	849
TRI-SERVICE DRILLING	S. PALOMA	COOPER#1	21	B	32S	26E	1406
ROCKY MT. DRILLING	S. PALOMA	MOHAWK#1	24	D	32S	26E	13604
			25	P	32S	26E	2100
			27	B	32S	26E	1484
ANDREWS BROS OF			28	Z	32S	26E	1040
FERGUSON & BOSWORTH	S. PALOMA	SHELL-FEE #1	30	A	32S	26E	13612
	SAN EMIGDIO	THOMPSON #2	31	P1	32S	26E	1505
	SAN EMIGDIO	FRICK #1	33	N1	32S	26E	1560
C.J. SANDERS	LAKEVIEW	WATERWELL #1	35	N1	32S	26E	2412
PARKS BROS EVANS	LAKEVIEW AREA	#2	36	P2	32S	26E	1820
			4	J	32S	27E	600
KERN COUNTY LAND COMPANY	KERN LAKE	#8 F 4	4	L	32S	27E	710
LAYNE-WESTERN CO	BUENA VISTA	L.A. ATHLETIC CLUB	6	E	32S	27E	902
HUMBLE OIL & REFINING		KCL J-1	8	N	32S	27E	1040
ATLANTIC OIL CO	S.E PALOMA	KCL #83-12	17	H	32S	27E	2050
HUMBLE OIL & REFINING CO.	PALOMA	KCL (41-18) #2	18	C	32S	27E	12333
KENNETH DUFF	OLD RIVER-HERRING	#1	20	Z	32S	27E	805
KENNETH DUFF	OLD RIVER/ HERRING	#1	20	Z	32S	27E	425
			21	A	32S	27E	15360
ATLANTIC OIL CO.		GEN. PET.#71	21	A	32S	27E	1350
PARKS BROS AND GARLOW	LAKEVIEW AREA	STANDARD #1	35	R1	32S	27E	1210
KERN COUNTY LAND COMPANY	KERN LAKE	W.W. 8F 36-1	36	F1	32S	27E	216
S.A.CAMP PUMP CO	ARVIN	SKI WEST #2	1	D	32S	28E	858
RANDY HEINRICK-TERRY RAYE	ARVIN		1	F	32S	28E	847
S.A. CAMP PUMP CO.	ARVIN	KD AQUA FARMS	2	K	32S	28E	826
J. H. SMITH	ADOBE ROAD AREA	W.W.# 3	4	H	32S	28E	960
KERN COUNTY LAND CO		8-G 6-4	6	Z	32S	28E	950
THOMAS P. MENZIES	MENZIES RANCH	WATER WELL	10	R1	32S	28E	745
SIG HOFFMAN	ARVIN	IRRIG. WELL	15	J	32S	28E	827
TENNECO WEST	BRAVO RANCH	#8G 22-4	22	R	32S	28E	1050
GEORGE NOROIAN (KCWA	ARVIN	#88-52	25	F	32S	28E	1000
NOROIAN FARMS	LAMONT	PERMIT #87-36	27	B	32S	28E	1000

Data Base of wells available for Kern County Water Agency Regional Structure Study

			28	H	32S	28E	1386
			29	Z	32S	28E	1500
U.S. BUREAU OF		32-28-30D	30	D	32S	28E	1460
WHEELER FARMS	METTLER STATION	W.W.#4	30	H2	32S	28E	2805
S.A. CAMP PUMP CO.	MERIDIAN	PERMIT #84-57	34	D	32S	28E	1030
CHAPARRAL PET .INC	SANDHILLS	#75	34	J	32S	28E	7941
SIGNAL OIL & GAS CO.		MITCHELL #11X	3	D	32S	29E	12826
S.A. CAMP PUMP CO.	ARVIN	QUMARN INVEST. N.V.	4	K	32S	29E	832
MITCHELL BROS.	ARVIN	W.W. #94	4	R	32S	29E	1315
NEWSTONE CORP.	ARVIN		7	H	32S	29E	922
L.W. FRICK & SONS	ARVIN	W.W. #1	7	R1	32S	29E	1198
ERBERT AND BRANDT		#1	9	N	32S	29E	16614
POMEROY AND JEWETT	ARVIN	W.W.#7	10	H	32S	29E	1504
W.B. CAMP RANCH	ARVIN	#7-5A	11	G	32S	29E	1005
POMEROY & JEWETT		W.W.# 6	11	J	32S	29E	1187
OCCIDENTAL PETROLEUM	COMANCHE LAND	#45X	11	L	32S	29E	12737
POMEROY AND JEWETT	S. ARVIN	W.W.# 8	11	N1	32S	29E	1005
POMROY JEWETT	ARVIN	W.W. #5	11	P1	32S	29E	1014
GULF WEST CORPORATION	ARVIN	#1	12	B	32S	29E	700
CHEVRON USA INC	TEJON	CORE H. #2	13	K	32S	29E	2590
LEE HERRING	ARVIN	WATER WELL	14	F1	32S	29E	972
ARVIN-EDISON WSD	TEJON WELL FIELD	AE #78 -15N1	15	N1	32S	29E	1040
ARVIN-EDISON WSD	TEJON WELL FIELD	AE #79-15P2	15	P2	32S	29E	1045
U. S. BUREAU OF	SO. WEEDPATCH	32-29-19A	19	A	32S	29E	1000
ARVIN EDISON WSD	TEJON WELL FIELD	A.E. #74 -21G	21	G	32S	29E	1083
		REX-ROTH#83	21	H	32S	29E	11738
ARVIN EDISON WSD	TEJON WELL FIELD	A.E. #75	21	H1	32S	29E	1100
ARVIN EDISON WSD	TEJON WELL FIELD	A.E. #73 -22C	22	C	32S	29E	1087
ARVIN EDISON WSD	TEJON WELL FIELD	A.E. #77 -22D1	22	D1	32S	29E	1040
GLEN HERRING	TEJON HILLS	WW #2	22	F1	32S	29E	1463
WHITE WOLF ASSOC.	TEJON	#43	23	F	32S	29E	1696
INTEX OIL CO.	TEJON	#2	23	G	32S	29E	1175
CCMO	COMANCHE POINT	TEJON RANCH #2	23	H	32S	29E	1282

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			23	N	32S	29E	2000
GENE REID DRILLING CO	COMMANCHE PT.	TEJON #3	25	F	32S	29E	1031
OIL SCOUT INC	COMANCHE POINT	#1	27	E1	32S	29E	5505
SUPERIOR FARMING CO		# 10F 209-10 TEST	27	L	32S	29E	1320
HADDAD FARMS	SW ARVIN	#81-13	30	F	32S	29E	1020
CARLA STAFFORD LEWIS	COMANCHE POINT	CARFRAN #1	35	Z	32S	29E	2910
HENRY LUBKING ASSOCIATES	COMANCHE POINT	#1	36	F	32S	29E	1045
L.C. GOULD	TEJON RANCH	#36-1	36	K	32S	29E	1244
B.C. MACKEY	COMANCHE POINT	COLLINS#1	31	F	32S	30E	714
LEROY C GOULD	TEJON HILLS	TEJON #31-1	31	N	32S	30E	1861
B.C. MACKEY	TEJON HILLS	TEJON CREEK#1	31	P	32S	30E	846

Number of wells in this Township 130

Useful for characterizing shallower than 2,000 feet.

PLATE I

KERN COUNTY WATER AGENCY
REGIONAL GEOLOGIC STRUCTURE STUDY

STRUCTURAL FORM MAP

Changing Contour Horizon on Shallowest Mappable Seismic Reflector

CONTOUR INTERVAL = 100 FEET

Kern County, California

Pacific Geotechnical Associates, Inc.

Author:
Project: KWA P.O. 10376
Drafted By: PGA
Date:

Base of E Clay?

0.53":4240'
0.74":5920'
42.4/59.2=71' dis
1":8000'

0.7":5600'
0.5":4000'
40/56=71' dis
1":8000'

0.14":1120'
0.66":5280'
1120/52.8=21' dis
1":8000'

0.8":6400' 100'
1":8000'
80/64=125' dis
1":8000'

0.4":3200' 50-60' dis
0.8":6400' 100'
1":8000'

Top of Pliocene Etchegoin?

Base of Tulare?

Top of Pliocene Etchegoin.

Top of Pliocene Etchegoin.

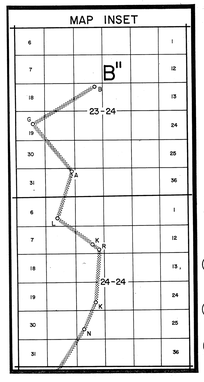
SEE MAP INSET

A — A' — A" — B — B' — B" — C — C'

DELANO
McFARLAND
WASCO
SHAFTER
BAKERSFIELD
ARVIN
LAMONT
GREENFIELD
FELLOWS
FORD CITY
TAFT
MARICOPA
MAXWELL
BUTTONWILLOW
McKITTRICK
LOST HILLS
TEMBLOR HILLS
SAN LUIS OBISPO COUNTY
CALIFORNIA
KERN WILDLIFE REFUGE
BOND FAULT ZONE
EDISON FAULT
WHITE WOLF FAULT
TEHACHAPI MOUNTAINS
SPRINGS FAULT
BUENA VISTA LAKE BED
KERN LAKE BED
CROSS VALLEY CANAL
WHEELER RIDGE PUMPING PLANT
WING GAP PUMPING PLANT
Rancho San Emidio
Ranchos Los Alamos Y Agua Caliente

T25S R17E … T25S R28E
T26S R17E … T26S R28E
T27S R18E … T27S R28E
T28S R18E … T28S R28E
T29S R20E … T29S R28E
T30S R22E … T30S R30E
T31S R22E … T31S R30E
T32S R23E … T32S R30E
T11N R24W … T11N R17W
T10N R24W … T10N R17W

MAP INSET



LEGEND

CONTOUR HORIZON CHANGE

C.I. = 100 FEET

FAULT U D

CROSS SECTION

(C) CONTOURS ON APPROXIMATE BASE "E" EQUIVALENT OR "CORCORAN" CLAY.

(T) CONTOURS ON APPROXIMATE BASE TULARE FM.

(E) CONTOURS ON APPROXIMATE TOP ETCHEGOIN FM.

FOOTHILL LINE
BEDROCK LINE
GROUND WATER BARRIER
CALIFORNIA AQUEDUCT AND TURNOUTS

KCWA BASE MAP LEGEND



MAP SCALE

1" = 8000'

FEET 0 8000 16000 24000 32000 40000

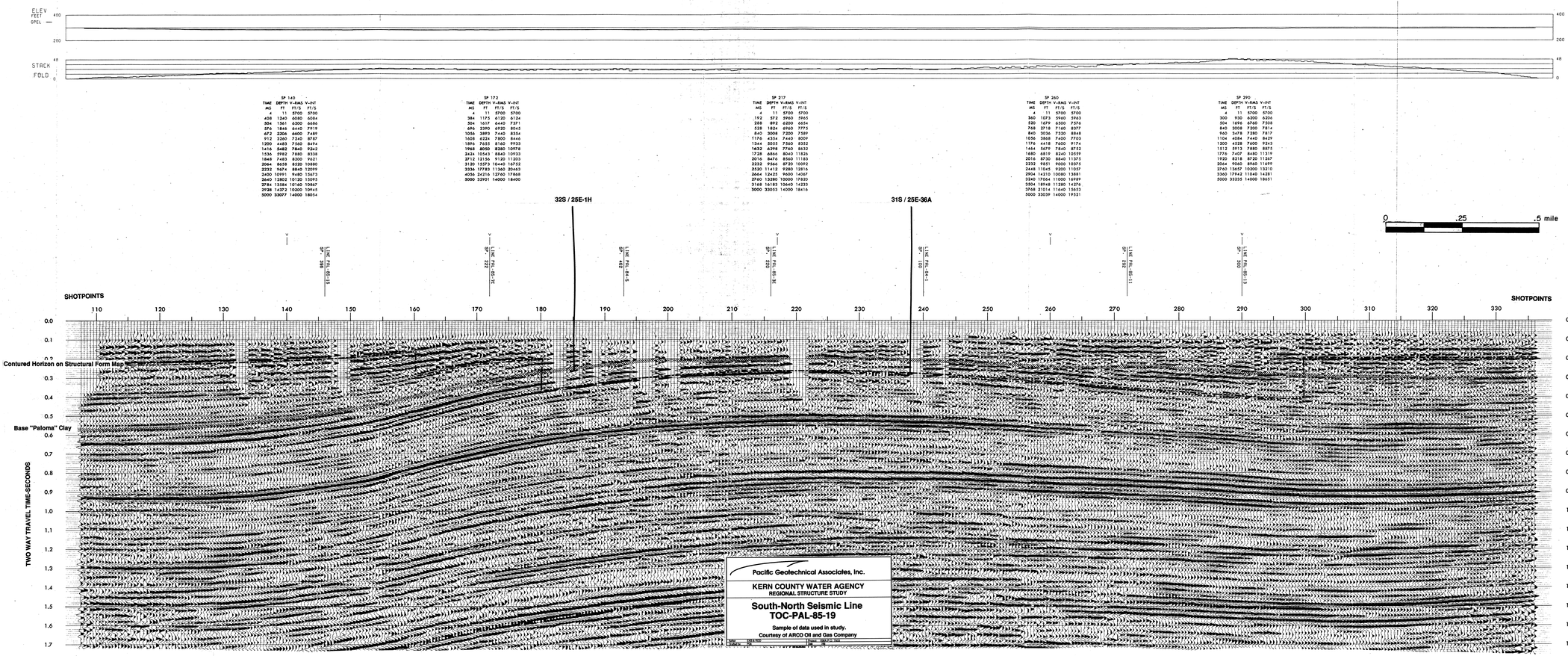
MILES 0 1 2 3 4 5 6 7

EXPLANATION

This map shows structure form contours (subsea depth) from various seismic reflectors and represents the present structural setting of the sediments in the southern San Joaquin Valley. The structural trends have been identified by selecting the most continuous seismic events present over broad areas of the valley. The methodology is detailed in the report: STUDY OF THE REGIONAL GEOLOGIC STRUCTURE RELATED TO GROUNDWATER AQUIFERS IN THE SOUTHERN SAN JOAQUIN VALLEY GROUNDWATER BASIN, SOUTHERN KERN COUNTY, CALIFORNIA.

This map was constructed using an integrated approach utilizing seismic data and well data for velocity control. The seismic data set was made available generously by ARCO Oil and Gas Company through an agreement with the Kern County Water Agency.

PLATE II



Seiscom Delta United

Line: TOC-PAL-85-19
Shotpoints: 114-337
Area: PALOMA
Location: KERN CO., CALIFORNIA
Client: TENNECO OIL
N
Process: FINAL STRUCTURE - AGC

(017)

Acquisition: PRAIRIE EAGLE EXPLORATION

PARTY NUMBER: V601
DATE: DECEMBER 1984

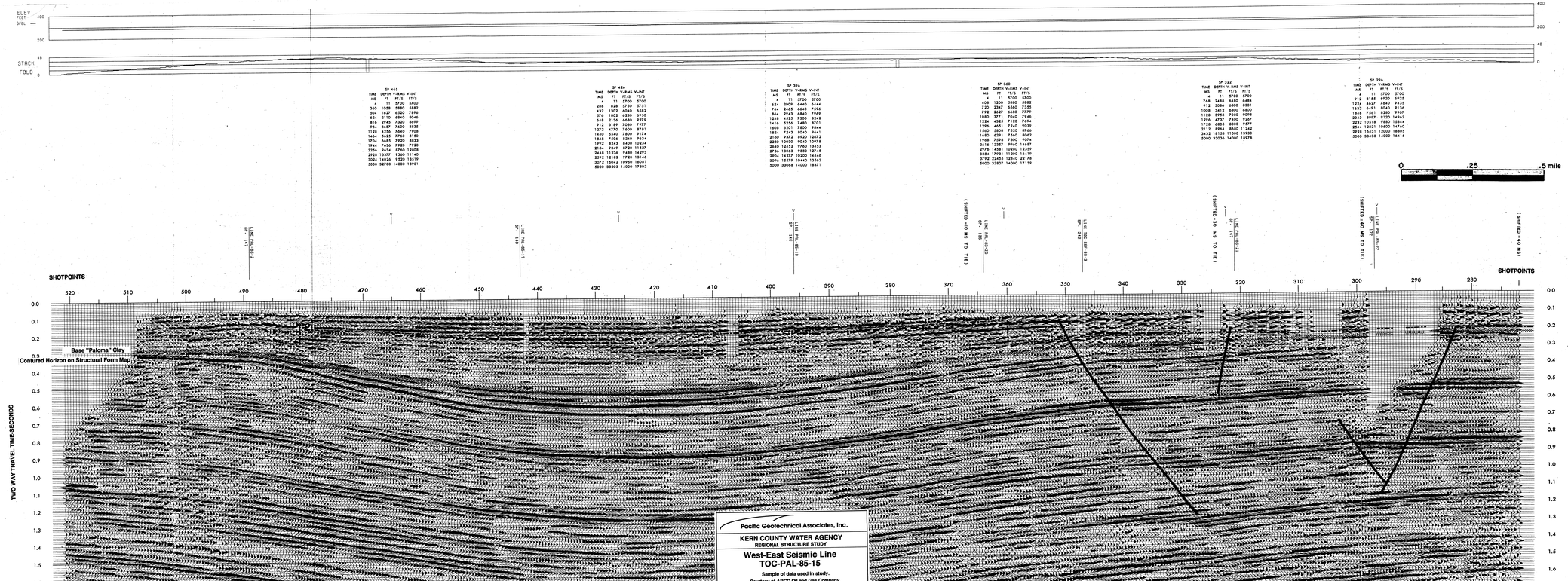
ENERGY SOURCE:			
type	VIBROSEIS		
direction of shooting	N		
shotpoint interval	220 ft		
source array	4 vibs inline		
sweep frequency	12–64 Hz		
sweep length	16 sec.		
RECEIVING ARRANGEMENT:			
fold of recording	24	type	off end
no. of groups	96	interval	110 ft
cable length	10450 ft		
near trace	1	offset	440 ft
far trace	96	offset	10890 ft
INSTRUMENTATION:			
geophones	MARK L21A		
recording system	MDS 10		
gain type	FP		
filters: low cut	9 Hz	slope	18 dB/octave
high cut	62.5 Hz	slope	72 dB/octave
record format	SEGB		
record length	21 sec		
sample interval	4 ms		

PROCESSING: SEISCOM DELTA UNITED

CENTER: BAKERSFIELD, CALIFORNIA
COMPUTER SYSTEM: MEGASEIS
DATE: MARCH 1985

INITIAL PROCESS:	
demultiplex	
Vibroseis correlation	
sample interval	4 ms
PULSE COMPRESSION:	
statistical wavelet shaping	
DATUM STATICS:	
datum	240 ft
datum velocity	3000 ft/sec
DECONVOLUTION BEFORE STACK:	
deconvolution type	predictive
operator length	124 ms
prediction lag	36 ms
VELOCITY ANALYSES:	
velocities computed	from Seiscom's Dove Velocity Spectra before and after DEWL
DEWL:	
surface consistent statics adjustment	
TRACE AMPLITUDE BALANCING:	
STACK:	
type	standard CDP
fold	24
FILTER:	
apply times, beginning at SP 114	
A) 2000 ms	18–64 Hz
B) 4000 ms	14–36 Hz
DISPLAY SYSTEM: SEISCHROME II	
type	trace equalized
vertical scale	5 inches/sec
horizontal scale	12 traces/inch
peaks represent	positive digital numbers
QUALITY CONTROL:	APPROVED:

PLATE III



Seiscom Delta United

Line: TOC-PAL-85-15
Shotpoints: 505-270
Area: PALOMA
Location: KERN CO., CALIFORNIA
Client: TENNECO OIL
Process: FINAL STRUCTURE – AGC

Acquisition: PRAIRIE EAGLE EXPLORATION

PARTY NUMBER: V601 DATE: FEBRUARY 1985

ENERGY SOURCE:
- type: VIBROSEIS
- direction of shooting: W
- shotpoint interval: 220 ft
- source array: 4 vibs inline
- sweep frequency: 12-64 Hz
- sweep length: 16 sec.

RECEIVING ARRANGEMENT:
- fold of recording: 24 type off end
- no. of groups: 96 interval 110 ft
- cable length: 10450 ft
- near trace: 1 offset 440 ft
- far trace: 96 offset 10890 ft

INSTRUMENTATION:
- geophones: MARK L21A
- recording system: AIDS 10
- gain type: IFP
- filters: low cut: 9 Hz slope 18 dB/octave
- high cut: 62.5 Hz slope 72 dB/octave
- record format: SEGB
- record length: 21 sec
- sample interval: 4 ms.

PROCESSING: SEISCOM DELTA UNITED

CENTER: BAKERSFIELD, CALIFORNIA DATE: APRIL 1985
COMPUTER SYSTEM: MEGASEIS

INITIAL PROCESS:
- demultiplex
- Wavelets correlation
- sample interval: 4 ms

PULSE COMPRESSION:
- statistical wavelet shaping

DATUM STATICS:
- datum: 240 ft
- datum velocity: 3000 ft/sec

DECONVOLUTION BEFORE STACK: predictive
- deconvolution type
- operator length: 124 ms
- prediction lag: 36 ms

VELOCITY ANALYSES:
- velocities: from Seiscom's Dove Velocity Spectra
- computed: before and after DEWL

DEWL:
- surface consistent statics adjusted

TRACE AMPLITUDE BALANCING:

STACK:
- type: standard CDP
- fold: 24

FILTER:
- apply times, beginning at SP 505
- A) 2000 ms 18-64 Hz
- B) 4000 ms 14-36 Hz

DISPLAY SYSTEM: SEISCHROME II
- type: trace equalized
- vertical scale: 5 inches/sec
- horizontal scale: 12 traces/inch
- peaks represent: positive digital numbers

QUALITY CONTROL: APPROVED:

A

N

S

A'

INTERSECTION WITH B - B' B'- B''

INTERSECTION WITH A'-A'' C - C'

T25S R21E 5B

T25S R21E 8A

T25S R21E 17R

T26S R21E 5A

T26S R21E 14G

T27S R22E 7D

T27S R22E 22F

T27S R22E 33H

T28S R22E 9B

T28S R22E 9R

T28S R22E 15M

T28S R22E 22D

T28S R22E 28G

T28S R22E 35G

T29S R22E 12B

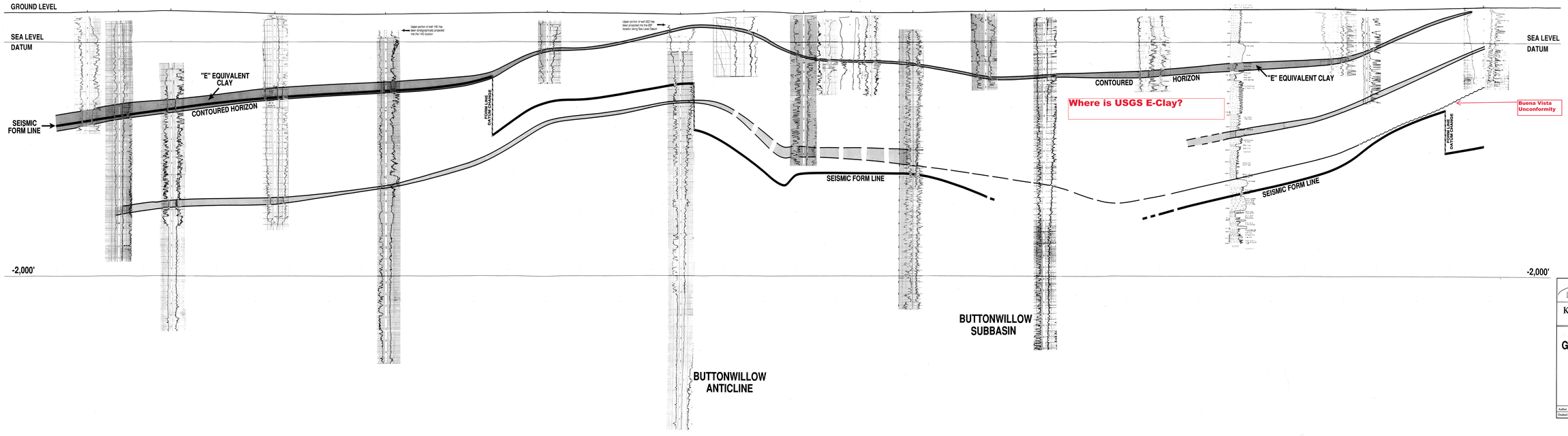
T29S R23E 16Z

T29S R23E 26A

T29S R24E 32K

T30S R24E 4C

T30S R24E 12H



SCALE

500'

15:1 Vertical Exaggeration

0

0 6,000'

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

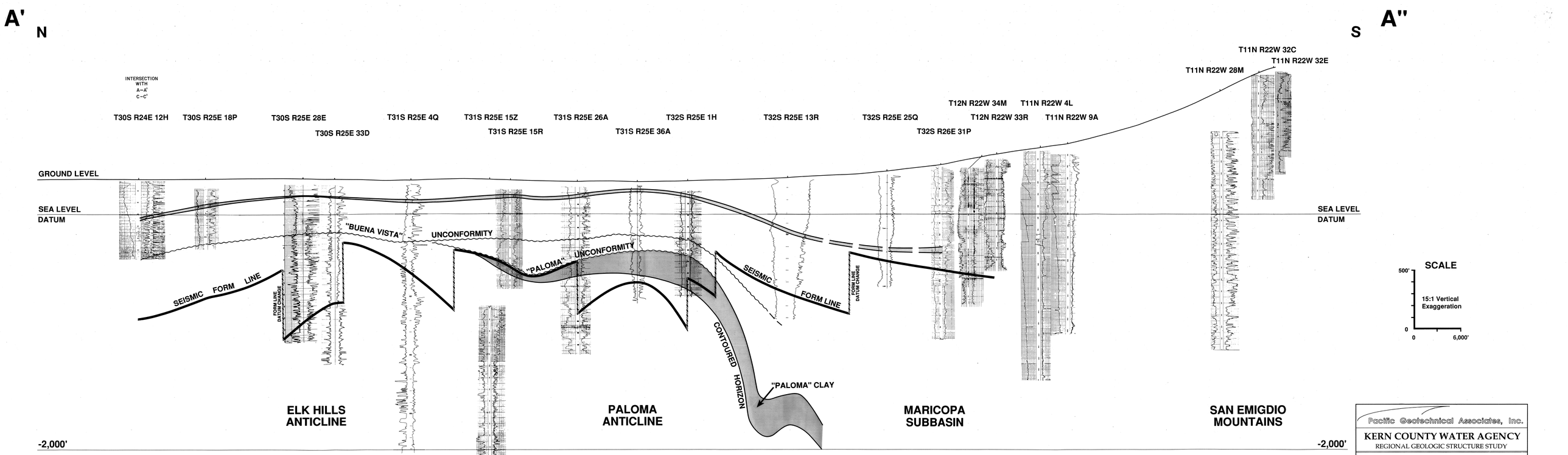
GEOLOGIC CROSS SECTION

A - A'

Kern County, California

Author: PGA	Project: KWA P.O. 1076
Drafted By: PGA	Date: 6/91

PLATE IV



Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

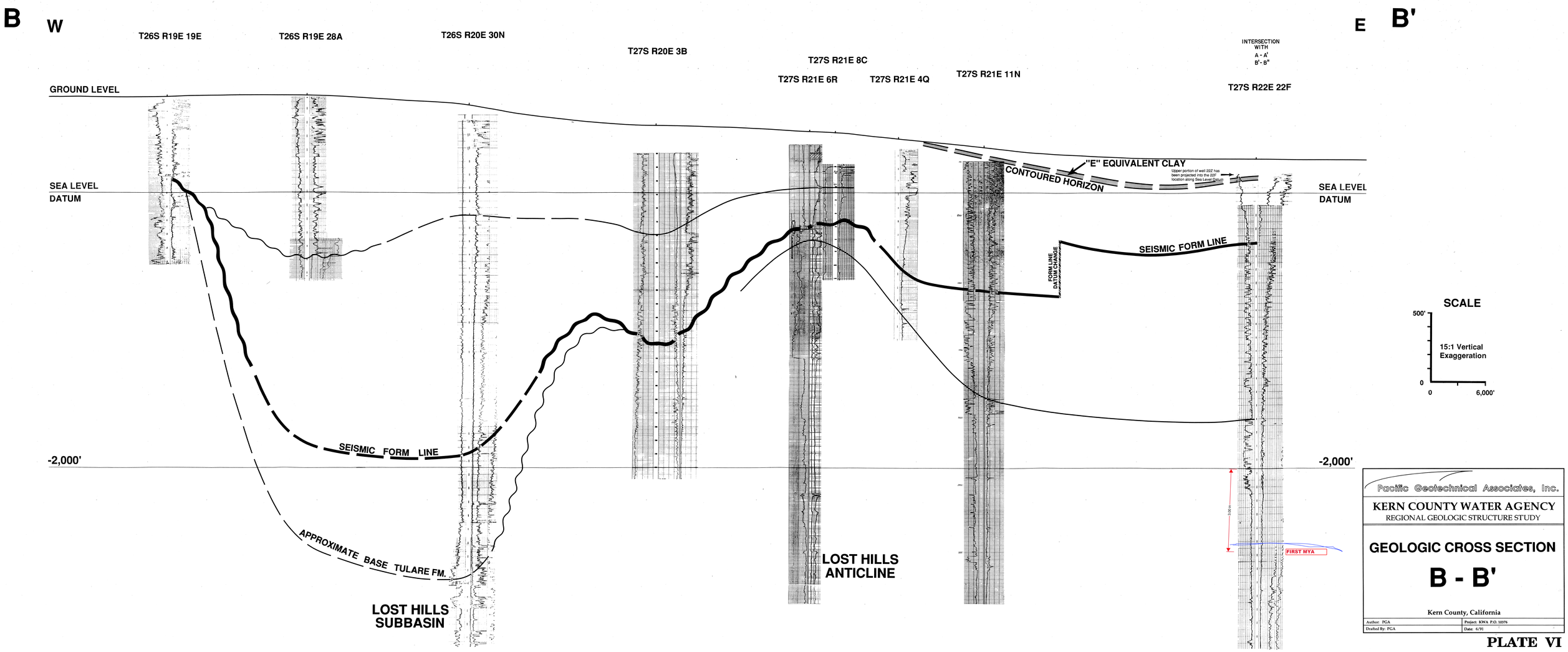
GEOLOGIC CROSS SECTION

A' - A"

Kern County, California

Author: PGA	Project: KWA P.O. 10576
Drafted By: PGA	Date: 6/91

PLATE V



Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY
REGIONAL GEOLOGIC STRUCTURE STUDY

GEOLOGIC CROSS SECTION
B - B'

Kern County, California

Author: PGA	Project: KWA P.O. 10376
Drafted By: PGA	Date: 6/91

PLATE VI

B' SW

INTERSECTION WITH A-A' B-B'

KERN COUNTY | TULARE COUNTY

NE B"

T27S R22E 22F | T27S R22E 11K | T27S R22E 1D | T26S R22E 25H | T26S R23E 18Z | T26S R23E 8N | T26S R23E 4F | T25S R23E 35A | T25S R23E 24F | T25S R24E 7C | T25S R24E 6H | T24S R24E 28N | T24S R24E 21K | T24S R24E 9R | T24S R24E 9K | T24S R24E 5L | T23S R24E 32A | T23S R24E 19G | T23S R24E 16B

TYPE WELL FOR "E" EQUIVALENT CLAY

GROUND LEVEL

SEA LEVEL DATUM

Upper portion of well 222 has been projected into the 22F location along Sea Level Datum

USGS E-Clay -156 ft msl
C2VS E-Clay -127 ft msl

USGS E-Clay -100 ft msl

FORM LINE DATUM SURFACE

SEISMIC FORM LINE

Upper portion of well 1S/25E-9Q03 has been projected into the 11K location along Sea Level Datum

USGS E-Clay -60 ft msl

CONTOURED HORIZON

Upper portion of well 1S/25E-4D01 has been projected into the 1D location along Sea Level Datum

USGS E-Clay -60 ft msl

Upper portion of well 182 has been projected into the 25H location along Sea Level Datum

USGS E-Clay -27 ft msl
C2V E-Clay -43 ft msl

"E" EQUIVALENT CLAY

CONTOURED HORIZON

USGS E-Clay -3 ft msl

USGS E-Clay 30 ft msl
C2V E-Clay 18 ft msl

Upper portion of well 242 has been straigraphically projected into the 24F location

USGS E-Clay 20 ft msl

SEISMIC FORM LINE

CONTOURED HORIZON

"E" EQUIVALENT CLAY

SEA LEVEL DATUM

-2,000'

10 inches = 2,000 feet
1 inch = 200 feet

1 inch = 200 feet

1.5 inch = 300 feet

B-E, 1998, First MYA 2600 ft

2200 ft

B-E, 1998, First MYA

2800 ft

2400 ft

2300 ft

B-E, 1998, First MYA

-2,000'

SEMITROPIC ANTICLINE

TRICO ANTICLINE

SCALE

500'

15:1 Vertical Exaggeration

0

0 6,000'

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY
REGIONAL GEOLOGIC STRUCTURE STUDY

GEOLOGIC CROSS SECTION

B' - B"

Kern County, California

Author: PGA	Project: KWA P.O. 10576
Drafted By: PGA	Date: 6/97

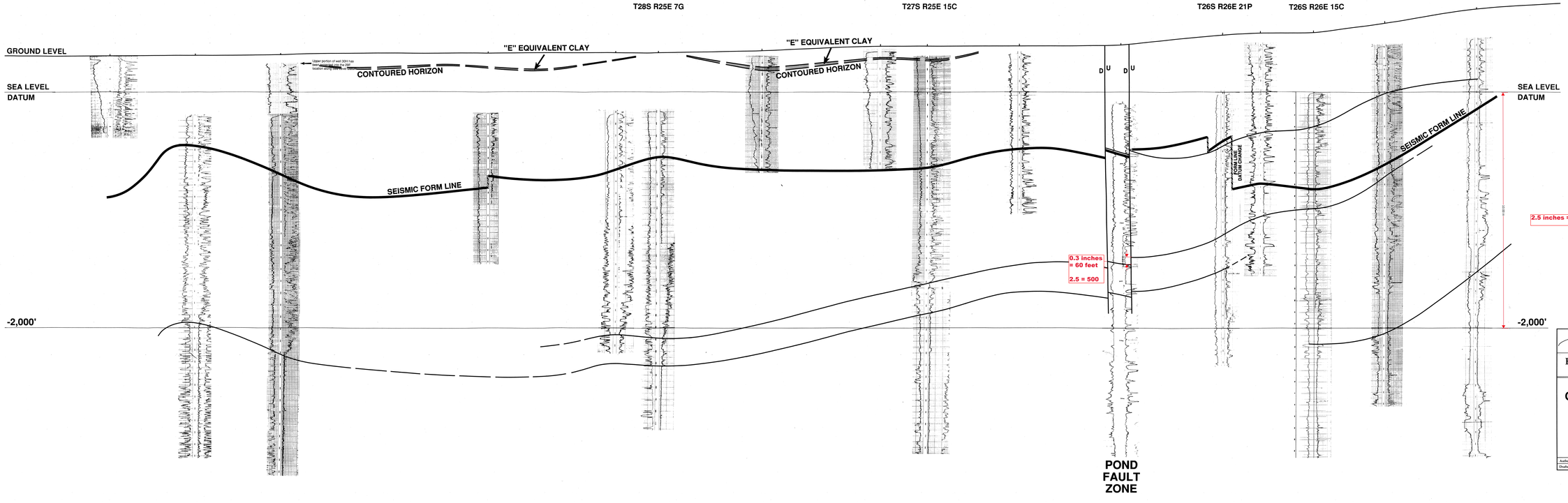
PLATE VII

C

SW

INTERSECTION WITH A – A' A' – A"

T30S R24E 12H | T30S R25E 5B | T29S R25E 29F | T28S R25E 31G | T28S R25E 18G | T28S R25E 7G | T27S R25E 32A | T27S R25E 22A | T27S R25E 15C | T27S R25E 1N | T26S R26E 30M | T26S R26E 22E | T26S R26E 21P | T26S R26E 15C | T26S R26E 11H | T26S R27E 8D



SCALE

2.5 inches = 500 feet

15:1 Vertical Exaggeration

0 6,000'

C'

NE

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL GEOLOGIC STRUCTURE STUDY

GEOLOGIC CROSS SECTION

C - C'

Kern County, California

Author: PGA	Project: KWA P.O. 10576
Drafted By: PGA	Date: 6/95

PLATE VIII

KERN COUNTY WATER AGENCY
REGIONAL GEOLOGIC STRUCTURE STUDY

STRUCTURE CONTOUR MAP
BASE "E" EQUIVALENT CLAY

NOTE: As defined in well 23S/24E-16B at a measured depth of 550 feet.

Integrated Well and Seismic Interpretation

CONTOUR INTERVAL = 100 FEET

Kern County, California

Pacific Geotechnical Associates, Inc.

Author: | Project: KWA P.O. 10376

Drafted By: PGA | Date:

0.11":880'
1.17":9360'
8.8/93.6'=10' dis

0.14":1120'
0.67":5360'
11.2/53.6=21' dis

1":8000'

0.21":1680'
1.25":10000'
16.8/100=17' dis
1":8000'

SEE MAP INSET B"

A

A'

B

B'

C

C'

SAN LUIS OBISPO COUNTY

KERN COUNTY

DELANO

McFARLAND

WASCO

SHAFTER

BAKERSFIELD

ARVIN

LAMONT

GREENFIELD

FELLOWS

FORD CITY

TAFT

MARICOPA

MAXTON

TUPMAN

McKITTRICK

BUTTONWILLOW

LOST HILLS

KERN WILDLIFE REFUGE

DEVILS DEN

TEMBLOR HILLS

POSO CREEK

KERN RIVER

BUENA VISTA LAKE BED

KERN LAKE BED

BUENA VISTA PUMPING PLANT

WHEELER RIDGE PUMPING PLANT

WIND GAP PUMPING PLANT

Ranchos Los Alamos Y Agua Caliente

Rancho San Emidio

TEHACHAPI MOUNTAINS

SAN EMIDIO NOSE

POSO CREEK FAULT

EDISON FAULT

LOST HILLS FAULT

POND-MAXTON FAULT ZONE

WHITE WOLF FAULT

SPRINGS FAULT

CALIFORNIA AQUEDUCT

T25S R17E | T25S R18E | T25S R19E | T25S R20E | T25S R21E | T25S R22E | T25S R23E | T25S R24E | T25S R25E | T25S R26E | T25S R27E | T25S R28E

T26S R17E | T26S R18E | T26S R19E | T26S R20E | T26S R21E | T26S R22E | T26S R23E | T26S R24E | T26S R25E | T26S R26E | T26S R27E | T26S R28E | T26S R29E

T27S R18E | T27S R19E | T27S R20E | T27S R21E | T27S R22E | T27S R23E | T27S R24E | T27S R25E | T27S R26E | T27S R27E | T27S R28E | T27S R29E | T27S R30E

T28S R18E | T28S R19E | T28S R20E | T28S R21E | T28S R22E | T28S R23E | T28S R24E | T28S R25E | T28S R26E | T28S R27E | T28S R28E | T28S R29E | T28S R30E

T29S R20E | T29S R21E | T29S R22E | T29S R23E | T29S R24E | T29S R25E | T29S R26E | T29S R27E | T29S R28E | T29S R29E | T29S R30E

T30S R20E | T30S R22E | T30S R23E | T30S R24E | T30S R25E | T30S R26E | T30S R27E | T30S R28E | T30S R29E | T30S R30E

T31S R22E | T31S R23E | T31S R24E | T31S R25E | T31S R26E | T31S R27E | T31S R28E | T31S R29E | T31S R30E

T32S R23E | T32S R24E | T32S R25E | T32S R26E | T32S R27E | T32S R28E | T32S R29E | T32S R30E

T12N R24W | T12N R23W | T12N R22W | T12N R21W | T12N R20W | T12N R19W | T12N R18W | T12N R17W

T11N R24W | T11N R23W | T11N R22W | T11N R21W | T11N R20W | T11N R19W | T11N R18W | T11N R17W

T10N R24W | T10N R23W | T10N R22W | T10N R21W | T10N R20W | T10N R19W | T10N R18W

FOOTHILL LINE

BEDROCK LINE

GROUND WATER BARRIER

CALIFORNIA AQUEDUCT AND TURNOUTS

KCWA BASE MAP LEGEND

MAP SCALE
FEET
0 8000 16000 24000 32000 40000
0 1 2 3 4 5 6 7
MILES

MAP INSET

B"

23-24

24-24

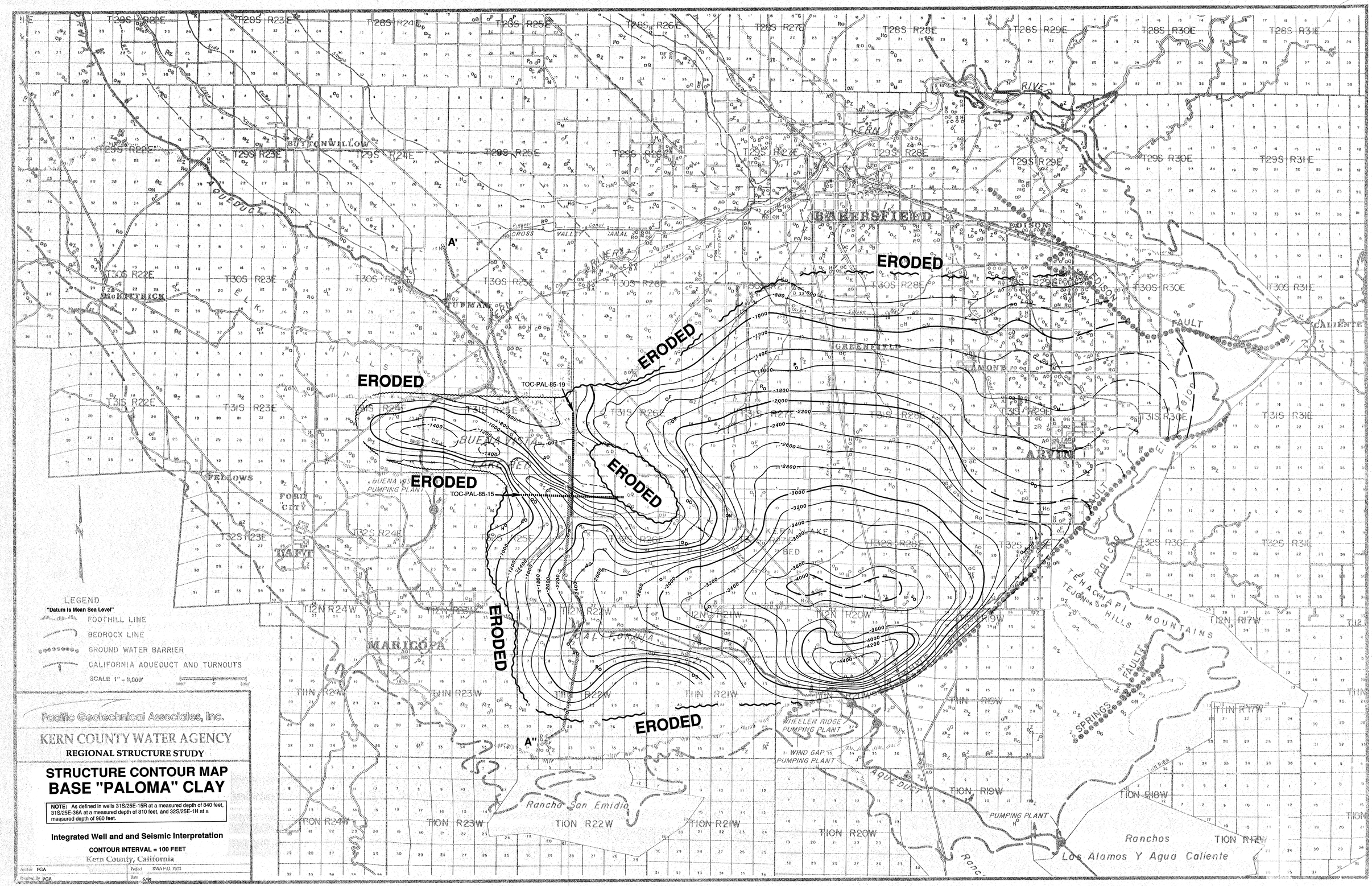
LEGEND

DATUM = SEA LEVEL

C.I. = 100 FEET

FAULT U D

CROSS SECTION



LEGEND

"Datum is Mean Sea Level"

FOOTHILL LINE

BEDROCK LINE

GROUND WATER BARRIER

CALIFORNIA AQUEDUCT AND TURNOUTS

SCALE 1" = 5,000'

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY

REGIONAL STRUCTURE STUDY

STRUCTURE CONTOUR MAP
BASE "PALOMA" CLAY

NOTE: As defined in wells 31S/25E-15R at a measured depth of 840 feet, 31S/25E-36A at a measured depth of 810 feet, and 32S/25E-1H at a measured depth of 960 feet.

Integrated Well and and Seismic Interpretation

CONTOUR INTERVAL = 100 FEET

Kern County, California

Author PGA		Project KWA P.O. 7903	
Drafted by PGA		Date 6/91	

PLATE X

Pacific Geotechnical Associates, Inc.

KERN COUNTY WATER AGENCY
REGIONAL GEOLOGIC STRUCTURE STUDY

PROPOSED SUBBASINS STRUCTURAL BOUNDARY MAP

Kern County, California

Author	Project: KWA P.O. 10376
Drafted By: PGA	Date:

TULARE SUBBASIN

LOST HILLS SUBBASIN

WASCO SUBBASIN

JERRY SLOUGH SUBBASIN

BUTTONWILLOW SUBBASIN

BUENA VISTA SUBBASIN

MARICOPA SUBBASIN

METTLER SUBBASIN

EDISON SUBBASIN

TEJON SUBBASIN

SAN LUIS OBISPO COUNTY

KERN WILDLIFE REFUGE

TEMBLOR HILLS

DELANO

McFARLAND

WASCO

SHAFTER

BUENA VISTA LAKE BED

KERN LAKE BED

BAKERSFIELD

KERN

RIVER

FAULT

WHITE WOLF FAULT

TEHACHAPI MOUNTAINS

SPRINGS

AQUEDUCT

WHEELER RIDGE PUMPING PLANT

WIND GAP PUMPING PLANT

PUMPING PLANT

Rancho San Emidio

Ranchos Los Alamos Y Agua Caliente

McKITTRICK

TUPMAN

GREENFIELD

LAMONE

ARVIN

FELLOWS

FORD CITY

TAFT

MARICOPA

CALIFORNIA

T25S R17E T25S R18E T25S R19E T25S R20E T25S R21E T25S R22E T25S R23E T25S R24E T25S R25E T25S R26E T25S R27E T25S R28E T25S R29E T25S R30E

T26S R17E T26S R18E T26S R19E T26S R20E T26S R21E T26S R22E T26S R23E T26S R24E T26S R25E T26S R26E T26S R27E T26S R28E T26S R29E T26S R30E

T27S R18E T27S R19E T27S R20E T27S R21E T27S R22E T27S R23E T27S R24E T27S R25E T27S R26E T27S R27E T27S R28E T27S R29E T27S R30E

T28S R18E T28S R19E T28S R20E T28S R21E T28S R22E T28S R23E T28S R24E T28S R25E T28S R26E T28S R27E T28S R28E T28S R29E T28S R30E

T29S R20E T29S R21E T29S R22E T29S R23E T29S R24E T29S R25E T29S R26E T29S R27E T29S R28E T29S R29E T29S R30E

T30S R20E T30S R21E T30S R22E T30S R23E T30S R24E T30S R25E T30S R26E T30S R27E T30S R28E T30S R29E T30S R30E

T31S R22E T31S R23E T31S R24E T31S R25E T31S R26E T31S R27E T31S R28E T31S R29E T31S R30E

T32S R23E T32S R24E T32S R25E T32S R26E T32S R27E T32S R28E T32S R29E T32S R30E

2N R24W T11N R23W T11N R22W T11N R21W T11N R20W T11N R19W T11N R18W T11N R17W

T11N R24W T11N R23W T11N R22W T11N R21W T11N R20W T11N R19W T11N R18W T11N R17W

T10N R24W T10N R23W T10N R22W T10N R21W T10N R20W T10N R19W T10N R18W T10N R17W

FOOTHILL LINE
BEDROCK LINE
GROUND WATER BARRIER
CALIFORNIA AQUEDUCT AND TURNOUTS

KCWA BASE MAP LEGEND

MAP SCALE
FEET 0 8000 16000 24000 32000 40000
MILES 0 1 2 3 4 5 6 7

EXPLANATION

This map shows the boundaries of subbasins within the southern San Joaquin Valley The indicated subbasins are bounded by distinct structural highs due to folding and faulting.The structural interpretation is based upon analyses of subsurface well and seismic data presented in the report: STUDY OF THE REGIONAL GEOLOGIC STRUCTURE RELATED TO GROUNDWATER AQUIFERS IN THE SOUTHERN SAN JOAQUIN VALLEY GROUNDWATER BASIN, SOUTHERN KERN COUNTY, CALIFORNIA.

These subbasins may contain isolated or partially isolated hydrogeologic systems. Solid lines represent prominent, continuous bounding highs. Dashed lines represent low areas along these boundaries where communication between subbasins is more likely.

NOTE - This map is derived solely from a structural interpretation. Other sources of hydrogeologic data such as gradients, geochemical analyses, etc. will help determine the role of these individual subbasins in the hydrogeology of the southern San Joaquin Valley.

B.A. BABCOCK

BUTTONWILLOW IMPROVEMENT DISTRICT
OF
SEMITROPIC WATER STORAGE DISTRICT
Kern County, California

ENGINEERING REPORT

IN SUPPORT OF

APPLICATION FOR FEDERAL LOAN UNDER PUBLIC LAW 984 FOR CONSTRUCTION OF AN IRRIGATION DISTRIBUTION SYSTEM

BOOKMAN and EDMONSTON
Consulting Civil Engineers
Glendale, California

Amended April 1968

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to ground waters underlying the District. However, Isabella Dam is expected to effectively control the Kern River, so future occurrence of flood flows through Jerry Slough will be rare and recharge from this source must be discounted.

Ground Water Geology and Hydrology

Physiography

The principal physiographic features associated with the Buttonwillow Improvement District include Buttonwillow Ridge, Semitropic Ridge, Kern River Flood Canal, Jerry Slough, Goose Lake and the low alluvial fans of the Kern River and Poso Creek.

Kern River Flood Canal, which lies westerly of the District, historically has transmitted overflow from Buena Vista Lake and the Kern River northward to Tulare Lake during periods of excessive run-off. As stated, flood waters from the Kern River have also spilled into Jerry Slough, a depression one to two miles wide located between Buttonwillow and Semitropic ridges, and flowed northward to Goose Lake and thence ultimately to Tulare Lake.

Buttonwillow Ridge, an elongated topographic high which trends northwest, separates Kern River Flood Canal from Jerry Slough and is located along the southwesterly portion of the District. It is a low-lying feature about two miles wide and 15 miles long with a maximum relief of about 65 feet. Semitropic Ridge lies parallel to and northeasterly of Buttonwillow Ridge and has a similar configuration. It is bounded by Jerry Slough on the west and low alluvial fans on the east.

The alluvial fans along the eastern boundary of the Buttonwillow District are relatively flat and featureless. They are derived principally from materials deposited by the Kern River and Poso Creek. In the northern portion of the District, Semitropic Ridge loses its identity and the area is characterized by low plains and overflow lands.

Ground Water Geology

The geologic units within the Buttonwillow Improvement District can be divided into two broad groups, based generally upon the degree to which the subsurface materials have been consolidated.

Consolidated rocks, including the metamorphic and igneous basement rocks as well as marine and continental sedimentary strata, are generally impermeable or only moderately so and are of lesser importance as a source of ground water in the Buttonwillow District.

The unconsolidated or semi-consolidated deposits of late Tertiary and Quaternary age include (1) continental deposits generally assigned to the Tulare Formation, (2) alluvial and terrace deposits, and (3) flood basin deposits.

The Tulare Formation is typically comprised of alternating beds of sand, gravel and clay. There apparently exists a high degree of lenticularity, as it is difficult to establish continuity for most of the individual strata. However, in the subsurface there persists an extensive silty clay zone within the Tulare Formation which has been designated the Corcoran Clay in areas north of the Buttonwillow District. The Corcoran Clay, as delineated to the north, has been traced southerly to the approximate northerly boundary of the District, and may be equivalent with other clay members of the Tulare Formation within the Buttonwillow District.

Figure 1 presents a generalized subsurface section crossing the Buttonwillow District. As shown on this figure, the Tulare Formation has been structurally warped into two anticlinal folds, the axes of which coincide with Buttonwillow and Semitropic Ridges. As a result of this folding, the lower and, therefore, older members of the Tulare Formation have been upwarped to relatively shallow depths beneath the ridges. The older strata contain relatively saline water and have been penetrated by

water wells, a condition which is discussed in further detail hereinafter. The location of the section on Figure 1 is shown on Plate 3.

Figure 1 also shows unconsolidated alluvial deposits unconformably overlying the folded and eroded Tulare Formation. Older alluvium is exposed on the surface along Buttonwillow and Semitropic ridges and appears to reach a maximum thickness of 250 feet. Continuing structural activity coincident with deposition of older alluvium is indicated, as evidenced by the slightly folded older alluvium beneath the ridges. Subsequent to cessation of folding, younger alluvium of Recent Age was deposited to the east of Semitropic Ridge by the Kern River and Poso Creek to a maximum depth of 100 feet. The eastern flank of Semitropic Ridge was buried by the Recent alluvial deposition, and the essentially featureless topographic expression easterly from the Ridge resulted from this activity. Both the Recent and Older Alluvium are generally dewatered, but are sufficiently permeable to allow downward percolation of surface water including excess applied irrigation water.

Fine-grained sands, silts and clays constitute a relatively thin, impermeable layer of material deposited in Jerry Slough, Goose Lake and on overflow lands north of Semitropic Ridge. These flood basin deposits are estimated to extend to a maximum depth of 50 feet and, owing to their reduced permeability, are not a significant source of ground water, nor do they provide a permeable medium for the downward transmission of surface water to the more permeable underlying material.

Occurrence and Movement of Ground Water

The semiconsolidated and unconsolidated Tulare Formation and alluvial deposits comprise a ground water storage reservoir within the Buttonwillow Improvement District. This reservoir consists of a generally unconfined to semiconfined aquifer system of lenticular strata of sand,

gravel, silt and clay which appear to have sufficient vertical and horizontal permeability to function as a single hydrologic unit.

Water levels vary somewhat in accordance with depth of perforations in water wells, confirming the presence of relatively impermeable materials in the upper portions of the semiconfined aquifer system. Variations in water levels observed during the pumping season disappear rapidly with cessation of pumping, thus indicating that the areal extent of these relatively impermeable materials is limited and that there prevails a substantial degree of vertical hydraulic communication within the semiconfined aquifer system.

As shown on Plate 3, ground water level contours indicate a general water level gradient to the northwest. Subsurface inflow to the Buttonwillow District is predominantly from the south and east, although a small increment is derived from the west.

The magnitude of subsurface flow into the Buttonwillow District was estimated by utilizing the slope-area method of computation. Results of aquifer tests performed by the U. S. Geological Survey indicate aquifer transmissibilities to be on the order of 300,000 gallons per day per foot of perimeter along the easterly and southerly boundary of the District and 100,000 gallons per day per foot along the westerly boundary. An average hydraulic gradient of 10 feet per mile was derived from ground water level contour maps. Utilizing the relationship $Q = TIL$, where T is the estimated aquifer transmissibility, I is the average hydraulic gradient, and L is the length of underflow perimeter, the total underflow into the Buttonwillow District was computed to be 50,000 acre-feet per year under current conditions of ground water utilization and water supply.

Plate 3 shows the presence of a ground water trough located generally along

the axis of Semitropic Ridge and near the easterly boundary of the Buttonwillow District. Large extractions of ground water over a relatively long-term period combined with an inadequate ground water supply have been responsible for the creation of the trough. The position of the trough has been established primarily by the pattern of pumping, availability of recharge, and transmissibility of the pumped aquifers.

As described herein under the section entitled "Ground Water Geology," the thickness of fresh water-bearing materials in the vicinity of Semitropic and Buttonwillow Ridges is limited by the occurrence of saline connate waters at a depth of 500 to 700 feet. Thus, with current water levels at a depth of 300 to 350 feet, the saturated thickness of usable aquifer material may be less than 200 feet in the most severe condition. Further, there are deep wells in the area which are perforated in the saline water zone and are now extracting water of marginal or unsuitable quality. The hydraulic gradients resulting from the presence of the pumping trough have induced the movement of poorer quality ground waters into the District toward the axis of the trough. The position of the trough is not expected to shift laterally under current or future conditions of groundwater recharge and pumping. However, with the introduction of supplemental water as contemplated under project conditions, hydraulic gradients are expected to flatten with a corresponding increase in the elevation of ground water levels along the axis of the trough.

Long-term hydrographs of water levels in wells indicate that relatively uniform ground water conditions prevailed until 1945, with seasonal fluctuations in drawdown and recovery of 20 to 30 feet. Increased pumping, beginning in 1945, caused water levels to decline at a rate of approximately 6 to 8 feet per year, and seasonal fluctuations have approached 100 feet per year. These fluctuations are depicted on Figure 2.

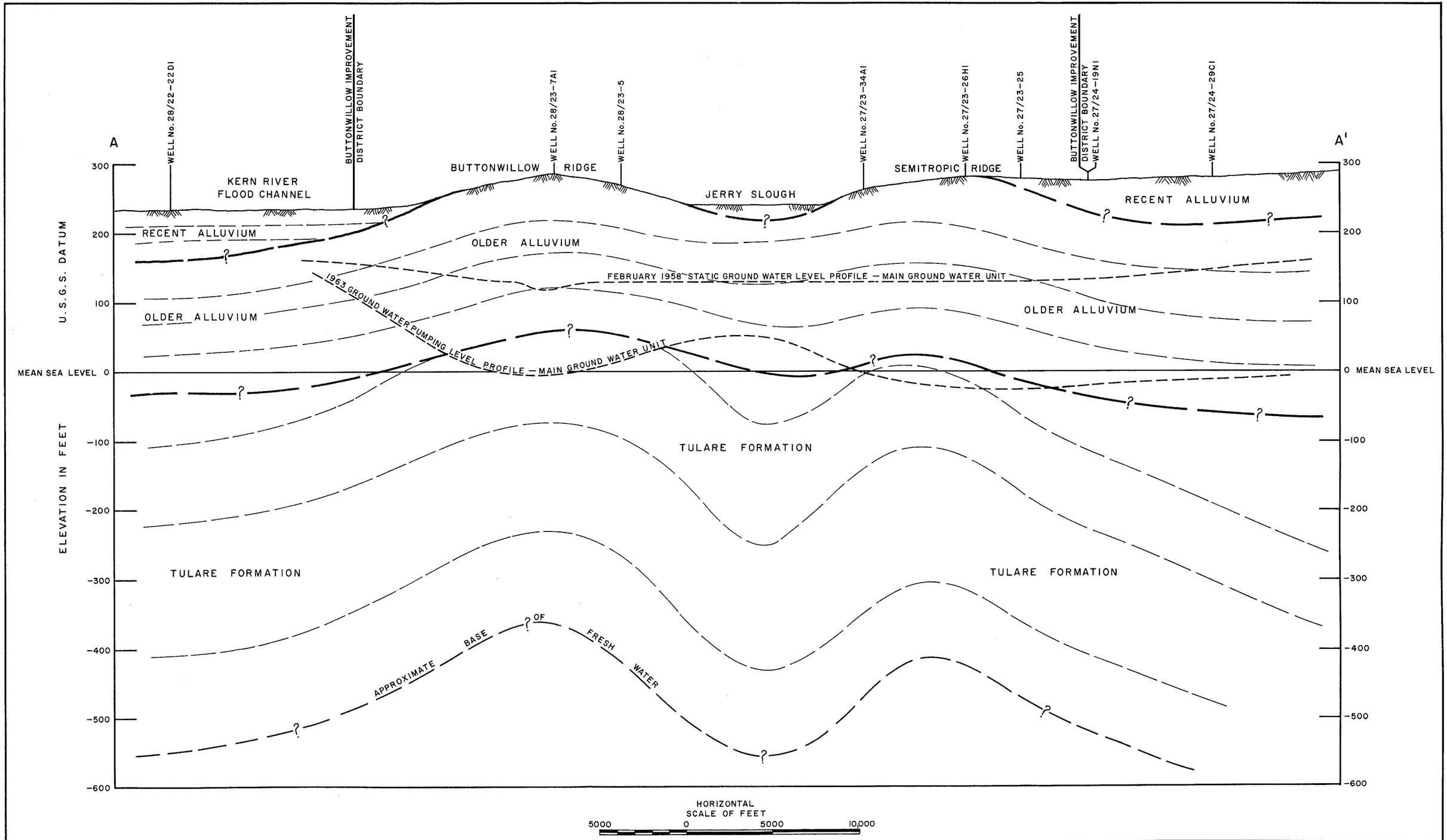
An average specific yield value of 8.7 per cent was estimated for the depth interval of fluctuating ground water levels, and the average annual change in ground water storage throughout the District was computed using an average decline in water levels of 6 to 8 feet per year. The average annual depletion of ground water storage in the Buttonwillow District during the period from 1958 to 1962 was computed by the above procedure to be on the order of 42,000 to 56,000 acre-feet. Without the introduction of supplemental water, it is estimated that the depletion of ground water would continue at about this same rate.

Ground Water Quality

Ground water within the Buttonwillow District shows major variations in chemical character due to the District's proximity to the axial trough of the San Joaquin Valley. The subsurface waters are divided areally into two general categories: (1) ground waters of the east side of the valley, generally of the sodium bicarbonate type with low to moderate concentrations of total salts, and (2) ground water of the west side of the valley, generally of the sulfate or chloride type and nearly always having higher salinity than waters of the east side. In addition, there is an irregular zone where these subsurface waters are mixed, and the range in chemical character and dissolved mineral constituents is substantially greater than in the east side waters.

There also occurs a rough vertical segregation of ground water quality. The upper zone consists of the shallow aquifer systems which have relatively free communication with the land surface and contain ground waters which are typically calcium chloride-sulfate in character with more than 400 parts per million of dissolved solids. Generally, these shallow zone waters are more apparent in local areas of poor drainage. An intermediate zone contains water typically sodium bicarbonate in character with dissolved solids concentrations of less than

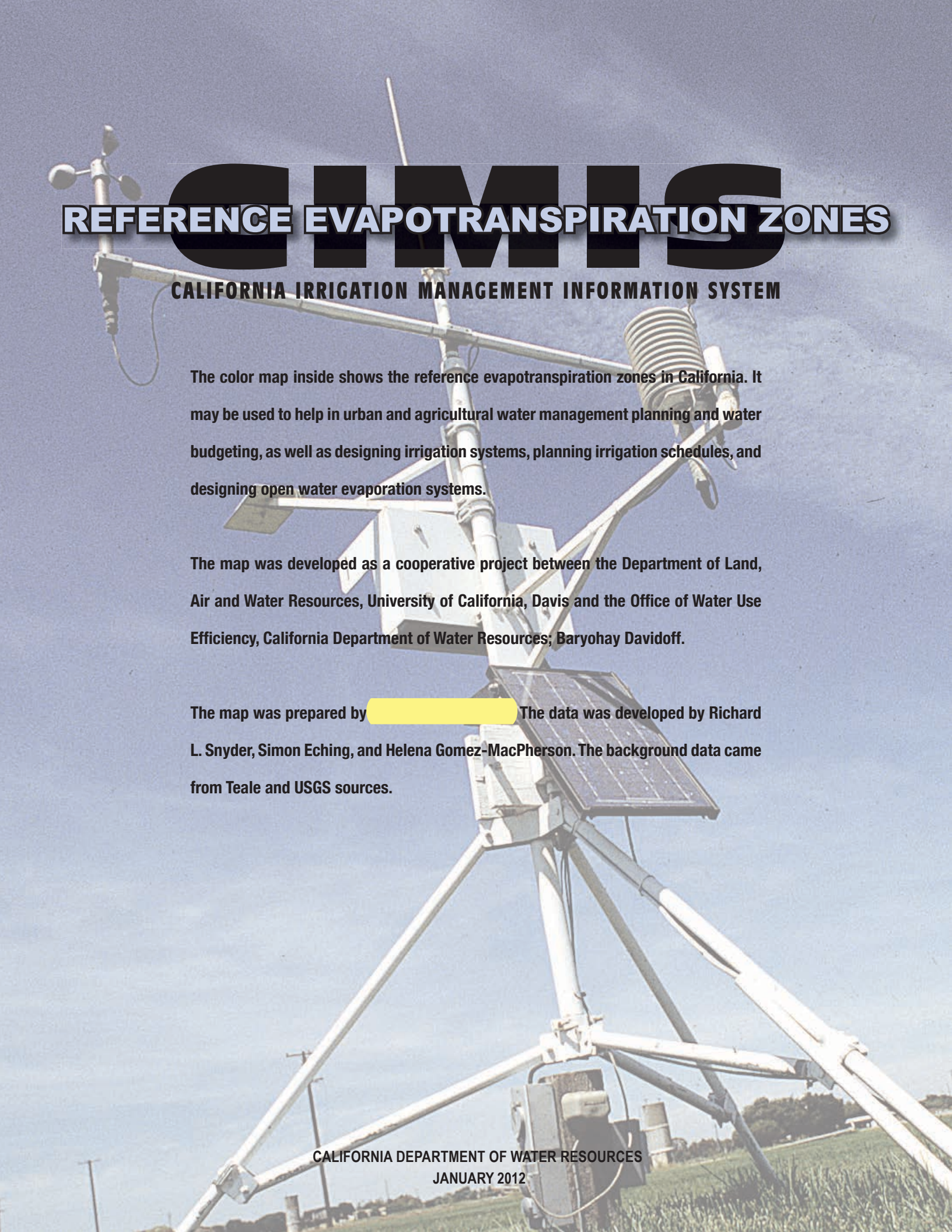
FIGURE 1



GENERALIZED GEOLOGIC SECTION

BOOKMAN and EDMONSTON
CONSULTING CIVIL ENGINEERS

APRIL 1967



CIMIS

REFERENCE EVAPOTRANSPIRATION ZONES

CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SYSTEM

The color map inside shows the reference evapotranspiration zones in California. It may be used to help in urban and agricultural water management planning and water budgeting, as well as designing irrigation systems, planning irrigation schedules, and designing open water evaporation systems.

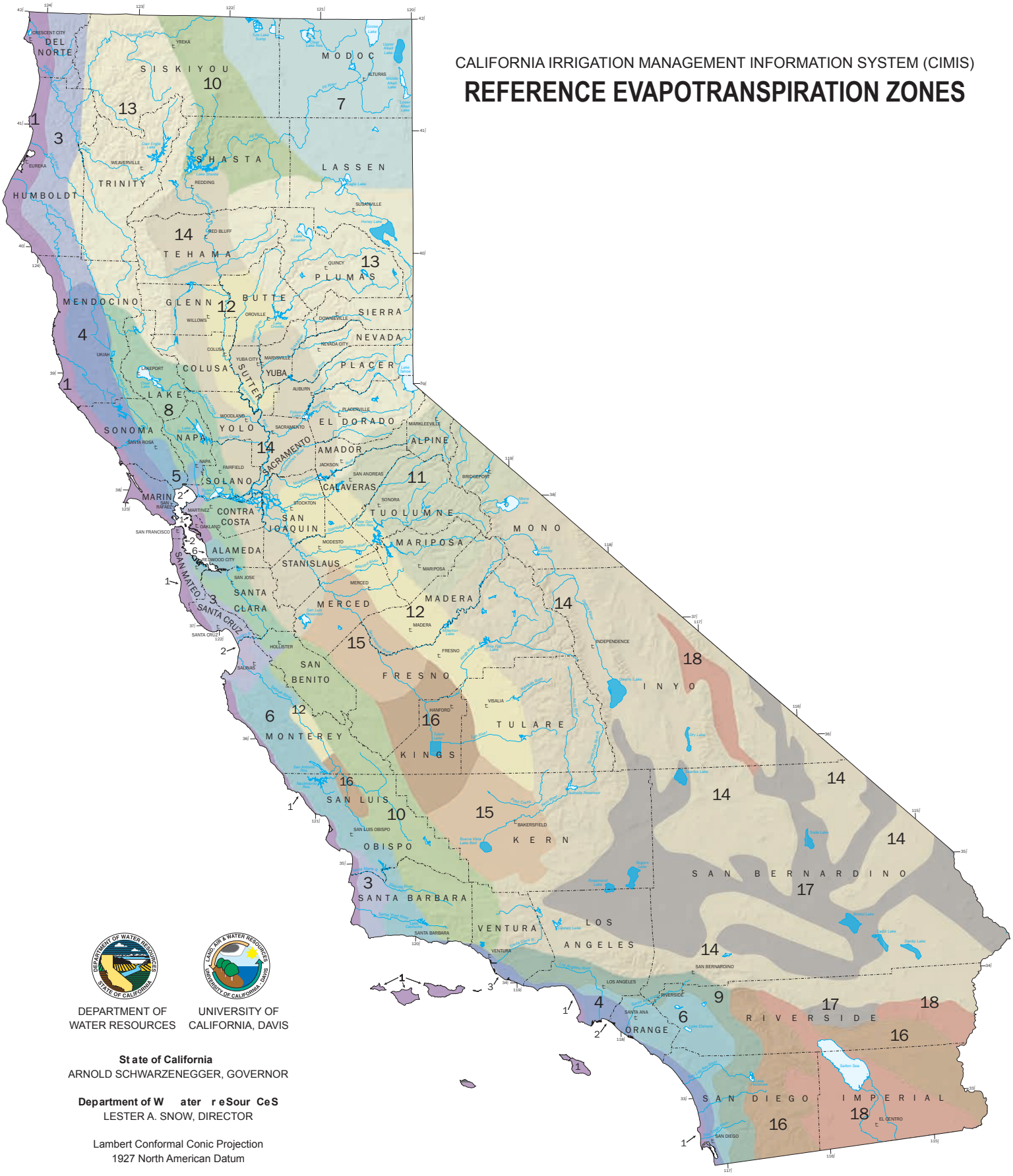
The map was developed as a cooperative project between the Department of Land, Air and Water Resources, University of California, Davis and the Office of Water Use Efficiency, California Department of Water Resources; Baryohay Davidoff.

The map was prepared by [redacted] The data was developed by Richard L. Snyder, Simon Eching, and Helena Gomez-MacPherson. The background data came from Teale and USGS sources.

CALIFORNIA DEPARTMENT OF WATER RESOURCES
JANUARY 2012

CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SYSTEM (CIMIS)

REFERENCE EVAPOTRANSPIRATION ZONES



DEPARTMENT OF WATER RESOURCES

UNIVERSITY OF CALIFORNIA, DAVIS

State of California
ARNOLD SCHWARZENEGGER, GOVERNOR

Department of Water Resources
LESTER A. SNOW, DIRECTOR

Lambert Conformal Conic Projection
1927 North American Datum

r eference e vapot ranspiration (et o) Zones

1 **COASTAL PLAINS HEAVY FOG BELT** lowest ETo in California, characterized by dense fog

2 **COASTAL MIXED FOG AREA** less fog and higher ETo than zone 1

3 **COASTAL VALLEYS & PLAINS & NORTH COAST MOUNTAINS** more sunlight than zone 2

4 **SOUTH COAST INLAND PLAINS & MOUNTAINS NORTH OF SAN FRANCISCO** more sunlight and higher summer ETo than zone 3

5 **NORTHERN INLAND VALLEYS** valleys north of San Franciaco

6 **UPLAND CENTRAL COAST & LOS ANGELES BASIN** higher elevation coastal areas

7 **NORTHEASTERN PLAINS**

8 **INLAND SAN FRANCISCO BAY AREA** inland area near San Francisco with some marine influence

9 **SOUTH COAST MARINE TO DESERT TRANSITION** inland area between marine & desert climates

10 **NORTH CENTRAL PLATEAU & CENTRAL COAST RANGE** cool, high elevation areas with strong summer sunlight; zone has limited climate data & the zones selection is somewhat subjective

11 **CENTRAL SIERRA NEVADA** mountain valleys east of Sacramento with some influence from delta breeze in summer

12 **EAST SIDE SACRAMENTO-SAN JOAQUIN VALLEY** low winter & high summer ETo with slightly lower ETo than zone 14

13 **NORTHERN SIERRA NEVADA** northern Sierra Nevada mountain valleys with less marine influence than zone 11

14 **MID-CENTRAL VALLEY, SOUTHERN SIERRA NEVADA, TEHACHAPI & HIGH DESERT MOUNTAINS** high summer sunshine and wind in some locations

15 **NORTHERN & SOUTHERN SAN JOAQUIN VALLEY** slightly lower winter ETo due to fog and slightly higher summer ETo than zones 12 & 14

16 **WESTSIDE SAN JOAQUIN VALLEY & MOUNTAINS EAST & WEST OF IMPERIAL VALLEY**

17 **HIGH DESERT VALLEYS** valleys in the high desert near Nevada and Arizona

18 **IMPERIAL VALLEY, DEATH VALLEY & PALO VERDE** low desert areas with high sunlight & considerable heat advection

monthly a verage r eference e vapotranspiration by et o Zone (inches/month)

Zone	Jan	f eb	mar	a pr	may	Jun	Jul	a ug	Sep	o ct	n ov	Dec	t otal
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	32.9
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.3
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.1
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.4
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variability between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites wihtin a zone for all months is about 0.01 inches per day for the 200 sites used to develop the map.



STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

CIMIS Information
wwwcimis.water.ca.gov



Prepared by Todd Engineers for Kern Fan Monitoring Committee

Technical Memorandum No. 1
Site Conceptual Model
"With and Without Banking" Evaluation, Kern Fan Area

September 18, 2012

Technical Memorandum No. 1

Site Conceptual Model

"With and Without Banking" Evaluation, Kern Fan Area

Kern Fan Monitoring Committee

DRAFT

September 18, 2012

TODD ENGINEERS

TECHNICAL MEMORANDUM NO. 1
Site Conceptual Model
"With and Without Banking" Evaluation, Kern Fan Area

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Appendix E: Estimation of Subsurface Inflows and Outflows for the Model Area

List of Acronyms

AFY – acre feet per year
BVWSD – Buena Vista Water Storage District
cfs – cubic feet per second
COB – City of Bakersfield
CWD – Cawelo Water District
DWR – (California) Department of Water Resources
ET - evapotranspiration
gpm – gallons per minute
ID4 – KCWA Improvement District No. 4
KDWD – Kern Delta Water District
KFMC – Kern Fan Monitoring Committee
KCWA – Kern County Water Agency
KWB – Kern Water Bank
MGD – million gallons per day
MOU – Memorandum of Understanding
msl – mean sea level
NKWSD – North Kern Water Storage District
NORMWC – North of the River Municipal Water Company
NORSD – North of the River Sanitary District
SWID – Shafter-Wasco Irrigation District
SWP – State Water Project
Vaughn or VWC – Vaughn Water Company
WKWD – West Kern Water District
WWTP – wastewater treatment plant

1 Introduction

The Kern Fan Monitoring Committee (KFMC) is working cooperatively to monitor groundwater conditions in the alluvial aquifers beneath and in the lower area of the Kern River, generally referred to as the Kern Fan. In this area, favorable hydrogeologic conditions, the availability of imported and local water, and the cooperation of numerous water agencies and stakeholders have allowed for the subsurface storage of significant water supplies in the local groundwater basin. Although significant intentional recharge has occurred in the County for almost 50 years, more focused large-scale groundwater banks have operated along the apex of the Kern River Fan since the 1990s.

In compliance with various memoranda of understanding (MOUs) associated with groundwater banking projects, the KFMC is conducting an evaluation to assess potential groundwater impacts from various banking projects. The basis of the impacts evaluation is the groundwater conditions that would have occurred in the *absence* of banking. The comparison of conditions with groundwater banking to conditions without groundwater banking is referred to as a "with and without" evaluation by the KFMC and in this memorandum.

To assist in the *with and without* evaluation of various banking projects, the KFMC has retained Todd Engineers to construct, calibrate, and apply a numerical groundwater flow model (also referred to as the Kern Fan Model) based on an updated conceptual model. This memorandum presents the first step of the analysis – the development of the site conceptual model. The memorandum summarizes data sets and analyses to support the development of the numerical model with which to analyze potential impacts of certain recharge and banking projects along the Kern Fan.

1.1 Background

Numerous water districts, irrigation districts and banking entities have been formed in Kern County for the conjunctive management of local and imported surface water and groundwater, most of which are shown on Figure 1-1. Kern County Water Agency (KCWA) is the local contracting agency for imported water from the State Water Project (SWP) that supplements local surface water and groundwater for both agricultural and urban water supply. SWP enters the Study Area via the California Aqueduct (Figure 1-1). Urban SWP water is provided in the Study Area by KCWA which acts through Improvement District No. 4 (ID-4) as a wholesale supplier to portions of the Bakersfield urban area. KCWA also operates and participates in several of the groundwater banking projects along the lower Kern River, collectively shown in light blue on Figure 1-1.

In order to maintain groundwater levels and secure storage of surface water supplies when available, a large number of surface recharge facilities have been constructed along the Kern River and in various water districts north and south of the river as shown on Figure 1-2. Although many water districts manage intentional recharge projects for the primary benefit of local customers within their service area (e.g., North Kern Water Storage District), more formalized banking projects have also been developed that often involve storage and recovery of water for third parties outside of the banking areas (e.g., the

Kern Water Bank Authority) (Figure 1-3). The first such banking project was constructed in 1978 by the City of Bakersfield and involved about 2,800 acres of recharge facilities along the Kern River (referred to as the COB 2800 project). In 1984 the Berrenda Mesa project was constructed along the river and beginning in the mid- to late-1990s, the Kern Water Bank (KWB), and the smaller Pioneer project were also constructed in the river corridor. The approximate delineation of these and other more-recent banking projects are shown on Figure 1-3.

Participants in the larger banking projects (Project Participants) and water agencies in the vicinity (Adjoining Entities) recognized that banking could have potentially both beneficial and adverse impacts on water levels or water quality beyond the project boundaries. In 1995, Project Participants and Adjoining Entities associated with the Kern Water Bank signed a Memorandum of Understanding (MOU), forming the KFMC, to monitor and evaluate banking impacts on groundwater levels and quality. Since that time, a series of MOUs associated with other banking projects have been executed. The MOUs unite the signatory parties toward a shared goal of ensuring that both beneficial and adverse impacts from groundwater banking are identifiable and, to the extent practical, adverse impacts are mitigated.

In October 2011, the Kern County Water Agency (KCWA), on behalf of the KFMC, retained Todd Engineers to assist on the *with and without* evaluation for various banking projects. The contract was based on the scope of work presented in *Proposal to Provide Hydrogeological Consulting Services for the Development of an Aquifer Model for the With and Without Evaluations of the Kern River Alluvial Fan, Groundwater Banking Projects, Kern County, California* (Proposal) prepared by Todd Engineers and submitted to the KFMC in December 2010. Since October 2011, Todd Engineers has met with the Technical Subcommittee of the KFMC (Technical Subcommittee) on six occasions (including a technical workshop with selected members of the subcommittee) to refine the project scope, update the subcommittee on project status, discuss details of data collection and analysis, and obtain technical input for the development of the site conceptual model on which the numerical groundwater flow model will be based.

1.2 Project Objectives and Scope of Work

The goal of the project is to evaluate the changes to groundwater levels and flow that have occurred as a result of specific banking or recharge projects. To accomplish this goal, the following project objectives have been identified:

- Develop a site conceptual model and water balance of the groundwater system
- Construct and calibrate a numerical groundwater flow model
- Apply the numerical model to evaluate groundwater conditions without banking projects.

Based on meetings with the Technical Subcommittee, seven banking/recharge projects have been identified for a *with and without* evaluation including the Kern Water Bank (KWB), Pioneer Project, Berrenda Mesa Project, Buena Vista Water Storage District (BVWSD), City of Bakersfield 2800 Acres (COB 2800), West Kern Water District (WKWD) Storage Project, and Rosedale-Rio-Bravo Water Storage

District (RRBWSD), collectively referred to in this memorandum as "Banking Projects." The project service areas of these seven projects are shown on Figure 1-3.

The objectives were incorporated into the scope of work for the project, which includes the following tasks:

1. Update Conceptual Model
2. Develop Numerical Flow Model
3. Simulate "With and Without" Banking Projects Scenarios
4. Identify Project Assumptions and Evaluation Accuracy
5. Prepare Technical Memoranda and Project Report
6. Conduct Conference Calls and Meetings.

Task 5 includes a series of memoranda to allow ongoing technical oversight from the KFMC. Four memoranda corresponding to Tasks 1 through 4 are included in the scope of work. Comments provided by the KFMC will be addressed and incorporated into the comprehensive Project Report. This memorandum is Technical Memorandum No. 1 (referred to herein as TM-1). TM-1 presents the results of Task 1 and introduces the proposed methodologies for translating the conceptual model into the numerical model (Task 2).

1.3 Study Area, Model Domain, and Study Period

The general Study Area, defined by the KFMC for the Proposal, generally includes the area from Poso Creek in the north to Kern Delta Water District (KDWD) in the south (Figure 1-1). In the initial stages of the project, hydrogeologic data were reviewed to delineate a preliminary model domain by Todd Engineers with assistance and input from the Technical Subcommittee.

The model domain (Model Area) covers approximately 454 square miles (about 290,500 acres) including portions of 23 townships/ranges north and south of the Kern River. Water districts included in the model domain are shown on Figure 1-1 and include all or portions of (from south to north): KDWD, ID-4, Kern River banking projects (collectively in blue), Buena Vista Water Storage District (BVWSD), Rosedale-Rio Bravo Water Storage District (RRBWSD), Semitropic Water Storage District (SWSD), Shafter-Wasco Irrigation District, North Kern Water Storage District, and the southwestern-most tip of Cawelo Water District (CWD). Purveyors supplying municipal and industrial supply (including groundwater pumping) are also located within the model domain as shown on Figure 1-4. The basis for the delineation of the model boundary and preliminary boundary conditions are described in more detail in Section 3 of this TM.

A Study Period has been selected to accommodate both wet and dry hydrologic cycles and to pre-date the major banking projects of interest, which began about 1995. Since data collection began prior to the end of 2011, data have been compiled through 2010. At the request of the Technical Subcommittee, data sets were collected from 1980 through 2010, when available. A review of data sets revealed that the amount and quality of data improved significantly beginning in about 1986. In particular, the primary water level database developed by Kern County Water Agency did not contain water level data prior to 1986, data on which the groundwater model would be calibrated. Remaining pre-1986 key data sets are

either non-existent or judged much less reliable including municipal pumping, imported water recharge, pre-banking area operations, and other data.

In addition, a review of hydrographs indicates that 1986 represented a time of relatively average hydrologic conditions and relatively stable water levels as documented in Section 2 of this memorandum. Stable groundwater levels provide benefits for developing initial conditions for the groundwater model. Further, the period between 1986 and the initiation of the major banking operations (1995) was judged sufficient time for the model to be calibrated to pre-banking conditions, recognizing that less formalized banking had already been developed in the region. For these reasons, the Study Period of calendar years 1986 – 2010 has been selected as the model time period (a period that is also consistent with the 2011 Proposal).

1.4 Data Sources

Numerous data sets have been compiled to support the conceptual and numerical models. Because monthly time steps are needed for the numerical model to allow for the analysis of seasonal variability in groundwater conditions, data have been collected on a monthly basis when available. For instances when data are available only on an annual basis, appropriate methodologies have been developed to allocate data monthly.

Data compilation has been coordinated through KCWA, but also has included direct communication and/or office meetings with individual water/irrigation districts, municipalities, mutual water companies, and the banking entities (including the Kern Water Bank Authority). KCWA also provided electronic scans of driller's logs and geophysical logs that covered the Study Area. Numerous datasets have been developed from the Kern River Hydrographic Annual Reports, referred to herein as the Kern River Annual Reports. These reports are prepared annually by the City of Bakersfield in cooperation with the Kern River Watermaster. Land use maps obtained from the County and DWR have been used in the estimation of agricultural irrigation, irrigation return flows, groundwater pumping, recharge from rainfall and other components of the conceptual model. Kern Fan Operations and Monitoring Reports prepared by the KFMC provide summary data for banking projects. All of these local documents and data have been supplemented by the vast amount of geologic and hydrogeologic technical publications prepared by state and federal agencies including the U. S. Geological Survey (USGS), California Department of Water Resources (DWR), University of California Bakersfield, and other investigators. These and other data sets and their use in the conceptual model are discussed in more detail throughout TM-1.

Data are available in either electronic (database or spreadsheet) formats or paper/pdf formats, which require either electronic manipulation for database consistency and/or hand-entry of data. A significant amount of data entry was undertaken by KCWA and Todd Engineers (and others) to develop an electronic database in a consistent format. The largest dataset developed by hand-entry of data has involved the thousands of records from the Kern River Annual Reports developed by the City of Bakersfield. These data include monthly records of flows in the Kern River, diversions from the river channel, use of diverted water for irrigation or recharge, movement of water among agencies, leakage along various reaches of the river channel, and estimates of canal losses. Well construction data from driller's logs have been hand-entered into the database for two of the larger water districts closest to

the banking projects; recovery well construction data associated with some of the banking projects also have been hand-entered. These well construction data supplemented well construction databases provided by several of the banking entities. In addition, municipal pumping from multiple purveyors (including CalWater, Oildale, and others) were hand-entered and added to the database.

Many of the spatial coverages of institutional boundaries or physical features were available from KCWA and others in formats compatible with the project's Database Management System and Geographical Information System (GIS), which can be readily imported into the pre-processor software of the numerical model. However, numerous data sets required digitizing and/or electronic conversion including pre-1997 land use data and geologic contours of regional clay layers. Details of these data sources and incorporation into the project are discussed in subsequent sections of TM-1.

Several data sources provided overlapping or similar data that were used for quality control and cross checking purposes. In several instances, duplicate data sources were in conflict and had to be reconciled. For example, annual banking data obtained from one source did not match monthly data provided from a separate source. In these instances of conflict, data sources were re-checked and assistance from the primary agency responsible for the data was obtained. In general, the primary entity responsible for collecting/compiling the data was considered the more reliable source.

Despite our best efforts, additional data and knowledge gaps remain. These are highlighted throughout this TM-1 along with the methods used to estimate values in the absence of data.

1.5 Use of the Technical Memorandum (TM-1)

TM-1 is the first in a series of technical memoranda to keep the KFMC informed of the incorporation of data and analysis into the project and to allow guidance and oversight for subsequent tasks. TM-1 is being provided to the KFMC and Technical Subcommittee for review and comment. Comments will be discussed in the meeting of the Technical Subcommittee in October 2012 with a focus on how comments should be addressed during development of the numerical model. Comments will be incorporated into the comprehensive Project Report at the end of the project.

2 Development of the Conceptual Model

The development of the site conceptual model has involved a review of the hydrologic and hydrogeologic conditions in the Study Area. This review has provided the foundational data to estimate the amounts and types of water moving through the groundwater system. These data are incorporated into the water balance and will be the basis for development of the numerical model.

2.1 Physical Setting

The Study Area is characterized by a relatively flat alluvial plain surrounded by the dissected uplands of the Coast Ranges to the west and the Sierra Nevada to the east. Within the Model Area, ground surface elevations range from about 600 feet mean sea level at the east-central edge to below 250 feet at the northwest corner. Ground surface elevations along the Kern River range from about 415 feet msl in the east to about 300 feet in the west across the Model Area, with an overall slope of about 6 feet per mile. Most of the Model Area has ground surface elevations between 300 feet and 400 feet msl.

2.1.1 Climate and Precipitation

The Model Area is characterized by cool, moist winters and hot, dry summers. The mean annual temperature is 65^{o} F and summer highs frequently exceed 100^{o} F. Average precipitation in the Model Area is about 6 inches per year.

Annual precipitation from 1890 through 2010 at the Bakersfield station is shown on the upper graph of Figure 2-1 with the Study Period of 1986 – 2010 highlighted on the graph. The period of record demonstrates the variability of rainfall in the Model Area ranging from less than 3 inches in extreme dry years to more than 10 inches in very wet years.

Figure 2-1 also shows monthly precipitation during the Study Period plotted on the lower graph with a cumulative departure curve (CDC). The CDC is used to more readily identify wet and dry periods in relation to average precipitation, which is shown as zero on the right-hand scale of Figure 2-1. When the curve is rising, conditions are wetter than average; a declining curve indicates dry conditions. Average precipitation for the Study Period is approximately 6.45 inches, slightly wetter than the long-term average. The cumulative departure curve also indicates a relatively wet period, but almost all of the change is controlled by the much wetter than normal conditions in December 2010, the last month of the Study Period. But for December rainfall, the Study Period would be very close to average hydrologic conditions.

With an average annual evapotranspiration (ET) rate of 57 inches, most of the rainfall evaporates, producing runoff only during intense rainfall events. Groundwater recharge from rainfall only occurs during wet years. Additional analysis of recharge from rainfall is presented in the Water Balance in Section 3.

2.1.2 Land Use

Land use data have been accessed from DWR and the Kern County Agricultural Commissioner's Office to better understand groundwater recharge and water supply and how those conditions have changed over the model period. The DWR land use maps identify areas of irrigated agriculture (including crop types), urban and industrial uses, native vegetation and numerous other uses. Land use data available from the Kern County Agricultural Commissioner's Office provide more detail on crop use because the maps are generated based on permit applications from growers. Both sources provide sufficient detail from which to estimate irrigation demand, the primary use of the maps for this project.

DWR land use maps are available for the years 1984, 1990, 1998, and 2006. The most recent DWR maps have been downloaded in electronic format and geo-referenced to the project GIS. The 1984 land use map was available in paper format only and has been digitized for use in the project. Electronic maps from the County are available in GIS format on an annual basis beginning in 1997, but 1997 and 1998 maps were found to be incomplete. A quality control check has been made by comparing DWR and County maps for overlapping time periods; this check indicates that acreages are generally within 15 percent and both sources are judged equally usable for the project. Because data are unavailable for each year of the model period, data have been reviewed for quality and representativeness over time for assignment to various years of the model. Based on this review, the following maps have been assigned to model years as summarized below in Table 2-1.

Table 2-1 Land Use Maps

Years in Model Period	Land Use Maps	Source
1986 - 1988	1984	DWR
1989 - 1995	1990	DWR
1996-1998	1998	DWR
1999 - 2010	1999 - 2010	Kern County

The 2010 crop map from Kern County is shown on Figure 2-2 to illustrate current land use conditions in the Model Area.

2.1.2.1 Agricultural Land

As seen on Figure 2-2, most of the Model Area contains irrigated agriculture. For recent years, irrigated agriculture has covered about 159,258 acres of the 290,500-acre Model Area, or about 55 percent. Another 6,790 acres have been determined to represent non-irrigated agriculture, or partially related to agricultural activities, adding another 2 percent to the agricultural coverage in the Model Area. Although the number of acres of irrigated agricultural acreage changes over the Model Period, it represents more than one-half of the acreage for all years in the model. In addition, cropping patterns, and resulting

irrigation demands, have changed significantly over the Model Period. In general, irrigation demand has increased from 1986 to 2010 based on changes in crops throughout the area.

Numerous water districts in the area develop internal district-specific crop surveys, which were requested during the data collection process for this project. However, these surveys are limited in a number of ways that restrict their use. Surveys are not available for most years of the model period. Most of the surveys are simple tables of annual acreage for particular crop groups and these categories vary from survey to survey. In addition, many surveys group similar-type crops together even when irrigation demands varied significantly among those crops. Most surveys are not location-specific and typically do not account for double-cropping. Further, many districts have now abandoned the crop surveys and have adopted use of the County land use maps, which are used in this project. To facilitate a comparison of the land use data against the crop survey tables, cropping acreages and irrigation demand have been developed on a district-basis. Most of the data compare relatively well (typically within about 15 to 20 percent) for time periods when data are sufficient for comparison. In general, the land use maps often indicate slightly larger acreages due to double-cropping and multiple crops grown on a parcel. Because the land use maps provide more detail on cropping patterns, are location-specific, are based on actual permits, and are available on an annual basis for most years of the Model Period, they are judged the more reliable source for analysis of irrigation demand.

2.1.2.2 Urbanized Areas

The Model Area includes much of the metropolitan area of the Cities of Bakersfield and Shafter, as well as several smaller communities. Urban areas have increased over time and currently represent about 75,266 acres of the Model Area, or about 26 percent of the area. This has increased from about 12 percent at the beginning of the Model Period.

2.1.2.3 Groundwater Banking Areas

As shown on Figures 1-2 and 2-2, the west-central portion of the Model Area contains most of the large banking projects located along the Kern River. Due to the permeable nature of the Kern River Fan sediments, almost all of the enhanced recharge projects both along the river and away from the river involve surface spreading through ponds, low-lying fields, or basins. These recharge areas, designated as "water" on the DWR land use maps, cover about 20,276 acres on recent maps, representing about 7 percent of the Model Area. With the exception of the COB 2800 banking area, most of these banking projects began after the mid- 1990s. Prior to that time, much of the land was irrigated agriculture, with only minor areas designated for intentional recharge (e.g., intentional flooding of open fields in the James Pioneer ID, where the KWB is currently located). Land use maps for pre-banking time periods (DWR 1984 and 1990) have been used to reflect conditions through 1995 (see Table 2-1 above).

2.1.3 Surface Water Features

The Kern River is the primary drainage of the Study Area and provides most of the water coming into the Model Area (Figure 1-1). The river is approximately 165 miles long and is fed by snowmelt and runoff in the Sierra Nevada, including areas near Mount Whitney, the highest peak in the contiguous United States. River flows are highly variable but have been regulated somewhat by operations at Isabella Dam

since its construction in 1953 (Figure 1-1). A stream gage downstream of the dam has recorded an average annual mean discharge of 946 cubic feet per second (cfs) (equivalent to about 680,000 acre feet per year (AFY)). Most of the river water is diverted into numerous canals (most unlined) for conveyance to agricultural fields, groundwater recharge facilities, and other uses. At a downstream gage west of Bakersfield, the river's average mean discharge is 312 cfs (about 226,000 AFY) or about one third of the discharge near the dam.

Prior to development, the Kern River terminated into a series of inland lakes (now dry), the largest of which is Tulare Lake located about 20 miles north of the model domain. In recent times, almost all of the river discharge is diverted for water supply or groundwater recharge prior to the drainage turning north at the western edge of the basin. Flood flows in the Kern River that cannot be used locally can exit the basin through the Kern River-California Aqueduct Intertie, located at the intersection of the lower Kern River and the aqueduct on the west-central boundary of the model (Figure 1-1).

River diversions are operated according to a complex system of water rights dating back to the 1800s. Three entities, Kern Delta Water District (KDWD), North Kern Water Storage District (NKWSD), and the City of Bakersfield (COB) hold various senior water rights determined by flows at a stream gage just east of the Model Area, referred to as First Point (Figure 1-1). The City of Bakersfield operates a system of stream gages and weirs along the channel and at diversion points to account for flows and losses (including groundwater recharge) throughout the area. The City reports these diversions and losses in annual hydrographic reports, referred to as Kern River Annual Reports. Canal losses and return flows from irrigated agricultures represent a large percentage of groundwater recharge in the Model Area.

2.2 Hydrogeologic Setting

The Study Area is located in the southern portion of the San Joaquin Valley, a long structural trough filled with more than 10,000 feet of marine and continental sediments. The continental sediments represent a variety of depositional environments including fluvial, deltaic, lacustrine, and alluvial fan sequences and form an alluvial wedge that thickens to the west across the valley.

Numerous investigators have described and mapped geologic units and water-bearing sediments throughout the valley for more than 100 years. That work has been presented and summarized in hundreds of publications and is not repeated here. Key elements of the geologic and hydrogeologic setting that describe the conceptual model and are relevant to the construction of the numerical model are summarized below.

2.2.1 Groundwater Basin

The Study Area is located within the Kern County Groundwater Subbasin, the southern-most portion of the San Joaquin Valley Groundwater Basin as defined by DWR. The subbasin covers approximately 3,040 square miles, 454 of which are in the Model Area. The subbasin has been estimated to contain approximately 40,000,000 AF of groundwater in storage with another 10,000,000 AF of storage capacity including areas where water levels have declined. A groundwater balance prepared by DWR and KCWA for a normalized year representing 1990 conditions included estimates for subbasin inflows and outflows. In that water balance, total subbasin inflows were estimated at 1,534,000 AFY with outflows

estimated at 1,400,300 AFY for a change in storage of 133,700 AFY under these conditions. The largest component of inflow was return flows from agricultural irrigation with both surface water and groundwater (843,000 AFY) and the largest outflow component was groundwater pumping for irrigation (1,600,000 AFY). A long-term water balance prepared by KCWA from 1970 to 1998 indicated a negative change in storage (average of -325,000 AFY), but did not consider all water balance components including subsurface inflow. A detailed water balance has been prepared for this project as a part of the conceptual model and is presented in Section 3 of TM-1.

2.2.2 Geology

A simplified geologic map is presented on Figure 2-3 that shows the Neogene and Holocene (late Tertiary and younger) basin sediments rimmed by Tertiary and pre-Tertiary bedrock to the east, south, and west. The Model Area is shown on the geologic map for reference. The Kern River bisects the area, underlain by recent channel deposits. The morphology of the recent alluvial fan sediments is indicated by the trajectory of the canal systems south of the river (Figure 2-3). The terminus of the ancestral river occurred at inland lakes including the Kern Lake and Buena Vista Lake beds, shown on the map. During long periods of large flows, the river drained north to the Tulare Lake Bed. These paleo-drainages are associated with the deposition of fine-grained sediments, shown on the map as flood-basin deposits and older lacustrine deposits. As shown by the Model Area, the presence of fine-grained sediments influenced the delineation of the boundaries of the model, especially along the southwestern edge.

Pleistocene-age lacustrine deposits have been mapped by numerous investigators including Croft (1972), who labeled the most prevalent units A – E. The most extensive unit is referred to as the E Clay, which has been mapped throughout much of the southern San Joaquin Valley. Recent work has either interpreted the E Clay to exist at different depths than previously estimated or has been correlated to non-time-stratigraphic units. In addition, others have indicated that the unit mapped as the E Clay is more correctly described as silt or silty clay.

Notwithstanding these qualifications, the unit mapped by Croft and others is evident in the hundreds of electric logs that have been reviewed for this project, and it represents a low-permeability surface that provides a reference for depicting hydrostratigraphic units in the area. It also appears to occur above or within a series of interbedded sands and clays that appear to be semi-confined based on water level data. The confining nature of the E Clay unit required consideration in the formation of the numerical model layers, discussed in Section 3 of this memorandum.

To investigate the stratigraphic nature of the E Clay and to incorporate it into the conceptual model, regional contour maps of the depth to the top of the unit and its thickness have been generated. These maps, generated from digitizing and interpreting information developed by Page, are shown on Figures 2-4 and 2-5.

2.2.3 Hydrostratigraphy and Aquifers

More than 220 electric logs have been reviewed to develop a hydrostratigraphic model on which to base numerical model layers. Regionally extensive low-resistivity units provide relatively reliable markers to assist in the interpretation. Low resistivity units are typically associated with low permeability sediments

such as silts or clays, with depositional environments that represent relatively slow deposition and often extend over large areas. The objective of the review was to identify aquifer packages that function as a hydraulic unit and are separated and delineated by relatively finer-grained aquitards. Using this methodology, three hydrostratigraphic units have been defined as illustrated by the electric log on Figure 2-6. The log was recorded in a well at the Pioneer Project, just north of the Kern River (for the general location, see the Pioneer Project on Figure 1-3).

As shown on the log, the Upper Unit is characterized by an approximate 300-foot sequence of primarily coarse-grained material (sands and gravels) as indicated by the higher resistivity readings. The geologic descriptions on the accompanying driller's logs indicate only minor amounts of silt and clay throughout this upper alluvial sequence. The character of the unit changes, especially to the northwest (beneath Semitropic WSD near the northwestern portion of the model) where the sand sequences are replaced by a thinner sequence of finer-grained sediments. The Upper Unit contains the water table throughout the model area and is variably saturated.

Below the upper 300 feet of sediments, a Middle Unit has been interpreted that is characterized by interbeds of sand/gravel and silt/clay with portions that vary throughout the model area. The upper portion of the Middle Unit is defined by the occurrence of lower resistivity units, typically below 20 ohm-meters on the Long Normal curve (RLN), which is the resistivity curve more representative of conditions in the aquifer away from the borehole. In the example well on Figure 2-6, the actual resistivity readings for these defining layers are below 10 ohm-meters in the upper portion of the Middle Unit (see scale at the bottom of the log). The top of the Middle Unit has been adjusted in some wells to accommodate construction data for representation in the model as described in Section 3 (e.g., the screen on Figure 2-5 is shown to extend from the Upper Unit into the Middle Unit.)

The lower-most unit (Lower Unit, Figure 2-6), has been defined at an approximate depth of 600 to 650 feet throughout the model area and is characterized by higher-resistivity, lower-permeability layers. The relatively high resistivity readings seen on most logs likely indicate more consolidated conditions. This unit is also typically characterized by discrete screens, as indicated by the third screen interval on the example log on Figure 2-6. Although the well on Figure 2-6 does not extend below about 740 feet, logs from several deeper wells in the area indicate that the nature of the sediments changes once again at about 800 feet, a depth used to define generally the bottom of the Lower Unit. For the few deep wells with available electric logs, this depth indicates more homogeneous consolidated units than seen in the upper intervals, with the Lower Unit functioning as a transition zone.

This methodology has been extended across the entire Model Area, recognizing that the textures and character of the units change significantly, especially with distance from the river. Changes in the character of the units will be accommodated in the model through the assignment of aquifer parameters, as discussed in Section 3.

2.3 Local Water Agencies and Institutional Framework

Surface water and groundwater are managed conjunctively throughout the Study Area to effectively match water supplies with demands; however, this complicates the tracking of water entering and

exiting the groundwater system. Although the site conceptual model focuses on the groundwater system, a brief description of local water agencies and the institutional framework provides some understanding as to which demands are met with each water source.

Several water sources are actively used and managed in the Kern Fan Area. Kern River water enters the Model Area through the river channel or from a series of unlined canals. Water is diverted from the river channel into lined or unlined canals in accordance with water rights administered by the Kern River Watermaster. Water is often transferred or re-directed to other destinations in real time when excess supplies are available. Most of the water is used for agricultural irrigation or groundwater recharge.

Local surface water is supplemented by imported water from the State Water Project (SWP) and Federal Central Valley Project (CVP). SWP water is conveyed into the Study Area via the California Aqueduct by KCWA, the local contracting agency. SWP water can be diverted into several canals on the west side of the Model Area or recharged in banking facilities on behalf of the agency or others. The Friant Water Users Authority operates the Friant-Kern Canal to convey CVP into the area. CVP water can be conveyed from the canal into a regional transmission canal (e.g., the Cross Valley Canal) or into the Kern River channel. CVP water enters the Study Area primarily through the Friant-Kern Canal. Local water and imported water are often involved in an exchange to facilitate conveyance.

A series of complex contracts, exchanges, and shared conveyance facilities offer Kern County water managers flexibility in water use, but complicate the ability to track the physical movement of water from various sources throughout the Model Period. The focus of the conceptual model has been to evaluate the inflows and outflows relating to the groundwater system regardless of water source while maintaining as detailed accounting as possible to minimize any double-counting in the water balance.

3 Conceptual Model of the Kern Fan Area

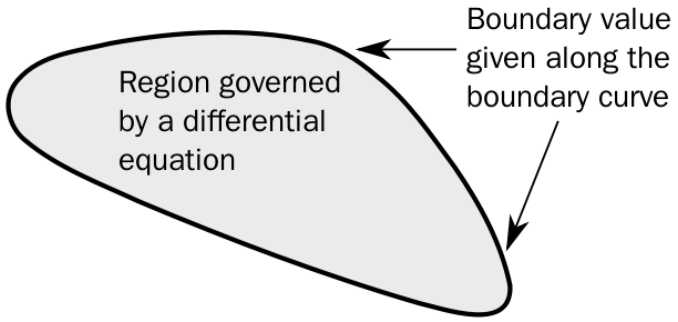
The conceptual model of the Kern Fan area provides a quantitative assessment of the hydrogeology of the Study Area by delineating aquifer systems into model layers, assigning aquifer parameters spatially and vertically, and providing a water balance for the study period. When the data analysis has involved multiple data sets and/or several analytical steps, details of the analysis are provided in a separate appendix and summarized in the text. Collectively, these data and analyses provide the basis on which the numerical model is being constructed.

3.1 Study Area and Model Area

Groundwater data throughout the Study Area have been used to characterize the numerical Model Area, which covers 454 square miles. The Study Area extends beyond the Model Area and its boundaries, which were identified and located on the basis of data over the larger study area.

3.1.1 Model Boundaries

Model boundaries are used in flow simulations of a large system (e.g., groundwater flow in the Southern Central Valley) by modeling a small part (e.g., the KWB area) that is far from its edge. Boundary conditions represent the dynamic sources of water (or no sources) that flow into or out of the model, and are used to constrain the mathematical solution of three-dimensional groundwater flow within the Model Area. The model domain (area) must have boundary conditions defined on all sides of the three-dimensional volume (top, bottom, and sides) as indicated by the schematic.



For the Kern Fan Model, a combination of time-varying specified head and time-varying specified flux (no flow and finite flow) conditions will be used for lateral boundaries in the numerical model. The top boundary for the model will be the land surface and/or water table with areal recharge over time. The sources and distribution of areal recharge which comprise the top boundary are discussed in detail in **Section 3.5**. The bottom boundary is discussed further in **Section 3.1.2** and will be defined as a no-flow boundary for the initial calibration simulations.

Lateral Boundaries

The lateral or side boundaries of the numerical model have been developed in conjunction with input from the KFMC, and were discussed at Project Meetings held on December 13, 2011 and April 18, 2012.

Model boundaries have been identified and constructed with consideration of geology/hydrogeology, regional groundwater flow directions throughout the study period, and have accounted for potential impacts on simulated flow from localized surface recharge from the river and canals. The lateral boundaries have been located at distances away from the KWB that minimize artificial influence on with and without predictions. Location of boundaries have been optimized to meet the multiple goals of properly constraining the flow model simulated with correct values of specified head or flux, and minimizing potential artificial influence of the boundaries on simulation of flow in the critical areas around the banking projects, while limiting the model and input data area to a manageable size.

To the degree possible, natural hydrologic boundaries in the study area such as persistent groundwater flowpaths and geologic boundaries have been selected so that simulated water levels could accurately respond to changing conditions without user-defined boundary condition heads or fluxes which would excessively constrain the simulations. Some boundaries have been located on the basis of both water levels and geology. Other boundaries have been selected on the basis of water level or flux irrespective of geology.

The available KCWA annual (spring) water level contour maps over 21 years (1980, 1987, 1991, 1993, 1995, and 1998 – 2010 - Appendix A) along with hydrographs for key study area wells have been reviewed to identify spatial and temporal trends in water levels. The individual spring maps between 1980 and 2010 also were digitally averaged to produce an average flow map (Figure 3-1). This map, along with the maps for individual years, has been used to assist the identification of consistent flowlines in some areas. Where contours and flowlines have been consistent over time, potential no-flow or other boundaries have been identified. However in some potential model boundary areas, local flow directions change from year to year in response to changing recharge and pumping patterns. Some model boundaries have been selected to be time-varying specified heads, to account for dynamic flux into and out of these boundaries. These boundaries have been aligned where heads were well-documented.

Figure 3-2 shows the Model Area and boundary types. Each boundary arc segment is numbered and color-coded by type for reference.

For time-varying specified head and specified flux boundaries, head and flux values will be assigned to multiple arc 'nodes' along each boundary arc. Different head or flux values can be assigned to different boundary nodes along a single arc segment, and can vary over time. Boundary heads or flux along the entire arc can then be extrapolated between the nodes. Using this approach, local variations in hydraulic gradient through the different sub-portions of the boundary arc segments can be simulated accurately. Head values used for the boundary arcs will be based on groundwater elevations measured in properly constructed wells adjacent or near to the arcs, along with regional water level maps and hydrographs. Vertical variations in boundary heads between model layers will be simulated if local water level data confirm the presence of vertical gradients between shallow and deep aquifers along the boundaries. Flux rates assigned to boundaries will be based on estimated inflows (or outflows) such as values canal leakage.

Note that during model calibration, some adjustments to boundary arc alignments, types, or values may be made in order to achieve proper calibration quality.

The lateral boundary conditions are described below. Beginning in the east, near the Kern River, boundary ***Segment 1*** was aligned with a generalized northwestern flowpath from the River to the north-northeast and may be represented as a no flow boundary. Average 1980 to 2010 water levels along this boundary (Figure 3-1) from south to north drop from around 280 to 160 feet msl. These are the average head values along the boundary arc; fluctuations in water levels over time occur along Segment 1 and many of the model boundaries as revealed on the annual water level contour maps (Appendix A) and KFMC hydrographs.

Segment 2 represents a time-varying head boundary along the northern edge of the model. This segment is also aligned roughly along a groundwater flow path from east-southeast to west-northwest. However, review of groundwater elevation contour maps indicates some groundwater flow occurs across this segment during some years. Dynamic flow directions occur in this area likely due to variable pumping and recharge over time. Accordingly, use of an 'open' boundary type as represented by time-varying specified heads is appropriate to allow inflow and outflow through the boundary segment. The head varies to be assigned to this boundary segment and the other time varying specified head segment will be developed based on groundwater elevations monitored over time in appropriately-constructed wells. Moderate differences in hydraulic heads are measured in between wells screened in shallow and deep aquifer zones in the vicinity of Buena Vista Water Storage District (BVWSD), Semitropic, and other areas in the northern portion of the proposed model domain. The vertical gradients reflect local recharge and pumping influences and the hydraulic resistance of the low permeability deposits including the E Clay and '300-foot Clay' present in the northern portions of the model. Vertical variations in time-varying heads may be assigned to the different model layers (see below) if head data support the presence of local vertical gradients. Average 1980 to 2010 Water levels along this boundary from range from around 160 to 100 feet msl.

Segment 3 continues west-northwest of Segment 2, and this arc represents a no-flow boundary aligned with a consistent east-southeast to west-northwest flowpath. Mapped flow directions along this boundary appear to be more consistent than in the area of Segment 2, therefore the arc alignment was parallel to the flow path. Average water levels along this boundary from east to west drop from around 100 to 70 feet msl.

Segment 4 represents a time-varying specified head boundary in the northwest portion of the model. The curvilinear arc alignment for this boundary was drawn parallel to relatively consistent groundwater elevation contours as presented on the KCWA Spring groundwater elevation maps. Based on water level data over time, groundwater outflow from the southeast to the northwest through this boundary occurs during most water years. However, during a few years inflow from the northwest to the southeast occurs. Recharge and pumping operations in the North Kern WSD and Semitropic Water Storage District (Semitropic) may affect heads along boundary Segments 2 and 4. The water banking and pumping activities of North Kern WSD and Semitropic that are outside of the Model Area can be accounted for by the time-varying heads assigned to the boundary arcs, which reflect the effects of these influences, without actually including the North Kern WSD and Semitropic activities inside the model domain. Average water levels along this boundary from range from around 80 to 60 feet msl.

Segment 5 represents a no-flow boundary in the northwest portion of the model. Groundwater flow directions along this boundary are to the northeast from the westside hills into the valley floor. Mapped flow directions along this boundary appear to be consistent over time; therefore the arc alignment was parallel to the flow path. Average water levels along this boundary from east to west drop from around 100 to 70 feet msl.

Segment 6 represents the western model boundary near Interstate 5. This boundary was created using ground surface elevations and geology and will be represented as a specified flux boundary. The flux rates represent leakage from canals and any mountain-front recharge from the southwest. Canals including the Outlet Canal, the Westside Canal, and the Kern River Flood Channel are a source of recharge that controls flow in that area. The fluxes assigned as inflow to this boundary will be based on the monthly canal losses along with natural recharge estimates. Note that water level data indicate there are some discontinuities in the area and that monitoring wells within one mile of each other on the western edge of the KWB record very different water level fluctuations (e.g., 19R and 19N). Faulting in the area may contribute to this head change. Average water levels along this boundary from range from around 170 to 200 feet msl.

Segment 7 represents the southwestern model boundary and is aligned with the northern edge of lower permeability sediments mapped as overbank and lacustrine deposits (Kern and Buena Vista Lake Beds). Mapped groundwater elevations and inferred flow directions in this area vary more than in most other areas within the model. Average water levels along this boundary range from around 160 to 220 feet msl. Large differences in hydraulic heads are measured in wells separated by relatively close distances, and between wells screened in shallow and deep aquifer zones. These head variations reflect local recharge and pumping influences and the hydraulic resistance of the low permeability deposits. Water level contour maps indicate that some groundwater is moving across the boundary. Moreover, there are transmissive sand units in this area (e.g., as logged in several wells in the Henry Miller Water District); therefore flow in this area may not be controlled by the local thick sequences of clay. Accordingly, the southern boundary was located south of the contact of the clay units to minimize the potential artificial influence of this boundary. As located, the low-permeability sediments are hypothesized to restrict the amount of flow through the southern boundary. The southern boundary is also aligned along a persistent flow divide between areas of high and low water levels. Potential revision of the southern boundary from a no-flow to specified head boundary may be considered during calibration. It should be noted that the boundary is relatively far away from the banking projects and likely will not affect model results near the KWB area.

Segment 8 represents the southeastern model boundary near the Central Branch Canal. The groundwater flow regime along with known canal loss rates at this location has been used to locate a logical boundary. Review of groundwater elevation data indicates that relatively minor groundwater inflow/outflow occurs beneath the Central Branch Canal. Water levels along this boundary range from around 180 to 280 feet msl. Heads also indicate that recharge from the canal losses creates local linear mounds with divergent groundwater flow beneath the canal. Therefore this boundary will be assigned time-varying specified flux boundary with 50 percent of monthly Canal losses assigned to the boundary arc.

Segment 9 represents a relatively short boundary segment perpendicular to the river near the Beardsley Canal and will be represented by time-varying specified flux or a time-varying specified head. Data and calculations to support the flux rates are provided in the Appendix E: Subsurface inflow and Outflow.

For the specified head and flux boundaries, estimates of associated volumetric flow into and out of the model have been made for the purposes of developing a conceptual model water balance. The methods used to quantify these and other water balance components are described further in Section 3.5.

3.1.2 Model Layers

The number and depths of layers for the numerical model have been developed with input from the KFMC, as discussed at the Project Meetings held April 18, 2012, May 10, 2012, and June 20, 2012.

Three-dimensional models like MODFLOW require discretization of the entire flow domain. The flow region is subdivided into model cells, both horizontally and vertically. The dimensions of the cells in the ***x*** and ***y*** directions are referred to as grid size. The grid size in the ***x*** and ***y*** directions should be sufficiently small to allow accurate simulation of areas of large hydraulic gradient, and the effects of sources and sinks. Vertical stacks of cells form model layers. Within each cell the various input parameters are maintained constant, but they may vary horizontally between the cells and vertically between layers.

Ultimately, the numerical model utilizes aquifer hydraulic properties (including layer top and bottom elevations, horizontal and vertical hydraulic conductivity, and storage properties) as key input parameters for each model cell and layer.

The numbers and thicknesses of constructed model layers should account for the objectives of the flow simulations (e.g., what is the depth interval of interest, what are the potential inflows and outflows from un-modeled deeper layers to the target depth interval of interest), depth of key facilities such as production wells, presence or absence of vertical hydraulic gradients, and available data. Model layers can sometimes represent major stratigraphic layers, if present. The top and bottom elevation surfaces of continuous geologic layers can be simulated, and aquifer hydraulic properties assigned to the layer. This approach can provide a relatively accurate numerical model if the hydraulic properties of the stratigraphic units are well known. If continuous stratigraphic layers are not present, model layers can be defined simply on the basis of aquifer hydraulic property distributions, well completion depths, or other parameters.

For the model, both geologic conditions and well depths have been used to define model layers. Most production wells in the study area have a maximum depth of around 700 to 800 feet. Appendix B lists the depths and perforated intervals of wells with known construction information. Figure 3-3 shows wells within the study area. Of the 3,786 wells in the study area, over 93 percent have total depths of less than 800 feet bgs. With a few exceptions, significant volumes of groundwater are not pumped below this depth.

The presence and distribution of relatively lower permeability stratigraphic layers has also been used to construct model layers. Some low-permeability confining units (such as the E Clay) appear to be laterally continuous or semi-continuous over portions of the Model Area, but the low-permeability units are generally not continuous in the KWB area. Figures 2-4 and 2-5 show the interpreted depths to the

top and thickness of the relatively low permeability unit(s) correlated to the E Clay. These relatively low permeability layers act to confine groundwater flow in deeper aquifer zones beneath the clays. Some vertical gradients are measured in the areas where the low permeability units are present, and in areas with recharge or pumping operations.

During the Project Meetings, comments were provided by KFMC members that the model layers should honor well construction and the presence of any continuous low permeability materials (e.g., the E Clay), as much as possible. Electric logs were subsequently reviewed and hydrogeologic cross sections developed to map the depths of confining units and, to the degree possible, build model layer geometries around these units. Because distribution of aquifer hydraulic properties is a critical input parameter for the numerical model, model layer development considered those wells that have high quality aquifer tests, recovery wells, and wells used for contouring depth discrete aquifer units.

At the May 2012 Project Meeting, Todd proposed an initial 3-layer model scheme with generalized layer depth ranges of approximately 0 to 300+, 300+ to 500+, and 500+ to 800 feet bgs. The elevations of the bottoms of Layers 1 and 2 would be refined based on presence and depths of confining units. Non-uniform elevations will be defined based on the depths of the lower permeability zones encountered in boreholes, to form elevation surfaces for the bottom of Layers 1 and 2. The bottom of Layer 3 will be set to a constant depth of 800 feet bgs. The upper layer will be unconfined and have variable saturated thickness. Layers 2 and 3 will be confined/convertible. Aquifer hydraulic properties will be assigned to each layer based on normalized hydraulic conductivities from high-quality pumping tests and specific sand intervals at locations with high quality lithologic information (see Section 3.2).

The hydrostratigraphy of the central Model Area can be conceptualized as a three-layer system. Geophysical and lithologic logs generally exhibit an upper higher permeability alluvial package that extends down to around 300 feet (Model Layer 1), a series of interbedded sands and silty clays down to about 550 feet or 600 feet (Model Layer 2) and a lower-permeability section extending to the bottom of most logs with total depths of around 700 feet (Model Layer 3). Deeper wells to the north indicate that the third zone transitions into a much higher resistivity zone at about 800 feet, providing the justification for the bottom of the model. Figure 3-4 shows locations of the hydrostratigraphic cross sections presented on Figures 3-5 through 3-10. These cross sections illustrate the locations of the model layer boundaries, the range of historical groundwater elevations along the cross sections, and the depth and distribution of the E Clay as reproduced from USGS contour maps. As illustrated on the cross sections, the three-layer model generally incorporates the lower permeability E Clay within model Layer 2. A small portion of the E Clay extends into Layer 3 near the southwestern boundary of the model.

In order to identify the specific depths of the contacts between the upper unconfined zone and middle confining zone, where present, geophysical resistivity logs and construction data have been reviewed for wells identified as having high-quality aquifer test information, and a methodology has been devised for developing model layers. Figure 2-6 shows an example geophysical log from the Pioneer Project annotated to show major changes in lithology. In addition, sand and clay intervals for these same wells were tabulated for use in characterizing hydraulic conductivities of the sands (Section 3.2).

Table 3-1 lists the depths of the three hydrostratigraphic zones identified in the geophysical logs evaluated for this project (including those wells with high quality aquifer test results available). Model

layer elevation surfaces (i.e., the bottom elevation of the upper unconfined alluvial sand zone, Model Layer 1, and the bottom of the interbedded lower permeability zone, Model Layer 2) were then constructed on the basis of these point elevations. Although the first approximation of model layers was based on connection and extrapolation of these hydrostratigraphic contact points, the model layer elevation surfaces were smoothed somewhat to provide layer bottom surfaces without large discontinuities. During this process a number of numerical interpolation methods were tested and some outlying contact elevation points were removed in order to construct layer surfaces. Ultimately, an inverse-distance weighted interpolation method was applied. The resulting layer elevation surfaces honor the hydrostratigraphic data and present functional surfaces for use in the numerical model.

Figures 3-11 through 3-13 show the final interpolated surfaces for the bottoms of Model Layers 1, 2, and 3, respectively. In all areas except near a portion of the northwestern boundary arc (Segment 4), the bottom of Layer 1 is located below the low water table, in order to maintain saturation during MODFLOW simulations (see below). Elevations of the bottom of Layer 1 (Figure 3-11) range from about -10 to 120 feet msl. Elevations of the bottom of Layer 2 (Figure 3-12) range from about -330 to -190 feet msl. Comparison of the top and bottom elevations of model Layer 2 with previous interpretations of the elevation of the E Clay (Figures 2-4 and 2-5) reveal that the confining unit is predominantly contained within Model Layer 2. The bottom of Layer 3 is set at a constant depth of 800 feet bgs. Elevations of the bottom of Layer 3 range from about -510 to -370 feet msl.

The thicknesses of each model layer have been calculated based on the top and bottom elevation surfaces. Layer 1 represents the unconfined alluvial zone and its saturated thickness fluctuates over time with the water table. To assess the approximate range of saturated thickness of Layer 1, the difference between the estimated “low” water table (representing historical low water levels as measured across the Model Area) and the Layer 1 bottom elevation surface was calculated. Similarly, the maximum thickness has been estimated as the difference between the “high” water table (representing historical high water levels as measured across the Model Area) and the Layer 1 bottom elevation surface.

Figures 3-14 and 3-15 show the saturated thickness of the shallow unconfined aquifer during these two periods. During dry conditions, the saturated thickness ranges from about 180 to 0 feet (Figure 3-14). Based on the estimated low water table, the area around the northwest model boundary (Segment 2) has minimal thickness. This may be due to the use of water levels from wells completed in the deep aquifer zone, which have lower hydraulic heads than the overlying shallow zone. Accordingly, higher boundary head values may be used and/or the bottom elevations for Layer 1 may be reduced slightly to maintain saturation of Layer 1 in this area. During wet periods, the saturated thickness of Layer 1 ranges from around 280 feet in the KWB area to 60 feet in the northern Model Area (Figure 3-15). Figures 3-16 and 3-17 show the thickness of Model Layers 2 and 3. The thickness of Layer 2 ranges from around 240 to 340 feet, while the thickness of Layer 3 ranges from around 260 to 160 feet. It is recognized that some newer production wells (e.g., Vaughn Water Company wells) north of the river have been drilled as deep as 1,200 feet to 1,400 feet. Because the maximum depth of the model is 800 feet, the portion of production from such deep zones below 800 will be excluded from the model.

These elevations and thickness will form the geometrical framework of the numerical flow model. Aquifer hydraulic properties including heterogeneous horizontal and vertical hydraulic conductivities, specific yields, and storage coefficients will be assigned to each model layer as discussed below.

3.1.3 Model Calibration Period

Selection of the historical model calibration period has been based on multiple considerations. These include the availability and reliability of key data sets compiled for the site conceptual model, and the need to simulate variable wet and dry conditions in order to validate the predictive model. In addition, the transient simulation period needs to be sufficiently long to simulate conditions before operation of the major banking projects (primarily beginning in about 1993) and is best initiated when water levels are relatively stable. Also, it may be beneficial to initiate the model after a relatively dry period that has allowed the vadose zone to drain. Finally, selection of a simulation period should account for uncertainties in model initial conditions, and allow sufficient model time for the simulation to 'attenuate' any errors caused by initial conditions.

The numerical flow model requires numerous input parameters, which are not well documented prior to 1986. The data sets improved significantly in 1986, another factor that entered into the model period recommendation. There are no water level data in the KCWA water level database prior to 1986; this database represents the most comprehensive compilation of consistently monitored wells in the basin and will be key data for model calibration. Prior to 1986 the only water level data available are from the Department of Water Resources (DWR) and these are sparse. Even in the (DWR) database, the number of wells appears to increase significantly in 1986.

Based on these criteria, a simulation period of 1986 through 2010 has been selected. Rationale for the 25-year period selection included the timing of banking projects, wet and dry hydrologic cycles, about three years of relatively stable water levels for initial conditions, and data availability. Recharge at the KWB and at other recharge facilities began in the mid-1990s, so inclusion of the earlier period beginning in 1986 allows evaluation of calibration quality before initiation of banking. Figure 2-1 shows annual precipitation data (presented on a calendar year basis) and a portion of the long-term (1890-2010) cumulative departure curve. Several wet and dry cycles occurred over the 25 year study period. The post-1986 time period precedes a major drought, with a very dry period occurring in 1990 and 1991, while relatively wet periods occurred in the late 1990's. Dry conditions returned in the late 2000's approaching the end of the historical simulation period. Simulation of these alternating dry and wet cycles allows validation of the model under differing recharge conditions.

3.2 Kern Fan Hydrostratigraphy

3.2.1 Distribution of Coarse and Fine-Grained Deposits

The distribution of coarse and fine-grained deposits across the study area has been characterized on the basis of lithologic and electrical logs, interpretations of stratigraphic and lithologic databases created by the KCWA and USGS, aquifer pumping test results, and published geologic studies, cross sections, and maps. The geologic information is summarized in Section 2, and references for the various stratigraphic studies and data are provided in Section 4. Several of the previous geologic studies have been used to

develop the model layer geometries for the numerical model. These data are also used to characterize and quantify aquifer hydraulic properties.

For this project, a methodology has been developed to simulate the distribution of coarse and fine grained deposits, and their aquifer hydraulic parameters in the numerical model. The distribution of these key model input parameters is based on the distribution of coarse and fine deposits more than 220 electrical resistivity logs from wells across the study area, along with aquifer hydraulic parameters from high quality pumping tests.

3.2.2 Aquifer Hydraulic Properties

Aquifer hydraulic properties are important input parameters for the numerical model. The key parameters are vertical and horizontal *hydraulic conductivity*, measures of the aquifer permeability, and *storage coefficients*, which affect the dynamic aquifer response to transient stresses such as recharge and pumping. These parameters, along with the aquifer and model layer thickness, form the physical framework or 'plumbing' of the groundwater system and the numerical model.

Some estimates of aquifer hydraulic properties within the study area previously were made from well pumping tests. Pumping test data and results have been obtained from KCWA, participating water Agencies and Districts. Additional estimates of hydraulic properties were made using undisturbed core samples from boreholes.

For most of the pumping tests, aquifer *transmissivity* was estimated. Transmissivity is the rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient. Transmissivity divided by the saturated thickness of aquifer is equal to the horizontal hydraulic conductivity. While a constant rate, long-term pumping test is the best method of determining transmissivity, it can also be estimated based on the ratio of pumping rate of the well and the observed drawdown (specific capacity). Storage properties of the aquifer include s*pecific yield* for unconfined aquifers and *confined storage coefficient* or *specific storage* (equivalent to storage coefficient divided by the saturated thickness of aquifer) for confined aquifers.

Aquifer hydraulic properties vary spatially across the study area because of the different sedimentary environments and dynamic geologic history of sediment deposition in the Central Valley. Well-sorted, coarse-grained sands have higher hydraulic conductivity and storage coefficients than fine-grained silts and clays. Because both types of geologic materials (coarse and fine-grained) are present in the Model Area and their distributions vary laterally and with depth (Section 2), an accurate representation of the distribution of these aquifer parameters must be developed. Representative three-dimensional distributions of these hydraulic properties allow accurate model predictions of the aquifer hydraulic response to dynamic recharge and pumping.

The approach and methodology for representing aquifer hydraulic parameters in the numerical model has been developed in conjunction with the KFMC, as discussed at the Project Meetings held April 18, 2012, May 10, 2012, and June 20, 2012. Each of the three model layers described in Section 3.1 will be 'populated' with hydraulic conductivities and storage parameters. The model will contain true-layer elevations for the top and bottom of each layer along with assigned hydraulic conductivities and storage parameters representing a composite value for the layer. Aquifer pumping test transmissivity results

along with borehole lithologies (sand and silt/clay intervals) at different locations within the Model Area will be used to estimate the distribution of horizontal hydraulic conductivities for each layer. Vertical hydraulic conductivities will be estimated initially on the basis of the presence or absence of clay layers and core sample permeameter tests. Storage coefficients will comprise specific yields for the uppermost aquifer and fully-confined or 'mixed' storage coefficients for the deeper layers.

The following sections describe the methodologies and results for estimating the distribution of hydraulic conductivities and storage parameters.

Aquifer Transmissivity and Horizontal Hydraulic Conductivity

Aquifer transmissivity values from high quality pumping tests were used to estimate horizontal hydraulic conductivities of the sand fraction at each test well location. Composite hydraulic conductivities at different locations were then developed based on the normalized hydraulic conductivities and actual percentages of coarse and fine aquifer materials at different locations.

Figure 3-3 shows the locations of wells in the study area, indicating those with pumping test data. The most accurate aquifer transmissivity values are from wells with high quality constant-rate pumping tests with observation wells and correct data analyses. The highest quality transmissivity values are from constant-rate pumping tests with observation wells performed on ID4 wells at Allen Road, Rosedale ENNS Pond Wells, Strand Ranch wells, and West Kern wells. For this set of tests, both drawdown and recovery data from pumping and observation wells were evaluated. Additional good quality tests were performed by KCWA on wells around the KWB. This set of tests involved single-well constant-rate pumping tests with 24-hour durations. Water level recovery data from the pumping wells were analyzed to estimate aquifer transmissivities. Of similar good quality were a third set of pumping tests and estimated aquifer transmissivities provided by the KFMC. Aquifer transmissivities for these high and good quality test wells range from 2,270 to 110,000 square feet per day (ft^2/day - Table 3-2). The average transmissivity is about 20,080 ft^2/day.

Figure 3-18 shows the distribution of transmissivity values estimated from high quality aquifer tests. Relatively high transmissivities are present in the center of the alluvial fan and KWB area; generally lower transmissivities are mapped in the northern and southern portions of the Model Area.

After discussion with the KFM, it was determined that aquifer transmissivities estimated from specific capacity values are of relatively lower quality, and would need to be normalized for the test duration and well screen interval. Therefore, these lower quality data have not been used to estimate horizontal hydraulic conductivities.

Using the reliable pumping tests as a baseline, hydraulic conductivity of the sand intervals for each test well has been estimated as follows. For each reliable pumping test, the electrical resistivity logs were reviewed and sand intervals identified. The total saturated sand thicknesses for each reliable test well were summed and the estimated transmissivities were divided by the total sand thickness to obtain a horizontal hydraulic conductivity for all sand layers at each well. This approach assumes that the inflow to the pumping well occurs via the sand intervals only, and that the horizontal hydraulic conductivity of each sand interval is the same. Using the normalized hydraulic conductivities and fractions of sand and lower permeability silts and clays, the hydraulic properties were further partitioned by model layer. The

horizontal hydraulic conductivity at each well for each layer was scaled based on the percentage of saturated sand logged in each depth interval. The resulting composite hydraulic conductivities for each model layer were reduced (scaled) based on the percentage of sand in each layer. Using this approach, the total aquifer transmissivity at each test well has been preserved and partitioned by model layer.

The analysis of sand fractions and calculation of hydraulic conductivities and scaled conductivities by layer is underway, but not complete. Representative values of horizontal hydraulic conductivity for the sand fraction from the analyses range from around 10 to 100 feet per day. The final analyses and hydraulic conductivity distribution used in the numerical model will be fully documented in Technical Memorandum No. 2.

Vertical Hydraulic Conductivity

Vertical hydraulic conductivities are generally lower than horizontal hydraulic conductivities. This is due to the stratified nature of alluvium: sediment grain imbrications that cause lower pore connectivity in the vertical direction as compared with horizontal, and the presence of discreet fine-grained silt and clay layers on both micro and macro scales. In areas where relatively continuous fine-grained stratigraphic layers (such as the E Clay shown in Figure 2-4) are present, vertical groundwater flow is impeded due to the low vertical permeability. The USGS has reported permeameter data from core samples of the E Clay; the average estimated vertical hydraulic conductivity of the E Clay is around 0.0004 feet per day. In such E Clay areas, vertical head differences exist between the shallow and deeper aquifer zones.

The numerical model must be able to simulate both horizontal and vertical groundwater flow. A three-dimensional distribution of vertical hydraulic conductivity will be developed during model calibration. Zones of vertical to horizontal hydraulic conductivity anisotropy ratios will be mapped, in part based on the distribution of coarse and fine grained deposits, and adjusted during calibration. In areas where coarse-grained deposit predominate, higher vertical-to-horizontal hydraulic conductivity anisotropy ratios will be simulated.

Storage Coefficients

Both unconfined and confined aquifer storage properties have been tabulated from published studies (USGS, DWR, and others), aquifer pumping tests, laboratory tests, and previous modeling of the KWB. Table 3-2 lists the storage coefficients estimated for high-quality pumping tests performed on West Kern and Strand Ranch wells. These confined or 'mixed' semi-confined storage coefficients range from around 0.0008 to 0.03 (unitless), and are appropriate for simulation of the semiconfined and confined model Layers 2 and 3. For the unconfined aquifer zones (Model Layer 1), specific yields will be used. Table 3-3 lists a range of specific yield values for different soil classifications (sand, clayey sand, etc.) in the Central Valley. Coarse-grained materials such as sand without fines have the highest specific yields (up to 35 percent), with lower values for finer-grained materials. The DWR has averaged measured specific yields in four Townships within the study area and reported averages of between 10 and 14 percent. Specific yields in the KWB area were also estimated as a part of the early DWR Kern Fan Groundwater Model. Heterogeneous distributions of specific yield were developed for that three-layer MODFLOW model; specific yields for the final model ranged from 12 to 21 percent. Note that a specific yield value of 0.15

has been used for the change in storage estimates developed for the preliminary water balance presented in Section 3.4.

As with hydraulic conductivity, three-dimensional distribution of specific yield and storage coefficients will be developed during model calibration. Zones of specific yield and storage coefficients will be mapped, in part based on the distribution of coarse and fine-grained deposits, and adjusted during calibration.

3.3 Groundwater Occurrence and Flow

Groundwater elevation data have been evaluated across the Study Area in order to assess horizontal and vertical hydraulic gradients, to define groundwater flow rates and directions, to estimate subsurface inflow and outflow, and to evaluate change in storage over time. Water level data also have been used to locate and align the model boundaries (Section 3.1.1). Water level data from a subset of these wells will be used to assess model calibration quality.

3.3.1 Groundwater Levels

Water level databases have been obtained from the KCWA and DWR. The KCWA began a water level monitoring program in 1980. Groundwater monitoring of selected wells in the study area has been conducted a monthly or semi-annual basis, with creation by KCWA of annual (Spring) water level contour maps. These maps, along with hydrographs for key wells in the KWB area, are reported in the Annual Operations Reports prepared by the KFMC. Figure 3-3 shows wells in the study area; many of these wells have reported water level data and are used in the groundwater flow evaluation.

3.3.2 Groundwater Flow

Horizontal flow conditions are characterized with the KCWA Spring groundwater elevation contour maps. As described above, an average Spring water level map has been created to demonstrate overall flow conditions (Figure 3-1). Annual (spring) groundwater elevation contour maps for individual years are included in Appendix A.

As illustrated on the average and annual water level maps, groundwater generally flows from natural and artificial recharge areas toward discharge points. For any given period, the highest groundwater elevations generally occur near the eastern model boundary as a result of subsurface inflow from the river valley and infiltration from the River and adjacent canals. A divergent groundwater flow divide typically coincides with the Kern River channel with flow away from the river. Groundwater flow across the southern portion of the study area is generally from north to south, with local perturbations around local recharge and pumping sources particularly in the southernmost areas of the model. Groundwater flow through the northern portion of the study area is generally from southeast to northwest, away from the River and KWB and toward Semitropic Water Storage District.

Review of the annual water level contour maps reveals the fluctuations in water levels from year to year. Overall increases and decreases in basin storage are correlated to annual recharge fluctuations, and local changes in groundwater elevation occur that are associated with specific recharge and

pumping facilities. These groundwater elevation fluctuations have been used to estimate the changes in groundwater storage for comparison with the water balance (Section 3.4).

The range of groundwater elevations over the study period is illustrated on the cross sections (Figures 3-5 through 3-10). As illustrated on the cross sections, during periods of high groundwater, the water table is sometimes near the ground surface along the western and southern model boundaries, and depth to water beneath the KWB is less than 50 feet. In other areas and during dry periods, depth to water exceeds 300 feet. This range of water levels reflects the dynamic nature of recharge and pumping in the study area.

Water level changes over time are also documented on hydrographs prepared by the KFMC and included in the Kern Fan Area Operations and Monitoring Reports. Changes in water levels over time and by depth are documented in these hydrographs from key wells.

Vertical hydraulic gradients are present in several portions of the study area. Downward vertical gradients have been measured beneath and adjacent to some of the recharge ponds, and in other areas where fine-grained confining units are present. Vertical hydraulic gradients are present in several areas. These areas include the northernmost and southernmost portions of the model and generally correspond to locations where fine-grained confining units are present. At some locations, the magnitude of the vertical hydraulic gradient exceeds that of horizontal gradients. Vertical hydraulic gradients present near the KWB are measured in "nested" well pairs within and between the Shallow and Deep aquifer zones.

Water level elevation data will be used to assess model calibration. Maps and hydrographs of measured and simulated water levels in space and time will be developed, and some water balance elements including boundary inflow and outflow and change in storage will be compared with the estimates developed as a part of the conceptual model water balance.

3.4 Water Balance

In order to better understand the volumes of water moving through the groundwater system and to develop inputs for the numerical model, a water balance has been developed for the Model Area. The water balance presented in this section accounts for inflows and outflows to groundwater, the subtraction of which represents changes in groundwater storage over time. The balance presented herein does not provide for spatial variation, which will be handled in the numerical model by assigning appropriate portions of the inflows and outflows to the corresponding locations. The water balance represents a first approximation of changes in groundwater storage that will be further assessed during model development and calibration. A summary of water balance components are shown on Table 3-4.

Data have been compiled monthly for model input; annual totals are summarized here to illustrate the annual average and cumulative change in groundwater storage in the Model Area for the entire Study Period. The data and methodology are described for each of the water balance components below.

3.4.1 Inflows

Inflows into the groundwater system include subsurface inflow, deep percolation from precipitation, return flows from agricultural and municipal uses, canal losses, and managed recharge including groundwater banking. Each inflow component is described briefly below, followed by a presentation of the data from 1986 through 2010.

3.4.1.1 Subsurface Inflow

Groundwater flow occurs into and out of the model area through lateral boundaries. As described in Section 3.1.1, time-varying specified head and specified flux boundaries allow subsurface flow into the model. The areas of inflow and methodology used to calculate the amounts over time are provided in Appendix E. As summarized in Table 3-4, the estimated rate of inflow varies over time, with a range from zero (in 2000) to 15,556 AFY (in 1991).

3.4.1.2 Recharge from Rainfall

For the purposes of this water balance, recharge from rainfall has been subdivided into several different inflow components of the water balance. Percolation from rainfall on areas with native vegetation has been estimated using a simple soil moisture balance, as documented in Appendix C. Percolation occurs only in very wet years: 1995, 1998, and 2010, and as shown in Table 3-4, total volumes of rainfall recharge are small. It should be noted that rainfall on agricultural areas and municipal areas are included in the irrigation return flows and municipal return flows (see sections below).

3.4.1.3 Irrigation Return Flows

This inflow component accounts for the portion of irrigation water that is applied in excess of the evapotranspiration (ET) of the crop, as well as excess precipitation that either percolates directly or runoffs and percolates in nearby areas (defined herein as irrigation return flows). For agricultural areas, individual crops are associated with different amounts of return flows based on crop ET and irrigation efficiencies. The methodology used to develop agricultural demand including crop ET and documentation of irrigation efficiencies used in the analysis are described in more detail in Appendix D. Irrigation return flows include irrigation from both surface water and groundwater. The irrigation return flows for urban areas, including lawns and swimming pools used by individual homeowners, are developed separately based on municipal water demands and are summarized in a subsequent subsection as *municipal return flows*. Table 3-5 shows the estimated irrigation return flow for agricultural areas by Water District and service area. Figure 3-19 shows the Water Districts and Service Areas.

It is recognized that return flows do not recharge groundwater immediately upon application of irrigation, and various scenarios of vadose zone transport times have been evaluated. For accuracy in the groundwater model, the MODFLOW UZF package will be employed to develop an appropriate lag time for recharge of irrigation return flows over the Model Area. For the purposes of this water balance,

no lag has been incorporated. Recognizing that most of the Model Area has consisted of irrigated agriculture throughout the entire Study Period, a relatively steady state of recharge has likely been established, although actual amounts may vary temporally with changes in crop and irrigation patterns. The water balance is being used as a first approximation for the groundwater system that will be modified in the groundwater model. Therefore, an annual water balance that does not provide for a time lag of irrigation return flows is judged sufficient for the purposes of the water balance in this TM.

3.4.1.4 Municipal Return Flows

Some water supplies to municipal users are applied as urban irrigation and other recreational uses. Based on estimates in the Bakersfield area, 50 to 70 percent of municipal supply is used outdoors in some capacity. It is assumed that 12 percent of the outdoor use recharges the aquifer as return flow.

This evaluation of return flows addresses only municipal use of groundwater. It is recognized that river water and SWP water also provide a portion of the municipal supply. The water balance addresses the return of water used indoors through wastewater return flows. Percolation of outdoor uses of surface and imported water is small (on the order of 7 percent of surface water and imported water urban use) and has not been included in the water balance because of the level of complexity to estimate monthly returns compared to the order of magnitude of other components in the water balance. Municipal return flows (percolation) from outdoor uses are shown on Table 3-6.

3.4.1.5 Canal and River Seepage

Many of the canals and part of the Kern River used to transport water in the area are unlined, and leakage from these canals contributes to the underlying groundwater aquifer. Figure 3-20 shows the location of the major unlined canals.

Seepage losses have been calculated based on the difference of flow between various points less deliveries. Monthly canal losses are reported in the Kern River Annual Reports for the major canals in Kern Delta Water District, City of Bakersfield, North Kern Water Storage District, Rosedale Ranch, Cawelo, and the former James Pioneer Irrigation District. Losses along the Kern River are also reported in the Kern River Annual Reports for several reaches. Canal losses were also supplied by Semitropic Water Storage District and Buena Vista Water Storage District for canals in their service areas. The portion of the canal losses that occur within the Model Area have been estimated to be equivalent to the portion of the canal that overlies the Model Area. For the Kern Island Service Area of KDWD, canal losses for the entire service area were divided over the Kern Island canal and the Central Branch canal based on the total length of these canals. The Central Branch canal is located on the model boundary and it has been assumed that one half of losses occurring here recharge the model, while the remaining half does not enter the Model Area. Table 3-7 and Figure 3-21 show annual canal losses by major canals.

3.4.1.6 Enhanced Recharge and Banking

Enhanced recharge and banking is performed in the area by multiple water agencies through various mechanisms (canal spreading, recharge ponds, and in lieu supplies). For the purposes of this TM, no distinction is made between enhanced recharge conducted by water agencies and others to simply increase groundwater resources and more formal banking projects where water is recharged on behalf

of an outside party for the purposes of recovery. For future modeling of the groundwater condition without banking projects a distinction will be required. Because the array of recharge and banking projects covers the entire spectrum of recharge mechanisms, number of participating parties, and recovery methods, this distinction must be well defined and accepted by the technical committee.

Monthly recharge data have been received from the Kern Water Bank Authority for the KWB recharge by individual ponds from 1995 to 2011. Annual recharge data (along with recovery data) are shown on Figure 3-22. KCWA provided monthly recharge for the Pioneer Project and Berrenda Mesa Project from 1995 to 2011. Annual recharge data (along with recovery data) are shown on Figures 3-23 and 3-24, respectively. The Kern River Annual Reports contain monthly recharge volumes for COB projects with the Model Area (including the COB 2,800 facility, Truxtun Lakes, The Park at River Walk, and Aera Park); annual banking recharge volumes for the COB 2,800 facility are summarized on Figure 3-25. Kern River Annual Reports also contain monthly intentional recharge data for NKWSD, Rosedale Ranch ID, and KDWD banking data. Additional recharge data have been provided by various water districts for their respective recharge projects including KDWD, Semitropic WSD, RRBWSD, BVWSD, and WKWD. Annual recharge data for RRBWSD, BVWSD, and WKWD are summarized on Figures 3-26, 3-27, and 3-28, respectively. Table 3-8 shows the annual recharge by major project and Figures 1-2 and 1-3 show the general locations of the recharge facilities.

3.4.1.7 Wastewater Discharge

Several wastewater treatment plants (WWTP) serve the metro Bakersfield area. Two WWTPs are within the Model Area. These are the City of Bakersfield WWTP #3 and the North of the River Sanitary District #1 WWTP as shown on Figure 1-4. Discharge from these two WWTPs also occurs within the Model Area and is discussed in this section.

Other WWTPs operate within the metro Bakersfield region but are outside the Model Area. These include the City of Bakersfield WWTP #2 and the Kern Sanitation Authority WWTP, which are just east of the model's eastern boundary, and the Shafter-Minter Field WWTP which is just north of the model's northern boundary. Discharge from these WWTPs is not included in the water balance because it occurs outside the Model Area. Wastewater infiltration from individual septic systems may also occur within the model boundaries but volumes are likely to be small and inconsequential compared to the other water balance components. They were not included in the water balance.

City of Bakersfield WWTP #3

WWTP #3 serves the City of Bakersfield area that lies west of Highway 99 while WWTP #2 serves the area east of Highway 99. WWTP #3 is between McCutchen Road and Highway 119 to the north and south and between Ashe and Gosford roads to the east and west. During the 1986-2010 Study Period, plant capacity doubled from 8 million gallons per day (MGD) to 16 MGD. Since 1989, most effluent has been piped to a site called Green Acres Farm just west of Interstate 5 for irrigation. When irrigation demands are low in the winter, effluent is discharged to four onsite ponds for storage and percolation.

The City has provided monthly effluent flow data for 2000 through 2010. Annual effluent flows for 1986 through 1999 were estimated using population growth trends and a typical per capita effluent flow rate. Annual flows were divided evenly over each 12-month period.

Between 1986 and 1988, it was assumed that all effluent went to the onsite ponds. An onsite pond infiltration rate of 900 AF/month was estimated from a groundwater conditions study of WWTP #3 by Schmidt (July 2006). For 1989 through 2010, all effluent discharged between February and September went to Green Acres Farm. October through January effluent went to the onsite ponds first (up to a percolation rate of 900 AF/month) with the remainder going to Green Acre Farms. An irrigation efficiency of 80 percent was assumed for Green Acre Farm irrigation, the same as the rest of the Model Area irrigation. This results in 20 percent agricultural return flows for the applied effluent.

North of the River Sanitary District #1 WWTP

The North of the River Sanitary District #1 (NORSD) WWTP is located within the City of Shafter and treats wastewater from the Oildale Mutual Water Company and the City of Shafter service areas. As of 1990, the City owns one-third of the plant's 7.5 MGD capacity. Wastewater is used to irrigate crops near the current plant location (Figure 1-4). Onsite ponds are used for winter storage and percolation.

Annual effluent volumes for 1998-2001 and 2008 are available from KCWA annual reports. Data for 2010 were obtained from the Tulare Lake IRWMP. Annual effluent flow between 2002 and 2009 was assumed to increase linearly. Effluent flows between 1986 and 1997 were estimated using population growth trends and a typical per capita effluent flow rate. Annual flow was then divided up evenly over each 12-month year. The effluent was then assumed to be available for local irrigation.

3.4.2 Outflows

The primary components of outflow from the Model Area include groundwater pumping and subsurface outflow. For the purposes of the water balance, several types of groundwater pumping are defined separately. Groundwater pumping amounts for recovery at the major banking projects have been documented by the operators of each project. Groundwater pumping for municipal and industrial purposes by the City of Bakersfield, Cal Water, and various smaller mutual water companies has been provided at various levels of detail by each purveyor. Groundwater pumping amounts by water districts for supplemental irrigation deliveries have been generally available from various data sources. The actual amount of agricultural irrigation groundwater pumping by private well owners in the Model Area is unknown and requires additional analysis.

Each component of outflow is described briefly below, followed by a presentation of the data from 1986 through 2010.

3.4.2.1 Groundwater Pumping for Banking Project Recovery

Groundwater that has been recharged or banked is recovered either by dedicated recovery wells or through increased production for municipal or agricultural supplies. For TM-1, recovery pumping includes only dedicated recovery wells. The banking projects with dedicated recovery wells include KWB (Figure 3-22), Pioneer Project (Figure 3-23), and Berrenda Mesa Project (Figure 3-24). Monthly pumping records by well have been provided by the KWB Authority and KCWA for these banking projects for 2001 through 2011 and annual data provided from 1996 to 2000. Table 3-9 shows the recovery pumping by general banking project. Other recharge projects (including COB 2800 acres and West Kern Water

District) do not differentiate banking recovery pumping from municipal use pumping and those amounts are included in the section on municipal pumping.

3.4.2.2 Agricultural Groundwater Pumping

The amount of groundwater pumped to satisfy agricultural demand has been estimated by first calculating the total crop demand for all agricultural irrigated areas. The amount of surface water used to meet a portion of this crop demand has been subtracted from the total (corrected for irrigation efficiencies) to estimate a remaining crop demand satisfied with groundwater. The sources of the surface water subtraction include all surface water deliveries to crops including local Kern River water, imported water, or groundwater pumped by agencies and delivered through surface facilities. Because this analysis has been conducted in several steps that involve numerous data types, the details of this analysis are presented in Appendix D.

The results of the analysis, the agricultural demand that is satisfied by private groundwater pumping, is shown by Water District and Service Area in Table 3-10 (Figure 3-19 shows the areas of these Water Districts and Service Areas). The estimated amount of irrigation demand supplied by groundwater and surface water in the Model Area is shown on Figure 3-29. The exact location of this local pumping is not well known. In most cases, a private well is used to supply a relatively small amount of water. Some water districts have inventories of private agricultural wells while others do not. For the purposes of the model, estimates on the distribution of pumping will be made based on the model cell size and magnitude of pumping per cell.

As noted above, additional groundwater is pumped by Water Districts and supplied to agricultural land through surface facilities. Total groundwater pumping by these districts (BVWSD, Semitropic WSD, and NKWSD) is available from BVWSD, Semitropic WSD, and the Annual Reports respectively. The amount of pumping within the Model Area has been estimated based on the percent of wells with the Model Area. The estimated groundwater pumping by District is shown on Table 3-11.

3.4.2.3 Municipal Groundwater Pumping

Municipal water is served in the Model Area by three major purveyors (California Water Company, City of Bakersfield, and Vaughn Water Company) and several smaller purveyors. The service areas of the water purveyors and water districts are shown on Figure 1-4. Municipal supplies include groundwater, surface water, and imported water sources. This section focuses on groundwater pumping for municipal use. Figure 3-30 presents annual municipal pumping by purveyor over the Study Period. For the purposes of this water balance, municipal groundwater pumping includes all groundwater uses other than agricultural irrigation. The water balance includes subtraction of pumped groundwater for municipal uses and addition of municipal use return flows (in the form of percolation) from wastewater (see Section 3.5.1.7) and through percolation of water used for irrigation of lawns, car washing, and other outside uses (see Section 3.5.1.4).

Most of the municipal pumping occurs in the eastern portion of the model. The water balance includes pumping from the purveyors listed below. Recent (2010) pumping is listed followed by the general range of groundwater pumping that occurred during the Study Period.

- California Water Company – 45,700 AFY (44,000-74,000 AFY)
- City of Bakersfield – 37,400 AFY (14,500-45,500 AFY)
- West Kern Water District – 21,700 AFY (9,600-28,300 AFY)
- Vaughn Water Company – 11,500 AFY (3,800-12,800 AFY)
- City of Shafter – 4,700 AFY (3,100-5,300 AFY)
- Greenfield County Water District – 2,300 AFY (870-2,600 AFY)
- North of the River Municipal Water Company – 400 AFY (0-1,000 AFY)
- Stockdale Mutual Water Company – 230 AFY (180-280 AFY)
- Buttonwillow County Water District – 210 AFY (160-210 AFY)
- Oildale Mutual Water Company – 150 AFY (0-2,100 AFY)
- Stockdale Annex Mutual Water Company – 120 AFY (90-140 AFY)

West Kern Water District municipal wells are within the Model Area, although almost all of the district lies outside the Model Boundaries. Recent pumpage has amounted to about 22,000 AFY. This pumping has been included in the water balance, but return flows have not because they occur outside the Model Area.

Some private domestic wells most likely pump within the Model Area but net consumption of this water is small and within the error of other water balance numbers. Because of the lack of documentation of this pumping and its likely insignificant volumes, it has not been included in the water balance.

Groundwater provides most of the area's municipal supply, which is replenished locally from natural recharge, canal seepage, spreading basins, and recycled water. The use of treated imported SWP water has increased in recent years with the expansion of local water treatment plants. The following text discusses groundwater pumping by purveyors within the Model Area.

California Water Service Company (Cal Water)

Cal Water is the largest municipal water supplier in Bakersfield. Their system serves a large portion of the City and segments of unincorporated lands adjacent to the City (encompassing about 49 square miles and a population of about 225,000) (Figure 1-4). Groundwater has historically supplied up to 80 percent of Cal Water's demands with surface and imported water making up the remainder. In 2011, Cal Water operated about 115 active wells with a design capacity of 142,000 AFY. About 14 percent of these wells are within the Model Area.

Cal Water has provided monthly production by well for the 2000 through 2010 time period. Data between 1986 and 1999 have been provided in the form of handwritten monthly production sheets. These data have been hand entered into the database and consist of over 28,000 lines of data. Only pumpage from wells within the Model Area have been used in the water balance. Also, only outside return flows from the 48 percent of the Cal Water service area that is inside the Model Area have been included. Inside return flows are incorporated within the wastewater return flows.

City of Bakersfield Water System (City Water System)

The City's Water System service area covers about 35 percent of the western portion of the Bakersfield (about 38 square miles) and provides water to a population of about 118,600 (Figure 1-4). Similar to Cal

Water, the City relies on a variety of water sources including groundwater, Kern River water, and imported SWP water. The City has contracted with Cal Water to operate its water distribution system. Groundwater supply is pumped from approximately 50 active groundwater wells within City boundaries. The City has provided monthly data by well for 1988 through 2010, while annual pumping totals are available for 1986 and 1987. The pumping distribution (by well and by month) in 1988 has been applied to 1986 and 1987.

Vaughn Water Company (VWC)

Vaughn Water Company has provided municipal water supply to the northwest portion of the City of Bakersfield and to areas of Kern County since 1928 and currently serves more than 9,300 connections (Figure 1-4). Groundwater is the only source of supply. In 2010, VWC pumped about 11,400 AFY from 12 production wells. VWC has provided monthly pumping data by well for 1992 through 2010. Only annual totals are available for 1987 through 1991, so pumping has been distributed to the same wells at the same percentages as in 1992. Pumping in 1986 is assumed the same as 1987.

West Kern Water District (WKWD)

WKWD has eight groundwater wells within the Model Area. WKWD provided monthly pumping by well from July 1998 through 2010 and monthly system totals from 1986 through 1998. While all of the WKWD wells are located within the Model Area, the service area lies almost entirely outside the Model Area. For this reason, municipal return flows are not included in the water balance.

City of Shafter (Shafter)

The City of Shafter is about 15 miles northwest of metropolitan Bakersfield and serves a population of about 18,200. Customers include those within Shafter City limits as well as some surrounding unincorporated County customers. Shafter currently has seven wells and groundwater is the sole source.

Shafter has provided 2002 through 2010 monthly totals but does not have monthly pumping by well information. Annual 1998 through 2001 data were obtained from its 2010 UWMP. For 1986 through 1997 data, an appropriate per capita use value was multiplied by estimated annual populations. Population estimates were obtained by assuming linear growth rates between known population values, accounting for those outside city limits as well. Annual 1986 through 2001 pumping totals were distributed monthly in the same monthly pattern as 2002 data.

Greenfield County Water District (Greenfield CWD)

Greenfield CWD supplies groundwater to a population of about 8,500 from five wells. Greenfield provided monthly pumping data for 2005 through 2010 and annual pumping totals for 2003 and 2004. Data from KCWA annual reports (1998-2001) provided annual pumping totals for those years. Pumping in 2002 was assumed as halfway between 2001 and 2003 values. For 1986 through 1997, pumping was estimated based on pumping increase rate data provided by Greenfield CWD. Monthly pumping averages from 2005 through 2010 were used to distribute 1986 through 2004 annual pumping.

North of the River Municipal Water District (NORMWD)

NORMWD is on the northern boundary of the Model Area and provides groundwater and ID4 water (surface and imported) to its customers. About 71 percent of NORMWD is within the Model Area. It

currently serves a population of about 6,000 and has five wells. KCWA provided pumping data in six-month intervals for 1989 through 2010. Pumping was divided up evenly between the six months in each time period. Data for 1989 were used for 1986 through 1988. All pumping and 71 percent of outside return flows were assumed to occur within the Model Area.

Stockdale Mutual Water Company (Stockdale MWC)

The Stockdale MWC is located in the City of Bakersfield (Figure 1-4). The mutual water company provides groundwater from two wells to about 80 connections. Stockdale MWC provided 1986 through 2010 pumping in six-month intervals. The pumping was divided evenly over each six-month period.

Buttonwillow County Water District (Buttonwillow CWD)

Buttonwillow CWD provides groundwater to a population of about 1,500 in the northwestern portion of the Model Area. The system has three wells. Data from KCWA annual reports (1998-2001 and 2008) provided annual pumping totals for those years. Data for the remaining years was estimated based on an appropriate per capita use value and estimated annual populations. Population estimates were obtained by assuming linear growth rates between known population values. Annual pumping was distributed monthly using the same average pumping percentages as those in Greenfield CWD.

Oildale Mutual Water Company (Oildale MWC)

Oildale MWC straddles the northern boundary of the Model, with 13 percent inside the Model Area. It serves a population of about 26,000. Oildale MWC supplies imported ID4 water and groundwater to its customers. Currently, groundwater provides about five percent of the supply from about nine wells, all located within the Model Area. Oildale provided 1986 through 2010 pumping in six-month intervals. This was divided up evenly over each six-month period. All pumping and 13 percent of outside return flows have been assumed to occur within the Model Area.

Stockdale Annex MWC (Stockdale Annex MWC)

Stockdale Annex MWC is next to Stockdale MWC within the City of Bakersfield but is operated as a separate entity. It has one active well and one standby/emergency well that supply water to about 140 connections. Pumping is not metered and not available from the mutual water company. However, the 2008 KCWA Annual Report listed annual pumping at about half of the Stockdale MWC pumping. Therefore, Stockdale Annex MWC pumping is assumed half of the Stockdale MWC pumping.

3.4.2.4 Subsurface Outflow

Groundwater flow occurs out of the model area through lateral boundaries. As described in Section 3.1.1, time-varying specified head and specified flux boundaries allow subsurface flow out of the model. The areas of outflow and methodology used to calculate the amounts over time are provided in Appendix E. The rate of outflow varies over time, and is estimated to range from zero to 8,361 AFY (Table 3-4). Additional outflow may occur out of the eastern boundary along the Kern River. This outflow is expected to be relatively small and has not been quantified for the water balance.

3.4.3 Inflow and Outflow Totals

Table 3-4 summarizes the annual inflows and outflows, which are illustrated in Figure 3-31, with inflows stacked above the zero line and outflows below the zero line. The most salient feature of Figure 3-31 is the variability of annual inflows relative to outflows. Total inflows range from less than 300,000 AFY to more than 1,500,000 AFY, while total outflows range between 500,000 AFY and about 1,000,000 AFY. Recharge and canal loses are the water balance components that vary the most from year to year. Less variation is seen in agricultural pumping and return flows as well as municipal pumping and return flows.

3.4.4 Changes in Groundwater Storage

Changes in groundwater storage can be derived in two ways. The first method is a simple accounting of the water balance elements described above and shown on Figure 3-31. Total inflows minus the total outflows is equal to the change in storage for the Model Area. The second method examines the change in groundwater elevations over time and applies a storativity coefficient (specific yield), which characterizes the volume of groundwater that an aquifer releases per unit volume of the aquifer.

Groundwater elevation maps from KCWA for spring water levels have been used to calculate changes in groundwater elevation with application of a storativity of 0.15 based on the published characterization of Model Area hydrogeology. The annual changes in storage from both methods are shown on Table 3-4 and on Figure 3-32. In brief, both methods capture the major trends in the Model Area and provide a reasonable check to the water balance.

Comparison of the change in storage calculated by each method indicates that the groundwater elevation method shows a more muted response in years with large volumes of managed recharge. This may reflect the timing and regional nature of water level monitoring and local nature of recharge. The water levels, generally measured in the spring, represent a regional snapshot in time. Managed recharge can result in mounding in the area of the recharge facilities that may not be captured in spring groundwater measurements. Accordingly, the lag between the two methods reflects possible differences between the surface recharge date and response in groundwater measurements.

Overall, the change in groundwater storage is reduced in years with less than average recharge and increased in years with more than average recharge. The average annual change in storage over the Model Period is a decrease of 45,000 AFY or 116,000 AFY, based on the water balance element calculation method or the groundwater elevation method, respectively. Because of the groundwater level lag response, the average change in storage based on groundwater levels would likely be closer to the water balance element method if early 2011 groundwater levels were included.

3.4.5 Model Water Budget

The previous sections have presented the water balance for the conceptual model. Development of this conceptual model is the first step of the analysis. This information will be used to construct, calibrate, and apply a numerical model, the Kern Fan Model, to analyze potential impacts of certain recharge and banking projects along the Kern Fan, also called the *with and without* evaluations. The change in storage graph (Figure 3-32), showing storage changes derived by two independent methods, affirms that the model water balance inflows and outflows reasonably represent the groundwater system and changes in groundwater levels.

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TABLES

Table 3-1: Model Layer Depths and Elevations from Geophysical Logs

					Model Layer 1				Model Layer 2				Model Layer 3			
Well Identification	Data Source	Ground Surface Elevation (feet MSL)	Date Drilled	Well Depth (feet)	Depth to Top of Layer 1 (feet)	Depth to Bottom of Layer 1 (feet)	Elevation of Top of Layer 1 (feet)	Elevation of Bottom of Layer 1 (feet)	Depth to Top of Layer 2 (feet)	Depth to Bottom of Layer 2 (feet)	Elevation of Top of Layer 2 (feet)	Elevation of Bottom of Layer 2 (feet)	Depth to Top of Layer 3 (feet)	Depth to Bottom of Layer 3 (feet)	Elevation of Top of Layer 3 (feet)	Elevation of Bottom of Layer 3 (feet)
28S/22E-08B	Geophysical Log	252.4			0	270	252.411178	-17.588822	270	660	-17.588822	-407.588822				
28S/22E-12M	Geophysical Log	252.3			0	250	252.260605	2.260605	250	700	2.260605	-447.739395				
28S/23E-35A01	Geophysical Log	274.0			0	438	274.035192	-163.964808	438	700	-163.964808	-425.964808				
28S/24E-03N01	Geophysical Log	301.4			0	330	301.409727	-28.590273	330	610	-28.590273	-308.590273				
28S/24E-05K01	Geophysical Log	296.5							300	670	-3.458259	-373.458259				
28S/24E-06H	Geophysical Log	297.4			0	390	297.3523	-92.6477	390	520	-92.6477	-222.6477				
28S/24E-09	Geophysical Log	301.3			0	310	301.282334	-8.717666	310	520	-8.717666	-218.717666				
28S/24E-12R01	Geophysical Log	322.4			0	220	322.378694	102.378694	220	534	102.378694	-211.621306				
28S/24E-15H	Geophysical Log	309.0			0	250	309.026365	59.026365	250	610	59.026365	-300.973635				
28S/24E-16K	Geophysical Log	305.1			0	304	305.080375	1.080375	304	720	1.080375	-414.919625				
28S/24E-18	Geophysical Log	281.6			0	255	281.567735	26.567735	255	650	26.567735	-368.432265				
28S/24E-22R	Geophysical Log	312.4			0	220	312.447113	92.447113	220	520	92.447113	-207.552887				
28S/24E-24C01	Geophysical Log	316.3	2/10/2006	711	0	250	316.28951	66.28951	250	550	66.28951	-233.71049				
28S/24E-25A	Geophysical Log	317.9			0	307	317.883564	10.883564	307	680	10.883564	-362.116436				
28S/24E-27	Geophysical Log	307.8			0	238	307.75859	69.75859	238	650	69.75859	-342.24141				
28S/24E-30Q	Geophysical Log	268.1			0	284	268.13757	-15.86243	284	684	-15.86243	-415.86243				
28S/24E-31K01	Geophysical Log	272.6	8/18/2009	420	0	325	272.621942	-52.378058	325	700	-52.378058	-427.378058				
28S/25E-02J01	Geophysical Log	381.3			0	310	381.328155	71.328155	310	686	71.328155	-304.671845				
28S/25E-06M	Geophysical Log	332.6			0	285	332.579619	47.579619	285	530	47.579619	-197.420381				
28S/25E-07P	Geophysical Log	325.7							300	700	25.737633	-374.262367				
28S/25E-14F01	Geophysical Log	352.4			0	310	352.430176	42.430176	310	540	42.430176	-187.569824				
28S/25E-17E	Geophysical Log	327.7			0	276	327.723044	51.723044	276	570	51.723044	-242.276956				
28S/25E-22J	Geophysical Log	336.3			0	220	336.343753	116.343753								
28S/25E-26F01	Geophysical Log	334.0			0	290	333.996429	43.996429	290	655	43.996429	-321.003571				
28S/25E-27P01	Geophysical Log	329.1							300	680	29.144945	-350.855055				
28S/25E-31G01	Geophysical Log	318.4							300	750	18.374682	-431.625318				
28S/25E-33J01	Geophysical Log	327.7			0	260	327.702707	67.702707	260	690	67.702707	-362.297293				
28S/25E-35M	Geophysical Log	331.9			0	262	331.90865	69.90865	262	680	69.90865	-348.09135				
28S/26E-05F01	Geophysical Log	433.3			0	322	433.250424	111.250424	322	650	111.250424	-216.749576				
28S/26E-17A01	Geophysical Log	409.2			0	280	409.231383	129.231383	280	602	129.231383	-192.768617				
28S/26E-20J01	Geophysical Log	378.0			0	305	378.005976	73.005976	305	580	73.005976	-201.994024				
28S/26E-22L01	Geophysical Log	391.2			0	300	391.215433	91.215433	300	590	91.215433	-198.784567				
28S/26E-23K01	Geophysical Log	399.5			0	310	399.475017	89.475017	310	530	89.475017	-130.524983				
28S/26E-26P01	Geophysical Log	375.6			0	400	375.551724	-24.448276	400	710	-24.448276	-334.448276				
28S/26E-27F01	Geophysical Log	373.5			0	470	373.519966	-96.480034	470	720	-96.480034	-346.480034				
28S/26E-27H01	Geophysical Log	378.1			0	370	378.123007	8.123007	370	610	8.123007	-231.876993				
28S/26E-30F01	Geophysical Log	345.8		642	0	225	345.781876	120.781876	225	700	120.781876	-354.218124				
28S/26E-33L01	Geophysical Log	355.6		602	0	460	355.642428	-104.357572	460	630	-104.357572	-274.357572				
28S/26E-36P01	Geophysical Log	387.3							300	640	87.255022	-252.744978				
28S/27E-32Q01	Geophysical Log	454.9			0	390	454.921929	64.921929	390	622	64.921929	-167.078071				
29S/23E-11F01	Geophysical Log	272.4			0	260	272.367534	12.367534								
29S/23E-13P01	Geophysical Log	273.5			0	380	273.476456	-106.523544	380	680	-106.523544	-406.523544				
29S/23E-16R01	Geophysical Log	267.2		510	0	300	267.17118	-32.82882	300	490	-32.82882	-222.82882				
29S/23E-24F01	Geophysical Log	273.3			0	348	273.278935	-74.721065								
29S/23E-35K01	Geophysical Log	277.6			0	300	277.649631	-22.350369								
29S/24E-04F	Geophysical Log	277.9			0	340	277.869692	-62.130308	340	680	-62.130308	-402.130308				
29S/24E-08L01	Geophysical Log	296.3	1/1/1981	430	0	392	296.324145	-95.675855	392	550	-95.675855	-253.675855				
29S/24E-16F01	Geophysical Log	296.6			0	260	296.634008	36.634008								
29S/24E-20K01	Geophysical Log	288.5			0	280	288.501556	8.501556	280	650	8.501556	-361.498444				
29S/24E-27Q01	Geophysical Log	289.2			0	310	289.189135	-20.810865	310	590	-20.810865	-300.810865				
29S/24E-29C	Geophysical Log	280.5			0	320	280.501831	-39.498169	320	680	-39.498169	-399.498169				
29S/24E-34N01	Geophysical Log	285.1	1/1/1992	470	0	395	285.128617	-109.871383	395	560	-109.871383	-274.871383				
29S/25E-03F01	Geophysical Log	329.0	9/6/1956	300	0	290	328.955314	38.955314	290	575	38.955314	-246.044686				
29S/25E-12M01	Geophysical Log	329.3			0	220	329.294558	109.294558	220	640	109.294558	-310.705442				
29S/25E-13F01	Geophysical Log	332.7	6/6/1960	609	0	250	332.732652	82.732652								
29S/25E-23F01	Geophysical Log	326.5			0	275	326.455486	51.455486	275	725	51.455486	-398.544514				
29S/25E-25M01	Geophysical Log	327.7	1/1/1992	700	0	350	327.652296	-22.347704	350	600	-22.347704	-272.347704				
29S/25E-27L01	Geophysical Log	317.8			0	300	317.828142	17.828142	300	624	17.828142	-306.171858				
29S/25E-27N01	Geophysical Log	313.5	1/1/1992	700	0	312	313.457448	1.457448	312	610	1.457448	-296.542552				
29S/25E-30H	Geophysical Log	302.8			0	300	302.813026	2.813026	300	490	2.813026	-187.186974				
29S/25E-34H01	Geophysical Log	322.0			0	280	321.999152	41.999152	280	570	41.999152	-248.000848				
29S/25E-36	Geophysical Log	330.3	6/12/1977	400	0	230	330.335104	100.335104								
29S/26E-14H01	Geophysical Log	362.7			0	300	362.708021	62.708021	300	610	62.708021	-247.291979	610	790	-247.291979	-427.291979
29S/26E-14M02	Geophysical Log	357.3			0	260	357.250905	97.250905	260	625	97.250905	-267.749095				
29S/26E-15R01	Geophysical Log	356.7			0	310	356.667999	46.667999	310	490	46.667999	-133.332001	490	790	-133.332001	-433.332001
29S/26E-22A02	Geophysical Log	357.4	11/10/2003	450	0	340	357.373455	17.373455	340	715	17.373455	-357.626545				

Table 3-1: Model Layer Depths and Elevations from Geophysical Logs

					Model Layer 1				Model Layer 2				Model Layer 3			
Well Identification	Data Source	Ground Surface Elevation (feet MSL)	Date Drilled	Well Depth (feet)	Depth to Top of Layer 1 (feet)	Depth to Bottom of Layer 1 (feet)	Elevation of Top of Layer 1 (feet)	Elevation of Bottom of Layer 1 (feet)	Depth to Top of Layer 2 (feet)	Depth to Bottom of Layer 2 (feet)	Elevation of Top of Layer 2 (feet)	Elevation of Bottom of Layer 2 (feet)	Depth to Top of Layer 3 (feet)	Depth to Bottom of Layer 3 (feet)	Elevation of Top of Layer 3 (feet)	Elevation of Bottom of Layer 3 (feet)
29S/26E-23D01	Geophysical Log	358.7			0	310	358.734404	48.734404	310	770	48.734404	-411.265596				
29S/26E-25N01	Geophysical Log	365.9		1270	0	300	365.907121	65.907121	300	550	65.907121	-184.092879	550	800	-184.092879	-434.092879
29S/26E-28K	Geophysical Log	350.4		383	0	270	350.437985	80.437985								
29S/26E-29E02	Geophysical Log	340.1			0	270	340.147617	70.147617								
29S/26E-31H	Geophysical Log	341.3	10/9/1992	720	0	310	341.338298	31.338298	310	570	31.338298	-228.661702				
29S/26E-35A	Geophysical Log	363.4			0	230	363.420985	133.420985	230	580	133.420985	-216.579015				
29S/26E-35G	Geophysical Log	358.6			0	280	358.625295	78.625295	280	560	78.625295	-201.374705				
29S/26E-36Q02	Geophysical Log	367.5	7/16/2001	730	0	290	367.534783	77.534783	290	570	77.534783	-202.465217				
29S/27E-01A01	Geophysical Log	597.8			0	360	597.821208	237.821208	360	700	237.821208	-102.178792				
29S/27E-05M01	Geophysical Log	400.4			0	415	400.357639	-14.642361	415	630	-14.642361	-229.642361				
29S/27E-06	Geophysical Log	394.6			0	300	394.620979	94.620979	300	695	94.620979	-300.379021				
29S/27E-15F01	Geophysical Log	424.4			0	295	424.422842	129.422842	295	635	129.422842	-210.577158				
29S/27E-16A01	Geophysical Log	417.8			0	300	417.823266	117.823266	300	640	117.823266	-222.176734				
29S/27E-20F01	Geophysical Log	392.4			0	300	392.369527	92.369527	300	690	92.369527	-297.630473				
29S/27E-21K01	Geophysical Log	397.2			0	250	397.17461	147.17461	250	700	147.17461	-302.82539				
29S/27E-23N01	Geophysical Log	402.5			0	325	402.533021	77.533021	325	680	77.533021	-277.466979				
29S/27E-24M01	Geophysical Log	406.4			0	240	406.356855	166.356855	240	670	166.356855	-263.643145				
29S/27E-26N01	Geophysical Log	397.2			0	330	397.17831	67.17831	330	610	67.17831	-212.82169				
29S/27E-27M01	Geophysical Log	396.4			0	370	396.409302	26.409302	370	690	26.409302	-293.590698				
29S/27E-28J01	Geophysical Log	390.3			0	270	390.302205	120.302205	270	670	120.302205	-279.697795				
29S/27E-31E01	Geophysical Log	369.4		750	0	235	369.442767	134.442767	235	670	134.442767	-300.557233				
29S/27E-31J	Geophysical Log	373.7			0	305	373.707188	68.707188	305	500	68.707188	-126.292812				
29S/27E-32H	Geophysical Log	382.6			0	250	382.551408	132.551408	250	670	132.551408	-287.448592				
29S/27E-34N01	Geophysical Log	387.4			0	290	387.441591	97.441591	290	710	97.441591	-322.558409				
29S/27E-36K02	Geophysical Log	394.0			0	260	394.048075	134.048075								
29S/28E-06G01	Geophysical Log	561.6			0	360	561.568586	201.568586	360	610	201.568586	-48.431414				
29S/28E-07D01	Geophysical Log	503.7			0	315	503.676869	188.676869	315	570	188.676869	-66.323131				
29S/28E-19F01	Geophysical Log	412.1			0	260	412.099858	152.099858	260	600	152.099858	-187.900142				
29S/28E-30A01	Geophysical Log	412.7							300	610	112.743537	-197.256463				
29S/28E-31B01	Geophysical Log	401.9			0	230	401.931754	171.931754	230	580	171.931754	-178.068246				
29S/28E-31F01	Geophysical Log	397.5			0	235	397.511204	162.511204	235	550	162.511204	-152.488796				
30S/24E-04C01	Geophysical Log	283.9			0	320	283.934812	-36.065188	320	530	-36.065188	-246.065188				
30S/24E-08D01	Geophysical Log	289.2			0	275	289.202287	14.202287								
30S/24E-12A	Geophysical Log	295.6			0	290	295.643911	5.643911	290	525	5.643911	-229.356089				
30S/24E-14M02	Geophysical Log	288.4	1/1/1992	700	0	285	288.444495	3.444495	285	580	3.444495	-291.555505				
30S/24E-22A	Geophysical Log	330.9			0	220	330.860534	110.860534								
30S/25E-01A01	Geophysical Log	332.1		50	0	285	332.109127	47.109127	285	480	47.109127	-147.890873				
30S/25E-07A01	Geophysical Log	301.1	4/27/1998	620	0	290	301.132385	11.132385	290	520	11.132385	-218.867615				
30S/25E-09C01	Geophysical Log	310.2	1/1/1991	716	0	300	310.197424	10.197424	300	490	10.197424	-179.802576				
30S/25E-11P	Geophysical Log	321.3			0	310	321.255188	11.255188	310	520	11.255188	-198.744812				
30S/25E-16B01	Geophysical Log	312.3	12/3/2000	730	0	360	312.344985	-47.655015	360	510	-47.655015	-197.655015				
30S/25E-19N	Geophysical Log	295.5			0	302	295.501312	-6.498688	302	475	-6.498688	-179.498688				
30S/25E-19R	Geophysical Log	297.9			0	310	297.8508	-12.1492	310	490	-12.1492	-192.1492				
30S/25E-21G01	Geophysical Log	308.4		700	0	265	308.433697	43.433697	265	590	43.433697	-281.566303				
30S/25E-22R01	Geophysical Log	316.0	1/1/1989	125	0	295	316.044361	21.044361	295	520	21.044361	-203.955639				
30S/25E-23N01	Geophysical Log	317.4			0	295	317.429657	22.429657	295	520	22.429657	-202.570343				
30S/25E-28K	Geophysical Log	306.8			0	320	306.751862	-13.248138	320	570	-13.248138	-263.248138				
30S/25E-34H	Geophysical Log	307.9			0	310	307.902863	-2.097137	310	540	-2.097137	-232.097137				
30S/25E-36R01	Geophysical Log	309.0	1/1/1992	640	0	275	308.985003	33.985003	275	530	33.985003	-221.014997				
30S/26E-02J03	Geophysical Log	357.9	6/8/1991	740	0	310	357.876385	47.876385	310	505	47.876385	-147.123615				
30S/26E-02R01	Geophysical Log	359.3	3/23/1991	730	0	330	359.284678	29.284678	330	555	29.284678	-195.715322				
30S/26E-04R01	Geophysical Log	350.9	4/28/1987	718	0	360	350.889964	-9.110036	360	595	-9.110036	-244.110036				
30S/26E-05E	Geophysical Log	338.7			0	260	338.653076	78.653076	260	560	78.653076	-221.346924				
30S/26E-05K01	Geophysical Log	342.5	1/17/2000	760	0	280	342.455088	62.455088	280	555	62.455088	-212.544912				
30S/26E-05L01	Geophysical Log	342.1			0	250	342.071503	92.071503	250	485	92.071503	-142.928497				
30S/26E-05N01	Geophysical Log	338.0	10/1/1998	770	0	310	337.954055	27.954055	310	480	27.954055	-142.045945				
30S/26E-05Q02	Geophysical Log	342.2	2/7/2000	750	0	350	342.209246	-7.790754	350	560	-7.790754	-217.790754				
30S/26E-05R01	Geophysical Log	344.1			0	350	344.089203	-5.910797	350	630	-5.910797	-285.910797				
30S/26E-06K	Geophysical Log	337.6			0	285	337.577942	52.577942	285	545	52.577942	-207.422058				
30S/26E-06K01	Geophysical Log	337.6	1/1/1998	750	0	290	337.578003	47.578003	290	460	47.578003	-122.421997				
30S/26E-06P01	Geophysical Log	333.3	6/14/2004	1033	0	340	333.263711	-6.736289	340	570	-6.736289	-236.736289				
30S/26E-08G01	Geophysical Log	342.5	2/28/2000	700	0	345	342.537861	-2.462139	345	660	-2.462139	-317.462139				
30S/26E-08H01	Geophysical Log	344.2	4/5/2000	710	0	370	344.236518	-25.763482	370	580	-25.763482	-235.763482				
30S/26E-09E01	Geophysical Log	345.0	3/23/2000	720	0	320	345.013713	25.013713	320	640	25.013713	-294.986287				
30S/26E-10A	Geophysical Log	357.3			0	310	357.33379	47.33379	310	630	47.33379	-272.66621				
30S/26E-10P01	Geophysical Log	346.3	1/1/1998	720	0	315	346.275306	31.275306	315	590	31.275306	-243.724694				

Table 3-1: Model Layer Depths and Elevations from Geophysical Logs

					Model Layer 1				Model Layer 2				Model Layer 3			
Well Identification	Data Source	Ground Surface Elevation (feet MSL)	Date Drilled	Well Depth (feet)	Depth to Top of Layer 1 (feet)	Depth to Bottom of Layer 1 (feet)	Elevation of Top of Layer 1 (feet)	Elevation of Bottom of Layer 1 (feet)	Depth to Top of Layer 2 (feet)	Depth to Bottom of Layer 2 (feet)	Elevation of Top of Layer 2 (feet)	Elevation of Bottom of Layer 2 (feet)	Depth to Top of Layer 3 (feet)	Depth to Bottom of Layer 3 (feet)	Elevation of Top of Layer 3 (feet)	Elevation of Bottom of Layer 3 (feet)
30S/26E-10Q01	Geophysical Log	350.4	1/1/1998	720	0	310	350.351405	40.351405	310	570	40.351405	-219.648595				
30S/26E-10Q02	Geophysical Log	353.3	4/24/2000	660	0	290	353.250851	63.250851	290	560	63.250851	-206.749149				
30S/26E-10R01	Geophysical Log	352.6	1/1/1999	770	0	340	352.587689	12.587689	340	540	12.587689	-187.412311				
30S/26E-11A01	Geophysical Log	357.8			0	260	357.815002	97.815002	260	640	97.815002	-282.184998				
30S/26E-11F01	Geophysical Log	354.9			0	250	354.853644	104.853644	250	610	104.853644	-255.146356				
30S/26E-11M01	Geophysical Log	353.7			0	290	353.699097	63.699097	290	580	63.699097	-226.300903				
30S/26E-15E01	Geophysical Log	347.7	6/19/2000	720	0	310	347.659357	37.659357	310	600	37.659357	-252.340643				
30S/26E-16L01	Geophysical Log	342.9	1/1/1998	720	0	330	342.895335	12.895335	330	510	12.895335	-167.104665				
30S/26E-16Q01	Geophysical Log	342.1	6/5/2000	690	0	320	342.129106	22.129106	320	600	22.129106	-257.870894				
30S/26E-16R01	Geophysical Log	342.6	5/15/2000	690	0	310	342.592013	32.592013	310	600	32.592013	-257.407987				
30S/26E-19B	Geophysical Log	327.7			0	275	327.70233	52.70233	275	550	52.70233	-222.29767				
30S/26E-22P	Geophysical Log	342.0	9/22/2006		0	400	341.966125	-58.033875	400	650	-58.033875	-308.033875				
30S/26E-24A01	Geophysical Log	356.4			0	245	356.437988	111.437988	245	560	111.437988	-203.562012				
30S/26E-25A04	Geophysical Log	350.3			0	275	350.34491	75.34491	275	590	75.34491	-239.65509				
30S/26E-28J	Geophysical Log	332.6			0	310	332.598836	22.598836	310	540	22.598836	-207.401164				
30S/26E-29B01	Geophysical Log	327.5			0	250	327.529019	77.529019	250	600	77.529019	-272.470981				
30S/26E-32N01	Geophysical Log	317.5	1/1/1989	330	0	300	317.537389	17.537389	300	575	17.537389	-257.462611				
30S/27E-01B01	Geophysical Log	392.5			0	240	392.497617	152.497617	240	570	152.497617	-177.502383				
30S/27E-01J01	Geophysical Log	388.7			0	290	388.660095	98.660095	290	570	98.660095	-181.339905				
30S/27E-02P01	Geophysical Log	388.3			0	270	388.318242	118.318242	270	590	118.318242	-201.681758				
30S/27E-02R01	Geophysical Log	384.4			0	245	384.438978	139.438978	245	560	139.438978	-175.561022				
30S/27E-03J02	Geophysical Log	382.7			0	340	382.719488	42.719488								
30S/27E-05A	Geophysical Log	381.0			0	290	381.016466	91.016466	290	545	91.016466	-163.983534				
30S/27E-07	Geophysical Log	366.6			0	295	366.578293	71.578293	295	500	71.578293	-133.421707				
30S/27E-08J	Geophysical Log	371.5			0	308	371.453048	63.453048	308	514	63.453048	-142.546952				
30S/27E-09P01	Geophysical Log	371.3			0	300	371.263039	71.263039	300	505	71.263039	-133.736961				
30S/27E-12F01	Geophysical Log	383.2			0	235	383.227916	148.227916	235	550	148.227916	-166.772084				
30S/27E-13C01	Geophysical Log	378.4			0	310	378.378673	68.378673	310	460	68.378673	-81.621327				
30S/27E-14F01	Geophysical Log	373.1			0	320	373.118169	53.118169	320	564	53.118169	-190.881831				
30S/27E-18F01	Geophysical Log	362.0			0	236	361.994048	125.994048	236	530	125.994048	-168.005952				
30S/27E-19J	Geophysical Log	356.8		712	0	280	356.750112	76.750112	280	655	76.750112	-298.249888				
30S/27E-19N01	Geophysical Log	352.4			0	310	352.44339	42.44339	310	550	42.44339	-197.55661				
30S/27E-20D	Geophysical Log	361.3			0	260	361.340348	101.340348	260	700	101.340348	-338.659652				
30S/27E-21N01	Geophysical Log	360.0			0	250	360.015534	110.015534	250	630	110.015534	-269.984466				
30S/27E-23C01	Geophysical Log	370.6			0	220	370.633867	150.633867	220	580	150.633867	-209.366133				
30S/27E-26D	Geophysical Log	363.7	3/20/1959	222	0	290	363.72516	73.72516	290	650	73.72516	-286.27484				
30S/27E-30C	Geophysical Log	351.9	7/15/1963	172	0	310	351.852453	41.852453	310	530	41.852453	-178.147547				
30S/28E-05B01	Geophysical Log	393.0			0	320	393.025975	73.025975								
30S/28E-06C01	Geophysical Log	395.2			0	315	395.206013	80.206013	315	640	80.206013	-244.793987				
30S/28E-07C	Geophysical Log	387.5			0	250	387.470334	137.470334	250	520	137.470334	-132.529666				
30S/28E-16K01	Geophysical Log	372.6			0	360	372.571524	12.571524	360	590	12.571524	-217.428476				
30S/28E-18E01	Geophysical Log	376.8			0	275	376.753286	101.753286								
30S/28E-18K01	Geophysical Log	377.5			0	245	377.503756	132.503756	245	560	132.503756	-182.496244				
30S/28E-19A01	Geophysical Log	373.3			0	310	373.30886	63.30886	310	565	63.30886	-191.69114				
31S/25E-03E01	Geophysical Log	299.5			0	260	299.508246	39.508246	260	490	39.508246	-190.491754				
31S/25E-03E02	Geophysical Log	299.5			0	260	299.508246	39.508246	260	480	39.508246	-180.491754				
31S/25E-04Q	Geophysical Log	297.8			0	275	297.751313	22.751313	275	475	22.751313	-177.248687				
31S/25E-14L01	Geophysical Log	293.5			0	342	293.49054	-48.50946	342	495	-48.50946	-201.50946				
31S/25E-15F01	Geophysical Log	299.7			0	310	299.748205	-10.251795	310	520	-10.251795	-220.251795				
31S/25E-15M	Geophysical Log	297.5			0	310	297.483704	-12.516296	310	515	-12.516296	-217.516296				
31S/25E-25D	Geophysical Log	290.6			0	255	290.591538	35.591538	255	540	35.591538	-249.408462				
31S/26E-02	Geophysical Log	326.8			0	290	326.78162	36.78162	290	550	36.78162	-223.21838				
31S/26E-03A01	Geophysical Log	329.7			0	310	329.734986	19.734986	310	570	19.734986	-240.265014				
31S/26E-12N	Geophysical Log	321.1			0	310	321.05416	11.05416	310	575	11.05416	-253.94584				
31S/26E-27L01	Geophysical Log	298.5		515	0	260	298.454043	38.454043	260	505	38.454043	-206.545957				
31S/26E-34D	Geophysical Log	295.8			0	310	295.777591	-14.222409	310	480	-14.222409	-184.222409				
31S/27E-01H01	Geophysical Log	346.0		97	0	260	346.035025	86.035025								
31S/27E-07A	Geophysical Log	332.7	11/15/1990	685	0	310	332.742029	22.742029	310	590	22.742029	-257.257971				
31S/27E-12	Geophysical Log	336.3	6/29/1964	552	0	290	336.321302	46.321302	290	600	46.321302	-263.678698				
31S/27E-13G	Geophysical Log	331.3			0	295	331.305856	36.305856	295	555	36.305856	-223.694144				
31S/27E-15	Geophysical Log	328.4	3/29/1973	600	0	300	328.369916	28.369916	300	610	28.369916	-281.630084				
31S/27E-17K	Geophysical Log	326.4			0	265	326.439341	61.439341	265	650	61.439341	-323.560659				
31S/27E-18G	Geophysical Log	322.8			0	330	322.818986	-7.181014	330	570	-7.181014	-247.181014				
31S/27E-28B01	Geophysical Log	313.1	3/26/1990	620	0	334	313.072984	-20.927016	334	515	-20.927016	-201.927016				
31S/27E-29P	Geophysical Log	303.6	11/2/1990	805	0	355	303.630578	-51.369422	355	660	-51.369422	-356.369422				
31S/27E-32J	Geophysical Log	299.0			0	325	298.959001	-26.040999	315	570	-16.040999	-271.040999				

Table 3-1: Model Layer Depths and Elevations from Geophysical Logs

Well Identification	Data Source	Ground Surface Elevation (feet MSL)	Date Drilled	Well Depth (feet)	Model Layer 1				Model Layer 2				Model Layer 3			
					Depth to Top of Layer 1 (feet)	Depth to Bottom of Layer 1 (feet)	Elevation of Top of Layer 1 (feet)	Elevation of Bottom of Layer 1 (feet)	Depth to Top of Layer 2 (feet)	Depth to Bottom of Layer 2 (feet)	Elevation of Top of Layer 2 (feet)	Elevation of Bottom of Layer 2 (feet)	Depth to Top of Layer 3 (feet)	Depth to Bottom of Layer 3 (feet)	Elevation of Top of Layer 3 (feet)	Elevation of Bottom of Layer 3 (feet)
31S/28E-06C01	Geophysical Log	347.4			0	320	347.36721	27.36721	320	630	27.36721	-282.63279				
31S/28E-06M01	Geophysical Log	344.5		300	0	310	344.455434	34.455434	310	615	34.455434	-270.544566				
31S/28E-08A	Geophysical Log	338.7			0	310	338.699159	28.699159	310	600	28.699159	-261.300841				
31S/28E-12R01	Geophysical Log	385.2		403	0	334	385.199562	51.199562	334	610	51.199562	-224.800438				
31S/28E-20N01	Geophysical Log	316.3			0	325	316.318347	-8.681653	325	540	-8.681653	-223.681653				
31S/28E-24A	Geophysical Log	375.6			0	300	375.552114	75.552114	300	582	75.552114	-206.447886				
31S/28E-28A01	Geophysical Log	316.9	3/11/1955	516	0	300	316.927757	16.927757	300	600	16.927757	-283.072243				
31S/28E-30M01	Geophysical Log	313.7		815	0	324	313.74177	-10.25823	324	580	-10.25823	-266.25823				
31S/28E-31N01	Geophysical Log	301.8		815	0	300	301.793894	1.793894	300	550	1.793894	-248.206106				
31S/28E-31R01	Geophysical Log	306.9							300	550	6.913514	-243.086486				
31S/28E-33F01	Geophysical Log	303.4			0	320	303.445027	-16.554973	320	590	-16.554973	-286.554973				
32S/27E-03C	Geophysical Log	299.4			0	420	299.351131	-120.648869	420	560	-120.648869	-260.648869				
32S/27E-04F01	Geophysical Log	296.1			0	330	296.076444	-33.923556	330	590	-33.923556	-293.923556				
32S/27E-04J	Geophysical Log	295.8			0	350	295.805228	-54.194772	350	570	-54.194772	-274.194772				
32S/27E-09L	Geophysical Log	287.0			0	385	287.045139	-97.954861	385	605	-97.954861	-317.954861				
32S/27E-10L	Geophysical Log	286.3			0	330	286.326015	-43.673985	330	545	-43.673985	-258.673985				
32S/28E-06F01	Geophysical Log	298.4			0	370	298.407605	-71.592395	370	620	-71.592395	-321.592395				
32S/28E-06H	Geophysical Log	296.6			0	400	296.6216	-103.3784	400	600	-103.3784	-303.3784				
32S/28E-09B	Geophysical Log	301.6			0	300	301.552745	1.552745	300	570	1.552745	-268.447255				
Strand Ranch SREX-1	Geophysical Log	321.9	5/5/2010	670	0	400	321.861786	-78.138214	400	580	-78.138214	-258.138214	580	800	-258.138214	-478.138214
Strand Ranch SREX-2	Geophysical Log	319.5	3/23/2011	630	0	395	319.49408	-75.50592	395	564	-75.50592	-244.50592	564	800	-244.50592	-480.50592

Table 3-2: Aquifer Transmissivities and Storage Coefficients from Pumping Tests

Well Identification	Date Drilled	Perforated Interval (feet)	Well Depth (feet)	Total Length of Perforations (feet)	Tested By	Date of Test	Test Type	Data Analysis Method	Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Transmissivity (T - ft^2/day)	Hydraulic Conductivity (K - ft/day) (T/perf length)	Storage Coefficient (S - unit less)
28S/22E-08B		320-660		340	Kenneth D. Schmidt and Associates	3/1/2010	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2000	14.9	2406.227316	7.077139	
28S/22E-08J		320-660		340	Kenneth D. Schmidt and Associates	3/1/2010	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2520	19	4678.775337	13.7611	
28S/22E-11H		480-740		260	Kenneth D. Schmidt and Associates	10/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1950	10.7	3743.02027	14.39623	
28S/22E-12M		410-700		290	Kenneth D. Schmidt and Associates	10/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2590	25.9	3609.340974	12.446	
28S/22E-17H		300-600		300	Kenneth D. Schmidt and Associates	10/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2520	20.7	5480.851109	18.2695	
28S/22E-17R	10/1/2008	300-600	610	300	Kenneth D. Schmidt and Associates	10/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3000	20.5	4010.37886	13.36793	
28S/22E-30C		244-269		25	Kenneth D. Schmidt and Associates	8/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	70	10	6015.568291	240.6227	
28S/23E-07N		200-500		300	Kenneth D. Schmidt and Associates	9/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1990	45	5347.171814	17.82391	
28S/25E-16F		535-835		300	Kenneth D. Schmidt and Associates	5/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2010	33	34489.2582	114.9642	
29S/22E-06L		126-146		20	Kenneth D. Schmidt and Associates	8/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	60	6.9	2272.548021	113.6274	
29S/23E-09J		200-440		240	Kenneth D. Schmidt and Associates	2/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3220	48.5	13501.60883	56.2567	
29S/24E-19J01		195-455		60	Kenneth D. Schmidt and Associates	3/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2810	27.5	9892.267856	164.8711	
29S/24E-24A01		210-455		245	Kenneth D. Schmidt and Associates	6/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3030	31.6	7352.361244	30.00964	
29S/25E-34A01	10/2/2009	185-455	475		RRBWSD/BW&P (Todd analysis)	10/19/2009	Constant Rate	Cooper-Jacob Straight Line (Recovery)	3215	45.5	39634.27453	146.7936094	
29S/26E-14H		730-1171		441	Kenneth D. Schmidt and Associates	8/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1230	14.1	6683.964767	15.15638	
29S/26E-15Q		840-1200		360	Kenneth D. Schmidt and Associates	4/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2500	25	4545.096042	12.62527	
29S/26E-25N		970-1270		40	Kenneth D. Schmidt and Associates	6/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1300	18.8	4946.133928	16.48711	
29S/26E-28D02	12/15/2005	780-1120	1165	340	Kenneth D. Schmidt and Associates	3/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2590	41.4	10560.66433	31.06078	
29S/26E-32R		335-600		265	Kenneth D. Schmidt and Associates	8/1/2002	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1500	10.6	5079.813223	19.16911	
29S/26E-35B01	12/1/2006	200-500, 560-700	740	440	Kenneth D. Schmidt and Associates	3/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2540	46.7	40772.18508	92.66405	
29S/26E-35G02	5/1/2006	200-440, 500-640	680	380	Kenneth D. Schmidt and Associates	3/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2980	116	35425.01327	80.51139	
29S/26E-35G02	5/1/2006	200-440, 500-640	660	380	KCWA / KWB	3/19/2007	Constant Rate	Cooper-Jacob Straight Line	3000		30000	78.94736	
29S/26E-35H		190-650		460	Kenneth D. Schmidt and Associates	5/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3000	179.4	58685.21066	127.5765	
29S/26E-35H05	3/1/2007	210-450, 500-745	785	485	KCWA / KWB	5/21/2007	Constant Rate	Cooper-Jacob Straight Line	3000		39000	80.41237	
29S/26E-35K01		205-665		460	Kenneth D. Schmidt and Associates	4/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3000	148.3	41440.58156	90.08822	
29S/26E-36K	12/15/2006	200-450, 500-680	720	480	Kenneth D. Schmidt and Associates	4/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	4080	150.6	41975.29874	87.44854	
29S/26E-36K01	12/15/2006	200-450, 500-680	720	430	KCWA / KWB	4/18/2007	Constant Rate	Cooper-Jacob Straight Line	4976		46000	106.9767	
29S/26E-36L01	12/15/2006	200-550, 590-700	740	460	KCWA / KWB	5/10/2007	Constant Rate	Cooper-Jacob Straight Line	5000		39000	84.78261	
29S/26E-36L01	12/15/2006	200-550, 590-700	740	460	Kenneth D. Schmidt and Associates	5/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	4430	147.6	40237.4679	80.47494	
30S/25E-21G		286-750		464	Kenneth D. Schmidt and Associates	9/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	4480	69.6	16843.59121	36.30084	
30S/25E-21R04	10/7/2002	229-656	820	30	Kenneth D. Schmidt and Associates	5/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	4430	46.3	16576.23262	38.82022	
30S/25E-22M01	12/21/2002	225-360, 390-625	750	370	Kenneth D. Schmidt and Associates	2/1/2003	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3000	37.3	12297.82114	33.23735	
30S/25E-25C01	12/15/2005	190-610	700	420	Kenneth D. Schmidt and Associates	2/1/2004	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	2420	17.2	4411.416747	10.50337	
30S/26E-02J03	6/8/1991	224-304, 384-724	740	420	KCWA / KWB	7/27/2001	Constant Rate	Cooper-Jacob Straight Line	2737		27000	64.28571	
30S/26E-04E03	9/8/2009	280-480, 540-740	820	400	KCWA / KWB	11/12/2009	Constant Rate	Cooper-Jacob Straight Line	1700		17800	44.5	

Table 3-2: Aquifer Transmissivities and Storage Coefficients from Pumping Tests

Well Identification	Date Drilled	Perforated Interval (feet)	Well Depth (feet)	Total Length of Perforations (feet)	Tested By	Date of Test	Test Type	Data Analysis Method	Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Transmissivity (T - ft^2/day)	Hydraulic Conductivity (K - ft/day) (T/perf length)	Storage Coefficient (S - unit less)
30S/26E-05K01	1/17/2000	160-480, 560-740	760	500	KCWA / KWB	2/9/2000	Constant Rate	Cooper-Jacob Straight Line	3005		24000	48	
30S/26E-05L01				480	KCWA / KWB	2/22/2000	Constant Rate	Cooper-Jacob Straight Line	3005		23000		
30S/26E-05N01	10/1/1998	169.8-299.8, 340-420, 480-700	770	430	KCWA / KWB	2/22/1999	Constant Rate	Cooper-Jacob Straight Line	3816		27000	62.7907	
30S/26E-05Q02	2/7/2000	190-350, 370-490, 570-730	750	440	KCWA / KWB	3/7/2000	Constant Rate	Cooper-Jacob Straight Line	3005		28000	63.63636	
30S/26E-05R01				500	KCWA / KWB	1/26/2000	Constant Rate	Cooper-Jacob Straight Line	3005		13000		
30S/26E-06K01	1/1/1998	220-280, 340-700	750	420	KCWA / KWB	1/18/1999	Constant Rate	Cooper-Jacob Straight Line	3977		33000	78.57143	
30S/26E-08G01	2/28/2000	160-340, 360-640, 660-680	700	480	KCWA / KWB	4/4/2000	Constant Rate	Cooper-Jacob Straight Line	3005		34000	70.83334	
30S/26E-08H01	4/5/2000	110-370, 390-690	710	560	KCWA / KWB	5/4/2000	Constant Rate	Cooper-Jacob Straight Line	3005		32000	57.14286	
30S/26E-09E01	3/23/2000	160-320, 340-580, 640-680	720	440	KCWA / KWB	4/17/2000	Constant Rate	Cooper-Jacob Straight Line	3592		110000	250	
30S/26E-10P01	1/1/1998	155-314.75, 355-635	720	439.75	KCWA / KWB	4/19/2000	Constant Rate	Cooper-Jacob Straight Line	3799		20000	45.48038	
30S/26E-10Q01	1/1/1998	180-300, 340-650	720	430	KCWA / KWB	12/23/1998	Constant Rate	Cooper-Jacob Straight Line	3841		15000	34.88372	
30S/26E-10Q02	4/24/2000	170-330, 380-500, 540-640	660	380	KCWA / KWB	5/26/2000	Constant Rate	Cooper-Jacob Straight Line	3592		18000	47.36842	
30S/26E-10R01	1/1/1999	159.6-339.6, 379.8-479.8, 540-730	770	470	KCWA / KWB	2/3/1999	Constant Rate	Cooper-Jacob Straight Line	3802		16000	34.04255	
30S/26E-11A		210-690		480	Kenneth D. Schmidt and Associates	12/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3530	124.9	24195.95246	50.40823	
30S/26E-11A01				440	KCWA / KWB	12/4/2007	Constant Rate	Cooper-Jacob Straight Line	3010		22000	50	
30S/26E-11G		200-780		580	Kenneth D. Schmidt and Associates	11/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3560	125.8	29543.12427	50.93642	
30S/26E-11G01					KCWA / KWB	11/16/2007	Constant Rate	Cooper-Jacob Straight Line	3035		36000	75	
30S/26E-11M		200-780		580	Kenneth D. Schmidt and Associates	12/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	3530	53.5	12164.81588	20.97382	
30S/26E-11M01				200	KCWA / KWB	12/5/2007	Constant Rate	Cooper-Jacob Straight Line	3003		9400	47	
30S/26E-15E01	6/19/2000	180-380, 420-700	720	480	KCWA / KWB	7/25/2000	Constant Rate	Cooper-Jacob Straight Line	3005		28000	58.33333	
30S/26E-16L01	1/1/1998	154.75-319.75, 360-390, 450-690	720	435	KCWA / KWB	12/21/1998	Constant Rate	Cooper-Jacob Straight Line	3811		19000	43.67816	
30S/26E-16Q01	6/5/2000	150-330, 400-670	690	450	KCWA / KWB	7/12/2000	Constant Rate	Cooper-Jacob Straight Line	3005		29000	64.44444	
30S/26E-16R01	5/15/2000	150-310, 370-670	690	460	KCWA / KWB	6/21/2000	Constant Rate	Cooper-Jacob Straight Line	3005		23000	50	
30S/26E-17B01	8/7/1999	170-290, 330-550, 590-690	710	440	KCWA / KWB	9/10/1999	Constant Rate	Cooper-Jacob Straight Line	3511		19000	43.18182	
30S/26E-17C01	7/20/1999	168-248, 268-308, 328-628, 648-688	708	460	KCWA / KWB	8/23/1999	Constant Rate	Cooper-Jacob Straight Line	3759		18000	39.13044	
30S/26E-18R01	7/7/1999	160-260, 300-400, 420-620, 640-680	700	440	KCWA / KWB	9/27/1999	Step-Discharge	Step-Drawdown of Single Well	2008		10000	22.72727	
30S/26E-22P03		280-390		184	Kenneth D. Schmidt and Associates	11/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1460	27.6	10961.70222	99.65184	
30S/26E-23M		270-455		185	Kenneth D. Schmidt and Associates	11/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1230	66.1	31013.59652	167.6411	
30S/26E-24J		630-730		100	Kenneth D. Schmidt and Associates	12/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1250	63.4	29275.76568	292.7577	
30S/27E-19J01	12/7/1948	449-770	712	321	Kenneth D. Schmidt and Associates	4/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1560	82.1	28607.36921	89.11953	
30S/27E-19R		550-710		160	Kenneth D. Schmidt and Associates	3/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1540	59.3	17511.98769	109.4499	
30S/27E-20D		479-669		190	Kenneth D. Schmidt and Associates	4/1/2009	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1570	60.5	18447.74276	97.09338	
30S/27E-20P	8/15/2006	475-730	750	30	Kenneth D. Schmidt and Associates	9/1/2006	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1360	66.7	20853.97008	82.42676	
30S/27E-22N		410-620		210	Kenneth D. Schmidt and Associates	1/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1250	30.6	32216.71018	153.4129	
30S/27E-30C		545-670		50	Kenneth D. Schmidt and Associates	3/1/2008	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1230	29.3	17378.3084	139.0265	
30S/27E-33H	11/19/2002	135-185	190	50	Kenneth D. Schmidt and Associates	12/1/2002	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	44	14.2	10293.30574	205.8661	
30S/27E-34B	6/1/2005	360-540	570	180	Kenneth D. Schmidt and Associates	9/1/2005	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	1100	61.2	26067.46259	144.8192	
31S/27E-16H		440-505		24	Kenneth D. Schmidt and Associates	5/1/2007	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	485	17.9	9892.267856	152.1887	
31S/27E-19A		420-510		190	Kenneth D. Schmidt and Associates	10/1/1991	Unknown	Cooper-Jacob Straight Line (Un-Reviewed)	230	21.3	6817.644063	35.88234	
Strand Ranch SREX-1	5/5/2010	380-650	670	270	Wildermuth	5/4/2010	Constant Rate	Hantush-Jacob	2496		7680	28.44	0.0128
Strand Ranch SREX-2	10/8/2010	410-530, 570-650	670	200	Wildermuth	5/12/2010	Constant Rate	Hantush-Jacob	2504		9191	32.53	0.0342
Strand Ranch SREX-3	3/23/2011	410-610	630	200	Wildermuth	1/25/2011	Constant Rate	Hantush-Jacob	2512		8138	29.06	0.0044
Strand Ranch SREX-4	9/23/2010	410-540, 580-650	670	200	Wildermuth	1/30/2011	Constant Rate	Hantush-Jacob	2513		6048	22.12	0.0008
Strand Ranch SREX-5	11/4/2010	410-505, 545-650	670	200	Wildermuth	2/9/2011	Constant Rate	Hantush-Jacob	2508		7172	26.56	0.0186
Strand Ranch SREX-7	10/29/2010	410-480, 520-660	680	210	Wildermuth	1/19/2011	Constant Rate	Hantush-Jacob	2507		5460	19.71	0.004

Table 3-2: Aquifer Transmissivities and Storage Coefficients from Pumping Tests

Well Identification	Date Drilled	Perforated Interval (feet)	Well Depth (feet)	Total Length of Perforations (feet)	Tested By	Date of Test	Test Type	Data Analysis Method	Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Transmissivity (T - ft^2/day)	Hydraulic Conductivity (K - ft/day) (T/perf length)	Storage Coefficient (S - unit less)
WKWD/NRRP - NW-1	4/13/2011	270-300, 310-395, 415-450, 470-515, 535-550, 560-570	590	220	WKWSD / Richard C. Slade & Associates	5/4/2011	Constant Rate	Theis Confined DD & Recovery (Observation well NW-5)	2995		35342.8686	160.6494027	0.002206
WKWD/NRRP - NW-1	4/13/2011	270-300, 310-395, 415-450, 470-515, 535-550, 560-570	590	220	WKWSD / Richard C. Slade & Associates	5/4/2011	Constant Rate	Hantush-Jacob Leaky DD & Recovery (Observation well NW-5)	2995		20331.50648	92.41593856	0.00213
WKWD/NRRP - NW-1	4/13/2011	270-300, 310-395, 415-450, 470-515, 535-550, 560-570	590	220	WKWSD / Richard C. Slade & Associates	5/4/2011	Constant Rate	Theis Confined (DD & Recovery)	2995	46.5	16321.34741	74.18794279	
WKWD/NRRP - NW-1	4/13/2011	270-300, 310-395, 415-450, 470-515, 535-550, 560-570	590	220	WKWSD / Richard C. Slade & Associates	5/4/2011	Constant Rate	Hantush-Jacob Leaky (DD & Recovery)	2995	46.5	12968.85443	58.94933832	
WKWD/NRRP - NW-2	8/4/2011	650-675, 695-760, 790-810, 835-850, 860-880, 940-980	1000	185	WKWSD / Richard C. Slade & Associates	8/30/2011	Constant Rate	Theis Confined (DD & Recovery)	3073	35.2	13968.72076	75.5065987	
WKWD/NRRP - NW-2	8/4/2011	650-675, 695-760, 790-810, 835-850, 860-880, 940-980	1000	185	WKWSD / Richard C. Slade & Associates	8/30/2011	Constant Rate	Hantush-Jacob Leaky (DD & Recovery)	3073	35.2	13968.72076	75.5065987	
WKWD/NRRP - NW-3	5/6/2011	245-280, 290-335, 365-390, 405-435, 445-480, 505-520, 530-545	565	200	WKWSD / Richard C. Slade & Associates	6/1/2011	Constant Rate	Hantush-Jacob Leaky (DD & Recovery)	2500	32.6	10157.73292	50.78866462	
WKWD/NRRP - NW-3	5/6/2011	245-280, 290-335, 365-390, 405-435, 445-480, 505-520, 530-545	565	200	WKWSD / Richard C. Slade & Associates	6/1/2011	Constant Rate	Theis Confined DD & Recovery (Observation wells NW-1 & 5)	2500		25317.47093	126.5873546	0.0012
WKWD/NRRP - NW-3	5/6/2011	245-280, 290-335, 365-390, 405-435, 445-480, 505-520, 530-545	565	200	WKWSD / Richard C. Slade & Associates	6/1/2011	Constant Rate	Hantush-Jacob Leaky DD & Recovery (Observation well NW-1 & 5)	2500		26413.58107	132.0679054	0.00108
WKWD/NRRP - NW-3	5/6/2011	245-280, 290-335, 365-390, 405-435, 445-480, 505-520, 530-545	565	200	WKWSD / Richard C. Slade & Associates	6/1/2011	Constant Rate	Theis Confined (DD & Recovery)	2500	32.6	13982.08796	69.91043978	
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	Theis Confined DD & Recovery (Observation wells NW-1, 3, & 5)	2536		20077.52974	143.4109267	0.002
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	Hantush-Jacob Leaky DD & Recovery (Observation wells NW-1, 3, & 5)	2536		15933.6987	113.8121336	0.002
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	Distance Drawdown (Observation wells NW-1, 3, & 5)	2536		17444.19195	124.6013711	0.0026
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	Hantush-Jacob Leaky (DD & Recovery)	2536	26	8029.675177	57.35482269	
WKWD/NRRP - NW-4	10/14/2011	285-330, 440-535	555	140	WKWSD / Richard C. Slade & Associates	11/1/2011	Constant Rate	Theis Confined (DD & Recovery)	2536	26	11895.46852	84.96763229	
WKWD/NRRP - NW-5	4/1/2011	220-285, 300-320, 330-390, 410-450, 510-540	560	215	WKWSD / Richard C. Slade & Associates	3/19/2011	Constant Rate	Theis Confined (Recovery only)	2497		15011.36212	69.82028892	
WKWD/NRRP - NW-5	4/1/2011	220-285, 300-320, 330-390, 410-450, 510-540	560	215	WKWSD / Richard C. Slade & Associates	3/19/2011	Constant Rate	Theis Unconfined (DD only)	2497	42.4	11932.89667	55.50184498	
WKWD/NRRP - NW-5	4/1/2011	220-285, 300-320, 330-390, 410-450, 510-540	560	215	WKWSD / Richard C. Slade & Associates	3/19/2011	Constant Rate	Theis Confined (DD only)	2497	42.4	11932.89667	55.50184498	
WKWD/NRRP - Well 2	12/1/1980	250-602	602	352	WKWSD / Richard C. Slade & Associates	5/8/2009	Constant Rate	Cooper-Jacob Straight Line	2000		30080	119.3659	

Table 3-3: Aquifer Specific Yields

Sediment Size	Number of Samples Measured	Range of Specific Yield (percent)
Sand	126	19 - 35
Clayey Sand	28	10 - 28
Sand-silt-clay	95	2 - 20
Sandy silt	49	1 - 12
Clayey silt	107	<1 - 7
Silt	79	1 - 7
Silty clay	86	<1 - 8

Table 3-4: Water Balance Summary

All Values in Acre Feet per Year (AFY)

Inflows	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Canal Loss	225,503	85,344	71,266	76,724	46,734	65,713	52,710	197,075	86,345	229,803	198,563	201,897	146,215	155,956	126,139	81,854	133,402	190,178	102,676	245,494	200,003	59,292	67,985	78,417	230,318	3,355,605	134,224
Recharge	464,635	51,644	26,583	38,548	5,815	14,109	23,218	322,236	30,422	1,111,805	694,119	554,677	1,300,149	177,856	150,682	30,992	37,151	159,210	81,605	1,466,726	1,111,271	82,802	7,418	41,881	378,203	8,363,758	334,550
Ag Return Flows	166,791	184,293	175,150	162,716	161,884	179,668	180,737	175,062	172,533	189,923	165,232	158,039	190,997	152,207	164,128	169,852	160,238	142,031	138,183	141,747	149,264	140,139	158,718	160,583	164,572	4,104,686	164,187
Muni Return Flows	3,973	3,945	4,143	4,340	4,522	4,289	4,709	5,013	5,300	5,171	5,619	5,710	5,104	6,140	5,277	5,818	6,000	5,913	5,909	5,667	6,032	6,586	6,743	6,399	5,983	134,306	5,372
Wastewater Percolation	11,985	12,352	12,673	7,221	7,747	7,962	8,188	8,417	8,576	8,806	8,923	8,995	9,097	9,086	9,086	9,084	9,149	9,214	9,279	9,528	9,093	9,473	9,538	10,209	10,881	234,564	9,383
Recharge from Rainfall	-	-	-	-	-	-	-	-	-	64	-	-	884	-	-	-	-	-	-	-	-	-	-	-	717	1,665	67
Subsurface Inflow	2,249	2,249	4,722	4,722	4,722	15,556	14,858	14,160	10,772	7,383	9,006	9,006	10,629	12,797	-	10,819	15,549	6,970	5,738	5,325	6,100	3,831	6,151	23,442	18,911	225,667	9,027
TOTAL INFLOW	**875,136**	**339,826**	**294,537**	**294,272**	**231,424**	**287,297**	**284,422**	**721,964**	**313,947**	**1,552,954**	**1,081,463**	**938,324**	**1,663,075**	**514,042**	**455,312**	**308,419**	**361,489**	**513,515**	**343,389**	**1,874,486**	**1,481,763**	**302,123**	**256,552**	**320,931**	**809,586**	**16,297,112**	**656,810**
Outflows																											
Recovery Pumping	-	-	-	-	-	-	-	-	-	-	1,781	14	2,819	3,366	3,426	199,630	61,308	62,788	75,956	1,476	-	347,102	380,673	274,024	78,224	1,492,589	59,704
District Pumping for Ag	815	14,670	22,518	29,535	27,983	32,878	35,861	9,405	21,709	7,708	10,652	8,917	7,707	10,973	19,879	35,177	31,559	16,698	33,573	12,590	13,936	49,358	47,878	49,940	14,673	566,592	22,664
Other Pumping for Ag	422,958	606,385	610,900	563,393	602,808	605,312	616,369	481,865	579,385	499,796	449,968	432,426	425,108	463,867	459,661	511,597	499,604	397,822	479,849	388,711	358,888	503,340	521,901	524,823	405,548	12,412,284	496,491
Municipal Pumping	93,051	92,053	97,213	96,858	101,417	99,462	105,812	111,338	115,036	110,466	119,071	127,079	111,735	132,262	112,119	119,346	123,658	125,106	125,513	127,665	132,505	144,171	140,376	132,190	124,412	2,919,913	116,797
Subsurface Outflow	8,361	8,361	-	-	-	-	-	-	-	-	-	-	-	-	6,480	-	-	1,407	1,791	-	1,705	-	-	-	-	28,105	1,124
TOTAL OUTFLOW	**525,186**	**721,468**	**730,631**	**689,786**	**732,208**	**737,652**	**758,042**	**602,609**	**716,130**	**617,971**	**581,472**	**568,436**	**547,370**	**610,468**	**601,565**	**865,749**	**716,129**	**603,822**	**716,682**	**530,442**	**507,034**	**1,043,970**	**1,090,828**	**980,977**	**622,857**	**17,419,483**	**696,779**
Storage Changes																											
Inflow-Outflow Residual	349,951	(381,642)	(436,094)	(395,514)	(500,784)	(450,355)	(473,621)	119,355	(402,183)	934,984	499,991	369,888	1,115,706	(96,426)	(146,253)	(557,330)	(354,640)	(90,307)	(373,293)	1,344,044	974,729	(741,847)	(834,276)	(660,046)	186,729	(1,122,371)	(39,969)
From Groundwater Levels	247,086	247,086	(400,096)	(400,096)	(400,096)	(400,096)	(559,052)	(559,052)	143,627	143,627	374,080	374,080	374,080	423,722	30,351	205,960	(669,044)	(490,514)	(51,814)	(118,414)	537,820	552,382	(1,292,567)	(918,784)	(291,609)	(2,897,331)	(115,893)

Table 3-5: Agricultural Return Flows

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Bolthouse	2,221	2,550	2,337	1,860	1,852	2,086	2,160	2,062	1,987	2,254	1,988	1,931	2,254	1,768	1,443	1,933	1,894	1,760	1,854	1,809	1,820	1,454	1,523	1,881	1,642	48,323	1,933
BVWSD	11,349	12,411	11,879	10,645	10,661	11,208	11,190	11,171	11,237	11,610	11,688	11,328	12,532	10,546	9,890	11,155	11,222	9,979	10,213	12,381	10,953	11,100	13,607	14,509	14,338	288,801	11,552
Cawelo	544	604	573	306	308	321	324	312	345	334	533	520	636	363	495	447	335	299	273	317	254	213	206	211	230	9,304	372
JPID	20,819	23,319	21,955	15,813	15,761	17,573	17,968	17,330	16,865	18,754	5,788	5,319	6,967	5,944	9,493	9,548	8,017	6,613	5,089	5,018	5,208	5,351	6,543	6,246	6,396	283,697	11,348
KDWD no Service Area	3,384	3,816	3,544	3,076	3,071	3,416	3,513	3,385	3,298	3,683	3,253	3,152	3,838	2,882	3,036	2,937	3,024	2,832	2,842	2,694	2,781	2,588	3,337	2,989	3,501	79,870	3,195
KD Buena Vista	9,227	10,385	9,661	8,068	8,062	8,778	9,018	8,756	8,583	9,380	11,118	10,752	12,879	7,968	6,995	9,209	8,881	8,061	8,214	8,422	7,507	7,600	9,663	10,639	10,856	228,681	9,147
KD Farmers	6,692	7,454	7,021	6,602	6,575	7,292	7,485	7,226	6,983	7,808	7,117	6,885	8,199	7,282	7,658	8,764	7,943	6,556	7,022	7,156	6,588	6,242	6,995	6,331	6,926	178,805	7,152
KD Kern Island	16,096	18,002	16,874	17,281	17,185	19,243	19,788	18,998	18,317	20,678	18,861	18,203	21,943	18,135	19,624	20,093	19,490	17,788	15,562	16,669	16,584	17,230	19,257	19,150	20,936	461,987	18,479
KD Stine	14,882	16,690	15,592	13,230	13,180	14,475	14,782	14,311	14,033	15,435	16,637	16,132	19,356	13,235	13,598	14,798	13,800	12,475	12,820	13,680	14,867	13,217	15,653	15,439	16,556	368,872	14,755
KRCI	3,455	3,667	3,619	3,303	3,262	3,727	3,595	3,480	3,447	3,876	2,926	2,759	3,508	2,633	1,755	2,280	1,649	1,168	1,044	1,056	908	582	769	800	855	60,123	2,405
North Kern-Other	1,464	1,595	1,528	1,588	1,573	1,758	1,739	1,693	1,691	1,855	1,938	1,861	2,215	1,846	1,631	1,299	1,654	1,428	1,175	1,091	1,168	1,096	1,154	1,544	1,359	38,941	1,558
North Kern-Class1	3,477	3,855	3,672	4,104	4,084	4,489	4,389	4,270	4,330	4,627	4,137	3,901	4,763	4,195	4,996	4,250	4,283	3,840	3,809	3,748	4,441	3,869	3,975	4,050	3,866	103,423	4,137
North Kern-Class2	4,427	4,788	4,654	5,083	5,034	5,731	5,656	5,431	5,357	6,007	4,541	4,332	5,252	4,328	5,078	4,724	4,524	3,746	3,735	3,957	5,371	4,899	5,261	5,339	4,209	121,465	4,859
No Water District	15,303	16,729	16,060	15,796	15,728	17,434	17,527	16,974	16,814	18,395	14,421	13,626	16,849	12,994	16,140	14,636	12,785	11,058	11,774	11,480	12,142	11,515	12,570	12,835	14,023	365,608	14,624
Rosedale Rio Bravo	22,483	24,477	23,625	23,106	22,931	25,666	25,448	24,640	24,450	26,950	24,674	23,606	28,837	24,077	25,432	27,393	24,584	21,871	21,626	21,038	23,174	21,448	23,365	23,394	22,696	600,989	24,040
RRB-BV Diversions	3,111	3,467	3,270	4,078	4,053	4,557	4,637	4,441	4,334	4,825	4,734	4,578	5,406	4,079	4,944	4,947	4,634	3,842	3,638	3,895	4,318	3,532	4,342	4,651	4,808	107,119	4,285
RRB-Other Diversions	1,348	1,506	1,411	1,205	1,206	1,294	1,332	1,305	1,275	1,384	1,464	1,429	1,681	1,575	1,372	1,382	1,289	1,103	1,044	1,275	1,459	1,450	1,593	1,815	1,684	34,883	1,395
Rosedale Ranch	8,301	9,233	8,719	8,039	7,957	9,010	8,977	8,647	8,478	9,513	7,412	6,579	9,036	7,464	10,377	9,288	9,400	8,982	7,562	6,712	8,554	7,640	8,342	7,864	8,872	210,958	8,438
Semitropic-Other	4,401	4,938	4,631	4,639	4,630	5,068	5,159	4,993	5,017	5,399	5,386	5,230	6,076	4,670	4,355	4,972	4,818	4,151	5,005	4,297	4,881	4,954	5,079	5,180	6,170	124,101	4,964
Semitropic-Wegis	4,651	4,992	4,908	5,081	5,045	5,603	5,410	5,315	5,368	5,775	5,539	5,339	6,064	5,863	4,916	5,750	5,522	5,078	5,294	5,996	6,791	5,680	6,126	6,179	5,604	137,888	5,516
Shafter-Wasco ID	9,157	9,814	9,617	9,815	9,727	10,938	10,639	10,322	10,324	11,381	11,078	10,575	12,704	10,359	10,899	10,046	10,490	9,400	8,589	9,056	9,493	8,478	9,358	9,540	9,045	250,846	10,034
TOTAL	**166,791**	**184,293**	**175,150**	**162,716**	**161,884**	**179,668**	**180,737**	**175,062**	**172,533**	**189,923**	**165,232**	**158,039**	**190,997**	**152,207**	**164,128**	**169,852**	**160,238**	**142,031**	**138,183**	**141,747**	**149,264**	**140,139**	**158,718**	**160,583**	**164,572**	**4,104,686**	**164,187**

Table 3-6: Municipal Return Flows

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Buttonwillow	13	13	13	14	14	14	13	13	13	13	13	13	13	12	12	15	14	14	15	15	15	16	16	16	16	349	14
CalWater	2,263	2,228	2,271	2,338	2,412	2,276	2,489	2,584	2,727	2,594	2,802	2,869	2,370	2,772	2,086	2,147	2,272	2,014	1,742	1,721	1,832	1,882	1,754	1,709	1,754	55,907	2,236
COB	1,086	1,086	1,185	1,303	1,378	1,297	1,474	1,631	1,709	1,726	1,865	1,858	1,809	2,288	2,033	2,435	2,480	2,589	2,805	2,569	2,713	3,129	3,373	3,159	2,790	51,770	2,071
Greenfield	65	65	67	68	69	71	72	72	75	76	78	81	83	85	99	101	112	123	151	162	184	191	189	182	170	2,692	108
North of River MWC	0	0	0	0	0	11	0	-	-	-	-	-	-	2	9	47	3	9		4	21	23	18	22	21	190	8
Oildale	1	0	0	3	20		2	1	0	0	1	0	0	0	1	3	5	14	15	13	10	20	19	14	1	142	6
Shafter	233	240	246	253	259	239	245	250	256	262	267	273	279	315	335	339	347	364	353	350	364	354	390	339	348	7,499	300
Stockdale Annex	8	8	9	8	8	7	9	9	8	9	8	8	7	8	8	8	8	8	7	7	7	10	9	9	8	202	8
Stockdale MWC	16	17	17	16	16	14	18	17	17	18	15	16	13	15	15	16	16	16	14	15	15	20	18	19	16	405	16
Vaughn	287	287	334	336	346	360	388	435	494	473	569	591	529	644	681	709	744	763	807	811	871	942	957	930	858	15,149	606
West Kern WD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**3,973**	**3,945**	**4,143**	**4,340**	**4,522**	**4,289**	**4,709**	**5,013**	**5,300**	**5,171**	**5,619**	**5,710**	**5,104**	**6,140**	**5,277**	**5,818**	**6,000**	**5,913**	**5,909**	**5,667**	**6,032**	**6,586**	**6,743**	**6,399**	**5,983**	**134,306**	**5,373**

Table 3-7: Losses from Unlined Canals

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Alejandro Canal	10,291	31	-	57	-	(2)	27	1,288	2	91	-	-	(1)	-	-	-	-	-	-	-	2,962	77	79	33	10	14,947	598
Carrier Canal	6,935	5,562	4,818	4,271	3,855	5,868	4,473	6,971	5,308	6,685	6,358	5,401	5,144	5,359	4,682	8,548	6,016	3,753	5,100	6,137	5,208	3,766	4,092	5,880	4,989	135,179	5,407
Cross Valley Canal (unlined portion)	-	-	-	-	-	-	-	-	-	-	-	1,046	1,188	4	68	67	62	-		-	-	-	-	383	205	3,023	126
Eastside Canal	17,790	15,641	13,273	17,250	11,037	10,425	13,121	17,305	15,966	24,459	18,615	22,775	15,584	13,880	16,453	10,869	38,013	42,556	18,112	14,244	15,039	8,965	9,400	13,445	16,125	430,342	17,214
James Canal	7,464	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,464	299
KD Buena Vista Canal	8,029	1,767	1,605	2,396	1,800	7,834	3,647	6,500	3,663	7,080	9,251	7,384	5,858	6,416	5,514	4,374	4,459	8,533	5,505	8,460	5,964	2,235	3,869	6,060	13,570	141,775	5,671
KD Central Branch	6,765	6,849	6,112	8,115	5,913	5,640	5,565	5,833	7,309	6,253	6,721	7,402	1,976	7,078	7,236	7,215	7,188	7,397	6,518	6,467	6,105	6,218	5,657	5,189	8,284	161,009	6,440
KD Eastside Canal	50	52	49	40	25	39	49	59	37	38	31	33	191	30	26	31	41	48	33	36	22	26	51	46	93	1,177	47
KD Farmers Canal	4,043	2,001	258	2,180	-	2,391	1,068	4,887	1,459	7,194	5,691	7,292	-	3,283	2,526	1,817	2,390	5,882	3,371	6,537	3,912	680	2,565	2,068	6,887	80,382	3,215
KD Kern Island Canal	19,056	19,292	17,214	22,857	16,654	15,886	15,674	16,430	20,588	17,611	18,931	20,850	5,566	19,935	20,382	20,322	20,247	20,835	18,358	18,215	17,197	17,515	15,934	14,616	23,332	453,496	18,140
KD Stine Canal	27,120	7,918	2,028	6,612	-	7,412	2,858	19,682	5,212	26,710	24,934	23,528	-	11,050	9,068	4,346	6,098	23,226	14,206	34,474	24,276	4,462	11,770	18,640	35,742	351,372	14,055
KRCI Ditch	4,022	2,151	1,763	1,852	1,541	1,307	1,361	2,078	1,316	3,974	3,611	2,964	2,343	2,078	1,981	1,213	1,267	1,033	1,294	1,354	1,685	896	922	890	640	45,536	1,821
Main Canal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	87	-	95	-	-	-	35	34	415	210	876	35
Calloway Canal	26,718	3,092	5,188	1,897	1,638	1,557	1,088	21,753	1,772	33,503	19,839	17,746	20,862	17,247	3,560	2,987	3,178	785	1,365	27,432	22,592	642	2,166	2,163	23,739	264,509	10,580
Outlet Canal	7,692	2,205	2,757	3,358	2,274	3,059	1,710	2,705	4,247	6,625	5,430	8,907	8,912	3,118	3,578	2,628	1,945	2,124	5,033	6,291	8,207	4,309	5,650	2,073	6,734	111,570	4,463
Pioneer Canal	17,146	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17,146	686
Goose Lake Slough	-	-	-	-	-	-	-	-	-	-	-	-	1,268	-	-	-	-	-	-	-	-	-	-	-	-	1,268	51
River Loss	62,381	18,783	16,200	5,840	1,997	4,297	2,070	91,583	19,467	89,579	79,150	76,568	77,324	66,479	51,063	17,350	42,497	73,911	23,780	115,848	86,833	9,465	5,794	6,516	89,759	1,134,534	45,381
TOTAL	**225,503**	**85,344**	**71,266**	**76,724**	**46,734**	**65,713**	**52,710**	**197,075**	**86,345**	**229,803**	**198,563**	**201,897**	**146,215**	**155,956**	**126,139**	**81,854**	**133,402**	**190,178**	**102,676**	**245,494**	**200,003**	**59,292**	**67,985**	**78,417**	**230,318**	**3,355,605**	**134,224**

Table 3-8: Managed Recharge by Facility

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
COB 2800	132,584	7,488	-	-	-	-	-	129,055	16,692	148,332	61,477	32,375	95,676	10,473	30,918	2,539	1,480	1,447	6,956	155,977	81,521	4,495	-	-	7,039	926,524	37,061
Aera Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,392	1,619	-	-	-	1,569	5,580	223
Berrenda Mesa	18,403							20,737	2,204	34,486	9,966	6,555	20,349	633	1,027	-	-	719	2,872	34,896	26,229	2,098	-	-	-	181,174	9,535
Buena Vista WSD	33,349	3,086	227	3,532	-	-	799	29,347	-	51,371	21,423	36,154	69,116	536	337	-	1,489	-	1,508	37,098	19,021	-	-	3,000	25,087	336,480	13,459
KCWA-Kern River	-	-	-	-	-	-	-	-	-	3,258	18,325	6,471	872	2,043	4,073	2,214	1,038	24,441	1,863	29,997	825	-		-		95,420	4,149
Kern Delta WD	17,666	-	-	-	-	-	-	2,021	-	-	-	-	-	-	-	-	-	-	-	-	40,775		-	-	82,363	142,825	5,951
Kern Water Bank	-	-	-	-	-	-	-	-	-	417,848	326,885	211,052	659,969	69,860	51,848	18,856	25,266	75,904	33,962	731,948	539,434	31,448	-	7,030	64,286	3,265,596	130,624
North Kern WSD	149,865	23,000	4,784	398	-	4,038	12,759	34,059	3,478	202,621	76,128	106,187	240,833	30,645	2,438	-	2,099	897	13,683	104,884	159,813	30,151	2,487	13,083	19,141	1,237,471	49,499
Pioneer Project	-	-	-	-	-	-	-	-	-	79,513	45,676	30,085	68,744	13,732	15,296	1,253	1,434	8,372	6,811	111,199	61,228	4,813	-	-	-	448,156	17,926
Rosedale Ranch ID	-	-	-	-	-	-	-	-	702	21,461	9,892	-	-	782	-	-	-	-	-	6,057	5,127	-	-	1,073	8,474	53,568	2,143
Rosedale Rio Bravo	112,768	18,070	19,026	33,699	5,815	9,138	9,323	107,017	6,414	144,642	116,618	116,735	135,652	47,817	42,982	5,653	4,038	27,182	6,964	195,184	147,151	3,200	-	2,354	141,521	1,458,963	58,359
Semitropic WSD	-	-	-	-	-	-	-	-	-	1,690	1,734	2,016	1,150	615	213	10	-	412	-	978	1,019	211	-	-	625	10,675	427
The Park at River Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	127	964	3,555	1,736	611	663	1,019	8,675	347
Truxtun Lakes	-	-	2,546	919	-	933	337	-	932	6,583	5,995	7,047	7,788	719	1,550	467	307	476	346	1,006	-	727	1,002	1,434	1,018	42,132	1,685
West Kern WD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19,360	6,513	54,146	23,954	3,923	3,318	13,244	26,061	150,519	6,021
TOTAL	**464,635**	**51,644**	**26,583**	**38,548**	**5,815**	**14,109**	**23,218**	**322,236**	**30,422**	**1,111,805**	**694,119**	**554,677**	**1,300,149**	**177,856**	**150,682**	**30,992**	**37,151**	**159,210**	**81,605**	**1,466,726**	**1,111,271**	**82,802**	**7,418**	**41,881**	**378,203**	**8,363,758**	**334,550**

Table 3-9: Recovery Pumping by Area

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
2800 Acres	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16,708	6,906	1,371	4,531	1,098	-	16,770	21,410	12,985	3,793	85,573	3,423
Berrenda Mesa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22,918	-	-	589	-	-	23,245	36,604	29,594	6,291	119,241	4,770
Bolthouse	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6,464	-	-	-	-	-	-	-	-	-	6,464	259
COB	-	-	-	-	-	-	-	-	-	-	1,781	14	2,819	3,366	3,426	31,334	17,688	8,808	13,267	-	-	18,634	12,548	7,127	2,287	123,099	4,924
ID4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,892	3,345	-	-	-	8,052	9,717	4,536	861	28,403	1,136
KWB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	88,695	24,904	46,350	48,641	-	-	-	-	-	-	208,590	8,344
KWB - James	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24,537	24,132	48,643	3,171	100,483	4,019
KWB - Main	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55,484	54,378	37,515	9,985	157,362	6,294
KWB - North	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,134	5,067	2,839	1,322	12,362	494
KWB - River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	56,889	55,213	-	10,365	122,467	4,899
KWB - Strand	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52,752	53,003	35,838	10,825	152,418	6,097
KWB - West	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33,345	33,889	29,846	11,845	108,925	4,357
Pioneer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33,511	9,919	2,914	8,928	378	-	51,958	65,283	61,059	17,479	251,429	10,057
RRB-ID4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,302	9,429	4,042	-	15,773	631
TOTAL	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1,781**	**14**	**2,819**	**3,366**	**3,426**	**199,630**	**61,308**	**62,788**	**75,956**	**1,476**	**-**	**347,102**	**380,673**	**274,024**	**78,224**	**1,492,589**	**59,704**

Table 3-10: Groundwater for Agricultural Irrigation from Private Wells

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Bolthouse	8,984	9,553	9,479	8,275	8,246	8,198	8,243	8,006	8,072	6,905	7,799	7,893	7,235	7,619	6,332	7,386	7,618	7,046	8,440	7,636	7,286	6,786	6,700	7,766	5,660	193,164	7,727
BVWSD	9,305	16,385	19,900	19,451	18,874	20,976	26,037	11,808	16,930	11,101	13,804	11,261	5,667	14,451	14,756	17,655	18,685	16,655	25,159	16,435	11,056	20,385	26,020	27,573	16,090	426,421	17,057
Cawelo	1,568	1,710	1,654	694	937	1,044	1,032	712	929	756	1,248	1,247	1,799	908	1,343	1,674	956	594	774	726	534	755	756	730	651	25,731	1,029
JPID	32,264	95,902	94,784	65,472	64,824	64,511	64,779	62,566	63,148	61,382	15,069	14,846	11,501	14,101	22,470	23,488	19,562	14,240	10,813	10,860	5,864	10,685	13,471	12,117	8,387	877,106	35,084
KDWD no Service Area	14,011	15,039	14,828	13,812	13,769	13,731	13,829	13,438	13,564	13,358	12,960	12,899	10,978	12,663	11,973	11,134	11,816	11,381	12,721	11,438	11,102	11,983	14,371	12,646	12,006	321,451	12,858
KD Buena Vista	17,127	31,620	34,264	28,913	35,676	32,179	31,536	18,546	27,603	17,810	30,338	27,968	27,656	25,692	22,120	29,932	29,531	20,535	30,881	20,815	14,960	30,855	32,486	36,707	24,314	680,065	27,203
KD Farmers	16,066	26,123	27,366	25,457	29,626	25,238	27,599	17,971	26,010	18,522	17,521	17,617	20,963	25,189	22,751	29,751	27,237	18,936	25,168	19,685	16,510	27,299	21,137	20,314	15,602	565,659	22,626
KD Kern Island	15,998	25,039	21,953	23,941	26,257	29,686	33,332	16,953	26,917	17,453	15,503	13,412	49,085	25,140	21,842	24,046	28,081	12,593	21,043	12,248	6,321	24,813	22,105	25,600	12,371	551,730	22,069
KD Stine	44,795	60,301	60,451	52,314	60,045	57,077	58,241	41,416	55,208	47,778	54,404	53,972	48,052	48,199	42,210	52,327	50,708	41,723	48,345	43,984	37,567	58,260	59,701	57,870	40,479	1,275,430	51,017
KRCI	4,205	6,180	13,684	5,407	4,681	6,873	6,986	5,433	4,800	12,374	3,552	3,427	7,451	2,867	138	1,035	198	75	58	681	691	69	367	679	847	92,758	3,710
North Kern-Other	6,505	7,036	6,926	7,179	7,175	7,163	7,242	7,057	7,142	7,003	8,235	8,135	7,061	8,146	6,188	5,469	6,777	5,860	5,336	4,840	4,630	5,123	5,122	6,729	5,286	163,364	6,535
North Kern-Class1	1,469	2,202	1,420	3,192	3,467	5,984	5,029	5,327	5,124	6,761	5,286	6,047	7,506	8,059	7,256	5,376	4,763	4,491	6,242	3,299	6,533	7,032	6,199	7,335	6,768	132,170	5,287
North Kern-Class2	12,032	17,715	18,662	21,613	22,267	22,914	22,890	13,072	18,158	12,316	10,768	9,255	9,354	13,333	14,087	13,812	14,877	11,704	11,203	8,141	9,666	12,881	12,972	12,378	8,620	354,689	14,188
No Water District	66,460	71,553	70,424	72,098	72,057	72,138	72,725	70,799	71,669	70,896	59,851	59,327	50,890	56,124	63,458	56,309	51,812	45,013	54,048	50,783	48,492	54,065	56,008	55,692	53,103	1,525,794	61,032
Rosedale Rio Bravo	99,493	107,083	105,269	105,519	105,504	105,544	106,569	103,836	105,111	103,737	102,841	101,853	87,160	105,775	101,288	105,536	99,621	88,268	99,513	94,527	90,727	101,251	106,550	103,985	90,441	2,527,001	101,080
RRB-BV Diversions	8,424	10,636	11,365	14,845	16,698	18,342	16,702	12,902	16,311	12,770	14,017	14,827	12,186	13,589	16,190	19,732	19,006	14,782	15,208	14,492	17,460	16,327	20,080	20,449	17,198	384,539	15,382
RRB-Other Diversions	5,859	6,269	1,846	719	5,516	5,540	5,582	157	5,517	5,473	260	100	148	845	3,179	4,810	5,736	3,249	4,540	23	139	6,720	6,865	7,777	804	87,674	3,507
Rosedale Ranch	15,303	38,216	37,681	36,219	36,184	36,059	36,366	23,387	35,803	25,505	22,345	19,961	15,629	27,380	38,725	37,699	40,043	36,828	36,019	25,540	26,475	36,295	38,928	36,316	35,627	794,533	31,781
Semitropic-Other	19,225	20,624	20,408	21,145	21,143	21,165	21,313	20,742	21,000	20,836	22,379	22,093	19,470	20,470	17,432	19,215	19,537	16,773	22,562	18,563	19,535	23,027	22,131	21,669	21,423	513,878	20,555
Semitropic-Wegis	7,050	8,486	9,934	8,375	15,196	20,617	18,678	7,131	17,226	6,636	5,250	3,356	1,686	5,084	1,218	17,947	13,884	5,892	15,145	2,650	4,696	16,737	20,063	20,800	10,584	264,321	10,573
Shafter-Wasco ID	16,816	28,712	28,603	28,753	34,666	30,335	31,660	20,603	33,142	20,424	26,538	22,931	23,629	28,232	24,704	27,262	29,156	21,184	26,631	21,344	18,643	31,994	29,869	29,689	19,285	654,805	26,192
TOTAL	**422,958**	**606,385**	**610,900**	**563,393**	**602,808**	**605,312**	**616,369**	**481,865**	**579,385**	**499,796**	**449,968**	**432,426**	**425,108**	**463,867**	**459,661**	**511,597**	**499,604**	**397,822**	**479,849**	**388,711**	**358,888**	**503,340**	**521,901**	**524,823**	**405,548**	**12,412,284**	**496,491**

Table 3-11: Groundwater for Agricultural Irrigation from District Wells

All Values in Acre Feet per Year (AFY)

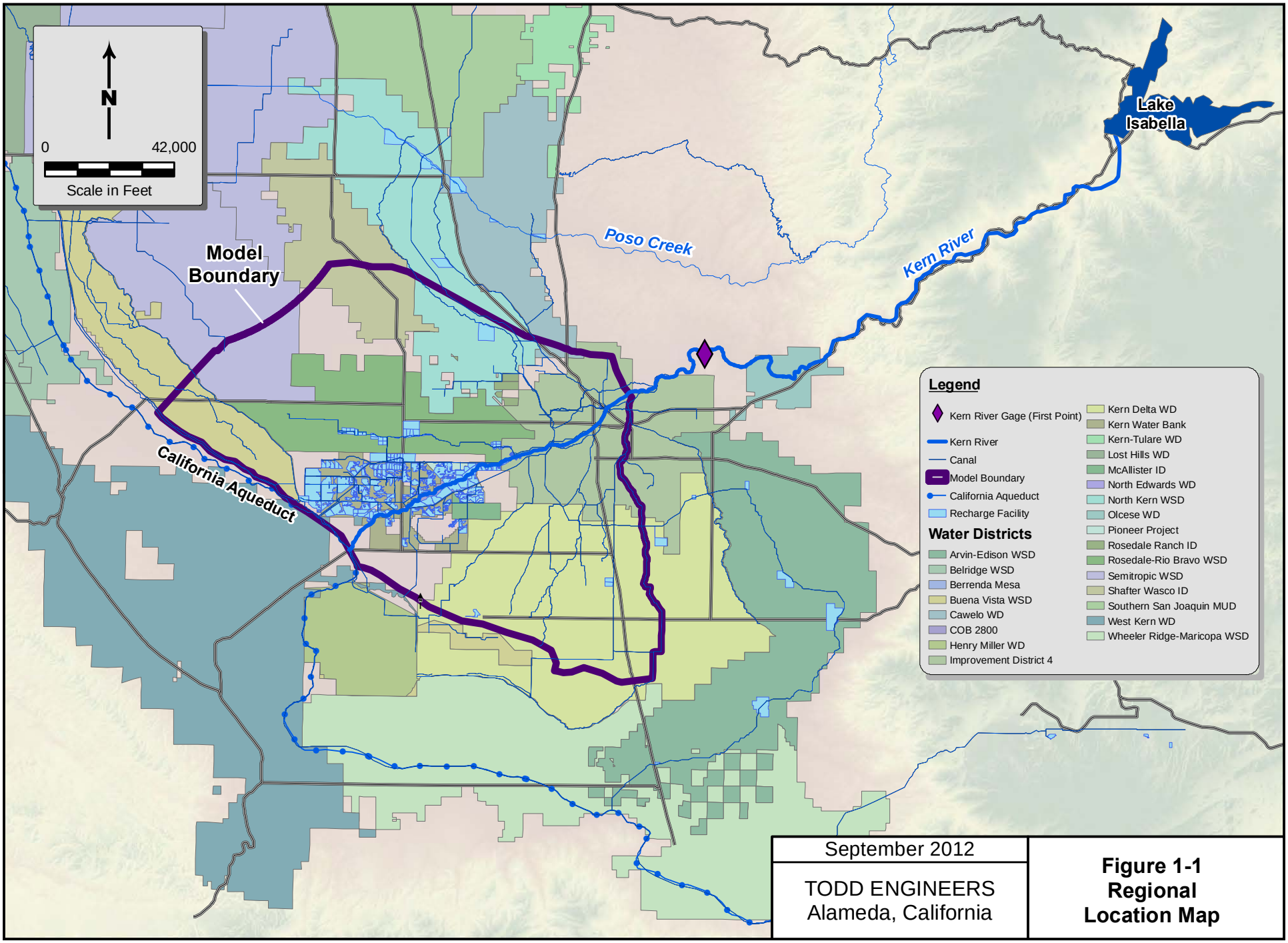
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
BVWSD	815	3,455	6,024	12,042	8,802	10,347	12,930	9,112	9,513	7,695	10,635	8,770	7,564	10,973	13,410	14,712	12,413	10,016	11,322	12,590	13,492	15,558	13,427	12,318	10,708	258,644	10,346
NKWD	-	11,215	16,240	17,450	17,828	18,111	16,123	-	8,428	-	-	-	-	-	4,116	13,981	15,387	4,765	12,810	-	444	23,022	21,606	23,084	1,488	226,096	9,044
Semitropic	-	-	254	43	1,353	4,420	6,808	293	3,768	13	16	147	143	-	2,352	6,485	3,759	1,918	9,442	-	-	10,777	12,845	14,538	2,477	81,852	3,274
TOTAL	**815**	**14,670**	**22,518**	**29,535**	**27,983**	**32,878**	**35,861**	**9,405**	**21,709**	**7,708**	**10,652**	**8,917**	**7,707**	**10,973**	**19,879**	**35,177**	**31,559**	**16,698**	**33,573**	**12,590**	**13,936**	**49,358**	**47,878**	**49,940**	**14,673**	**566,592**	**22,664**

Table 3-12: Municipal Pumping by Purveyor

All Values in Acre Feet per Year (AFY)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Average
Buttonwillow	180	181	181	182	182	182	181	181	180	179	179	178	178	161	161	199	186	191	196	200	205	210	212	212	212	4,689	188
CalWater	54,522	53,322	55,579	58,681	61,486	57,856	63,263	65,992	68,782	63,678	67,757	74,707	61,497	72,111	52,021	53,872	58,348	51,953	45,566	45,590	49,249	50,417	46,783	44,781	45,747	1,423,560	56,942
COB	14,762	14,762	16,010	17,621	18,622	17,523	19,901	22,040	23,008	23,271	24,948	24,939	24,361	30,599	27,417	32,675	33,362	35,056	37,829	34,554	36,558	42,291	45,517	42,603	37,414	697,642	27,906
Greenfield	873	880	906	919	927	956	964	974	1,005	1,019	1,052	1,085	1,120	1,140	1,329	1,360	1,507	1,653	2,026	2,169	2,486	2,574	2,554	2,445	2,282	36,205	1,448
North of River MSc	6	6	6	6	6	226	3	-	-	-	-	-	-	30	178	939	52	181		82	416	443	364	434	414	3,792	158
Oildale	157	33	17	308	2,104		176	55	6	11	158	27	23	39	62	277	501	1,488	1,629	1,377	992	2,091	1,955	1,419	151	15,055	627
Shafter	3,122	3,211	3,299	3,388	3,476	3,204	3,280	3,356	3,432	3,507	3,583	3,659	3,743	4,219	4,488	4,539	4,653	4,881	4,727	4,688	4,887	4,770	5,258	4,578	4,663	100,612	4,024
Stockdale Annex	112	118	119	115	113	101	124	121	118	127	109	113	93	107	106	109	111	109	100	102	102	140	123	131	115	2,838	114
Stockdale MWC	224	236	239	230	226	203	247	243	236	254	217	226	187	214	212	218	221	218	199	204	204	280	246	263	230	5,676	227
Vaughn	3,800	3,800	4,420	4,468	4,633	4,805	5,178	5,804	6,574	6,270	7,544	7,844	7,021	8,600	9,095	9,433	9,929	10,194	10,776	10,812	11,668	12,666	12,825	12,481	11,447	202,089	8,084
West Kern WD	15,294	15,504	16,436	10,942	9,641	14,405	12,495	12,572	11,695	12,150	13,524	14,300	13,513	15,042	17,050	15,724	14,789	19,182	22,465	27,888	25,737	28,290	24,538	22,843	21,735	427,755	17,110
TOTAL	**93,051**	**92,053**	**97,213**	**96,858**	**101,417**	**99,462**	**105,812**	**111,338**	**115,036**	**110,466**	**119,071**	**127,079**	**111,735**	**132,262**	**112,119**	**119,346**	**123,658**	**125,106**	**125,513**	**127,665**	**132,505**	**144,171**	**140,376**	**132,190**	**124,412**	**2,919,913**	**116,797**

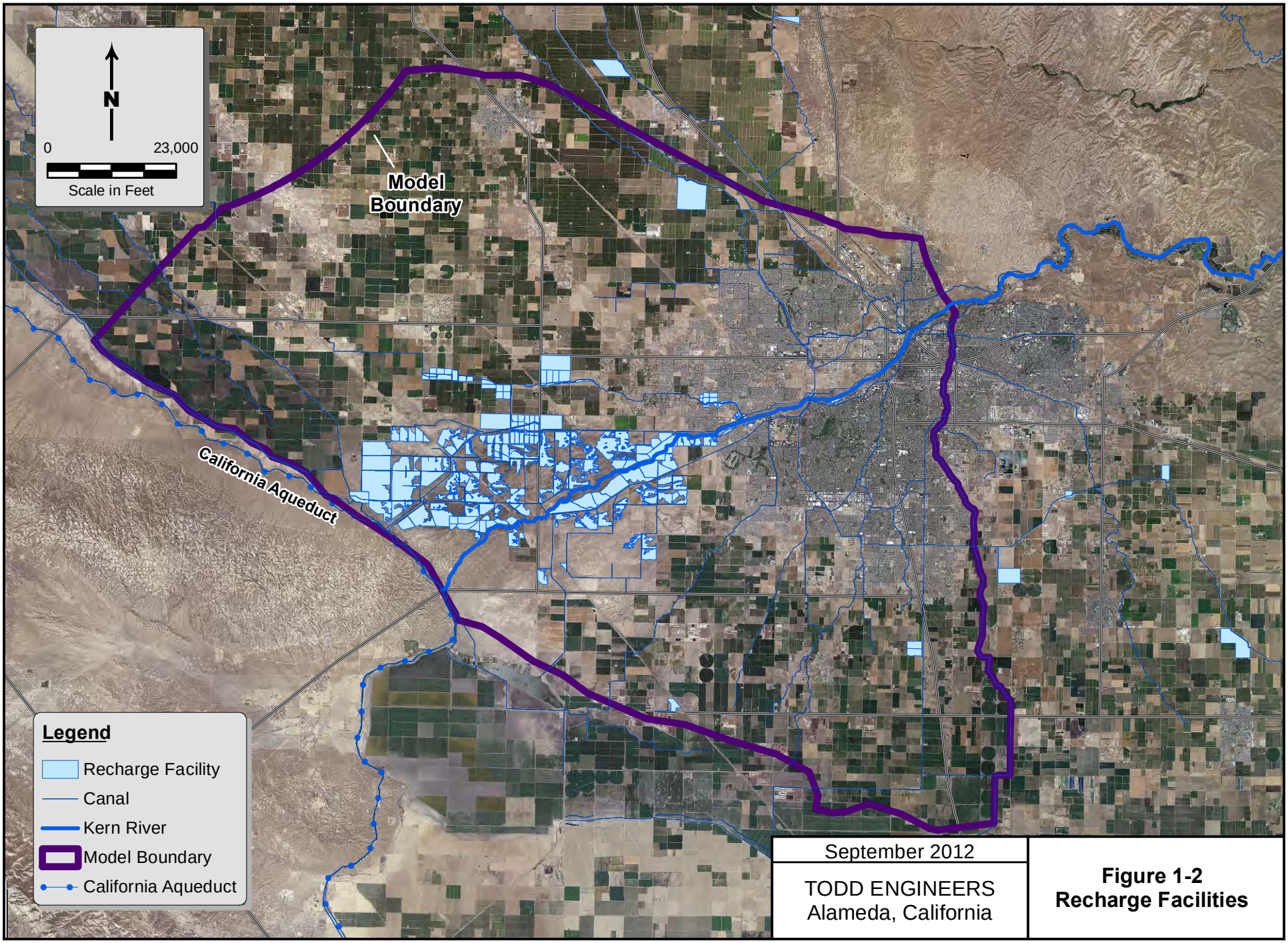
FIGURES



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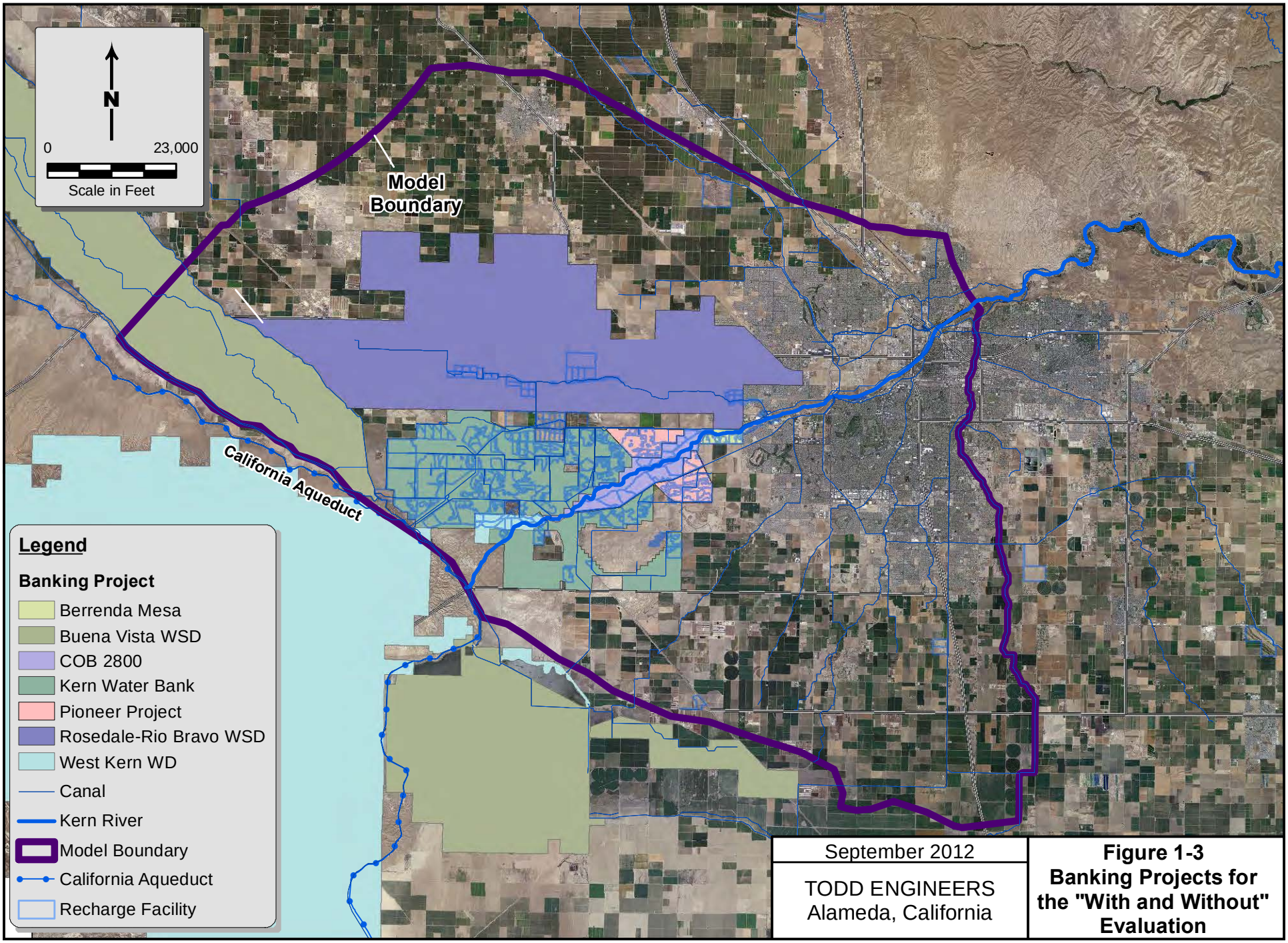
Figure 1-1
Regional Location Map



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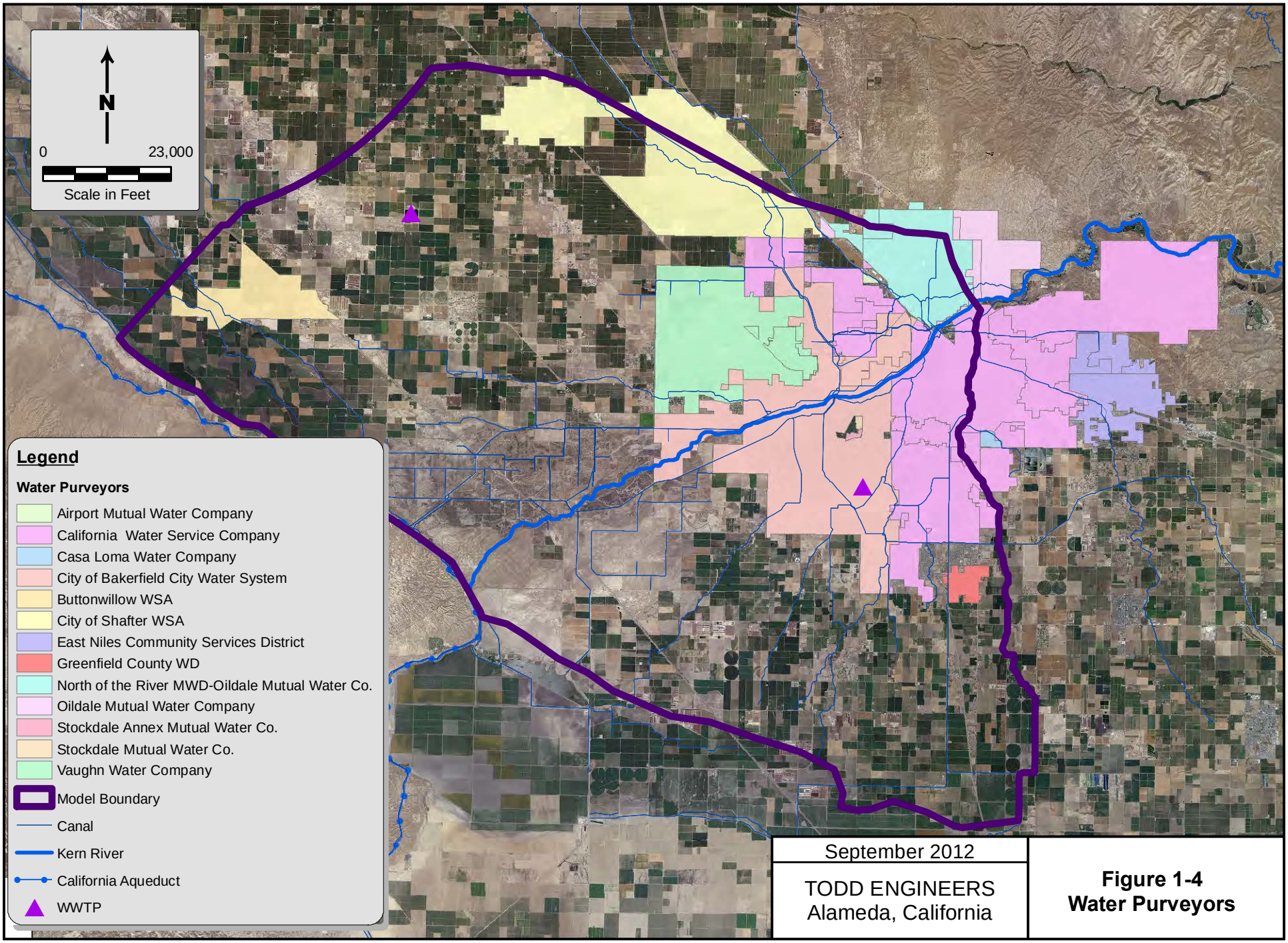
Figure 1-2
Recharge Facilities

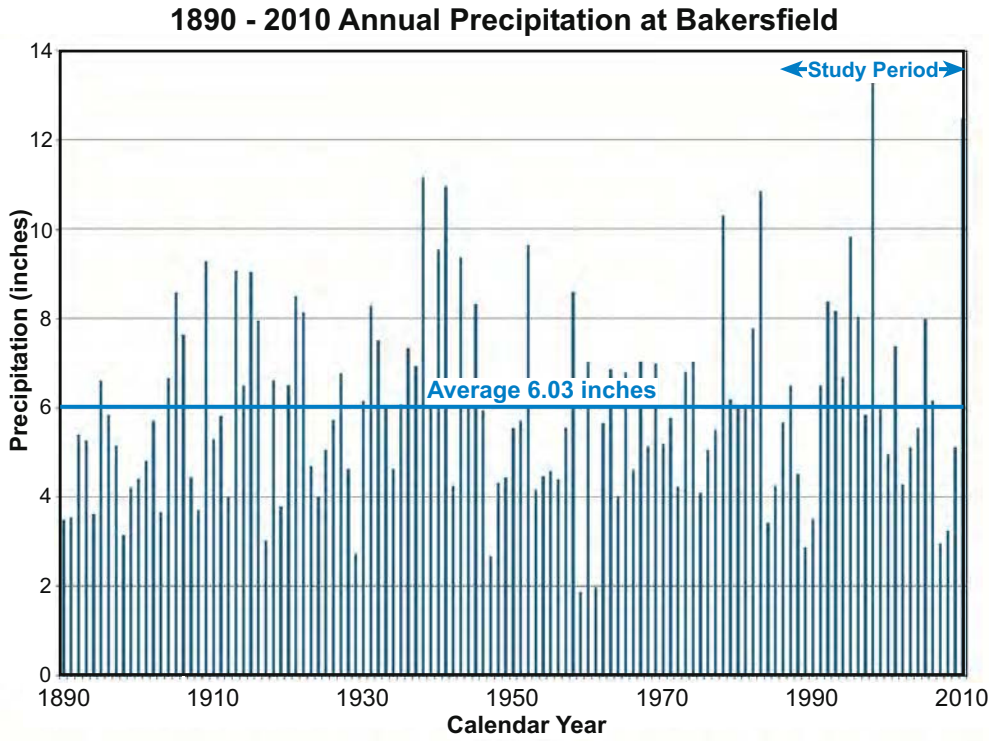


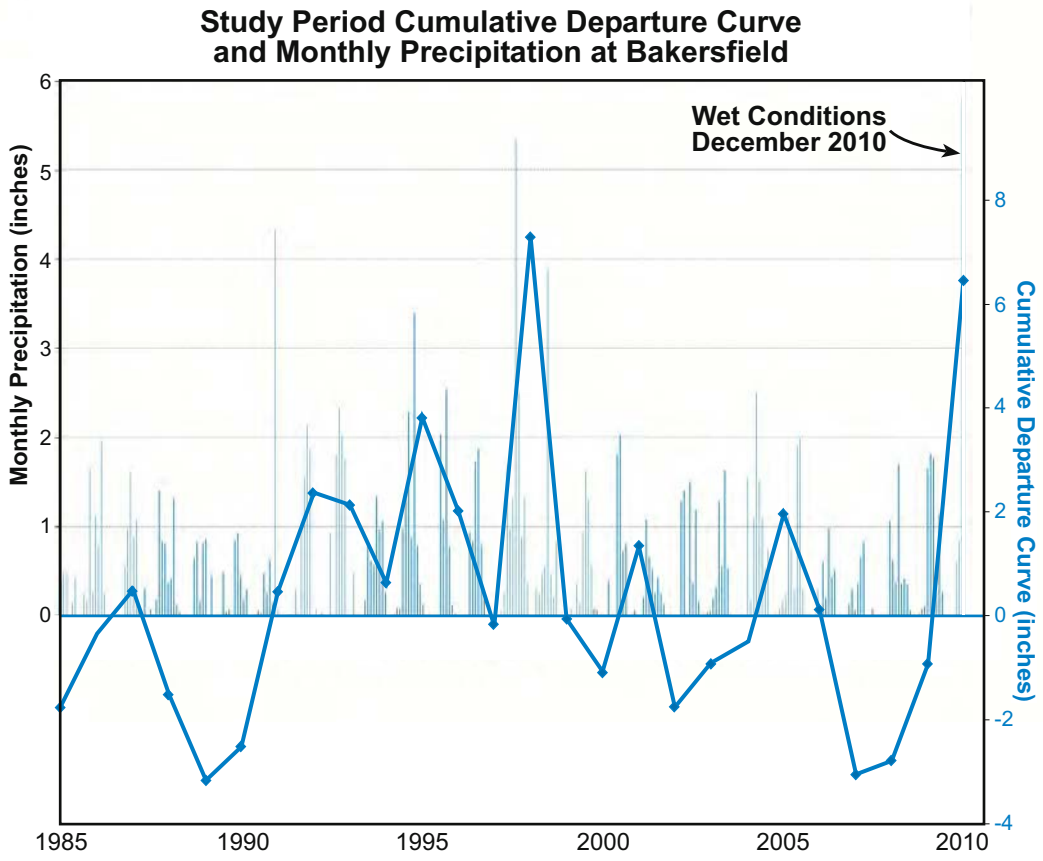
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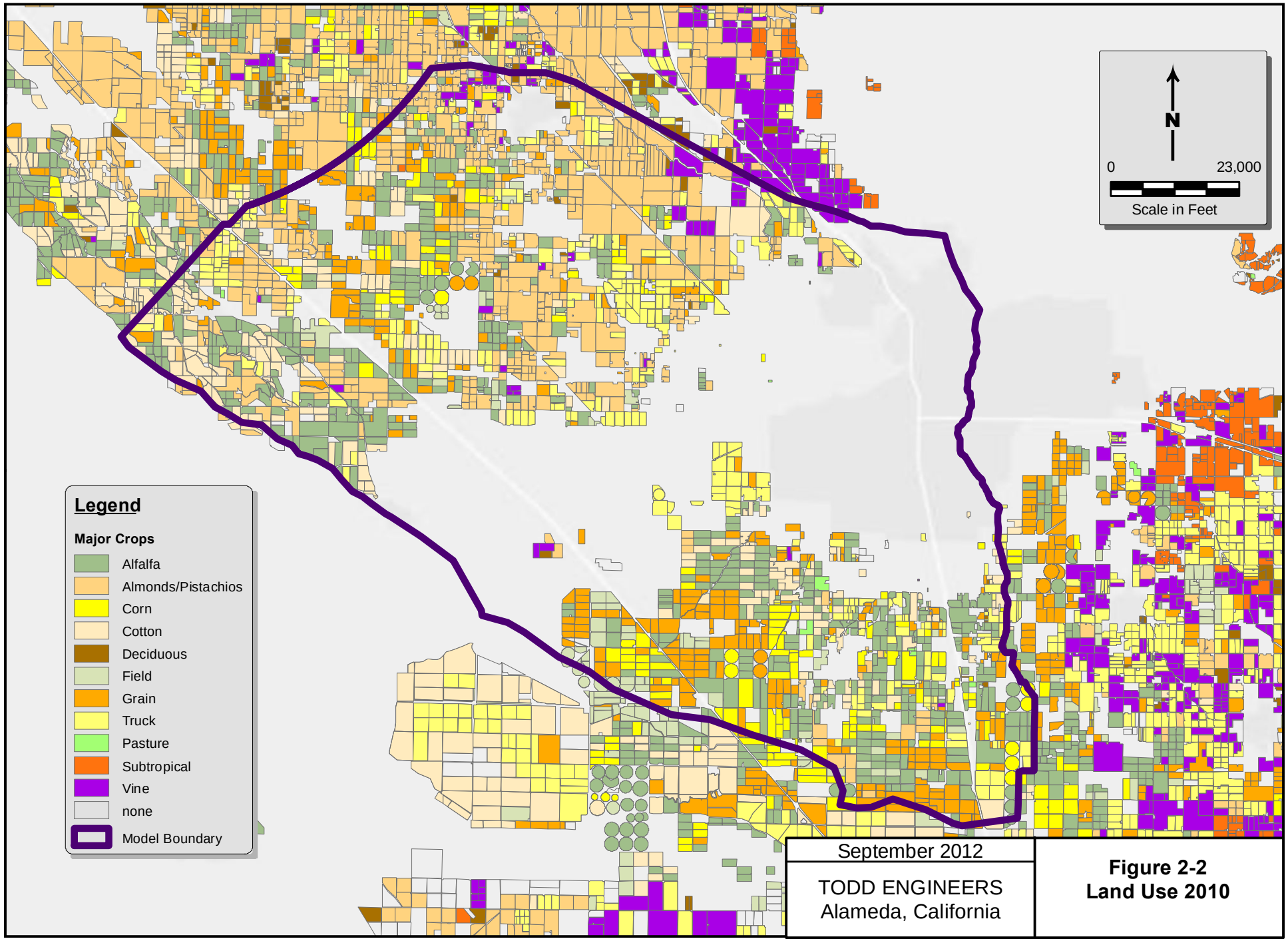
Figure 1-3
Banking Projects for the "With and Without" Evaluation


N
0
23,000
Scale in Feet
Legend
Water Purveyors
Airport Mutual Water Company
California Water Service Company
Casa Loma Water Company
City of Bakerfield City Water System
Buttonwillow WSA
City of Shafter WSA
East Niles Community Services District
Greenfield County WD
North of the River MWD-Oildale Mutual Water Co.
Oildale Mutual Water Company
Stockdale Annex Mutual Water Co.
Stockdale Mutual Water Co.
Vaughn Water Company
Model Boundary
Canal
Kern River
California Aqueduct
WWTP
September 2012
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Alameda, California
Figure 1-4
Water Purveyors





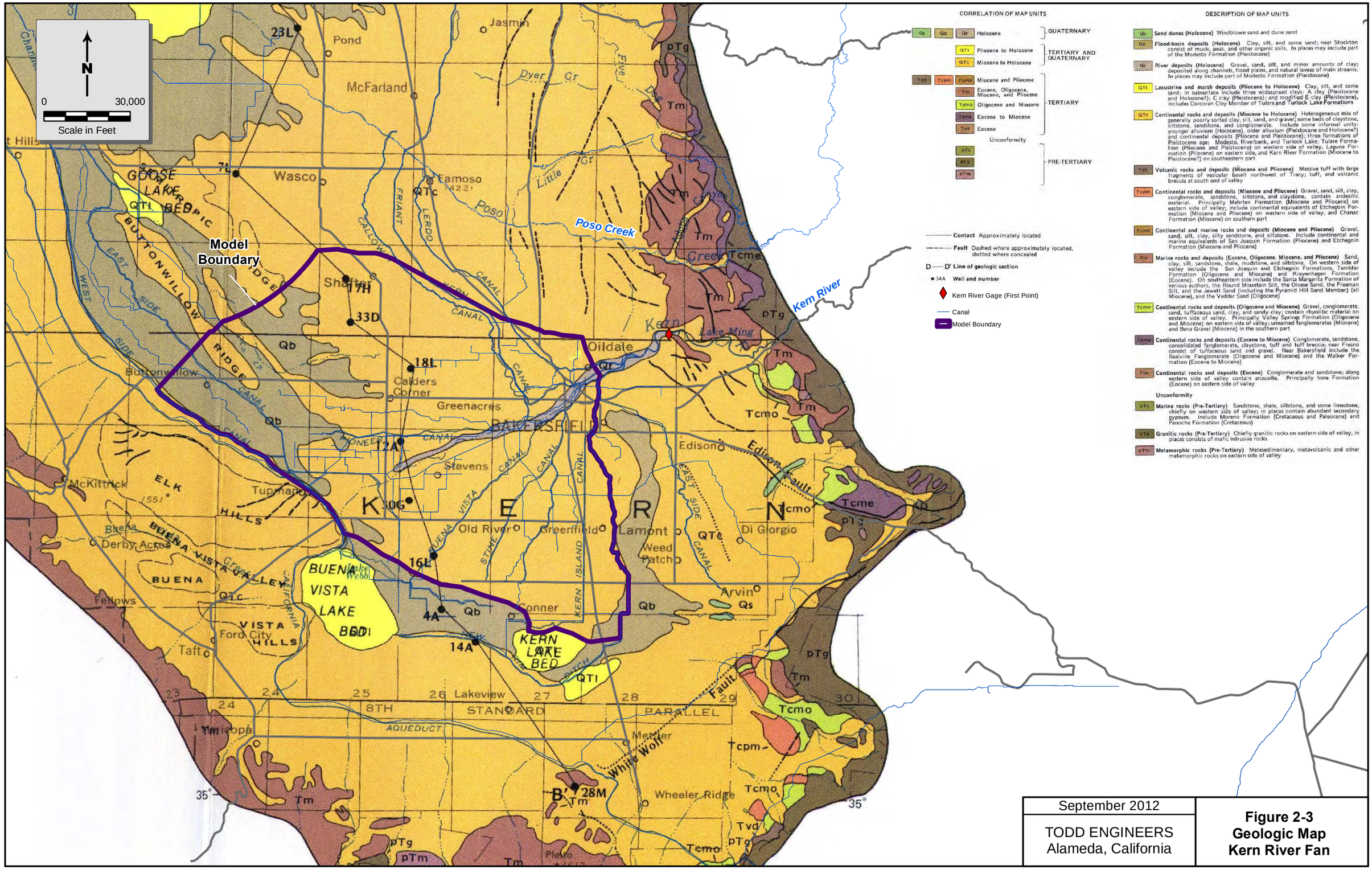
September 2012	**Figure 2-1**
TODD ENGINEERS Alameda, California	**Precipitation and Cumulative Departure Curve**



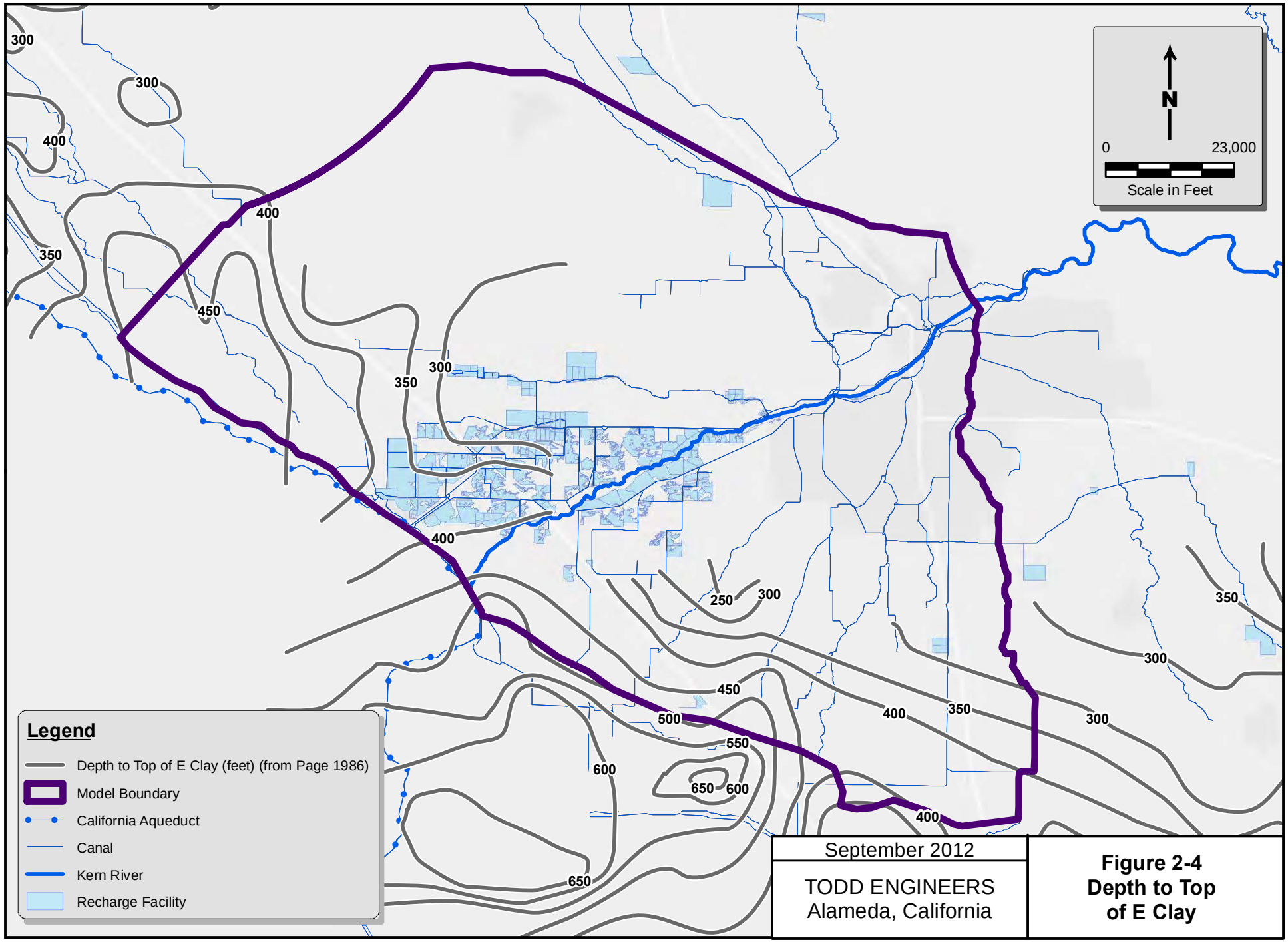
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Figure 2-2
Land Use 2010



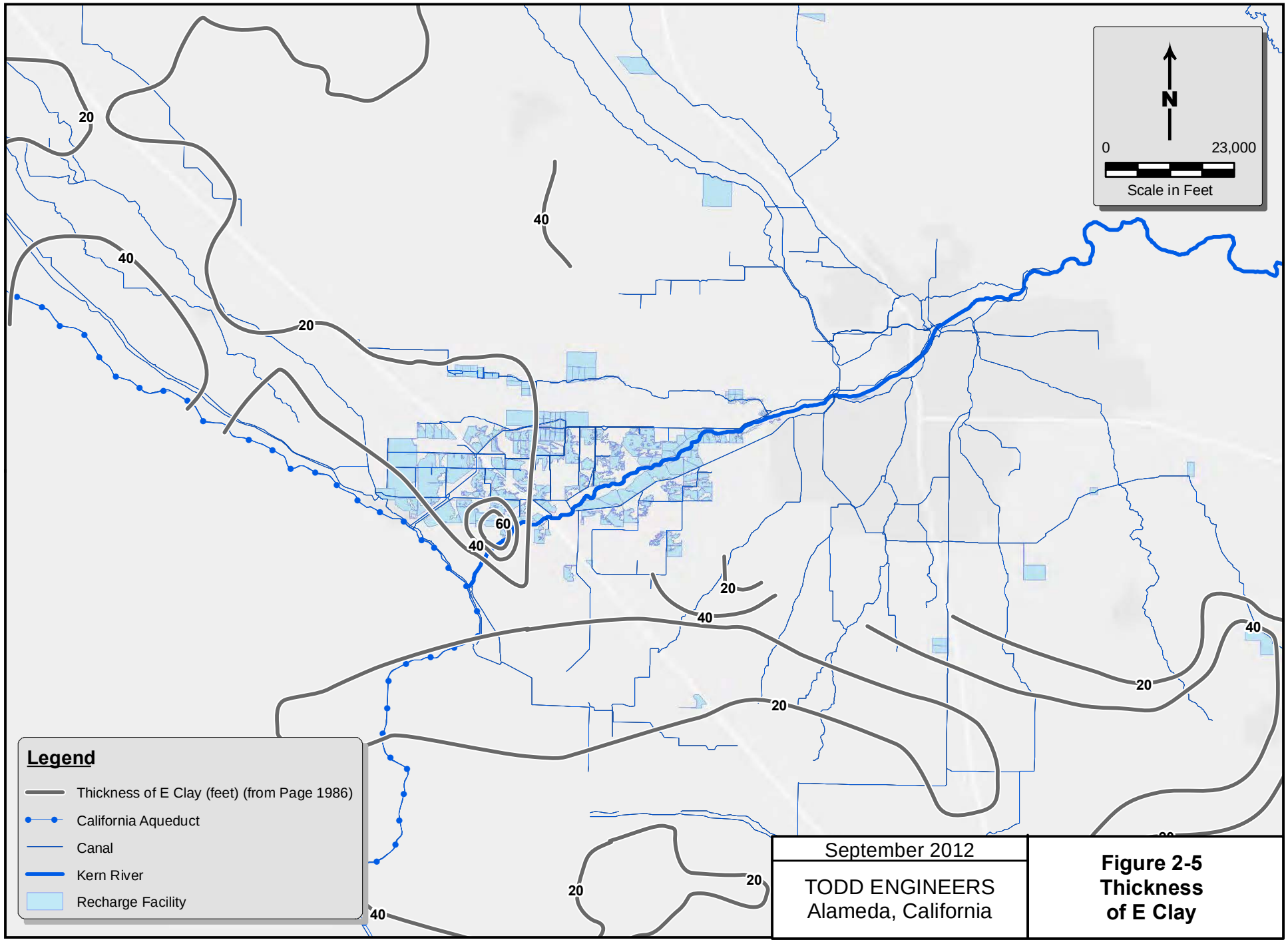
September 2012	**Figure 2-3**
TODD ENGINEERS Alameda, California	**Geologic Map** **Kern River Fan**



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Figure 2-4
Depth to Top of E Clay


N
0
23,000
Scale in Feet
20
40
20
40
60
40
20
40
20
20
40
20
20
40
20
Legend
Thickness of E Clay (feet) (from Page 1986)
California Aqueduct
Canal
Kern River
Recharge Facility
September 2012
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Alameda, California
Figure 2-5
Thickness
of E Clay

Example Electric Log
Pioneer Project
30S/26E-9E01

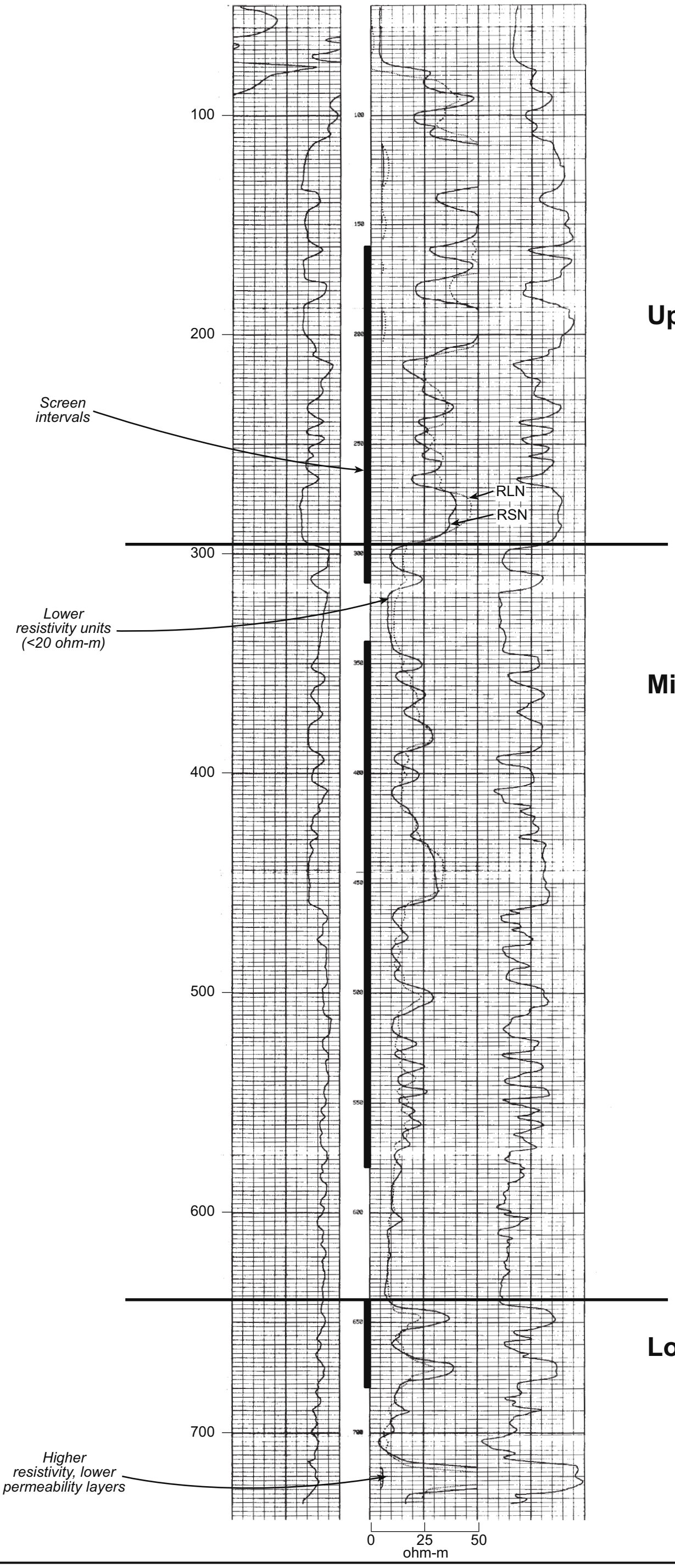
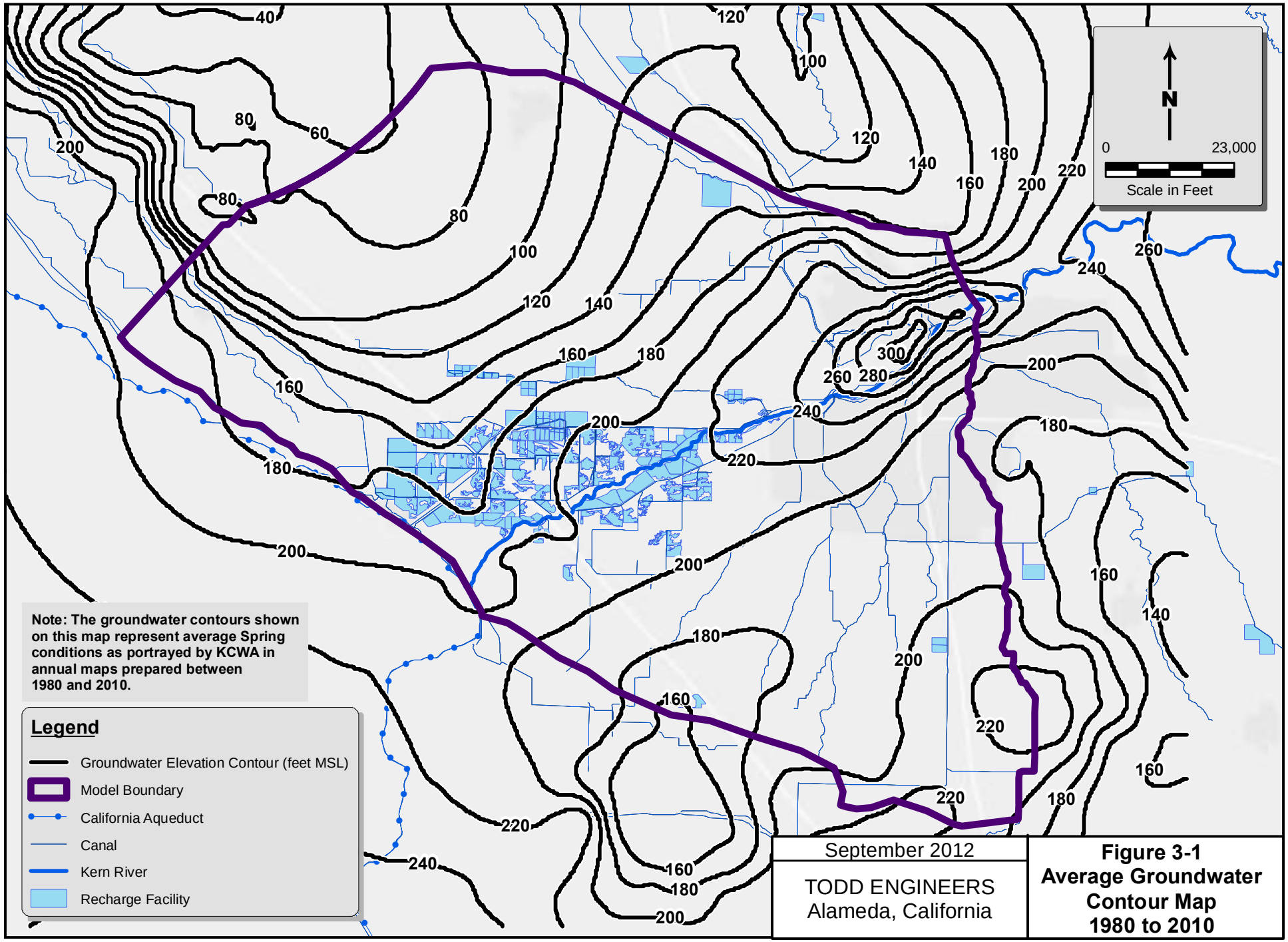
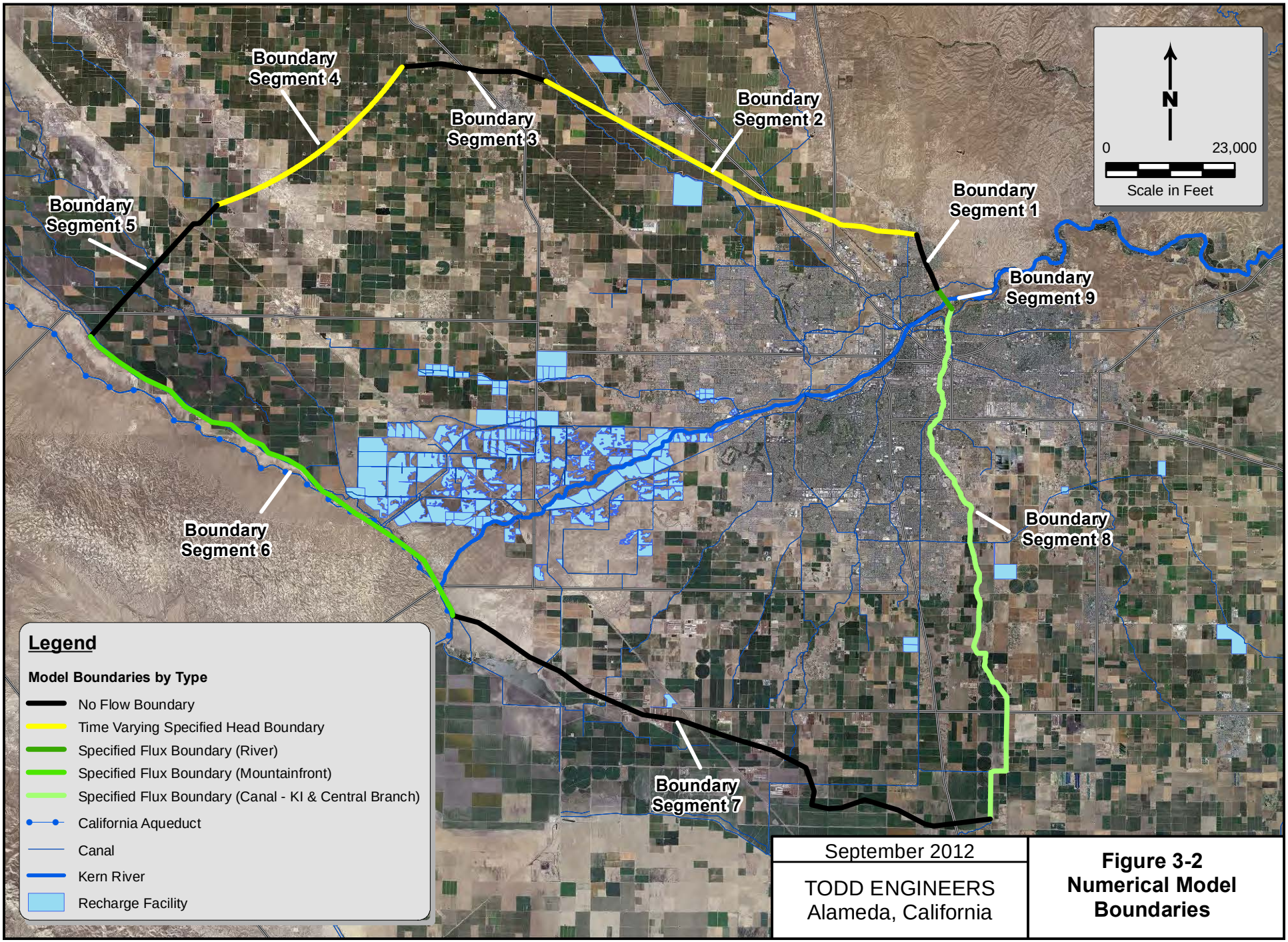


Figure 2-6
Hydrostratigraphic Units

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N
0
23,000
Scale in Feet
Note: The groundwater contours shown on this map represent average Spring conditions as portrayed by KCWA in annual maps prepared between 1980 and 2010.
Legend
Groundwater Elevation Contour (feet MSL)
Model Boundary
California Aqueduct
Canal
Kern River
Recharge Facility
September 2012
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Figure 3-1
Average Groundwater Contour Map
1980 to 2010



September 2012

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Figure 3-2
Numerical Model Boundaries

N

0 15,000

Scale in Feet

Legend

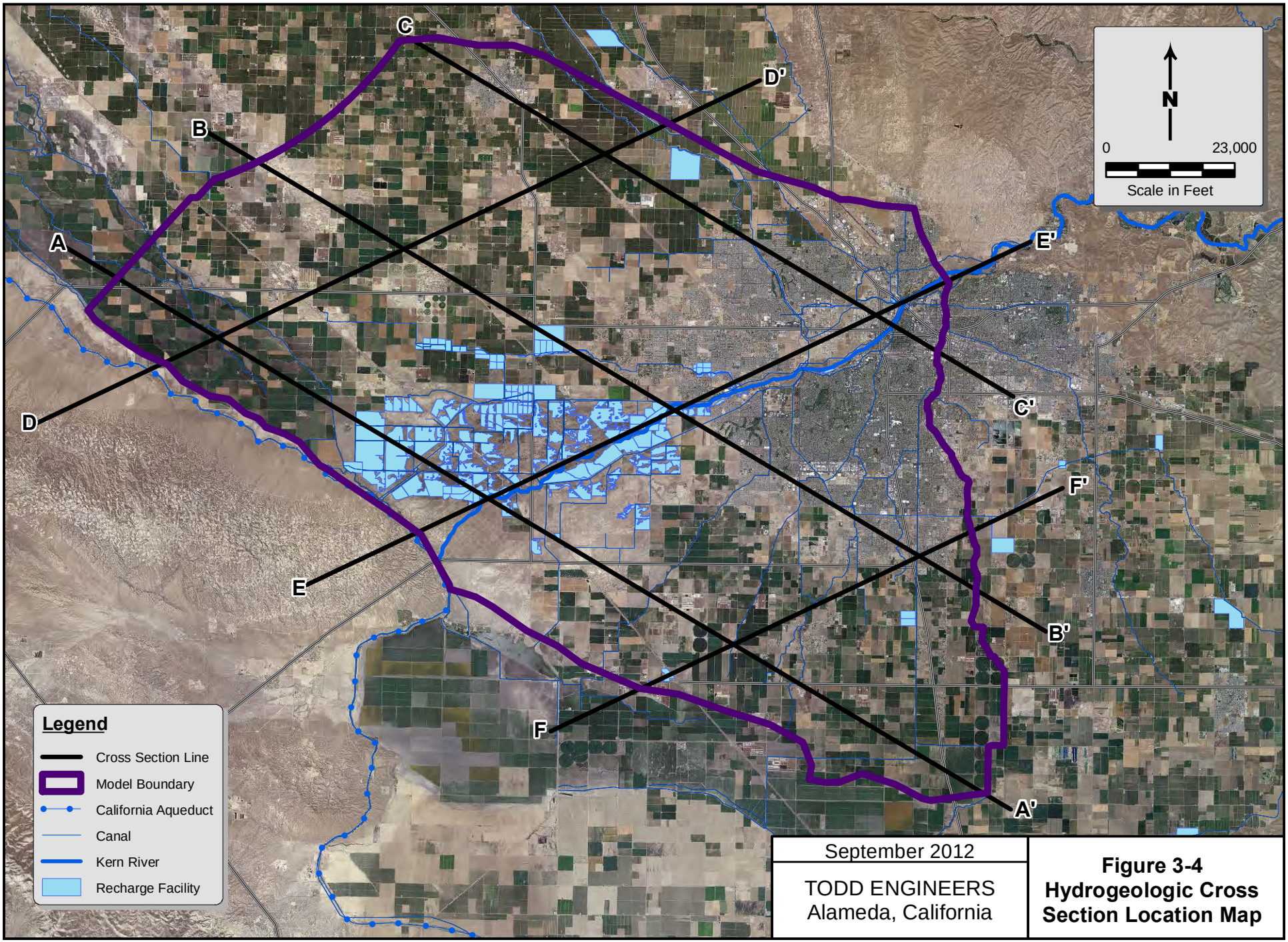
Wells in the Study Area

- Well with Construction and Aquifer Test Data
- Well with Construction Data (no aquifer test data)
- Well with Aquifer Test Data (no construction data)
- Well without Construction or Aquifer Test Data
- Model Boundary
- California Aqueduct
- Canal
- Kern River
- Recharge Facility

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Alameda, California

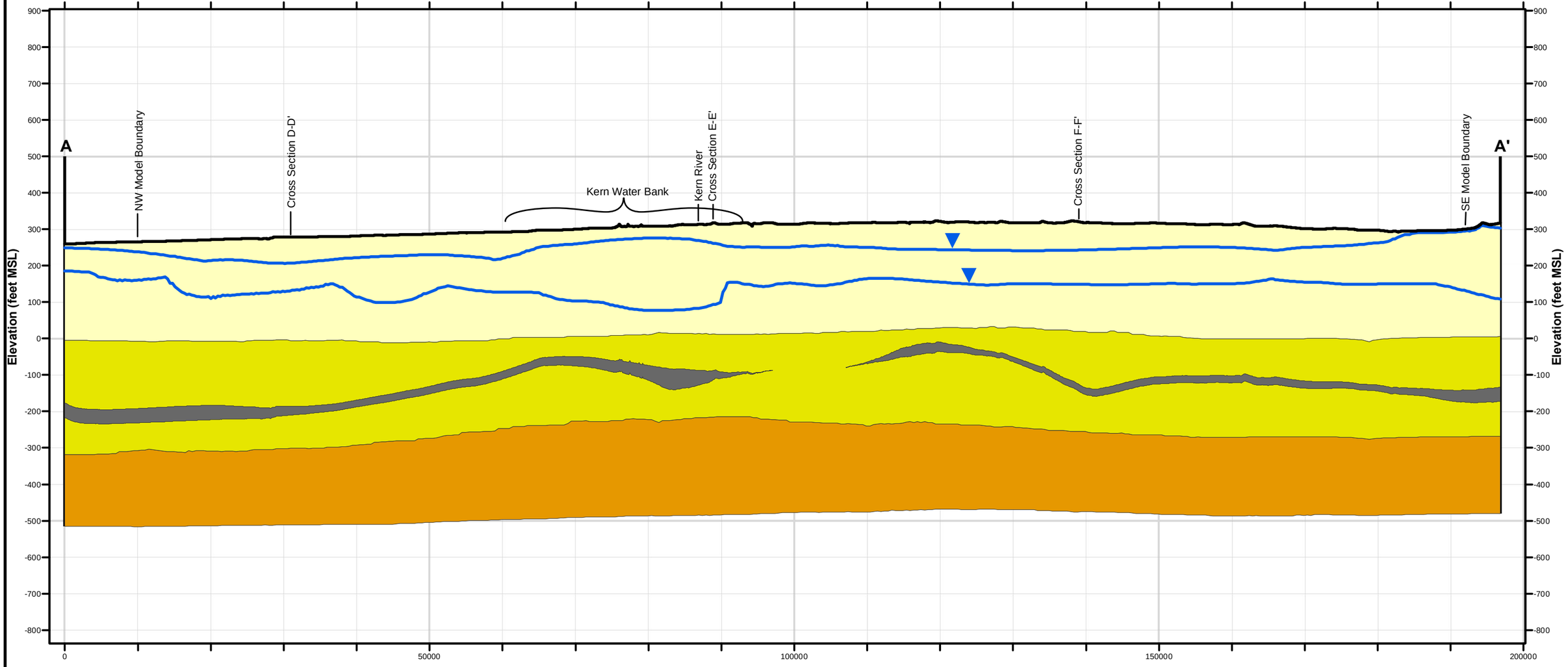
Figure 3-3
All Wells in Study Area



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Figure 3-4
Hydrogeologic Cross Section Location Map



Legend

Range of Historical Groundwater Elevations (from KCWA)

Hydrogeologic Unit

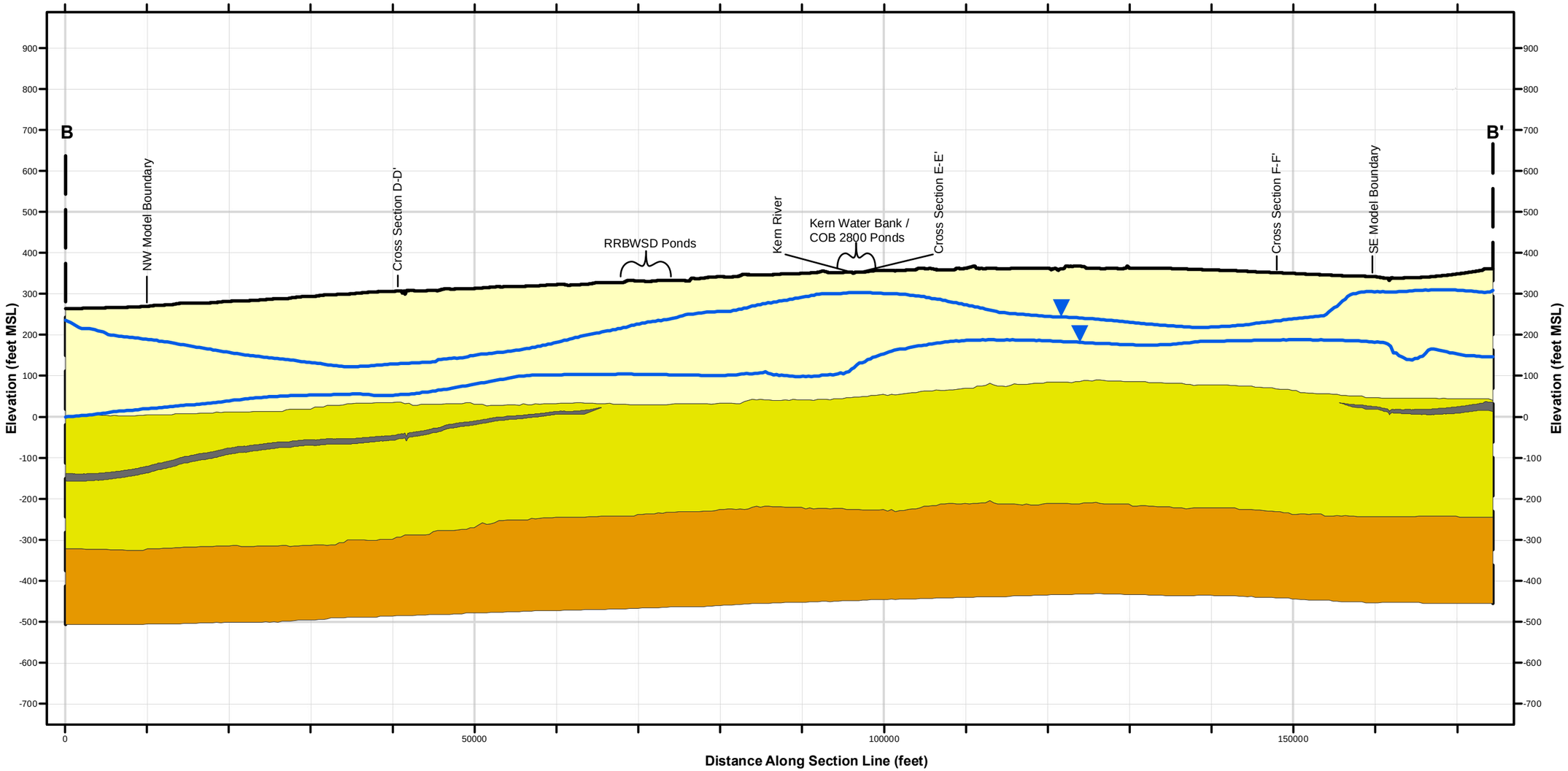
- Model Layer 1
- Model Layer 2
- Model Layer 3
- E Clay (from Page 1986)

50 x Vertical Exaggeration

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Alameda, California

Figure 3-5
Hydrogeologic Cross Section A - A'



Legend

Range of Historical Groundwater Elevations (from KCWA)

Hydrogeologic Unit

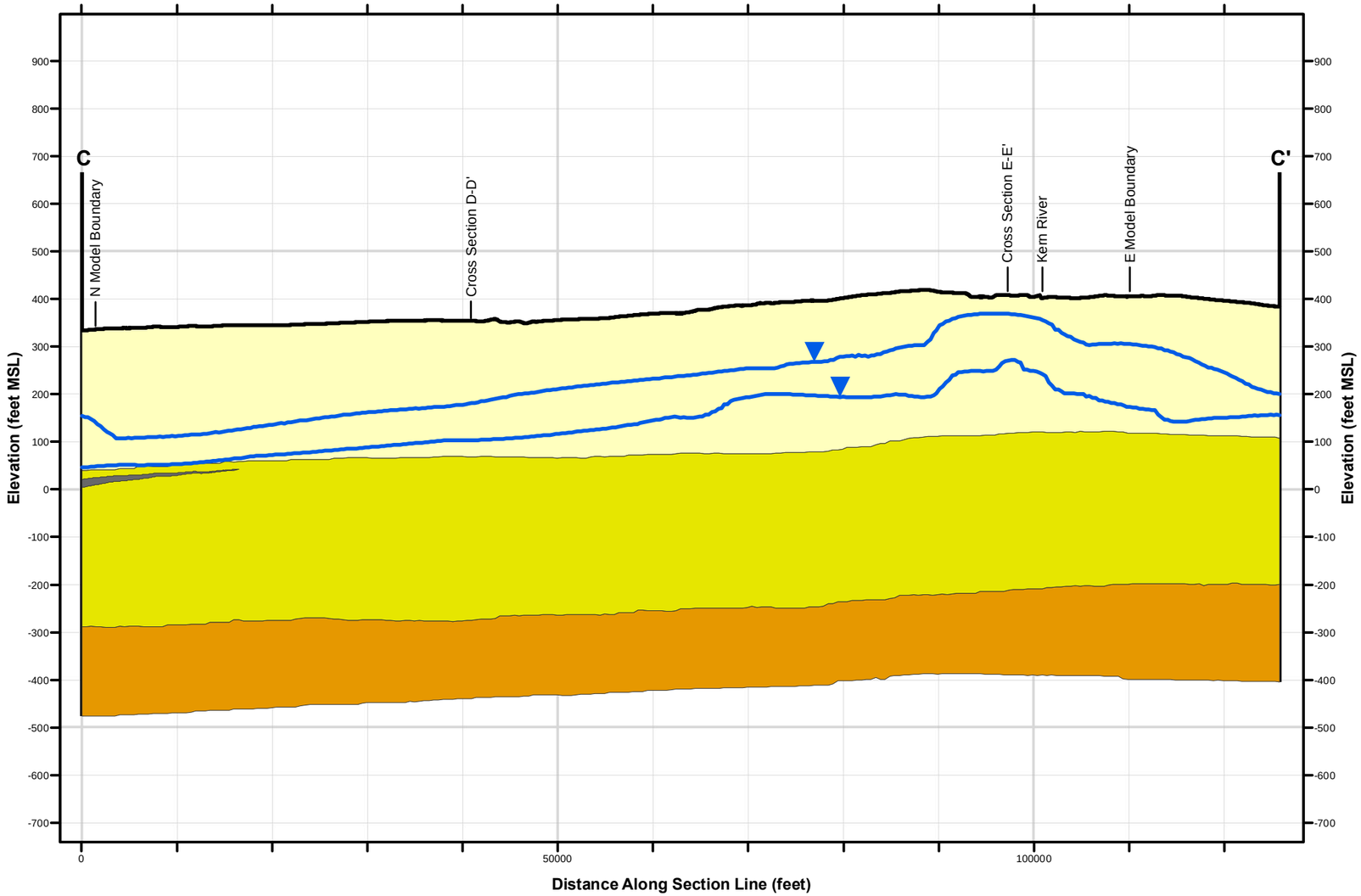
- Model Layer 1
- Model Layer 2
- Model Layer 3
- E Clay (from Page 1986)

50 x Vertical Exaggeration

September 2012

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Alameda, California

Figure 3-6
Hydrogeologic Cross Section B - B'



Legend

Range of Historical Groundwater Elevations (from KCWA)

Hydrogeologic Unit

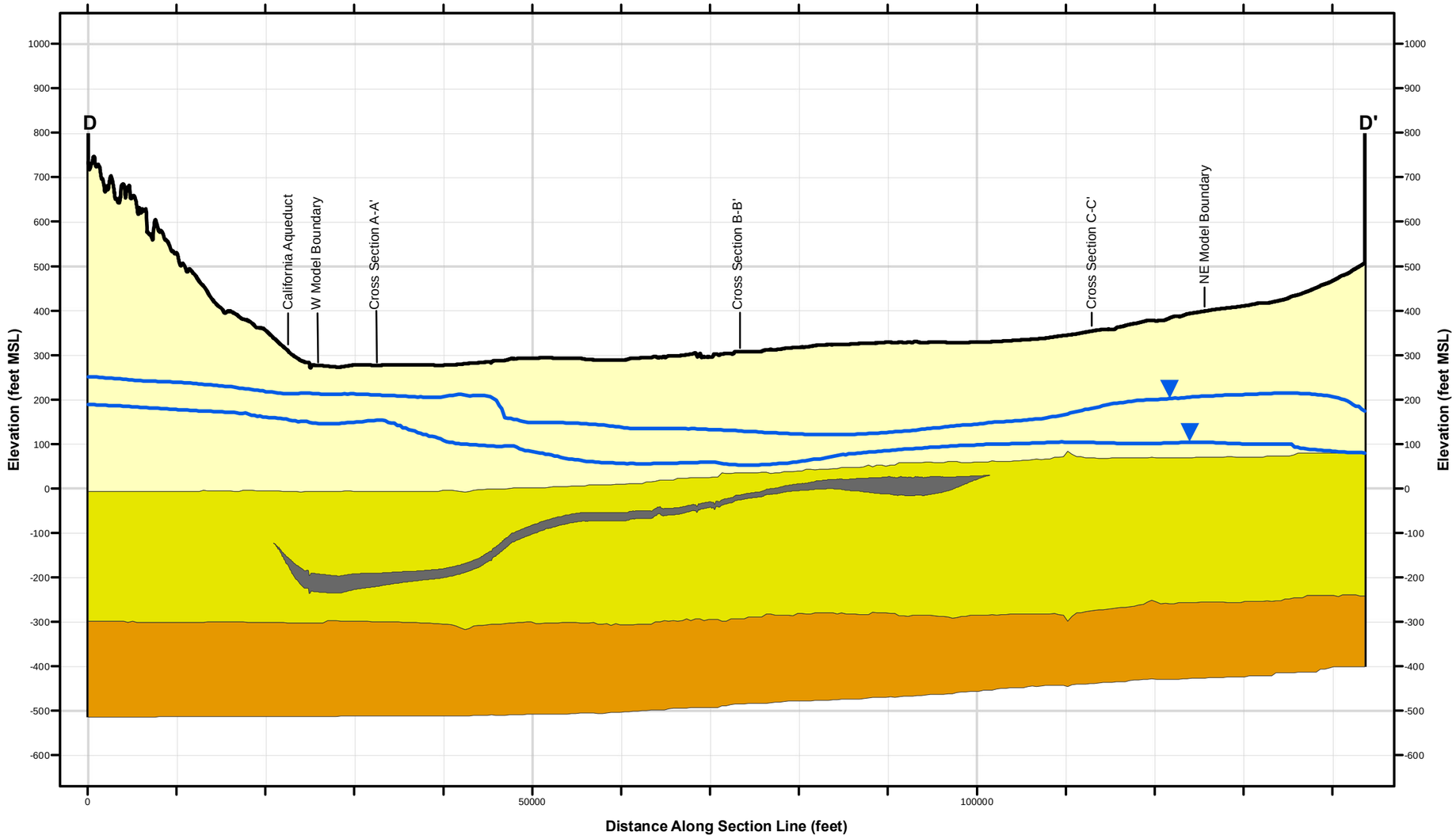
- Model Layer 1
- Model Layer 2
- Model Layer 3
- E Clay (from Page 1986)

50 x Vertical Exaggeration

September 2012

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Alameda, California

Figure 3-7
Hydrogeologic Cross Section C - C'



Legend

Range of Historical Groundwater Elevations (from KCWA)

Hydrogeologic Unit

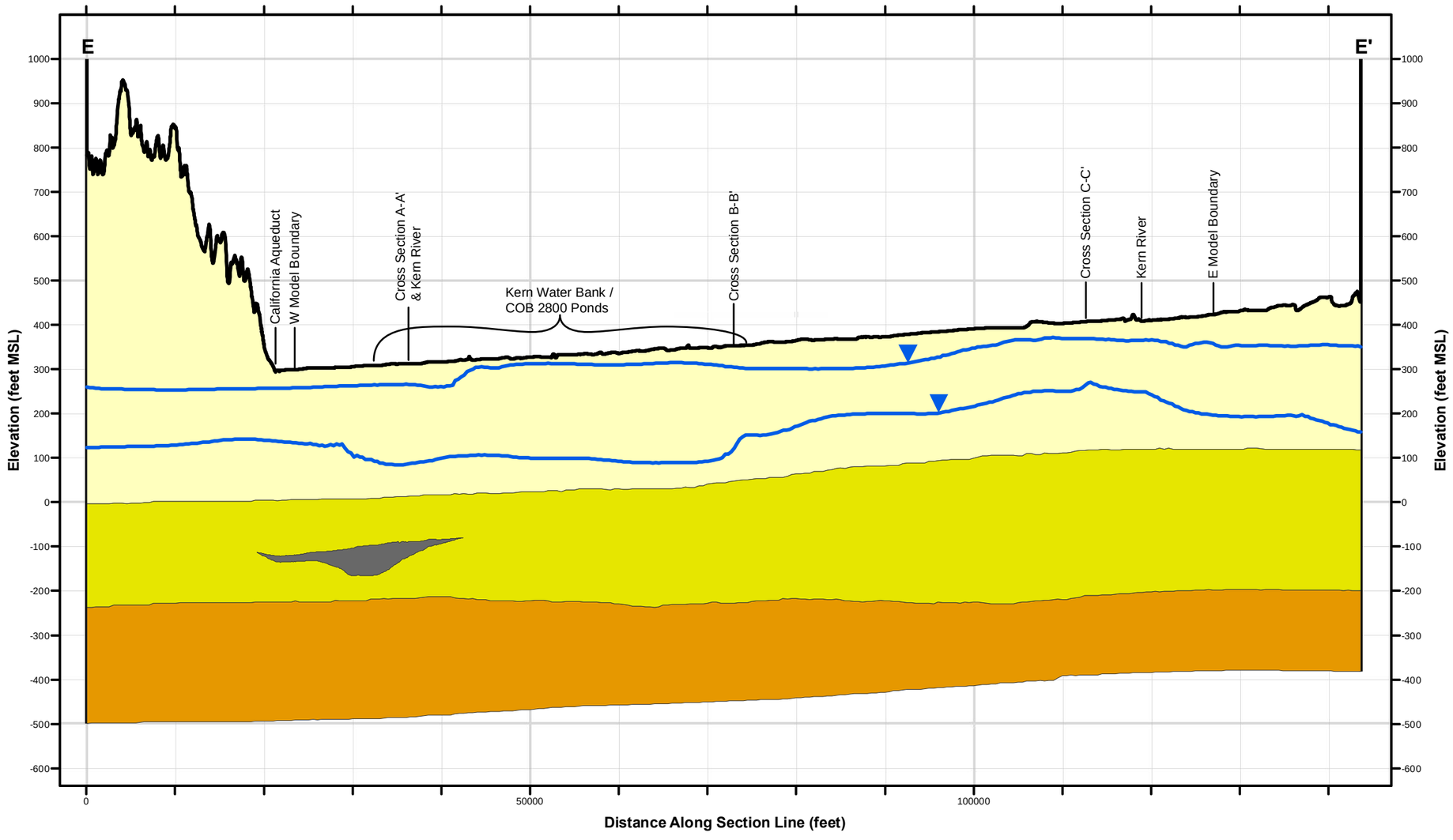
- Model Layer 1
- Model Layer 2
- Model Layer 3
- E Clay (from Page 1986)

50 x Vertical Exaggeration

September 2012

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Alameda, California

Figure 3-8
Hydrogeologic Cross Section D - D'



Legend

Range of Historical Groundwater Elevations (from KCWA)

Hydrogeologic Unit

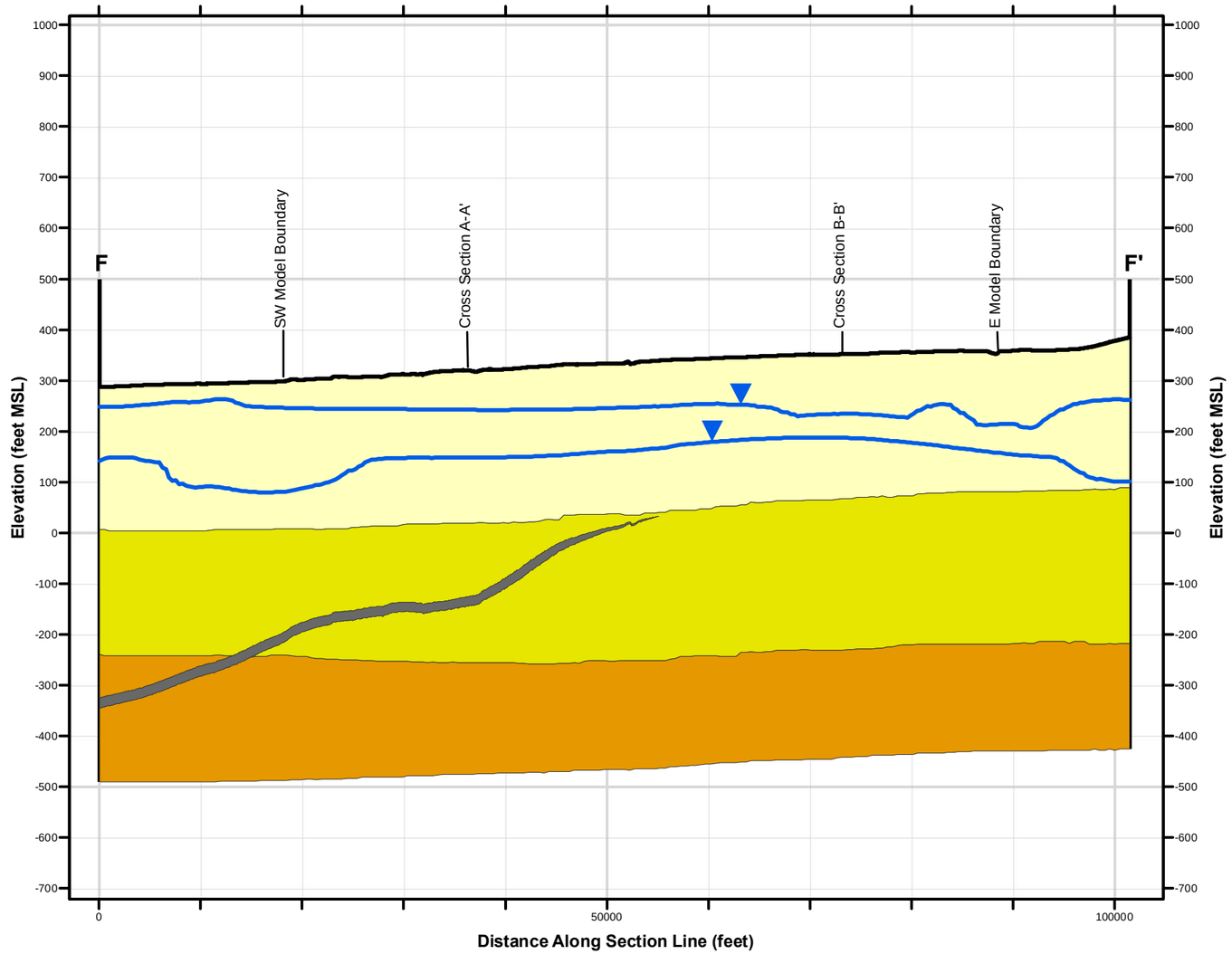
- Model Layer 1
- Model Layer 2
- Model Layer 3
- E Clay (from Page 1986)

50 x Vertical Exaggeration

September 2012

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Alameda, California

Figure 3-9
Hydrogeologic Cross Section E - E'



Legend

Range of Historical Groundwater Elevations (from KCWA)

Hydrogeologic Unit

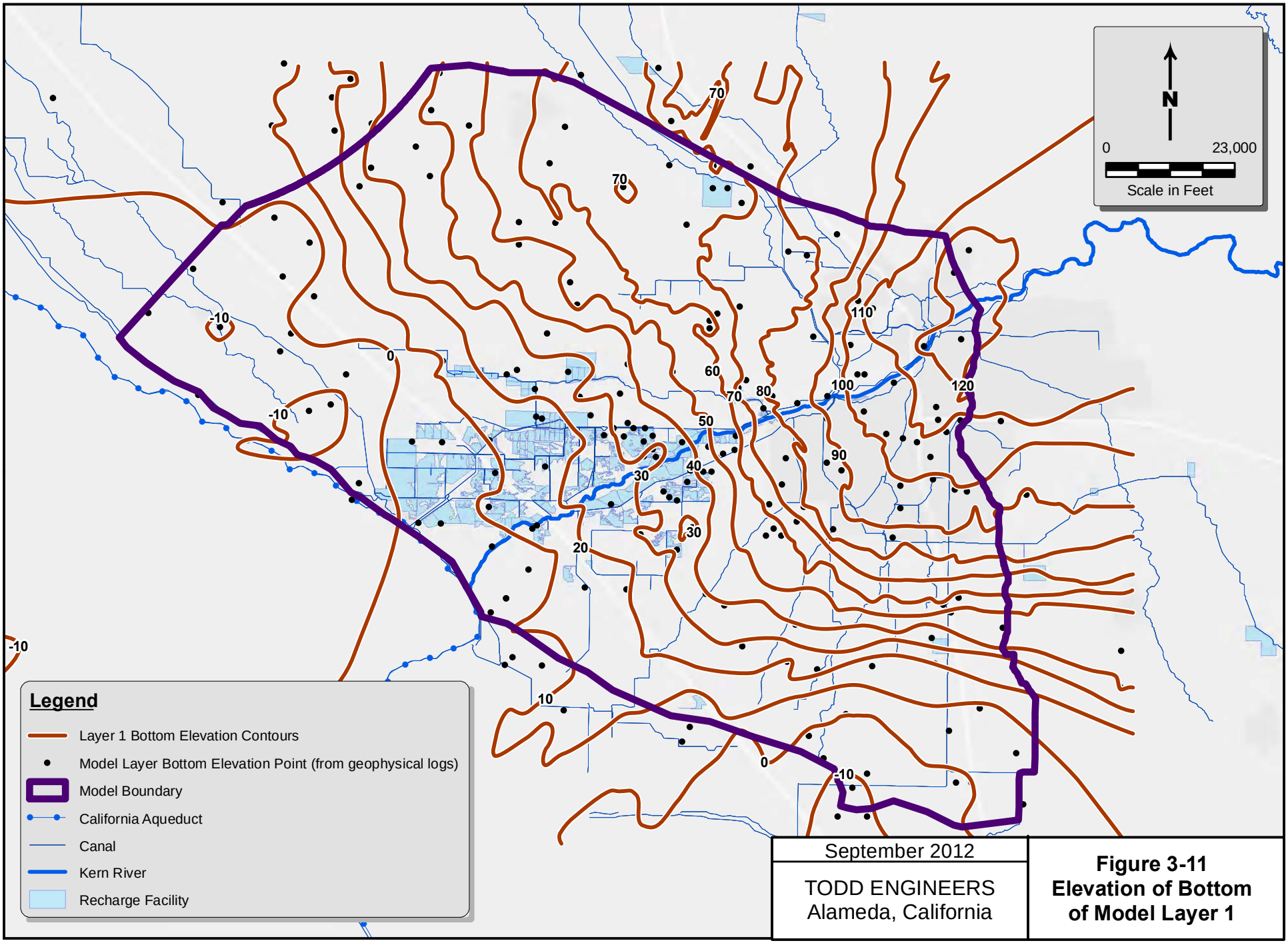
- Model Layer 1
- Model Layer 2
- Model Layer 3
- E Clay (from Page 1986)

50 x Vertical Exaggeration

September 2012

TODD ENGINEERS
Alameda, California

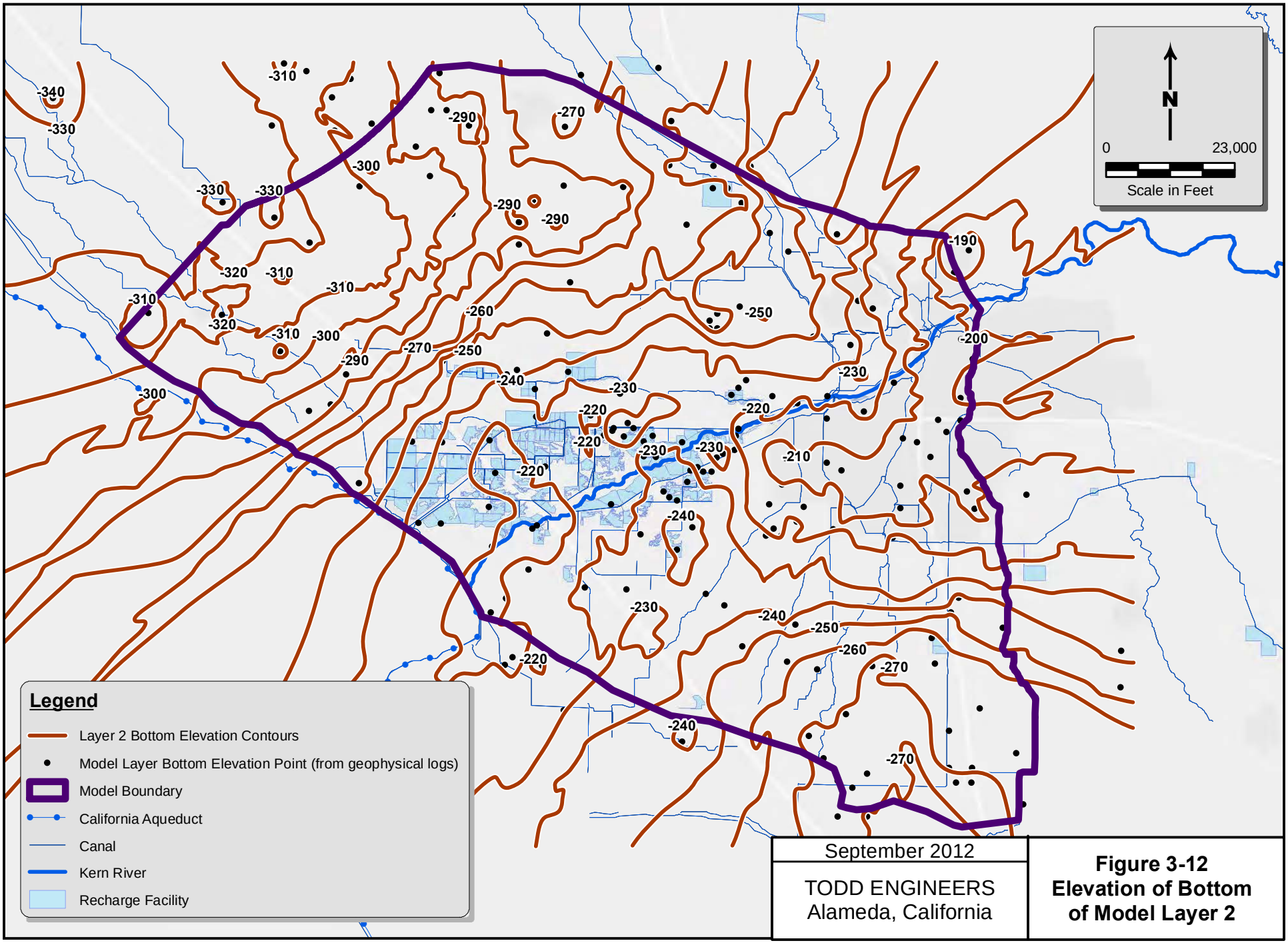
Figure 3-10
Hydrogeologic Cross Section F - F'

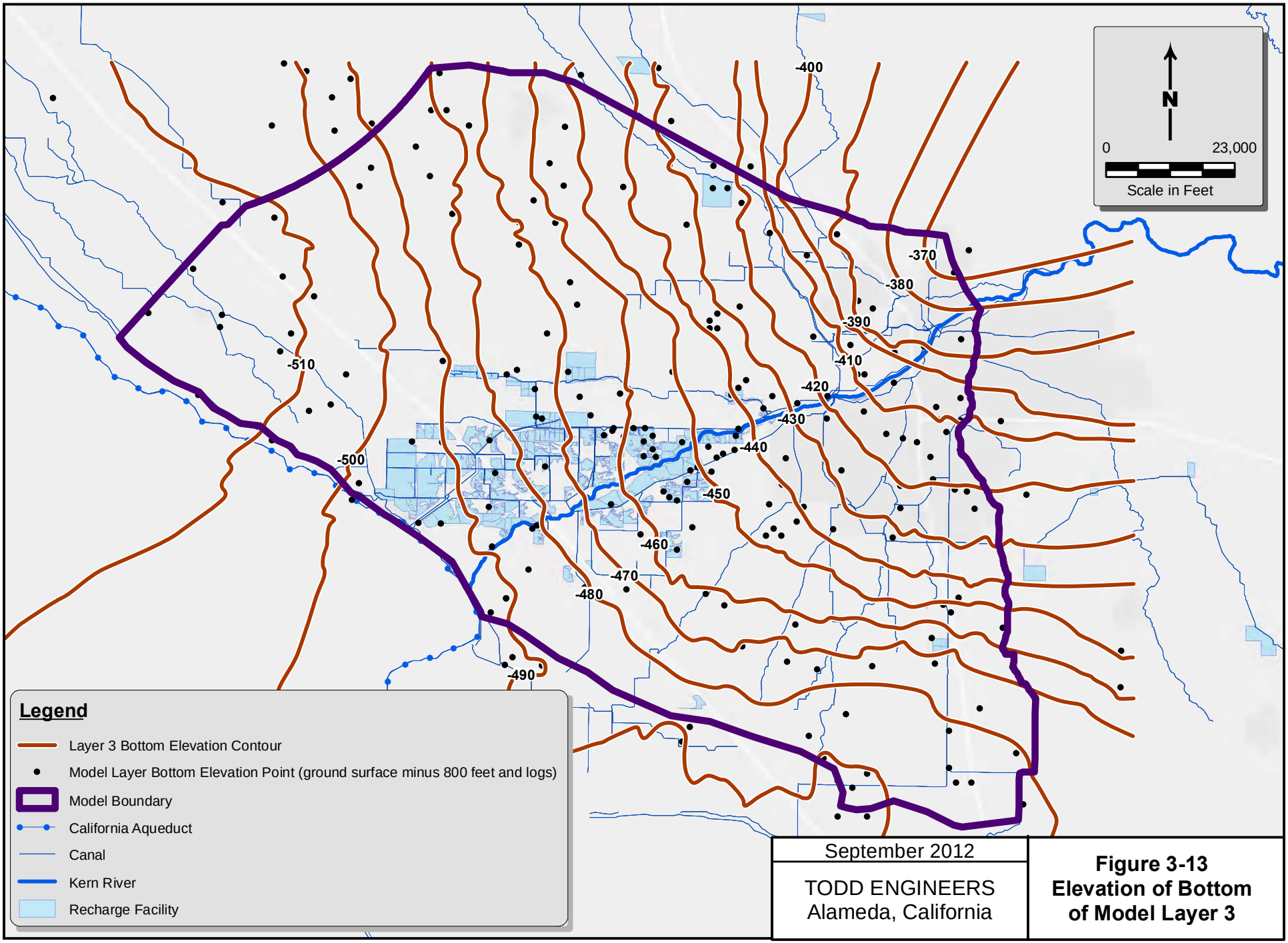


September 2012

TODD ENGINEERS
Alameda, California

Figure 3-11
Elevation of Bottom of Model Layer 1

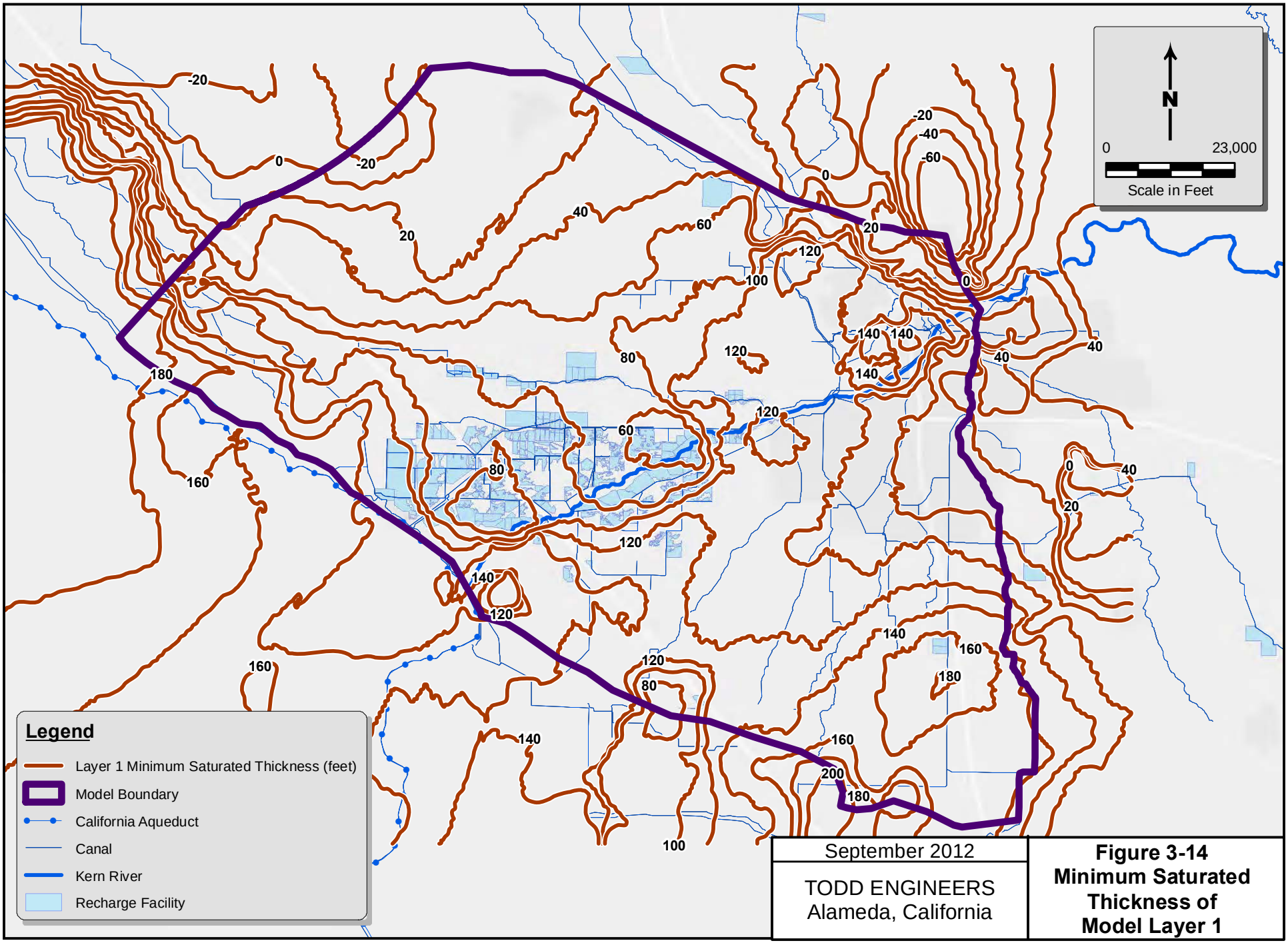

N
0
23,000
Scale in Feet
-340
-330
-310
-290
-270
-300
-330
-330
-290
-290
-320
-310
-310
-310
-260
-320
-310
-300
-270
-250
-290
-240
-230
-300
-220
-220
-220
-230
-230
-220
-240
-230
-240
-250
-260
-270
-240
-270
-190
-250
-200
-230
-220
-210
Legend
Layer 2 Bottom Elevation Contours
Model Layer Bottom Elevation Point (from geophysical logs)
Model Boundary
California Aqueduct
Canal
Kern River
Recharge Facility
September 2012
TODD ENGINEERS
Alameda, California
Figure 3-12
Elevation of Bottom
of Model Layer 2



September 2012

TODD ENGINEERS
Alameda, California

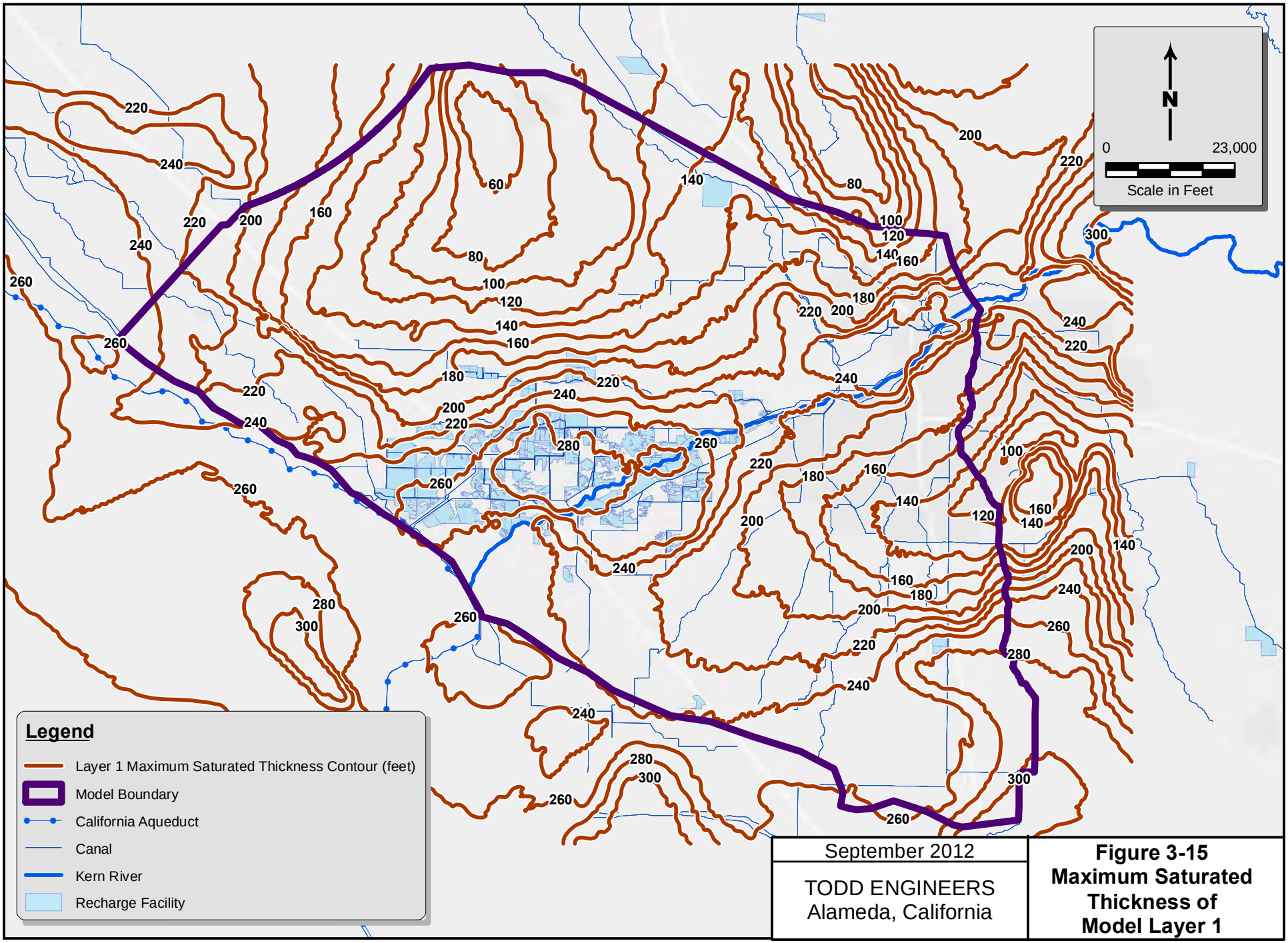
Figure 3-13
Elevation of Bottom of Model Layer 3

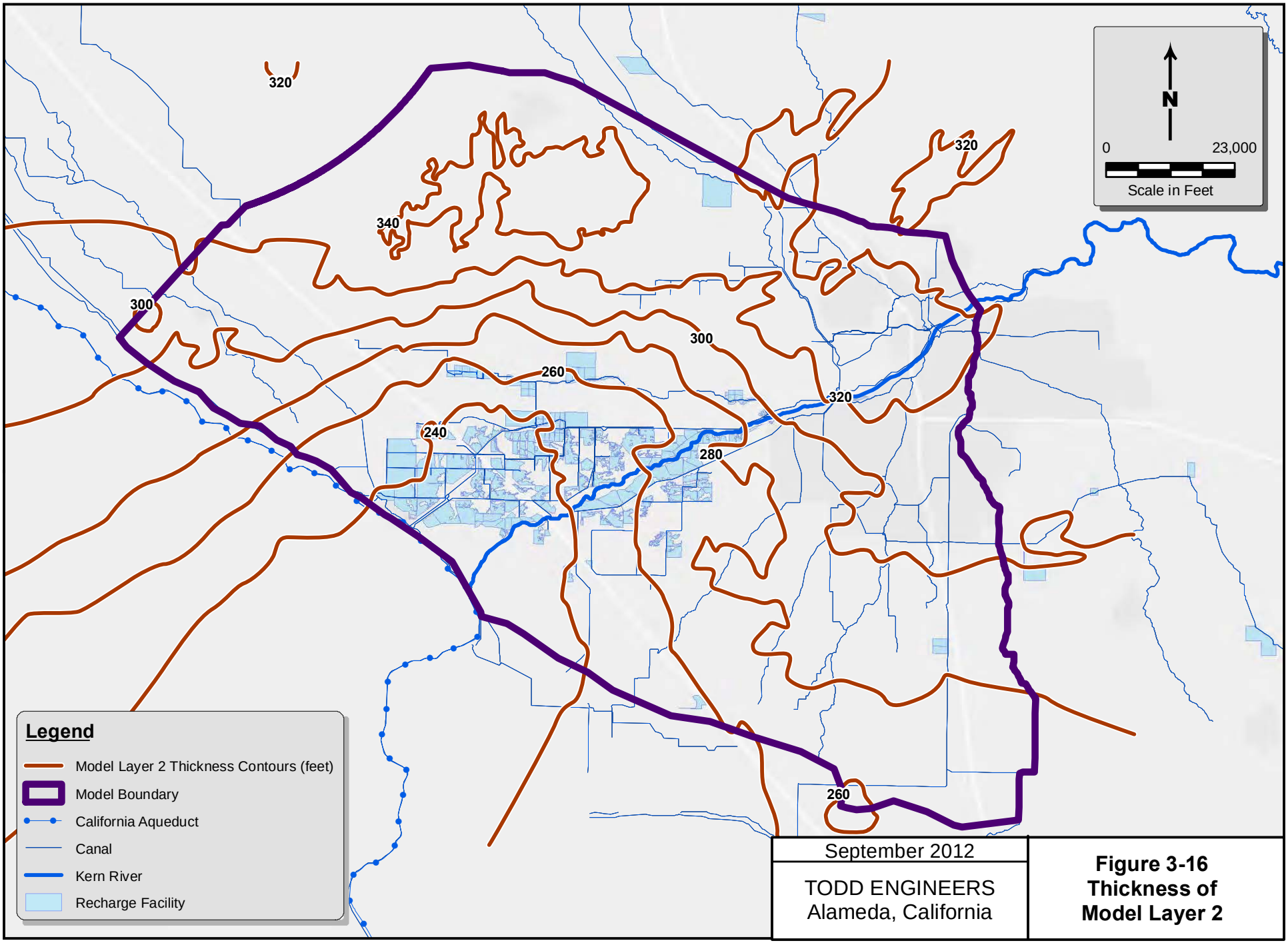


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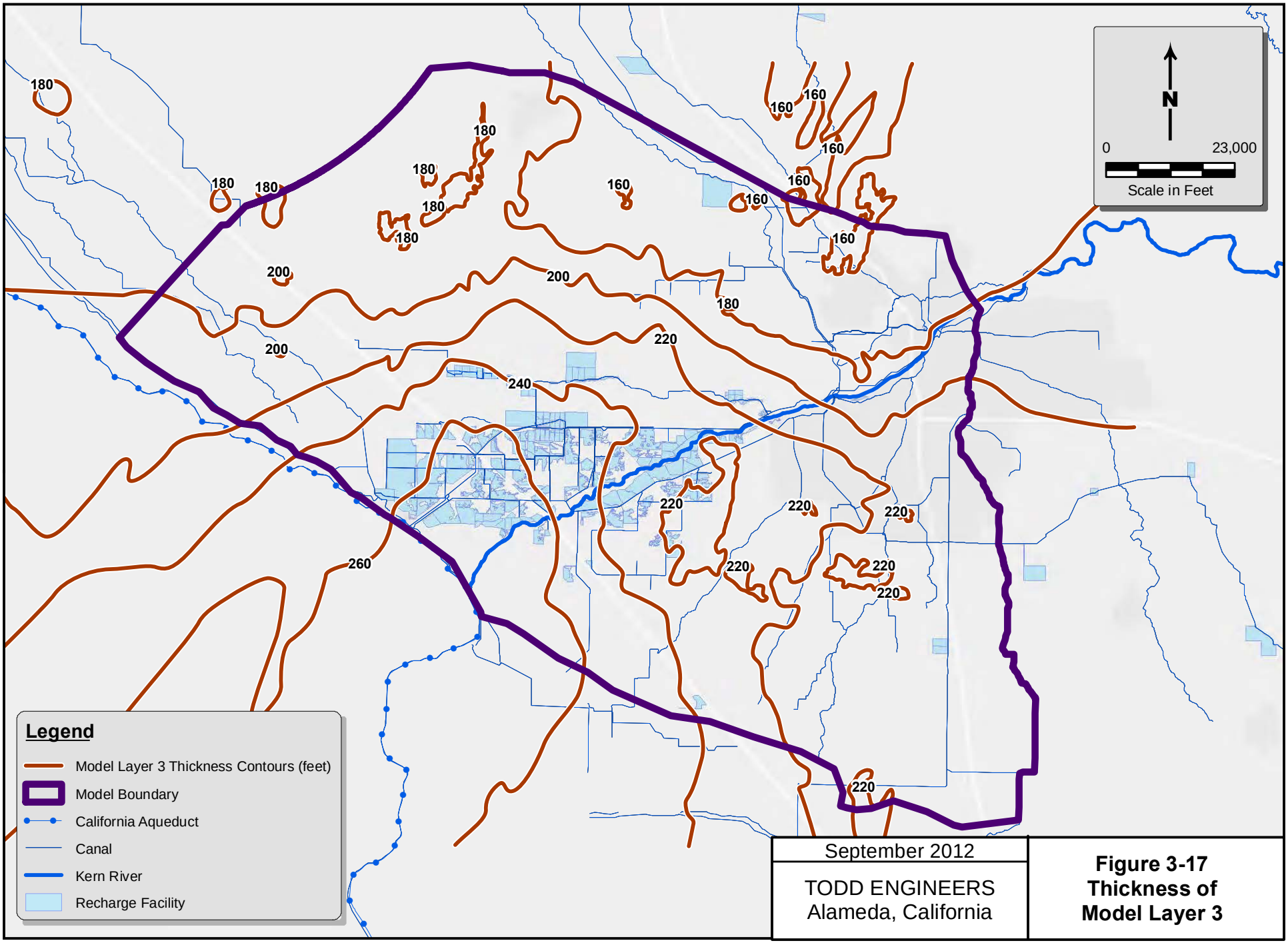

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23,000
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Layer 1 Maximum Saturated Thickness Contour (feet)
Model Boundary
California Aqueduct
Canal
Kern River
Recharge Facility
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Figure 3-15
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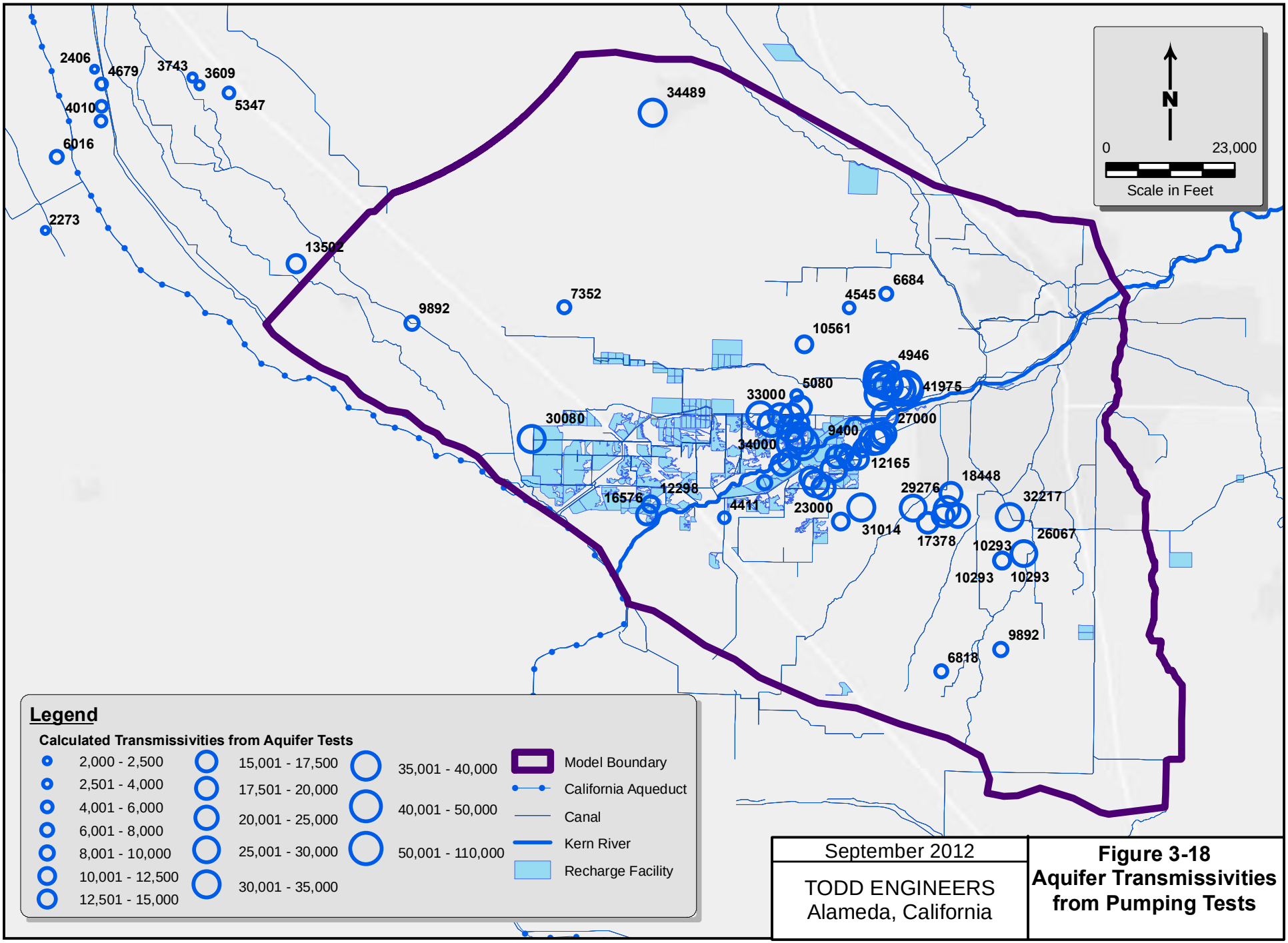


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Figure 3-16
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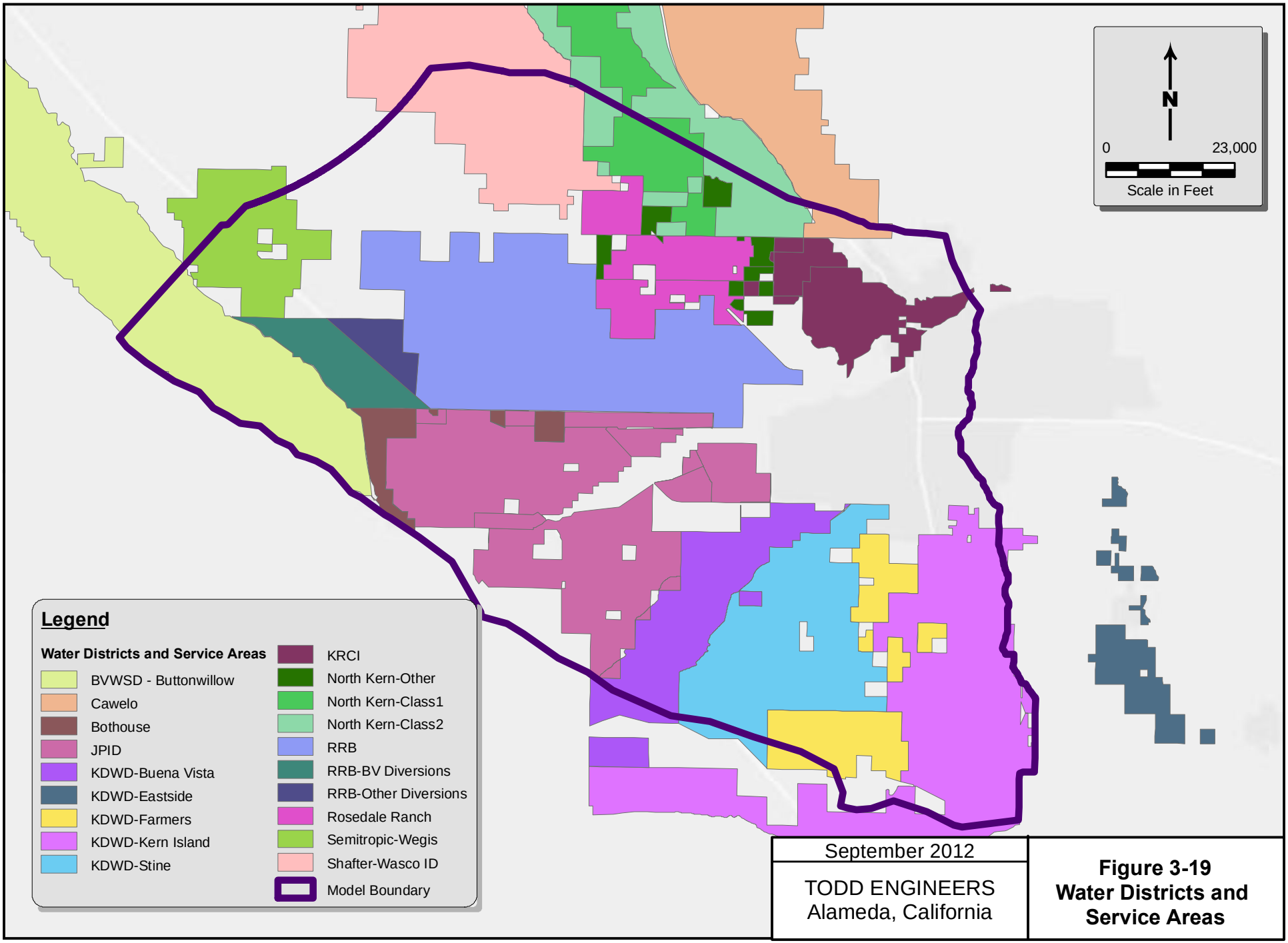

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0
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Scale in Feet
180
160
200
220
240
260
Legend
Model Layer 3 Thickness Contours (feet)
Model Boundary
California Aqueduct
Canal
Kern River
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Thickness of
Model Layer 3



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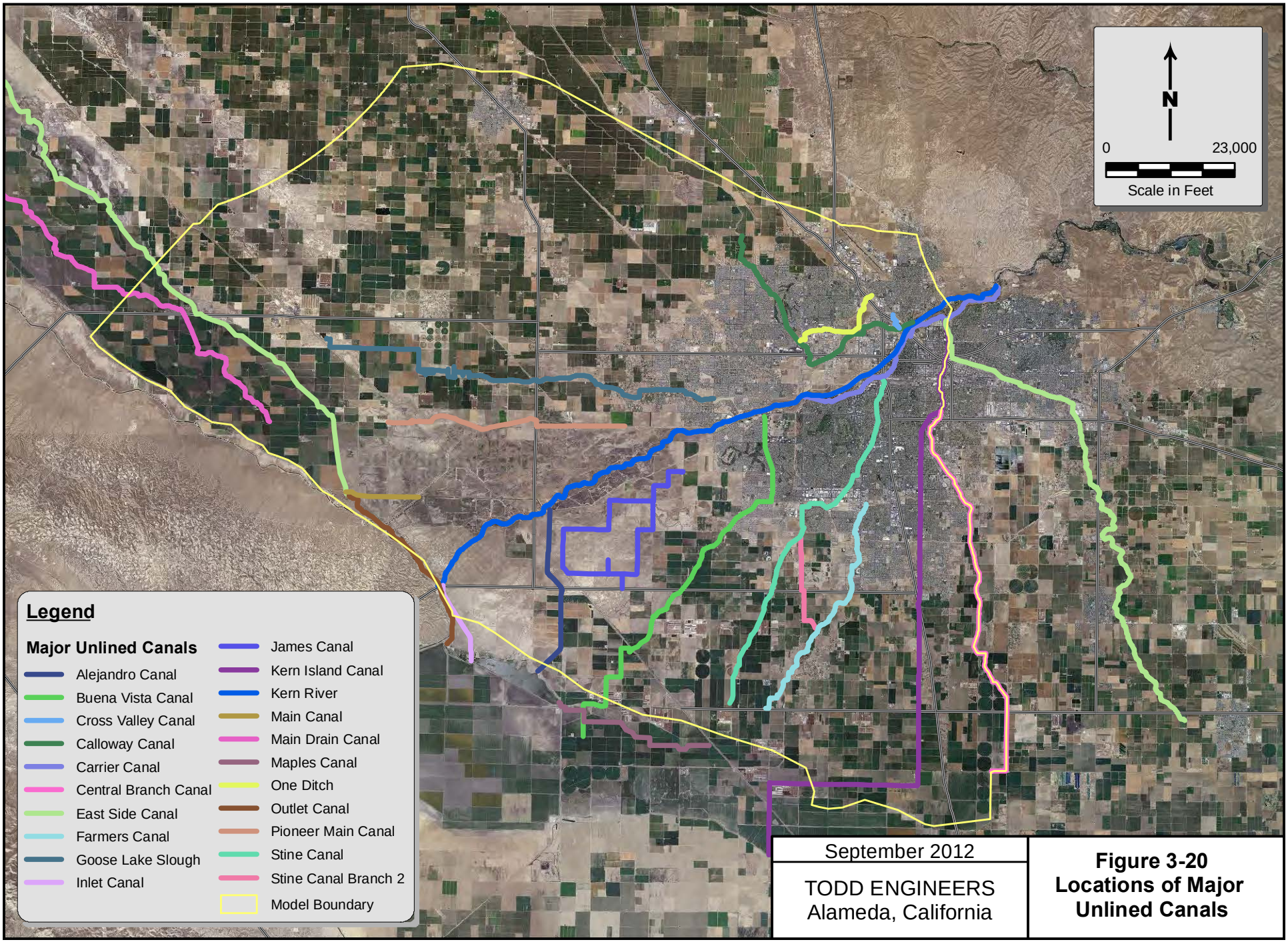
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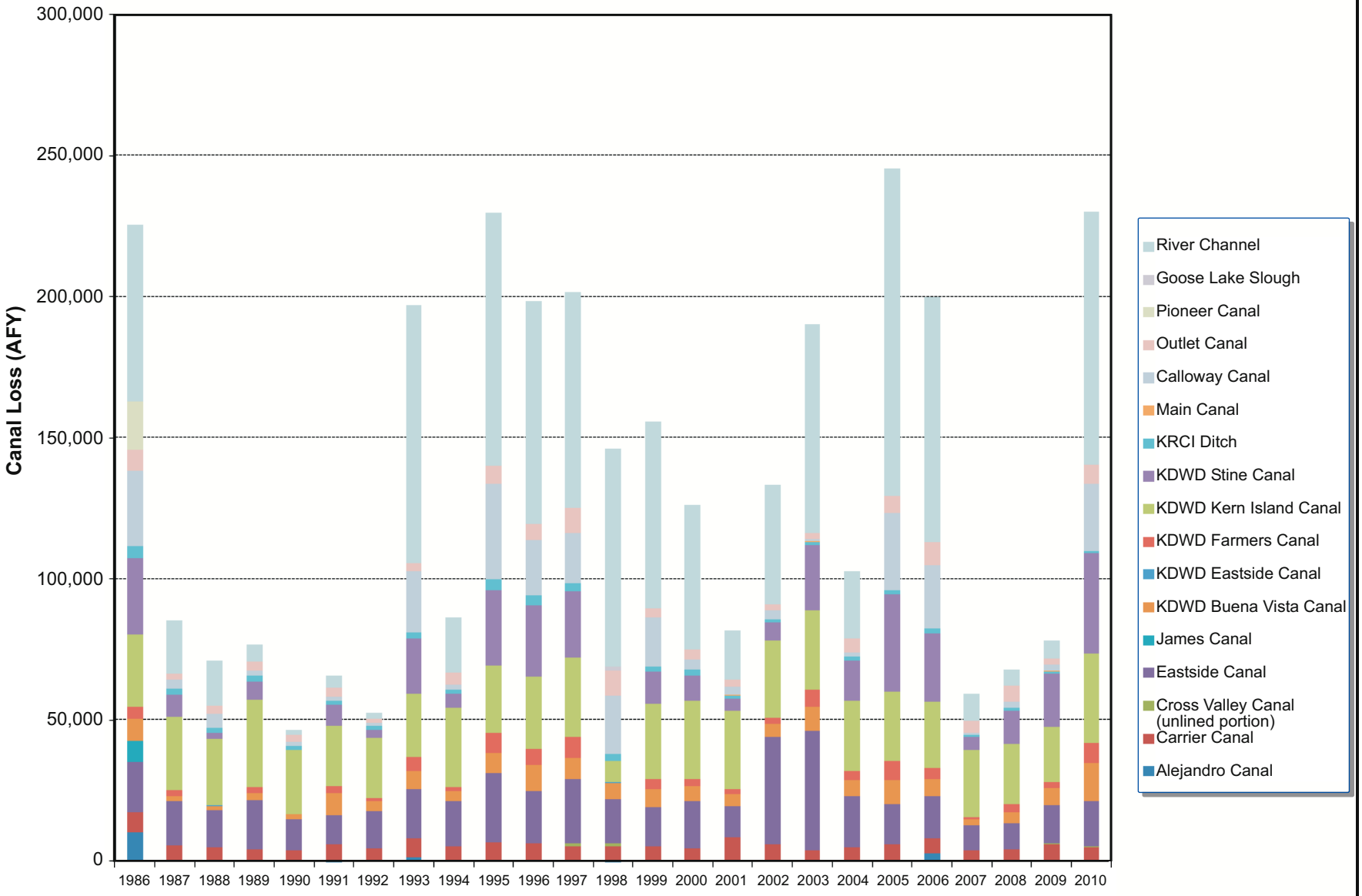
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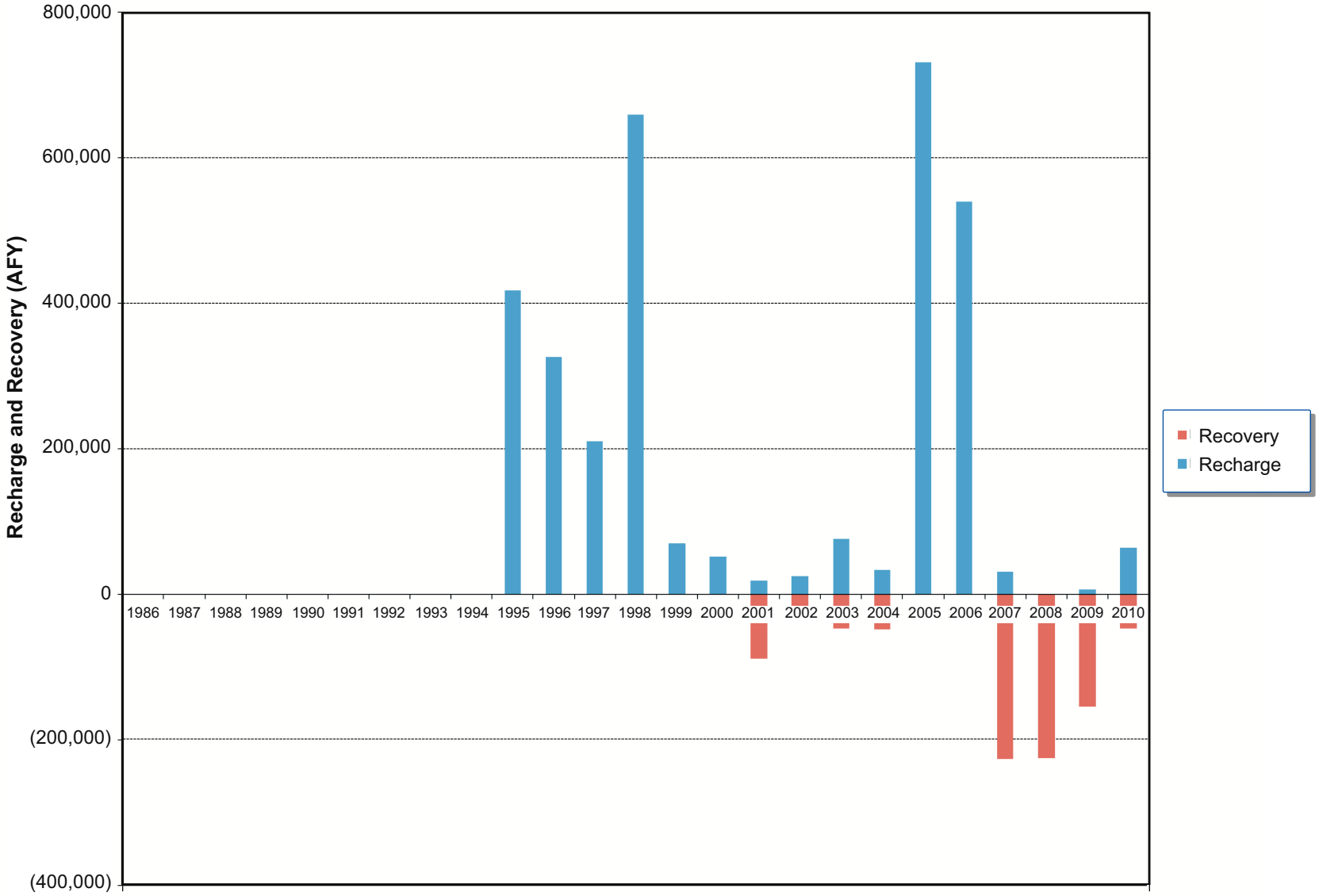
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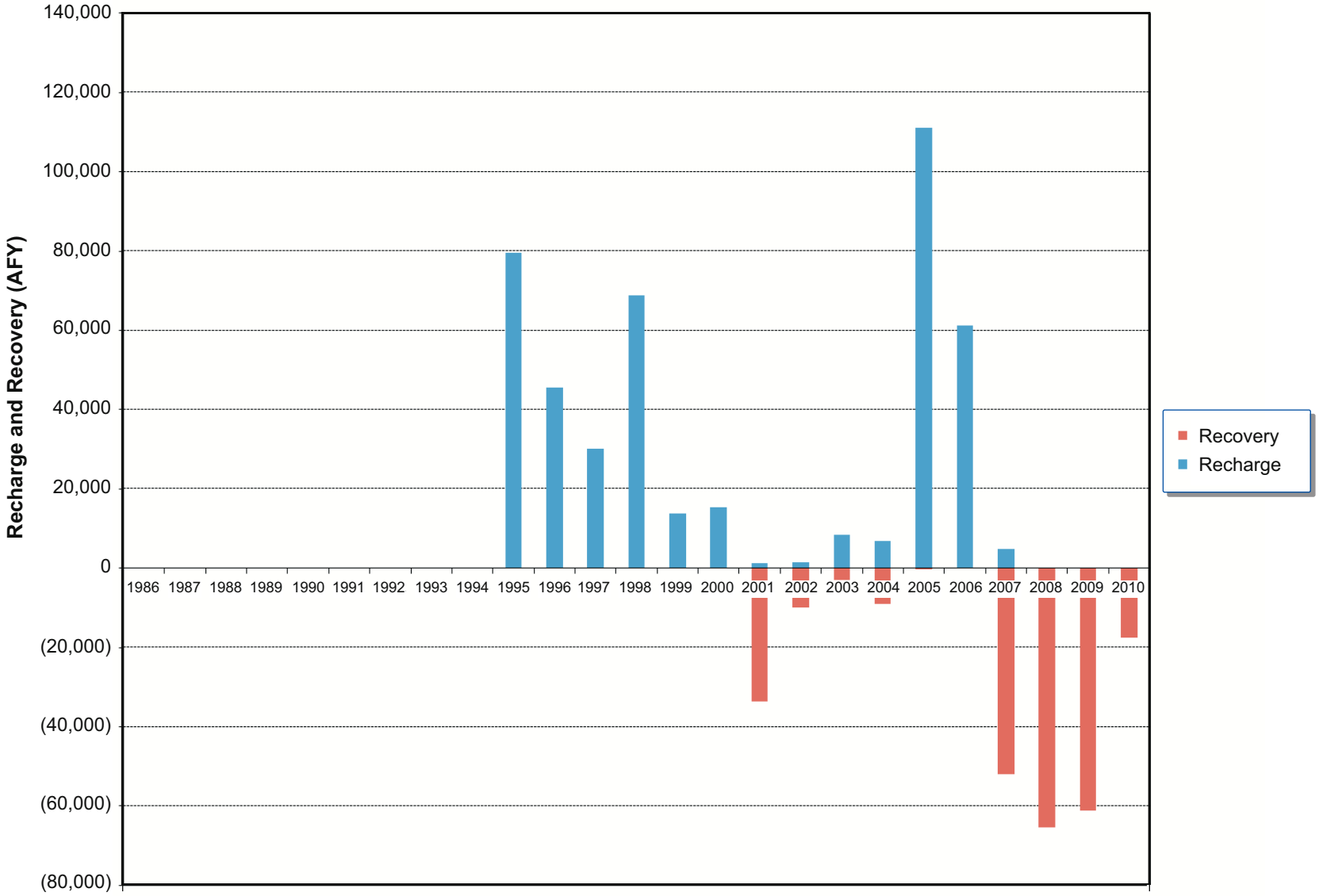
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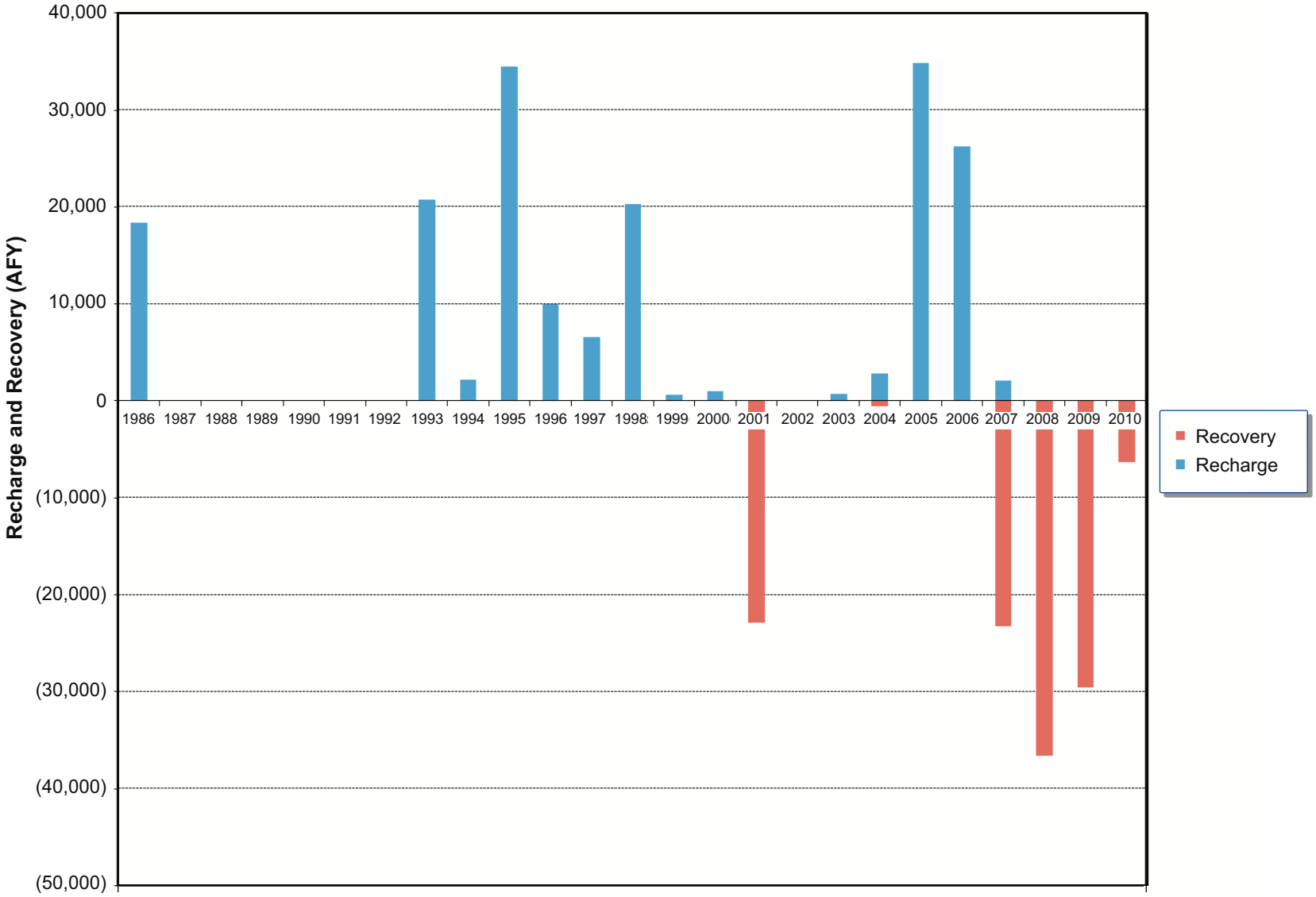
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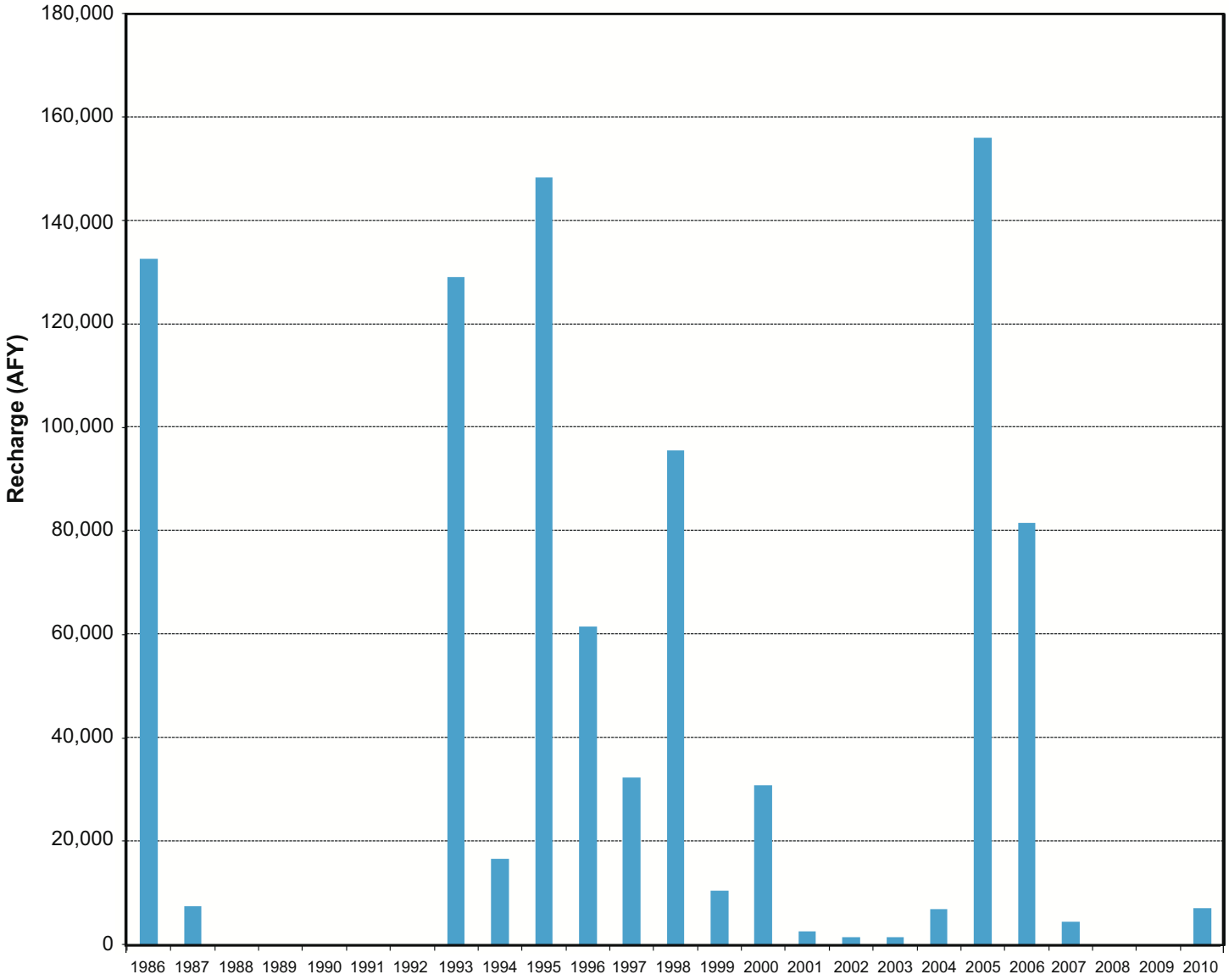
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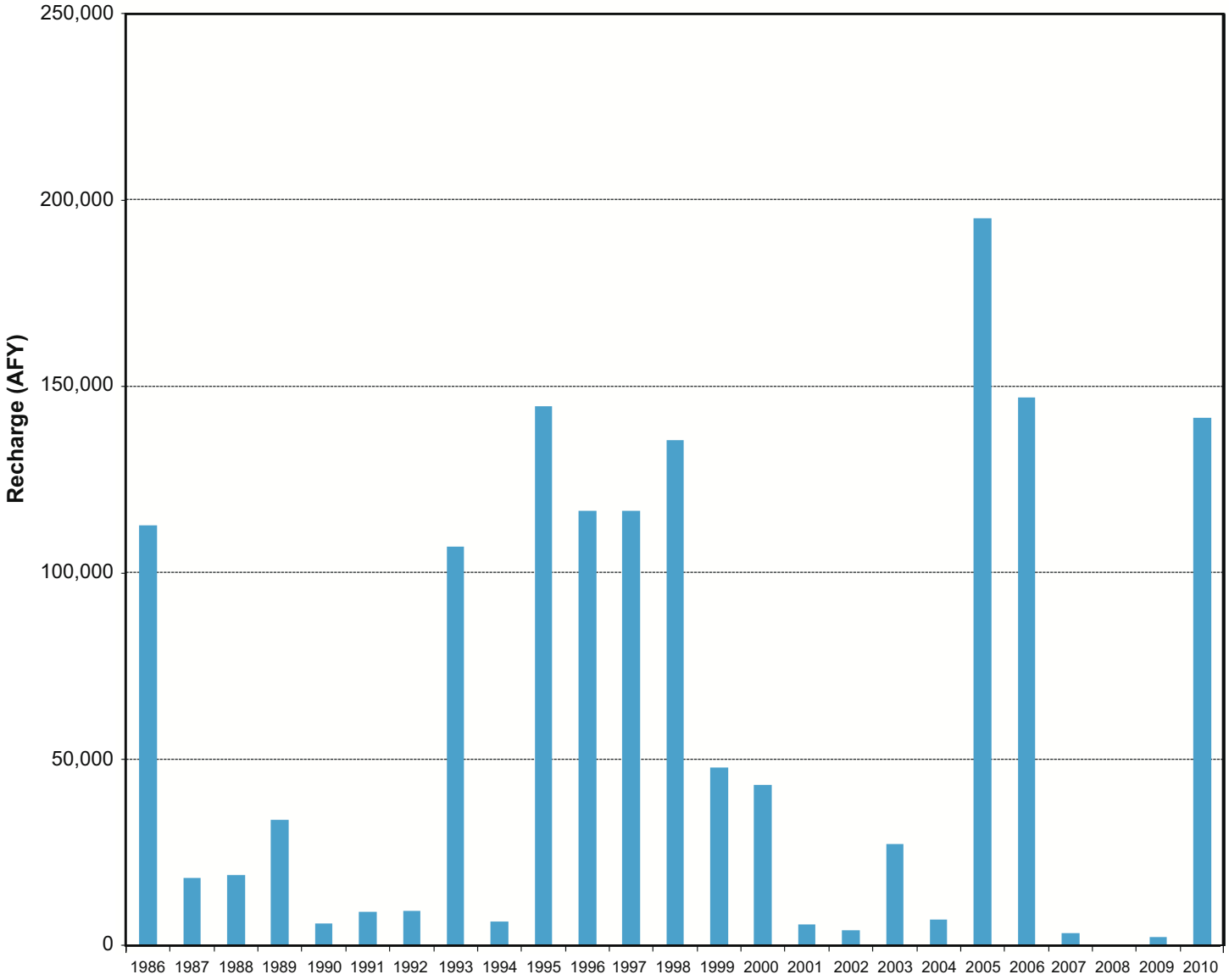
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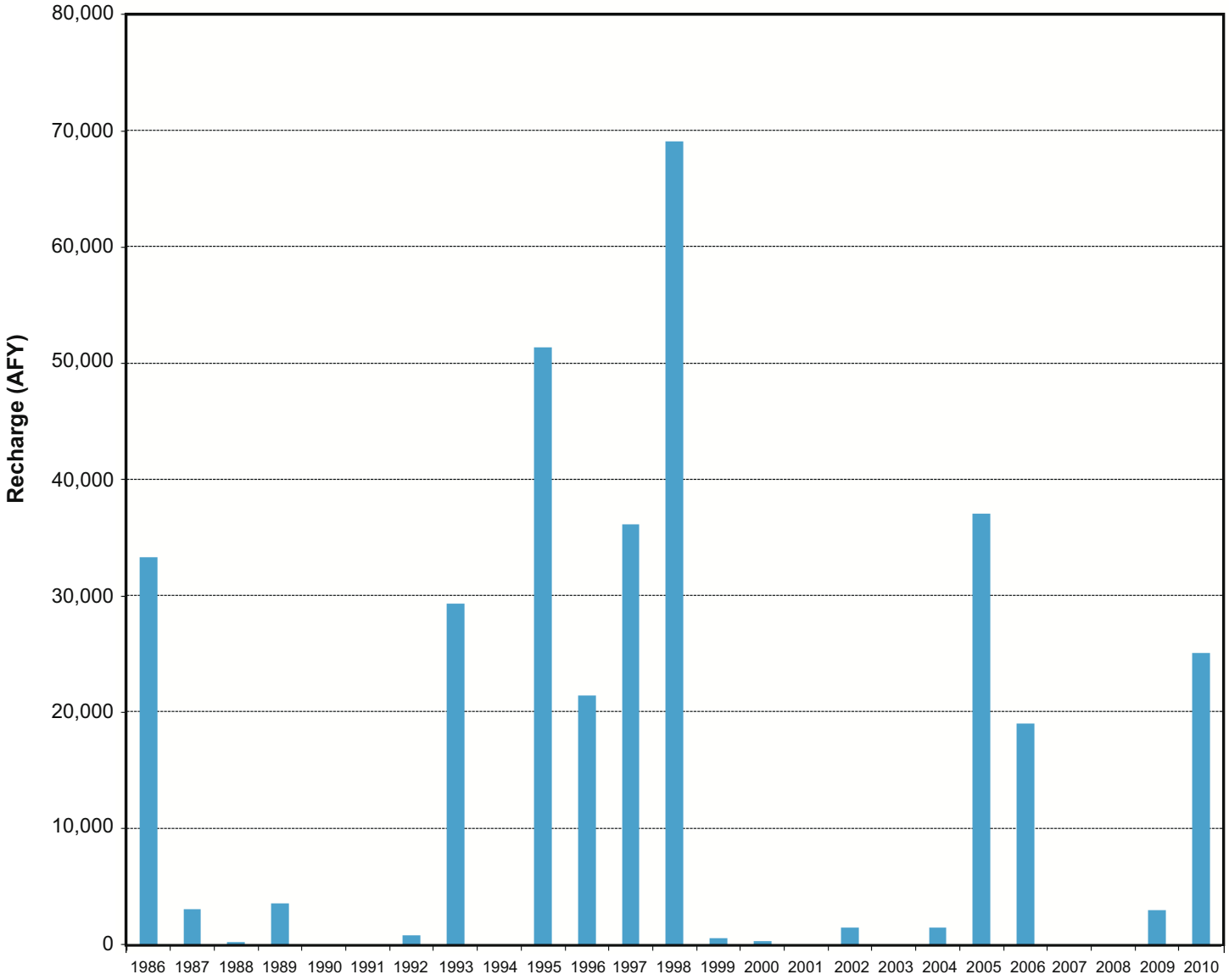
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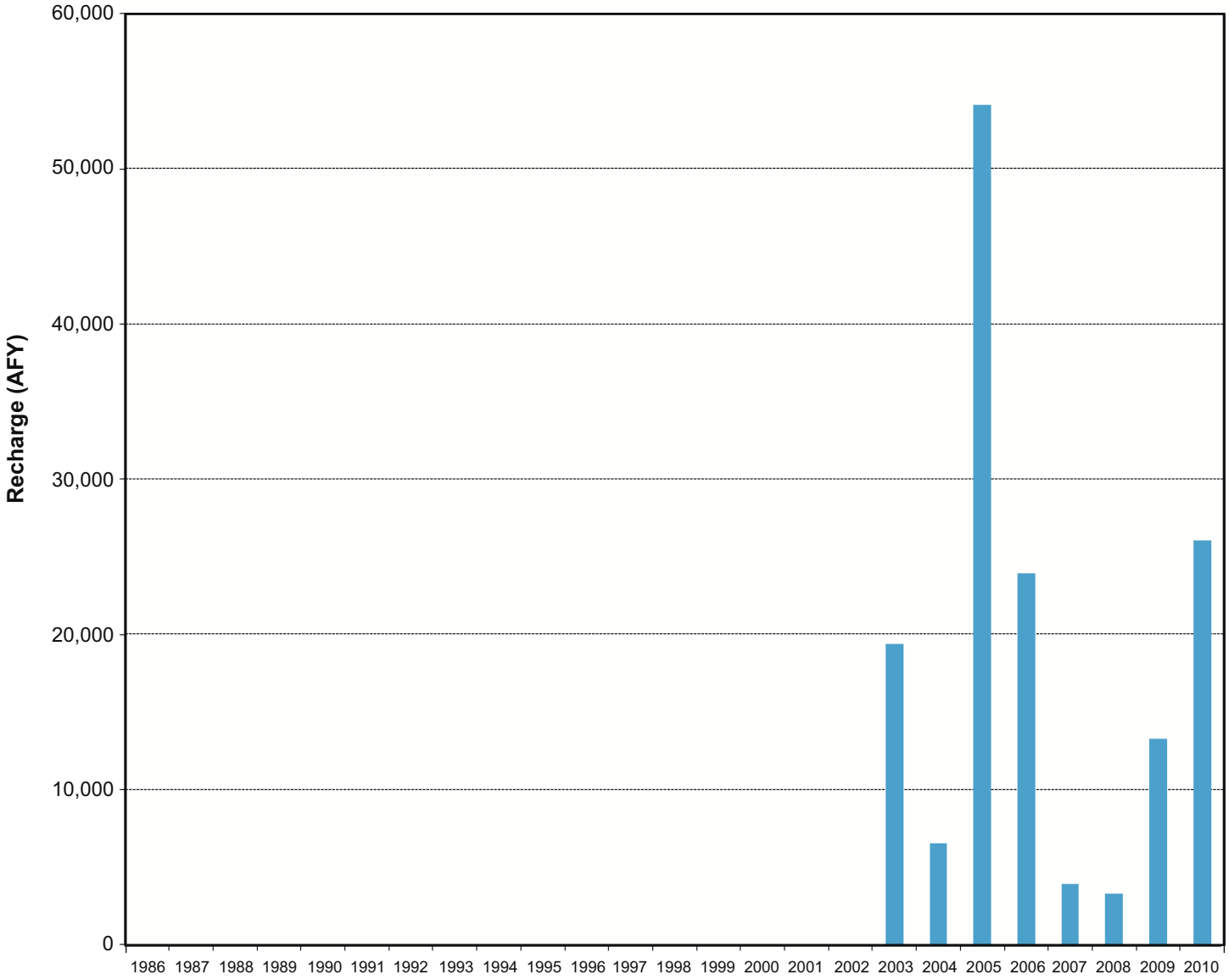
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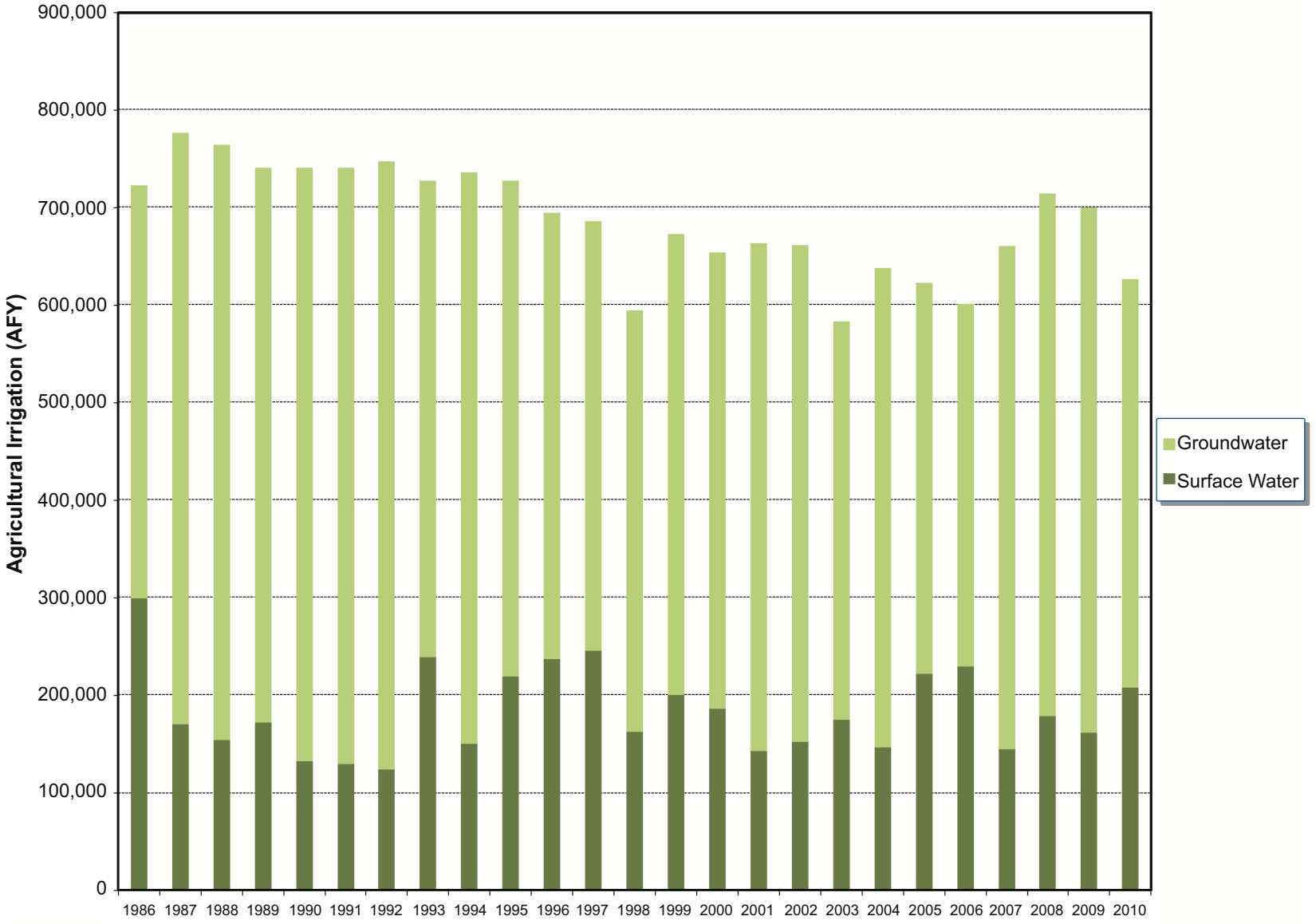
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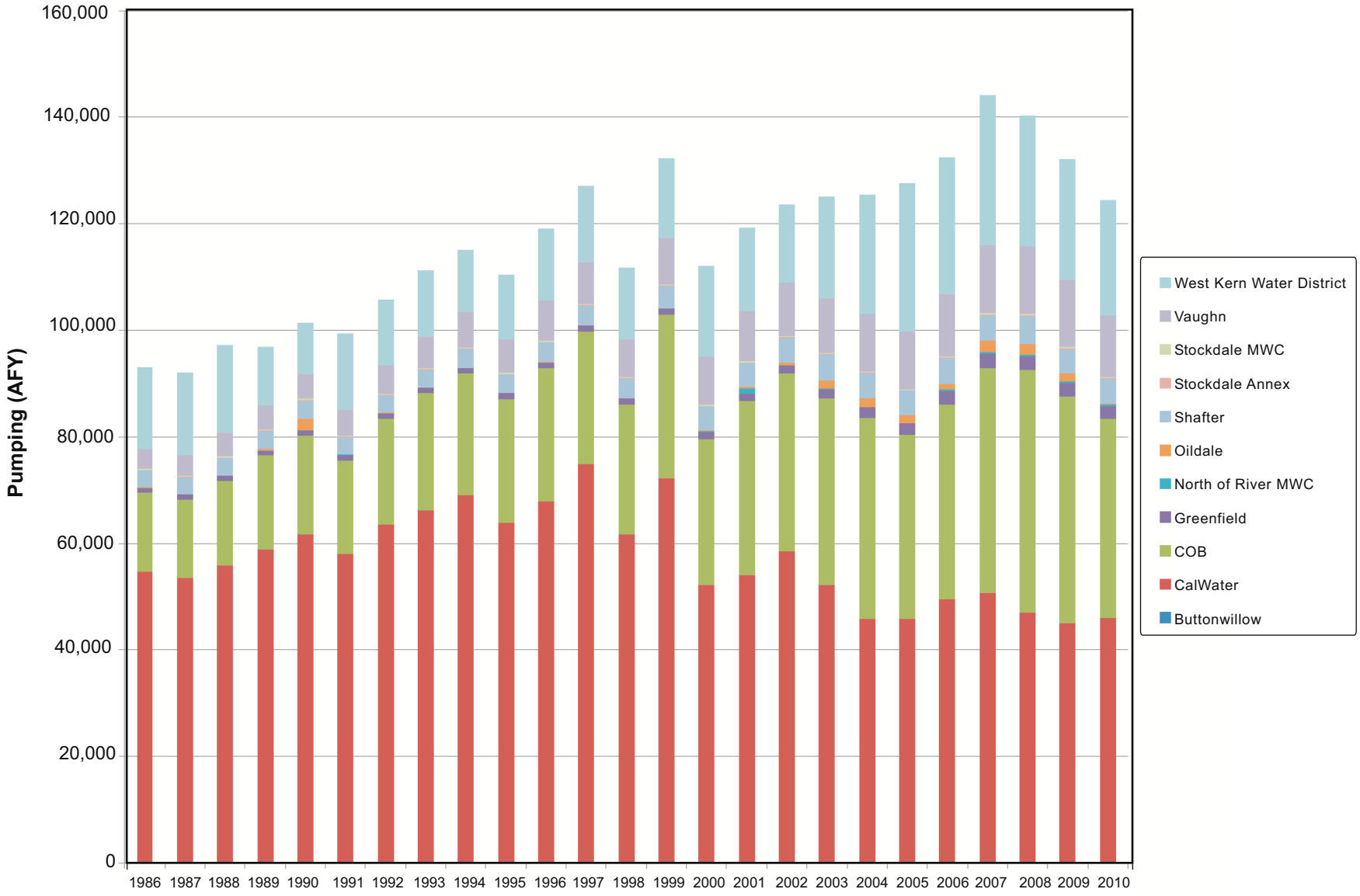
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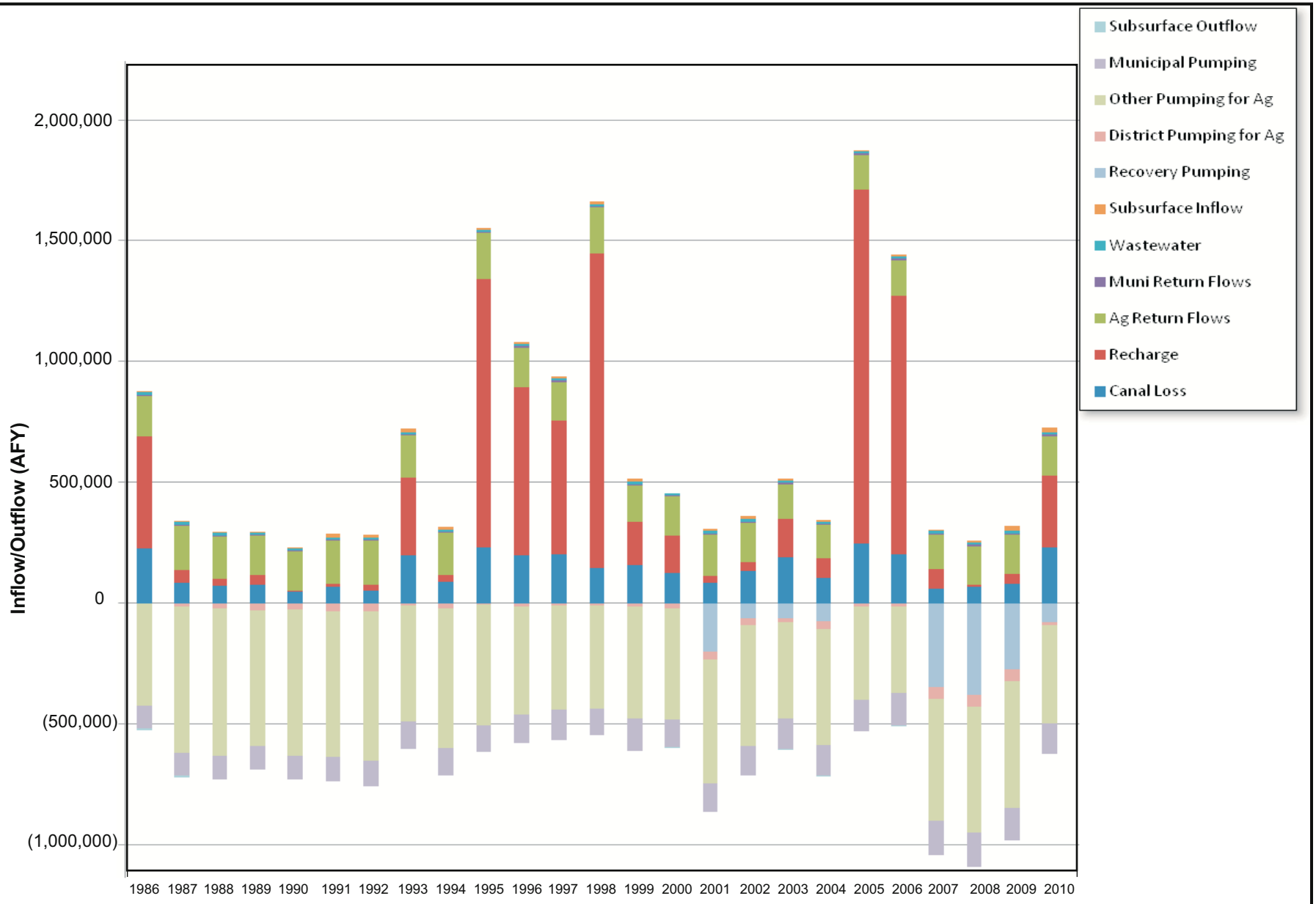
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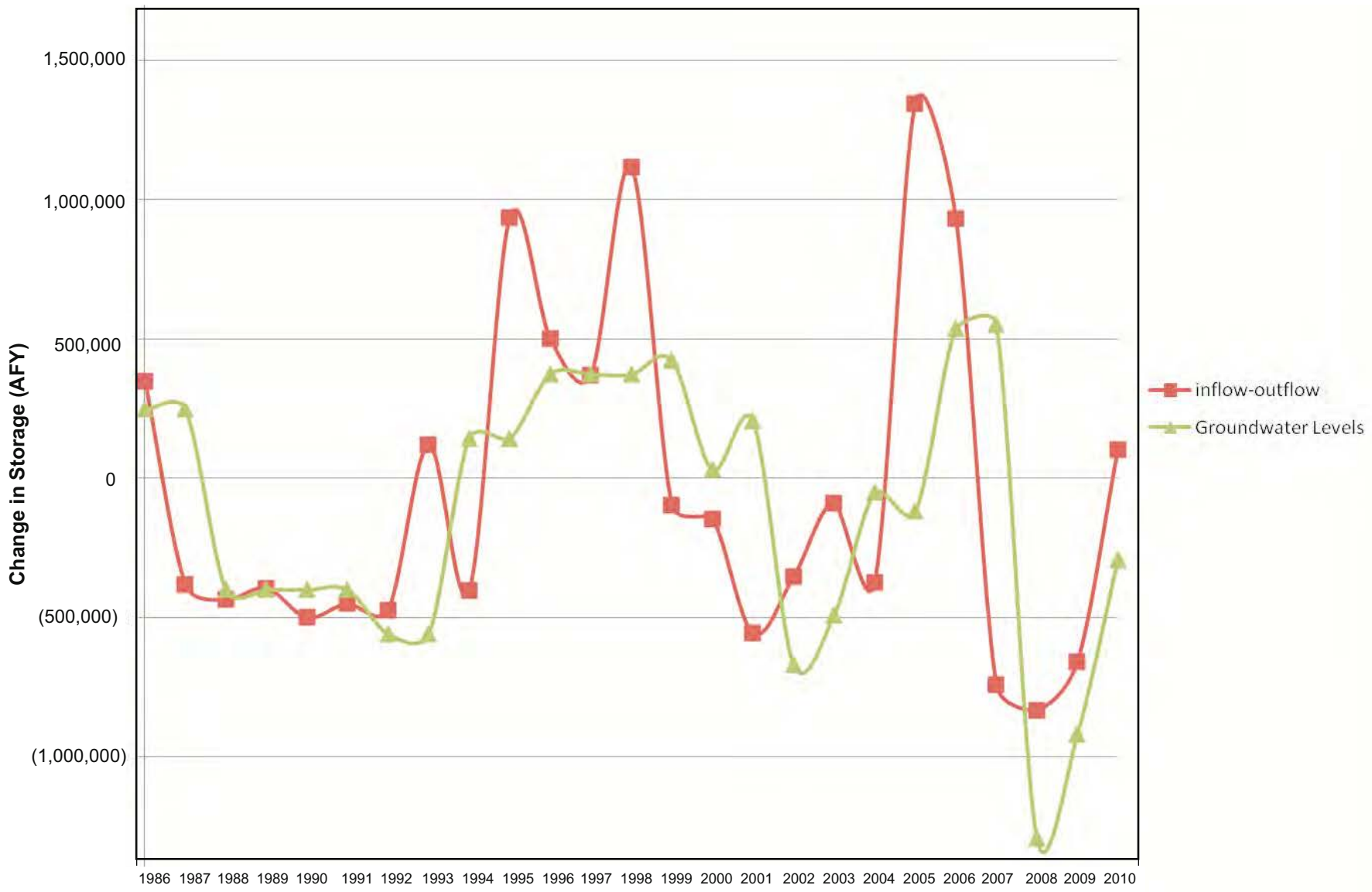
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Water Supply Report: 2011

James M. Beck
General Manager



The data presented in the Water Supply Report are derived from multiple sources, are the best available at the time of publication and are subject to change. The analyses presented are in the interpretations of Kern County Water Agency staff and are not intended to support, refute or replace any analyses by other parties. All supporting data and calculations used to prepare this report are available for public review at the Kern County Water Agency.

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Glossary

Acre-foot (af) - The quantity of water required to cover one acre of land to a depth of one foot (325,851 gallons). This amount of water is normally used by a family of four during a one-year period for residential use.

Aquifer - Geologic formations or parts of formations containing sufficient saturated permeable material able to yield sufficient quantities of water.

California Department of Water Resources (DWR) – Manages the water resources for California, including the State Water Project, in cooperation with other agencies across the state.

Central Valley Project (CVP) - Federally sponsored water transportation and storage project in California. The Friant-Kern Canal is its major water transportation feature in Kern County.

Change in Groundwater Storage - The change in volume of water retained by subsurface aquifers within the groundwater basin. A negative change reflects the fact that extractions have exceeded recharge.

Confined Aquifer - A groundwater-bearing stratum constrained at its upper surface by an impervious unit, such as a regional layer of clay.

Consumptive Use - Water put to beneficial use and retained within the groundwater basin (i.e., any water that is not lost or removed from the groundwater basin) is consumptively used.

Corcoran Clay - A thick, impermeable layer of clay which lies under much of the San Joaquin Valley, separating the groundwater basin into the "unconfined" aquifer above the Corcoran Clay and the "confined" aquifer beneath the Corcoran Clay.

Cross Valley Canal (CVC) - A 22-mile canal connecting the California Aqueduct with the City of Bakersfield.

Cubic Feet per Second (cfs) - Cubic feet per second, a rate of flow.

1 cfs = 449 gallons per minute
1 cfs = 646,320 gallons per day
1 cfs = 1.983 af per day

Electrical Conductance (EC) - A measure of the ability of water to conduct an electrical current, which can be related to the concentration of total dissolved solids. The normal unit of measurement is micromhos per centimeter.

First Point of Measurement - Measuring point for distribution of Kern River water. Located immediately downstream of Hart Park, east of Bakersfield.

Gallons per Capita per Day (gpcd) - The volume of water (in gallons) used per person per day.

Groundwater Basin - An area underlain by one or more permeable formations (aquifers) capable of furnishing a substantial and beneficial water supply.

Groundwater Recharge - Any act of nature or man which replenishes or adds water to the supply stored within the natural subsurface aquifer system.

Groundwater Recovery - The recovery (pumping) of groundwater from one or more of the groundwater banking facilities in Kern County.

In-lieu Recharge - The process of recharging groundwater supplies by substituting surface water for groundwater that would otherwise be pumped.



Irrigation Efficiency - The amount of irrigation water stored within the crop root zone in relation to the total amount applied, expressed as a percent.

KCWA - Kern County Water Agency (Agency).

Overdraft - A long-term condition in which groundwater recovery of a basin exceeds groundwater recharge in that basin.

Sacramento River Index (SRI) - An index used by the California Department of Water Resources to forecast available water supplies and State Water Project delivery capabilities. The index consists of the forecasted or computed unimpaired flows of the Sacramento River near Red Bluff, Feather River at Oroville Reservoir, Yuba River at Smartville and American River at Folsom Reservoir.

Sacramento-San Joaquin Delta (Delta) - A tidally influenced estuary located east of the upper lobe of the San Francisco Bay. The Sacramento-San Joaquin Delta is the largest estuary on the west coast of the United States.

State Water Contractors - Public agencies that have long-term contracts with the California Department of Water Resources for State Water Project water.

State Water Project (SWP) - A state-sponsored water transportation and storage project. In Kern County, its major feature is the Edmund G. Brown California Aqueduct.

Table A Water - The amount of State Water Project water available under Table A of the Kern County Water Agency's Master Contract with the California Department of Water Resources.

Total Dissolved Solids (TDS) - A measurement of the dissolved solids in water, consisting mainly of inorganic salts and small amounts of organic matter and gases. Usually measured in parts per million (ppm).

Unconfined Aquifer - A groundwater-bearing stratum that is not constrained at its upper surface by an impervious or semi-impervious unit, such as a regional clay.

U.S. Bureau of Reclamation (USBR) - A branch of the U.S. Department of the Interior responsible for the construction and management of numerous water supply facilities across the United States, including the Central Valley Project in California.

Water Year - The period from October 1 of one year to September 30 of the following year.



Introduction

The Kern County Water Agency (Agency) was created by an act of the California Legislature in July 1961 and ratified by the electorate of Kern County in September 1961. The Agency was granted the authority to acquire and contract for water supplies for the San Joaquin Valley portion of Kern County, with additional powers to control flood and storm waters, drain and reclaim land, store and reclaim water, protect the quality of groundwater and conduct investigations relative to water resources. The primary focus of the Agency, working with other water entities, is to coordinate management of the water supplies of the San Joaquin Valley portion of Kern County, with particular emphasis on State Water Project (SWP) supplies, in order to enhance the local economy. Local water districts with which the Agency has long-term contracts to provide a water supply are referred to as Member Units (Table 1).

Since its formation in 1961, the Agency has collected information on the water supply and demand characteristics of the San Joaquin Valley portion of Kern County. Since 1977, the Agency has published an annual Water Supply Report to present these statistics in one document and to assist water leaders and users in making water management decisions.

The Water Supply Report attempts to identify and quantify the interrelationships of the hydrologic cycle (Figure 1) with human activities in the San Joaquin Valley portion of Kern County. For instance, the planting and harvesting of crops has altered the natural pattern of evapotranspiration. Groundwater storage has been affected by groundwater pumping and recharge. Local surface storage facilities and contracts for imported surface supplies have lessened Kern County's dependence upon groundwater supplies. Also, various coordinated groundwater recharge and conjunctive use programs, mainly along the Kern River Fan, have supplemented local surface supplies during dry years.

The net result of the interactions between the available water supplies and the various demands for those water supplies is a change in groundwater storage and groundwater quality. The Water Supply Report documents this change and its causes. Figure 2 shows the location of the water districts and facilities discussed in the Water Supply Report.

2011

2011 was ushered in by above-average hydrology across California. As a result of a series of storms in Fall 2010, reservoirs across the state were full for the first time since 2006. The wet hydrology continued well into the spring, further bolstering water supplies for the SWP, Central Valley Project (CVP) and Kern River. Additionally, Kern County groundwater banking projects were able to continue groundwater recharge operations that began in Fall 2011. As a result, groundwater levels across the San Joaquin Valley portion of Kern County began to rebound.

Water Supplies

State Water Project

In Fall 2010, SWP reservoir storage remained below average, prompting the California Department of Water Resources (DWR) to announce an initial allocation of only 25 percent for SWP contractors. However, a series of storms in November and December 2010 resulted in 19 inches of precipitation across the watersheds that feed the SWP. The storms increased the snowpack and resulted in increased runoff. As a result, DWR increased the allocation to 50 percent on December 16, 2010. Additionally, DWR announced the availability of Article 21 water.

Further storms in December 2010 and Spring 2011 increased precipitation totals across the state. Precipitation totals in northern California watersheds tracked fairly close with the record-setting wet water year of 1982-83. Storage in Lake Oroville increase by approximately 1.7 million acre-feet (af) from December 2010 to April 2011. As a result, DWR repeatedly increased the SWP allocation. However, SWP operations remained impacted by regulatory constraints regarding Delta smelt, longfin smelt and salmonids. Ultimately, DWR announced a final allocation of 80 percent on April 20, 2011.

Kern River



2011 ended with a Sacramento River Index of 25.1 (Figures 3 and 4). In total, Kern County interests were able to take delivery of 1,707,734 af of SWP water in 2011, including 194,119 af of Article 21 water (Tables 3 and 4; Figure 5).

Central Valley Project

Like the SWP, the CVP experienced above-average hydrology during Fall 2010 through Spring 2011. While the initial allocation for CVP South of Delta contractors was only 50 percent, continually improving reservoir conditions allowed the allocation to be increased to 80 percent (Table 5). The Friant Division also experienced wet hydrologic conditions. As a result, Friant Division contractors received an initial allocation of 100 percent of Class I supplies and 20 percent of Class II supplies.

Additionally, Section 215 water was made available to CVP and non-CVP contractors within the CVP place of use. Deliveries to Kern County, including Class I, Class II and Section 215 water, totaled 664,321 af in 2011 (Table 6; Figure 6). Since 1950, Kern County interests have received nearly 20.5 million af of CVP water (Table 7).

Kern River

After a wet 2010, storm after storm made its way to the southern Sierra Nevada mountains during 2011. Snowpack measurements from eight stations located throughout the Kern River watershed were well above average (Table 8). The April 1 Kern River runoff was estimated to be 186 percent of normal or approximately 860,000 af (Table 9). In 2011, Kern River runoff totaled 942,858 af, resulting in a natural flow of 1,374,894 af (Tables 9 and 10). Total Kern River regulated flow, as measured at First Point of Measurement, was 1,404,645 af (Table 10; Figure 7). 2011 deliveries to Kern County purveyors totaled 1,402,977 af (Table 11).

Minor Streams

Flows from minor streams draining into the San Joaquin Valley portion of Kern County are the second largest local source of surface water, after the Kern River, for this region. Streams yielding measurable runoff are aggregated into four stream groups: the Poso Group (including Poso Creek), the Caliente Group (including Caliente and Tehachapi Creeks), the El Paso Group (including El Paso Creek) and the San Emigdio Group (including San Emigdio Creek). Grouping of minor streams is based upon hydrologic similarity of the watersheds and representative gauging records.

Runoff for ungauged streams is estimated by statistical methods based on historical relationships of watershed areas, precipitation and runoff for similar gauged streams. Gauges are in place on Poso and Tehachapi Creeks; therefore, actual measurements can usually be used for these watersheds. However, in very dry years, the flow on Tehachapi and Poso Creeks is too small for the gauges to record. In this report, flows are assumed to be sustained to the foothill line before they disappear into the valley alluvium.

Stream flow from minor streams is used for irrigation by farmers within North Kern Water Storage District (WSD) and Semitropic WSD. Much of the remaining water percolates into the underlying aquifer. Some of this recharge probably contributes to shallow groundwater in the Kern Lake Bed area and near the Kern National Wildlife Refuge (Plate 1). It is estimated that minor streams contributed approximately 149,722 af of water in 2011 (Table 12; Figure 8). In total, minor streams are estimated to have contributed 4,079,917 af since 1970 (Table 13).

Kelso Creek Flow at Rocky Point



Effective Precipitation

Effective precipitation occurs during the growing season of a crop or is stored in the soil and available during the growing season. Effective precipitation reduces the need for other water sources for irrigation, such as imported water or pumped groundwater. Only that portion of rainfall that satisfies crop water requirements can properly be called effective precipitation. A large portion of rainfall evaporates from the soil surface or the soil profile before it can be used by the crop. Timing of rainfall is also an important factor in determining its effectiveness. During years of extremely heavy rainfall, a small amount may percolate past the crop root zone and recharge the underlying aquifer, particularly during early stages of crop growth, thus becoming unavailable to the crop. In addition, heavy rain immediately after an irrigation cycle may not be usable by a crop.

The Agency gathers monthly rainfall data for most of the measuring stations in the San Joaquin Valley portion of Kern County and for some mountain stations (Table 14; Figure 9). During 2011, rainfall contributed 174,899 af of effective precipitation, with approximately 22,817 af occurring over the usable groundwater basin (Table 15; Figure 10).

Recycled Water

The reuse of municipal and industrial wastewater provides an irrigation water source for Kern County agriculture. There are 14 active wastewater recycling treatment plants in the San Joaquin Valley portion of Kern County. Recycling processes are classified as follows:

- **"Primary" treatment** removes most suspended matter from the sewage (usually via settling ponds), but removes little or no colloidal or dissolved substances;
- **"Secondary" treatment** provides some biological action or filtration to remove any remaining colloidal or dissolved substances from the sewage (nearly all recycling treatment facilities in Kern County provide secondary treatment of sewage); and
- **"Tertiary" treatment** involves further filtration and disinfection to inactivate pathogens.

Most of the effluent from treatment plants in Kern County is recycled and used to irrigate salt-tolerant crops on bordering lands, such as cotton, pasture and some grains. A small amount percolates directly to the groundwater basin. The remainder evaporates.

In 2011, approximately 53,855 af of water were recycled (Table 16). The Agency estimated that approximately 49,000 af of this recycled water were used by agriculture. Since 1970, approximately 1.77 million af of recycled wastewater have been reused (Table 17; Figure 11).

Another source of reusable wastewater results from agricultural tailwater return systems. Many farming operations have installed these systems to intercept water that would normally run off fields during irrigation. This recovered water is either transported back to the main irrigation system or is applied on an adjacent field (from the foot of one field to the head of another). Tailwater return systems are widely used on fields that are furrow or border irrigated. Their efficiency lies in saving the energy required to recover the water from wells or by reducing the need to import additional surface supplies. From a groundwater basin balance standpoint, these two water reuse activities are internal and do not add to the hydrologic system.



Oilfield-Produced Water

Another source of wastewater is a byproduct of oil production. Unlike treated municipal effluent or tailwater, oilfield-produced waters are a true addition to the hydrologic system, being drawn from deep, connate waters that are intermixed with oil deposits. In the Kern Front oilfield, which lies astride the Kern River northeast of Bakersfield, substantial quantities of water are removed with each barrel of oil. With treatment, the chemical quality of this water is generally within acceptable limits for agriculture. Thus, a small amount of this water is discharged into irrigation canals after treatment.

2011 was the fourth consecutive year that no oilfield-produced water was discharged into irrigation canals (Table 18; Figure 12). Oilfield-produced water has declined because steaming operations consume a larger share of the produced water than in previous years.

Groundwater Recovery

Most of the groundwater recovery in Kern County is not recorded. In this report, groundwater extractions are estimated by solving for the missing number in the groundwater change-in-storage equation shown on Figure 13. Total groundwater extractions were calculated to be approximately 419,000 af in 2011 (Table 19; Figures 13 and 14).

Water Requirements

Agricultural

Crops grown in Kern County are consumed throughout the U.S. and are exported to countries around the world. Irrigated acreage had been slowly increasing since the drought of 1988-1991 as previously fallowed land was brought back into production. However, aside relative small year-to-year fluctuations, irrigated acreage had hovered around 780,000 acres since 2000. After a substantial increase in irrigated acreage in 2010, 2011 experienced another small increase with acreage totaling 887,506 acres (Table 20; Figure 15). Permanent crops (trees and vines) made up approximately 54 percent of Kern County's total acreage (Figure 16). Feed crops, such as alfalfa and grains, grown primarily to support the dairy and cattle industries, accounted for approximately 27 percent of Kern County's agricultural total acreage. Vegetables represent another 10 percent of Kern County's agricultural acreage. Lastly, cotton production remains a valuable commodity in Kern County representing approximately 8 percent of total crop production.

The Kern County Agricultural Commissioner's annual crop report shows that all of Kern County's top five agricultural products generated approximately $3.1 billion in 2011 (Table 21). Additionally, Kern County's agricultural products had a total combined market value of approximately $5.4 billion. This represents a 12.8 percent increase in crop value from 2010. Trees and vines account for almost half of Kern County's gross agricultural value, reflecting the importance of these crops to the local economy.

Based on local pan evaporation data, per unit crop demands in 2011 were approximately 92 percent of the historical average (Table 22; Figure 17). This resulted in an average consumptive water use of approximately 2.65 af per acre (Table 23). However, areal differences, such as soil type, cultural practices, leaching requirements (typically 5 to 10 percent), and irrigation technologies employed around the valley result in different applied water rates on specific crops (Table 24).

Gross applied agricultural requirements in 2011 were about 3,307,700 af, with approximately 2,817,800 af occurring over the usable groundwater basin (Figure 13). Net agricultural requirements in 2011 were approximately 2,619,000 af, with about 2,231,000 af occurring over the groundwater basin. Agricultural return flows to groundwater are estimated as the difference between gross and net water requirements over the basin. Not all return flows return to usable groundwater. Some water may be lost to saline sinks such as shallow groundwater areas (Plate 1). In moisture-deficient soils, return flows are absorbed by the soils and are irrecoverable. In 2011, approximately 753,300 af of applied agricultural water returned to usable groundwater storage.

Municipal and Industrial

Gross Municipal and Industrial (M&I) water demand in 2011 was about 222,400 af, with approximately 166,800 af required over the usable groundwater basin (Table 25). During 2011, average M&I water use was 238 gallons per capita per day (gpcd); however, this includes commercial and industrial uses such as oilfield production and golf courses (Table 25). Residential water use was estimated to be approximately 190 gpcd in 2011. Net M&I consumptive use in 2011 was approximately 157,800 af.



The Agency's Improvement District No. 4 Henry C. Garnett Water Purification Plant

Water Surface Evaporation

Water surface evaporation accounts for a small portion of water lost from the San Joaquin Valley portion of Kern County. Conveyance facilities such as open canals, ditches and recharge ponds all lose water via evaporation. In 2011, about 39,000 af evaporated from conveyance facilities, groundwater recharge facilities and other open water bodies (Figure 13).

Change in Groundwater Storage

Figure 18 shows gross water supplies for the San Joaquin Valley portion of Kern County of 4,635,900 af in 2011. Approximately 4,042,600 af of this demand occurred over the groundwater basin. Total net consumptive water use in 2011 was 2,864,000 af. There was a net increase in groundwater storage of approximately 992,700 af, meaning more water was recharged into the groundwater aquifer than was recovered.

Figure 19 is a graph displaying the water supplies and demands of the San Joaquin Valley portion of Kern County since 1970, when SWP water was first introduced over the groundwater basin. From 1970 to 1975, delivery systems were being developed and the Cross Valley Canal (CVC) had not been completed. During the 1976-77 drought, hydrologic conditions restricted surface water supplies.

Between 1970 and 2011, the difference between the recharge and recovery of groundwater has averaged a negative 79,846 af per year. Figure 19 shows the cumulative groundwater balance since 1970.

Kern County's groundwater management depends upon the sustained delivery of surface water from all three major sources: the Kern River, CVP and SWP. A reduction in one supply, unless accompanied by an increase in another, can have a serious impact on the groundwater basin. Table 26 and Figure 18 summarize supplies from these sources and depict their interdependence.

Basin-wide Water Use Efficiency

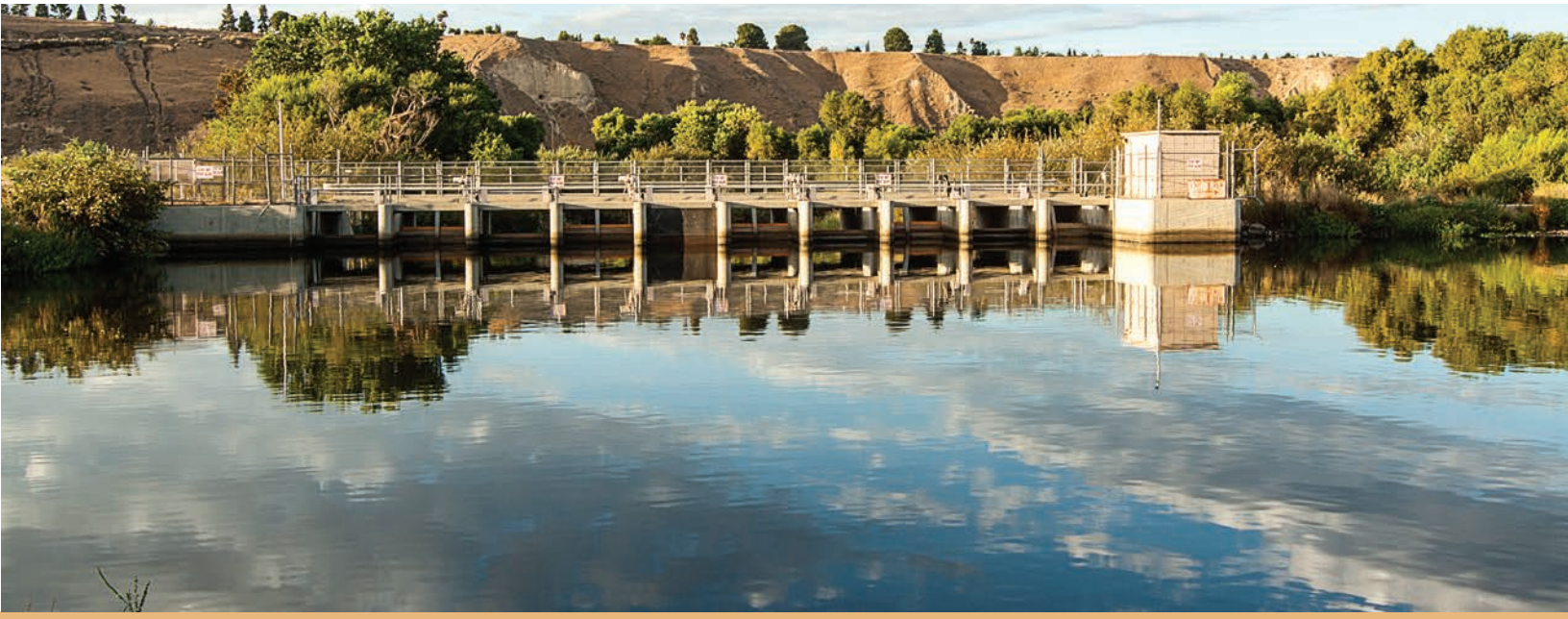
Water applied to a crop in excess of its evapotranspiration requirements percolates past the root zone and enters groundwater supplies, where it is available for reuse. Sometimes shallow clay layers in the soil can intercept this deep percolation, resulting in a condition called "shallow groundwater" (Plate 1). In some area deep percolation may mix with unusable saline groundwater. In the western portion of Kern County, most soils are moisture-deficient (the water held in the soil is less than the amount of water the soil would normally retain after drainage via gravity). Any deep percolation occurring in these moisture-deficient soils will be absorbed until the water-holding capacity of the soils is reached.

Over the entire San Joaquin Valley portion of Kern County, gross water uses were approximately 4,596,400 af during 2011 (Figure 13). Total consumption of water was about 2,864,000 af. Effective precipitation was approximately 175,000 af. Agricultural irrigation efficiency was approximately 79 percent. A total of 53,855 af of M&I water was treated and reused, predominantly by agriculture. The difference between gross and net requirements is an estimate of groundwater returns, which amounted to approximately 1,392,400 af.

Of the 4,635,900 af of gross water supply during 2011, virtually all of the water was beneficially used or available for reuse via net deep percolation. This means that essentially 99 percent of the water used in 2011 was put to beneficial use or was available for reuse. This percentage is termed "basin-wide water use efficiency." Kern County is among the most water-efficient areas in the state.

Kern River-California Aqueduct Intertie Activity

The Kern River-California Aqueduct Intertie (Intertie) is a structure connecting the Kern River to the California Aqueduct near Tupman. Its basic purpose is to dispose of floodwater, preventing damages downstream of the Kern River flood plain. Flows into the California Aqueduct through the Intertie may contain water from the Kern, Kaweah, Kings, San Joaquin and/or Tule rivers. Generally, Kern River flows must exceed about 200 percent of normal before the Intertie gates need to be opened. The structure has a capacity of 3,500 cubic feet per second. However, downstream SWP demands can become the limiting factor in wet years, when demands are low. The Intertie did not operate in 2011. Table 27 shows the history of flows through the Intertie.





Groundwater Conditions

Groundwater Banking

Many entities in Kern County are engaged in groundwater banking activities. Semitropic WSD, Rosedale-Rio Bravo WSD, North Kern WSD, Arvin-Edison WSD, the City of Bakersfield, the Kern Water Bank Authority and the Agency all operate groundwater facilities. Kern River water is recharged by a combination of deliberate spreading in recharge areas, by losses in unlined canals or by percolation in the Kern River channel (Table 28; Figure 20). CVP water is recharged in spreading ponds operated by Arvin-Edison WSD or in the channels of the Kern River and Poso Creek, as well as in recharge facilities on the Kern River Alluvial Fan (Kern Fan). SWP water is recharged by the Agency and several water districts in the Kern River channel (via the CVC), in unlined irrigation canals and in district or Agency-operated recharge sites. During wet periods, every effort is made to deliver water through unlined canals to maximize groundwater recharge.

Many water districts in Kern County utilize conjunctive use and banking programs to help balance their supplies. A well-managed conjunctive use or banking program is an effective groundwater management tool that allows a district to maintain an adequate supply during periods when sufficient surface water is unavailable. The intent is to store surface water during times when available supply exceeds demand and to recover groundwater during periods when the opposite occurs. A correctly managed program monitors the effects of water recharge and withdrawals in any year to help understand and anticipate local and regional groundwater impacts. A tremendous amount of groundwater recharge in Kern County is accomplished through these programs.

Of the groundwater banking projects operated or participated in by the Agency, all are located on the Kern Fan. The largest of these projects is the Kern Water Bank, which has a storage capacity of nearly one million af. In 1992, the Agency purchased 2,253 acres of land to develop additional water recharge and banking facilities, referred to as the Pioneer Properties. The Pioneer Properties consist of two parcels on either side of the Kern River southwest of Bakersfield. The Agency manages the properties, referred to as the Pioneer Project, to recharge water to and recover water from the groundwater basin. Lastly, the Agency also operates the Berrenda Mesa banking project, located along the south side of the Kern River just upstream of the Pioneer Properties. The project consists of 369 acres with an annual recharge capacity of 58,000 af and an annual recovery capacity of 46,000 af.

Table 28 shows banking account balances for those entities involved as banking partners in various banking programs. It displays in detail the banking portion of the information on Table 29, and includes recharge, extractions and transfers/sales of bank accounts. Recharge and recovery balances shown on Tables 28 and 29 have not been reduced to reflect evaporation or other losses. In 2011, no groundwater was recovered from the Kern Fan projects.

Groundwater Quality

The groundwater basin of the Kern County portion of the San Joaquin Valley is a basin of interior drainage. It has no appreciable surface or subsurface outflow, except in extremely wet years. Therefore, new salts introduced into the basin with imported surface water supplies are retained in the basin. Groundwater is the recipient of these salts via recharge water or return flows from irrigation and urban users. In 2011, surface water supplies over the usable groundwater basin introduced approximately 424,000 tons of new salts into the groundwater basin (Plates 2 and 3).

Groundwater pumped and used for irrigation becomes degraded as salts are leached from the crop root zone. A portion of applied water (averaging about 20 percent in the basin) percolates through the soil profile to the groundwater. This smaller volume of water carries the salts once held by the total volume applied, and the result is a concentration of salts. Local drainage projects reduce this buildup of salts by removing some near-surface accumulations in shallow groundwater areas (Plates 1-3). In areas of interior drainage like Kern County, importing water for large-scale agriculture, unless properly managed, will eventually result in the degradation of groundwater supplies. This is a normal consequence of water use by humans, whether for agriculture or urban purposes.

Groundwater Levels

Water level changes for four key areas are displayed on hydrographs in Figures 21a, 21b, 21c and 21d. Each hydrograph represents water levels for a pair of wells – one well is used to monitor shallow groundwater levels (Table 30), while the other is used to monitor deep groundwater levels. One well pair is located in the Pond-Poso area, another between the City of Shafter and Rosedale-Rio Bravo WSD, a third pair southwest of Bakersfield, and the fourth pair in the Arvin area. The hydrographs demonstrate the variability of groundwater levels in response to hydrologic conditions, with levels declining during dry periods and rebounding during wet periods.

The two wells in the Pond-Poso area represent the confined and unconfined aquifer systems in that region (Figure 21a). The hydrographs are plotted together to compare water level changes in both aquifers. The unconfined well reflects an upward trend since the 1977 drought, probably a continuation of a long-term rise in water levels caused by surface water deliveries via the Friant-Kern canal system. During 1990-92, drought conditions were more severe, with an increased dependence on groundwater, which is reflected by the decline in water levels during that period. The hydrograph for the confined well shows a variable pattern of water levels from year to year.

The City of Shafter/Rosedale-Rio Bravo WSD area hydrographs represent the unconfined aquifer (Figure 21b). The wells are located between the Kern River channel and Rosedale-Rio Bravo WSD's recharge facilities. The hydrograph reflects a long-term decline in water levels from 1970 through the 1977 drought, with transient rises during years when Kern River flows were above average. Since these wells are situated close to the Kern River and recharge facilities, the hydrographs show rapid rises in water level during the 1978-86 and 1993-98 wet periods and declines during the 1987-92 drought. These wells show a downward trend since 1999 due to generally dry conditions.

The more moderate groundwater level changes in the Shafter well (T28S/R25E-32F01) reflect the greater distance from the main areas of groundwater recharge. This well appears to be at the southeastern terminus of the Corcoran Clay. Recent groundwater level data suggests that no confined aquifer exists east and south of this location. Deep wells in these areas show annual groundwater levels and fluctuations that are consistent with the shallow wells. Confined and unconfined aquifers usually exhibit characteristic differences in seasonal groundwater level changes.

The southwest Bakersfield hydrographs show continual declines until 1978 (Figure 21c). The wet period of 1978-86 appears as a rise in groundwater levels. The 1987-92 drought shows another period of decline. Water levels have declined since the beginning of 1999 due to dry conditions. In the past, these two wells (T30S/R26E-22P1 and T30S/R26E-22P3) were classified as unconfined and confined, respectively. However, similar groundwater levels in both wells over a long period of time suggest that a confined aquifer may not exist in this area.

The Arvin-Edison WSD area wells are designated as shallow (T32S/R29E-04P1) and deep (T32S/R29E-03Q1) (Figure 21d). The Arvin-Edison WSD deep well may be in a confined aquifer, since it has shown annual variability in groundwater levels more consistent with the behavior of a confined aquifer. The large difference in groundwater levels between the two wells also suggests that two or more aquifers may exist in this area. The delivery of CVP water to Arvin-Edison WSD in the mid-1970s caused groundwater levels to rise, as seen in the shallow well hydrograph. During the 1976-77 and 1978-86 droughts, groundwater levels declined. During the 1978-86 and current wet years, water levels rose. This well shows a slight downward trend since 1998, with a steep drop in 2003. The rebound in water levels during 2005 and 2006 is reflective on wet hydrologic conditions. With the return of dry hydrologic conditions in 2007, water levels began to drop again.

Changes in groundwater levels are further demonstrated in Plates 4 and 5. Additionally, groundwater level changes from 2011 to 2012 show predominantly rising groundwater levels in response to 2011 recharge operations at many of the banking projects around Kern County (Plate 6).

Tables & Figures

Table 1. Kern County Water Agency Member Units

Member Units
Berrenda Mesa WD
Lost Hills WD
Belridge WSD
Buttonwillow ID
Pond Poso ID
Semitropic WSD
Cawelo WD
Improvement District No. 4
Rosedale-Rio Bravo WSD
Buena Vista WSD
Kern Delta WD
Henry Miller WD
West Kern WD
Wheeler Ridge-Maricopa WSD
Tehachapi-Cummings CWD
Tejon-Castac WD

Table 2. Kern County Water Agency Member Units' Entitlement

	Table 1 Water (af)			Table A Water by Use (af)		
Member Unit	Firm [5]	Surplus [1]	Former Table 1 Entitlement [2]	M&I	Ag	Total
Berrenda Mesa WD	92,600	6,301	98,901		108,600	108,600
Lost Hills WD	119,110	0	119,110	2,000 [3]	117,110	119,110
Belridge WSD	121,508	0	121,508	15,000 [3]	106,508	121,508
Buttonwillow ID	83,000	13,100 [4]	96,100		83,000	83,000
Pond Poso ID	67,000	11,100 [4]	78,100		67,000	67,000
Semitropic WSD	5,000	562 [4]	5,562		5,000	5,000
Cawelo WD	38,200	6,800	45,000		38,200	38,200
Improvement District No. 4	82,946	899	83,845	77,000	5,946	82,946
Rosedale-Rio Bravo WSD	29,900	5,100	35,000		29,900	29,900
Buena Vista WSD	21,300	3,750	25,050		21,300	21,300
Kern Delta WD	25,500	4,500	30,000		25,500	25,500
Henry Miller WD	35,500	6,250	41,750		35,500	35,500
West Kern WD	31,500	0	31,500	25,000	6,500	31,500
Wheeler Ridge-Maricopa WSD	197,088	34,205	231,293		197,088	197,088
Tehachapi-Cummings CWD	19,300	700	20,000	15,000	4,300	19,300
Tejon-Castac WD	5,278	471	5,749	2,000	3,278	5,278
Kern County Water Agency	8,000	360	8,360		8,000	8,000
Total	**982,730**	**94,098**	**1,076,828**	**136,000**	**862,730**	**998,730**

Note: Maximum annual entitlement is reached in 1990.

(1) Per the Monterey Agreement, surplus water was removed from the Member Unit contracts. Surplus water entitlements are still used in the allocation of Article 21 water in proportion to the Member Units' Former Table 1 Entitlements, if demands for Article 21 water are greater than the supply of interruptible water (see footnote 2).

(2) Former Table 1 Entitlement is the Member Units' contract entitlement plus the amount of surplus water (see footnote 1).

(3) Agricultural entitlement converted to M&I use.

(4) Pond Poso ID and Buttonwillow ID are included with Semitropic WSD allocations. Add all three totals to get allocation for Semitropic WSD.

(5) Reflects 40,670 af relinquished (KWB), 25,000 af sold (BMWD to Mojave WD); 41,000 af sold (WRMWSD to Castaic WD); 4,000 af sold (BWSD to Palmdale WD); 15,000 af sold (LHWD to Alamenda Zone 7); 5,756 af sold (BWSD to Solano County WA); 4,025 af sold (BWSD to Napa County FC&WCD); 2219 af sold in 2004 (BWSD to Alameda Co. Zone 7); and 6500 af transferred in 2004 (BMWD to WKWD).

Table 3. SWP Deliveries, Including Water Transfers and Exchanges, by KCWA Member Units for 2011

Year	Annual [1] Deliveries (af)	Cumulative Deliveries (af)	Intertie Deliveries (af)	Deliveries [2] Outside SJV (af)	Annual Importations (af)	Cumulative Importations (af)
Prior to 1970		268,649			-	268,649
1970	204,634	473,283			204,634	473,283
1971	375,505	848,788			375,505	848,788
1972	535,573	1,384,361			535,573	1,384,361
1973	515,546	1,899,907		25	515,521	1,899,882
1974	656,773	2,556,680		4,992	651,781	2,551,663
1975	828,437	3,385,117		6,699	821,738	3,373,401
1976	888,112	4,273,229		4,755	883,357	4,256,758
1977	432,837	4,706,066		3,424	429,413	4,686,171
1978	678,400	5,384,466	64,100	2,826	611,474	5,297,645
1979	1,295,388	6,679,854		3,630	1,291,758	6,589,403
1980	968,092	7,647,946	64,792	3,041	900,259	7,489,662
1981	1,386,641	9,034,587		1,897	1,384,744	8,874,406
1982	900,973	9,935,560	13,679	2,791	884,503	9,758,909
1983	601,183	10,536,743	365,505	724	234,954	9,993,863
1984	1,138,040	11,674,783	13,639	1,360	1,123,041	11,116,904
1985	1,078,147	12,752,930		4,015	1,074,132	12,191,036
1986	929,178	13,682,108	12,701	2,916	913,561	13,104,597
1987	1,028,124	14,710,232		2,217	1,025,907	14,130,504
1988	1,009,520	15,719,752		3,307	1,006,213	15,136,717
1989	1,146,062	16,865,814		48,833	1,097,229	16,233,946
1990	862,448	17,728,262		21,643	840,805	17,074,751
1991	34,886	17,763,148		2,213	32,673	17,107,424
1992	421,520	18,184,668		3,508	418,012	17,525,436
1993	1,219,653	19,404,321		14,139	1,205,514	18,730,950
1994	711,002	20,115,323		15,616	695,386	19,426,336
1995	1,219,146	21,334,469		107,950	1,111,196	20,537,532
1996	1,335,394	22,669,863		88,209	1,247,185	21,784,717
1997	1,303,900	23,973,763		290,523	1,013,377	22,798,094
1998	987,299	24,961,062		148,101	839,198	23,637,292
1999	1,386,481	26,347,543		78,181	1,308,300	24,945,592
2000	1,438,120	27,785,663		229,619	1,208,501	26,154,093
2001	573,382	28,359,045		173,962	399,420	26,553,513
2002	818,440	29,177,485		85,849	732,591	27,286,104
2003	1,135,299	30,312,784		208,638	926,661	28,212,765
2004	812,610	31,125,394		131,584	681,026	28,893,791
2005	1,535,608	32,661,002		104,203	1,431,405	30,325,196
2006	1,337,456	33,998,458		88,209	1,249,247	31,574,443
2007	693,653	34,692,111		290,523	403,130	31,977,573
2008	296,480	34,988,591		148,101	148,379	32,125,952
2009	810,710	35,799,301		241,978	568,732	32,694,684
2010	1,275,691	37,074,992		119,254	1,156,437	33,851,121
2011	1,707,734	38,782,726		95,370	1,612,364	35,463,485

Mean Deliveries	881,426 af	Minimum Deliveries (1991)	34,886 af
Median Deliveries	888,112 af	Maximum Deliveries (2011)	1,707,734 af
Mean Importations	805,988 af	Minimum Importations (1991)	32,673 af
Median Importations	862,081 af	Maximum Importations (2011)	1,612,364 af

[1] Includes Pre-consolidation water deliveries, 1977 Dry Year Pool, 1991 State Bank water.

[2] Includes Tehachapi-Cummings CWD and other deliveries outside the San Joaquin Valley portion of Kern County. Beginning in 1990, also includes local groundwater programs.

Table 4. SWP Deliveries to the San Joaquin Valley Portion of Kern County

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	SWP Water Supplies (af)					Turn-in Water Program (af)			Agency Approved Transfers (af)								Total Deliveries (af)		
District	Table A Allocation	Carryover of 2010 Allocation into 2011	DWR Turn-Back Pool Purchase	DWR Article 21 Water Program	Total SWP Water Supply	KCWA	Others	Total	Miscellaneous Xfers/Exch Out of Kern County	Miscellaneous Xfers/Exch into Kern County	Miscellaneous Xfers/Exch Other	Miscellaneous Xfers/Exch Other	Miscellaneous Xfers/Exc Other	Miscellaneous Xfers/Exch Other	Miscellaneous Xfers/Exch Other	Miscellaneous Operational Exchanges	Total Water Supply Available	Total Deliveries	Balance to be Delivered
Member Units																			
Berrenda Mesa WD	74,080	19,335	1,632	28,056	123,103		2,681	2,681		1,724	3,200 [20]	(1,465) [22] [37]	1,293 [24]	914 [31]	15,623 [12]	(2,782) [28] [34]	144,291	140,164	4,127
Lost Hills WD	95,288	14,930	2,099	28,373	140,690		4,905	4,905		4,966			3,048 [24]	1,100 [31]		(2,902) [28]	151,807	152,323	(516)
Belridge WSD	97,206	27,840	2,141	33,237	160,424		20,045	20,045		24,205		(755) [22] [37]	4,180 [24] [25]	4,952 [31] [39]	(623) [12]	11,528 [28] [34]	223,956	217,977	5,979
Semitropic WSD	124,000	23,390	2,731	41,813	191,934					248,253	20,785 [1] [5]	1,853 [6]	263 [23] [25]	196 [31]		(24,513) [28] [34]	438,771	447,674	(8,903)
Cawelo WD	30,560	6,456		2,156	39,172					10,000		(10,000) [24]	(8,805) [24]	(3,414) [31] [39]		(1,900) [28] [34]	25,053	20,791	4,262
Improvement District No. 4	66,357	8,182	1,462	15,424	91,425		2,797	2,797			(5,785) [1] [15]	(1,736) [22] [2]	(640) [27] [25]	(6,226) [31] [33]	(27,250) [12]	1,729 [28] [34]	54,314	54,103	211
Rosedale-Rio Bravo WSD	23,920	5,956	527	4,355	34,758					5,608		3,728 [37]			2,000 [12]	(10) [28]	46,084	26,760	19,324
Buena Vista WSD	17,040	7,166	98	121	24,425		716	716			15,000 [7] [5]	23,500 [16] [24]	20,518 [30]			2,441 [34]	86,600	69,490	17,110
Kern Delta WD	20,400	-	449	1,000	21,849					69,424	(25,845) [7] [40]		(20,821) [23] [30]				44,607	44,664	(57)
Henry Miller WD	28,400	4,277	626		33,303												33,303	29,325	3,978
West Kern WD	25,200	2,511	555	2,588	30,854					12,000	2,750 [9] [10]	(13,500) [16]	6,000 [29]				38,104	38,214	(110)
Wheeler Ridge-Maricopa WSD	157,670	42,037	3,473	34,802	237,982		5,620	5,620		6,018		(1,853) [6]	448 [25]	2,137 [31]		3,080 [28] [34]	253,432	250,801	2,631
Tehachapi-Cummings CWD Ag	3,440	325			3,765												3,765	3,765	-
Tehachapi-Cummings CWD M&I	12,000	3,160	251	1,086	16,497		400	400			(2,750) [9] [10]		(5,416) [27] [29]			187 [34]	8,918	8,918	-
Tejon-Castac WD M&I	1,600	1,423	24		3,047								(12) [25]				3,035	3,050	(15)
Tejon-Castac WD Ag	2,623	3,727		1,108	7,458						(3,200) [20]					(62) [28]	4,196	4,243	(47)
Non Member Units																			
Arvin-Edison WSD					-	9,536	16,065	25,601	(39,484)	101,600	845 [40]	228 [2]			10,250 [12]	13,038 [28]	112,078	112,078	-
Kern County Water Agency	6,400	259			6,659		6,100	6,100	(1,112)		(5,000) [5]			341 [31] [33]			6,988	7,000	(12)
Westside Mutual WC					-											101 [34]	101		101
Dudley Ridge WD (KWB)					-					34,733			(56) [25]			65 [34]	34,742	34,798	(56)
Western Hills WD					-				1,112								1,112	1,112	-
Metropolitan Water District					-				39,484								39,484	39,484	-
Others					-					1,000							1,000	1,000	-
Total	**786,184**	**170,974**	**16,068**	**194,119**	**1,167,345**	**9,536**	**59,329**	**68,865**	**-**	**519,531**	**-**	**-**	**-**	**-**	**-**	**-**	**1,755,741**	**1,707,734**	**48,007**

Note: This table shows contracted deliveries for calendar year 2011. District deliveries may vary from amounts shown, due to: (a) SWP/Kern River exchanges, (b) payback of SWP water from prior year exchanges, and (c) conjunctive use agreements. The footnotes below may omit numbers.

[1] - Transfer of BWSD 2010 SWP carryover water (2,231 af) to AEWSD and for a like amount of AE/ID4/KT 2011 ID4 SWP Table A water (2,231 af) to BWSD; and exchange of ID4 Article 21 water (785 af) with SWSD for a like amount of KWB banked groundwater.

[2] - Transfer of ID4 2010 SWP carryover water (228 af) to AEWSD under annual KTWD exchange.

[3] - Transfer of 2011 CVP water (3,220 af) from Westlands WD; carryover water from SCVWD (4,000 af), ACWD (6,441 af) and Zone 7 (5,745 af); and Article 21 water from MWD (4,568 af), SCVWD (3,780 af) and ACWD (1,959 af); and Table A water from MWD (144,444 af), SCVWD (22,285 af) and ACWD (13,000 af); and DRWD/Sandridge L/O transfer (2,400 af); and SCVWD CVP water (36,411 af).

[4] - Landowner transfer of Tulare Lake Basin WSD SWP water to LHWD (2,500 af) and BWSD (3,500 af); and landowner transfer of DRWD SWP water to BMWD (200af), LHWD (500 af) and BWSD (300 af).

[5] - Nickel obligation (10,000 af) transferred to DMB Communities II, Inc. (Homer) (8,393 af) and Newhall Land & Farming Co. for storage in SWSD (1,607 af); transfer of BVWSD (KDWD) SWP Table A water (10,000 af) to SWSD.

[6] - Landowner transfer of Article 21 water (1,853 af) from WRMWSD to SWSD on behalf of common landowner Poso Creek WC.

[7] - Exchange of BVWSD Kern River water (25,000 af) for a like amount of KDWD (MWD) 2011 SWP Table A water.

[8] - Transfer of 2011 SWP water (6,889 af) from Palmdale WD to WKWD as a partial payback for a previous exchange of WKWD SWP Table A.

[9] - Transfer of 2010 SWP water (750 af) from TCCWD to WKWD as a 2-for-1 exchange program with water to be retuned in a future year.

[10] - Transfer of 2010 SWP water (2,000 af) from TCCWD to WKWD as part of a multi-year transfer program.

[11] - Exchange of Castaic Lake WA carryover water (5,608 af) to RRBWSD for a like amount of RRBWSD 2011 SWP Table A.

[12] - Transfer of 2011 SWP water (2,000 af) from BMWD (1,377 af) and BWSD (623 af) to RRBWSD for a like amount of RRBWSD groundwater currently stored in the Pioneer Project.

[13] - Transfer of MWD SWP Table A water (49,150 af) and SBVWD SWP Table A water (8,066 af) to KDWD for banking.

[14] - Transfer of KTWD CVP water (1,000 af) for banking in RRBWSD.

[15] - Transfer of DRWD carryover water (5,010 af) and Article 21 water (8,129 af).

[16] - Transfer of WKWD SWP Table A water (13,500 af) to BVWSD pursuant to annual program.

[17] - Transfer of Alameda County Flood Control & Water Conservation District - Zone 7 2011 SWP water (10,000 af) to CWD in exchange for 5,000 af to be returned in a future year.

[18] - Transfer of ID4 SWP Table A water (584 af) to TCCWD for a like amount of Kern River water.

[19] - Exchange of BVWSD Kern River water (20,804 af) for a like amount of KDWD 2011 SWP Table A water.

[20] - Transfer of TCWD banked Friant-Kern water (3,200 af) via TCWD 2011 SWP Table A water.

[21] - Transfer of Western Hills WD 2011 water supply to Western Hills WD (1,112 af).

[22] - Exchange of ID4 SWP water (1,508 af) for a like amount of Lower Kern River water from BMWD (705 af) and BWSD (803 af).

[23] - Exchange of KDWD/MWD SWP water (303 af) for a like amount of Lower Kern River water from SWSD (303 af).

[24] - Exchange of CWD SWP water (5,000 af) for a like amount of Kern River water to BWSD (1,400 af) and Lower Kern River water to (BMWD (1,293 af), LHWD (3,048 af) and BWSD (3,064 af) and Cawelo Carmel KR water (1,400 af) to BWSD for a like amount of CWD SWP Table A water.

[25] - Transfer water (588 af) from KWB participants to Pastoria Energy from SWSD(40 af), ID4 (56 af), WRMWSD (140 af), TCWD(12 af), WMWC (284 af) and DRWD (56 af).

[26] - Transfer exchange of TCCWD SWP Table A water (6,000 af) to WKWD for a 2-for-1 future payback.

[27] - Exchange of ID4 SWP Table A water (584 af) with TCCWD for a like amount of Lower River water.

[28] - Exchange of 2011 Article 21 water (Feb: 2,171 af and Apr: 7,485 af), to AEWSD on the Aqueduct for a like amount of Friant-Kern CVP water to the banking projects.

[29] - Exchange of TCCWD 2011 SWP Table A water (6,000 af) to WKWD under a 2-for-1 exchange program.

[30] - Exchange of KKWD 2011 SWP Table A water (10,518 af) to BVWSD for a like amount of BVWSD Kern River water.

[31] - KCWA Table A water (6,659 af) sale to Member Units (BMWD 914 af, LHWD 1,100 af, BWSD 1,123 af, SWSD 196 af, CWD 415 af, ID4 774 af and WRMWSD 2,137 af).

[32] - Transfer of Santa Barbara FCWA 2011 SWP Table A water (14,795 af) to the Westside Five (BMWD 971 af, LHWD 651 af, BWSD 8,933 af, WRMWSD 1,340 af and DRWD 2,900 af); and Friant Recirculation water (18,018 af) to the Westside Five (BMWD 553 af, LHWD 1,315 af, BWSD 11,472 af and WRMWSD 4,678 af [note: all WMWC (8,189 af) and DRWD (1,940 af) delivered to BWSD - KWB to do GW transfer to DRWD later]).

[33] - Exchange of ID4 2012 SWP Table A water for a like amount of Lower River water BMWD (705 af) and BWSD (803 af).

[34] - Operational exchange of Member Unit Lower River water for SWSD 2011 SWP Table A water.

[35] - Exchange of BMWD SWP Table A water (1,939 af) and BWSD (1,789 af) to RRBWSD for previously banked water in the Pioneer Project.

[36] - Transfer of CLWA 2011 SWP Table A water (5,000 af) to WKWD.

[37] - Exchange of 2010 SWP carryover water (BMWD 2,170 af and BWSD 1,558 af) for a like amount of RRBWSD Pioneer bank account water.

[38] - Transfer of ID4 2011 Table A water (15,000 af) to RRBWSD on behalf of KTWD and landowner transfer (15,000 af) from RRBWSD to BMWD on behalf of Paramount Farming Co.

[39] - Exchange of BWSD Friant-Kern water (3,829 af) for a like amount of CWD 2011 SWP Table A water.

[40] - Transfer of KDWD MWD SWP water (845 af) to AEWSD (MWD) for a like amount of AEWSD Friant-Kern CVP water.

Table 5. Annual Progression of CVP Allocation Forecasts

	Friant Division		South of Delta Agriculture
	Class I	Class II	Class I
February	100%	20%	50%
April	100%	20%	80%
May	100%	20%	80%
June	100%	20%	80%

Table 6. 2011 CVP Deliveries to Kern County Entities

	Total (af) [3]
Arvin-Edison WSD [1]	193,835
City of Bakersfield	-
Delano-Earlimart ID	152,217
Kern County Water Agency	63,158
Kern Delta WD	-
Kern-Tulare WD [2]	45,299
North Kern WSD	1,949
Rosedale-Rio Bravo WSD	6,448
Semitropic WSD	-
Shafter-Wasco ID	75,526
So. San Joaquin MUD [1]	125,889
Total	**664,321**

[1] Deliveries per USBR.
[2] Per exchange of Cross Valley Canal water with Arvin-Edison WSD.
[3] Includes M&I water, operational spill water and non-project water delivered via CVP.

Table 7. CVP Historical Deliveries into Kern County

Year	Annual Delivery (af)	Cumulative Delivery (af)	Year	Annual Delivery (af)	Cumulative Delivery (af)
Prior to 1970		3,524,548	2000	494,023	15,825,606
1970	351,392	3,875,940	2001	331,416	16,157,022
1971	348,865	4,224,805	2002	250,598	16,407,620
1972	238,475	4,463,280	2003	363,108	16,770,728
1973	412,178	4,875,458	2004	241,290	17,012,018
1974	480,575	5,356,033	2005	702,465	17,714,483
1975	442,130	5,798,163	2006	582,490	18,296,973
1976	226,512	6,024,675	2007	197,894	18,494,867
1977	121,469	6,146,144	2008	259,998	18,754,865
1978	357,847	6,503,991	2009	453,803	19,208,668
1979	462,526	6,966,517	2010	621,962	19,830,630
1980	462,772	7,429,289	2011	664,321	20,494,951
1981	469,966	7,899,255			
1982	656,608	8,555,863			
1983	550,874	9,106,737			
1984	425,371	9,532,108			
1985	337,514	9,869,622			
1986	589,262	10,458,884			
1987	291,981	10,750,865			
1988	292,828	11,043,693			
1989	293,865	11,337,558			
1990	200,141	11,537,699			
1991	204,396	11,742,095			
1992	208,021	11,950,116			
1993	489,783	12,439,899			
1994	186,303	12,626,202			
1995	647,077	13,273,279			
1996	611,262	13,884,541			
1997	630,026	14,514,567			
1998	466,490	14,981,057			
1999	350,526	15,331,583			

Mean Delivery	330,564 af
Median Delivery	293,347 af
Mean Delivery 1975-2011	404,057 af
Median Delivery	387,643 af
Min. Delivery (1977)	121,469 af
Max. Delivery (2005)	702,465 af

Table 8. 2011 Inches of Water Content for Eight Remote Snow Sensor Sites in the Kern River Watershed

	Inches of Water Content	
	2011	**Normal**
Upper Tyndall Cr.	35	27.7
Crabtree Meadow	26.5	19.8
Chagoopa Plateau	22.6	21.8
Pascoe	52.6	24.9
Wet Meadow	48.3	30.3
Tunnel Guard	22.9	15.6
Casa Vieja Meadow	32.8	20.7
Beach Meadows	22.5	11

Table 9. 2011 Annual Progression of the April-July Kern River Runoff Forecasts

	Percent of Normal Runoff	Runoff (af)
February 1	147%	680,000
March 1	141%	650,000
April 1	184%	850,000
May 1	186%	860,000
Actual	**201%**	**942,858**

Table 10. Natural and Regulated Flows on the Kern River

Calendar Year	Natural Flows (af)	Regulated Flows (af) (1) (2)	Cumulative Flows	
			Natural (af)	Regulated (af)
Prior to 1970			54,183,302	10,962,457
1970	589,474	601,254	54,772,776	11,563,711
1971	427,454	442,651	55,200,230	12,006,362
1972	268,427	311,291	55,468,657	12,317,653
1973	979,652	785,133	56,448,309	13,102,786
1974	818,608	745,903	57,266,917	13,848,689
1975	564,567	572,091	57,831,484	14,420,780
1976	249,468	320,784	58,080,952	14,741,564
1977	196,998	200,702	58,277,950	14,942,266
1978	1,653,505	1,390,675	59,931,455	16,332,941
1979	672,661	656,068	60,604,116	16,989,009
1980	1,639,957	1,560,652	62,244,073	18,549,661
1981	449,263	460,469	62,693,336	19,010,130
1982	1,271,139	1,121,088	63,964,475	20,131,218
1983	2,489,128	2,381,575	66,453,603	22,512,793
1984	821,797	834,036	67,275,400	23,346,829
1985	672,431	668,971	67,947,831	24,015,800
1986	1,444,939	1,331,561	69,392,770	25,347,361
1987	375,935	432,309	69,768,705	25,779,670
1988	294,685	335,473	70,063,390	26,115,143
1989	397,038	348,773	70,460,428	26,463,916
1990	203,571	219,501	70,663,999	26,683,417
1991	406,289	333,494	71,070,288	27,016,911
1992	296,829	272,822	71,367,117	27,289,733
1993	853,760	642,339	72,220,877	27,932,072
1994	336,456	422,361	72,557,333	28,354,433
1995	1,385,160	1,197,100	73,942,493	29,551,533
1996	1,038,261	968,036	74,980,754	30,519,569
1997	1,181,969	1,133,463	76,162,723	31,653,032
1998	1,717,967	1,662,556	77,880,690	33,315,588
1999	433,971	461,621	78,314,661	33,777,209
2000	476,819	472,536	78,791,480	34,249,745
2001	391,451	375,769	79,182,931	34,625,514
2002	424,696	357,160	79,607,627	34,982,674
2003	519,724	460,406	80,127,351	35,443,080
2004	407,305	407,272	80,534,656	35,850,352
2005	1,156,109	935,439	81,690,765	36,785,791
2006	1,071,841	1,027,688	82,762,606	37,813,479
2007	252,692	318,050	83,015,298	38,131,529
2008	517,997	455,874	83,533,295	38,587,403
2009	470,166	442,268	84,003,461	39,029,671
2010	910,878	752,302	84,914,339	39,781,973
2011	1,374,894	1,404,645	86,289,233	41,186,618

118 Year Mean Natural First Point Flow	731,300 af
118 Year Median Natural First Point Flow	550,700 af
58 Year Mean Regulated First Point Flow	710,100 af
58 Year Median Regulated First Point Flow	507,400 af
Minimum Natural First Point Flow (1961)	177,642 af
Maximum Natural First Point Flow (1916)	2,520,149 af
Mimimum Regulated First Point Flow (1961)	177,063 af
Maximum Regulated First Point Flow (1983)	2,381,575 af

Table 11. Kern River Diversions by Entity

Area of Use	Diversions (af) [1]
Above First Point	
California Water Service Co.	14,222
City of Bakersfield	0
Kern Valley Golf Course (Kernville)	211
La Hacienda, Inc.	0
Lake Ming	1,180
Olcese WD	654
Subtotal	**16,267**
Below First Point	
Arvin-Edison WSD	0
Buena Vista WSD	63,829
Cawelo WD	77,638
City of Bakersfield, Irrigation and Spreading [2]	334,296
Improvement District No. 4	60,898
Kern County Water Agency	0
Kern Delta WD	228,107
Kern-Tulare WD	0
North Kern WSD	358,888
Rosedale Ranch Improvement District	16,349
Rosedale-Rio Bravo WSD	246,146
South Fork	559
Subtotal	**1,386,710**
Total	**1,402,977**

(1) The list of diversions is not comprehensive. Therefore, diversions do no equal the total amount of Kern River water available.

(2) Includes Kern River Canal & Irrigating Company deliveries, Truxtun Lakes deliveries, Carrier Canal losses and percolation, Kern River channel losses and percolation.

Table 12. 2011 Streamflow for Each of the Kern County Watershed Groups

Stream Group	(af)
Poso	37,500
Caliente	32,219
El Paso	2,703
San Emigdio	77,300
Total	**149,722**

Table 13. Runoff from All Minor Streams Draining into the San Joaquin Valley Portion of Kern County

Year	Annual Stream Flows (af)	Cumulative Stream Flows (af)
1970	53,400	53,400
1971	31,100	84,500
1972	16,700	101,200
1973	93,100	194,300
1974	66,300	260,600
1975	38,600	299,200
1976	29,000	328,200
1977	27,900	356,100
1978	379,500	735,600
1979	51,000	786,600
1980	70,300	856,900
1981	45,100	902,000
1982	93,600	995,600
1983	503,300	1,498,900
1984	46,500	1,545,400
1985	37,800	1,583,200
1986	52,400	1,635,600
1987	70,900	1,706,500
1988	29,900	1,736,400
1989	27,800	1,764,200
1990	17,500	1,781,700
1991	41,900	1,823,600
1992	87,300	1,910,900
1993	110,900	2,021,800
1994	37,400	2,059,200
1995	426,400	2,485,600
1996	79,500	2,565,100
1997	103,000	2,668,100
1998	709,500	3,377,600
1999	40,100	3,417,700
2000	27,700	3,445,400
2001	37,200	3,482,600
2002	22,800	3,505,400
2003	55,900	3,561,300
2004	30,700	3,592,000
2005	89,900	3,681,900
2006	54,100	3,736,000
2007	20,500	3,756,500
2008	60,300	3,816,800
2009	40,870	3,857,670
2010	72,525	3,930,195
2011	149,722	4,079,917

Mean Flow	97,100 af
Median Flow	51,700 af
Minimum Flow (1972)	16,700 af
Maximum Flow (1998)	709,500 af

Table 14. 2011 Monthly Rainfall at Selected Stations

OPERATOR/Station	Elev. (ft)	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
ARVIN-EDISON WATER STORAGE DISTRICT															
District Headquarters	500	31S/30E-29	0.57	1.49	2.10	0.20	0.70	0.03	0.00	0.00	0.03	0.97	0.93	0.10	7.12
Sycamore	420	31S/30E-20	0.53	1.40	1.94	0.18	0.66	0.03	0.00	0.00	0.04	0.90	0.89	0.09	6.66
Tejon	480	32S/29E-15	0.39	1.24	1.91	0.08	0.45	0.04	0.00	0.00	0.04	0.73	0.78	0.05	5.71
CALIFORNIA DEPARTMENT OF WATER RESOURCES															
Arvin-Edison (CIMIS)	500	35°12'N, 119°57'W	0.59	1.34	1.93	0.13	0.60	0.04	0.04	0.00	0.00	0.91	1.04	0.08	6.70
Belridge (CIMIS)	410	35°30'N, 119°41'W	0.45	0.64	1.88	0.01	0.18	0.08	0.00	0.03	0.00	0.13	1.33	0.05	4.78
Blackwell's Corner (CIMIS)	705	35°38'N, 119°57'W	0.97	0.60	2.63	0.21	1.00	0.08	0.00	0.00	0.05	1.11	1.58	0.01	8.24
Famoso (CIMIS)	415	35°36'N, 119°12'W	0.25	0.29	1.28	1.44	0.03	0.00	0.00	0.00	0.04	0.00	0.11	0.00	3.44
Lost Hills O&M Center	300	27S/21E-03	0.45	0.64	1.88	0.01	0.18	0.08	0.00	0.03	0.00	0.13	1.33	0.05	4.78
Wasco 7E (CIMIS)	410	27S/26E-06	0.28	0.52	1.25	1.76	0.00	0.00	0.00	0.00	0.04	0.00	0.11	0.00	3.96
Wind Gap O&M Center	780	11N/20W-26	0.43	1.53	2.55	0.03	0.57	0.03	0.00	0.00	0.00	0.76	1.10	0.00	7.00
J.G. BOSWELL COMPANY															
Buena Vista Gin	300	32S/25E-12	0.31	0.39	1.09	0.00	0.27	0.04	0.00	0.27	0.00	0.31	0.84	0.00	3.52
Section 4	Unk.	32S/25E-04H	0.49	0.23	0.99	0.01	0.33	0.08	0.00	0.00	0.81	0.20	1.23	0.01	4.38
Buena Vista Office	290	31S/25E-25	0.45	0.40	1.20	0.02	0.29	0.14	0.00	0.00	0.24	0.21	0.96	0.02	3.93
Kern Lake Shop	280	32S/28E-18	0.43	0.77	1.37	0.00	0.36	0.08	0.00	0.00	0.13	0.43	0.58	0.00	4.15
Kern Lake Time Room	280	32S/27E-16	0.38	0.66	1.43	0.01	0.28	0.01	0.00	0.00	0.08	0.55	0.60	0.00	4.00
Paloma	290	32S/24E-02	0.37	0.47	1.11	0.01	0.25	0.11	0.00	0.00	0.23	0.43	0.72	0.01	3.71
T Station	285	31S/25E-28G	0.42	0.20	1.33	0.06	0.29	0.04	0.00	0.00	0.68	0.23	1.17	0.01	4.43
KERN COUNTY PLANNING DEPARTMENT															
Arvin Fire Station	450	31S/29E-28	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Buena Vista Aquatic Rec Area	300	31S/25E-15	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Buttonwillow Fire Station	270	29S/23E-14	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Frazier Park Fire Station	4,600		M	M	M	M	M	M	M	M	M	M	M	M	0.00
K.C. Communications Center	770	29S/28E-16	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Edmonston Pump Station	1,310	10N/18W-17M	M	M	M	M	M	M	M	M	M	M	M	M	0.00
McFarland Fire Station	350	26S/25E-10	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Pine Mountain	5,200	09N/21W-19	0.71	1.68	2.22	0.35	1.42	0.04	0.38	0.00	0.53	0.58	2.62	0.01	10.54
Rio Bravo Fire Station	610	29S/29E-04	M	M	M	M	M	M	M	M	M	M	M	M	0.00
NATIONAL WEATHER SERVICE															
Bakersfield Airport	489	35°26'N/119°03'W	0.40	0.49	1.67	0.21	0.23	0.08	0.00	0.00	0.00	0.55	0.76	0.00	4.39
Bakersfield 5 NW	470	35°25'N/119°03'W	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Bear Valley	4,100	32S/31E-03	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Buttonwillow	269	35°24'N/119°28'W	0.48	0.21	1.38	0.00	0.42	0.31	0.01	0.00	0.00	0.22	1.01	0.00	4.04
Delano	302	35°46'N/119°16'W	1.13	0.70	2.15	0.00	0.28	0.54	0.00	0.00	0.02	0.56	0.89	0.00	6.27
Glennville	3,140	35°44'N/119°42'W	1.69	7.54	4.93	0.37	2.05	0.21	0.00	0.09	0.10	1.93	1.17	0.05	20.13
Keene	2,900	31S/32E-20	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Kern River PH 3	2,703	35°47'N/118°26'W	2.92	1.20	2.33	0.10	0.76	0.01	0.00	0.19	0.00	0.73	0.35	0.39	8.98
Lebec	3,585	34°50'N/118°52'W	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Piute	4,290	29S/33E-36	1.00	0.89	1.61	0.17	0.34	0.03	0.83	0.04	1.07	1.15	1.09	0.47	8.69
Taft	987	35°08'N/119°27'W	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Tehachapi 4 SE	3,960	35°08'N/119°26'W	0.51	0.99	4.59	0.35	1.17	0.05	0.00	0.00	0.20	0.90	1.68	0.16	10.60
Tejon Rancho	1,425	35°01'N/118°45'W	0.71	1.22	4.35	0.21	0.96	0.02	0.00	0.00	0.00	1.62	1.15	0.13	10.37
Wasco	345	35°36'N/119°21'W	0.40	0.31	1.37	0.38	0.32	0.81	0.00	0.00	0.00	0.58	1.06	0.00	5.23
Woody	1,631	35°43'N/118°51'W	1.56	1.82	3.27	0.35	1.35	0.17	0.00	0.00	0.09	1.45	1.00	0.01	11.07
TEHACHAPI-CUMMINGS COUNTY WATER DISTRICT															0.00
Station 6	4,890	12N/15W-01	1.12	2.19	2.04	0.73	2.16	0.01	0.77	0.00	0.12	1.37	1.32	0.20	12.03
Station 20	5,730	12N/15W-12	1.47	2.16	2.35	0.80	2.59	0.05	0.75	0.00	0.15	1.70	2.25	0.32	14.59
WHEELER RIDGE-MARICOPA WATER STORAGE DISTRICT															0.00
5P-P2	590	11N/22W-09	0.31	0.65	1.51	0.07	0.27	0.00	0.00	0.00	0.15	0.16	0.96	0.00	4.08
District Headquarters	480	11N/12W-11	0.44	1.22	2.50	0.00	0.38	0.24	0.00	0.00	0.56	0.51	2.73	0.00	8.58
Greenlee's Pasture	380	12N/21W-36	0.47	1.06	2.10	0.03	0.57	0.18	0.00	0.00	0.45	0.37	2.01	0.00	7.24
PA-2	960	11N/19W-30	0.50	0.77	3.06	0.00	0.67	0.00	0.00	0.00	0.00	0.67	0.65	0.00	6.32
Spill Basin	850	11N/18W-31	0.65	1.29	3.05	0.00	0.62	0.00	0.00	0.00	0.00	0.77	1.02	0.00	7.40
WRM-2	510	32S-24E-35	0.35	0.32	1.13	0.00	0.31	0.00	0.00	0.00	0.00	0.11	0.82	0.00	3.04
OTHER OPERATORS															0.00
Belridge WSD Office	550	28S/21E-34	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Blackwell's Corner (BMWD)	630	27S/20E-06	0.64	0.72	2.55	0.15	0.25	0.40	0.00	0.00	0.00	0.17	1.73	0.00	6.61
City of Bakersfield DWR Yd.	400	30S/27E-06	0.35	0.30	1.59	0.31	0.39	0.02	0.00	0.00	0.22	0.31	0.69	0.00	4.18
Del Kern Station (KDWD)	350	31S/28E-06C	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Shafter Cotton Research Sta.	360	35°32'N/119°17'W	0.63	0.43	1.39	0.00	0.00	0.00	0.00	0.01	0.13	0.58	1.10	0.02	4.29
So. Belridge (Aera Energy)	600	28S/21E-33	M	M	M	M	M	M	M	M	M	M	M	M	0.00
Approximate Average For All Stations			**0.67**	**1.05**	**2.08**	**0.22**	**0.61**	**0.10**	**0.07**	**0.02**	**0.16**	**0.64**	**1.11**	**0.06**	**6.80**

Note: "M" indicates missing data.

Table 15. Effective Precipitation in the San Joaquin Valley Portion of Kern County

	Annual Effective Precipitation (af)	Unit Rate (inches per acre)	Cumulative Effective Precipitation (af)
1970	380,200	6.23	380,200
1971	148,300	2.60	528,500
1972	264,900	4.48	793,400
1973	131,900	2.52	925,300
1974	220,200	3.25	1,145,500
1975	240,500	3.48	1,386,000
1976	175,300	2.63	1,561,300
1977	198,400	3.15	1,759,700
1978	612,500	9.06	2,372,200
1979	152,600	2.32	2,524,800
1980	281,200	4.21	2,806,000
1981	255,400	3.73	3,061,400
1982	332,300	4.39	3,393,700
1983	438,100	6.92	3,831,800
1984	139,300	2.00	3,971,100
1985	160,700	2.32	4,131,800
1986	162,600	2.81	4,294,400
1987	168,200	2.83	4,462,600
1988	144,200	2.39	4,606,800
1989	106,100	1.61	4,712,900
1990	90,500	1.35	4,803,400
1991	171,700	2.42	4,975,100
1992	142,300	2.05	5,117,400
1993	168,700	2.40	5,286,100
1994	169,100	2.37	5,455,200
1995	192,400	2.71	5,647,600
1996	192,500	2.55	5,840,100
1997	105,600	1.51	5,945,700
1998	575,200	8.07	6,520,900
1999	136,500	1.80	6,657,400
2000	123,800	1.91	6,781,200
2001	213,900	3.07	6,995,100
2002	124,400	1.87	7,119,500 (1)
2003	157,000	2.43	7,276,500
2004	114,200	1.72	7,390,700
2005	244,000	3.69	7,634,700
2006	179,600	2.66	7,814,300
2007	96,500	1.42	7,910,800
2008	50,094	0.77	7,960,894
2009	105,965	1.64	8,066,859
2010	182,031	2.47	8,248,890
2011	174,899	2.36	8,423,789

Mean EP (total)	200,600	af
Median EP (total)	168,900	af
Mean EP (per acre)	3.00	Inches/Acre
Median EP (per acre)	2.50	Inches/Acre

Table 16. Production of Recycled Wastewater in the San Joaquin Valley Portion of Kern County

Facility	Volume [1] (MG)	Volume [1] (af)	Influent Source [2]	Treatment System [3]	Effluent Use
City of Arvin	449	1,377	Dom	Secondary	Agriculture
City of Bakersfield					
#2	5,002	15,350	Dom/Ind	Secondary	Restricted Agriculture
#3	6,552	20,106	Dom/Ind	Secondary	Same
Kern County Waste Management Department					
Kern Sanitation Authority	1,224	3,755	Dom	Secondary	Agriculture
BVARA	3	10	Rec	Secondary	Percolation
Sheriff's Lerdo Facility	134	411	Dom	Secondary	Same
Reeder Tract	10	32	Dom	Secondary	Same
NOR Sanitary District #1	1,608	4,934	Dom/Ind	Secondary	Restricted Agriculture Percolation
City of Delano	1,604	4,922	Dom	Secondary	Restricted Agriculture
Lamont Public Utilities District	Unk	Unk	Dom	Primary	Agriculture
City of McFarland	Unk	Unk	Dom	Secondary	Agriculture
City of Shafter	445	1,365	Dom/Ind	Secondary	Agriculture
City of Wasco	519	1,593	Dom/Ind	Secondary	Agriculture
Total	**17,549**	**53,855**			

(1) Data received from wastewater treatment facilities.

(2) For influent source:

Dom - domestic
Ind - industrial
Agr - agricultural
Rec - recreational

(3) Primary treatment removes settleable solids. Secondary treatment involves further oxidation of wastewater to remove dissolved and biologically degradable substances. Tertiary treatment involves further filtration and disinfection to inactivate pathogens.

Table 17. Historical Water Reuse in the San Joaquin Valley Portion of Kern County

Year	Annual Flows (af)	Cumulative Flows (af)
1970	26,900	26,900
1971	27,800	54,700
1972	25,300	80,000
1973	25,600	105,600
1974	26,000	131,600
1975	26,100	157,700
1976	26,600	184,300
1977	28,100	212,400
1978	28,200	240,600
1979	28,800	269,400
1980	32,800	302,200
1981	34,100	336,300
1982	32,100	368,400
1983	35,300	403,700
1984	35,800	439,500
1985	34,200	473,700
1986	39,200	512,900
1987	41,400	554,300
1988	44,200	598,500
1989	44,000	642,500
1990	42,500	685,000
1991	45,200	730,200
1992	46,100	776,300
1993	47,600	823,900
1994	49,700	873,600
1995	49,700	923,300
1996	51,300	974,600
1997	50,800	1,025,400
1998	48,800	1,074,200
1999	48,500	1,122,700
2000	50,000	1,172,700
2001	51,000	1,223,700
2002	51,600	1,275,300
2003	56,600	1,331,900
2004	54,800	1,386,700
2005	55,200	1,441,900
2006	56,800	1,498,700
2007	59,000	1,557,700
2008	51,900	1,609,600
2009	50,800	1,660,400
2010	53,400	1,713,800
2011	53,900	1,767,700

Mean Water Reuse	42,100 af
Median Water Reuse	44,700 af
Minimum Water Reuse (1972)	25,300 af
Maximum Water Reuse (2007)	59,030 af

Table 18. Annual Oilfield-Produced Water

Year	Annual Flows (af)	Cumulative Flows (af)
1970	5,300	5,300
1971	5,600	10,900
1972	6,100	17,000
1973	6,400	23,400
1974	6,900	30,300
1975	7,400	37,700
1976	7,700	45,400
1977	8,100	53,500
1978	8,500	62,000
1979	9,400	71,400
1980	10,100	81,500
1981	10,100	91,600
1982	10,600	102,200
1983	11,600	113,800
1984	11,700	125,500
1985	11,700	137,200
1986	11,800	149,000
1987	10,000	159,000
1988	12,700	171,700
1989	9,100	180,800
1990	5,300	186,100
1991	14,100	200,200
1992	8,700	208,900
1993	9,600	218,500
1994	16,800	235,300
1995	19,800	255,100
1996	13,800	268,900
1997	4,200	273,100
1998	2,000	275,100
1999	2,700	277,800
2000	4,100	281,900
2001	3,600	285,500
2002	1,100	286,600
2003	100	286,700
2004	500	287,200
2005	4,600	291,800
2006	21,200	313,000
2007	5,800	318,800
2008	-	318,800
2009	-	318,800
2010	-	318,800
2011	-	318,800

Mean Oil Field Water	7,600 af
Median Oil Field Water	7,600 af
Minimum Oil Field Water (Multiple)	0 af
Maximum Oil Field Water (2006)	21,239 af

Table 19. Estimated Annual Groundwater Pumping in the San Joaquin Valley Portion of Kern County

Year	Annual Groundwater Pumped (af)	Cumulative Groundwater Pumped (af)
1970	1,422,000	1,422,000
1971	1,700,000	3,122,000
1972	1,857,000	4,979,000
1973	1,662,000	6,641,000
1974	1,333,000	7,974,000
1975	1,587,000	9,561,000
1976	1,738,000	11,299,000
1977	1,703,000	13,002,000
1978	825,000	13,827,000
1979	1,260,000	15,087,000
1980	977,000	16,064,000
1981	1,161,000	17,225,000
1982	802,200	18,027,200
1983	762,700	18,789,900
1984	1,252,200	20,042,100
1985	1,293,800	21,335,900
1986	947,600	22,283,500
1987	1,208,700	23,492,200
1988	1,540,200	25,032,400
1989	1,588,500	26,620,900
1990	1,796,500	28,417,400
1991	2,002,400	30,419,800
1992	1,673,600	32,093,400
1993	987,700	33,081,100
1994	1,897,700	34,978,800
1995	1,242,800	36,221,600
1996	1,609,600	37,831,200
1997	1,091,400	38,922,600
1998	1,290,200	40,212,800
1999	1,471,500	41,684,300
2000	1,360,100	43,044,400
2001	1,953,900	44,998,300
2002	1,575,000	46,573,300
2003	1,203,900	47,777,200
2004	1,842,300	49,619,500
2005	599,800	50,219,300
2006	717,500	50,936,800
2007	2,212,300	53,149,100
2008	2,306,500	55,455,600
2009	1,212,400	56,668,000
2010	230,400	56,898,400
2011	419,000	57,317,400

Mean Groundwater Pumping	1,364,700 af
Median Groundwater Pumping	1,346,600 af
Minimum Pumping (2010)	230,400 af
Maximum Pumping (2008)	2,306,500 af

Table 20. Historical Annual Irrigated Acreage in the San Joaquin Valley Portion of Kern County

Year	Total Irrigated Acreage	Year	Total Irrigated Acreage (1)
1970	731,753	1996	904,117
1971	685,482	1997	836,662
1972	710,226	1998	855,039
1973	628,836	1999	907,909
1974	813,002	2000	776,846
1975	828,769	2001	835,400
1976	799,986	2002	797,700
1977	755,219	2003	775,100
1978	811,593	2004	797,100
1979	790,496	2005	793,300
1980	801,665	2006	810,000
1981	821,609	2007	815,945
1982	908,784	2008	780,793
1983	759,454	2009	774,968
1984	837,886	2010	883,085
1985	830,204	2011	887,506
1986	694,699		
1987	714,236		
1988	723,574		
1989	789,460		
1990	803,913		
1991	852,247		
1992	833,878		
1993	844,618		
1994	855,389		
1995	850,407		

(1) Double-cropped acreage is counted twice, since it is irrigated twice. Double-cropping is generally a small percentage of total irrigated acreage, in the order of 10,000 to 20,000 acres annually.

Mean Irrigated Acreage 799,100 Acres

Table 21. 2011 Market Values of Selected Kern County Agricultural Products

Top 5 Commodities	Production Value (millions)
Milk	$745
Almonds (inc. by-products)	$727
Grapes (all)	$708
Citrus (fresh & processing)	$540
Carrots (fresh & processing)	$419

Table 22. Monthly Evaporation for San Joaquin Valley Climate Stations

	Wasco 7E	USDA Cotton Station	Greenlee's Pasture	Avg. All Stations
January	1.62	1.27	1.28	1.39
February	1.32	2.92	2.27	2.17
March	5.60	3.77	3.22	4.20
April	5.31	6.43	6.49	6.08
May	7.67	8.75	6.71	7.71
June	11.80	8.95	8.31	9.69
July	10.12	9.78	9.28	9.73
August	10.58	8.93	8.18	9.23
September	6.03	7.41	6.89	6.78
October	4.20	4.40	4.09	4.23
November	2.94	2.23	1.52	2.23
December	1.17	1.77	1.66	1.53
Total	**68.36**	**66.61**	**59.90**	**64.96**
Percent of Normal	**105**	**79**	**92**	**92**

Station Locations

Wasco 7E — Section 6Q, T27S, R26E, MDB&M.
Equipment: USWB Class "A" evaporation pan in an irrigated pasture environment.

USDA Cotton Station — Section 33F, T27S, R25E, MDB&M.
Equipment: USWB Class "A" evaporation pan in an irrigated grass turf environment.

Greenlee's Pasture — Section 36N, T12N, R21W, SBB&M
Equipment: USWB Class "A" evaporation pan in an irrigated pasture environment.

Table 23. 2011 Irrigated Acreage by Crop in the San Joaquin Valley Portion of Kern County

Crop	Acres [2]	Consumptive Water Use [1] (af/Acre)
Alfalfa (including seed)	80,856	4.10
Almonds	188,889	3.28
Apples, Pears, Plums	2,733	3.45
Apricots, Nectarines, Peaches	2,227	3.35
Beans	1,744	2.11
Carrots	26,817	2.55
Citrus	65,926	3.37
Corn, Grain Sorghum	41,809	2.95
Cotton	73,632	2.71
Grapes	114,844	2.81
Grain and Grain Hay	98,372	2.07
Idle, Fallow Lands	83,396	0.33
Melons, Squash, Cucumbers	4,519	1.46
Misc. Deciduous Trees	24,641	3.34
Misc. Field Crops	4,553	2.09
Misc. Subtropical Trees	80	3.38
Misc. Vegetables	14,371	1.62
Nursery	2,845	3.28
Onions, Garlic	12,252	1.70
Pasture, Turf, Misc. Grasses	2,175	4.13
Pistachios	78,922	4.11
Potatoes	22,364	1.98
Safflower, Sunflower	3,216	2.23
Sugar Beets	603	3.29
Tomatoes	17,745	2.51
Turnips	534	1.62
Walnuts	835	3.89
Total Irrigated Lands	**887,503**	**2.65**
Total Crop Lands	**970,900**	
Double Cropped	**11,390**	

Note: Double-cropped acreage is counted twice, since it is irrigated twice.

[1] Weighted average consumptive use of all crops.

[2] Excludes acreage in Arvin-Edison WSD/Wheeler Ridge-Maricopa WSD overlap area.

Table 24. Average Applied Water Requirements for Various Crops in the San Joaquin Valley

Crop	Drip (af/ac) [1]	Sprinkler (af/ac) [2]	Row/Border (af/ac) [3]
Alfalfa		3.45-4.35	3.5-5.15
Almonds	2.85-4.10	2.85-4.50	2.85-4.50
Apples	1.95-3.80	3.40-4.75	
Beans (dry)			2.00-2.75
Carrots		1.75-2.45	
Citrus	2.05-3.75	2.75-4.40	3.50-4.50
Corn (field)			3.00-5.00
Cotton		2.25-3.75	2.45-3.75
Grapes	2.00-4.00	2.15-4.50	2.35-4.85
Lettuce			1.50-2.50
Onions, Garlic		1.00-2.65	1.25-4.25
Melons, Squash, Cucumbers			2.00-3.40
Misc. Deciduous Trees	2.75-3.35	3.00-4.00	3.00-4.50
Nursery			2.25-3.50
Pasture, Irrigated		3.50-4.50	3.50-6.00
Pistachios	2.65-4.40	2.35-3.35	3.00-3.50
Potatoes		1.10-2.30	
Small Grains		1.00-2.50	1.00-2.50
Tomatoes			2.50-3.50
Walnuts			3.50-5.00

[1] Includes emitters, misters, mini-sprinklers and fan jets.
[2] Includes portables, solid-sets, linear moves, sprinkler guns.
[3] Border includes border strip, level basin, contour strip.

Note: A blank entry indicates that an irrigation system is generally not utilized on a crop.

Table 25. 2011 Urban Water Use

Water Purveyor Service Area	Active Connections	Annual Water Use [1] (MG)	(af)	Permanent Population	GPCD [2]
Arvin					
Arvin CSD	4,684	169	517	18,000	26
Bakersfield Metro Area					
California Water Service Co.	81,806	19,028	58,395	270,496	193 [3]
Casa Loma WC	221	Unk	Unk	970	Unk
City of Bakersfield	41,125	10,973	33,675	137,945	218
East Niles CSD	7,835	4,130	12,675	26,000	435
Greenfield CWD	2,660	736	2,259	7,800	259
North of the River MWD	2,022	304	933	7,500	111
Oildale MWC	8,115	7,178	22,028	26,000	756
Vaughn WC	9,284	3,846	11,804	28,451	370
Metro Area Subtotal	**153,068**	**46,195**	**141,769**	**505,162**	**251**
Buttonwillow					
Buttonwillow CWD	443	127	390	1,266	275
Delano					
City of Delano	11,192	3,157	9,689	55,900	155 [4]
Lamont					
Lamont PUD	3,448	1,264	3,880	13,471	257
Lost Hills					
Lost Hills Utility District	375	133	409	2,772	132
McFarland					
McFarland MWC	2,455	67	206	12,333	15
Shafter					
City of Shafter	4,178	1,646	5,051	16,208	278
Taft-Maricopa-McKittrick					
West Kern WD	7,550	20,317	62,351	16,800	3,313 [5]
Wasco					
City of Wasco	4,533	1,493	4,582	19,511	210
Wasco State Prison	1,767	255	781	5,058	138
Total	**193,693**	**74,824**	**229,625**	**666,481**	**238** [6]

(1) Data was obtained from the California Department of Public Health Division of Drinking Water and Environmental Management.

(2) The GPCD computed in this table includes residential, commercial, industrial and public authority water use. The inclusion of commercial, industrial and public authority water use may substantially increase the GPCD for some purveyors. Additionally, these values do not include private well use by M&I users which may substantially reduce the GPCD for some purveyors.

(3) California Water Service Co. includes Olcese Water District.

(4) City of Delano values include Kern Valley State Prison.

(5) Includes significant quantities of water used by oil companies.

(6) Average GPCD exlcudes Taft-Maricopa-McKittrick.

Table 26. Surface and Groundwater Usage or Availability in the San Joaquin Valley Portion of Kern County

	Kern River		Other Local Water		Central Valley Project		State Water Project		Groundwater		
	Available (af)	% of Total	Available (af)	% of Total	Available (af)	% of Total	Available (af)	% of Total	Usage (af)	% of Total	Total Supplies (af)
1970	589,500	19.6	438,900	14.6	351,400	11.7	204,600	6.8	1,422,000	47.3	3,006,400
1971	427,500	14.1	185,000	6.1	348,900	11.5	375,500	12.4	1,700,000	56.0	3,036,900
1972	268,400	8.4	287,700	9.0	238,500	7.5	535,600	16.8	1,857,000	58.3	3,187,200
1973	979,700	25.8	231,400	6.1	412,200	10.8	515,500	13.6	1,662,000	43.7	3,800,800
1974	818,600	22.9	293,400	8.2	480,600	13.4	651,800	18.2	1,333,000	37.3	3,577,400
1975	564,600	15.3	286,500	7.7	442,100	11.9	821,700	22.2	1,587,000	42.9	3,701,900
1976	249,500	7.5	212,000	6.4	226,500	6.8	883,400	26.7	1,738,000	52.5	3,309,400
1977	197,000	7.3	234,400	8.7	121,500	4.5	429,400	16.0	1,703,000	63.4	2,685,300
1978	1,653,500	37.2	1,000,500	22.5	357,800	8.0	611,500	13.7	825,000	18.5	4,448,300
1979	672,700	17.2	213,000	5.5	462,500	11.9	1,291,800	33.1	1,260,000	32.3	3,900,000
1980	1,640,000	37.8	361,600	8.3	462,800	10.7	900,300	20.7	977,000	22.5	4,341,700
1981	449,300	11.9	310,600	8.2	470,000	12.4	1,384,700	36.7	1,161,000	30.8	3,775,600
1982	1,271,100	31.4	436,500	10.8	656,600	16.2	884,500	21.8	802,200	19.8	4,050,900
1983	2,489,100	49.9	953,000	19.1	550,900	11.0	235,000	4.7	762,700	15.3	4,990,700
1984	821,800	21.5	197,500	5.2	425,400	11.1	1,123,000	29.4	1,252,200	32.8	3,819,900
1985	672,400	18.7	210,200	5.9	337,500	9.4	1,074,100	29.9	1,293,800	36.1	3,588,000
1986	1,444,900	35.1	226,800	5.5	589,300	14.3	913,600	22.2	947,600	23.0	4,122,200
1987	375,900	11.9	249,100	7.9	292,000	9.3	1,025,900	32.6	1,208,700	38.4	3,151,600
1988	294,700	8.9	186,800	5.6	292,800	8.8	1,006,200	30.3	1,540,200	46.4	3,320,700
1989	397,000	11.3	143,000	4.1	293,900	8.4	1,097,200	31.2	1,588,500	45.1	3,519,600
1990	203,600	6.5	113,300	3.6	200,100	6.3	840,800	26.7	1,796,500	57.0	3,154,300
1991	406,300	14.1	227,700	7.9	204,400	7.1	32,700	1.1	2,002,400	69.7	2,873,500
1992	296,800	10.5	238,300	8.4	208,000	7.3	418,000	14.7	1,673,600	59.0	2,834,700
1993	853,800	22.3	289,200	7.6	489,800	12.8	1,205,500	31.5	987,700	25.8	3,826,000
1994	336,500	10.1	223,300	6.7	186,300	5.6	695,400	20.8	1,897,700	56.8	3,339,200
1995	1,385,200	27.6	638,600	12.7	647,100	12.9	1,111,200	22.1	1,242,800	24.7	5,024,900
1996	1,038,300	21.7	285,800	6.0	611,300	12.8	1,247,200	26.0	1,609,600	33.6	4,792,200
1997	1,182,000	28.6	212,800	5.2	630,000	15.3	1,013,400	24.5	1,091,400	26.4	4,129,600
1998	1,718,000	30.7	1,286,700	23.0	466,500	8.3	839,200	15.0	1,290,200	23.0	5,600,600
1999	434,000	11.6	179,300	4.8	350,500	9.4	1,308,300	34.9	1,471,500	39.3	3,743,600
2000	476,800	12.9	155,600	4.2	494,000	13.4	1,208,500	32.7	1,360,100	36.8	3,695,000
2001	391,500	11.8	254,700	7.6	331,400	9.9	399,400	12.0	1,953,900	58.7	3,330,900
2002	424,700	13.6	148,300	4.7	250,600	8.0	732,600	23.4	1,575,000	50.3	3,131,200
2003	519,700	16.1	213,000	6.6	363,100	11.3	926,700	28.7	1,203,900	37.3	3,226,400
2004	407,300	12.3	145,400	4.4	241,300	7.3	681,000	20.5	1,842,300	55.5	3,317,300
2005	1,156,100	27.3	338,500	8.0	702,500	16.6	1,431,400	33.9	599,800	14.2	4,228,300
2006	1,071,800	27.7	254,900	6.6	582,500	15.0	1,249,200	32.2	717,500	18.5	3,875,900
2007	252,700	7.9	122,800	3.9	197,900	6.2	403,100	12.6	2,212,300	69.4	3,188,800
2008	518,000	15.5	110,400	3.3	260,000	7.8	148,400	4.4	2,306,500	69.0	3,343,300
2009	470,200	16.5	146,800	5.1	453,800	15.9	568,700	19.9	1,212,400	42.5	2,851,900
2010	910,900	28.7	254,600	8.0	622,000	19.6	1,156,400	36.4	230,400	7.3	3,174,300
2011	1,374,900	31.3	324,600	7.4	664,300	15.1	1,612,400	36.7	419,000	9.5	4,395,200
Avg.	**764,400**	**20.8**	**305,300**	**8.3**	**404,100**	**11.0**	**838,000**	**22.8**	**1,364,700**	**37.1**	**3,676,500**

* Adjusted for deliveries within Kern County. SWP includes Intertie deliveries.

Table 27. Summary of Kern River-California Aqueduct Intertie Activity

	Intertie Inflow (af)			Amount Exported (af)			Retained in County (af)		
	Kern River	Friant-Kern	Total	Kern River	Friant-Kern	Total	Kern River	Friant-Kern	Total
1978	168,818	9,113	177,931	n/a*	n/a*	113,831	n/a*	n/a*	64,100
1980	138,816	0	138,816	74,024	0	74,024	64,792	0	64,792
1982	10,339	11,968	22,307	5,928	2,700	8,628	4,411	9,268	13,679
1983	662,856	96,200	759,056	n/a*	n/a*	393,551	n/a*	n/a*	365,505
1984	27,524	0	27,524	13,885	0	13,885	13,639	0	13,639
1986	1,867	15,580	17,447	0	4,746	4,746	1,867	10,834	12,701
1995	(13,117)	0	(13,117) [1]	0	0	0	(13,117)	0	(13,117) [1]
1997	1,793	51,055	52,848	1,793	47,496	49,289	0	5,352	5,352 [1]
1998	130,226	57,822	188,048	130,226	57,822	188,048	0	0	0
2006	70,624	31,116	101,740	70,624	31,116	101,740	0	0	0
Total	**1,199,746**	**272,854**	**1,472,600** [2]			**947,742**			**526,651** [2]

* A breakdown between sources was not available.

[1] A major flood event north of Kern County caused SWP water to be reverse flowed into the Kern River flood channel. This is the opposite operation for which the Intertie was designed and constructed.

[2] The year 1995 is not included in totals.

Source: California Department of Water Resources and anual City of Bakersfield Kern River Reports.

Table 28. Summary of Groundwater Recharge Activities (af)

Entity/Location		Source	1971-99	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010		Total
BANKING																
City of Bakersfield [2]																
2800 Acres		Combined [1]	780,016	--	--	1,480	1,788	6,956	32,567	30,740	--	--	--	--	--	853,547
																--
Kern County Water Agency																0
Kern Water Bank		Combined [1]	18,757	--	--	--	--	--	--	--	--	--	--	28,238	445,983	492,978
Pioneer Property		Combined [1]	251,378	15,049	5,193	1,434	8,366	6,811	203,379	80,935	4,954	--	--	11,163	175,908	764,570
Berrenda Mesa Spreading Area		Combined [1]	116,508	--	--	--	719	2,872	32,749	25,979	1,961	--	--	1,047	37,250	219,085 [1]
Kern River Channel		Combined [1]	76,598	--	--	--	--	--	12,628	294	--	--	--	--	541	90,061
2800 Acres		Combined [1]	319,842	--	--	--	--	--	--	--	--	--	--	--	--	319,842
Subtotal KCWA			**783,083**	**15,049**	**5,193**	**1,434**	**9,085**	**9,683**	**248,756**	**107,208**	**6,915**	**--**	**--**	**40,448**	**659,682**	**1,886,536**
DWR-Kern Water Bank																
2800 Acres		SWP	7,379	--	--	--	--	--	--	--	--	--	--	--	--	7,379
Local Elements In-lieu Rechg.		SWP	136,300	--	--	--	--	--	--	--	--	--	--	--	--	136,300
Local Elements Direct Rechg.		SWP	4,200	--	--	--	--	--	--	--	--	--	--	--	--	4,200
Subtotal DWR			**147,879**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**147,879**
Kern Water Bank Authority																
Kern Water Bank		Combined [1]	832,815	40,323	10,030	13,439	40,374	18,065	356,807	273,739	16,627	--	--	--	--	1,602,219
2800 Acres		Combined [1]	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pioneer Property		Combined [1]	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Subtotal KWBA			**832,815**	**40,323**	**10,030**	**13,439**	**40,374**	**18,065**	**356,807**	**273,739**	**16,627**	**--**	**--**	**--**	**--**	**1,602,219**
Semitropic WSD	In-lieu	SWP	36,031	40,323	4,500	8,793	--	--	220,218	27,419	5,438	2,949	--	--	--	345,671
Kern Delta WD	Direct	SWP	--	--	--	--	--	--	13,419	9,249	--	--	--	--	--	22,668
Rosedale-Rio Bravo WSD	Direct	SWP	--	--	--	--	--	--	20,000	1,450	8,200	600	--	--	--	30,250
Arvin-Edison WSD	Direct	SWP	118,066	101,950	--	--	40,509	--	--	7,321	--	--	--	--	--	267,846
		SWP	24,048	30,439	--	--	--	--	--	--	--	--	--	--	--	54,487
Total Banking			**2,543,793**	**228,084**	**19,723**	**16,353**	**51,247**	**34,704**	**638,130**	**411,687**	**23,542**	**--**	**--**	**40,448**	**659,682**	**4,490,181**
CONJUNCTIVE USE																
Arvin-Edison WSD Direct Rechg.		Combined [1]	1,144,375	--	23,357	8,764	5,314	49,169	101,806	65,131	4,460	3,300	84,507	83,174	25,270	1,598,627
		F-K	1,144,375	--	2,557	8,764	5,314	31,404	101,806	65,131	4,460	3,300	45,992	82,843	18,952	1,514,898
		SWP	--	--	--	--	--	--	--	--	--	--	--	331	6,318	6,649
In-Lieu Rechg.		SWP	--	--	20,800	--	--	17,765	--	--	--	--	38,515	--	--	77,080
Buena Vista WSD Direct Rechg.		Combined [1]	1,823,450	2	--	--	--	--	7,719	3,355	3,941	--	--	N/A	N/A	1,838,467
		Kern	28,634	29,790	30,692	34,853	40,951	82,793	56,951	38,480	21,286	--	--	N/A	N/A	364,430
		SWP	7,640	17,652	5,599	--	--	--	5,674	7,295	4,223	--	--	N/A	N/A	48,083
		F-K	3,807	--	--	--	--	--	1,418	10,998	159	--	--	N/A	N/A	16,382
In-Lieu Rechg.		Combined [1]	15,617	17,389	--	--	--	--	4,764	5,949	17,344	--	--	N/A	N/A	61,063
		Kern	25,385	28,977	19,587	--	--	--	85,783	81,257	41,561	--	--	N/A	N/A	282,550
		SWP	75,529	57,939	28,683	--	--	--	18,075	42,519	27,808	--	--	N/A	N/A	250,553
		F-K	5,135	--	--	--	--	--	393	924	1,424	--	--	N/A	N/A	7,876
Cawelo WD Direct Rechg.		Combined [1]	--	--	3,171	6,577	8,479	10,054	--	--	--	5,610	--	--	--	33,891
		SWP	--	--	--	--	--	--	--	4,441	--	--	--	--	--	4,441
		Kern	--	--	--	--	--	--	--	--	--	--	--	--	--	--
In-Lieu Rechg.		Combined [1]	--	--	--	--	--	--	--	6,094	--	--	--	--	--	6,094
Semitropic WSD Direct Rechg.		SWP	274,761	10,703	8,459	--	--	--	N/A	N/A	N/A	N/A	N/A	N/A	N/A	293,923
		Combined [1]	273	--	--	8,793	11,961	11,101	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32,128
		Kern	495	541	125	--	--	--	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,161
In-Lieu Rechg.		SWP	1,148,666	179,958	16,132	--	--	--	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,344,756
		F-K	1,383	--	--	--	--	--	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,383
ID4 Direct Rechg.		Combined [1]	76,329	--	4,496	55,322	83,282	37,356	--	--	--	--	--	--	--	256,785 [1]
		Kern	666,867	22,843	18,601	--	--	--	36,502	16,088	5,308	9,530	--	--	6,244	781,983
		SWP	410,901	26,304	4,440	--	--	--	50,704	58,002	10,223	716	38,231	64,102	21,052	684,675
		F-K	49,982	4,699	--	--	--	--	16,557	8,070	1,567	--	--	--	172	81,047
Kern Delta WD Direct Rechg.		Combined [1]	1,491,893	--	--	--	--	--	--	615	867	--	--	--	--	1,493,375
		Kern	53,636	49,609	49,687	52,557	68,774	52,544	60,333	51,341	38,700	43,619	40,879	53,589	90,634	705,902
		SWP	5,275	8,393	2,016	--	--	--	788	5,375	1,923	845	845	127	8,339	33,926
North Kern WSD Direct Rechg.		Kern	2,358,372	29,412	29,480	--	--	--	89,675	94,784	6,726	2,384	--	N/A	N/A	2,610,833
		Combined [1]	9,736	3,477	--	367	575	12,109	56,540	52,970	31,414	25,379	--	N/A	N/A	192,567
		F-K	--	--	--	--	--	--	3,911	46,062	19,565	--	--	N/A	N/A	69,538
In-Lieu Rechg.		Kern	3,039,269	75,707	44,503	--	--	--	138,753	140,039	133,953	149,998	--	N/A	N/A	3,722,222
		SWP	68,043	21,868	--	--	--	--	--	--	--	--	--	N/A	N/A	89,911
		F-K	5,175	--	--	--	--	--	--	--	--	--	--	N/A	N/A	5,175
		Combined [1]	239	3,005	2,498	--	--	--	--	--	--	--	--	N/A	N/A	5,742
Rosedale-Rio Bravo WSD Direct Rechg.		Kern	885,052	8,384	3,972	--	--	--	104,906	87,437	3,295	--	--	N/A	N/A	1,093,046
		SWP	740,612	7,030	17,871	--	--	--	23,629	47,835	718	--	--	N/A	N/A	837,695
		F-K	242,807	31,871	2,650	--	--	--	66,063	10,728	1,800	--	--	N/A	N/A	355,919
		Combined [1]	279,800	--	7,015	4,166	28,361	8,681	--	--	--	--	--	N/A	N/A	328,023 [1]
In-Lieu Rechg.		SWP	13,001	66	402	--	--	--	--	--	--	--	--	N/A	N/A	13,469
		F-K	--	3,030	--	--	--	--	--	--	--	--	--	N/A	N/A	3,030
		Kern	354	--	--	--	--	--	--	--	--	--	--	N/A	N/A	354
Rosedale Ranch ID Direct Rechg.		Kern	413	--	--	--	--	--	--	--	--	--	--	--	--	413
In-Lieu Rechg.		Kern	5,387	1,621	593	--	--	--	--	--	--	--	--	--	--	7,601
		SWP	121	--	--	--	--	--	--	--	--	--	--	--	--	121
Wheeler Ridge-Maricopa WSD		SWP	2,788	--	--	--	--	--	--	--	--	--	--	N/A	N/A	2,788
In-Lieu Recharge		SWP	213,246	--	--	--	--	--	--	--	--	--	--	N/A	N/A	213,246
Total Conjunctive Use			**16,318,823**	**640,270**	**347,386**	**180,163**	**253,011**	**312,976**	**1,032,750**	**950,920**	**382,725**	**244,681**	**248,969**	**284,166**		**21,373,821**
OVERDRAFT CORRECTION																
Groundwater Replenishment Programs																
Direct Rechg.		Kern	261,955	--	--	--	--	--	8,228	14,548	4,491	20,107	13,590	761	33,254	356,934
		SWP	3,286,607	180	--	--	--	--	6,286	7,724	--	--	--	--	--	3,300,797
		F-K	24,302	23,341	--	--	--	--	65,164	8,453	--	--	--	--	2,961	124,221
In Lieu Rechg.		Kern	15,007	--	--	--	--	--	--	--	--	--	--	--	--	15,007
		SWP	98,065	--	--	--	--	--	--	--	--	--	--	--	--	98,065
Total Overdraft Correction			**3,685,936**	**23,521**	**--**	**--**	**--**	**--**	**79,678**	**30,725**	**4,491**	**20,107**	**13,590**	**761**	**36,215**	**3,895,024**
GRAND TOTALS		**Kern**	**7,340,826**	**246,884**	**197,240**	**87,410**	**109,725**	**135,337**	**581,131**	**523,974**	**255,320**	**225,638**	**54,469**	**54,350**	**130,132**	**9,942,436**
		SWP	**6,671,279**	**502,805**	**108,902**	**8,793**	**40,509**	**17,765**	**358,793**	**218,630**	**58,533**	**5,110**	**77,591**	**64,560**	**35,709**	**8,168,979**
		F-K	**1,471,831**	**62,941**	**5,207**	**8,764**	**5,314**	**31,404**	**255,312**	**150,366**	**28,975**	**3,300**	**45,992**	**82,843**	**22,085**	**2,179,469**
		Combined [1]	**7,237,626**	**79,245**	**55,760**	**100,342**	**189,219**	**163,174**	**808,959**	**545,801**	**81,568**	**34,289**	**84,507**	**123,622**	**684,952**	**10,189,064 [1]**
		Total	**22,721,562**	**891,875**	**367,109**	**205,309**	**344,767**	**347,680**	**2,004,195**	**1,438,771**	**424,396**	**268,337**	**262,559**	**325,375**	**872,878**	**30,479,948**

[1] Breakdown between sources not available.
N/A Data not available at time of printing.

Table 29. Summary of Groundwater Banking by Entity (af)

	1978-1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Alameda County WD													
Recharge/Purchase	64,340	37,320	5,000	16,370	25,300	13,740	36,040	12,567	1,746				212,423
Recovery/Sale	-		(1,807)				-	-	(5,000)	(17,000)	(3,083)		(26,890)
Storage Balance	64,340	101,660	104,853	121,223	146,523	160,263	196,303	208,870	205,616	188,616	185,533	185,533	185,533
Belridge WSD													
Recharge/Purchase	52,747	4,947	1,537	638	359	2,681	39,477	19,402	881			2,476	125,145
Recovery/Sale	(2,029)		(10,999)	(3,096)	(371)	(7,983)	-	2,700	(12,556)	(23,376)	(19,751)	(5,301)	(82,762)
Storage Balance	50,718	55,665	46,203	43,745	43,733	38,431	77,908	100,010	88,335	64,959	45,208	42,383	42,383
Berrenda Mesa WD													
Recharge/Purchase	132,127	2,593	1,536	772	816	2,003	47,693	28,899	1,846			1,936	220,221
Recovery/Sale	(13,902)		(12,504)	(129)	(1,395)	(519)	-	-	(33,537)	(37,941)	(24,922)	(7,960)	(132,809)
Storage Balance	118,225	120,818	109,850	110,493	109,914	111,398	159,091	187,990	156,299	118,358	93,436	87,412	87,412
Buena Vista WSD													
Recharge/Purchase	122,118			359			15,826	7,893	-				146,196
Recovery/Sale	(24,794)		(9,538)	(10,574)	(7,330)		-	-	(9,765)	(9,729)	(3,136)	(1,628)	(76,494)
Storage Balance	97,324	97,324	87,786	77,571	70,241	70,241	86,067	93,960	84,195	74,466	71,330	69,702	69,702
California Water Service Co.													
Recharge/Purchase	-	41,826					-	-	-				41,826
Recovery/Sale	-						-	-	-				-
Storage Balance	-	41,826	41,826	41,826	41,826	41,826	41,826	41,826	41,826	41,826	41,826	41,826	41,826
Castaic Lake WA													
Recharge/Purchase	-			24,000		32,522	20,000	1,450	8,200				86,172
Recovery/Sale	-			-			-	-	-		(4,950)		(4,950)
Storage Balance	-			24,000	24,000	56,522	76,522	77,972	86,172	86,172	81,222	81,222	81,222
Cawelo WD													
Recharge/Purchase	19,313				341		-	-	-				19,654
Recovery/Sale	(44)		(5,014)	(6,305)	(115)	(6,231)	-	-	-				(17,709)
Storage Balance	19,269	19,269	14,255	7,950	8,176	1,945	1,945	1,945	1,945	1,945	1,945	1,945	1,945
City of Bakersfield													
Recharge/Purchase	495,191		64				32,567	30,740	-				558,562
Recovery/Sale	(285,403)	(3,426)	(9,227)	(3,716)	(5,426)		-	-	-				(307,198)
Storage Balance	209,788	206,362	197,199	193,483	188,057	188,057	220,624	251,364	251,364	251,364	251,364	251,364	251,364
City of Tracy													
Recharge/Purchase	-						-	-	1,000				1,000
Recovery/Sale	-						-	-	(100)	(100)			(200)
Storage Balance	-						-	-	900	800	800	800	800
Dudley Ridge WD													
Recharge/Purchase	56,609	952	1,710	736	350	1,657	20,575	13,621	2,161			304	98,675
Recovery/Sale	-		(3,348)	(1,395)	(374)	(4,945)	-	-	(6,055)	(20,517)	(17,328)	(14,031)	(67,993)
Storage Balance	56,609	57,561	55,923	55,264	55,240	51,952	72,527	86,148	82,254	61,737	44,409	30,682	30,682
Henry Miller WD													
Recharge/Purchase	13,254					799	9,706	29	-				23,788
Recovery/Sale	-		(210)				-	-	-				(210)
Storage Balance	13,254	13,254	13,044	13,044	13,044	13,843	23,549	23,578	23,578	23,578	23,578	23,578	23,578
Improvement District No. 4													
Recharge/Purchase	260,700	2			17,730	3,811	41,955	33,475	2,623			715	361,011
Recovery/Sale	(5,100)		(19,923)	(10,115)	(4,014)	(1,762)	-	-	(8,413)	(12,312)	(13,435)	(4,160)	(79,234)
Storage Balance	255,600	255,602	235,679	225,564	239,280	241,329	283,284	316,759	310,969	298,657	285,222	281,777	281,777
Kern County Water Agency													
Recharge/Purchase	265,329	7,505					6,007	1,235	2,559				282,635
Recovery/Sale	(105,564)		(4,413)	(8,240)			-	-	-	(968)	(1,460)	(659)	(121,304)
Storage Balance	159,765	167,270	162,857	154,617	154,617	154,617	160,624	161,859	164,418	163,450	161,990	161,331	161,331
Kern Delta WD													
Recharge/Purchase	1,181				199	2,185	13,419	9,249	-				26,233
Recovery/Sale	-						-	-	-				-
Storage Balance	1,181	1,181	1,181	1,181	1,380	3,565	16,984	26,233	26,233	26,233	26,233	26,233	26,233
Lost Hills WD													
Recharge/Purchase	107,544		804	774	3,343	2,643	27,187	18,017	772			1,618	162,702
Recovery/Sale	-		(9,001)	(199)	(248)	(439)	-	-	(10,035)	(20,284)	(21,098)	(6,882)	(68,186)
Storage Balance	107,544	107,544	99,347	99,922	103,017	105,221	132,408	150,425	141,162	120,878	99,780	94,516	94,516
Madera WD													
Recharge/Purchase	-			1,100	1,200	2,643	-	-	-				4,943
Recovery/Sale	-					(439)	-	-	-				(439)
Storage Balance	-	-	-	1,100	2,300	4,504	4,504	4,504	4,504	4,504	4,504	4,504	4,504
Metropolitan WD of So. California (in Semitropic WSD)													
Recharge/Purchase	452,069				70,940		31,210	14,852	-				569,071
Recovery/Sale	-		(31,500)		(10,000)	(98,368)	-	-	(93,986)	(124,745)	(65,499)		(424,098)
Storage Balance	452,069	452,069	420,569	420,569	481,509	383,141	414,351	429,203	335,217	210,472	144,973	144,973	144,973
Metropolitan WD of So. California (in Arvin-Edison WSD)													
Recharge/Purchase	85,311	133,944		20,866	40,631		-	-	1,881				282,633
Recovery/Sale	-		(20,800)		(12,380)	(43,277)	-	-	(24,225)	(37,602)	(56,448)		(194,732)
Storage Balance	85,311	219,255	198,455	219,321	247,572	204,295	204,295	204,295	181,951	144,349	87,901	87,901	87,901
Metropolitan WD of So. California (in Kern Delta WD)													
Recharge/Purchase	-				20,134		15,576	-	-				35,710
Recovery/Sale	-					(43,277)	-	-	(5,000)	(8,402)	(13,016)		(69,695)
Storage Balance	-	-	-	-	20,134	(23,143)	(7,567)	(7,567)	(12,567)	(20,969)	(33,985)	(33,985)	(33,985)
OlceseWD/Hacienda WD													
Recharge/Purchase	206,686						-	-	-				206,686
Recovery/Sale	(136,284)	(41,826)					-	-	-				(178,110)
Storage Balance	70,402	28,576	28,576	28,576	28,576	28,576	28,576	28,576	28,576	28,576	28,576	28,576	28,576
Rosedale-Rio Bravo WSD													
Recharge/Purchase	22,985		1,262	1,946	9,275		25,764	987	-				62,219
Recovery/Sale	(12,265)						-	7,292	-				(4,973)
Storage Balance	10,720	10,720	11,982	13,928	23,203	23,203	48,967	57,246	57,246	57,246	57,246	57,246	57,246
Semitropic WSD													
Recharge/Purchase	122,569		634	8,179	31,951	1,014	97,572	24,463	2,473			19,587	308,442
Recovery/Sale	(181)		(27,492)	(9,682)	(15,893)	(45,786)	(10,000)	-	(32,685)	(61,924)	(9,047)		(212,690)
Storage Balance	122,388	122,388	95,530	94,027	110,085	65,313	152,885	177,348	147,136	85,212	76,165	95,752	95,752
Santa Clara Valley WD													
Recharge/Purchase	129,300	23,730		3,311	33,000		75,889	14,852	3,692				283,774
Recovery/Sale	-		(30,000)				-	-	(20,000)	(10,000)	(33,453)		(93,453)
Storage Balance	129,300	153,030	123,030	126,341	159,341	159,341	235,230	250,082	233,774	223,774	190,321	190,321	190,321
State of California													
Recharge/Purchase	255,384						-	-	-				255,384
Recovery/Sale	(126,822)						-	-	-				(126,822)
Storage Balance	128,562	128,562	128,562	128,562	128,562	128,562	128,562	128,562	128,562	128,562	128,562	128,562	128,562
Tehachapi-Cummings County WD													
Recharge/Purchase													-
Recovery/Sale													-
Storage Balance													-
Tejon-Castac WD													
Recharge/Purchase	16,434	1,895	245	3,205	135	583	4,014	5,251	1,640			267	33,669
Recovery/Sale	-			(124)	(186)	(47)	-	-	-				(357)
Storage Balance	16,434	18,329	18,574	21,655	21,604	22,140	26,154	31,405	33,045	33,045	33,045	33,312	33,312
Westlands Water District													
Recharge/Purchase	-						10,717	-	8,867				19,584
Recovery/Sale	-						-	-	(5,000)		(6,063)		(11,063)
Storage Balance	-						10,717	10,717	14,584	14,584	8,521	8,521	8,521
Westside Mutual Water Co.													
Recharge/Purchase	409,824	29,650	4,786	2,946	6,368	12,277	114,871	146,833	9,162			8,456	745,173
Recovery/Sale	(5,000)		(47,291)	(16,118)	(37,710)	(3,393)	-	-	(133,421)	(96,697)	(80,687)	(17,519)	(437,836)
Storage Balance	404,824	434,474	391,969	378,797	347,455	356,339	471,210	618,043	493,784	397,087	316,400	307,337	307,337
Wheeler Ridge-Maricopa WSD													
Recharge/Purchase	275,857	7,826	2,706	5,118	11,175	10,764	132,218	71,593	-			5,089	522,346
Recovery/Sale	(7,551)		(32,414)	(520)	(867)	(2,293)	-	(22,700)	(78,374)	(85,199)	(76,660)	(20,781)	(327,359)
Storage Balance	268,306	276,132	246,424	251,022	261,330	269,801	402,019	450,912	372,538	287,339	210,679	194,987	194,987
Total of All Accounts													
Recharge/Purchase	3,566,872	292,190	20,284	90,320	273,247	89,322	818,283	455,408	49,503	-	-	40,448	5,695,877
Recovery/Sale	(724,939)	(45,252)	(275,481)	(70,213)	(96,309)	(258,759)	(10,000)	(12,708)	(478,152)	(566,796)	(450,036)	(78,921)	(3,067,566)
Storage Balance	2,841,933	3,088,871	2,833,674	2,853,781	3,030,719	2,861,282	3,669,565	4,112,265	3,683,616	3,116,820	2,666,784	2,628,311	2,628,311

Note: Storage balances have not been adjusted to reflect evaporation or other losses.
Some numbers may have been revised from previous years Water Supply Report.

Table 30. Areal Extent of Shallow Groundwater

	Summer Measurements						Winter Measurements			
Year	0-5 ft.	5-10 ft.	10-15 ft.	15-20 ft.	Total	No. of Piezo's	0-5 ft.	5-10 ft.	10-15 ft.	15-20 ft.
1976	27,940	64,700	--	79,680 (1)	172,320	--	--	--	--	--
1977	19,320	68,980	--	95,960 (1)	184,260	180	16,930	52,530	--	67,300 (3)
1978	27,680	65,760	--	87,920 (1)	181,360	174	9,600	59,520	--	86,400 -3
1979	30,270	67,310	--	95,870 (1)	193,450	--	15,320	83,200	--	80,640 (3)
1980	74,357	82,787	--	125,883 (1)	283,027	--	45,882	92,998	126,665	62,578
1981	62,002	85,556	--	128,323 (1)	275,881	178	46,746	75,318	36,736	104,200
1982	78,725	95,615	76,271	30,226	280,837	259	90,658	85,541	55,392	43,181
1983	109,915	90,090	63,510	48,980	312,495	227	--	--	--	--
1984	110,500	57,650	45,400	47,649	261,199	246	--	--	--	--
1985	49,396	120,396	123,776	90,323	383,891	290	--	--	--	--
1986	84,160	79,774	73,698	83,264	320,896	330	--	--	--	--
1987	57,600	84,864	89,816	76,672	308,952	261	90,800	74,100	61,200	72,200
1988	82,700	86,500	83,900	93,400	346,500	288	--	--	--	--
1989	65,536	95,949	83,558	85,760	330,803	328	--	--	--	--
1990	67,561	91,257	82,823	-- (2)	241,641 (3)	350	--	--	--	--
1991	40,363	101,888	45,141	-- (2)	187,392 (3)	351	--	--	--	--
1992	9,954	102,114	46,287	-- (2)	158,355 (3)	344	--	--	--	--
1993	25,184	97,357	46,893	-- (2)	169,434 (3)	518	--	--	--	--
1994	19,176	106,506	69,362	-- (2)	195,044 (3)	422	--	--	--	--
1995	96,431	82,231	57,427	55,416	291,505	377	--	--	--	--
1996	27,117	157,484	68,300	65,176	318,077	398	--	--	--	--
1997	29,597	146,439	58,702	62,982	297,720	240	--	--	--	--
1998	27,117	157,484	68,300	65,176	318,077	398	--	--	--	--
1999	37,016	119,333	56,017	71,638	284,004	264	--	--	--	--
2000	33,956	130,232	69,056	63,816	297,060	232	--	--	--	--
2001	32,874	137,560	69,521	52,857	292,812	256	--	--	--	--
2002	25,569	131,960	76,206	56,922	290,657	238	--	--	--	--
2003	11,083	150,082	71,191	72,487	304,843	267	--	--	--	--
2004	10,840	147,862	68,836	81,849	309,387	270	--	--	--	--
2005	15,057	138,833	74,989	82,993	311,873	288	--	--	--	--
2006	16,544	139,293	73,839	69,140	298,816	286	--	--	--	--
2007	13,408	143,676	75,966	75,915	308,964	288	--	--	--	--
2008	13,072	139,898	80,053	76,005	309,028	296	--	--	--	--
2009	11,466	141,595	74,281	79,500	306,842	299	--	--	--	--
2010	26,498	241,407	120,126	100,412	488,443	264	--	--	--	--
2011	7,510	132,459	70,734	99,077	309,781	303	--	--	--	--

(1) 10-20 ft. measurement.

(2) Data insufficient to establish a 20 foot contour. Total is area within 15 feet.

(3) No 15 foot contour established. Total is within 20 feet.

-- Data not available.

Note: Annual changes in shallow groundwater area may be perceived rather than real, due to increases in the number of monitoring prepare the maps. More monitoring wells may have provided better coverage, allowing for a more accurate map to be produc

Figure 1. Hydrological Cycle Diagram

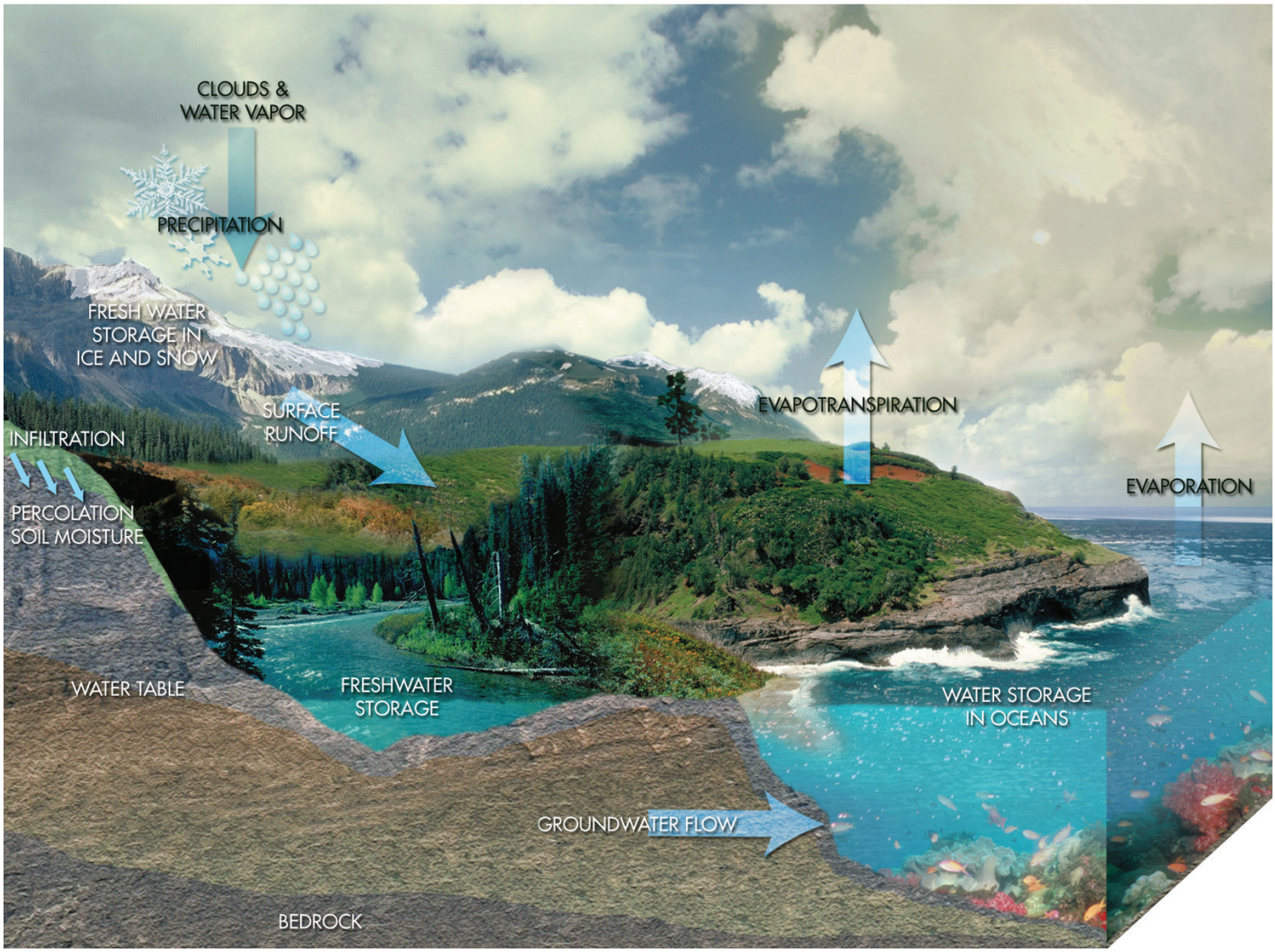


Figure 2. General Location of the Kern County Water Agency and its Member Units

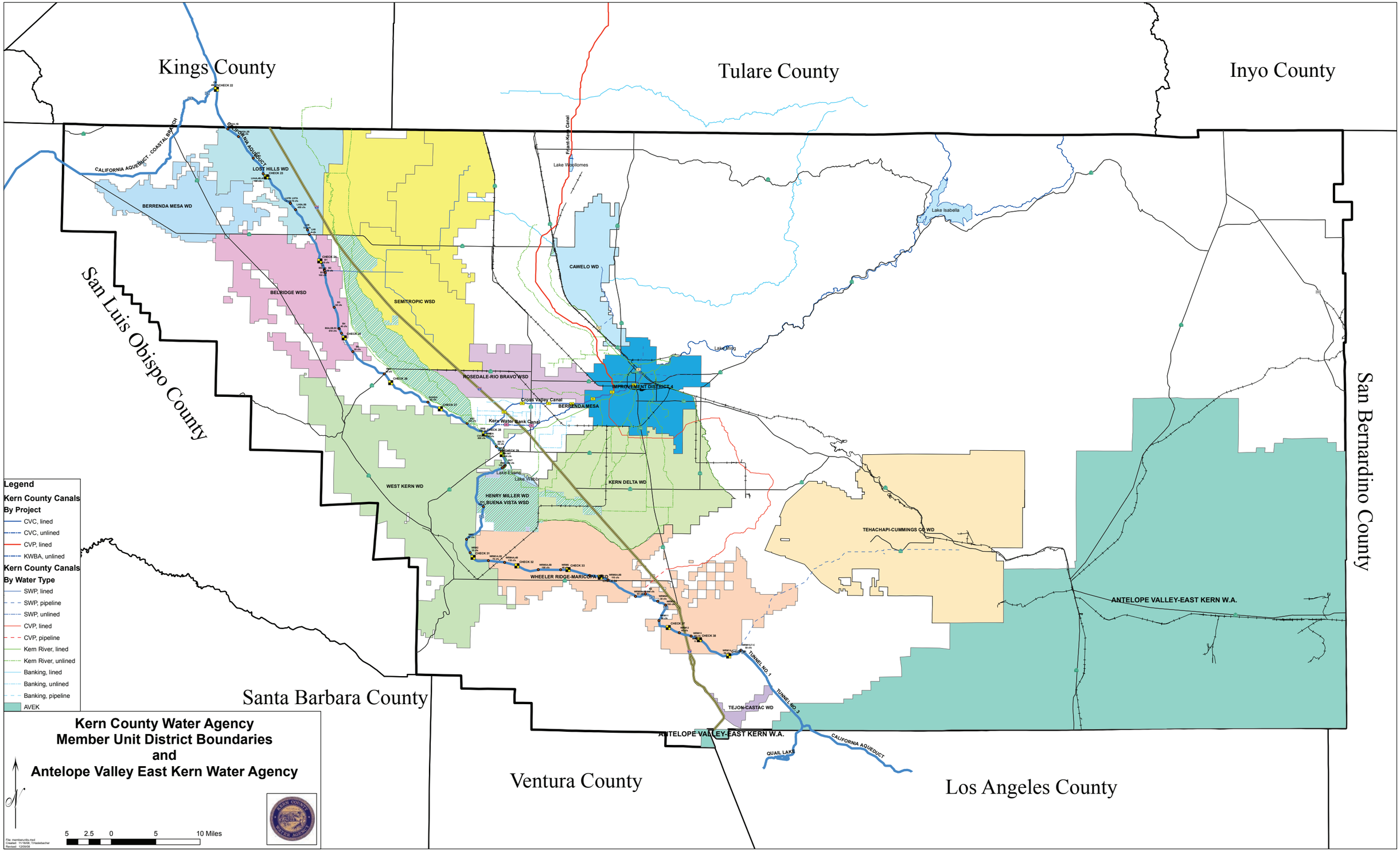


Figure 3. Historical Sacramento Valley Unimpaired Runoff

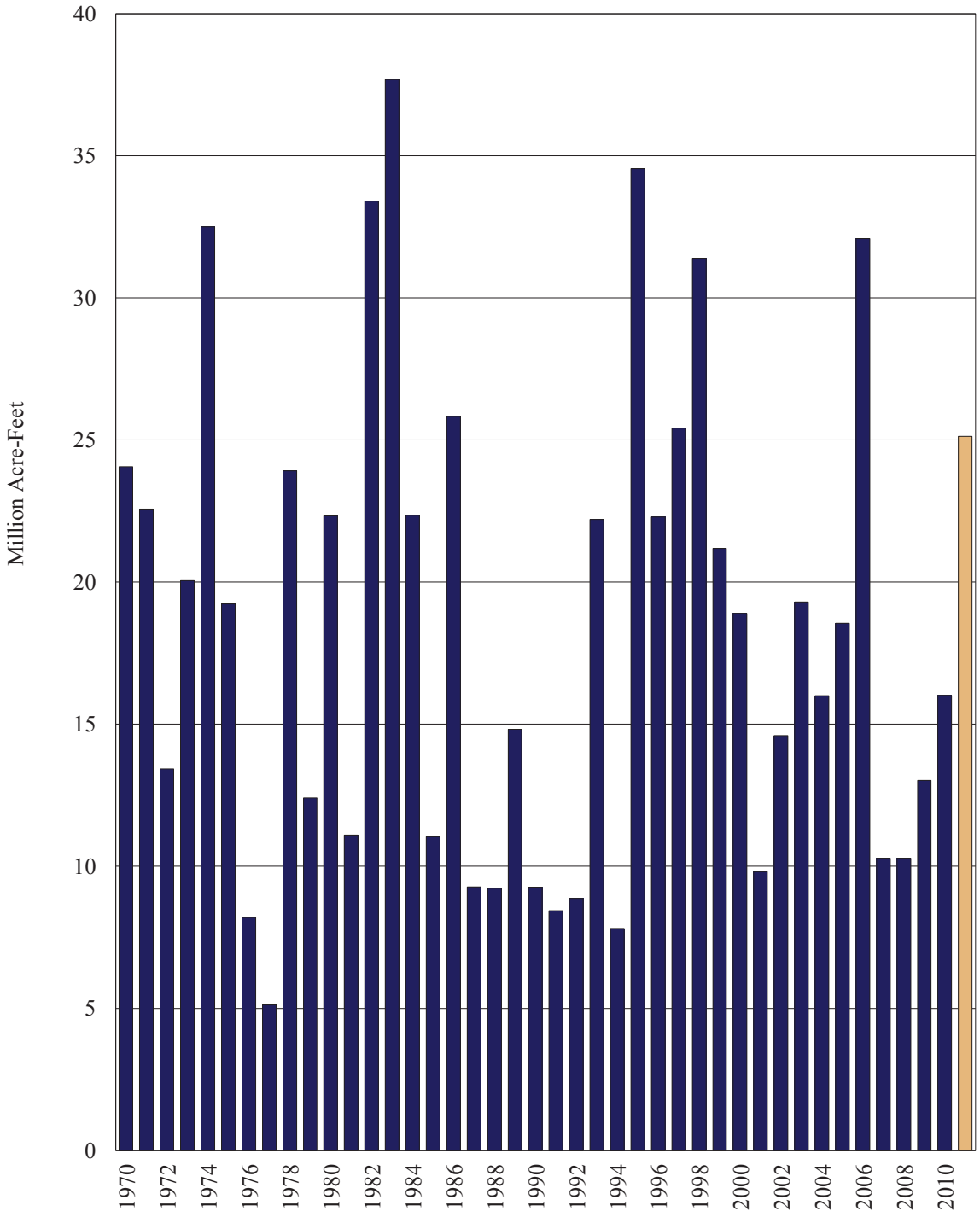


Figure 4. Historical Sacramento Valley Water Year Indices

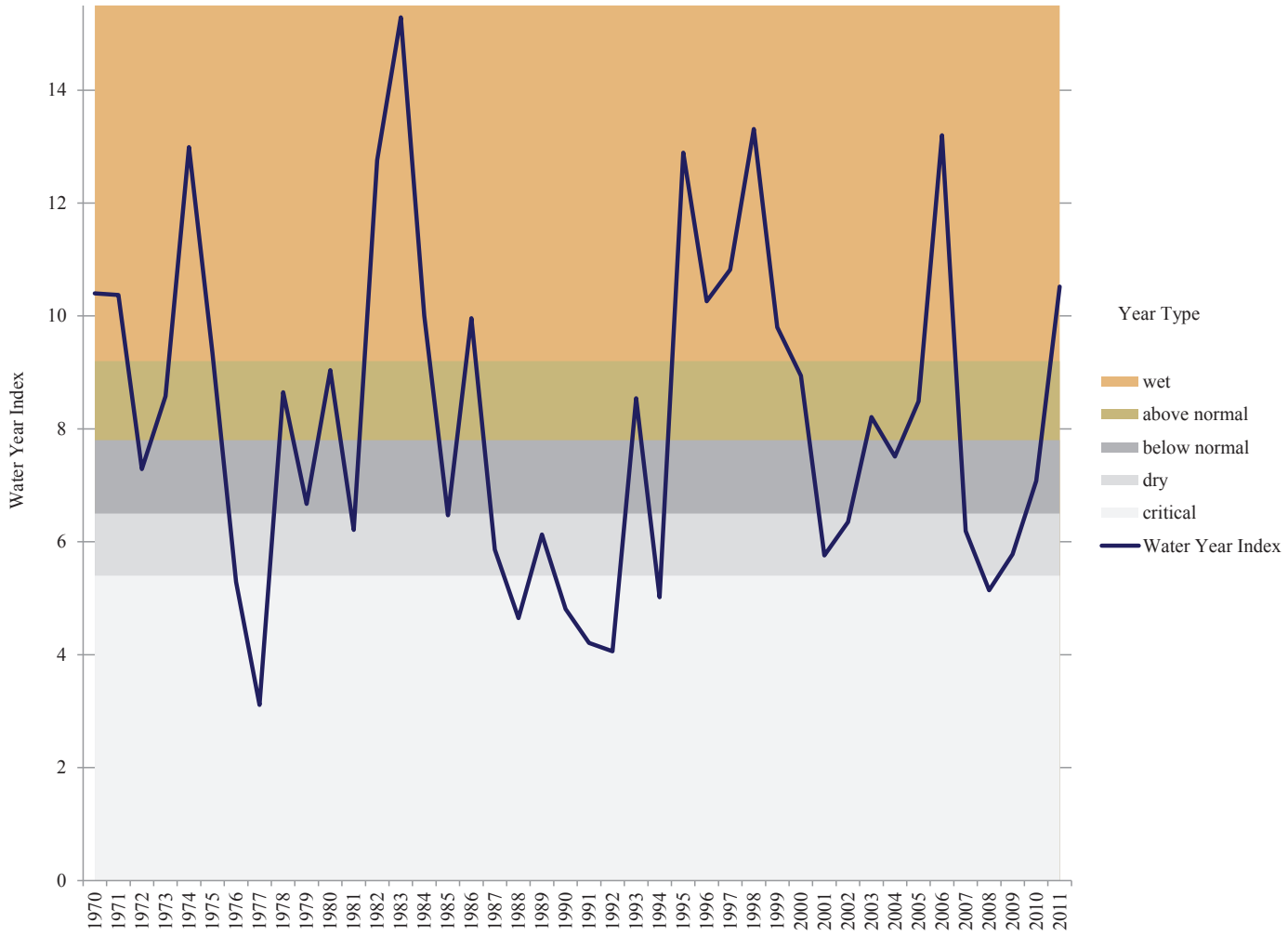


Figure 5. Historical SWP Deliveries into Kern County

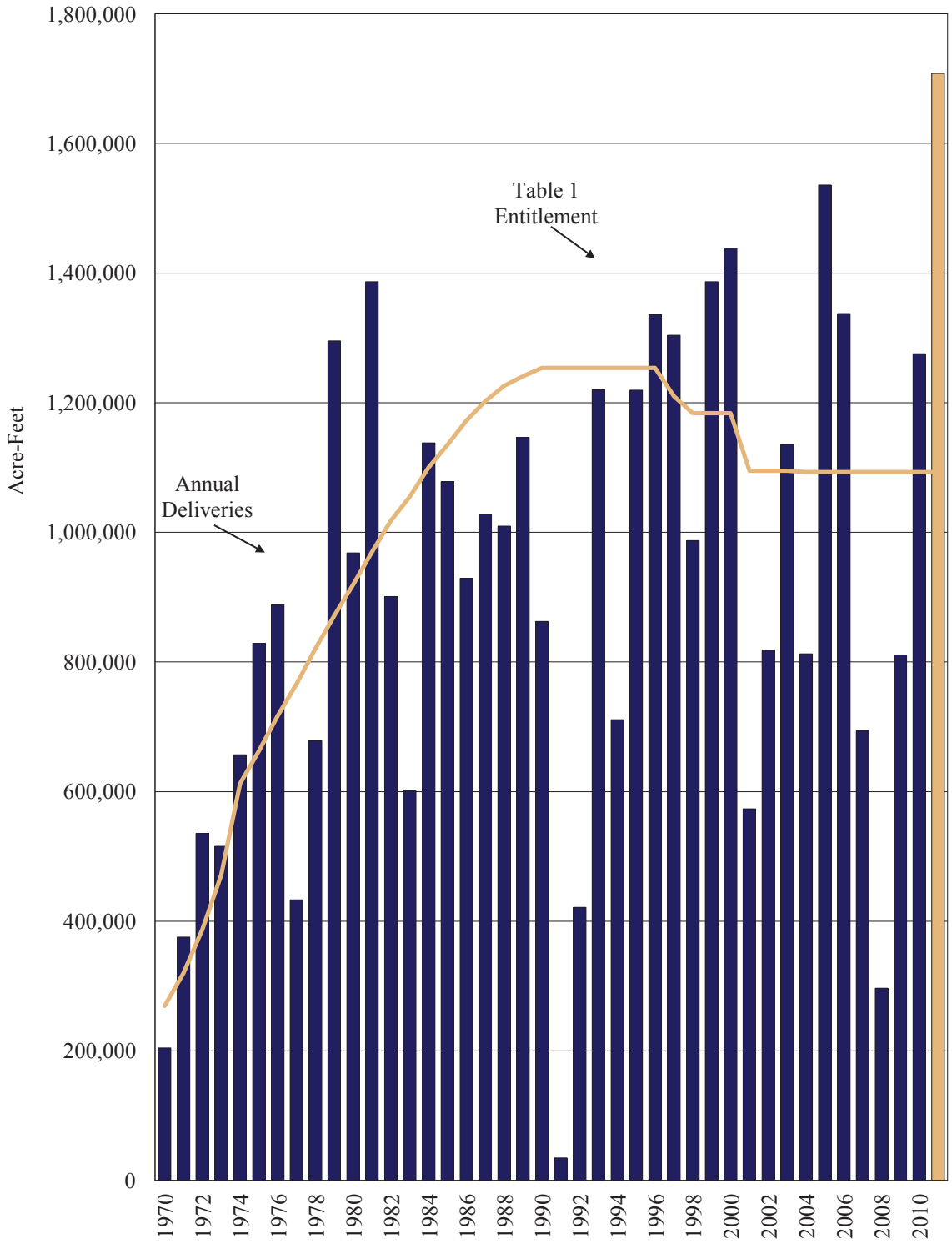


Figure 6. Historical CVP Deliveries into Kern County

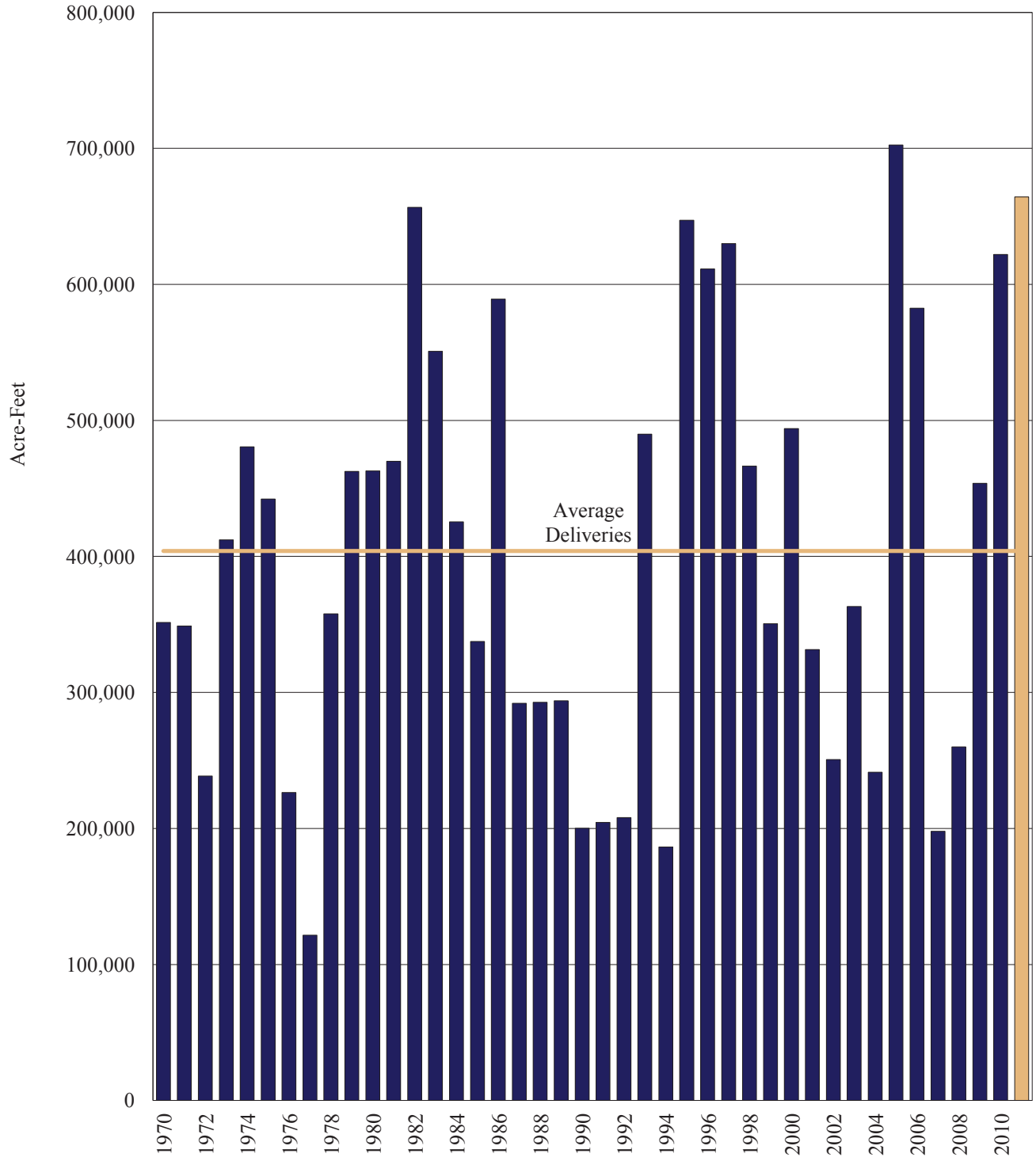


Figure 7. Kern River Regulated Flow from Isabella Reservoir Measured at the Kern River First Point of Measurement

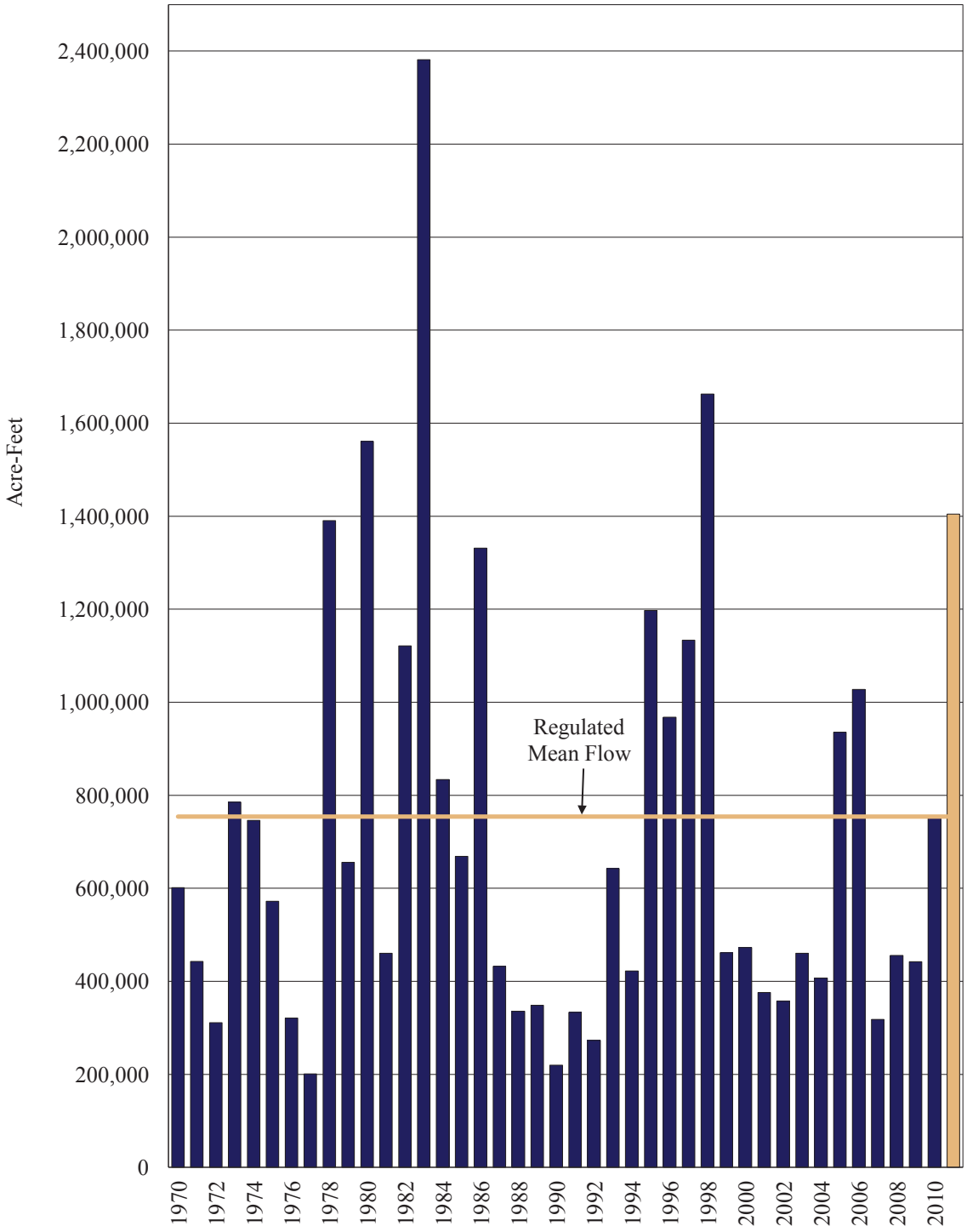


Figure 8. Annual Runoff From All Minor Streams Draining into the San Joaquin Valley Portion of Kern County

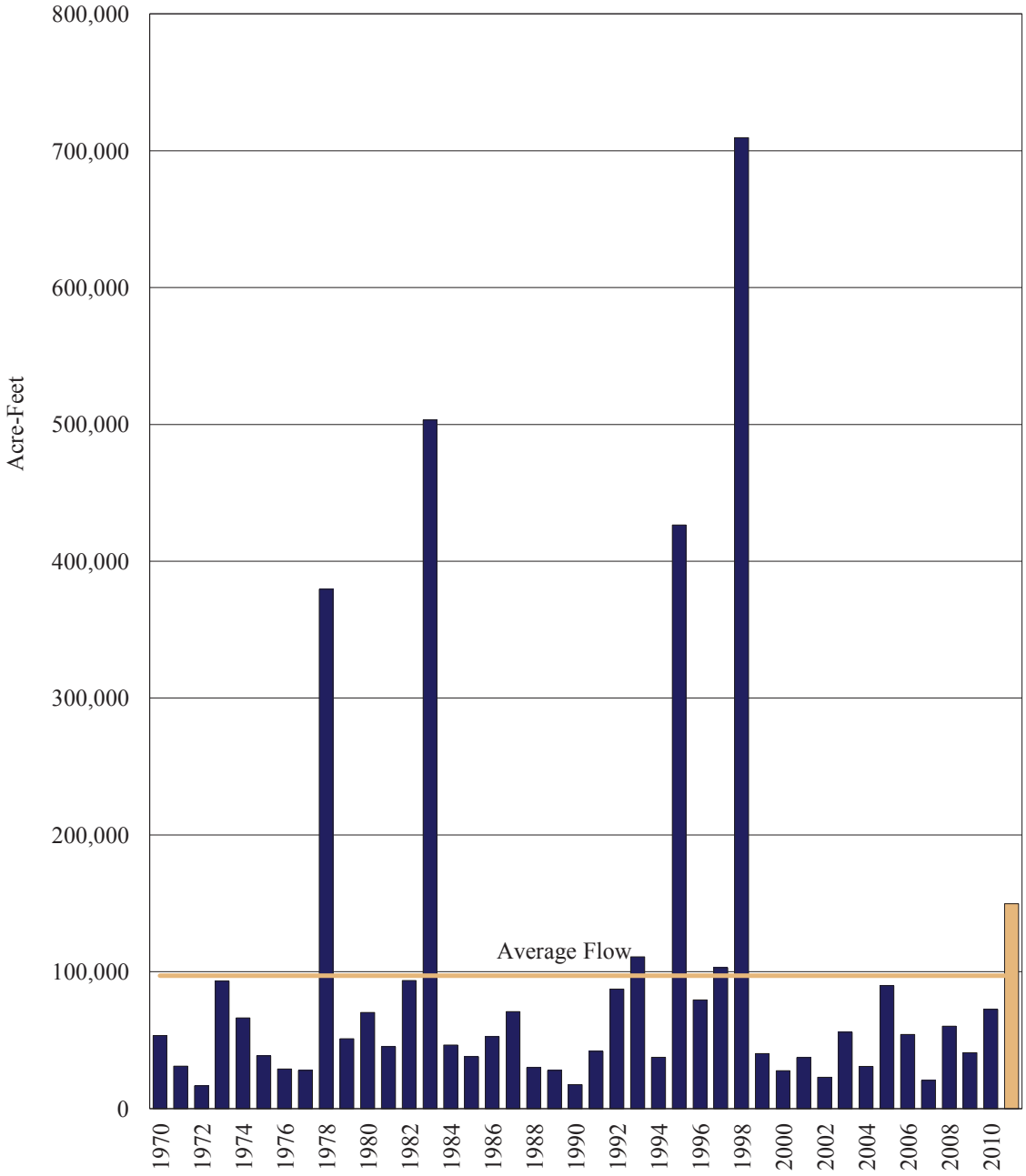


Figure 9. Annual Rainfall at Three Stations in the San Joaquin Valley Portion of Kern County

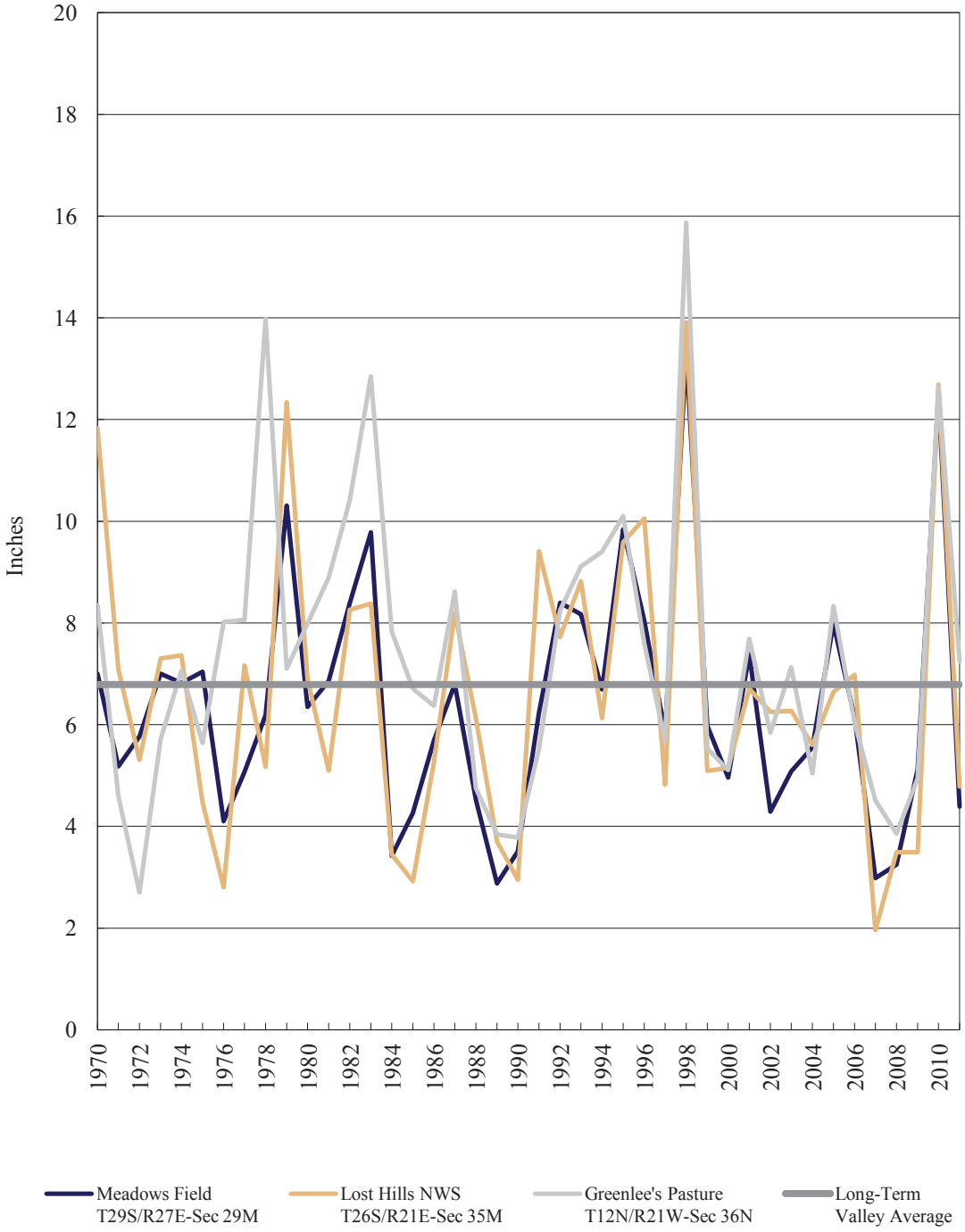


Figure 10. Effective Precipitation for the San Joaquin Valley Portion of Kern County

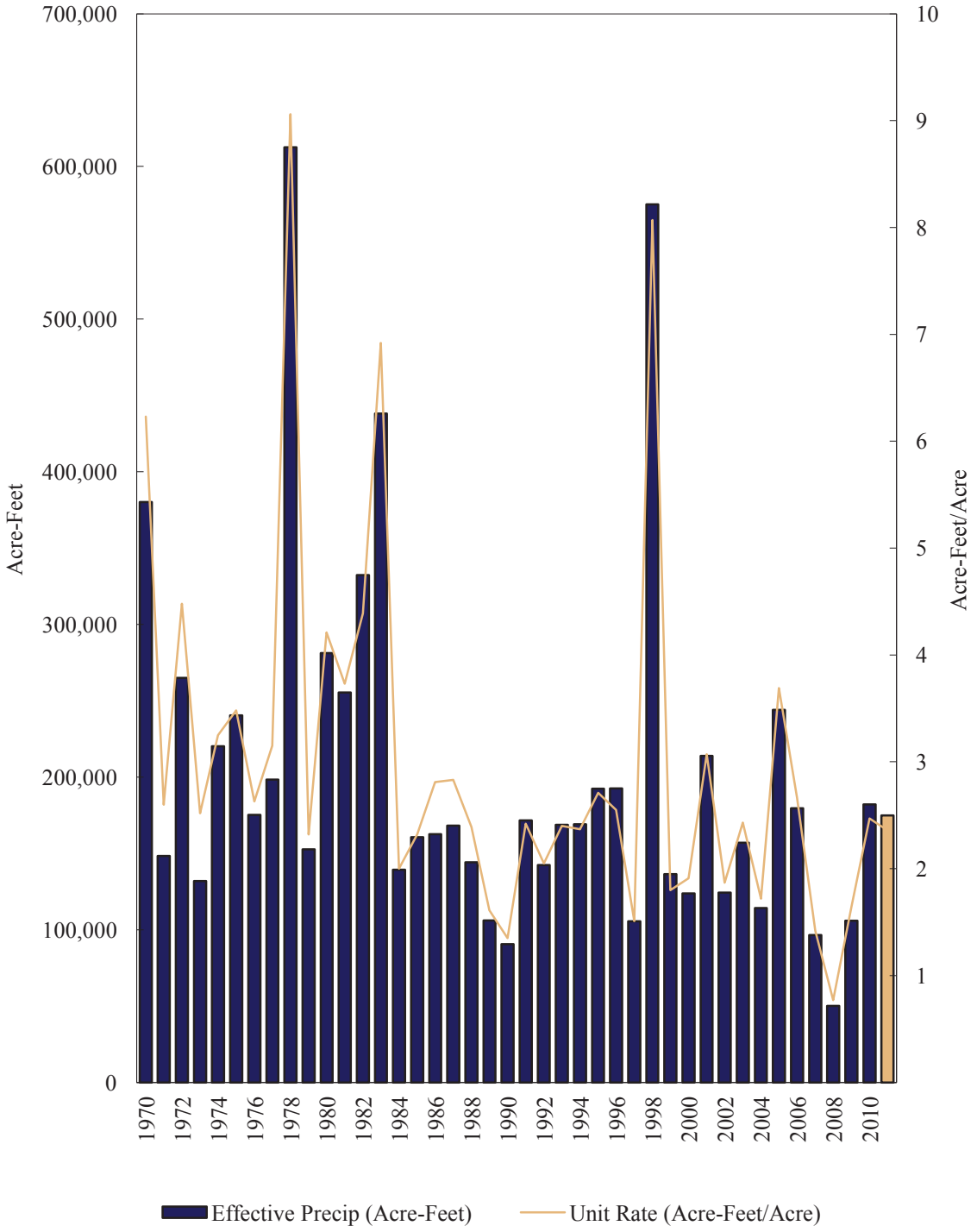


Figure 11. Historical Water Reuse in the San Joaquin Valley Portion of Kern County

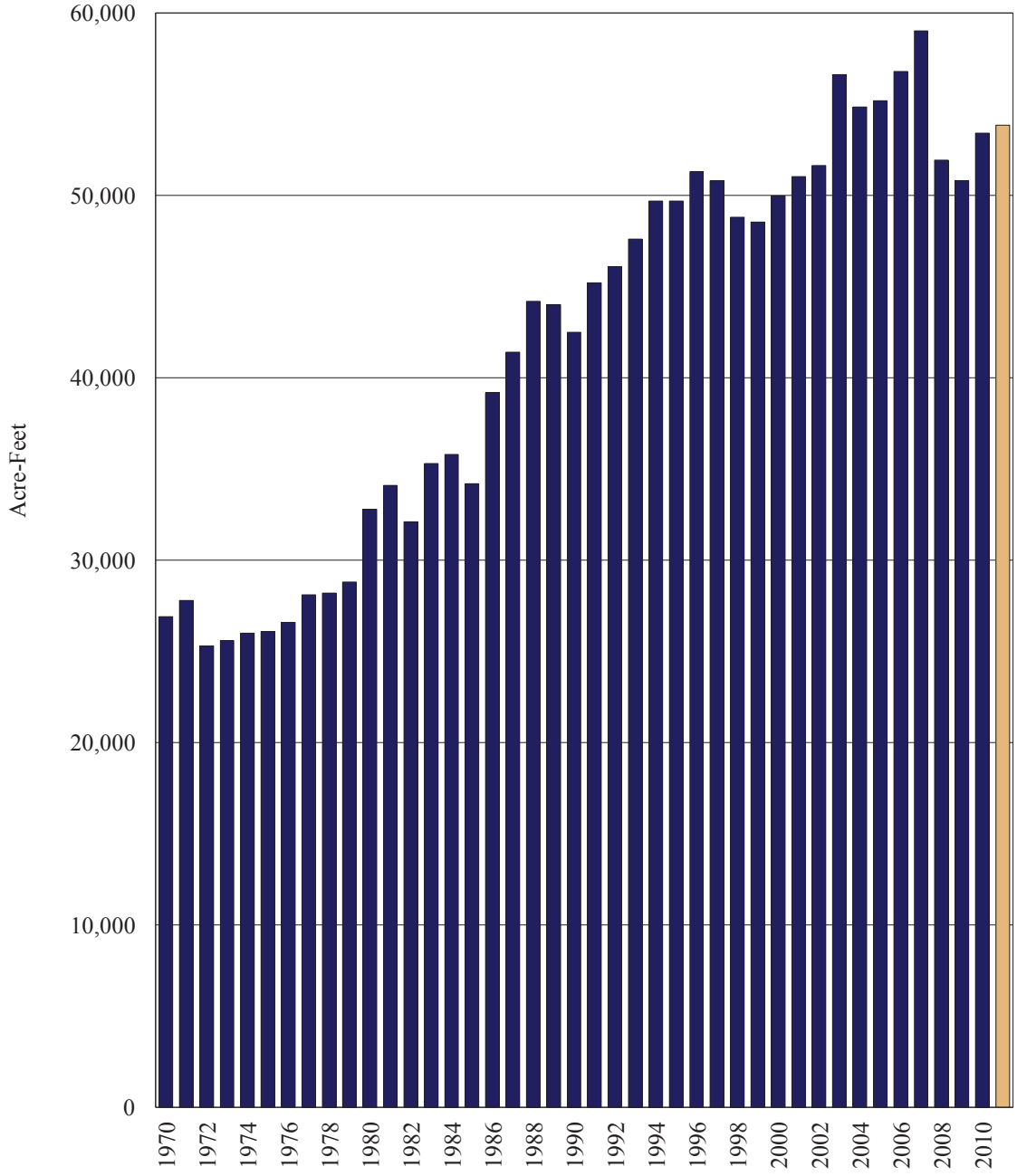


Figure 12. Annual Oilfield-Produced Water in Kern County

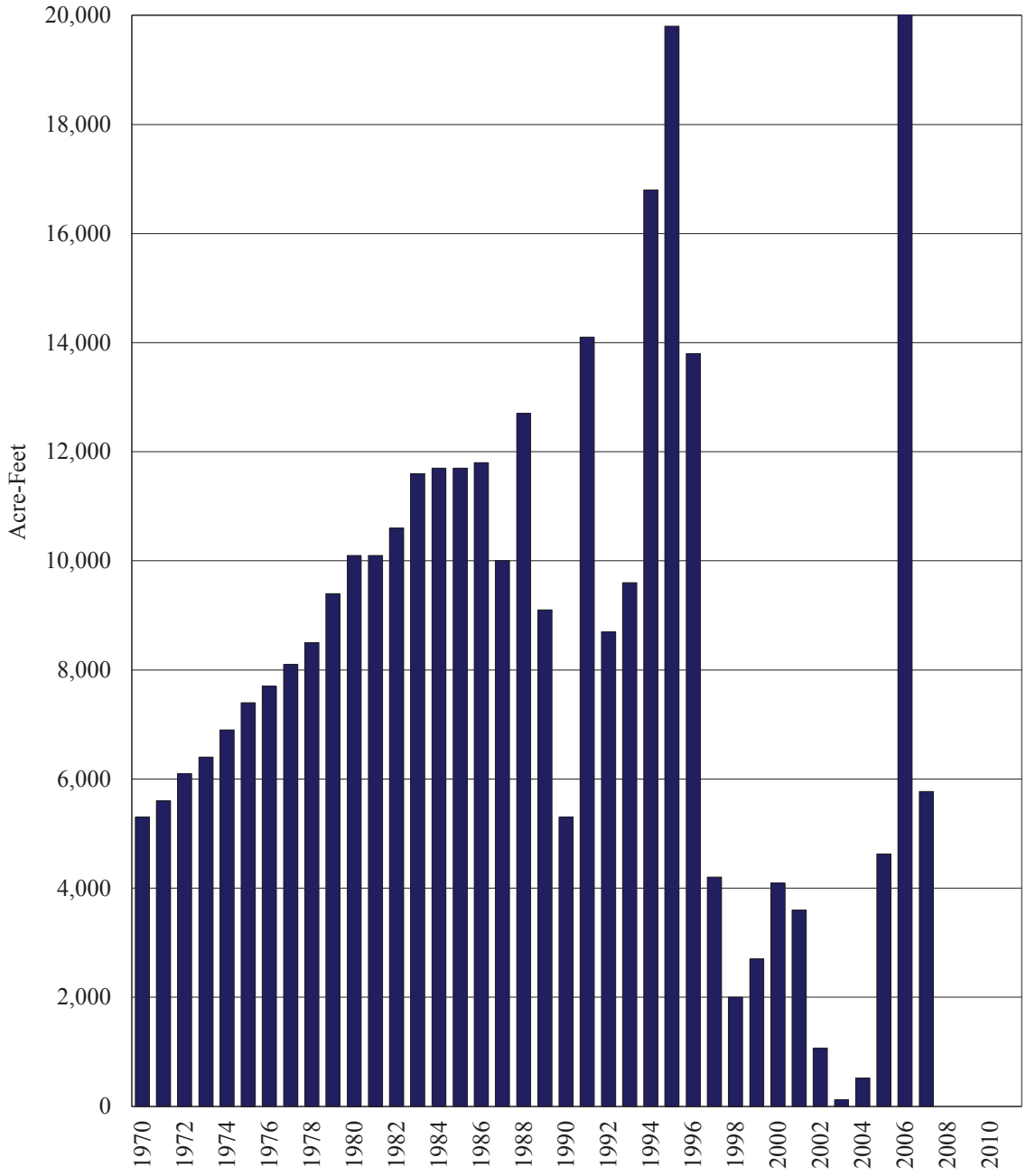
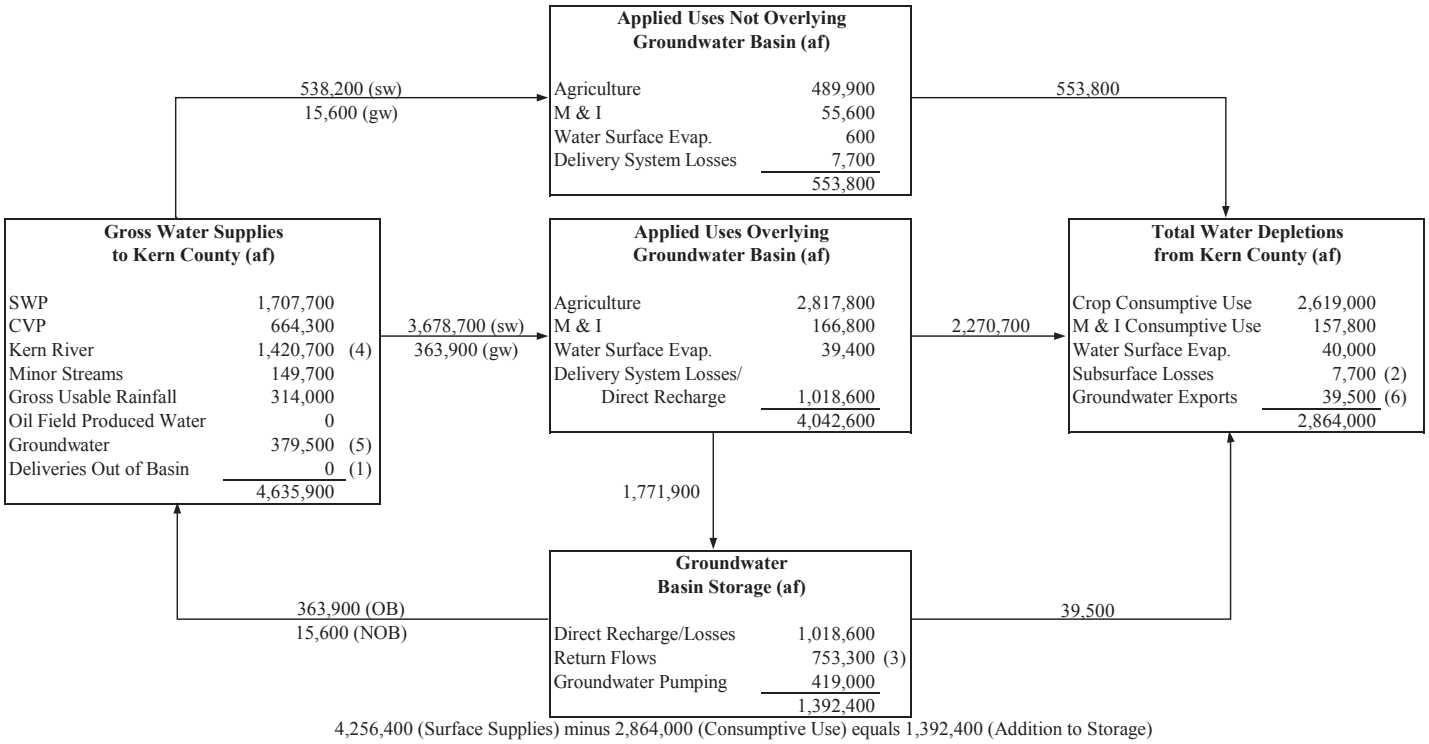


Figure 13. 2011 Water Resources Inventory in the San Joaquin Valley Portion of Kern County



4,256,400 (Surface Supplies) minus 2,864,000 (Consumptive Use) equals 1,392,400 (Addition to Storage)

(1) Deliveries out of the basin were primarily to: Western Hills WD (1,124 af), Dudley Ridge WD (15,363 af) and MWD (85,171 af). See Table 4 for additional details.
(2) Losses to moisture deficient soils.
(3) A total of 53,900 af of municipal waste water was treated and reused. The reuse is not included here.
(4) Total excludes af delivered to Kern Valley Golf Course (Kernville).
(5) Includes groundwater exported out of the groundwater basin for municipal and industrial uses.
(6) Groundwater exports are from groundwater banking programs around Kern County, including, but not limited to, Arvin-Edison Water Storage District, Semitropic Water Storage District and Rosedale-Rio Bravo Water Storage District.

(sw) Surface Water
(gw) Groundwater
(OB) Over groundwater basin
(NOB) Not over groundwater basin

Figure 14. Estimated Groundwater Pumping in the San Joaquin Valley Portion of Kern County

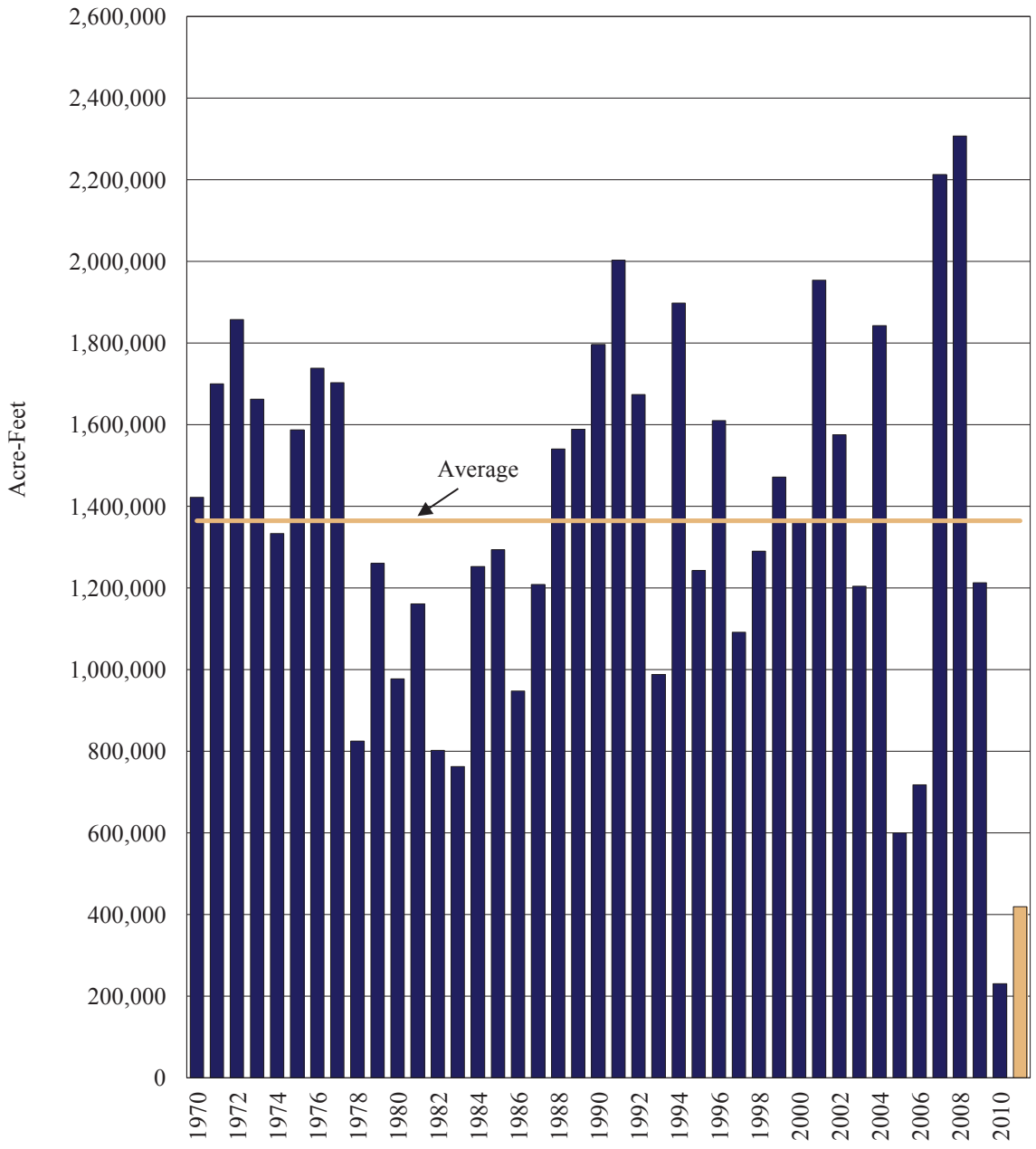


Figure 15. Irrigated Acreage in the San Joaquin Valley Portion of Kern County

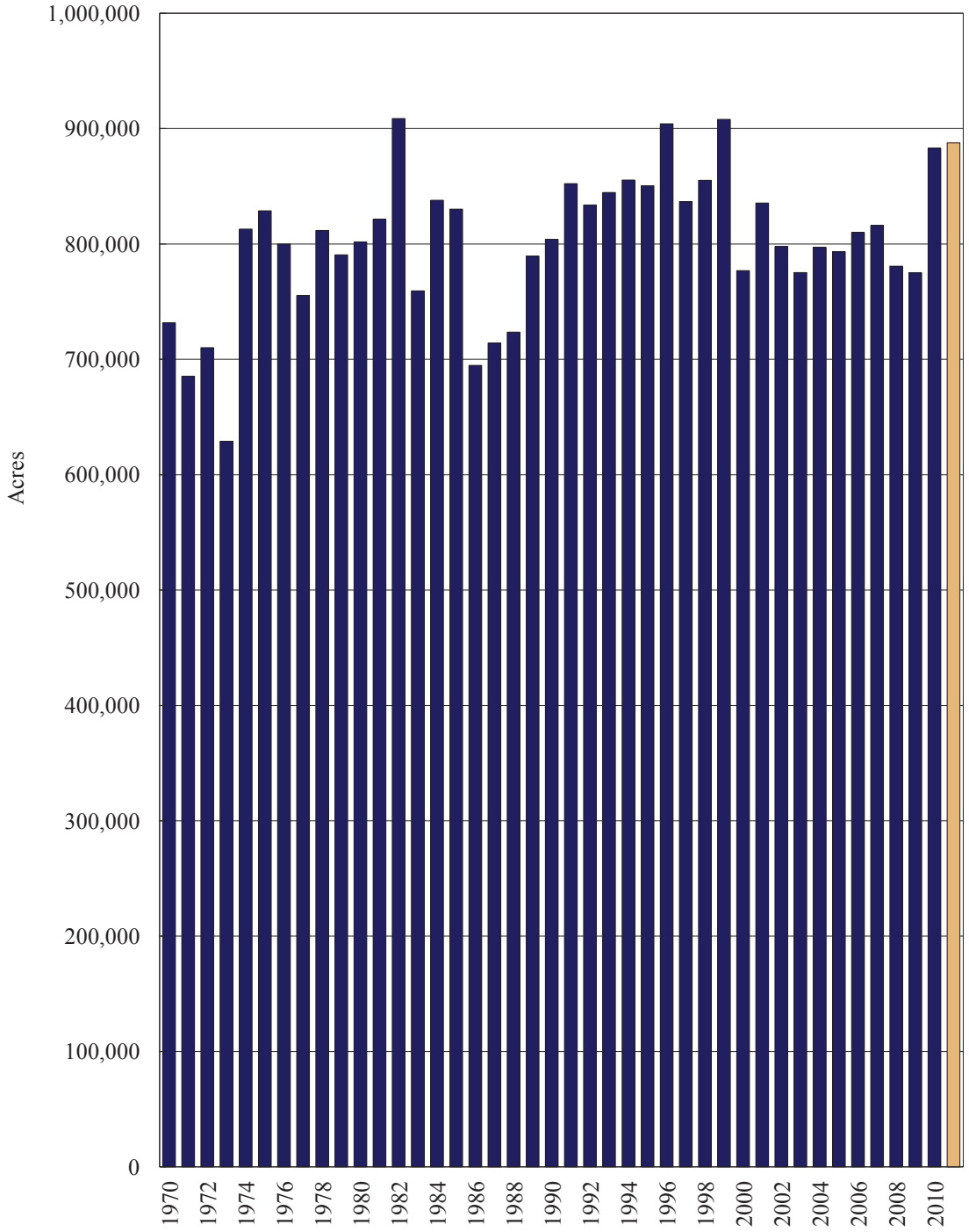


Figure 16. Summary of Irrigated Acreage in the San Joaquin Valley Portion of Kern County

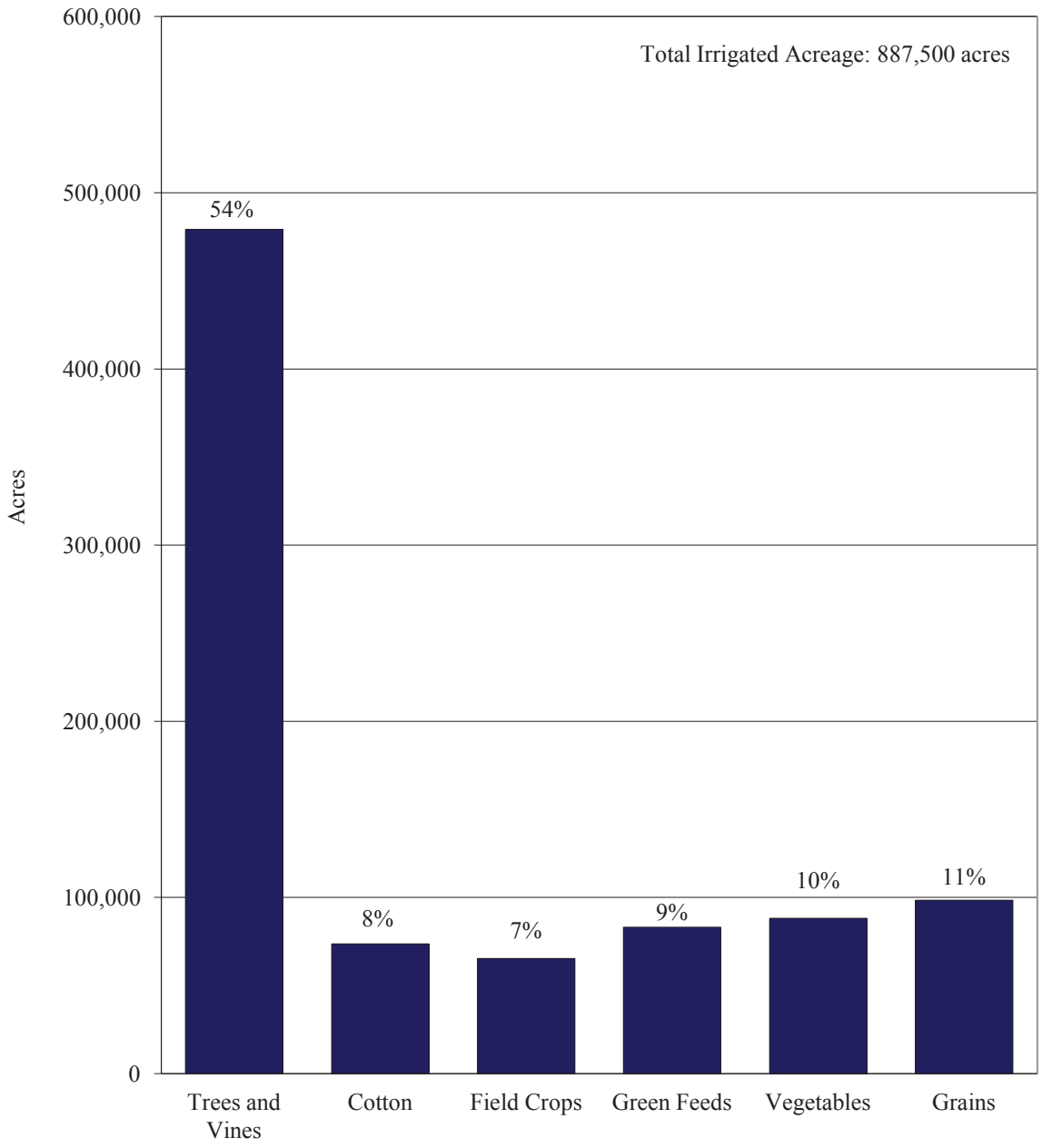
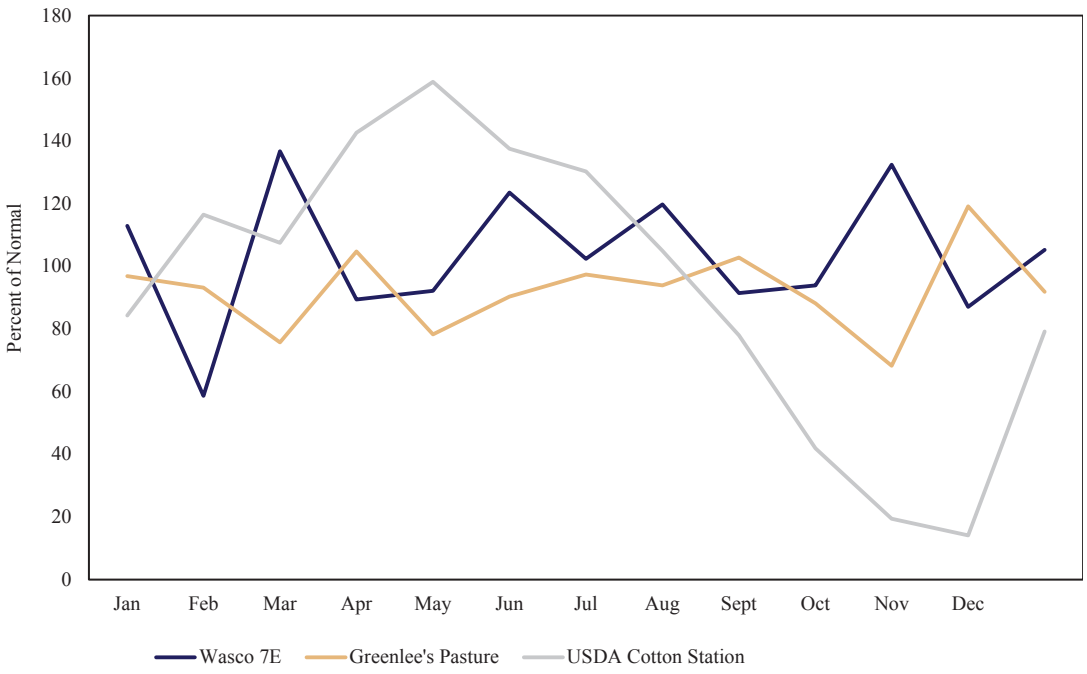


Figure 17. Percent of Normal Evaporation in the San Joaquin Valley Portion of Kern County



Percent of Normal, Total:

Wasco 7E	**105.3**
Greenlee's Pasture	**91.9**
USDA Cotton Station	**79.2**

Wasco 7E

2009 observed monthly EP, Wasco 7E (irrigated pasture) compared to long-term average for pasture pans in the San Joaquin Valley. This station is indicative of EP on the valley floor.

Greenlee's Pasture

2009 observed monthly EP, Greenlee's Pasture (irrigated pasture - Wheeler Ridge area) compared to long-term average for pasture pans in the San Joaquin Valley. This station is indicative of EP in the foothill regions of the valley.

USDA Cotton Station

2009 observed monthly EP, USDA Cotton Station (irrigated turf) compared to long-term average for USDA Cotton Station in the San Joaquin Valley. This station is indicative of EP for cotton in Kern County.

Figure 18. Gross Water Supplies and Net Water Requirements in the San Joaquin Valley Portion of Kern County

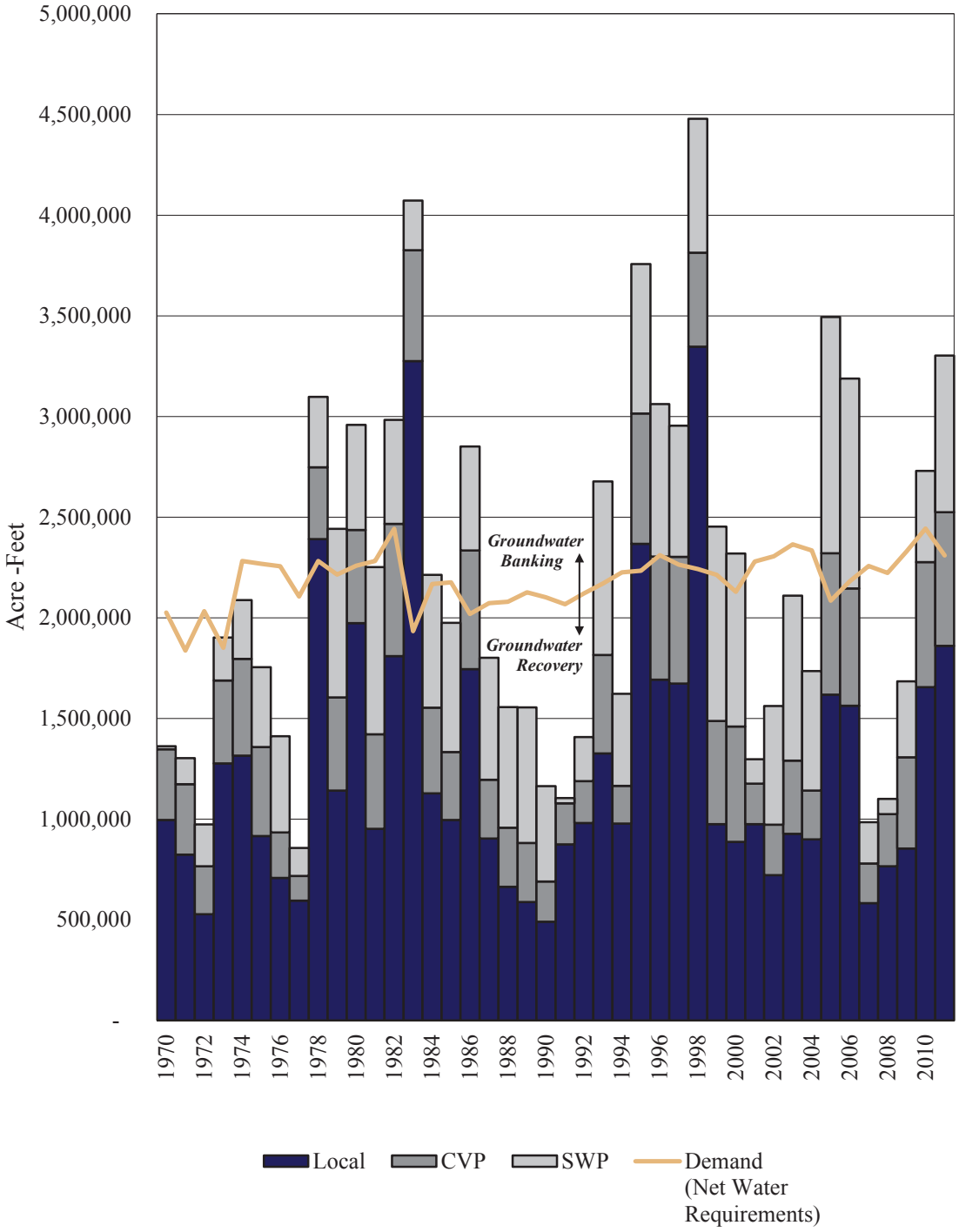


Figure 19. Cumulative Change in Groundwater Storage in the San Joaquin Valley Portion of Kern County

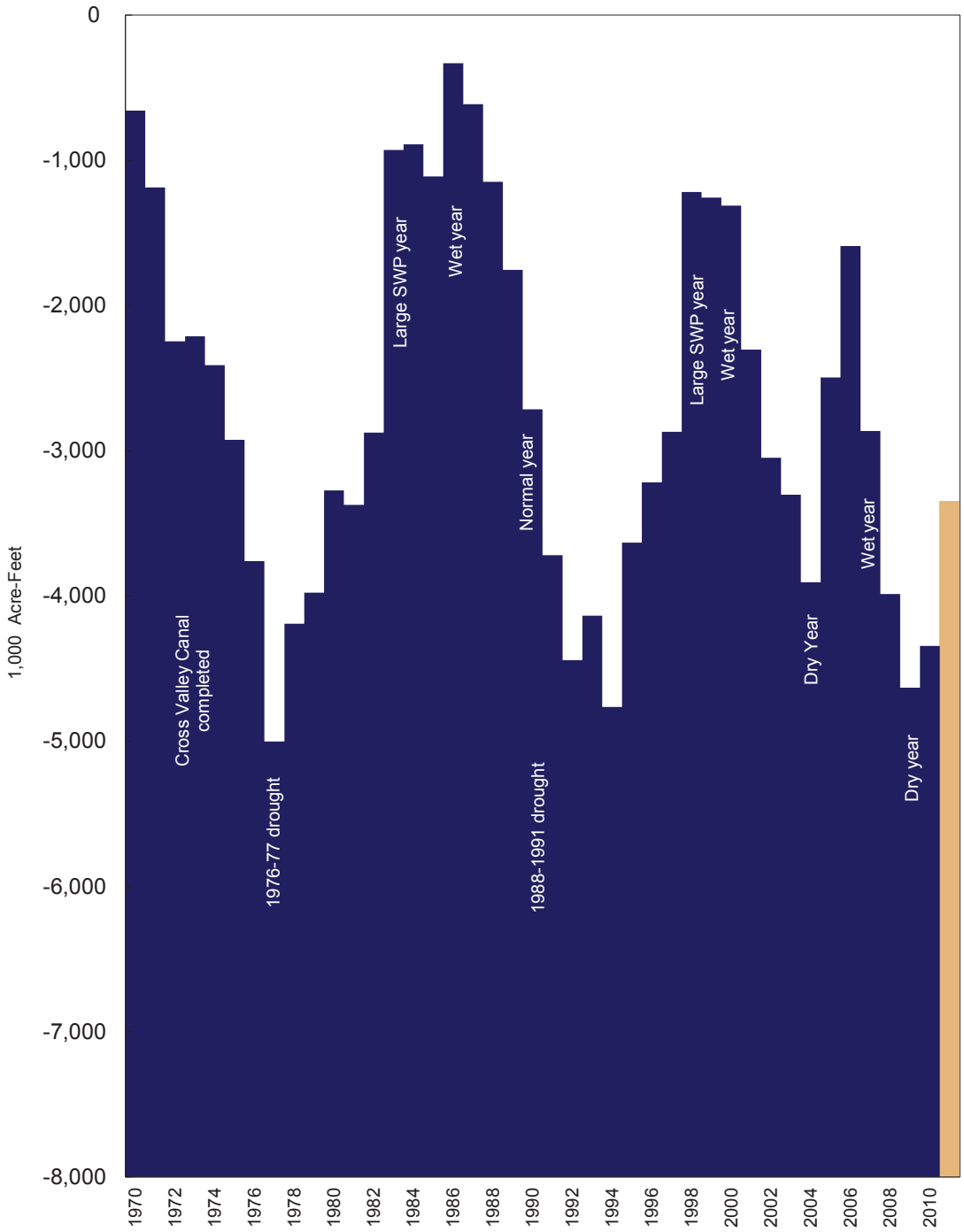


Figure 20. Groundwater Recharge Summary in the San Joaquin Valley Portion of Kern County

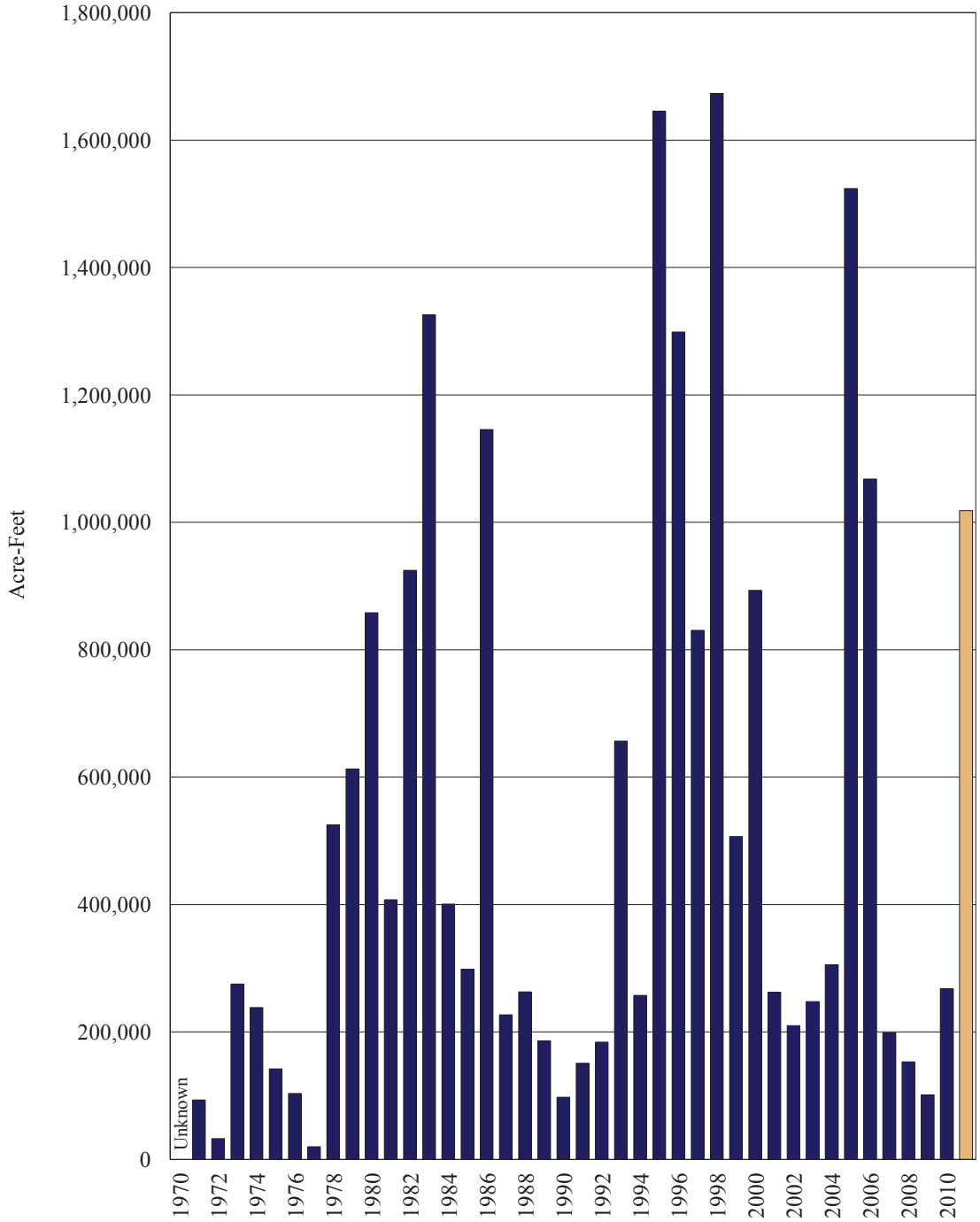


Figure 21a. Water Well Hydrograph: Pond-Poso Area

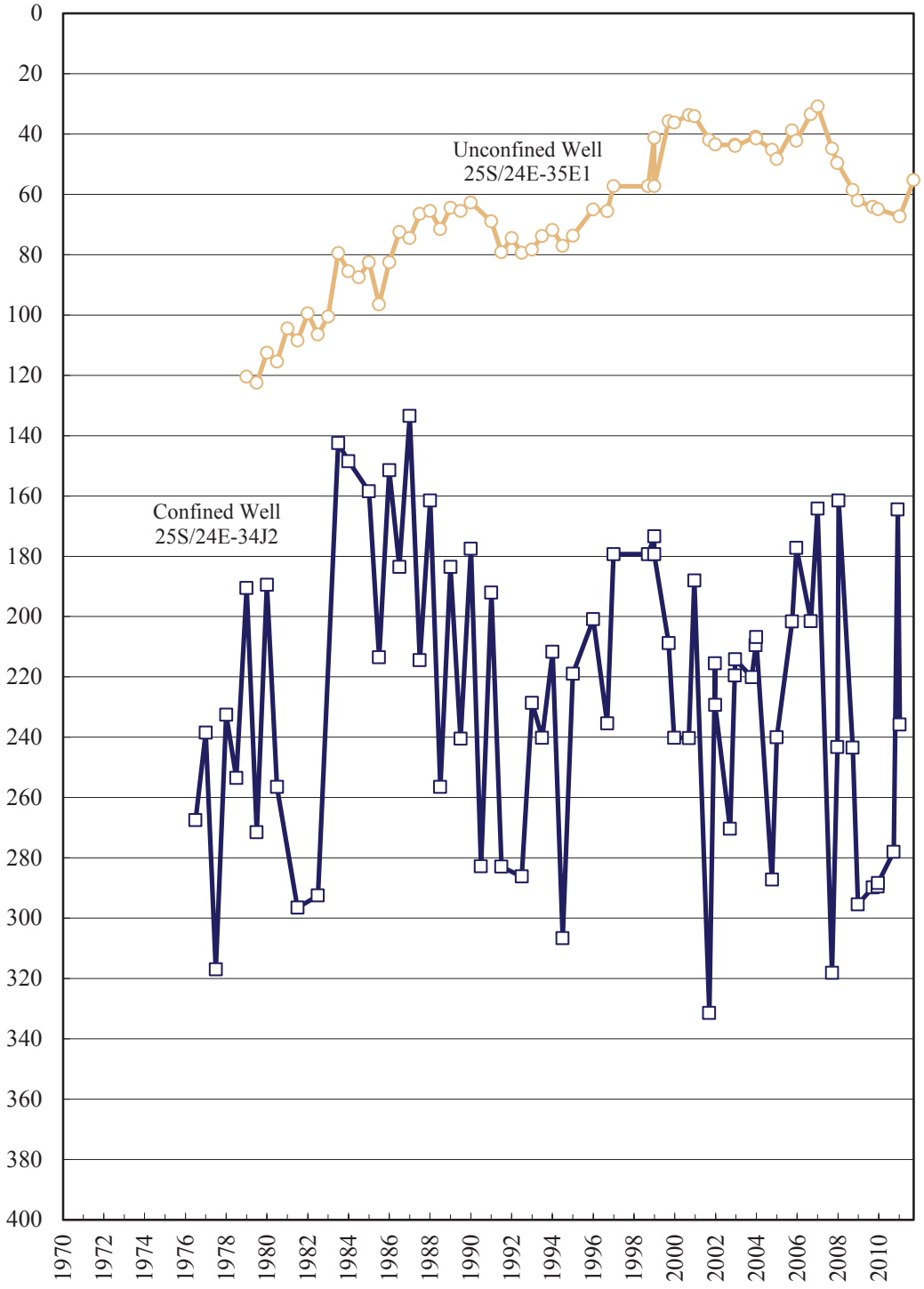


Figure 21b. Water Well Hydrograph: Shafter/Rosedale Area

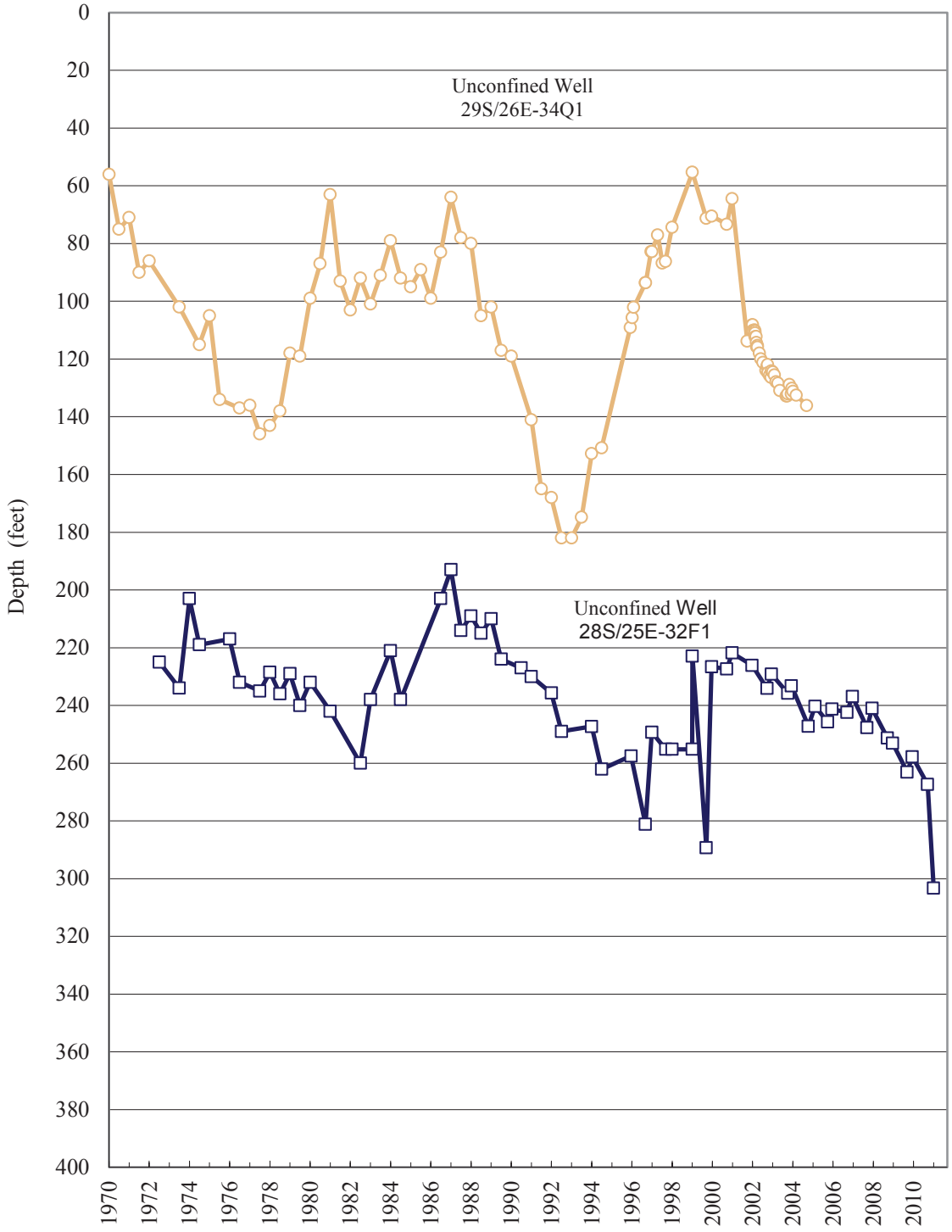


Figure 21c. Water Well Hydrograph: Southwest Bakersfield Area

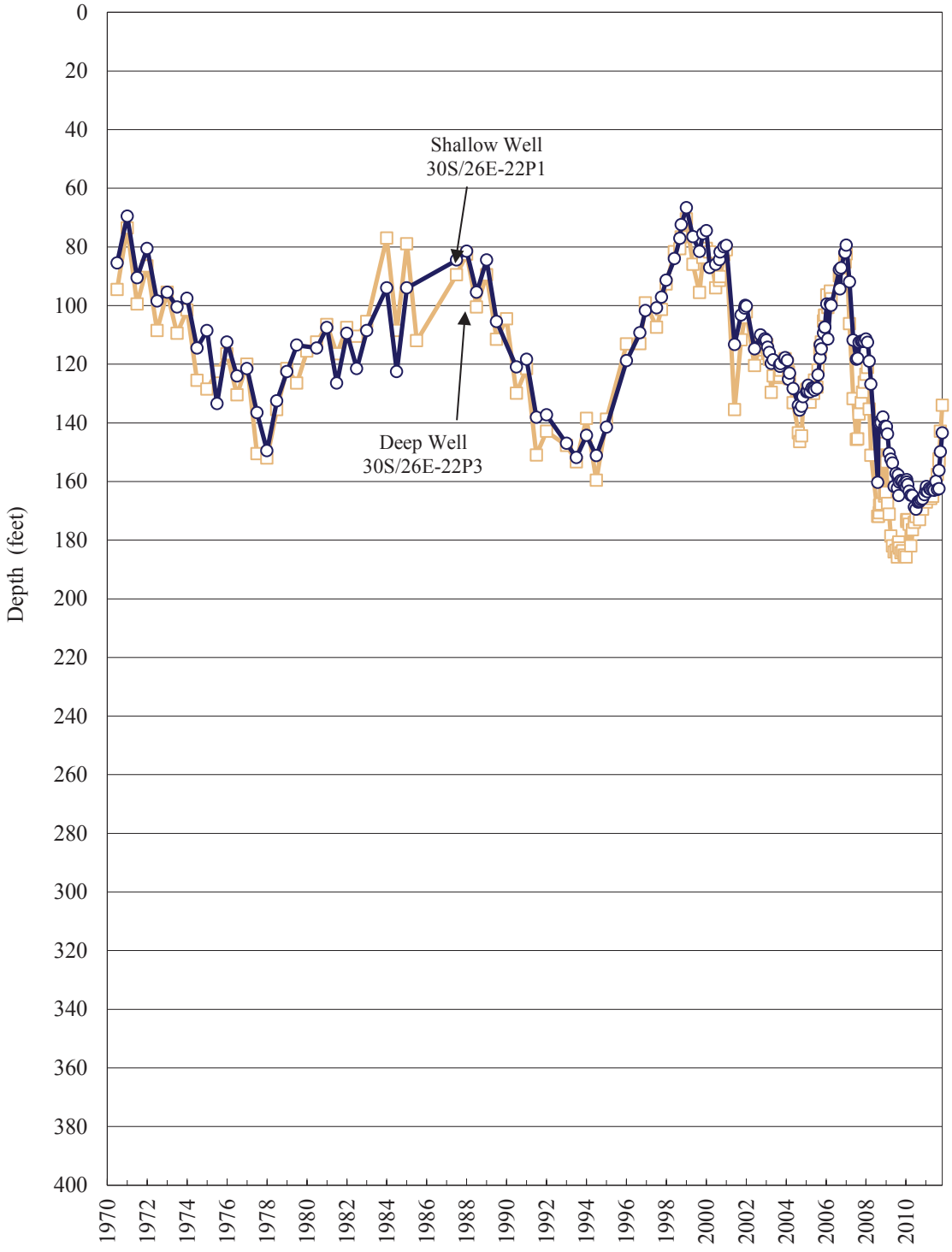


Figure 21d. Water Well Hydrograph: Arvin-Edison Area

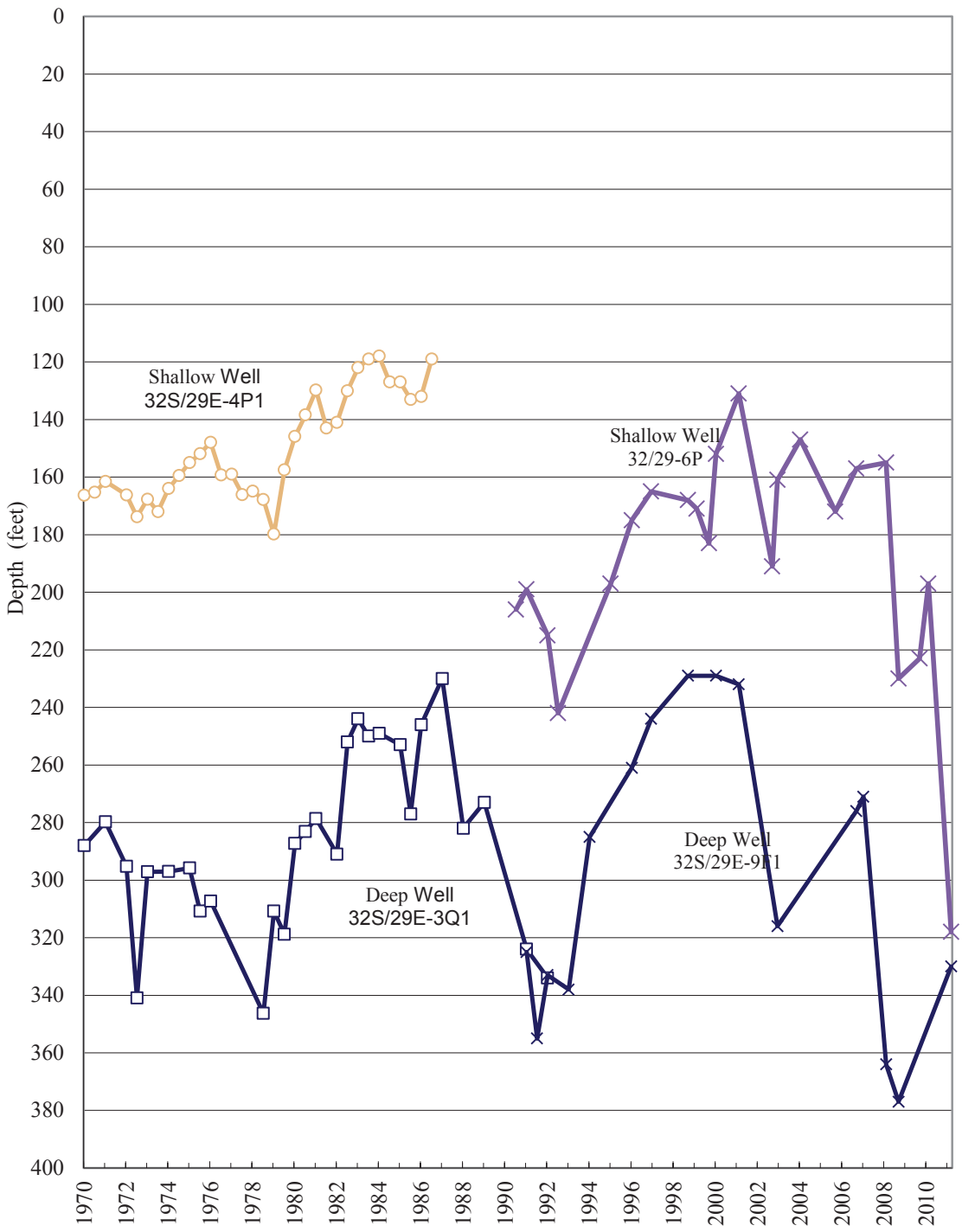


Plate 1. Depth to Shallow Groundwater Summer 2011

PLATE 1–2011

KERN COUNTY WATER AGENCY
Bakersfield, California

DEPTH TO SHALLOW GROUNDWATER

SUMMER 2011

CONTOURED BY: M. CASTERLINE, PG #8898
REVIEWED BY: T. HASLEBACHER PG #4739 CHG #446

JAN 2012

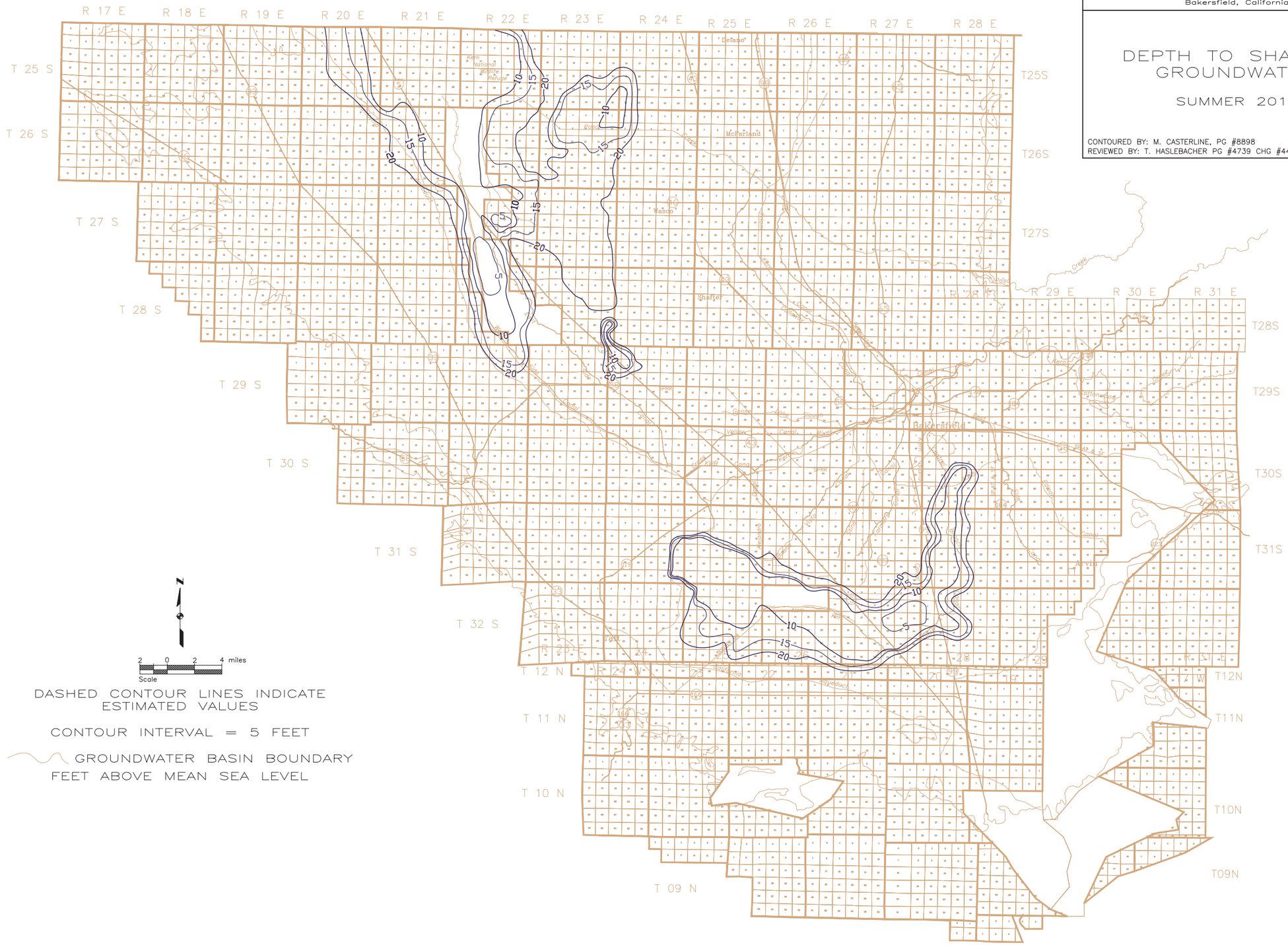


Plate 2. Groundwater Quality Confined Aquifer

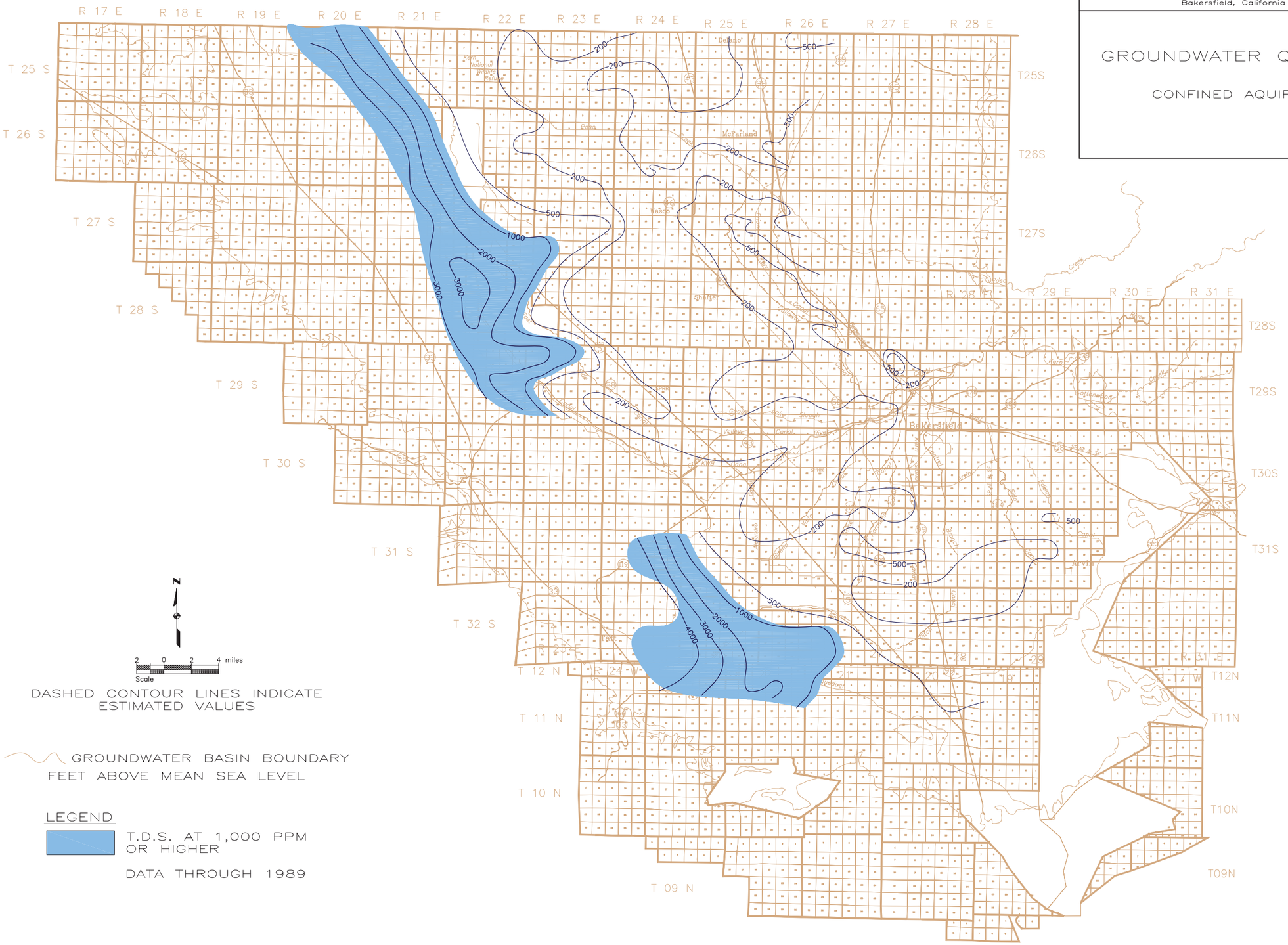
PLATE 2–2011

KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER QUALITY

CONFINED AQUIFER

MARCH 1997



DASHED CONTOUR LINES INDICATE ESTIMATED VALUES

GROUNDWATER BASIN BOUNDARY

FEET ABOVE MEAN SEA LEVEL

LEGEND

T.D.S. AT 1,000 PPM OR HIGHER

DATA THROUGH 1989

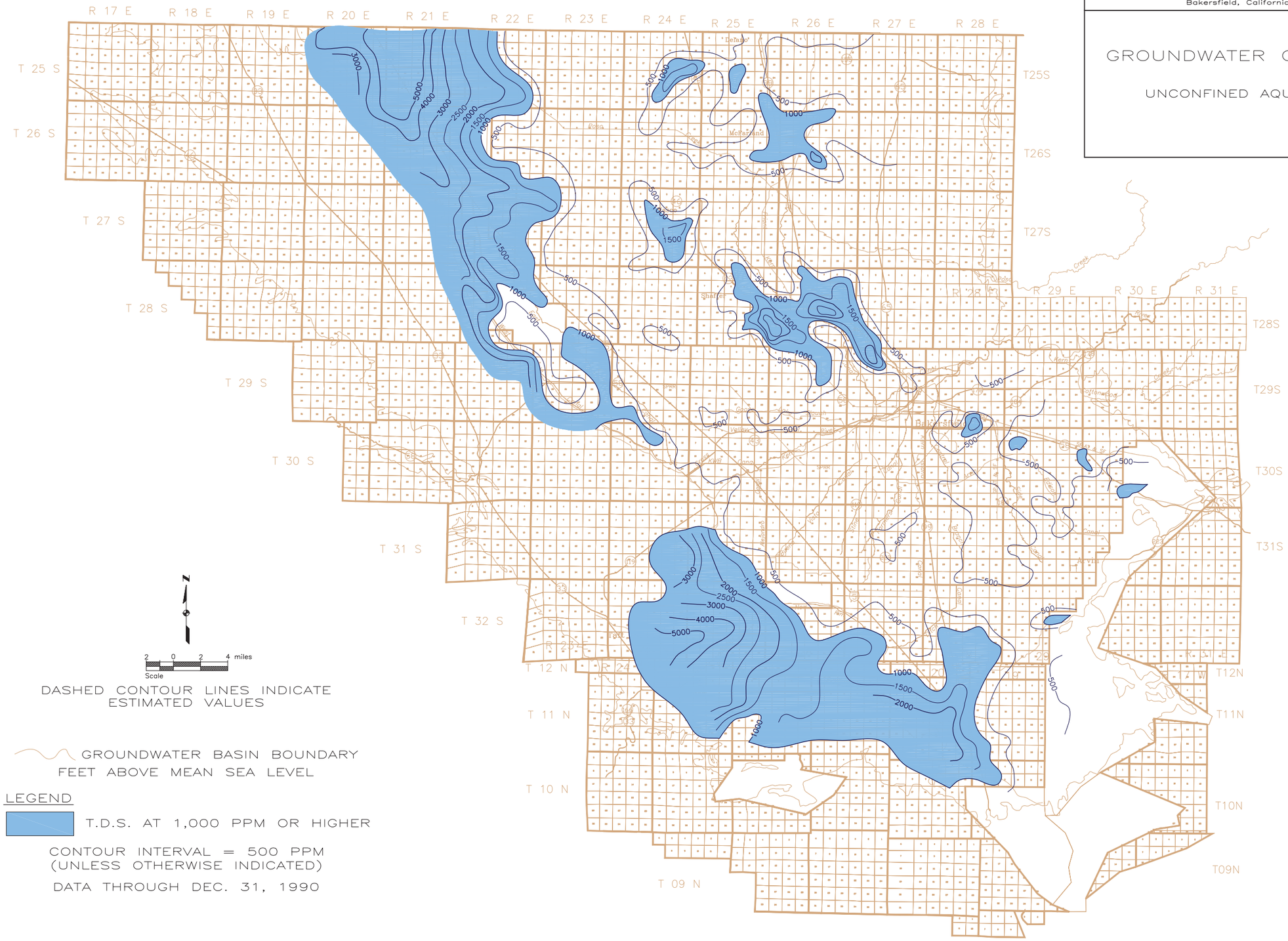
PLATE 3–2011

KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER QUALITY

UNCONFINED AQUIFER

MARCH 1997



DASHED CONTOUR LINES INDICATE ESTIMATED VALUES

GROUNDWATER BASIN BOUNDARY

FEET ABOVE MEAN SEA LEVEL

LEGEND

T.D.S. AT 1,000 PPM OR HIGHER

CONTOUR INTERVAL = 500 PPM
(UNLESS OTHERWISE INDICATED)

DATA THROUGH DEC. 31, 1990

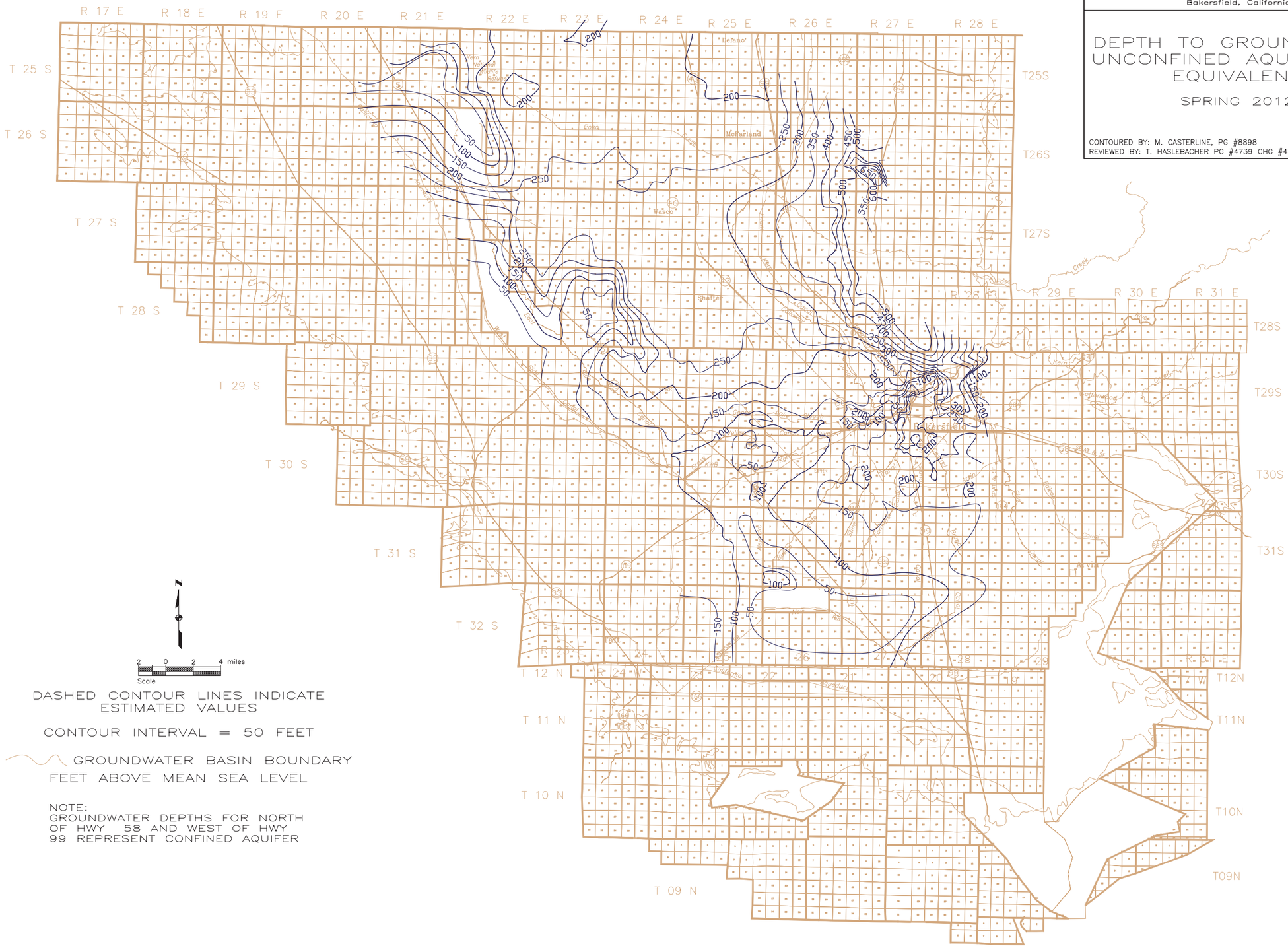
PLATE 4–2011

KERN COUNTY WATER AGENCY
Bakersfield, California

DEPTH TO GROUNDWATER UNCONFINED AQUIFER OR EQUIVALENT

SPRING 2012

CONTOURED BY: M. CASTERLINE, PG #8898
REVIEWED BY: T. HASLEBACHER PG #4739 CHG #446
AUGUST 2012



N

2 0 2 4 miles
Scale

DASHED CONTOUR LINES INDICATE ESTIMATED VALUES

CONTOUR INTERVAL = 50 FEET

GROUNDWATER BASIN BOUNDARY

FEET ABOVE MEAN SEA LEVEL

NOTE:
GROUNDWATER DEPTHS FOR NORTH OF HWY 58 AND WEST OF HWY 99 REPRESENT CONFINED AQUIFER

PLATE 5–2011

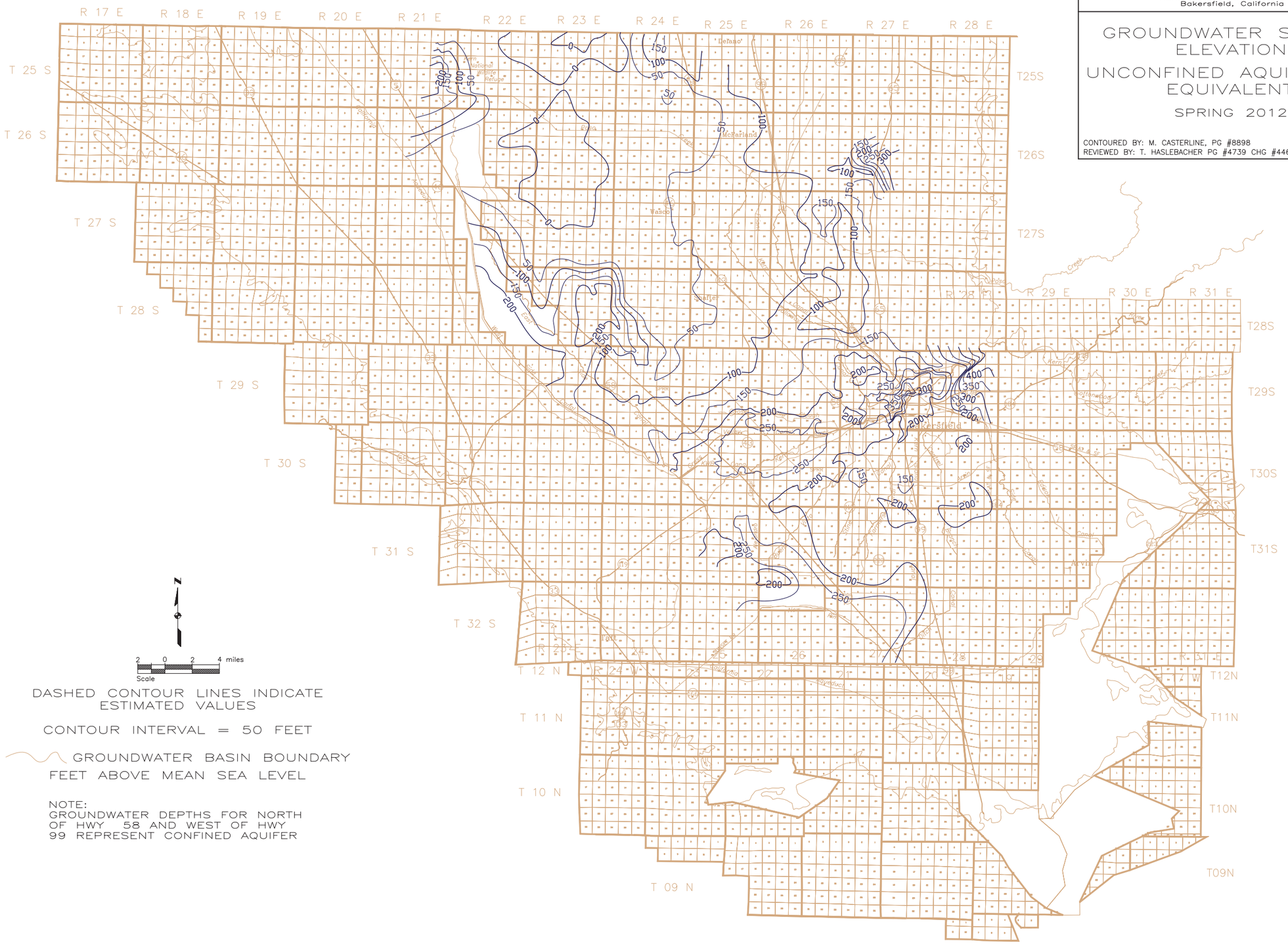
KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER SURFACE ELEVATION

UNCONFINED AQUIFER OR EQUIVALENT

SPRING 2012

CONTOURED BY: M. CASTERLINE, PG #8898
REVIEWED BY: T. HASLEBACHER PG #4739 CHG #446 August 2012



N

2 0 2 4 miles
Scale

DASHED CONTOUR LINES INDICATE ESTIMATED VALUES

CONTOUR INTERVAL = 50 FEET

GROUNDWATER BASIN BOUNDARY

FEET ABOVE MEAN SEA LEVEL

NOTE:
GROUNDWATER DEPTHS FOR NORTH OF HWY 58 AND WEST OF HWY 99 REPRESENT CONFINED AQUIFER

Plate 6. Groundwater Level Changes Unconfined Aquifer Spring 2011 to Spring 2012

PLATE 6–2011

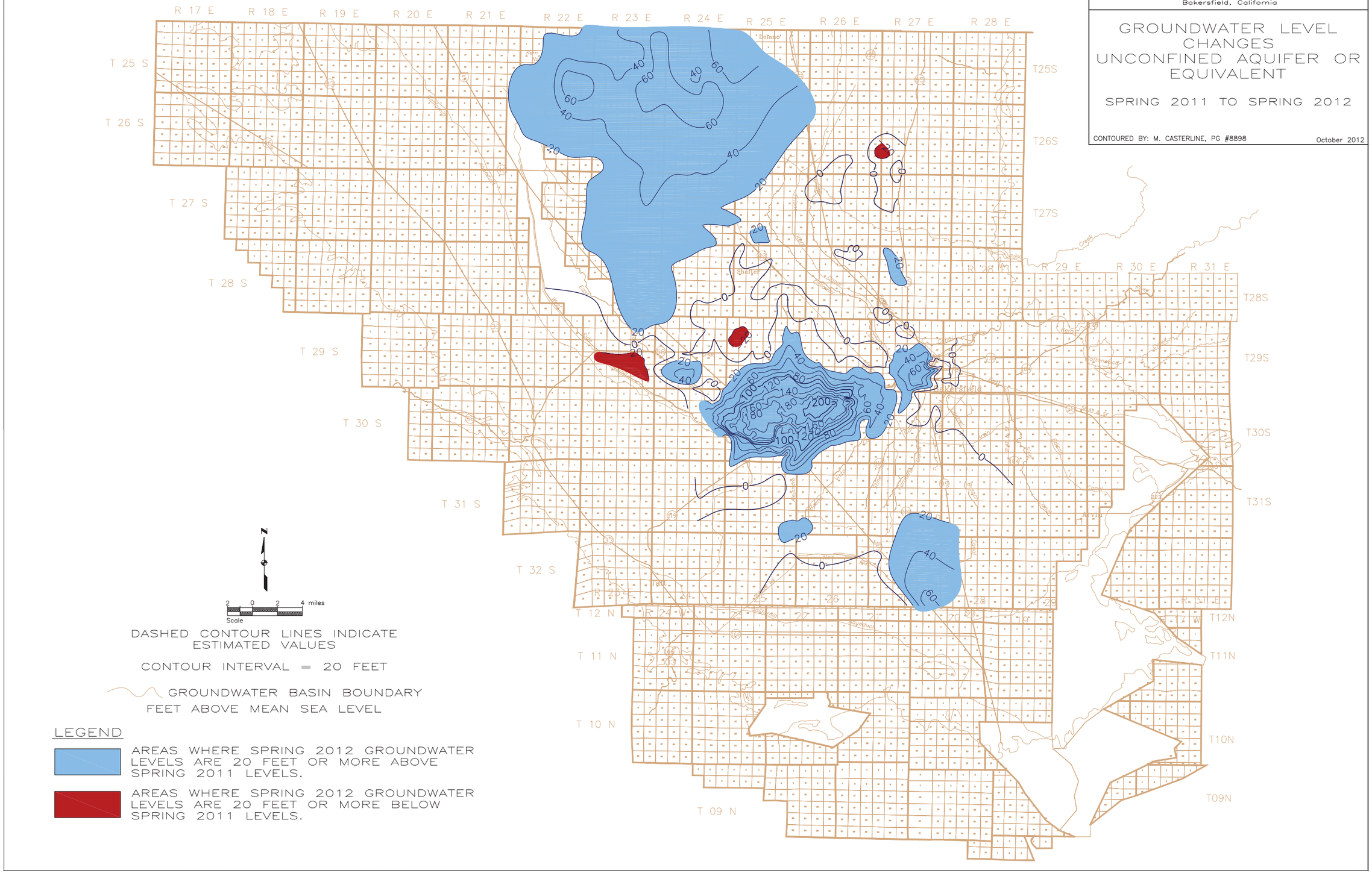
KERN COUNTY WATER AGENCY
Bakersfield, California

GROUNDWATER LEVEL CHANGES UNCONFINED AQUIFER OR EQUIVALENT

SPRING 2011 TO SPRING 2012

CONTOURED BY: M. CASTERLINE, PG #8898

October 2012



N

2 0 2 4 miles
Scale

DASHED CONTOUR LINES INDICATE ESTIMATED VALUES

CONTOUR INTERVAL = 20 FEET

GROUNDWATER BASIN BOUNDARY

FEET ABOVE MEAN SEA LEVEL

LEGEND

AREAS WHERE SPRING 2012 GROUNDWATER LEVELS ARE 20 FEET OR MORE ABOVE SPRING 2011 LEVELS.

AREAS WHERE SPRING 2012 GROUNDWATER LEVELS ARE 20 FEET OR MORE BELOW SPRING 2011 LEVELS.

Progress Report: Subsidence in the Central Valley, California

Tom G Farr, Cathleen Jones, Zhen Liu
Jet Propulsion Laboratory
California Institute of Technology

Executive summary

Subsidence caused by groundwater pumping in the Central Valley has been a problem for decades. Over the last few years, interferometric synthetic aperture radar (InSAR) has been used from satellites and aircraft to produce maps of subsidence with sensitivity of fractions of an inch. For this study, we have obtained and analyzed Japanese PALSAR data for 2006 - 2010 and Canadian Radarsat-2 data for the period May 2014 – January 2015 and produced maps of the total subsidence for those periods. As multiple scenes were acquired during these periods, we can also produce time histories of subsidence at selected locations and transects showing how subsidence varies both spatially and temporally. Geographic Information System (GIS) files will be furnished to DWR for further analysis of the 4 dimensional subsidence time-series maps.

For both periods, two already known main subsidence bowls in the San Joaquin Valley have been mapped: The larger is centered on Corcoran and extends 60 miles to the NW, affecting the California Aqueduct. For the period 2006 - 2010, maximum total subsidence was found to be about 37" near Corcoran. From May 2014 – January 2015, maximum subsidence of over 13" was found just SE of Corcoran. A second bowl is centered on El Nido and is approximately 25 miles in diameter, encompassing most of the East Side Bypass. From 2006 - 2010 maximum subsidence totaled about 24" S of El Nido. From May 2014 – January 2015, maximum subsidence of about 10" occurred in the same area. In the Sacramento Valley, a single area N of Yolo subsided about 6" from 2006 - 2010. From May to November 2014, an extended area W of Yolo showed small areas with a maximum subsidence of about 3"; another diffuse area N of Yolo had a maximum subsidence of about 2.5"; and an unusually small intense area of subsidence just W of Arbuckle showed a maximum subsidence of about 5".

InSAR data were also collected by the NASA UAVSAR airborne platform over two swaths centered on the California Aqueduct to evaluate subsidence on or near the aqueduct using a high spatial resolution instrument. The first swath covered the California Aqueduct from San Luis Reservoir to Kettleman City, and the second from due west of Buttonwillow to the Edmonston Pumping Plant. Time series analysis showed subsidence to be highly variable across this extent and to have increased sharply starting in summer 2014. Impact on the Aqueduct from groundwater withdrawal is greater in the northern swath. The greatest subsidence directly impacting the California Aqueduct was observed between Huron and Kettleman City, where a subsidence bowl of depth about 14" was centered less than half a mile from the Aqueduct. The subsidence bowl extended beyond the aqueduct and caused >8" of subsidence along a 1.3 mile stretch of the aqueduct, with a maximum of about 13" subsidence. We note that subsidence values measured with UAVSAR InSAR are averaged across a pixel of area > 20' x 20', so maximum values measured on the ground could be higher at locations within the pixel.

Introduction

The problem of subsidence

The aquifer system of the southern Central Valley has both unconfined and confined parts caused by alternating layers of coarse and fine-grained sediments. Water in the coarse-grained, unconfined or water-table aquifers can be extracted or recharged easily and causes only minor 'elastic' compaction reflected as seasonal subsidence and rebound of water levels and the land surface. Most water wells exploit the deeper confined aquifers, and withdrawal of water from them causes drainage of the fine-grained confining layers called aquitards. Significant water is available in the aquitards. These, however, drain slowly and compact both elastically as well as inelastically. In general, if water levels are not drawn too low, when pumping ceases water recharges the aquitards and their structure expands. However, if water levels are drawn too low, then an irreversible compaction of the fine-grained aquitards occurs. The water cannot recharge the layers, causing permanent subsidence and loss of some groundwater storage capacity (see Galloway et al., 1999 pages 8-13; Bertholdi et al., 1991 for reviews).

Measuring and understanding subsidence as a function of groundwater dynamics will greatly improve management of that important resource, and in addition the effect of subsidence on infrastructure can also be monitored using InSAR. Roads can be broken by fissures, pipelines have been exhumed, and the slope of the land can be altered, changing drainage patterns. This last effect has proven to be a significant problem on the California Aqueduct, where the canal lining has been raised in multiple locations over the years in order to preserve flow. Areas of low relief that have subsided are also subject to flooding.

How InSAR works

Key points:

1) InSAR measures subsidence relative to a stable location chosen during processing.
2) InSAR measures subsidence relative to the first image date in a series.
3) Radar measurements from multiple satellites can not be combined interferometrically.
4) However, subsidence measurements may be combined if they overlap in time.

Interferometric synthetic aperture radar (InSAR) is a technique whereby surface change occurring between two radar imaging passes may be measured and mapped to high precision (see Madsen and Zebker, 1998; Massonnet, 1997 for reviews). The ability to map surface deformation of a fraction of an inch over large areas at spatial resolutions of 100 feet or so has opened up new possibilities for remote monitoring of groundwater resources. Most applications have used satellite radar systems, although airborne systems are also available.

The technique works by acquiring images from the same viewing geometry at two different times between which a change in the surface position has occurred. The phases of the returning radar waves from the two acquisitions are subtracted to create a phase-difference map, or interferogram, that can be processed to create a map of changes in

distance along the line-of-sight direction that are precise to fractions of the radar wavelength (typical wavelengths are 1-10 inches). There are however some noise factors which must be considered: orbital error, atmospheric noise, topography error and phase decorrelation error. Orbital and topography errors are largely handled in the InSAR data processing. Atmospheric water vapor and other variations in Earth's troposphere can introduce phase delay artifacts that mimic surface changes. This is usually dealt with by analyzing many interferometric pairs and averaging (stacking) assuming ground deformation is steady and atmospheric phase is random in time. For time-varying deformation signals, more sophisticated spatiotemporal filtering can be applied during InSAR time series analysis to mitigate the effects of atmospheric noise (e.g., Galloway et al., 1998; Lanari et al., 2004; Ozawa and Ueda, 2011; Chaussard et al., 2013). Another problem, especially acute in agricultural areas like the Central Valley, is small-scale surface changes near the scale of the radar wavelength. Crops blowing in the wind or fields plowed between radar image acquisitions can spoil the phase coherence between the two radar images and cause loss of information. This effect can be ameliorated by using a longer wavelength and selecting interferometric pairs that have small orbital baseline separations and temporal differences.

After many pairs of radar images over an area have been processed into interferograms, they can be further analyzed to create a time series of surface deformation. This is done by an InSAR time series inversion algorithm called the Small Baseline Subset (SBAS) method (e.g., Berardino et al., 2002; Sansosti et al., 2010). SBAS makes use of interferometric pairs that have small spatial baselines and short temporal separations. The time series is constructed pixel by pixel and requires no assumptions on the continuity or stability of phase in time. Proper choice of the reference location is needed in order to tie together the relative InSAR measurements into a consistent reference frame. The reference location (or pixel) is usually chosen at a place that is stable compared to the deformation of interest based on *in situ* geodetic measurements or *a priori* information.

The InSAR time series analysis produces a history of line-of-sight (LOS) surface displacements similar to GPS time series observations but with much higher spatial resolution. Unlike stacking, which has no temporal resolution, InSAR time series recover both long-term mean velocities, and time varying components, while at the same time isolating atmospheric delays (as well as surface deformation) into the respective SAR image epochs (e.g., Lanari et al., 2004). This technique has been applied successfully for imaging non-steady-state deformation at volcanoes (Lundgren et al., 2004), deforming plate boundaries (Lundgren et al., 2009), and aquifer dynamics (Farr and Liu, 2015; Farr, 2011; Lanari et al., 2004). After the initial time series inversion, temporal and spatial filtering can be applied to further suppress atmospheric noise and smooth the deformation time series. Since atmospheric noise is spatially correlated but temporally uncorrelated, its net effect on the InSAR time series is negligible. The estimated measurement precision for InSAR time series is generally a small fraction of a wavelength, depending on the InSAR acquisitions and noise levels (e.g., Galloway et al., 1998; Ozawa and Ueda, 2011; Chaussard et al., 2013). In the case of the Radarsat-2 measurements shown later, uncertainties associated with the vertical displacement (subsidence/uplift) measurements were determined to be less than 1" and usually less than 0.5". These uncertainties cover random

errors, but do not include systematic errors related to choice of reference location or unwrapping errors.

A final step in post-processing is to use the assumption that subsidence is mainly in the vertical direction, so the line-of-sight measurement from the radars can be projected to the vertical. This allows measurements from multiple satellites to be compared with each other and with GPS and traditional surveying data.

Several groups have made studies of the effects of groundwater withdrawal and recharge on InSAR measurements of deformation of the Earth's surface (e.g. Reeves et al., 2011; Calderhead et al., 2011; Lu and Danskin, 2001; Amelung et al., 1999). Preliminary evaluations of InSAR applications to groundwater monitoring have been made over the last few years in Los Angeles (Bawden et al., 2001), the Antelope Valley (Galloway et al., 1998), Las Vegas (Hoffmann et al., 2001; Bell et al., 2008), the Santa Clara Valley (Sneed et al., 2003), the Coachella Valley (Sneed and Brandt, 2007), and the southern Central Valley (Farr and Liu, 2015; Farr, 2011; Sneed et al., 2013; Borchers and Carpenter, 2014).

A number of satellite systems have been flown over the years to provide InSAR data (Table 1). Note that while the satellites span only a few years each, they overlap in time allowing their time series to be compared. That is a focus of ongoing research in our group at JPL. For this report, PALSAR images spanning the period June 2007 – December 2010 and Radarsat-2 images for the period May 2014 – January 2015 were processed to two independent time series. Details of the data used are listed in the Appendix. Further work under this task will fill the gap between the PALSAR and Radarsat-2 results using Radarsat-1 data.

Satellite	dates	resolution (m)	swath (km)	incidence angles	minimum revisit (days)	band*/pol
ERS 1,2	1991-2010	25	100	25°	35	CVV
Envisat	2002-2010	25	100	15-45°	35	CVV, CHH
PALSAR	2006-2011	10-100	40-350	10-60°	46	L-quad
Radarsat 1	1995-2013	10-100	45-500	20-49°	24	CHH
Radarsat 2	2008-	3-100	25-500	10-60°	24	C-quad
TerraSAR-X	2007-	1-16	5-100	15-60°	11	X-quad
Cosmo-Skymed	2007-	1-100	10-200	20-60°	<1	X-quad
PALSAR-2	2014-	3-60	50-350	8-70°	14	L-quad
Sentinel-1A	2014-	20	250	30-45°	12	C-dual
NISAR	2020?	35	350	15-60°	12	L-quad

* wavelengths: X ~ 3 cm, C ~ 5 cm, L ~ 25 cm

Table 1. Past, present, and future radar satellites.

UAVSAR, which is an L-band SAR flown on a G-3 aircraft, has a much higher signal-to-noise ratio than satellite SARs, usually achieving a factor of 100 increase in signal through the use of a high-power instrument transmitting from 41,000 ft. altitude rather than from Earth orbit. It also has higher spatial resolution than the satellite SARs, with <6' single-look resolution, which allows higher resolution following spatial averaging to reduce the phase noise. The reduction in phase noise means that deformation measurement accuracy is increased and temporal decorrelation is reduced. The practical outcome is that a larger proportion of a UAVSAR scene will produce useful measurements. Previous InSAR results from UAVSAR include measurements of fault slip in California (Donnellan et al., 2014), landslides along the San Andreas fault (Scheingross et al., 2013), and sinkhole precursory ground movement in Louisiana (Jones and Blom, 2014).

UAVSAR data processing followed similar steps to those used for the satellite data. We eliminated very low coherence areas from the analysis by masking out pixels with average coherence less than 0.285 or with coherence < 0.60 in all interferograms. The average is taken over the interferometric coherence associated with each interferogram in the stack. This masking step eliminated most open water and land areas that experienced high and persistent temporal decorrelation. A temporal filter of width 1 month was applied to smooth the results; this value was chosen to be sufficiently short that we are able to resolve when subsidence rates changed during 2014. Pixels were classified based upon their average coherence, and adaptive spatial filtering was applied such that low coherence areas were averaged with nearby same-class pixels to reduce noise, and high coherence pixels were not averaged at all. Uncertainties in the derived subsidence values were obtained through a Jacknife resampling procedure whereby the SBAS processing was run on the stack with data from a single acquisition removed, repeated with removal of each acquisition date in the series. This procedure estimates the combined effect of random errors and systematic errors associated with a single acquisition. The uncertainties in the cumulative subsidence derived from UAVSAR InSAR are in the range of 0.25" to 1.0" across most of the imaged area. Estimates for each pixel are included in the GIS products provided to DWR, and shown in plots in an appendix to this document.

The UAVSAR data analysis methods used in this work are based on procedures developed to monitor the levees in the Sacramento-San Joaquin Delta using the instrument (Jones et al., 2011; 2012; 2015). Unlike in the Central Valley, groundwater pumping is not a problem in the Sacramento-San Joaquin Delta. However, subsidence from aerobic oxidation of the soil and compaction of the soil from pumping to remove water from the upper layers of the soil is common throughout the area (Deverel and Leighton, 2010).

San Joaquin Valley Subsidence

Maps of subsidence in the San Joaquin Valley were made for the period June 2007 – December 2010 (Fig. 1; PALSAR) and May 2014 – January 2015 (Fig. 2; Radarsat-2). Two main subsidence bowls can be seen in the maps of total subsidence: one in the Tulare basin centered on Corcoran and one S of the town of El Nido. The maximum total subsidence for the earlier period in the Tulare Basin was over 37" near Corcoran. The maximum subsidence S of El Nido was approximately 24". During the more recent period, we see that, while the two bowls are generally similar, some of the details have changed. The largest

subsidence S of Corcoran totals over 13" while another diffuse area is located NW of Corcoran with a subsidence of up to 9". Subsidence of over 3" extends W to the California Aqueduct. This southern subsidence bowl is about 60 x 25 miles. The other main subsidence bowl S of El Nido subsided about 5-6" with pockets up to 10". The East Side Bypass runs right through the main part of the subsidence in this area.

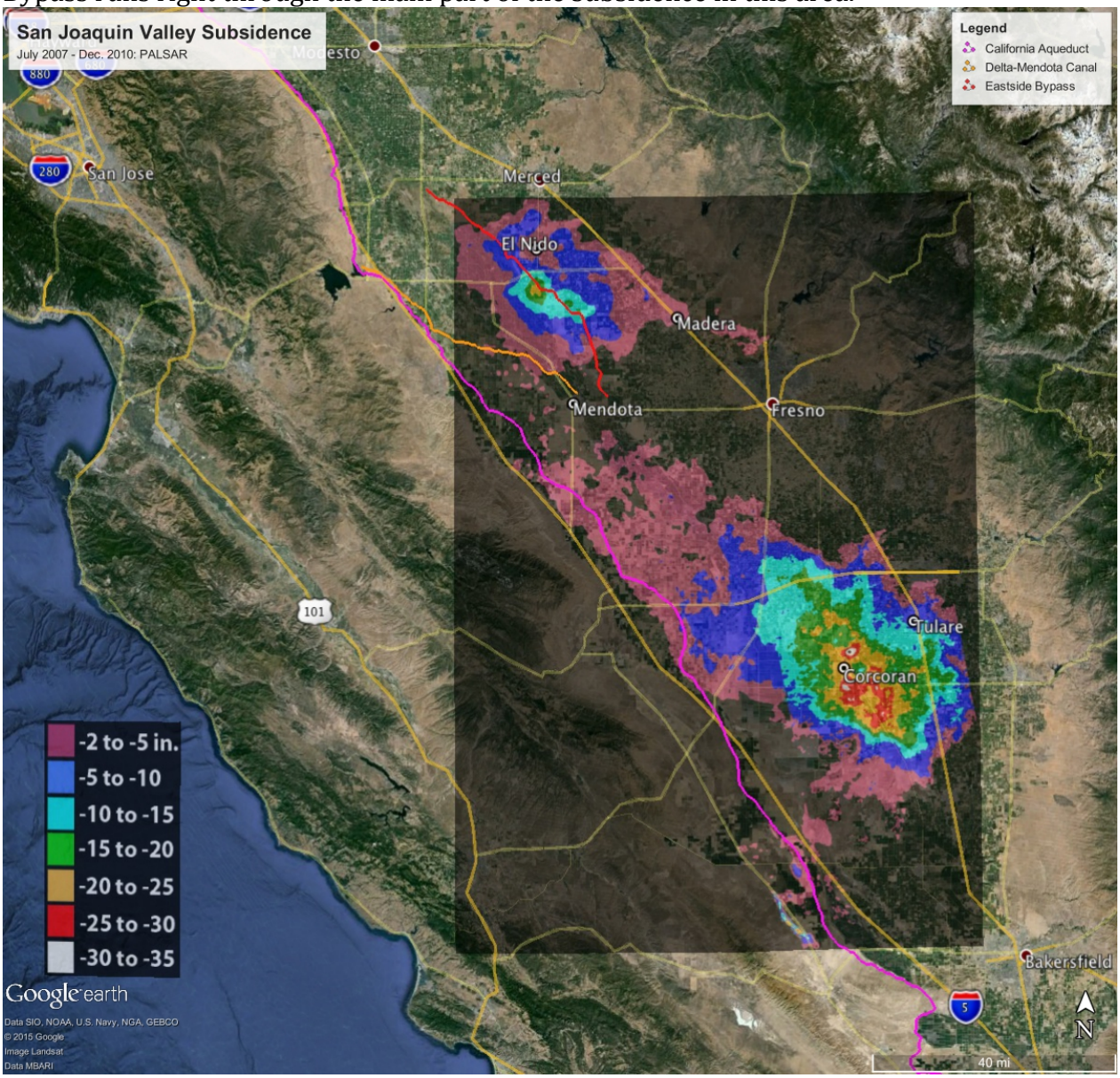


Figure 1. Total subsidence in the San Joaquin Valley for the period June 2007 – December 2010 as measured by the Japanese PALSAR and processed at JPL. Two large subsidence bowls are evident centered on Corcoran and S of El Nido. Note the narrow banana-shaped subsidence feature at bottom center. That corresponds to the Belridge Oil Field, which is subsiding due to oil extraction (Fielding et al., 1998). An animation of the subsidence in the Tulare basin can be seen at: http://photojournal.jpl.nasa.gov/catalog/PIA16293.

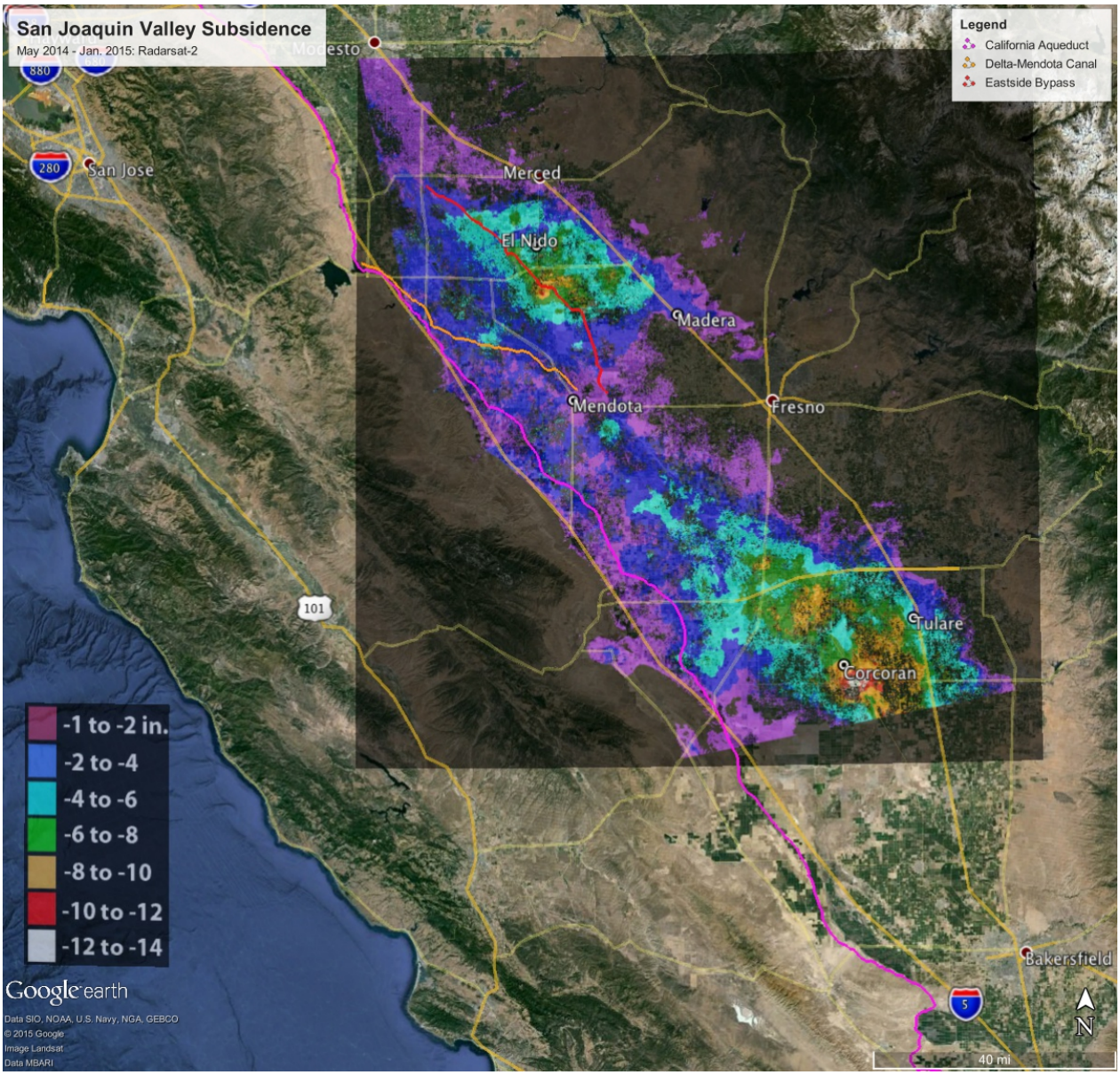


Figure 2. Total subsidence in the San Joaquin Valley for the period 3 May 2014 – 22 January 2015 as measured by the Canadian Radarsat-2 and processed at JPL. The same two large subsidence bowls visible in Figure 1 at Corcoran and El Nido are clearly visible. A preliminary version of this map was presented as Figure 15 in the recent Public Update for Drought Response (CDWR, 2014).

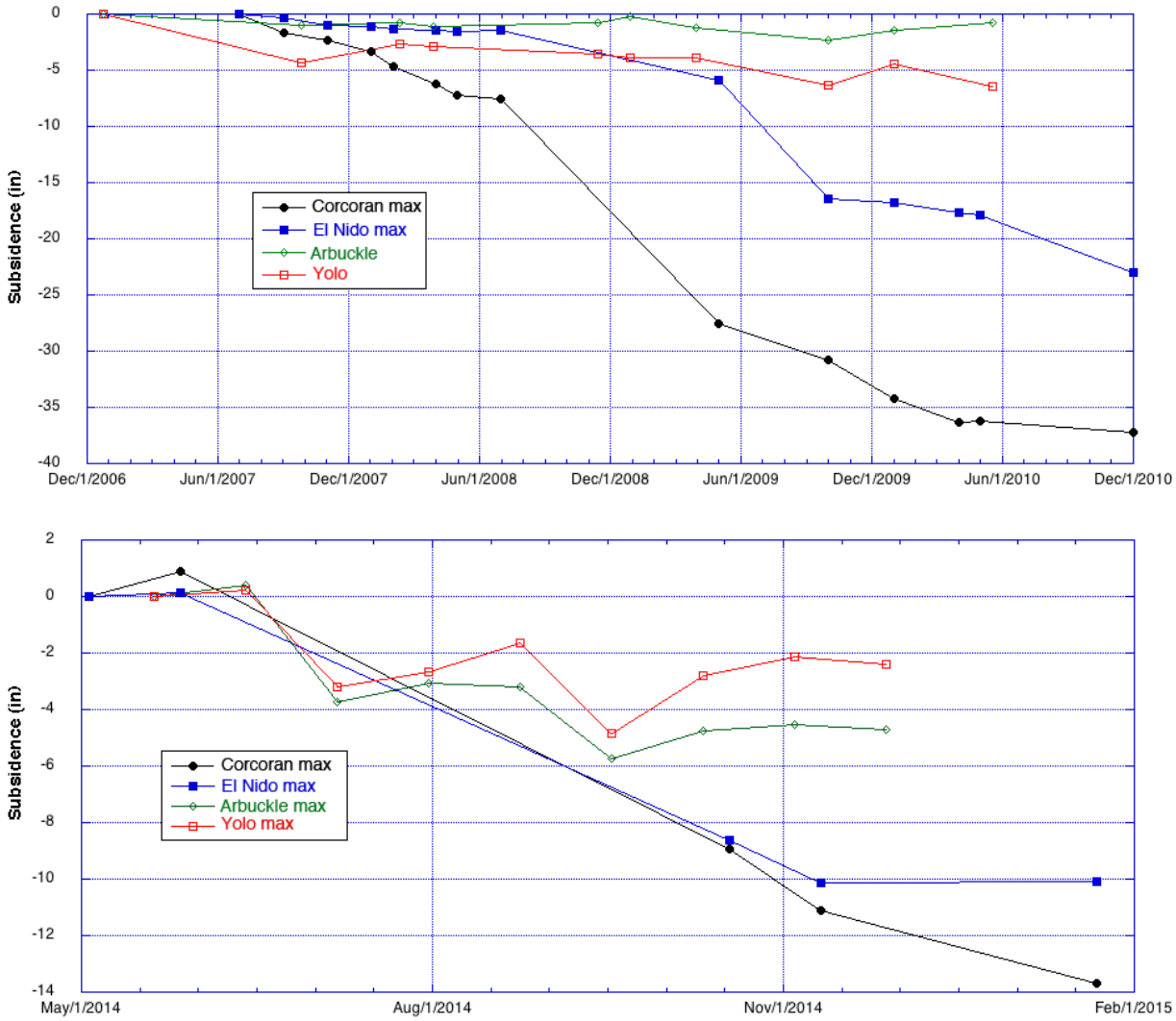


Figure 3. Subsidence histories of a few locations in the San Joaquin and Sacramento Valleys. Top: 2006 – 2010 (PALSAR); Bottom: May 2014 – Jan. 2015 (Radarsat-2). Corcoran max is located in the maximum subsidence pocket just N of Corcoran. El Nido max is located in the pocket just S of El Nido. Arbuckle is located just W of the town of Arbuckle in the Sacramento Valley and Yolo is at the center of the subsidence feature N of Yolo (Fig. 5).

The deformation histories of a few selected locations in the San Joaquin Valley are plotted in Figure 3. The large maximum subsidence in the Corcoran area is clear and shows virtually no recovery at any time in either period of measurement, although the rate seems to decrease in 2010. Likewise, the maximum subsidence location near El Nido shows little seasonal change except for some flattening in 2010 and January 2015. The histories for Arbuckle and Yolo are discussed later in the Sacramento Valley section.

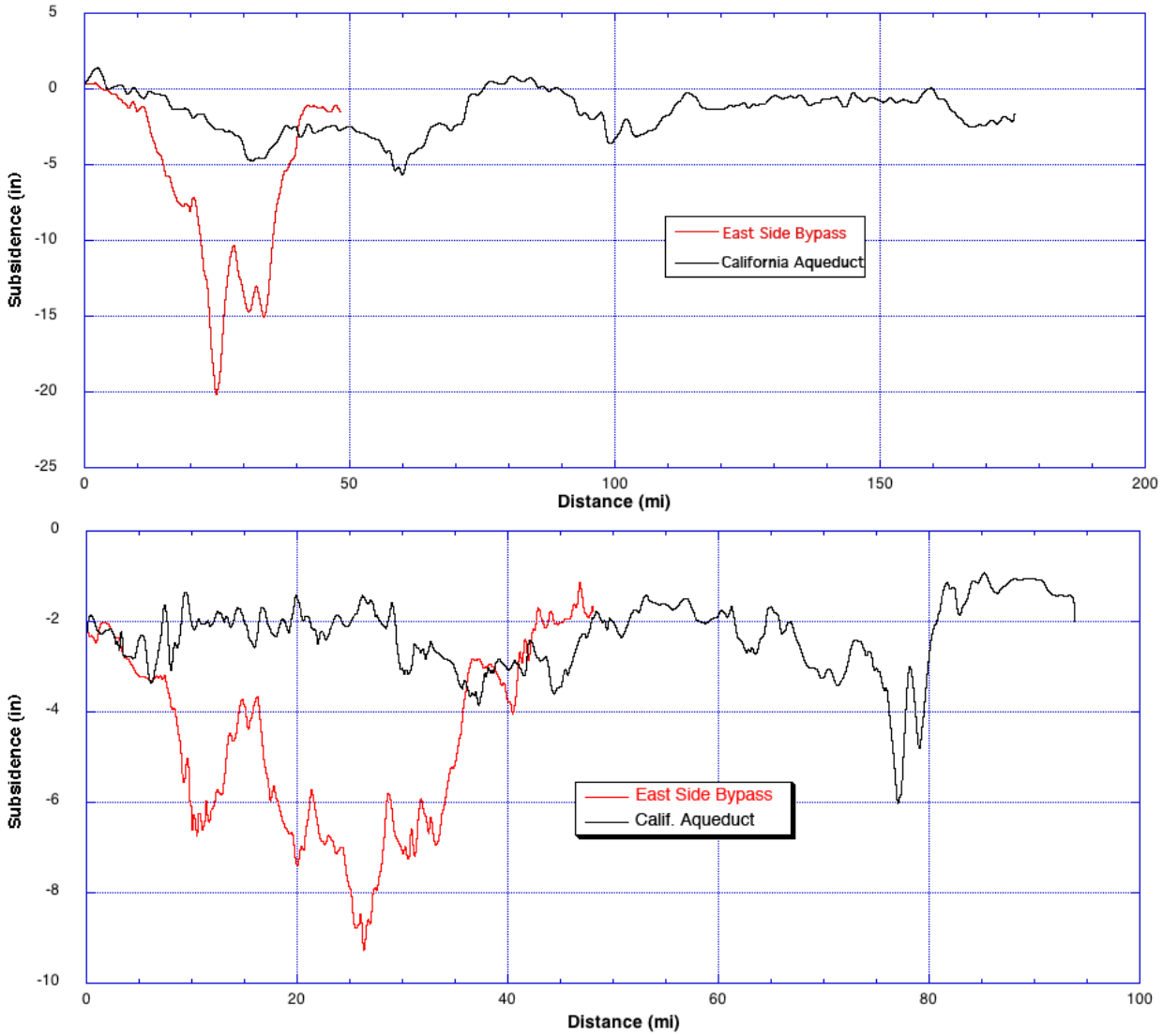


Figure 4. Transects showing total subsidence in the vicinity of the California Aqueduct and the East Side Bypass. The transects extend from N to S with the end points located where the canals intersect the radar images. Top: Total subsidence from June 2007 – December 2010 (PALSAR). Note the deep subsidence pit about midway along the East Side Bypass. That corresponds to the orange area on the map (Fig. 1). Bottom: total subsidence from 3 May 2014 – 22 January 2015 (Radarsat-2). Note the deep subsidence pit about midway along the East Side Bypass. That corresponds to the orange and red area on the map (Fig. 2). The two sharp pits between miles 75 and 80 on the California Aqueduct correspond to the features observed by UAVSAR (Fig. 12).

The transects shown in Figure 4 give a more detailed picture of the total subsidence measured in the vicinity of the California Aqueduct and the East Side Bypass over the two periods of measurement. It is clear that the East Side Bypass has suffered much more subsidence, concentrated in its central area. In contrast, areas in the vicinity of the California Aqueduct experienced up to 5" of subsidence in 2006 - 2010, and a similar amount in the May 2014 – January 2015 time period. These amounts correspond to averages over the processed pixel, not the values on the aqueduct structure itself.

One new concentrated zone along the California Aqueduct stands out in Figure 4, between 75 and 80 miles. This subsidence area appears to be a new zone, and was detected at higher spatial resolution by UAVSAR, as discussed later in this report.

Sacramento Valley Subsidence

Subsidence maps for the southern part of the Sacramento Valley were also produced for this report, covering the period December 2006 to May 2010 (PALSAR; Fig. 5) and 20 May 2014 to 28 November 2014 (Radarsat-2; Fig. 6). Only one area of significant subsidence was detected and mapped in the earlier period: just N of Yolo a bowl about 7 miles across had a maximum subsidence of about 6". This matches well with subsidence mapped by GPS survey from 1999 - 2005 and reported in D'Onofrio and Frame (2006).

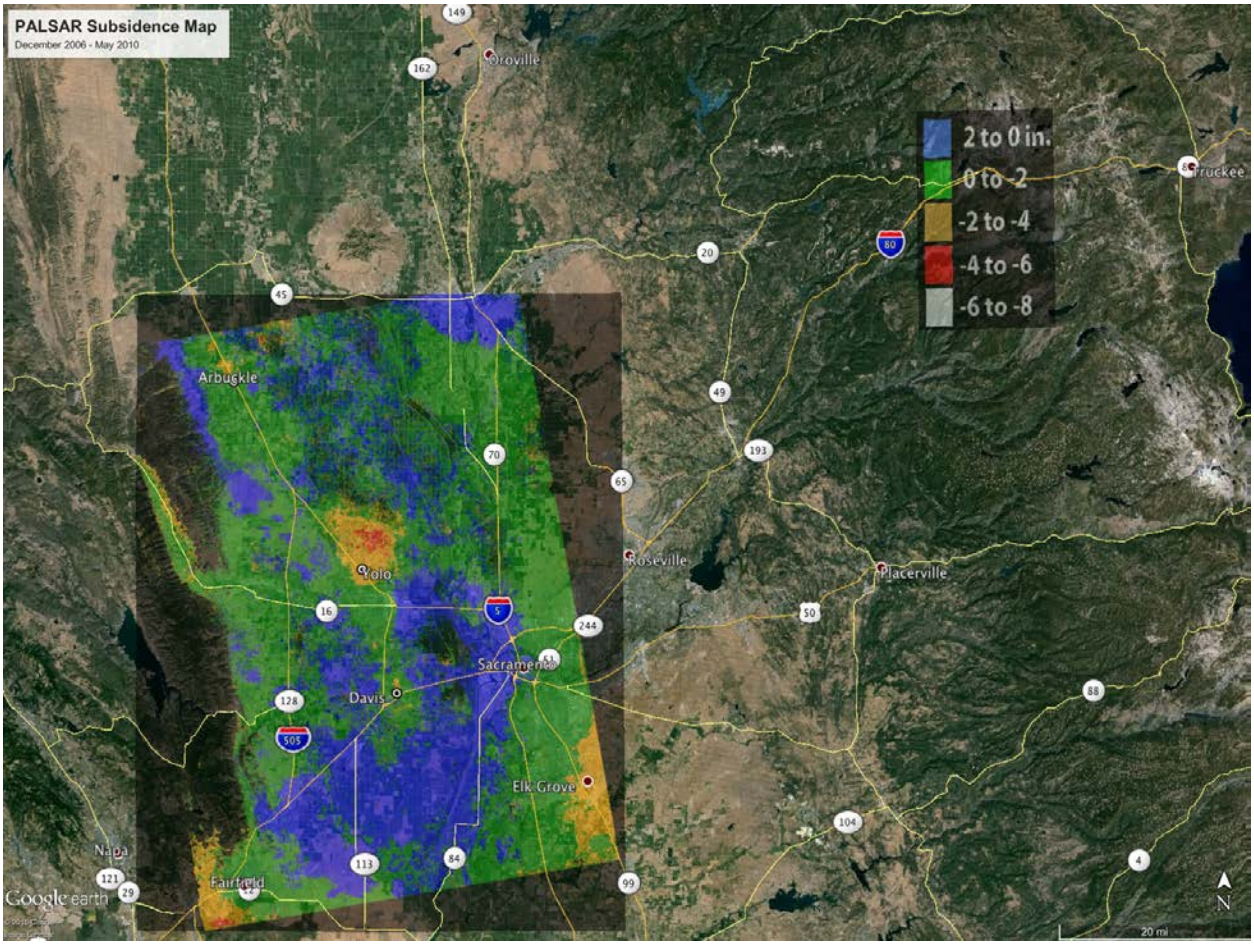


Figure 5. Total subsidence in the Sacramento Valley for the period Dec. 2006 - May 2010 as measured by the Japanese PALSAR and processed at JPL. One subsidence bowl is shown north of Yolo.

The Radarsat-2 map (Fig. 6) shows 3 areas of significant subsidence between 20 May 2014 to 28 November 2014: an extended area W of Yolo includes small areas with a maximum subsidence of about 3"; another diffuse area N of Yolo had a maximum subsidence of about 2.5"; and an unusually small heavily subsiding area just W of Arbuckle showed a maximum subsidence of about 5".

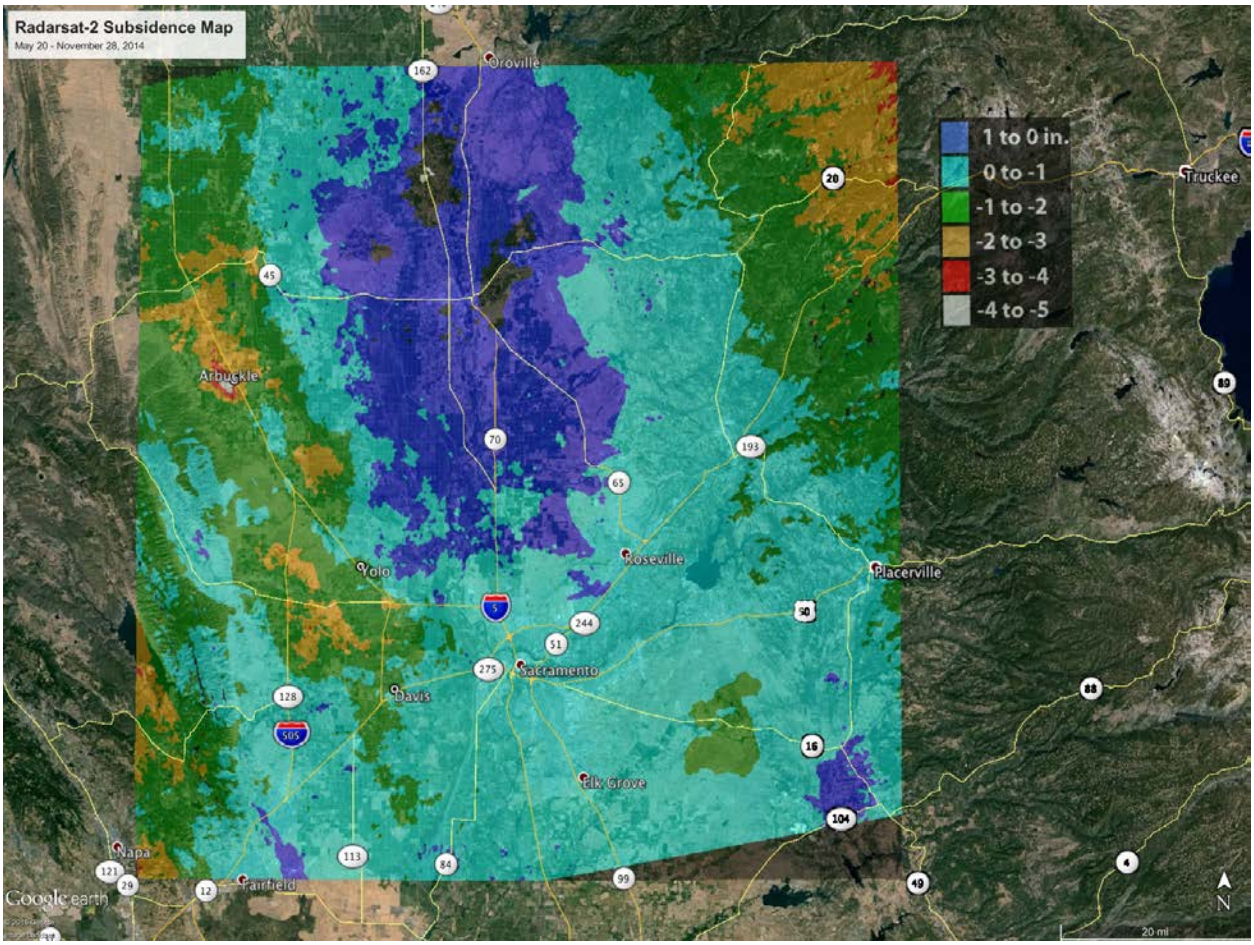


Figure 6. Total subsidence in the Sacramento Valley for the period 20 May 2014 – 28 November 2014 as measured by the Canadian Radarsat-2 and processed at JPL. Two diffuse subsidence areas can be seen west and north of Yolo and a small, deep subsidence bowl is evident just west of Arbuckle.

Subsidence histories of two locations in the Sacramento Valley are shown in Figure 3. The area of maximum subsidence in the PALSAR data north of Yolo (Fig. 5) totals about 6" over the earlier 3.5 year period and about 2" in the last half of 2014. The small area of intense subsidence evident near Arbuckle in 2014 (Fig. 6) shows an uneven subsidence with time in Figure 3, totaling about 5" for the last half of 2014, but no subsidence in 2006 - 2010.

UAVSAR Results Along California Aqueduct

Figure 7 shows the areas in the Central Valley covered by the two UAVSAR flight lines, and the measured subsidence in both imaged areas. The swath to the north showed locations experiencing significantly greater subsidence than was observed in the southern swath. Figure 8 shows only the northern imaged swath. In this stretch of the aqueduct there is an extended region of subsidence in the center, an area of very high subsidence with a very well-defined locus to the south, and several other areas showing subsidence of 3"-5". These areas are shown in more detail in Figures 9-11, where time histories of individual points made clear that even though the northern swath (line 14511) was imaged for a longer

period of time than the southern swath (line 13300), this is not the reason why higher cumulative subsidence was measured there.

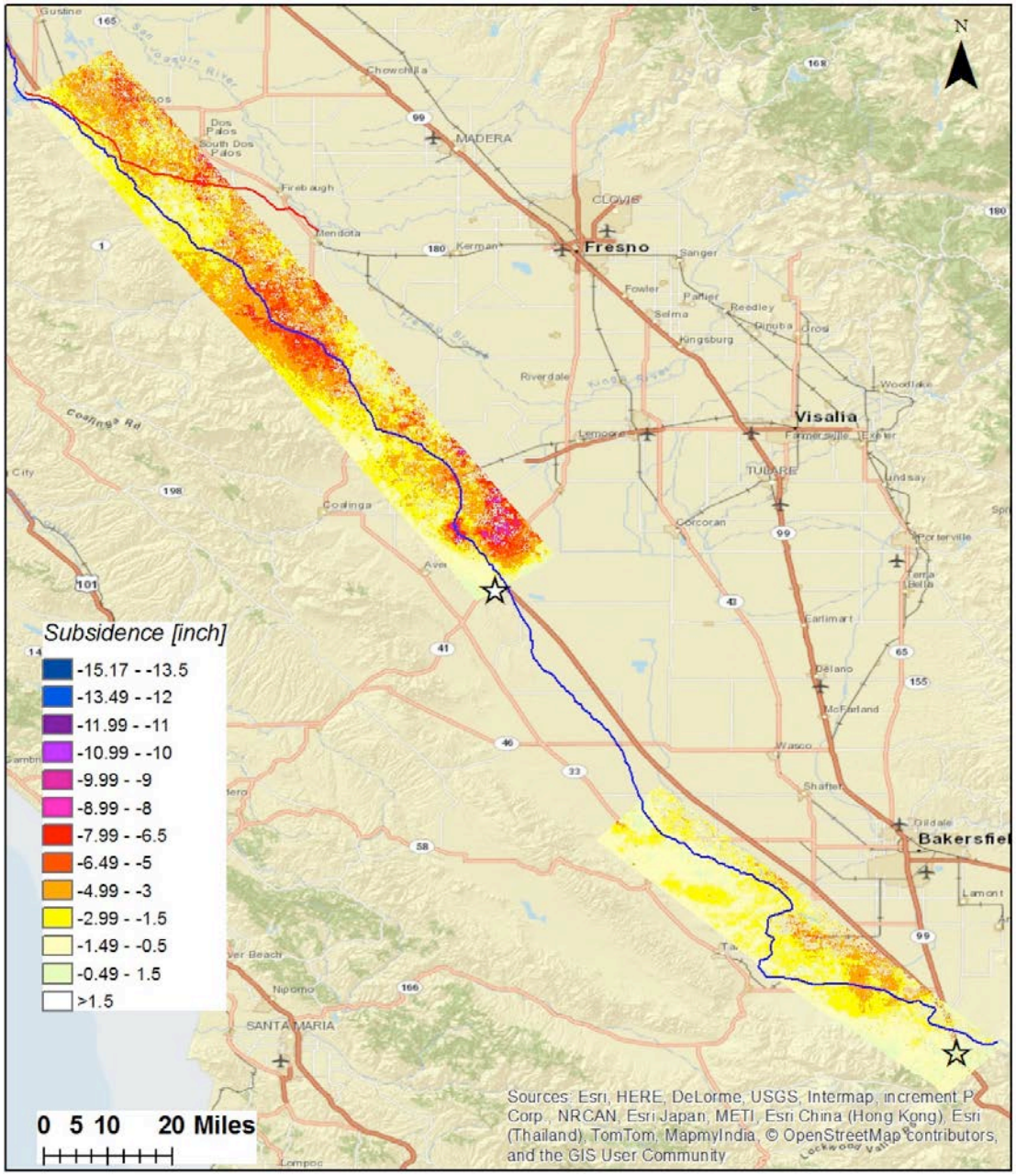


Figure 7. Overview of area in the Central Valley imaged with UAVSAR, showing the broad patterns of subsidence observed. The areas of significant subsidence encompassing the aqueduct during the imaged time period occur entirely in the northern section .These swaths were planned to well image the California Aqueduct, and therefore miss the large subsidence bowls to the east that were seen in the satellite SAR results. The swath to the north is UAVSAR line 14511 and shows cumulative subsidence between 19 July 2013 and 10 March 2015. The swath to the south is UAVSAR line 13300 and shows cumulative subsidence between 2 April 2014 and 7 January 2015. The stars indicate the reference points used for each line, which are the locations in each swath taken to have experienced no subsidence and against which other locations are compared.

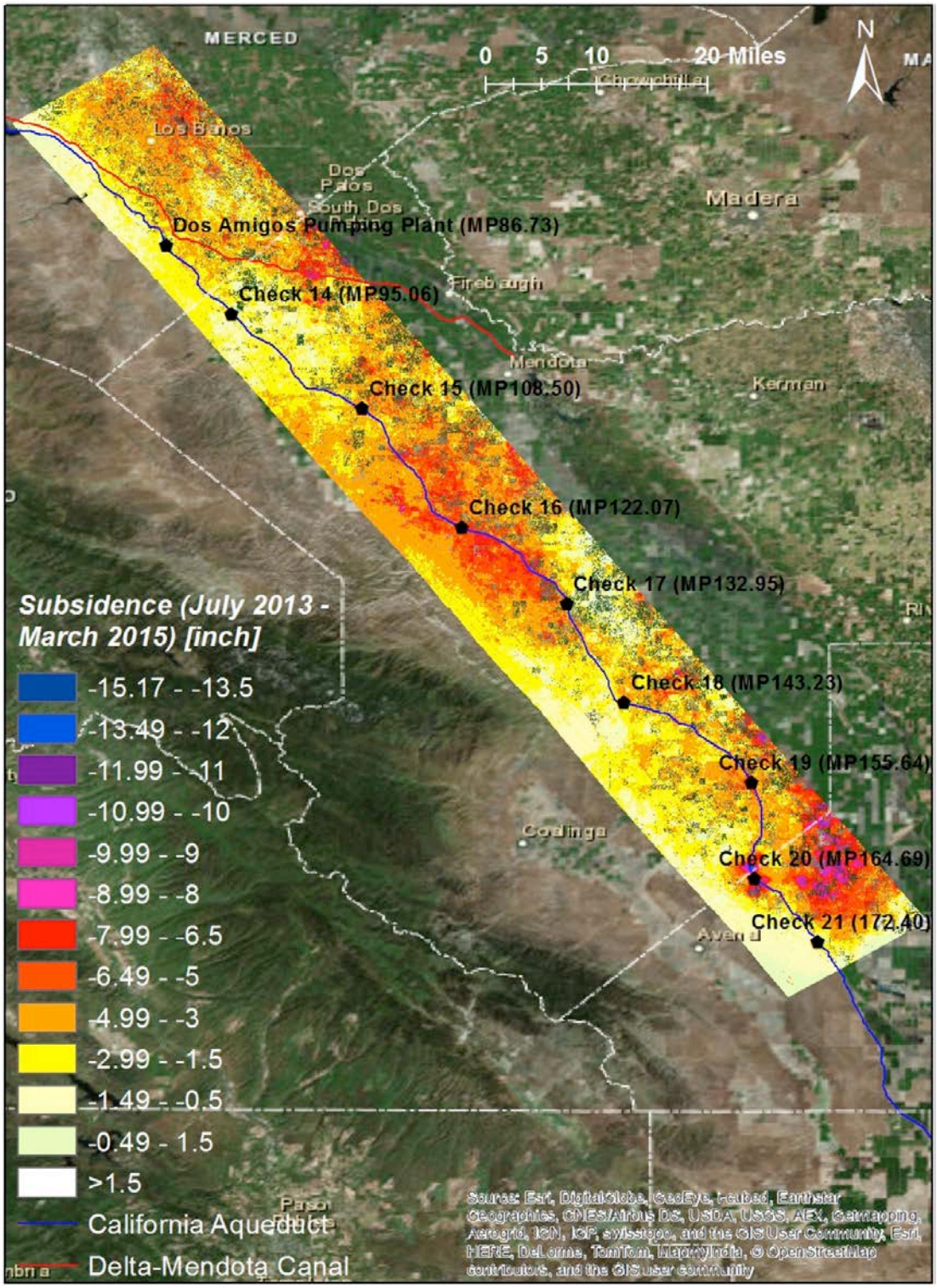


Figure 8. Cumulative subsidence between July 2013 and March 2015 measured with UAVSAR in the Central Valley between San Luis Reservoir and just south of Check 21. A new locus of subsidence, which had the largest aqueduct impact, occurred near Check 20 (see Fig. 9). From south of Check 15 to Check 17 is an area that has historically shown large subsidence of the aqueduct (see Fig. 10). Near Huron (Check 19) is another area of subsidence, this one less extensive in length (see Fig. 11).

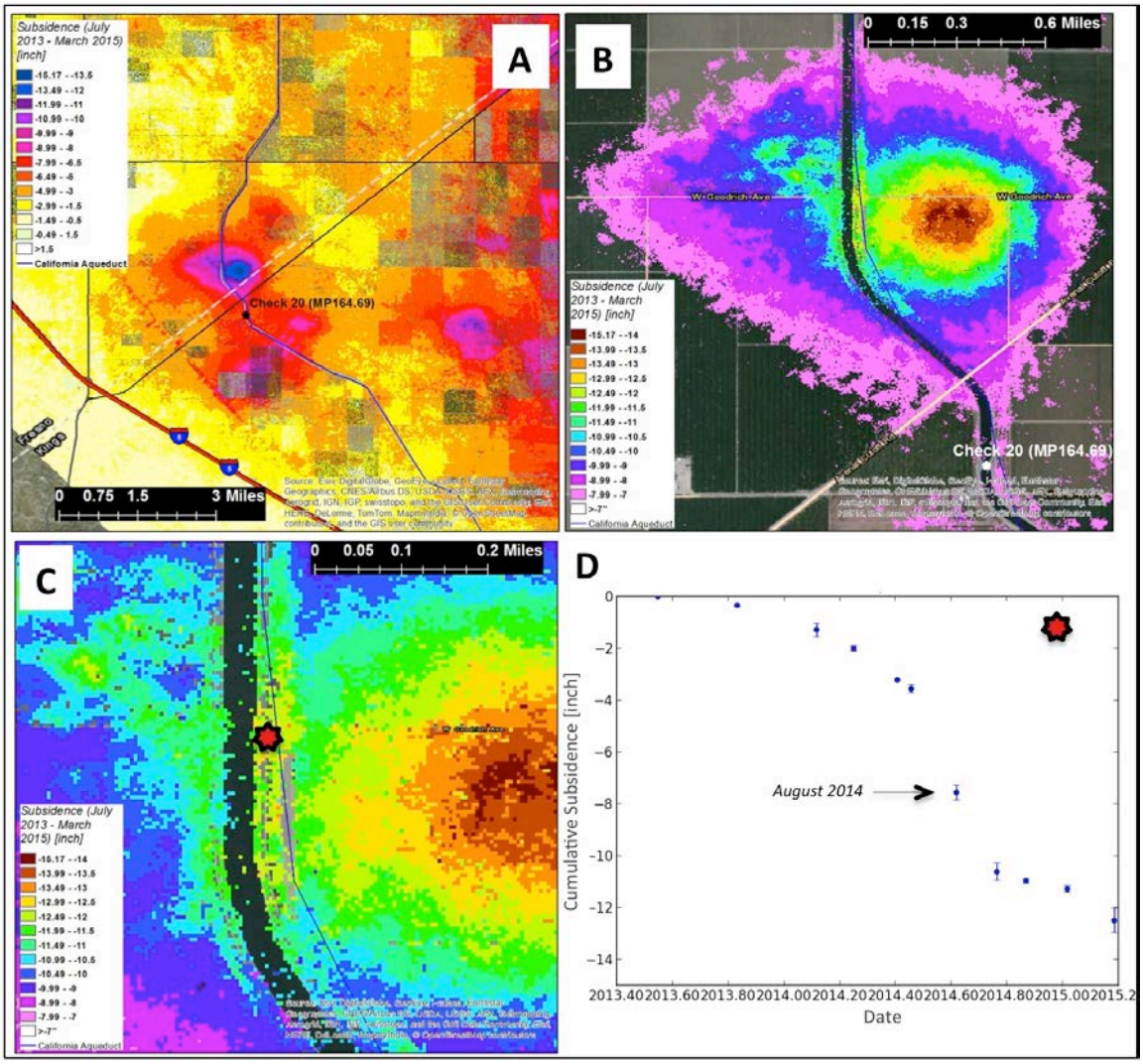


Figure 9. (A) Overview of the cumulative subsidence across an extended area east of Interstate 5, near Check 20 (MP 164.69) at the southern end of swath 14511 (Fig. 8). Several round, localized features are seen in this section, but the one closest to the aqueduct experienced the most subsidence of any area in the two UAVSAR swaths. (B) Enlargement showing the subsidence bowl just north of Avenal Cut-off Road, with a well localized center and extended impact to the surrounding area, including the aqueduct. Limits are placed on the subsidence overlay layer to indicate areas that experienced more than 8" of subsidence between July 2013 and March 2015. Values represent an average over the smoothed pixels, not the maximum subsidence within each pixel. (C) Close-up of the section of the aqueduct nearest the center of the bowl. The star marks the location for which the time history of subsidence is plotted in D. (D) Cumulative subsidence vs. time from July 2013 (zero) to March 2015 (12.5"). This area experienced a dramatic increase in subsidence starting in summer 2014, which slowed abruptly in October 2014.

The greatest subsidence directly impacting the California Aqueduct was observed immediately north of the intersection of the aqueduct with Avenal Cutoff Rd., between Huron and Kettleman City, just north of Check 20 (MP164.69). At this location, a subsidence bowl centered less than half a mile from the aqueduct formed during the study period. Figure 9A shows the subsidence in the vicinity of this location, showing at least three similar features that appear to be associated with wells. Figure 9B shows the locus of the subsidence bowl north of Avenal Cutoff Rd. Limits are placed to indicate the area that experienced >8" of subsidence. The main subsidence bowl impacted the aqueduct significantly, extending from its center in an adjacent field to west of the structure, and caused >8" of subsidence along a 1.3 mile stretch of the aqueduct. In addition, nearly 0.5 miles experienced >11" subsidence (Fig. 9C). Figure 9D shows the temporal development of the subsidence, indicating that high subsidence in this area started around June 2015. The eastern edge of the aqueduct closest to the center of the bowl experienced up to 12.5" of subsidence. The bulk of the subsidence (8") occurred very rapidly, over the period between June and October 2014. There is an indication of increasing subsidence prior to that time, around Feb. 2014, but at a much lower rate than experienced later in the year. The subsidence rate decreased by November 2014. More acquisitions are needed to determine whether the rate is increasing again in March 2015. Comparison with results from Radarsat-2 (Fig. 2, 4) show a larger amount of subsidence measured by UAVSAR, even accounting for the longer time interval covered by the UAVSAR data. This is likely caused by the larger pixel size used in the satellite processing (300' vs. 25') and a slightly longer temporal filter (2 mo. vs. 1 mo.).

Figure 10 shows the cumulative subsidence between Check 16 (MP122.07) and Check 17 (MP132.95) of the California Aqueduct, near Cantua Creek. Although subsidence in this area was less (only up to 8"), a longer stretch of the aqueduct was affected. Similar to the Avenal subsidence bowl, the subsidence rate appears to have increased dramatically in spring 2014, and to have lessened in autumn 2014. Figure 11 shows the area immediately east of Huron, in the vicinity of Check 19 (MP155.64). Unlike the other two areas, subsidence here has been more consistent, albeit with a noticeable but less precipitous increase in rate in spring/summer 2014. Here the cumulative subsidence was about 7" during the 20 months that the area was monitored.

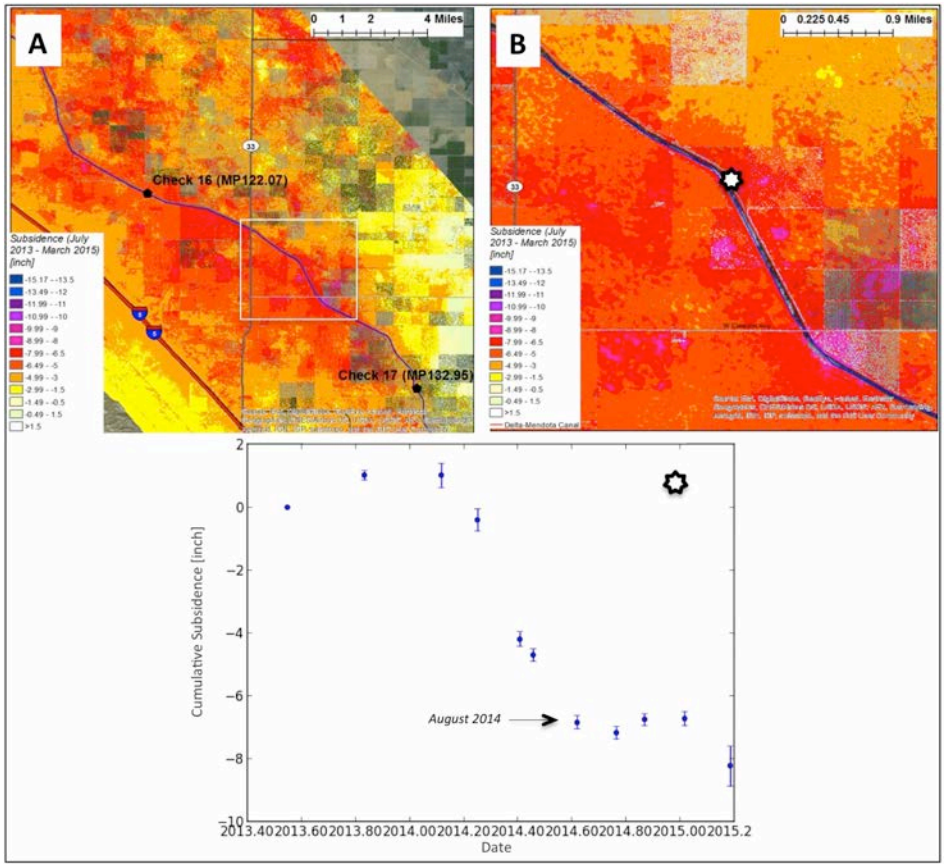


Figure 10. (A) Subsidence in the Cantua Creek area, showing an extended section of the California Aqueduct encompassing Checks 16 and 17 that experienced as much as 8" of subsidence between July 2013 and March 2015. The time series shows that in this area there is seasonal uplift/subsidence and that the subsidence accelerated in spring 2014 and tapered off in fall 2014.

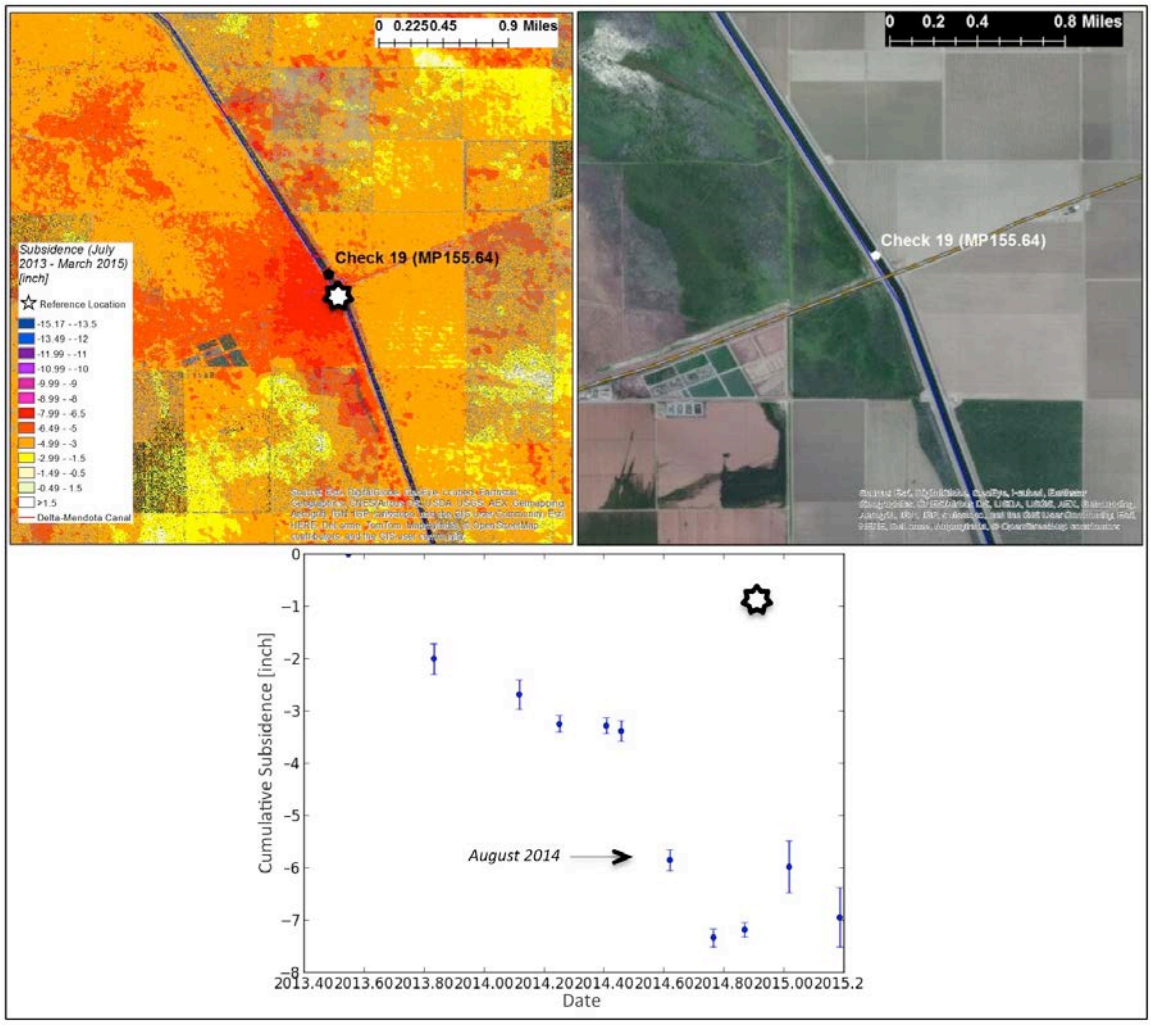


Figure 11. Location immediately east of Huron where a short stretch of the California Aqueduct has experienced nearly steady subsidence since July 2013, accumulating about 7" of vertical displacement between July 2013 and March 2015. There is larger uncertainty at the last two time steps, which can be decreased with additional UAVSAR acquisitions.

Figure 12 shows subsidence in the southern swath, where only one area indicated particularly anomalous subsidence directly affecting the California Aqueduct. This is near where Old River Rd. crosses the aqueduct, between Check 33 (MP267.36) and Check 34 (MP271.27) (Figure 13). For this line, we have no data prior to April 2014 so we cannot tell whether this is an area showing persistent or recent subsidence. We do observe subsidence in the south-central part of the imaged swath (Fig. 13A), but it did not directly affect the aqueduct during April 2014 – Jan. 2015. No substantial subsidence is seen west of Buttonwillow, although ground subsidence associated with oil extraction is apparent (Fig. 13C).

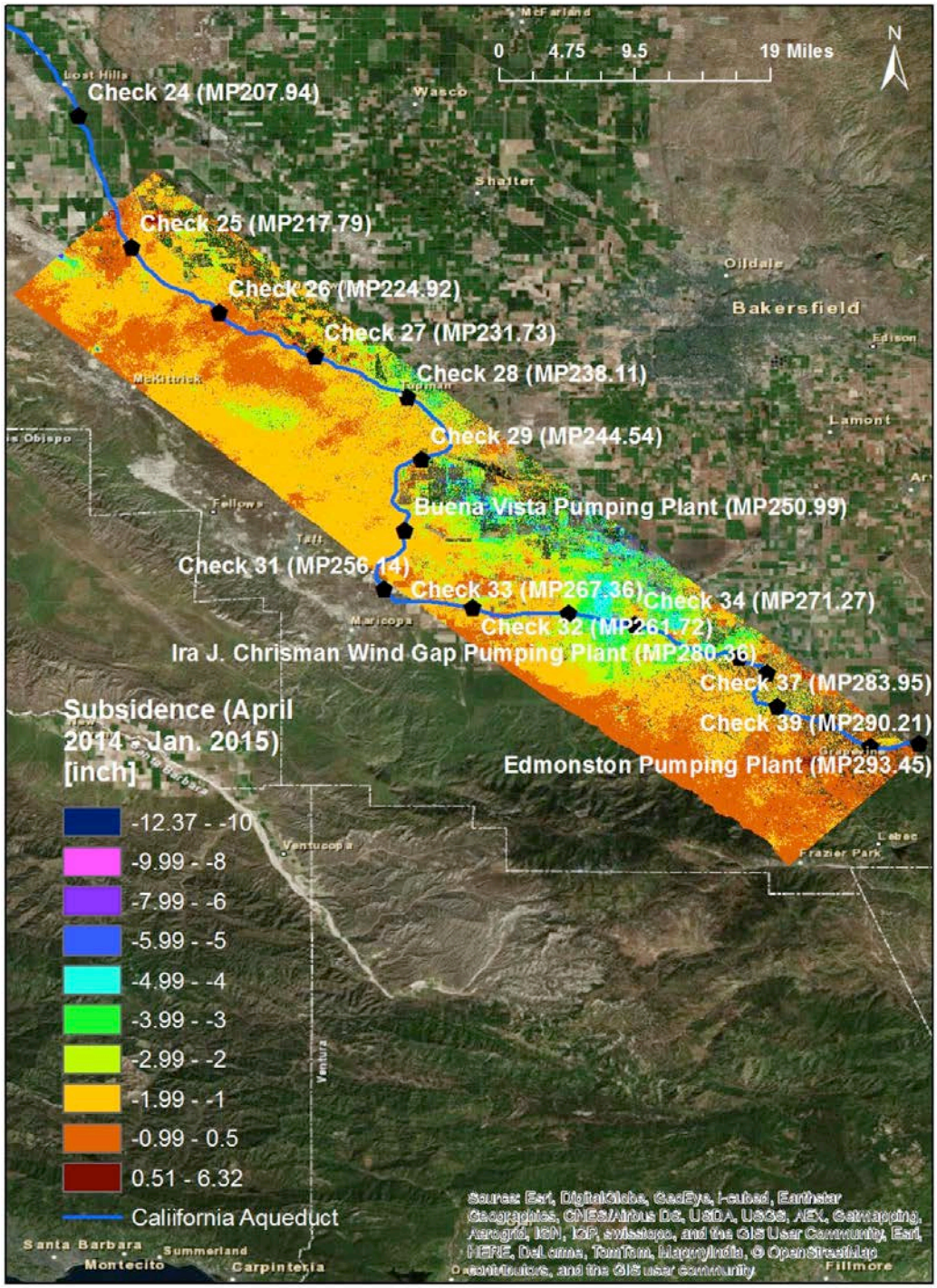


Figure 12. (Top) Cumulative subsidence between April 2014 and January 2015 measured with UAVSAR in the Central Valley between Buttonwillow and the Edmonston Pumping Station. The subsidence is much less in this area than in the area to the north shown in Figure 9.

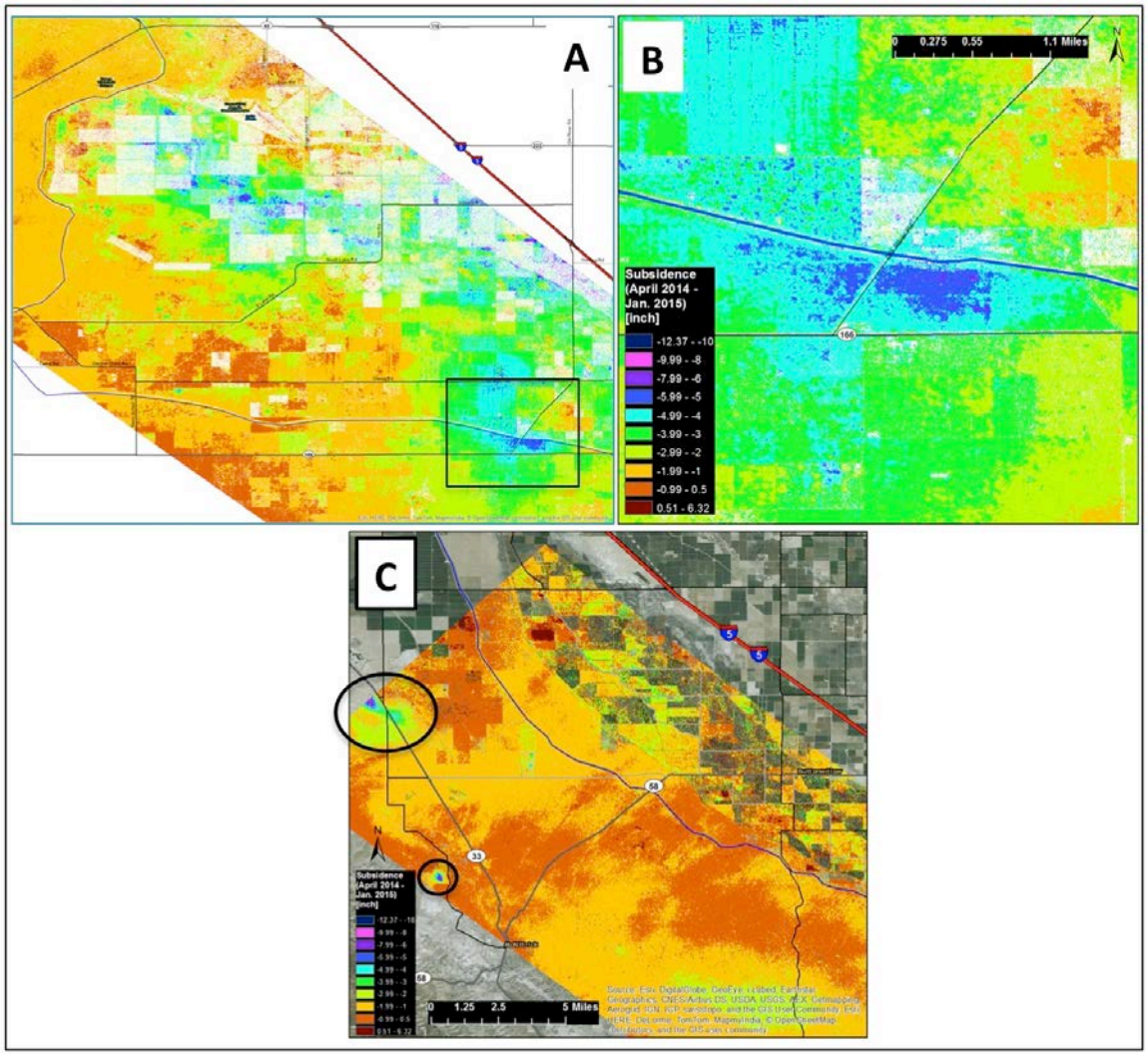


Figure 13. (A) The central section of UAVSAR line 13300 (Fig. 12) showing the greatest subsidence. (B) The one area that showed significant subsidence (outlined in A), with up to 5" on the sides of the aqueduct. (C) North end of line 13300, near Buttonwillow. The only high subsidence in this area occurs near oil fields (circled) and does not impact the aqueduct.

Conclusions and Future Plans

PALSAR and Radarsat-2 have proved to be useful for making maps of Central Valley subsidence. Maps as well as pixel histories of subsidence and transects showing temporal and spatial details of subsidence can be produced from the InSAR data. Updates of the subsidence maps for the Central Valley will continue with the advent of Europe's Sentinel-1A (Table 1). The first acquisitions for the Central Valley were in January 2015 and are continuing, in general every 24 days. Figure 14 shows example coverage of Sentinel-1A.

The UAVSAR results show that radar remote sensing using high resolution, L-band (10" wavelength) SAR can rapidly identify the localized areas of subsidence, so that resources can be targeted efficiently to protect and maintain critical infrastructure. Using UAVSAR,

we were able to locate and monitor a previously unknown locus of subsidence that caused the California Aqueduct to subside by as much as 13", so that further work can be done to identify the cause of the subsidence and prevent it from happening in the future. Furthermore, with frequent monitoring we were able to isolate the time period during which rapid subsidence occurred. Without this kind of comprehensive, rapidly acquired mapping capability it would not be possible to identify through ground surveys alone this type of problem that rapidly developed during the ongoing drought. UAVSAR acquisitions of the two swaths imaging the California Aqueduct are planned to continue for another 6-9 months at least.

As described above, the InSAR time series we produce are essentially series of maps representing the change in surface elevation for each satellite acquisition date. In a sense, we produce 4-dimensional data sets. We have found a convenient format for storage and post-processing is a multi-band GeoTiff format, where each 'band' is an acquisition date. Most common Geographic Information System software packages recognize this format and can display map products from the data. We will furnish all of our products to the DWR in this format for future use and generation of additional products.

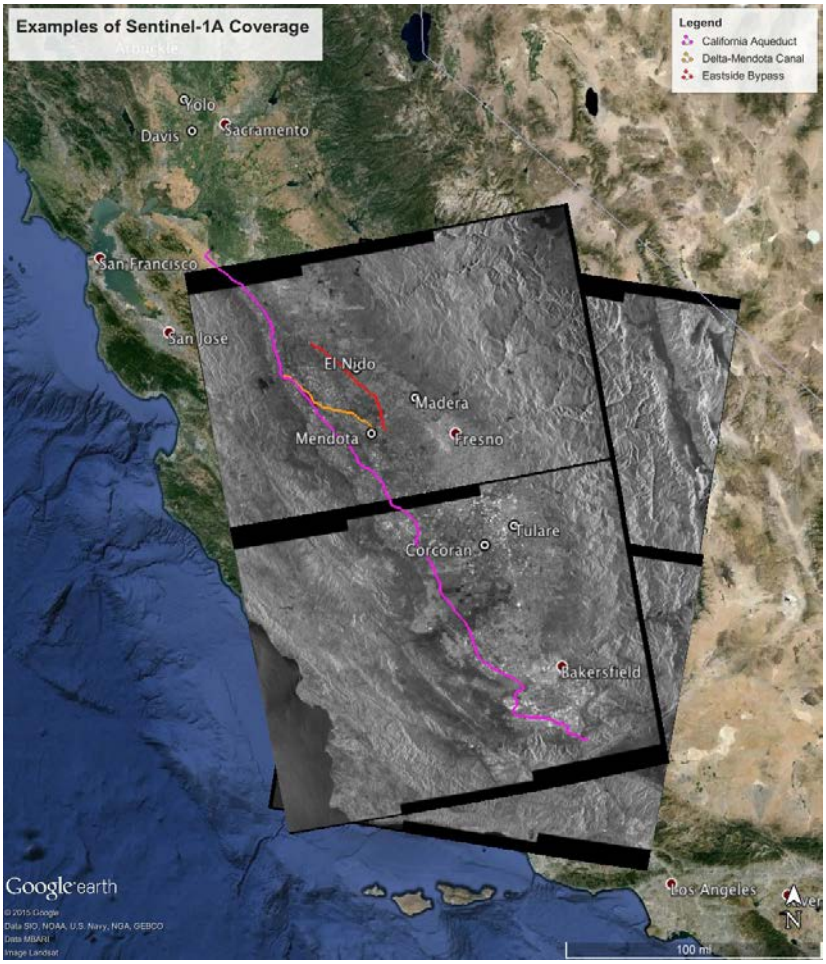


Figure 14. Examples of Sentinel-1A coverage of the San Joaquin Valley. All of California will be covered by this satellite approximately every 24 days from both ascending (SE-NW) and descending (NE-SW) tracks.

Acknowledgements

This work was funded by the California Department of Water Resources. Part of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA. The Alaska Satellite Facility (http://www.asf.alaska.edu/) archives and distributes the PALSAR data used in this study. The Japanese Space Agency contributed the PALSAR data.

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Appendix: Detailed lists of data used

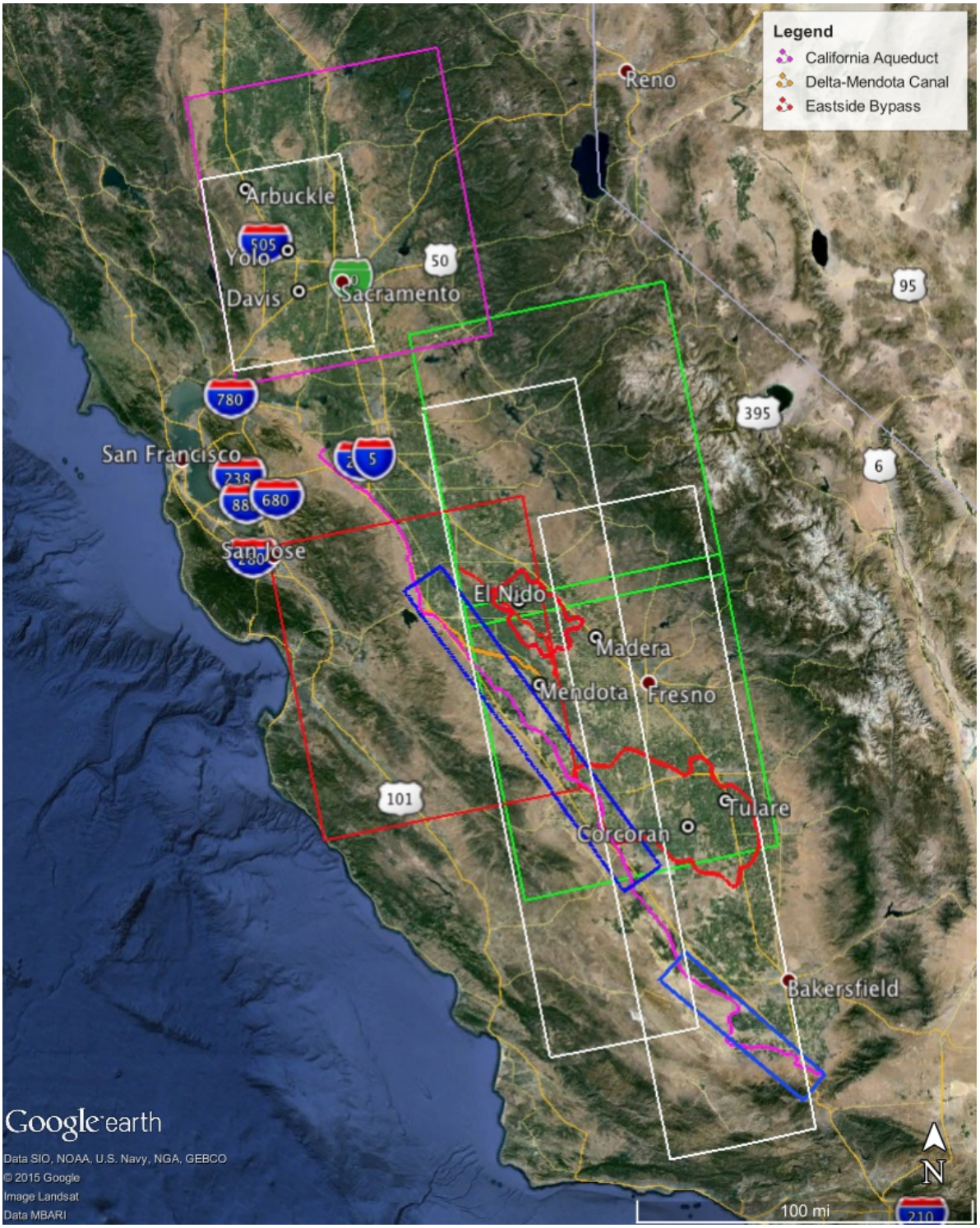


Figure A1. Map showing PALSAR (white), Radarsat-2 (green, red, purple), and UAVSAR (blue) coverage of the Central Valley. Note that the southern edge of the Radarsat-2 tracks (green) was determined by competing data acquisitions by oil companies monitoring subsidence in the oil fields west of Bakersfield. The red box represents the San Joaquin Valley frame of the western track that is not shown in this report.

PALSAR Data Listing

The Phased-Array L-band Synthetic Aperture Radar (PALSAR) of the Japanese Space Agency (JAXA) was used for the earlier data in this report. Data were obtained from the Alaska Satellite Facility (https://www.asf.alaska.edu). See Table 1 for some characteristics of the instrument. Three orbital paths were used, all ascending (SE to NW) and shown in Figure A1: 2 to cover the San Joaquin Valley and 1 for the southern part of the Sacramento Valley. Swaths are broken into frames, which are stitched together in the processing. HH polarization was used for all InSAR products. Details of the frames used are given below.

Table A1. Details of PALSAR frames used for this report.

Granule Name	Orbit	Path	Frame	Acquisition Date	Center Lat	Center Lon	Angle
San Joaquin Valley, East swath							
ALPSRP074860690	7486	218	690	6/21/07 6:26	35.1596	-119.4419	34.3
ALPSRP074860700	7486	218	700	6/21/07 6:26	35.6542	-119.5492	34.3
ALPSRP074860710	7486	218	710	6/21/07 6:26	36.1486	-119.6569	34.3
ALPSRP074860720	7486	218	720	6/21/07 6:26	36.6431	-119.7657	34.3
ALPSRP074860730	7486	218	730	6/21/07 6:26	37.1376	-119.8732	34.3
ALPSRP088280690	8828	218	690	9/21/07 6:26	35.1623	-119.4405	34.3
ALPSRP088280700	8828	218	700	9/21/07 6:26	35.6568	-119.5488	34.3
ALPSRP088280710	8828	218	710	9/21/07 6:26	36.1472	-119.6537	34.3
ALPSRP088280720	8828	218	720	9/21/07 6:26	36.6421	-119.7619	34.3
ALPSRP088280730	8828	218	730	9/21/07 6:26	37.1363	-119.8705	34.3
ALPSRP094990690	9499	218	690	11/6/07 6:25	35.1617	-119.4337	34.3
ALPSRP094990700	9499	218	700	11/6/07 6:25	35.6566	-119.5399	34.3
ALPSRP094990710	9499	218	710	11/6/07 6:25	36.1512	-119.6462	34.3
ALPSRP094990720	9499	218	720	11/6/07 6:26	36.6461	-119.7529	34.3
ALPSRP094990730	9499	218	730	11/6/07 6:26	37.1406	-119.8619	34.3
ALPSRP101700690	10170	218	690	12/22/07 6:25	35.1585	-119.4356	34.3
ALPSRP101700700	10170	218	700	12/22/07 6:25	35.6533	-119.5415	34.3
ALPSRP101700710	10170	218	710	12/22/07 6:25	36.1481	-119.6479	34.3
ALPSRP101700720	10170	218	720	12/22/07 6:25	36.6429	-119.7548	34.3
ALPSRP101700730	10170	218	730	12/22/07 6:25	37.1376	-119.8619	34.3
ALPSRP108410690	10841	218	690	2/6/08 6:24	35.1452	-119.424	34.3
ALPSRP108410700	10841	218	700	2/6/08 6:24	35.6401	-119.5294	34.3
ALPSRP108410710	10841	218	710	2/6/08 6:25	36.1348	-119.6358	34.3
ALPSRP108410720	10841	218	720	2/6/08 6:25	36.6296	-119.7424	34.3
ALPSRP108410730	10841	218	730	2/6/08 6:25	37.124	-119.8496	34.3
ALPSRP115120690	11512	218	690	3/23/08 6:24	35.1622	-119.4257	34.3
ALPSRP115120700	11512	218	700	3/23/08 6:24	35.6571	-119.5324	34.3
ALPSRP115120710	11512	218	710	3/23/08 6:24	36.1516	-119.6384	34.3
ALPSRP115120720	11512	218	720	3/23/08 6:24	36.6465	-119.7451	34.3
ALPSRP115120730	11512	218	730	3/23/08 6:24	37.1408	-119.8525	34.3
ALPSRP121830690	12183	218	690	5/8/08 6:23	35.1633	-119.4195	34.3
ALPSRP121830700	12183	218	700	5/8/08 6:23	35.6581	-119.5264	34.3
ALPSRP121830710	12183	218	710	5/8/08 6:23	36.1531	-119.6324	34.3
ALPSRP121830720	12183	218	720	5/8/08 6:23	36.6475	-119.7391	34.3
ALPSRP121830730	12183	218	730	5/8/08 6:23	37.142	-119.8461	34.3
ALPSRP128540690	12854	218	690	6/23/08 6:22	35.1462	-119.4407	34.3
ALPSRP128540700	12854	218	700	6/23/08 6:22	35.6408	-119.548	34.3

ALPSRP128540710	12854	218	710	6/23/08 6:23	36.1353	-119.656	34.3
ALPSRP128540720	12854	218	720	6/23/08 6:23	36.6299	-119.7628	34.3
ALPSRP128540730	12854	218	730	6/23/08 6:23	37.1241	-119.8719	34.3
ALPSRP135250690	13525	218	690	8/8/08 6:23	35.1617	-119.4842	34.3
ALPSRP135250700	13525	218	700	8/8/08 6:23	35.6563	-119.5923	34.3
ALPSRP135250710	13525	218	710	8/8/08 6:23	36.1507	-119.7007	34.3
ALPSRP135250720	13525	218	720	8/8/08 6:23	36.6453	-119.8085	34.3
ALPSRP135250730	13525	218	730	8/8/08 6:23	37.14	-119.9166	34.3
ALPSRP182220690	18222	218	690	6/26/09 6:27	35.1638	-119.456	34.3
ALPSRP182220700	18222	218	700	6/26/09 6:27	35.6585	-119.5623	34.3
ALPSRP182220710	18222	218	710	6/26/09 6:27	36.1533	-119.669	34.3
ALPSRP182220720	18222	218	720	6/26/09 6:27	36.6481	-119.7759	34.3
ALPSRP182220730	18222	218	730	6/26/09 6:27	37.1426	-119.8842	34.3
ALPSRP195640690	19564	218	690	9/26/09 6:27	35.16	-119.4506	34.3
ALPSRP195640700	19564	218	700	9/26/09 6:28	35.6551	-119.5569	34.3
ALPSRP195640710	19564	218	710	9/26/09 6:28	36.1495	-119.6636	34.3
ALPSRP195640720	19564	218	720	9/26/09 6:28	36.6443	-119.771	34.3
ALPSRP195640730	19564	218	730	9/26/09 6:28	37.1386	-119.8799	34.3
ALPSRP209060690	20906	218	690	12/27/09 6:27	35.156	-119.4426	34.3
ALPSRP209060700	20906	218	700	12/27/09 6:28	35.6508	-119.5485	34.3
ALPSRP209060710	20906	218	710	12/27/09 6:28	36.1453	-119.6565	34.3
ALPSRP209060720	20906	218	720	12/27/09 6:28	36.6399	-119.7648	34.3
ALPSRP209060730	20906	218	730	12/27/09 6:28	37.1343	-119.8725	34.3
ALPSRP222480690	22248	218	690	3/29/10 6:27	35.1356	-119.4289	34.3
ALPSRP222480700	22248	218	700	3/29/10 6:27	35.6301	-119.5359	34.3
ALPSRP222480710	22248	218	710	3/29/10 6:27	36.1248	-119.6435	34.3
ALPSRP222480720	22248	218	720	3/29/10 6:27	36.6193	-119.7505	34.3
ALPSRP222480730	22248	218	730	3/29/10 6:28	37.114	-119.8576	34.3
ALPSRP229190690	22919	218	690	5/14/10 6:27	35.1595	-119.4351	34.3
ALPSRP229190700	22919	218	700	5/14/10 6:27	35.6543	-119.541	34.3
ALPSRP229190710	22919	218	710	5/14/10 6:27	36.149	-119.6471	34.3
ALPSRP229190720	22919	218	720	5/14/10 6:27	36.6436	-119.7539	34.3
ALPSRP229190730	22919	218	730	5/14/10 6:27	37.1381	-119.8614	34.3
ALPSRP235900690	23590	218	690	6/29/10 6:26	35.1623	-119.4335	34.3
ALPSRP235900700	23590	218	700	6/29/10 6:26	35.6571	-119.5404	34.3
ALPSRP235900710	23590	218	710	6/29/10 6:26	36.1516	-119.6464	34.3
ALPSRP235900720	23590	218	720	6/29/10 6:27	36.6463	-119.7535	34.3
ALPSRP235900730	23590	218	730	6/29/10 6:27	37.1408	-119.8605	34.3
ALPSRP262740690	26274	218	690	12/30/10 6:23	35.1628	-119.4223	34.3
ALPSRP262740700	26274	218	700	12/30/10 6:24	35.658	-119.5281	34.3
ALPSRP262740710	26274	218	710	12/30/10 6:24	36.1525	-119.6341	34.3
ALPSRP262740720	26274	218	720	12/30/10 6:24	36.6471	-119.7404	34.3
ALPSRP262740730	26274	218	730	12/30/10 6:24	37.1419	-119.8478	34.3
San Joaquin Valley, Center swath							
ALPSRP077340710	7734	219	710	7/8/07 6:28	36.1438	-120.1903	34.3
ALPSRP077340720	7734	219	720	7/8/07 6:28	36.6383	-120.2975	34.3
ALPSRP077340730	7734	219	730	7/8/07 6:28	37.1326	-120.4049	34.3
ALPSRP084050710	8405	219	710	8/23/07 6:28	36.1498	-120.1903	34.3
ALPSRP084050720	8405	219	720	8/23/07 6:28	36.6442	-120.2972	34.3
ALPSRP084050730	8405	219	730	8/23/07 6:28	37.139	-120.4046	34.3
ALPSRP097470710	9747	219	710	11/23/07 6:27	36.1511	-120.1839	34.3

ALPSRP097470720	9747	219	720	11/23/07 6:28	36.6456	-120.2909	34.3
ALPSRP097470730	9747	219	730	11/23/07 6:28	37.1396	-120.3999	34.3
ALPSRP104180710	10418	219	710	1/8/08 6:27	36.1413	-120.181	34.3
ALPSRP104180720	10418	219	720	1/8/08 6:27	36.6361	-120.2879	34.3
ALPSRP104180730	10418	219	730	1/8/08 6:27	37.1306	-120.3949	34.3
ALPSRP110890710	11089	219	710	2/23/08 6:26	36.151	-120.1721	34.3
ALPSRP110890720	11089	219	720	2/23/08 6:27	36.6458	-120.2785	34.3
ALPSRP110890730	11089	219	730	2/23/08 6:27	37.1406	-120.3872	34.3
ALPSRP117600710	11760	219	710	4/9/08 6:26	36.1285	-120.1621	34.3
ALPSRP117600720	11760	219	720	4/9/08 6:26	36.6231	-120.2689	34.3
ALPSRP117600730	11760	219	730	4/9/08 6:26	37.1177	-120.3762	34.3
ALPSRP124310710	12431	219	710	5/25/08 6:25	36.1481	-120.1694	34.3
ALPSRP124310720	12431	219	720	5/25/08 6:25	36.6425	-120.2761	34.3
ALPSRP124310730	12431	219	730	5/25/08 6:25	37.1371	-120.3834	34.3
ALPSRP131020710	13102	219	710	7/10/08 6:25	36.1508	-120.2045	34.3
ALPSRP131020720	13102	219	720	7/10/08 6:25	36.6451	-120.3129	34.3
ALPSRP131020730	13102	219	730	7/10/08 6:25	37.1393	-120.422	34.3
ALPSRP164570710	16457	219	710	2/25/09 6:28	36.1436	-120.2129	34.3
ALPSRP164570720	16457	219	720	2/25/09 6:29	36.6382	-120.3202	34.3
ALPSRP164570730	16457	219	730	2/25/09 6:29	37.1326	-120.4297	34.3
ALPSRP171280710	17128	219	710	4/12/09 6:29	36.1441	-120.2029	34.3
ALPSRP171280720	17128	219	720	4/12/09 6:29	36.6389	-120.3098	34.3
ALPSRP171280730	17128	219	730	4/12/09 6:29	37.1331	-120.4194	34.3
ALPSRP198120710	19812	219	710	10/13/09 6:30	36.1382	-120.1937	34.3
ALPSRP198120720	19812	219	720	10/13/09 6:30	36.6325	-120.3021	34.3
ALPSRP198120730	19812	219	730	10/13/09 6:30	37.1266	-120.4124	34.3
ALPSRP211540710	21154	219	710	1/13/10 6:30	36.1448	-120.1908	34.3
ALPSRP211540720	21154	219	720	1/13/10 6:30	36.6396	-120.2979	34.3
ALPSRP211540730	21154	219	730	1/13/10 6:30	37.1338	-120.407	34.3
ALPSRP224960710	22496	219	710	4/15/10 6:29	36.1538	-120.1853	34.3
ALPSRP224960720	22496	219	720	4/15/10 6:29	36.6482	-120.2922	34.3
ALPSRP224960730	22496	219	730	4/15/10 6:30	37.1431	-120.3994	34.3
ALPSRP231670710	23167	219	710	5/31/10 6:29	36.1432	-120.1807	34.3
ALPSRP231670720	23167	219	720	5/31/10 6:29	36.6381	-120.2874	34.3
ALPSRP231670730	23167	219	730	5/31/10 6:29	37.1326	-120.3944	34.3
ALPSRP258510710	25851	219	710	12/1/10 6:26	36.1273	-120.169	34.3
ALPSRP258510720	25851	219	720	12/1/10 6:27	36.6221	-120.2754	34.3
ALPSRP258510730	25851	219	730	12/1/10 6:27	37.1165	-120.3836	34.3
Southern Sacramento Valley							
ALPSRP048750760	4875	221	760	12/24/06 6:33	38.6236	-121.8327	34.3
ALPSRP048750770	4875	221	770	12/24/06 6:33	39.1176	-121.9427	34.3
ALPSRP048750780	4875	221	780	12/24/06 6:33	39.6116	-122.0537	34.3
ALPSRP048750790	4875	221	790	12/24/06 6:33	40.1057	-122.1647	34.3
ALPSRP062170760	6217	221	760	3/26/07 6:33	38.6226	-121.8129	34.3
ALPSRP062170770	6217	221	770	3/26/07 6:33	39.1168	-121.923	34.3
ALPSRP062170780	6217	221	780	3/26/07 6:33	39.6111	-122.0337	34.3
ALPSRP062170790	6217	221	790	3/26/07 6:34	40.1052	-122.1447	34.3
ALPSRP089010760	8901	221	760	9/26/07 6:33	38.6206	-121.8074	34.3
ALPSRP089010770	8901	221	770	9/26/07 6:33	39.1146	-121.9187	34.3
ALPSRP089010780	8901	221	780	9/26/07 6:33	39.6085	-122.0291	34.3
ALPSRP089010790	8901	221	790	9/26/07 6:33	40.1027	-122.1402	34.3

ALPSRP102430760	10243	221	760	12/27/07 6:32	38.6228	-121.803	34.3
ALPSRP102430770	10243	221	770	12/27/07 6:32	39.1171	-121.9127	34.3
ALPSRP102430780	10243	221	780	12/27/07 6:32	39.6111	-122.0227	34.3
ALPSRP102430790	10243	221	790	12/27/07 6:33	40.1051	-122.1339	34.3
ALPSRP109140760	10914	221	760	2/11/08 6:32	38.6216	-121.7892	34.3
ALPSRP115850760	11585	221	760	3/28/08 6:31	38.6229	-121.7873	34.3
ALPSRP115850770	11585	221	770	3/28/08 6:31	39.1171	-121.8964	34.3
ALPSRP115850780	11585	221	780	3/28/08 6:31	39.6111	-122.0067	34.3
ALPSRP115850790	11585	221	790	3/28/08 6:31	40.1052	-122.1172	34.3
ALPSRP122560760	12256	221	760	5/13/08 6:30	38.3944	-121.7402	34.3
ALPSRP122560770	12256	221	770	5/13/08 6:30	38.8894	-121.8487	34.3
ALPSRP122560780	12256	221	780	5/13/08 6:30	39.3851	-121.9588	34.3
ALPSRP122560790	12256	221	790	5/13/08 6:31	39.8814	-122.072	34.3
ALPSRP149400760	14940	221	760	11/13/08 6:32	38.6226	-121.8397	34.3
ALPSRP149400770	14940	221	770	11/13/08 6:32	39.1165	-121.9501	34.3
ALPSRP149400780	14940	221	780	11/13/08 6:32	39.6107	-122.0615	34.3
ALPSRP149400790	14940	221	790	11/13/08 6:32	40.1047	-122.1732	34.3
ALPSRP156110760	15611	221	760	12/29/08 6:33	38.6233	-121.8382	34.3
ALPSRP156110770	15611	221	770	12/29/08 6:33	39.1176	-121.9487	34.3
ALPSRP156110780	15611	221	780	12/29/08 6:33	39.6106	-122.0622	34.3
ALPSRP156110790	15611	221	790	12/29/08 6:33	40.1046	-122.1744	34.3
ALPSRP169530760	16953	221	760	3/31/09 6:34	38.6096	-121.8247	34.3
ALPSRP182950760	18295	221	760	7/1/09 6:34	38.6195	-121.8251	34.3
ALPSRP182950770	18295	221	770	7/1/09 6:35	39.1136	-121.9352	34.3
ALPSRP182950780	18295	221	780	7/1/09 6:35	39.6076	-122.0459	34.3
ALPSRP182950790	18295	221	790	7/1/09 6:35	40.1017	-122.1577	34.3
ALPSRP196370760	19637	221	760	10/1/09 6:35	38.6246	-121.8177	34.3
ALPSRP196370770	19637	221	770	10/1/09 6:35	39.1186	-121.9279	34.3
ALPSRP196370780	19637	221	780	10/1/09 6:35	39.6126	-122.0387	34.3
ALPSRP196370790	19637	221	790	10/1/09 6:35	40.1067	-122.1497	34.3
ALPSRP209790760	20979	221	760	1/1/10 6:35	38.6206	-121.8099	34.3
ALPSRP209790770	20979	221	770	1/1/10 6:35	39.1148	-121.92	34.3
ALPSRP209790780	20979	221	780	1/1/10 6:35	39.6091	-122.0307	34.3
ALPSRP209790790	20979	221	790	1/1/10 6:35	40.1032	-122.1417	34.3
ALPSRP229920760	22992	221	760	5/19/10 6:34	38.6068	-121.7945	34.3
ALPSRP229920770	22992	221	770	5/19/10 6:34	39.1011	-121.9042	34.3
ALPSRP229920780	22992	221	780	5/19/10 6:34	39.5951	-122.0159	34.3
ALPSRP229920790	22992	221	790	5/19/10 6:34	40.0892	-122.1282	34.3
ALPSRP236630760	23663	221	760	7/4/10 6:33	38.6218	-121.796	34.3
ALPSRP236630770	23663	221	770	7/4/10 6:34	39.1161	-121.9054	34.3
ALPSRP236630780	23663	221	780	7/4/10 6:34	39.6101	-122.0157	34.3
ALPSRP236630790	23663	221	790	7/4/10 6:34	40.1042	-122.1267	34.3
ALPSRP243340780	24334	221	780	8/19/10 6:33	39.6121	-122.0147	34.3
ALPSRP243340790	24334	221	790	8/19/10 6:33	40.1061	-122.1259	34.3
ALPSRP256760760	25676	221	760	11/19/10 6:32	38.6221	-121.7922	34.3
ALPSRP256760770	25676	221	770	11/19/10 6:32	39.1164	-121.9018	34.3
ALPSRP256760780	25676	221	780	11/19/10 6:32	39.6109	-122.0123	34.3
ALPSRP256760790	25676	221	790	11/19/10 6:32	40.1048	-122.123	34.3

Radarsat-2 Data Listing

The Radarsat-2 satellite (Table 1) provided the more recent satellite data used for this report. Radarsat-2 is the second radar satellite launched by the Canadian Space Agency. It is in a polar orbit which allows it to view any point on the globe every 24 days (its minimum repeat period for subsidence detection). It uses a wavelength of about 2", which makes it more sensitive than longer-wavelength radar systems to disturbances of the ground that can spoil the phase information. Spatial resolution is typically around 50-100 feet, but during InSAR processing, we usually average to about 300' to decrease noise.

For this study, we purchased Radarsat-2 data for 2 orbital tracks, covering most of the San Joaquin Valley and the southern part of the Sacramento Valley (Fig. A1). Tracks are cut up into frames; 2 frames were acquired for the eastern track covering the eastern part of the San Joaquin Valley and 1 frame was acquired for the western track covering the western side of the San Joaquin Valley, with an additional frame on the same track covering the southern part of the Sacramento Valley. Dates and frame ID numbers are listed below.

By working with the Canadian Space Agency, we acquired 6 dates of coverage for the eastern track and 9 dates for the western track . For the eastern track, we obtained coverage on 3 May 2014, 27 May 2014, 18 October 2014, 11 November 2014, 5 December 2014, and 22 January 2015. The gap between May and October was caused by a miscommunication so that satellite acquisition was stopped during that time. The southern boundary of the eastern track was determined due to the competing data acquisitions in a different data mode by oil companies monitoring subsidence in the oil fields west of Bakersfield. For the western track, including the west side of the San Joaquin Valley and the southern part of the Sacramento Valley, we obtained SAR coverage from 20 May 2014 to 28 November 2014.

As we processed the data for the eastern track, we realized that the 5 December 2014 acquisition had problems with the data. Missing lines were detected and the interferograms associated with that date are distinctly different from other interferometric pairs. For this reason, we excluded that date from our processing and present results from the remaining 5 dates from that track. The subsidence map derived from the western track for the San Joaquin Valley showed the same subsidence features as the eastern track, so we used it as a validation for the eastern result, but don't show the map here.

A detailed listing of all Radarsat-2 data used for this report is given in Table A2 below. Orbits are all ascending (SE – NW), Beam mode is Fine resolution, Wide-swath mode. Polarization is HH. Data were purchased from MDA Geospatial Services Inc. through Resource Strategies Inc.

Table A2. Listing of all Radarsat-2 data used in this report.

Date	Time	Orbit	Abs. Orbit	Beam	Pol.	Angle	Center Lat/Lon
San Joaquin Valley- East							
5/3/14	1:57:27	96-157A	33321.1	F0W2	HH	31.27	36°34'N/119°56'W
5/3/14	1:57:48	96-157A	33321.11	F0W2	HH	31.27	37°48'N/120°13'W
5/27/14	1:57:26	97-157A	33664.1	F0W2	HH	31.27	36°34'N/119°56'W
5/27/14	1:57:47	97-157A	33664.11	F0W2	HH	31.27	37°48'N/120°13'W
10/18/14	1:56:47	103-157A	35722.1	F0W2	HH	31.27	36°35'N/119°56'W
10/18/14	1:57:08	103-157A	35722.1	F0W2	HH	31.27	37°49'N/120°13'W
11/11/14	1:56:47	104-157A	36065.1	F0W2	HH	31.27	36°35'N/119°56'W
11/11/14	1:57:08	104-157A	36065.1	F0W2	HH	31.27	37°49'N/120°13'W
12/5/14	1:56:47	105-157A	36408.1	F0W2	HH	31.27	36°35'N/119°56'W
12/5/14	1:57:08	105-157A	36408.1	F0W2	HH	31.27	37°49'N/120°13'W
1/22/15	1:57:20		37094	F0W2	HH	31.27	36°36'N/119°56'W
1/22/15	1:57:40		37094	F0W2	HH	31.27	37°48'N/120°13'W
Sacramento Valley							
5/20/14	2:02:18	97-57A	33564.11	F0W2	HH	31.27	38°53'N/121°31'W
6/13/14	2:02:17	98-57A	33907.11	F0W2	HH	31.27	38°53'N/121°31'W
7/7/14	2:02:16	99-57A	34250.11	F0W2	HH	31.27	38°53'N/121°31'W
7/31/14	2:02:16	100-57A	34593.11	F0W2	HH	31.27	38°53'N/121°31'W
8/24/14	2:02:17	101-57A	34936.11	F0W2	HH	31.27	38°53'N/121°31'W
9/17/14	2:02:17	102-57A	35279.11	F0W2	HH	31.27	38°52'N/121°31'W
10/11/14	2:01:39	103-57A	35622.1	F0W2	HH	31.27	38°56'N/121°32'W
11/4/14	2:01:39	104-57A	35965.1	F0W2	HH	31.27	38°56'N/121°32'W
11/28/14	2:01:39	105-57A	36308.1	F0W2	HH	31.27	38°56'N/121°32'W
San Joaquin Valley- West							
5/20/14	2:01:43	97-57A	33564.11	F0W2	HH	31.27	36°50'N/121°02'W
6/13/14	2:01:42	98-57A	33907.11	F0W2	HH	31.27	36°50'N/121°02'W
7/7/14	2:01:42	99-57A	34250.1	F0W2	HH	31.27	36°50'N/121°02'W
7/31/14	2:01:42	100-57A	34593.1	F0W2	HH	31.27	36°50'N/121°02'W
8/24/14	2:01:42	101-57A	34936.11	F0W2	HH	31.27	36°50'N/121°03'W
9/17/14	2:01:42	102-57A	35279.11	F0W2	HH	31.27	36°50'N/121°03'W
10/11/14	2:01:41	103-57A	35622.1	F0W2	HH	31.27	36°50'N/121°03'W
11/4/14	2:01:41	104-57A	35965.1	F0W2	HH	31.27	36°50'N/121°03'W
11/28/14	2:01:39	105-57A	36308.1	F0W2	HH	31.27	36°50'N/121°03'W

UAVSAR

The two UAVSAR flight lines used for evaluating subsidence of the California Aqueduct were line ID CValle_13300 (southern section) and line ID Snjoaq_14511 (northern section). Table A3 shows the flight dates, UAVSAR flight IDs, and temporal baselines for lines 13300 and 14511. Each acquisition was used in at least three interferograms to provide sufficient redundancy to eliminate systematic effects from atmospheric variation and aircraft motion artifacts. Acquisition of line 14511 began earliest, in July 2013, and extended through

March 2015. We were able to use 1-year temporal baseline, same-season interferograms with this data set, increasing the accuracy of small-scale cumulative subsidence measurements. Acquisition of line 13300 began in April 2014 and extended through January 2015, so we were not able to include the season-to-season interferograms in that analysis. Further information about UAVSAR can be found at http://uavsar.jpl.nasa.gov.

Table A3. UAVSAR line ID, flight ID, and acquisition date of the data used for evaluating subsidence of the California Aqueduct during the 2014 drought.

UAVSAR Line ID 14511			UAVSAR Line ID 13300		
Acq. No.	**Flight ID**	**Date of acquisition**	**Acq. No.**	**Flight ID**	**Date of acquisition**
1	13129	7/19/2013	1	14033	4/2/2014
2	13165	10/31/2013	2	14062	5/15/2014
3	14005	1/17/2014	3	14086	6/16/2014
4	14019	2/12/2014	4	14112	8/14/2014
5	14033	4/2/2014	5	14140	10/6/2014
6	14068	5/29/2014	6	14166	11/13/2014
7	14086	6/16/2014	7	15002	1/7/2015
8	14112	8/14/2014			
9	14140	10/6/2014			
10	14166	11/13/2014			
11	15002	1/7/2015			
12	15017	3/10/2015			

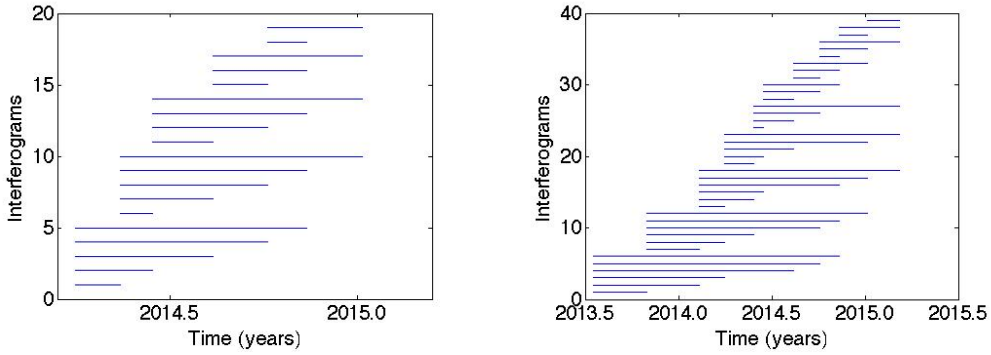


Figure A2. Graph showing the pairs of images used to form interferograms used for UAVSAR line ID 13300 (left) and line ID 14511 (right). In the plot, the bar extends from the date of acquisition 1 to the date of acquisition 2.

UAVSAR uncertainties

Figures A3 and A4 show the uncertainties associated with the vertical displacement (subsidence/uplift) measurements. These uncertainties cover random errors, but do not include systematic errors, i.e., systematic shifts that affect all interferograms, for example, persistent water vapor within mountain valleys, were it present in all images, would not be included in the error estimation.

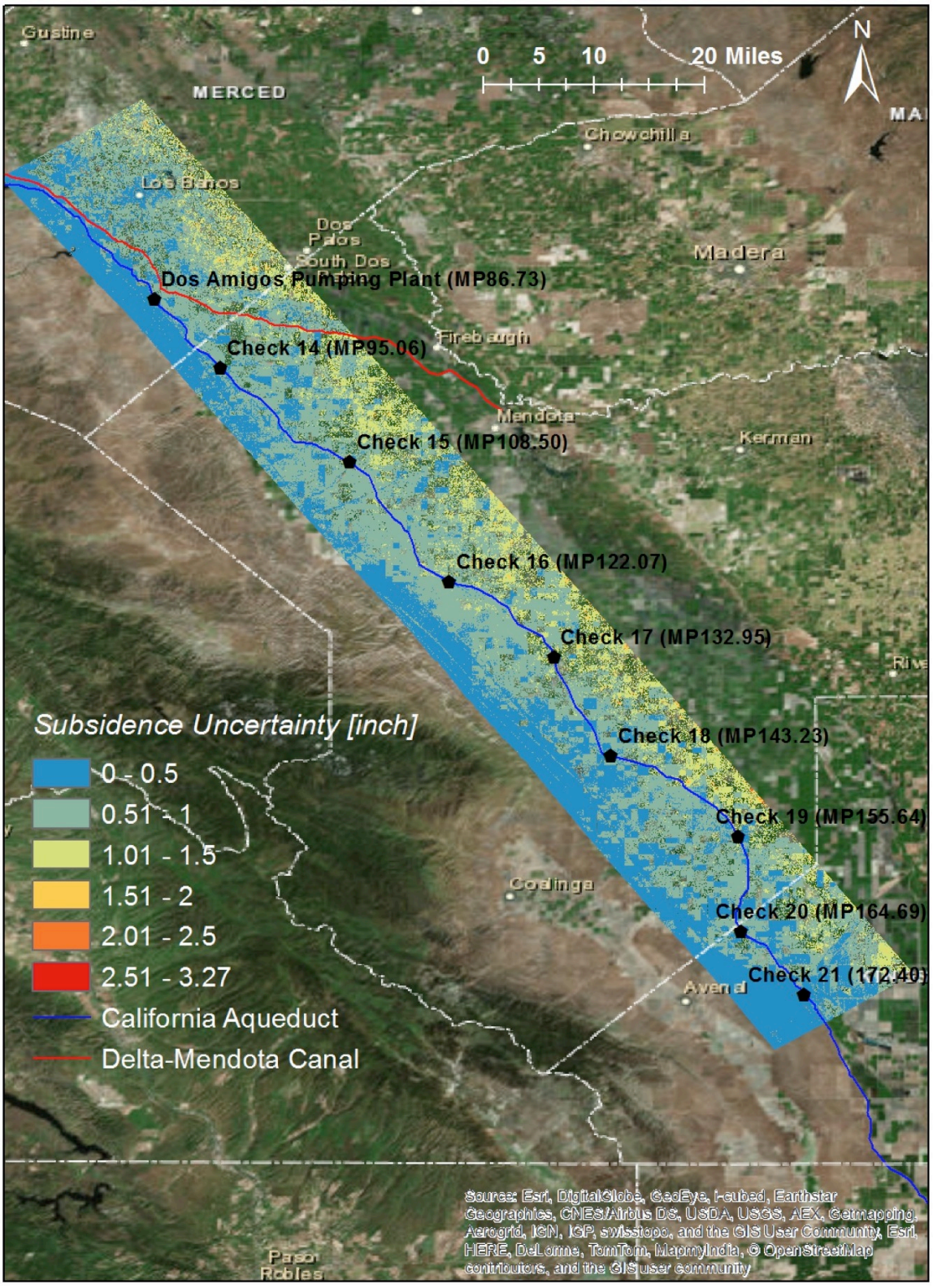


Figure A3. Uncertainty in the vertical movement derived from UAVSAR line ID 14511, covering the northern section of the California Aqueduct within the area overseen by the San Luis Field Division.

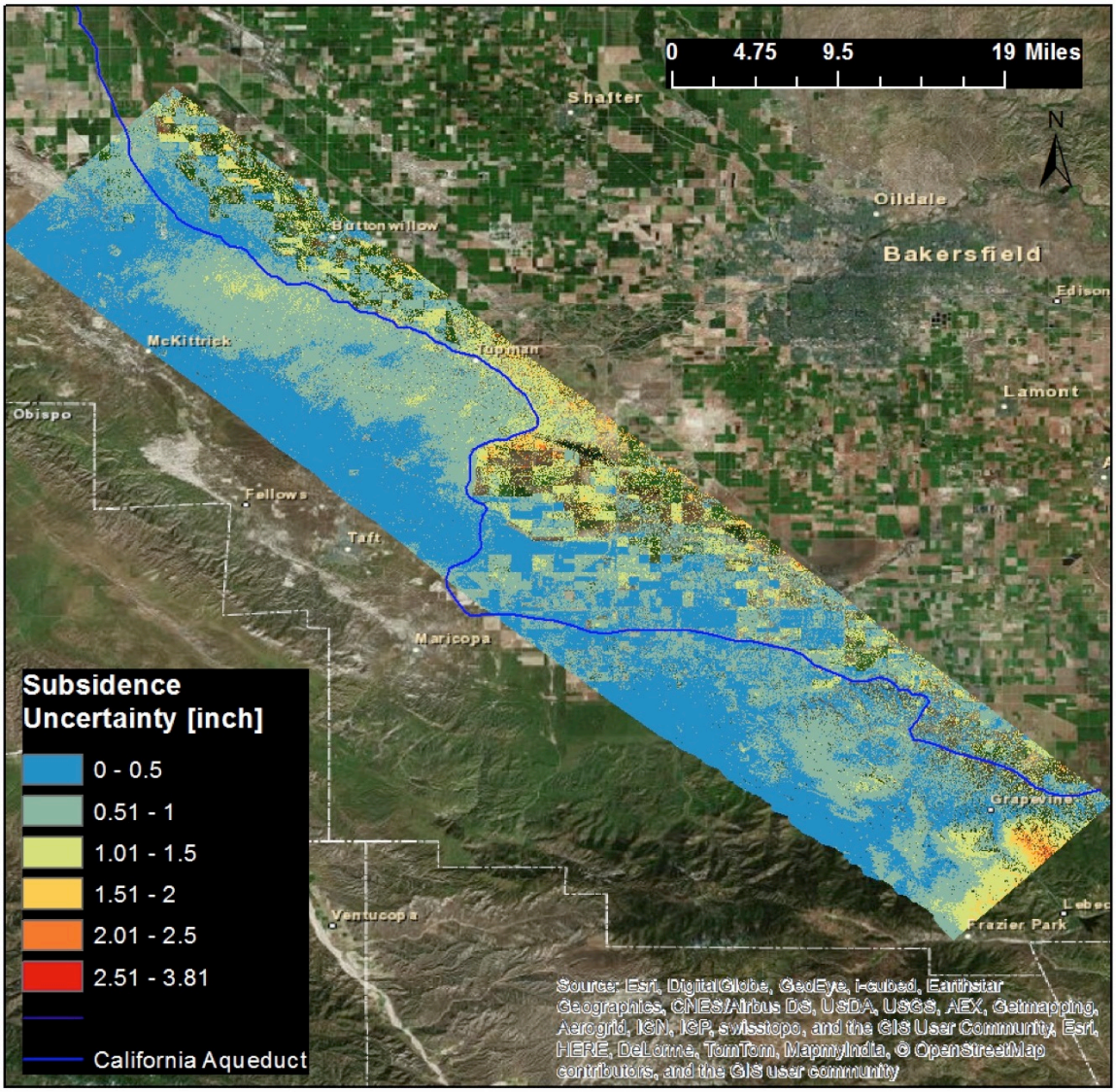


Figure A4. Uncertainty in the subsidence derived from UAVSAR line ID 13300, covering the southern section of the California Aqueduct within the area overseen by the San Joaquin Field Division.

POND-POSO IMPROVEMENT DISTRICT
OF
SEMITROPIC WATER STORAGE DISTRICT
Kern County, California

ENGINEERING REPORT

IN SUPPORT OF

APPLICATION FOR FEDERAL LOAN UNDER PUBLIC LAW 984 FOR CONSTRUCTION OF AN IRRIGATION DISTRIBUTION SYSTEM

BOOKMAN-EDMONSTON ENGINEERING, INC.
Consulting Civil Engineers
Glendale, California

March 1972

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The average annual estimated and measured inflow for the 34-year period 1936-69 was 6,500 acre-feet. During infrequent extremely wet years, substantial quantities of water reach the District and contribute to ground water recharge therein. For example, in 1969 an estimated 40,600 acre-feet reached the easterly boundary of the District and the estimated quantity of water which reached the National Wildlife Refuge was 20,200 acre-feet. The average recharge to ground water from percolation of Poso Creek flows within the District is estimated to be 3,000 acre-feet per year.

Ground Water Geology and Hydrology

Physiography

The Pond-Poso Improvement District is characterized by the low, broad, relatively smooth alluvial fan of Poso Creek. There are no abrupt changes in topographic relief. Along the eastern boundary of the District, the land surface slopes uniformly in a westerly direction at about 10 feet per mile. Along the western boundary, these slopes decrease to about 5 feet per mile or less. Ground surface elevations range from 205 feet above sea level in the extreme northwestern corner of the District to a maximum of 310 feet above sea level in the southeastern portion of the District.

Ground Water Geology

The geologic units within the Pond-Poso Improvement District can be divided into two broad groups, based generally upon the degree to which the subsurface materials have been consolidated.

Consolidated rocks, including the metamorphic and igneous basement rocks as well as marine and continental sedimentary strata, are generally impermeable and are of little importance as a source of ground water in the Pond-Poso District.

The unconsolidated or semiconsolidated deposits of late Tertiary and Quaternary age include (1) continental deposits generally assigned to the Kern River or Tulare formations and (2) Older and Recent alluvial deposits. These are the formations which constitute ground water storage units of economic significance.

The semiconsolidated continental deposits underlying the middle and southerly portions of the Pond-Poso District are herein assigned to the Kern River formation, in that the ancestral Kern River is believed to have transported most of the material into the area, whereas the Tulare formation includes those equivalent deposits derived from the west side of the San Joaquin Valley and which underlie generally the northwestern portion of the District.

The Kern River formation underlying the Pond-Poso District is relatively coarse and permeable, as evidenced by drilling logs and well-yield characteristics. The subsurface materials are typically sandy clays interbedded with loosely consolidated sand and gravel. All materials appear to be poorly stratified and are lenticular in nature, and it is difficult to establish continuity for most of the individual zones.

The Tulare formation exhibits somewhat more continuity in that one persistent and extensive silty clay zone, designated the Corcoran Clay, has been traced over a large area of the southern San Joaquin Valley as well as within the District. The Corcoran Clay member of the Tulare formation has been encountered by water wells drilled in the northwesterly portion of Pond-Poso District and constitutes an important feature in the ground water

hydrology of the District. The easterly limit of the Corcoran Clay is delineated on Plate 3.

Overlying the Kern River and Tulare formations is a deposit of Older and Recent alluvium. The Older alluvium is composed of poorly sorted lenticular deposits of clay, silt, sand and gravel that are loosely consolidated. Older alluvium is difficult to distinguish from the underlying deposits, but the maximum thickness is estimated to be no more than 250 feet.

Recent alluvium includes the deposits in the channel of Poso Creek and the shallow materials comprising the Poso Creek alluvial fan. These deposits consist of unconsolidated sand, silt, gravel and clay which become finer and better sorted toward the trough of the valley.

Presented on Figure 1 is a generalized geologic section taken in an east-west direction across the northerly portion of the District. The location of the section is shown on Plate 3.

Occurrence and Movement of Ground Water

The Kern River and Tulare formations and overlying alluvial deposits comprise a ground water storage reservoir within the Pond-Poso Improvement District. The storage reservoir can be separated into two general aquifer units, designated the confined and the semi-confined aquifer systems.

The confined aquifer system occurs in the northwesterly portion of the Pond-Poso District. This system is comprised of sands and interbedded silts and clays of the Tulare formation which underlie the Corcoran Clay member. There appears to be little or no vertical hydraulic continuity above and below the Corcoran Clay; however, there does occur direct lateral hydraulic interconnection with the semiconfined aquifer system easterly of the limits of the

Corcoran Clay. Recharge to the confined aquifer system occurs from the semiconfined system by this interconnection.

The semiconfined aquifer system includes that portion of the Tulare formation above the Corcoran Clay westerly of the limits shown on Plate 3, as well as the shallow alluvial deposits. Easterly of the Corcoran Clay, the Kern River Formation and overlying alluvium constitute the semiconfined aquifer system. Within the semiconfined aquifer system, water levels vary in accordance with depth of perforations in water wells, which indicates the presence of poorly permeable materials in the upper portions of the zone. However, in most areas variation in water levels observed during pumping disappear rapidly with cessation of pumping, thus indicating the areal extent of less permeable materials is limited and that there prevails a substantial degree of vertical communication within the system. This effect is shown by the hydrographs of water level fluctuations in representative wells in the District presented on Figure 2.

Presented on Plate 3 are contours of equal elevation of ground water levels in wells, which indicate a general water level gradient to the northwest. Recharge to the semiconfined aquifer system in the District occurs principally as subsurface inflow from adjacent areas to the east and to a lesser degree from percolation of Poso Creek surface flows which reach the District. Sources of replenishment to subsurface inflow include (1) percolation of surface flows in Poso Creek channel, (2) water spreading activities of the North Kern Water Storage District utilizing water from the Kern River, (3) return flow of excess applied irrigation water imported from the Kern River through the Calloway and Lerdo canals; and (4) more recently, excess applications of Central Valley Project water in the Shafter-Wasco Irrigation District.

The magnitude of subsurface flow into the Pond-Poso District was estimated by utilizing the slope-area method of computation. Results of aquifer tests performed by the U.S. Geological Survey indicate aquifer transmissibilities to be on the order of 300,000 gallons per day per foot of underflow perimeter along the easterly boundary of the District. An average hydraulic gradient of 15 feet per mile was derived from ground water level contour maps. Utilizing the relationship $\Omega = T\ I\ L$, where T is the estimated aquifer transmissibility, I is the average hydraulic gradient, and L the length of underflow perimeter, the total subsurface flow into the Pond-Poso District was computed to be 87,000 acre-feet per year under current conditions of ground water utilization and water supply.

Although the evidence is not conclusive, it appears there probably is some subsurface outflow during the non-pumping season along the westerly boundary of the District; however, heavy pumping during the growing season results in a reversal of hydraulic gradients and the inducement of subsurface inflow along the western boundary. A direct quantitative estimate of the magnitude of this subsurface flow could not be made with available data in the same manner as that of subsurface inflow to the District.

Increased pumping, beginning in 1945, caused water levels in the semiconfined system to decline at a rate of approximately 7 feet per year, and seasonal fluctuations have been on the order of 100 feet per year. Recent measurements indicate the rate of decline may currently be 5 to 6 feet per year. These conditions are shown on Figure 2.

Estimates were made of net ground water storage depletion in the District using an average specific yield value of 8.7 percent for the depth interval of fluctuating ground water levels, and an average annual change in ground water levels throughout the District of 6 feet

per year. The average annual depletion of ground water storage in the Pond-Poso District under current conditions of land use and water supply was computed by the above procedure to be on the order of 43,000 acre-feet per year. Without the introduction of supplemental water, it is estimated that the depletion of ground water would continue but probably at a somewhat lesser rate because of the inducement of a greater amount of subsurface inflow.

Land Subsidence

In the Tulare-Wasco area to the east and north of the District and including a portion thereof, more than 1,500 square miles have experienced land subsidence up to a maximum in excess of 8 feet since 1948 and over 12 feet since 1926. As shown on Plate 3, approximately 49,000 acres in the northerly portion of the Pond-Poso District have experienced 2 feet or more of land surface subsidence. An additional area of 17,000 acres has experienced between 1 and 2 feet, and the remaining portion of the District has been affected, but to a lesser degree. The maximum land surface subsidence within the District has been approximately 5 feet since 1948.

It has been conclusively demonstrated that this type of land subsidence, commonly termed "deep subsidence," occurs in areas where intensive pumpage of ground water from confined and semiconfined aquifer systems has resulted in overdraft. Records indicate that compaction measured by recorders is directly related to decline in water levels.

Importation of irrigation water via canals and a coincident decrease in pumping activity resulted in rising water levels and a virtual cessation of land subsidence between 1954 and 1959 in some areas adjacent to the District. However, relevelling in 1962 revealed that approximately 300 square miles of land, which previously had appeared

to be stabilized,were again subsiding at rates of 0.1 feet per year. The resumption of subsidence was directly related to increased pumping of ground water necessitated by the availability of below-average supplies of imported surface water.

Resurveys performed in 1970 indicate a broad area east of the District and lying generally adjacent to the Friant-Kern Canal has experienced subsidence of 0.5 feet or less since 1962, thus indicating relative stability. However subsidence within the District has continued at rates in excess of 0.25 feet per year between 1962 and 1970.

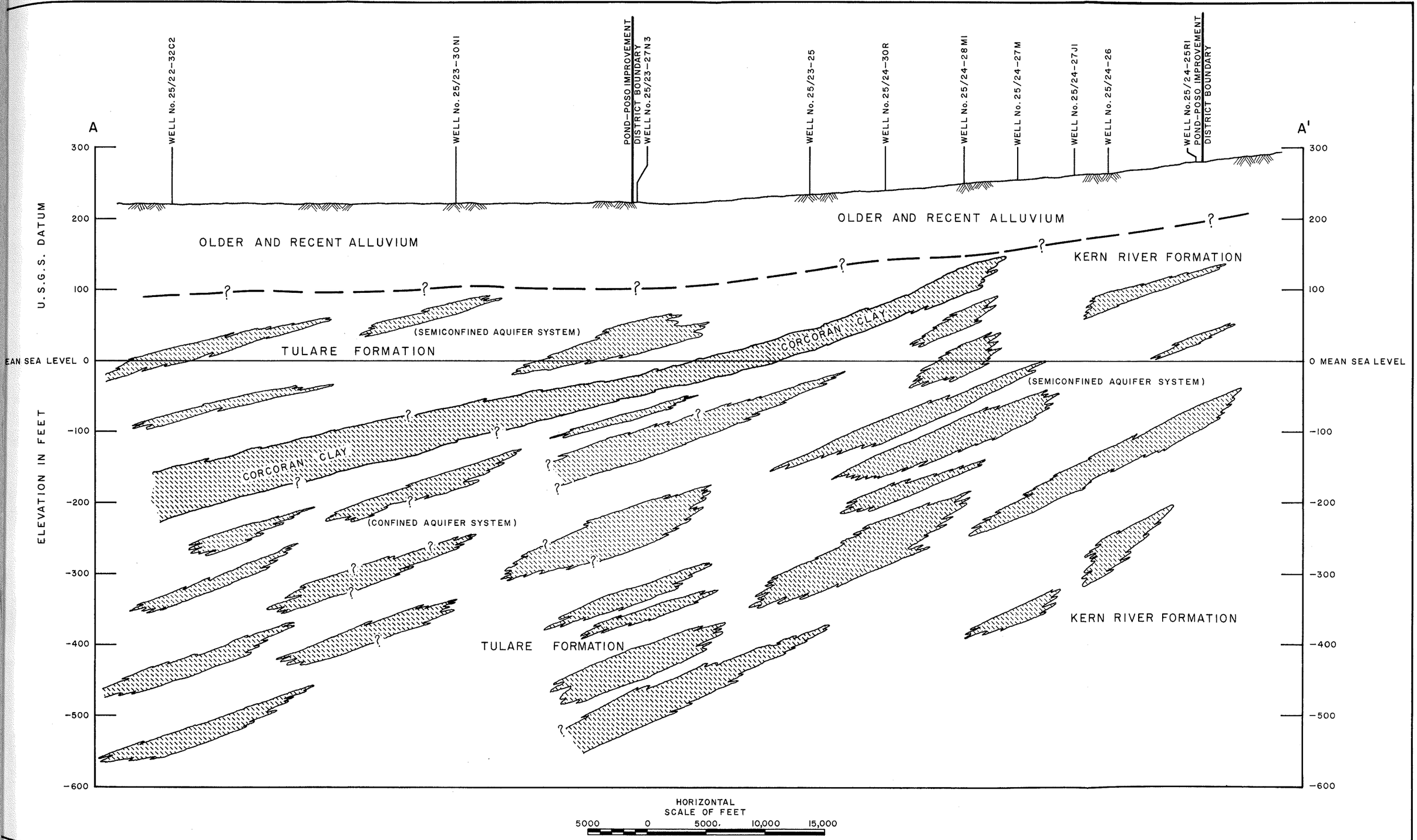
Introduction of project water to the District with a corresponding reduction in ground water extractions is expected to aid in the halting of land subsidence.

Ground Water Quality

The chemical character of ground water within the Pond-Poso District is typical of waters occurring in the eastern portion of the San Joaquin Valley, being generally of the sodium bicarbonate type with low to moderate concentrations (less than 300 ppm) of total salts. Presented in Table IV-3 are results of selected chemical analyses of ground waters considered representative of the Pond-Poso District.

Calcium Carbonate Encrustation. Throughout the Pond-Poso District there have been reported severe accumulations of calcium carbonate on pump parts and well casings. Available chemical analyses of ground waters indicate the occurrence of calcium and carbonate and attendant high pH values in many wells. The most common occurrences of calcium and carbonate in ground water are found along the western boundary of the District in Townships 25 and 26 South, and generally along the eastern boundary in Townships 26 and 27 South.

FIGURE 1



GENERALIZED GEOLOGIC SECTION

DOKMAN-EDMONSTON ENGINEERING, INC.
CONSULTING CIVIL ENGINEERS
GLENDALE, CALIFORNIA

MARCH 1972

INTERIM REPORT
GEOTECHNICAL INVESTIGATION
NORTHEAST REACTOR CONTAINMENT
LOCATION (UNIT 1)

SAN JOAQUIN NUCLEAR PROJECT
SAN JOAQUIN VALLEY, CALIFORNIA

Conducted for

LOS ANGELES DEPARTMENT OF WATER AND POWER
P.O. Box 111
Los Angeles, California 90051

By

FUGRO, INC.,
Consulting Engineers and Geologists
3777 Long Beach Boulevard
Long Beach, California 90807

April 28, 1978
Project No. 73-081-20

DWP Task Fugro 20

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1. INTRODUCTION

This interim report presents the results of 1) geotechnical investigations performed to date (June, 1977) at the proposed location of Unit 1 Reactor Containment Structure for the San Joaquin Nuclear Project, and 2) groundwater and ground surface subsidence monitoring performed at the San Joaquin Nuclear Project Site from January 1974 through June 1977. The geotechnical investigations at Unit 1 location mainly consisted of drilling engineering borings, performing geophysical surveys and laboratory testing of the soil samples obtained from the borings. In this report all the pertinent results of these geotechnical investigations are compiled. The groundwater and ground surface subsidence monitoring at the Site has been on going since January, 1974, and the results are being presented to the Los Angeles Department of Water and Power (LADWP) as Quarterly Reports. In this report the results of groundwater and subsidence monitoring are summarized for the past 3 1/2 years.

Some of the results of the geotechnical investigations were presented in Early Site Review Report (ESRR, Ref. 1) submitted to U.S. Nuclear Regulatory Commission on February 28, 1974. Subsequent to the preparation of the ESRR, additional borings were drilled, laboratory tests performed on soil samples, and groundwater levels and ground surface subsidence at the Site were monitored. The data previously presented in the ESRR were reevaluated and some minor changes were made for uniformity and consistency. In this report all the revised and up-to-date geotechnical data have been compiled for easy retrieval.

In view of future geotechnical work that will be performed at the SJNP Site, some additional modifications to data in this report may have to be made at a later date for incorporation in the Preliminary Safety Analysis Report (PSAR). Detailed geology and earthquake engineering aspects of the SJNP are not contained in this report due to their extensive and up to date coverage in the ESRR and its 19 amendments.

2. GENERAL SITE DESCRIPTION

The Site is in the southern portion of the San Joaquin Valley, which occupies the southern end of the Great Valley province of California. The Valley forms a large sedimentary basin, separating the Sierra Nevada on the east and the Coast Ranges on the west. The Site is located approximately 10 miles northwest of the city of Wasco, as shown on Figure 1. Ground surface terrain of the Site gently slopes northwest at a gradient of about 0.1 percent. The Site Vicinity is underlain by unlithified Holocene to Plio-Pleistocene alluvial fan, alluvial plain, and lacustrine deposits derived primarily from the Sierra Nevada. These units are underlain by semilithified to lithified marine and non-marine Tertiary and possibly Cretaceous sediments. Crystalline basement rock is believed to exist at a depth of about 20,000 feet beneath the Site.

The near-surface stratigraphy underlying the Site (within the upper 500 feet) consists of three distinct stratigraphic units: (i) the Upper Oxidized Zone consisting of light brown sands,

silty sands, silts and clays to a depth of about 240 feet, which were deposited primarily in an alluvial fan environment; (ii) the Middle Reduced Zone, between depths of 240 and 290 feet, composed generally of grayish-blue, grayish-green and dark brown sand, silt and clay, which were deposited primarily in a lacustrine environment; and (iii) the Lower Oxidized Zone, below about 290 feet to at least 500 feet, consisting primarily of light brown sands and silty sands with minor clay, which were deposited primarily in an alluvial fan environment. The Upper and Lower Oxidized Zones consist of water bearing aquifers from which groundwater is pumped regionally for irrigation. The Middle Reduced Zone correlates with the regionally recognized Corcoran Clay, or E-Clay. Regional and Site geology have been discussed extensively in the ESRR.

3. FIELD WORK

The field work at the Site consisted primarily of the following: Geologic Borings, Engineering Borings, Geophysical Investigations, Groundwater Monitoring and Ground Surface Subsidence Monitoring. The results of the field work are presented in Appendices A and B.

3.1 Geologic Borings

Initially, 35 borings (H-1 through H-35) were drilled at the Site primarily for geologic purposes. These borings ranged in depth from 400 to 540 feet and were drilled using truck-mounted rotary wash drilling equipment. The cuttings from the borings were examined at intervals of about ten feet and logged. In order to supplement field classification of the subsurface

soils based on wash cuttings, and to secure soil samples for laboratory testing, Fugro Drive, Pitcher Tube and core samples were obtained selectively in borings H-14, H-24, and H-35. Laboratory tests were later performed on selected soil samples from borings H-14 and H-24.

All the geologic boring logs (H-1 through H-35) are presented in the ESRR. Only logs of borings H-14 and H-24 are included in Subappendix A1 of this report. The locations of borings H-14, H-24, and H-35 are shown on Figure 2.

3.2 Engineering Borings

Twenty borings (H-36 through H-43, H-43A through H-51, and H-53 through H-55) were drilled during 1973 and 1974 at the proposed location of the Unit 1 Reactor Containment primarily for engineering data. Four additional borings (H-56 through H-59) were were also drilled at Unit 1 location in May, 1976, to obtain undisturbed samples for long-term liquefaction tests. The locations of all the borings are shown on Figure 2. Boring H-52 was drilled for geophysical purposes only and, therefore, a log was not kept. Borings H-36 through H-43A, H-46 through H-49, H-52, and H-56 through H-59 were advanced using rotary wash drilling equipment, while borings H-44, H-45, H-50, H-51, H-53, H-54 and H-55 were advanced, using bucket auger equipment. The depths of the borings ranged between 31.5 feet and 350 feet. The logs of all the engineering borings are presented in Subappendix A1. During drilling, six different techniques were used to obtain soil samples.

a. Pitcher Sampler: Good quality undisturbed samples were obtained using a Pitcher Sampler in borings H-14, H-35, H-37, H-39, H-42, H-43A and H-46 through H-49. The Pitcher Sampler yielded 2-7/8-inch diameter samples, with a maximum length of 30 inches. The sampler was advanced into the soil using downward pressure from hydraulic feed mechanism of the rotary wash rig.

b. Core Barrel Sampler: Selective continuous core samples of soil, up to 5-3/4 inches in diameter and 144 inches in length, were obtained in borings H-24 and H-35, using a Core Barrel Sampler. Relatively undisturbed samples were obtained from this sampler. The sampler was advanced into the soil using downward hydraulic pressure, as with the Pitcher Sampler.

c. Fugro Drive Sampler: Relatively undisturbed soil samples were also obtained using a Fugro Drive Sampler in borings H-36, H-37, H-38, H-40, H-41, H-42, H-45, H-50, H-51, H-53, and H-54. The Drive Sampler yielded 2-1/2-inch diameter soil samples contained within 12 one-inch long brass rings. The sampler was generally advanced using a 502 lb. weight with a freefall of 18 inches, or with the weight of Kelly bars in case of bucket auger rigs.

d. Standard Penetrometer (Standard Split-Spoon Sampler): Representative, but disturbed, soil samples were obtained using a standard split-spoon sampler in borings H-36 through H-43, and H-53 through H-55. Standard penetration tests were performed whenever the sampler was advanced into the ground.

The sampler was advanced using a 140 lb. weight with a free fall of 30 inches yielding 1-3/8-inch diameter and up to 18-inch long soil samples.

e. Block Sampling: A 28-inch diameter casing with "windows" cut out at five-foot intervals was inserted in two 30-inch diameter bucket auger borings, H-53 and H-54. Attempts were made to obtain block samples of soil by hand excavation from the sides of the borings through the "windows" at depths from 25 to 45 feet.

f. Bulk Samples: Fifty-pound bulk samples of soil (disturbed but representative) were also obtained from bucket auger borings H-44, H-45, H-50, H-51, H-53, and H-54.

The soil samples obtained from the borings were visually classified in the field and logged. The samples were subsequently transported to the Fugro laboratory in Long Beach for testing. A list of the type of drill rigs used in the borings, the total depth of the borings, and the various samplers used is presented in Table A1-1 of Subappendix A1.

3.3 Geophysical Investigations

3.3.1 Geophysical Logging: A suite of geophysical logs comprising natural gamma, neutron gamma, gamma gamma and neutron epithermal neutron logs was acquired from boring H-43 drilled at the center of Unit 1. The logs are shown on Figure A2-1 of Subappendix A2. These logs were compared with the geophysical logs acquired from nearby geological borings and were found to be in agreement. A comparison of geophysical zones (from selected

geological borings) with lithologic data is presented in Appendix 2.5A of the ESRR.

3.3.2 In Situ Engineering Seismic Measurements: An engineering seismic study consisting of crosshole and downhole surveys, and a short surface refraction profile was performed at the location of Unit 1. The purpose of this study was to measure the in situ compressional and shear wave velocities to a depth of 320 feet. The results are summarized on Figures A2-2 through A2-5 of Subappendix A2. The velocities determined were used to calculate in situ values of Poisson's Ratio, shear modulus, Young's Modulus and Bulk Modulus for various depth intervals. A summary of the calculated parameters is presented in Table A2-1 of Subappendix A2. The details of the procedures used in the seismic study and discussion of the results are presented in Appendix 2.5K of the ESRR.

3.4 Groundwater

3.4.1 Groundwater Monitoring: In order to monitor the groundwater levels and groundwater quality in the aquifer zones above and below the E-clay at the Site, five monitoring wells M-1, M-2, M-3, M-3A, and M-4 were installed in 1974. The depths of the monitoring wells varied from 225 to 350 feet. The locations of these wells are shown on Figure 3. The installation details of the monitoring wells are presented in Figure B1-1 of Subappendix B1. After well construction was completed Stevens Type F water level recorders were installed on wells M-1, M-2, M-3A and M-4. In 1976 a similar water level recorder was installed on well M-3.

These recorders provide continuous records of groundwater levels. The results of groundwater monitoring program are being submitted to LADWP in the form of quarterly reports.

3.4.2 Aquifer Testing:

(i) Short-term test: A small scale short-term aquifer pumping test, approximately 8 hours in duration, was performed in October, 1974, to determine the possible existence of a multiple aquifer system in the Zone above the E-Clay and the zone's transmissive characteristics. Three observation wells (OBS-1, 2 & 3) were installed for this test; the locations of these wells are shown in Figure 3. The installation details of the observations wells are included in Subappendix B2. Well M-1 (225 feet deep) was used as a pumping well for pumping the groundwater. The details of the testing, analysis, and conclusions are included in Subappendix B2. Information obtained from this test was used in design of a long-term aquifer test performed in January, 1976.

(ii) Long-term test: The results of the short-term test indicated the possibility of existence of two aquifer zones above the E-Clay, between depths of 80 and 250 feet. For the long-term aquifer test two pumping wells were installed into an upper zone (80-140 feet), and an intermediate zone (180-250 feet) above the E-Clay and one pumping well was installed in the lower aquifer

(below 290 feet) below the E-Clay; in addition 15 observation wells were installed to monitor the grondwater levels in the three aquifer zones during the pumping test. The pumping test was performed during January, 1976. A preliminary analysis of the test data was presented to LADWP in Fugro Report (Ref. 2) of March 23, 1976. This report also shows the locations of the pumping and observation wells. A detailed analysis of the data obtained is planned during the PSAR preparation.

3.5 Ground Surface Subsidence Monitoring

Historically ground surface subsidence has been occurring in the San Joaquin Valley due to the withdrawal of groundwater from the soil. In order to monitor the ground surface subsidence at the Site, two compaction recorders, C-1 and C-2, were installed in 1974. Compaction recorder C-1 is 350 feet deep and measures the compaction between ground surface and a depth of 350 feet. Compaction recorder C-2 is 1000 feet deep and measures compaction of soils between ground surface and a depth of 1000 feet. Modified Stevens Type-F recorders were installed on top of the compaction recorders to monitor the ground surface subsidence continuously. The installation details of the compaction recorders are presented in Figure B1-2 of Subappendix B1. The results of the subsidence monitoring program are being submitted to LADWP along with the results of the groundwater monitoring program as quarterly reports.

4. LABORATORY TESTING

The soil samples from the borings were brought to Fugro, Long Beach, Laboratory for testing. The laboratory tests consisted of the following:

1. Index properties tests,
2. Consolidation tests,
4. Maximum and minimum density tests,
5. Permeability tests,
6. Expansion tests, and
7. Dynamic tests.

All testing was done in general accordance with the standards of American Society for Testing and Materials. Some variations from these standards were made to satisfy specific testing needs and/or soil conditions. Any variation is properly documented in our project files. The results of all the laboratory tests are presented in Appendix C.

4.1 Index Properties Tests

The tests for index properties consisted of in situ moisture content, in situ dry density, Atterberg limits, grain size distribution and specific gravity of the soil samples. The tests were performed on both undisturbed and disturbed soil samples as appropriate. The results of the moisture content, dry density and Atterberg limit tests are summarized in Table I, Soil Testing Summary of Subappendix C1. Visual classifications of the soil samples and classifications verified by complete or partial laboratory tests are also listed in Table I. The plots

of the results of grain size distribution tests are presented in Subappendix C2. The results of the specific gravity tests are presented in Table II of Subappendix C1.

4.2 Consolidation Tests

One-dimensional consolidation tests were performed on selected undisturbed samples to determine the compressibility characteristics of the soil. Consolidation test samples above the groundwater level of 80 feet were loaded incrementally at field moisture content to their in situ overburden pressure and then saturated with water. After sample swell or compression was determined, the samples were unloaded in stages to 0.3 kips per square foot (ksf) and then reloaded in stages to a maximum load of 64 ksf. In some tests, after adding water, one or two additional load increments were put on the sample; then the samples were unloaded and reloaded as in the other tests. Consolidation test samples from below 80 feet were saturated at the beginning of the test and then were loaded in the same sequence as the other samples. The results of the consolidation tests are presented as plots of load versus percent consolidation in Subappendix C3.

4.3 Shear Strength Tests

Triaxial compression tests were performed on selected undisturbed samples to determine the shear strength characteristics of the soil. The types of triaxial tests were: (i) consolidated-drained (CD) triaxial test, (ii) consolidated-undrained (CU) triaxial test, and (iii) unconsolidated-undrained (UU) triaxial

test. In all the CU tests, pore pressure measurements were made. The results of all the triaxial tests are presented as plots of (i) deviator stress versus axial strain, (ii) volumetric strain or pore pressure versus axial strain, and (iii) Mohr's circle for the failure condition for each test and all the test plots are presented in Subappendix C4.

Due to the lenticular nature of the soils encountered, it was not always possible to perform a conventional set of three triaxial tests on the same type of material. Therefore, the soil samples were grouped into three broad soil types: poorly graded sands, with little fines (SP, SP-SM), silty sands (SM), and silts and clays (ML, MH, CL, CH). The tests were performed on representative samples and the results were plotted on p-q diagrams.* This plotting procedure enables a line to be drawn through the data points for determination of the strength parameters, i.e., friction angle and cohesion. The p-q diagrams for the three soil types are presented on Figures C4-1 through C4-6 in Subappendix C4. A failure criterion of peak deviator stress or 10 percent axial strain, whichever occurs first, was used in calculation of strength parameters.

4.4 Maximum and Minimum Density Tests

Density tests were performed on cohesionless soil samples to determine their in situ, maximum and minimum dry densities.

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*The p-q diagram is an alternate to the Mohr-circle method for plotting stress states for many different specimens. In this report each point on the p-q diagram represents the failure state depicted by a Mohr's circle.

The block samples obtained from the bucket auger borings were not used for these tests because of sample disturbance. From the density test results the in situ relative densities were calculated. Soil samples with not more than 12 percent passing through No. 200 sieve were used in these tests. The results of the relative density tests are presented in Subappendix C5. Figure C5-1 presents the range and average of minimum and maximum dry densities at various depths, along with average in situ density determined from pitcher tube and drive samples. Figure C5-2 presents comparison of in situ relative densities as calculated from the laboratory tests with those estimated from standard penetration resistance values.

4.5 Permeability Tests

Permeability tests were performed on undisturbed soil samples from various depths to determine their vertical and horizontal permeability values. The tests were performed on small diameter samples of both coarse-grained and fine-grained soil samples. In these tests the samples were subjected to a constant head of water. The results of the permeability tests are presented in Table III of Subappendix C1.

4.6 Expansion Tests (Swell Tests)

A limited number of expansion tests was performed on fine-grained soils to determine their swelling characteristics. The results are presented on Table IV of Subappendix C1.

4.7 Dynamic Tests

In order to determine the behavior of the soils under a dynamic load, resonant column and cyclic triaxial tests were performed. The details and results of all the dynamic tests were presented in separate reports (References 3, 4, 5 and 6) to the LADWP.

5. SUMMARY OF SUBSURFACE CONDITIONS

5.1 Stratigraphy at Unit 1 Location

Based on interpretation from the borings and laboratory test results, the stratigraphy of the soils at Unit 1 location has been evaluated and the principal soil strata have been identified. In general, the soils consist of interbeds and lenses of sands, silts, and clays which randomly pinch out or grade laterally and vertically into finer or coarser soils. The sands are predominantly fine to medium graded, and vary from clean sands with little fines (SP) to silty or clayey sands (SM or SC). The compactness of the sand layers varies from dense to very dense. The silts vary from non-plastic sandy silt (ML) to highly plastic silt (MH). The clays vary from slightly plastic silty clay (CL) to highly plastic clay (CH). The consistency of the silts and clays varies from stiff to hard.

Because of interbedding of layers, it has not been possible to separate the soil strata distinctly. However, an attempt has been made to identify the principal soil strata. In order to describe the subsurface soils they were divided into two major categories: coarse-grained soils (sands); and fine-grained soils (silts and clays). In this section, sand with little or

no fines (SP, SP-SM), silty sand (SM) and clayey sand (SC) will be hereinafter referred to as "sands". Sandy and clayey silt (ML), highly plastic silt (MH), silty and sandy clay (CL) and highly plastic clay (CH) will be hereinafter referred to as "silts and clays."

A generalized soil column at the location of Unit 1 indicating the soil types, strata numbers and average depths is shown on Figure 4. The soil column is based on the interpretation from the borings and laboratory test results, and will be used for future engineering analyses required for the PSAR.

Generalized north-south and east-west subsurface profiles at the proposed Unit 1 location are shown on Figures 5 and 6 respectively. The generalized soil layers were determined by grouping zones of predominant soil types. In all cases the properties of the predominant soil vary considerably within the stratum. Even within individual lenses, there are smaller lenses of different soil types. Due to this lenticular nature, there is limited continuity of layers between the borings.

The principal soil strata are described in descending order from the surface. The average depths of the various strata are based on the generalized soil column shown on Figure 4.

Stratum 1 (From Ground Surface to an Average Depth of 20 Feet)

The surface soils identified as Stratum 1, consist of "silts and clays" to depths ranging from about 14 to 26 feet. Average thickness of the surficial stratum is 20 feet. Several sand

lenses, ranging in thickness from 2 to 4 feet, randomly occur within Stratum 1.

In the east-west direction there is a layer of "sands" ranging in thickness from 2 to 9 feet.

Stratum 2 (Between Average Depths of 20 Feet and 63 Feet)

Stratum 2 consists of "sands" with an average thickness of 43 feet (range 38 to 50 feet). Several lenses of "silts and clays," ranging in thickness from 2 to 11 feet, randomly occur within the "sands" of Stratum 2.

Strata 3 and 4 (Between Average Depths of 63 Feet and 138 Feet)

Stratum 3 consists of "silts and clays" with an average thickness of 28 feet. Stratum 4 consists of "sands" with an average thickness of 47 feet.

Along north-south section A-A (Figure 5), Stratum 3 consists of "silts and clays," with an average thickness of 31 feet (range 20 to 36 feet) with one 17-foot thick "sand" lens and several thinner "sand" lenses (2 to 7 feet thick). Stratum 4 consists of "sands" with an average thickness of 39 feet (range 34 to 42 feet) with random "silt and clay" lenses (3 to 6 feet thick).

Along the east-west section B-B (Figure 6), Strata 3 and 4 are combined and the average thickness is 73 feet (range 64 to 89 feet); they predominantly consist of "sands" with one 20-foot thick "silt and clays" lens and one "silt and clay" layer (3 to 9 feet thick).

Strata 5 and 6 (Between Average Depths of 138 Feet and 169 Feet)

Stratum 5 consists of "silts and clays" with an average thickness of 9 feet. Stratum 6 consists of "sands" with an average thickness of 22 feet.

Along the north-south section, Stratum 5 consists of "silts and clays" with an average thickness of 9 feet (range 7 to 11 feet) with a 4-foot thick "sand" lens. Stratum 6 consists of "sands" with an average thickness of 27 feet (range 22 to 32 feet), with 3- to 7-foot thick lenses of "silts and clays."

Along the east-west section, Strata 5 and 6 have a combined average thickness of 30 feet (range 19 to 38 feet), and consist of both "sands" and "silts and clays."

Strata 7 and 8 (Between Average Depths of 169 Feet and 248 Feet)

Stratum 7 consists of "silts and clays" with an average thickness of 31 feet. Straum 8 consists of "sands" with an average thickness of 47 feet.

Along the north-south section, Stratum 7 consists of "silts and clays" with an average thickness of 40 feet (range 26 to 54 feet) with a 29-foot (average) thick lens consisting of interbedded silty sands and sandy silts. Stratum 8 consists of "sands" with average thickness of 39 feet (range 32 to 49 feet) with one 3-foot thick lens of "silt and clay."

Along the eastwest section, Strata 7 and 8 have a combined average thickness of 83 feet (range 81 to 86 feet) and consist

of "sands" with several 1- to 3-foot thick lenses of "silts and clays."

Stratum 9 (Between Average Depths of 248 and 289 Feet)

Stratum 9 corresponds to the regional E-Clay zone and consists of both "silt and clay" and "sand" layers and lenses. At the location of Unit 1, the thickness of the E-Clay zone varies between 32 and 64 feet.

Stratum 10 (Below an Average Depth of 289 Feet)

Below Stratum 9 to the maximum depth of exploration, Stratum 10 occurs, consisting predominantly of "sands." Several lenses (3 to 8 feet thick) of "silts and clays" occur within Stratum 10.

The various strata are shown on Generalized Subsurface Profiles on Figures 5 and 6.

5.2 Groundwater at Site

Based on the results of the aquifer pumping tests and groundwater monitoring performed at the Site since 1974, groundwater occurs beneath the Site in three separate aquifer zones. The approximate extent of the three aquifer zones is as follows:

i) Upper aquifer - from 80 feet to 140 feet
ii) Intermediate aquifer - from 180 feet to 250 feet
iii) Lower aquifer - below 290 feet

Due to the lenticular nature of soils there are local variations in the extent of the aquifers. The two upper aquifers appear to be confined or semi-confined and consist predominantly of sand

with a few lenses and layers of silt and clay. The aquitard, which confined the upper aquifer (80 feet to 140 feet), consists of several layers and lenses of sand, silt and clay and does not appear to be areally extensive. The aquitard separating the upper two aquifers extends from about 140 feet to 180 feet and appears to be more continuous and areally extensive than the aquitard above the upper zone. The lower aquifer is the regional aquifer and consists of sands with occasional lenses of silt and clay. This aquifer is confined by the E-Clay which extends from about 250 feet to 290 feet and is a major regional aquitard in the San Joaquin Valley.

The variation in the piezometric water levels of the three aquifers with time, from 1974 through 1976, are shown on Figures B1-3, B1-4, B1-5, and B1-6 of Subappendix B1. The apparent piezometric water level in the upper aquifer is at a depth of about 80 feet with little seasonal fluctuation. The piezometric water level in the intermediate aquifer is at a depth of about 135 feet during midwinter months when irrigation is minimal; it declines annually on an average of 40 feet during summer and then recovers to approximately 135 feet. For the years 1974 to 1976, no "net loss" in the piezometric head of the intermediate aquifer has been observed. In the lower aquifer the piezometric water level at the beginning of 1974 was about 220 feet below ground level. Average annual fluctuation from 1974 to 1976 has been as much as 110 feet. By the end of 1976 the "net" decline in the piezometric head was about 15 feet indicating an average net decline of about 5 feet per year.

The decline in the piezometric head of the lower aquifer is due to the extensive pumping and apparent overdraft of groundwater for irrigation in the region.

5.3 Ground Surface Subsidence

Ground surface subsidence at the Site is due to pumping of groundwater. The subsidence at the Site from January, 1974 to June, 1977, measured by the two compaction recorders, is shown on Figures B1-3, B1-4, B1-5, and B1-6 of Subappendix B1. As seen from these figures, the subsidence pattern follows that of groundwater with a time lag of approximately one month. The average rate of net ground surface subsidence measured at the Site from 1974 to 1977 is approximately 0.1 foot per year.

6. GEOTECHNICAL PROPERTIES OF SOILS

The physical soil properties of the subsurface soils at Unit 1 location have been derived primarily from laboratory tests. Some soil properties have also been derived from field measurements and tests. The soil properties are briefly discussed in the following paragraphs:

6.1 Index Properties

a. Coarse-grained soils: These consist mainly of sands which vary from clean sands (SP) with less than 5 percent fines, to silty or clayey sands (SM, SC) with as much as 49 percent fines. The sandy soils are predominantly poorly graded and have medium to fine gradation (2 mm to 0.074 mm size). The standard penetration tests performed during drilling and subsequent laboratory relative density determinations of the in situ soils indicate

that the compactness of the sandy soils varies from dense to very dense.

b. Fine-grained soils: These consist of inorganic silts and clays. The silts range from non-plastic sandy silts (ML) to highly plastic silt (MH). The clayey soils range from slightly plastic silty clay (CL) to highly plastic clay (CH). The standard penetration tests performed during drilling indicate that the consistency of the fine-grained soils varies from stiff to hard.

The index properties of the soils are presented in Subappendices C1 and C2.

6.2 Compressibility

The results of the consolidation tests are presented in Appendix C3. The sands have low compressibility (compression index C_c = 0 to 0.19). The compressibility of the silts and clays ranges from low to moderate (C_c = 0.2 to 0.39). The soils in the top 80 feet are slightly overconsolidated probably due to fluctuations in the groundwater level and dessication. The soils below 80 feet are normally consolidated.

6.3 Shear Strength

The total and effective stress data from the triaxial tests were used to prepare p-q diagrams, shown on Figures C4-1 through C4-6 in Subappendix C4, for these three soil types: Sand with little fines, Silty Sand, and Silts and Clays. On the p-q diagrams, lower and upper bound envelopes were drawn

and from these, the range of cohesion and angle of internal friction for each type of soil was calculated. The shear strength parameters are tabulated below. The data indicate that the soils at the Site have high shear strength.

NO.	SOIL TYPE	SHEAR STRENGTH PARAMETERS							
		Total Stresses				Effective Stresses			
		Lower Bound		Upper Bound		Lower Bound		Upper Bound	
		C(PSI)	$\phi(^{o})$	C(PSI)	$\phi(^{o})$	$\bar{C}$(PSI)	$\bar{\phi}(^{o})$	$\bar{C}$(PSI)	$\bar{\phi}(^{o})$
1	Sand with little fines (SP, SP-SM)	0	31	20	38	0	37	0	44
2	Silty sands (SM)	0	29	29	34	0	35	0	40
3	Silts and Clays (ML, CL, CH)	0	21	19	21	0	27	0	36

6.4 Relative Density

The range of laboratory minimum and maximum dry densities of the sandy soils in the upper 80 feet of the soil profile at Unit 1 is shown on Figure C5-1 of Subappendix C5. The average minimum and maximum dry densities were then calculated and plotted on Figure C5-1 along with average in situ dry densities calculated from Pitcher tube and Drive samples. The plot on Figure C5-1 indicates that the difference between the average in situ density and average maximum dry density is about 4

percent of the average maximum dry density in all cases except at depths of 55 and 60 feet; at these depths the difference is 7.3 and 10.7 percent, respectively.

Figure C5-2 shows a plot of standard penetration resistance versus effective overburden pressure for the sandy soils encountered in the upper 120 feet. On this plot is also shown a relationship between standard penetration resistance, effective overburden pressure and relative density developed by Gibbs and Holtz (Ref. 7) and extrapolated later by Seed and Idriss (Ref. 8) and Fugro. The plot indicates that the in situ relative density of the sandy soils is greater than 70 percent in all cases except in two isolated cases at depths of 72 and 80 feet. The lower values at these depths are probably due to drilling disturbance prior to sampling.

The average in situ relative densities of the sandy soils in the top 80 feet were also calculated from the laboratory test results and these results are shown on Figure C5-2. The results compare well with the relative density calculated from standard penetration resistance values except at a depth of 60 feet where the relative density is about 55 percent; this is considered to be an isolated case and is probably due to drilling disturbance.

6.5 Permeability

Small diameter samples were used in permeability testing and, therefore, the test results may not truly represent permeability values of the in situ soils. However, the tests gave the general order of magnitude of permeability. A summary of the

permeability test results is presented in Table III of Subappendix C1. For sands with little fines (SP, SP-SM, SW, SW-SM) the range of vertical coefficient of permeability (K) was 0.2×10^{-4} to 14.4×10^{-4} cm/sec. For silty sands (SM, SM-SC) the range of vertical K was 0.002×10^{-4} to 1.6×10^{-4} cm/sec. For silts and clays (ML, CL) the range of vertical K was 0.0001×10^{-4} to 0.03×10^{-4} cm/sec. In general, the values of the coefficient of permeability determined from the laboratory tests agreed with those presented in "Permeability and Drainage Characteristics of Soils" by Terzaghi and Peck (Ref. 9). Horizontal coefficients of permeability of the soils were also determined and these are also presented in Table III.

6.6 Swelling Potential

The results of the expansion tests (swell tests) are presented on Table IV of Subappendix C1. The test results indicate that the inherent swelling capacity of the Surficial Stratum 1 is low.

6.7 Dynamic Properties

The dynamic properties of the soils, their interpretation and analyses were presented in detail in separate reports (Ref. 3, 4, 5, 6 and 10) to the LADWP.

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SUBAPPENDIX B2
SHORT-TERM AQUIFER TEST

Introduction

A short-term aquifer test was performed on October 10, 1974, utilizing the existing monitoring well M-1 for pumping groundwater. The objectives of the pump test were to determine average approximate coeffients of transmissivity and storage for the aquifer(s) tested, and existence of a multiple aquifer system above E-Clay Zone.

Pump Well

Groundwater pumping for the aquifer test was done from an existing monitoring well, M-1. The well was 225 feet deep and had a 6-5/8 inch casing from ground surface to a depth of 225 feet. The casing was perforated from 80 to 225 feet and the well was gravel-packed from 25 to 225 feet (see Figure B1-1).

Observation Wells

In order to monitor groundwater levels during the test, three observation wells (OBS-1, 2 and 3) were drilled approximately 50 feet from the pumping well M-1; see Figure 3 in text for location of these wells. After drilling of OBS-1 to a depth of 250 feet was completed an S.P.&R. log was obtained for the well. The log indicated that homogeneous fine-grained soils existed between depths of 132 and 152 feet. This zone was selected as the possible aquitard separating a two-aquifer system above E-Clay. The other two observation wells were designed and drilled subsequently in order to monitor the

water levels in the aquifers above and below the 132 ft. - 152 ft. zone. The construction details of the three observation wells are as follows:

Observation Well No.	Dia. of Hole, Inches	Total Depth of Hole, Feet	Casing				Gravel Pack (Feet)	
			Dia. (Inches)	Depth of Casing (Feet)	Perforated Interval (Feet) From	To	From	To
OBS-1	8.5	250	3	250	72	250	0	250
OBS-2	8.5	131	3	131	71	131	0	131
OBS-3*	8.5	250	3	250	161	250		

*Grouted between 130 and 150 feet

A typical cross section of the observation wells is shown in Figure B2-1.

Pump Test Upper Aquifer - all above the clay

A 20 H.P. Sta-Rite submersible pump with a 3-inch discharge pipe was installed in the Well M-1 at a depth of 219 feet. The discharge rate during the aquifer test was monitored by a 2-1/2-inch orifice plate. The discharge for the first 6 hours of the test was 60 gallons per minute, and the discharge for the final 2-1/2 hours of the aquifer test was 72 gallons per minute.

Water levels in the observation wells were measured periodically during the test with electronic sounders. Water levels in the pumping well were measured periodically with an air line-pressure gauge system. Water levels in the wells were also monitored for about 2-1/2 hours after the pump was turned off.

Data Analysis

The data obtained from the test were plotted as time versus drawdown and recovery and shown on Figures B2-2 and B2-3. From these plots the coefficients of transmissivity (T) and storage (S) were computed and the range of these values is as follows:

Coefficient of Transmissivity: T = 10,000 to 22,000 gpd/ft.

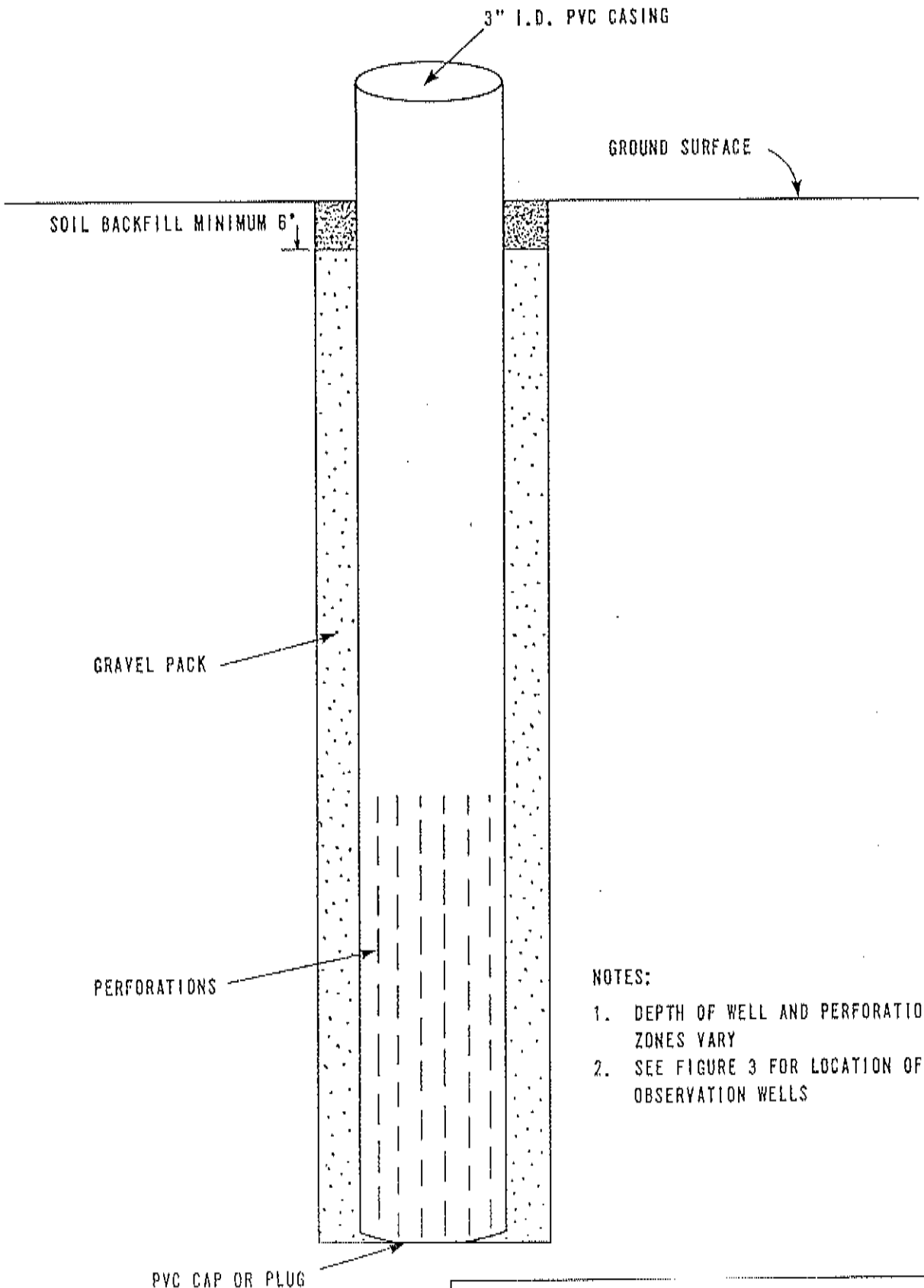
Coefficient of Storage: S = 0.001 to 0.0003

Conclusions

1. Due to the short duration of pumping, the calculated aquifer transmissivity and storage coefficient values may not reflect the true values because of the effects of gravity drainage not being overcome.

2. The test was not conclusive to evaluate the existence of multiple aquifers above E-Clay. However, based on the drawdown observed in the observation wells OBS-1, 2, and 3, there is some indication that an aquitard may exist between depths of 130 feet and 160 feet.

3. A long term aquifer pumping test will have to be performed to delineate the aquifers above and below E-Clay and to determine their characteristics.



NOTES:

1. DEPTH OF WELL AND PERFORATION ZONES VARY
2. SEE FIGURE 3 FOR LOCATION OF OBSERVATION WELLS

SAN JOAQUIN NUCLEAR PROJECT

TYPICAL OBSERVATION WELL

FIGURE B2-1

COMPILED BY _____ DRAWN BY _____ /4/78 CHECKED BY G. Ramajeya 4/78 APPROVED BY G. Ramajeya 4/78

COMPILED BY _____ DRAWN BY L. Hicks 7-13-77 CHECKED BY [illegible] APPROVED BY [illegible] 7/77

SAN JOAQUIN NUCLEAR PROJECT

SHORT-TERM AQUIFER TEST

DRAWDOWN VS TIME

FIGURE B2-2

COMPILED BY _____ DRAWN BY L. Ruiz 12-13-77 CHECKED BY G. Rawlinson APPROVED BY G. Rawlinson 12/27

SAN JOAQUIN NUCLEAR PROJECT

SHORT-TERM AQUIFER TEST
RECOVERY VS TIME

FIGURE B2-3

BIENNIAL GROUNDWATER MONITORING REPORT FOR THE SEMITROPIC WATER STORAGE DISTRICT WATER BANKING PROJECT (2015-2016)

prepared for:
Semitropic Water Storage District
Buena Vista Water Storage District
North Kern Water Storage District
Rosedale-Rio Bravo Water Storage District
Shafter-Wasco Irrigation District
Southern San Joaquin Municipal Utility District

by
Kenneth D. Schmidt and Associates
Groundwater Quality Consultants
Bakersfield, California

February 2018

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February 26, 2018

Mr. Jason Gianquinto, Manager
Semitropic Water Storage District
P.O. Box Z
Wasco, CA 93280

Re: Water Banking Project 2015-16 Biennial
Groundwater Monitoring Report

Dear Jason:

Submitted herewith is the biennial groundwater monitoring report for 2015-16 for the Semitropic Water Storage District Water Banking Project. I appreciate the cooperation of Isela Medina of the District and Ron Eid of GEI Consultants in providing information and preparing the illustrations, and the other districts in providing information on water-banking activities and results of groundwater monitoring.

Sincerely Yours,

Ken Schmidt

Kenneth D. Schmidt

KDS/td

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BIENNIAL GROUNDWATER MONITORING REPORT FOR THE SEMITROPIC WATER STORAGE DISTRICT WATER BANKING PROJECT (2015-2016)

INTRODUCTION

Except for two demonstration projects that were conducted in the early 1990's, the Semitropic Water Banking Project began in 1995. One demonstration project was conducted with the State of California in 1990, and another with the Metropolitan Water District of Southern California (MWD) in 1993. Through 2016, the Semitropic Banking Project entailed delivery of surface water to irrigated lands to reduce groundwater pumping. Water has been delivered to lands in "in-lieu" areas, through newly developed distribution systems, and also to lands in the existing District service area. This water has then been accrued in water banking accounts, to be later placed in the California Aqueduct. This was done either through a release of entitlement or a direct pumpback of groundwater to the Aqueduct. The first biennial monitoring report was for 1995-96 and was submitted in May 1998. The second report was for 1997-98 and was submitted in October 1999. The third report was for 1999-00 and was submitted in October 2003. The fourth report was for 2001-02 and was submitted in January 2005. The fifth report was for 2003-04 and was submitted in May 2007. The sixth report was for 2005-06 and was

submitted in May 2011. The seventh report was for 2007-08 and was submitted in August 2015. The eight report was for 2009-10 and was submitted in September 2016. The ninth report was for 2011-14 and was submitted in May 2017.

WATER BANKING ACTIVITIES

There were six original banking partners (Metropolitan Water District (MWD), Santa Clara Valley Water District (SCVMD), Accounts 1 and 2 of Alameda County Water District (ACWD), Zone 7 of ACWD, Vidler Water Company (Vidler), and San Diego County Water Authority (SDCWA). ACWD is a single entity with two accounts. Zone 7 of ACWD is a different banking partner and for this program is treated as a separate entity. The total amount of groundwater storage capacity that had been identified for water banking purposes as of July 1994 was one million acre-feet. In January 2000, Semitropic WSD (SWSD) expanded the water banking capacity by 650,000 acre-feet (to a total of 1,650,000 acre-feet) with the addition of the Stored Water Recovery Unit (SWRU). By 2001, Newhall Land & Farming had become the seventh banking partner. In 2002, the Castaic Lake Water Agency became a lower priority banking partner. In 2005, Irvine Ranch Water District, and Zone 7 were added as part of the SWRU. The following banking partners were added as part of the SWRU: Poso Creek Water Company, LLC

(2007), SDCWA (2008), City of Tracy (2010), Homer, LLC (2012, Harris Farms, Inc. (2013), Shows Family Farms, LP (2014), Mid Valley Ranch, LLC, Lazy Dog (2015), and Castaic Water Agency (2015). The following became lower priority banking partners: Buena Vista Water Storage District (2010), Homer (2011), and Kern-Tulare Water District (2012).

Table 1 shows the history of water banking activity through 2016. As of the end of 2016, the following net amounts remained in storage by entity: MWD 124,782 acre-feet, SCVWD 190,340 acre-feet, ACWD Account No. 2 83,358 acre-feet, ACWD Zone 7 63,410 acre-feet, ACWD Account No. 1 40,532 acre-feet, Castaic Lake Water Agency 35,970 acre-feet, Newhall Land & Farming 32,507 acre-feet, Poso Creek Water Co. 30,867 acre-feet, the State of California 20,065 acre-feet, SDWA Account No. 1 16,117 acre-feet, Wheeler Ridge WSD 7,500 acre-feet, the City of Tracy 6,100 acre-feet, Sandridge 4,918 acre-feet, Buena Vista WSD 3,100 acre-feet, and Shafter-Wasco I. D. 1,162 acre-feet. By the end of 2016, a total of 651,306 acre-feet of water remained in storage within the project. All of these amounts are net values after a ten percent deduction for project losses, and also after any recovery of banked water has been accounted for.

Figure 1 shows the location of water distribution systems where the banked water was delivered and banked water was recovered as of 2016. There were 22 systems in the District as of 2016. Appendix A

TABLE 1-HISTORY OF WATER BANKING ACTIVITY

SEMITROPIC WATER STORAGE DISTRICT

History of Water Banking Activity {Stored water after losses, and (Recovery)} acre-feet

	BANKING PARTNER		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016		EOY 2016 Total
	State of California	STATE	91,663		(41,499)					(10,033)											(10,033)	(10,033)	0							Put Take Transfer	20,065
Original Banking Project	Metropolitan Water District of So. Cal.	MWD				45,377		45,000	85,500	112,500	35,550	68,265	0	0 (31,500)	0	63,846 (10,000)	0 (98,368)	28,090	0	0 (136,000)	0 (92,054) (16,117)	0 (56,175)	66,600	134,111	40,500	0 (56,000)	0 (35,115)	0 (58,380)	(10,848)	Put Take Transfer	124,782
	Santa Clara Valley Water District	SCVWD							40,500	31,500	21,420	27,000	21,357	0 (30,000)	2,980	29,700	0	80,120	57,632	3,323 (20,000)	5,967 (10,000)	0 (33,453) (10,000)	46,791	59,828	0 (17,000)	0 (45,000)	0 (35,115)	0 (45,881)	8,671	Put Take Transfer	190,340
	Alameda County Water District - 1	Alameda - 1							5,580	9,000	3,402	14,490	12,042	0	625	2,439	0	0	7,940	0 (5,000)	0 (10,000)	0 (3,083)	3,976	3,977	3,979	0 (4,000)	0 (5,016)	0 (5,301)	5,482	Put Take Transfer	40,532
	Alameda County Water District - 2	Alameda - 2												0 4,763	1,250	14,481	7,200	27,270	16,762	926	0	0	2,324	15,283	2,771	0 0	0 (10,034)	0 (10,601)	10,963	Put Take Transfer	83,358
	Zone 7	Zone 7									5,373	20,619	21,546	4,500 (1,807)	12,858	5,850	5,166	5,166	5,166	645	0 (7,000)	0	2,700	5,171	0	0 (4,000)	0 (10,144)	0 (12,899)	4,500	Put Take Transfer	63,410
	Vidler Water Company	Vidler									0	6,291	6,246 (3,691)	0 (7,417)	0	0	0	7,765	1,058	0	0	0 (10,253)								Put Take Transfer	(0)
	San Diego Water Authority - 1	San Diego - 1																			0 16,117	0	0	0	0	0	0	0		Put Take Transfer	16,117
	Newhall Land & Farming Co.	Newhall												2,654	0	0	0	15,680	1,941	0	1,446	0 0	1,446	1,446	1,446	1,446	0 (4,950) 9,950	0		Put Take Transfer	32,507
Lower Priority	Castaic Lake Water Agency	CLWA													21,600	0	29,270	0	0	0	0	0 (4,950)	0	0		0	0 (9,950)	0		Put Take Transfer	35,970
	Homer 1	Homer 1																						7,554		0	0	0	(7,554)	Put Take Transfer	(0)
	Buena Vista Water Storage District	BVWSD																					3,600	4,500	(5,000)	0	0	0		Put Take Transfer	3,100
	Kern Tulare Water District	KTWD																							1,185 (601)	0	0	0	(584)	Put Take Transfer	(0)
	Shafter Wasco Irrigation Dist	SWID						2,153	4,704	1,902	118	474			(547)	(247)	(1,284)			(4,900)									(1,210)	Put Take Transfer	1,162
	Wheeler Ridge WSD														8,500		(1,000)													Put Take Transfer	7,500
SWRU	Irvine Ranch Water District	Irvine																1,508	1,334 (2,842)											Put Take Transfer	0
	City of Tracy	Tracy																		900 (100)	0 (100)	0 0	0	0	5,400	0 0	0 0	0 0		Put Take Transfer	6,100
	Poso Creek Water Company LLC	Poso Creek																10,156	2,000	17,131 (5,000)	0 (12,779)	0 0 20,253	0	9,949	0	0 (3,000)	0 (6,742)	0 (1,100)		Put Take Transfer	30,867
	San Diego Water Authority - 2 (STWB & AVWB)	San Diego - 2																								0	0	0		Put Take Transfer	0
	Homer - 2	Homer 2																							9,900	7,000 (7,000)	(5,000)	0 (4,900)		Put Take Transfer	0
	Harris Ranch	Harris																								2,244 (2,244)	3,572 (3,572)	3,055 (3,055)		Put Take Transfer	0
LO Banking	Sandridge	Sandridge																	4,500	3,015	720	(557)	2,160 (960)	2,160 (1,251)	1,170 (1,329)	(1,351)	(1,837)	1,436 (2,959)		Put Take Transfer	4,918
	Total Stored (Total Recovered) Total Transferred	TOTAL	91,663 0 0	0 0 0	0 (41,499) 0	45,377 0 0	0 0 0	47,153 0 0	136,284 0 0	154,902 (10,033) 0	65,863 0 0	137,139 0 0	61,191 (3,691) 0	4,500 (63,307) 0	47,813 (547) 0	116,316 (10,247) 0	41,636 (100,652) 0	175,755 0 0	98,334 (2,842) 0	25,940 (171,000) 0	8,133 (141,966) 0	0 (108,251) 0	129,597 (960) 0	243,978 (1,251) 0	66,351 (23,929) 0	10,690 (122,595) 0	3,572 (117,525) 0	4,491 (145,076) 0	29,615 (20,196) 0		651,306

Numbers inside parentheses () are negative and are removed from storage account. Numbers not in parentheses are positive and are added to account.

Shaded areas are for closed accounts

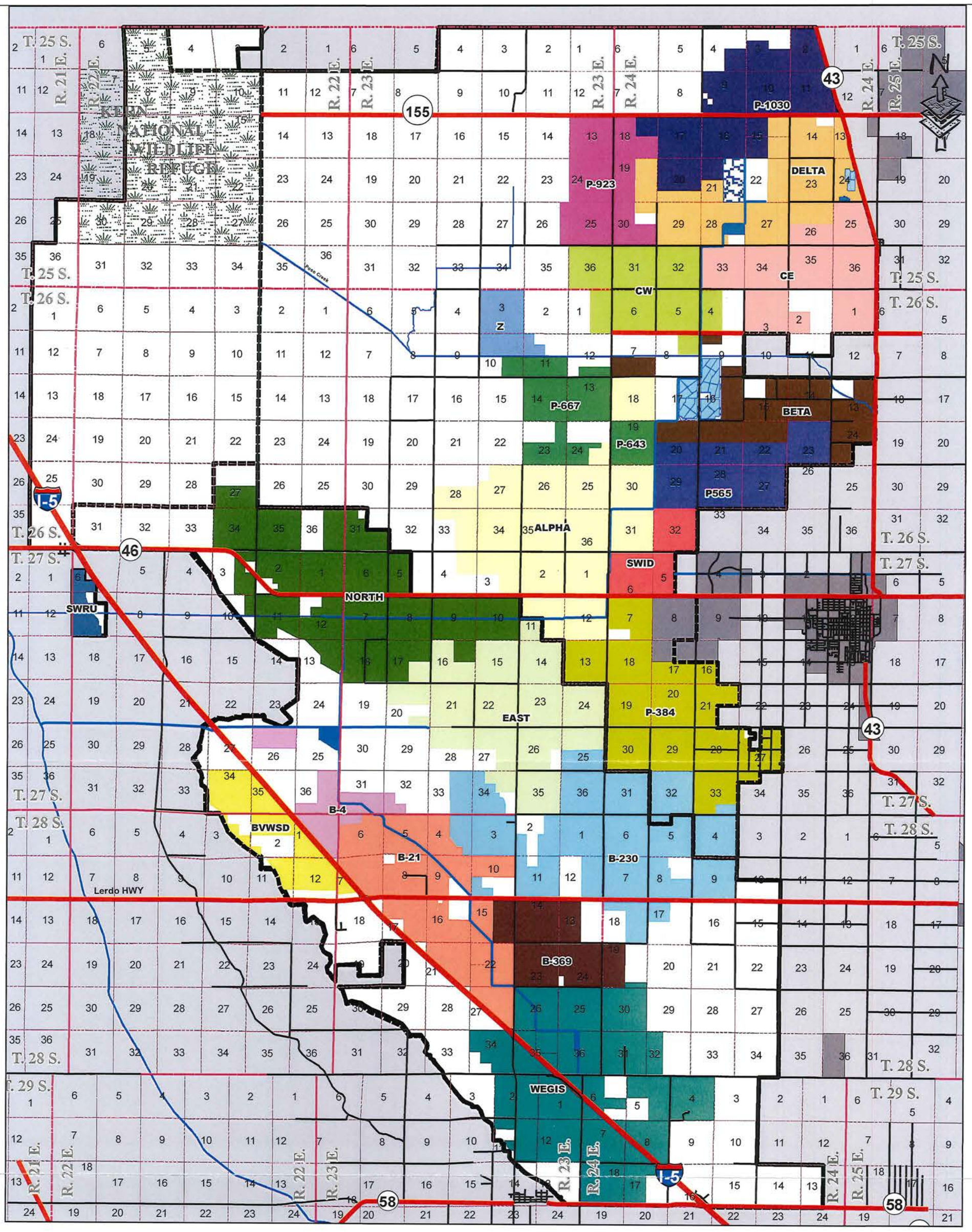


FIGURE 1
SEMITROPIC WATER STORAGE DISTRICT SYSTEM MAP

0 0.5 1 2 3 4 5 Miles

Legend

- DistrictBoundary
- Improvement District Boundary
- Transportation
- Canals, Pipelines, and Aqueduct
- Distribution System

\\GIS Projects\System Routes\DistributionBanking\Water figure 1 08-10 Dec 1, 2016

contains a breakdown of where the banked water and recovered water were allocated in 2015, and 2016. The allocation of banked water within each system excludes entitlement deliveries and is proportioned to the total amount of banked water delivered divided by the sum of all other deliveries except entitlement.

In 2015, the allocation of banked water (3,055 acre-feet) was 20% to the northern systems and the Poso Creek recharge facility, 54% to the central systems, and 26% to the southern systems. In 2015, the allocation of recovered water (142,117 acre-feet) was 19% to the northern water systems, 41% to the central systems, and 40% to the southern systems.

In 2016, the allocation of banked water (29,617 acre-feet) was 35% for the northern systems, 45% for the central systems, and 20% for the southern systems. For the recovered water (20,195 acre-feet), the allocation was 28% to the northern systems, 64% to the central systems, and 28% to the southern systems.

SUBSURFACE GEOLOGIC CONDITIONS

There are several subsurface geologic trends that are important in terms of groundwater monitoring for this project. First, one major aquifer had been assumed to be present in most of the area south of Seventh Standard Road and east of Wasco (the fore-

bay area). The fine-grained strata that are present in this area had been assumed to not function as effective confining beds. Water levels in shallow and deep water-producing strata in the forebay area tend to be at about the same depth at most locations during periods of minimal pumping. In contrast, within much of the part of the SWSD that is north of Seventh Standard Road, at least one significant confining bed is present. This bed averages about 300 feet in depth, and contributes to significant differences in water levels with depth at most locations. To the northwest, closer to the Tulare Lake bed, this clay is equivalent to the Corcoran Clay. For purposes of the monitoring program, two aquifers have been assumed to be present in this part of the study area. The upper zone is above this confining bed and the lower zone is below it. Because of this, two different series of water-level elevation maps have been prepared. In most of the area east of the SWSD, water levels for the shallow groundwater (i.e., above a depth of 300 feet) are not available. However, recent subsurface geologic data indicate that a clay layer is also present in much of the North Kern WSD at a comparable depth as to that in the SWSD. In the future, if more information on shallow water levels in the area east of SWSD becomes available, it may be possible to subdivide the water levels in that part of the forebay into two aquifers.

Another important trend in the subsurface is that fine-grained deposits and high salinity groundwater are present in much of the area generally along and west of Interstate 5, north of Seventh Standard Road. Because of these conditions, there is little pumping of groundwater in this area, and groundwater levels are shallow (near the land surface). Water levels in wells in this area generally correspond to those that are above the widespread confining layer located farther to the east.

GROUNDWATER MONITORING PROGRAM

A Memorandum of Understanding (MOU) was reached between the SWSD and the surrounding entities in July 1994. As part of this MOU, a monitoring committee was established to develop, review, and oversee a groundwater monitoring program. The goal of this program is to develop information so that possible adverse impacts of the water banking project can be mitigated to the extent possible. Members of the monitoring committee represent the SWSD and five adjoining districts. The SWSD banking partners, the Kern County Water Agency, and the California Department of Water Resources are interested parties and participate in committee activities. Ken Schmidt was retained as a groundwater specialist to develop and oversee the monitoring program, and to prepare periodic reports on the results of monitoring. Impacts of the

SWSD Groundwater Banking Program are to be evaluated through interpretation of the results of monitoring, and through a groundwater model being developed by GEI Consultants, Inc.

Activities of the committee commenced in Summer 1994, and a groundwater monitoring program was proposed in June 1994. This plan contained the details of water-level and groundwater quality monitoring, and included two maps, showing the wells to be monitored for water levels and chemical quality. Monitoring pursuant to this plan commenced in Spring 1995. A sampling plan was subsequently developed in September 1996, which presented the recommended procedures to be used for the monitoring, to the extent feasible.

To date, the groundwater monitoring comprised the following:

1. Water level measurements in numerous water supply and monitor wells (normally at least semi-annually).
2. Installation of a number of new monitor wells.
3. Continuous water-level measurements from transducers in 22 monitor wells and supply wells in the SWSD.
4. Monthly water-level measurements in some wells.
5. Operation of a compaction recorder (extensometer) associated with the SWRU.

   Annual water quality sampling of selected actively used water supply wells, and periodic sampling of some monitor wells.

Interpretive procedures for the groundwater monitoring have included:

1. Preparation of water-level elevation maps (for the deep and shallow groundwater). The direction of groundwater flow has also been indicated on these maps.
2. Water-level hydrographs have been prepared for many wells, including ones with long-term records.
3. Water-level change maps have been prepared, including for Spring 1995-Spring 2017, for use in evaluating the water banking activities.
4. Maps of total dissolved solids (TDS) in the shallow and deep groundwater have been prepared.
5. TDS hydrographs have been prepared for selected monitor wells.
6. Nitrate, arsenic, uranium, and hexavalent chromium maps have been prepared for groundwater.
7. Land subsidence has been monitored by the SWSD at a compaction recorder southeast of the Kern National Wildlife Refuge since 2006. Land surface elevations have also been monitored for about ten years at the Wasco Airport and at two other sites along I-5, as part of a program by the U.S. Geological Survey.

In addition to the water-level and groundwater quality moni-

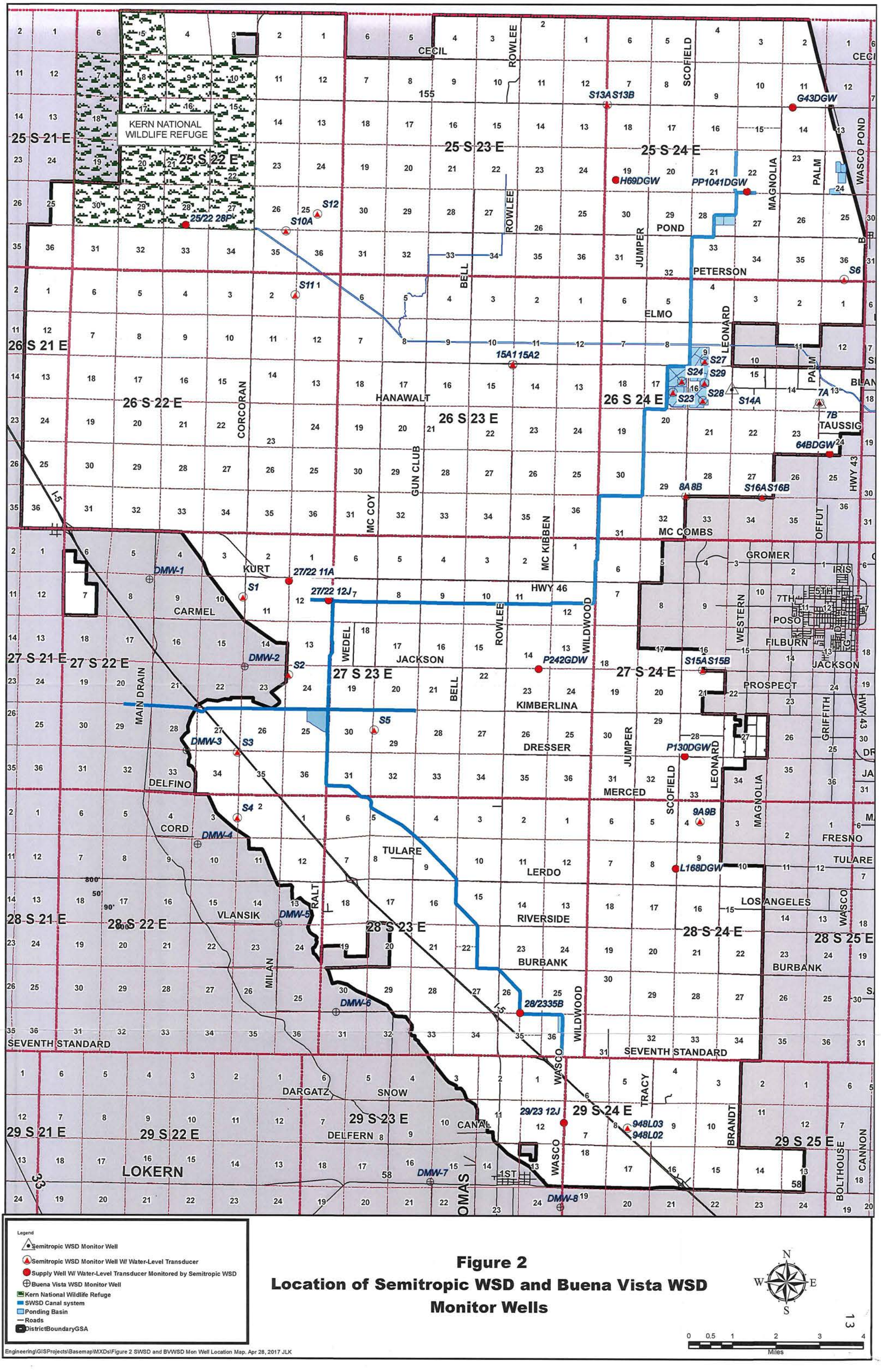
toring, activities of the SWSD and the adjoining entities that affect groundwater conditions has been obtained and compiled. Included are diversions of surface water into each District, crop surveys and estimates of crop consumptive use, and where available, groundwater pumpage. Knowledge of this information is essential in order to determine changes in groundwater conditions due to this water banking project. A groundwater model is used by GEI Consultants, Inc. to compare the with and without Semitropic banking project conditions.

MONITOR WELLS

A double completion monitor well (948L) was installed in the south part of the SWSD in 1994 as part of the Kern-Fan Water Bank project monitoring project. As of 2010, there were two westerly series of monitor wells, which were single completion wells near the westerly boundary of SWSD with the Buena Vista WSD. One series (DMW-1 through DMW-7) was installed west of the boundary in the Buena Vista WSD, and the other (S-1 through S-5) to the east, in the SWSD. Except for S-1, the remaining S-series monitor wells tap the lower zone. Another Buena Vista WSD monitor well (DMW-8) is located south of the SWSD about a mile south of Seventh Standard Road. The first easterly series monitor wells (S-6 through S-9) were installed at four sites along the east side of the SWSD by the District in Summer 1995. Dou-

ble completion monitor wells were installed at three of these sites and a single completion well was installed at the fourth site (S-6). Both shallow and deep wells in the easterly series were designed to tap strata below the regional 300-foot clay layer, because this is where most of the recovery pumpage was expected to be from. The deeper wells were completed beneath a significant local clay layer (below a depth of 550 feet). The shallow completion easterly wells generally tapped strata about 350 to 400 feet deep and above this local clay layer. Continuous water-level recorders were subsequently installed in many of the monitor wells.

As part of the SWRU in the northwest part of the SWSD, one triple completion monitor well (S-10) was installed in Spring 1999. Two casing hammer test wells were installed in this vicinity and converted to deep monitor wells (S-11 and S-12) in November 2001. Additional monitor wells were installed at four other sites (S-13, 14, 15, and 16) in the easterly area in 2003. At each of these sites, double completion wells were completed, similar to the previous easterly monitor wells. Figure 2 shows the locations of these monitor wells. Continuous water-level recorders have been installed in a number of monitor wells and supply wells and the location are also shown in Figure 2. There records are especially valuable, since they clearly indicate the shallow and deepest



Legend

- Semitropic WSD Monitor Well
- Semitropic WSD Monitor Well W/ Water-Level Transducer
- Supply Well W/ Water-Level Transducer Monitored by Semitropic WSD
- Buena Vista WSD Monitor Well
- Kern National Wildlife Refuge
- SWSD Canal system
- Ponding Basin
- Roads
- DistrictBoundaryGSA

Figure 2
Location of Semitropic WSD and Buena Vista WSD Monitor Wells

N W E S

0 0.5 1 2 3 4 Miles

Engineering\GISProjects\Basemap\MXDs\Figure 2 SWSD and BVWSD Mon Well Location Map. Apr 28, 2017 JLK

levels for each year. A series of single completion monitor wells (DMW) was installed along the east edge of the Buena Vista WSD, generally opposite from the single completion monitor wells installed by the SWSD to the east.

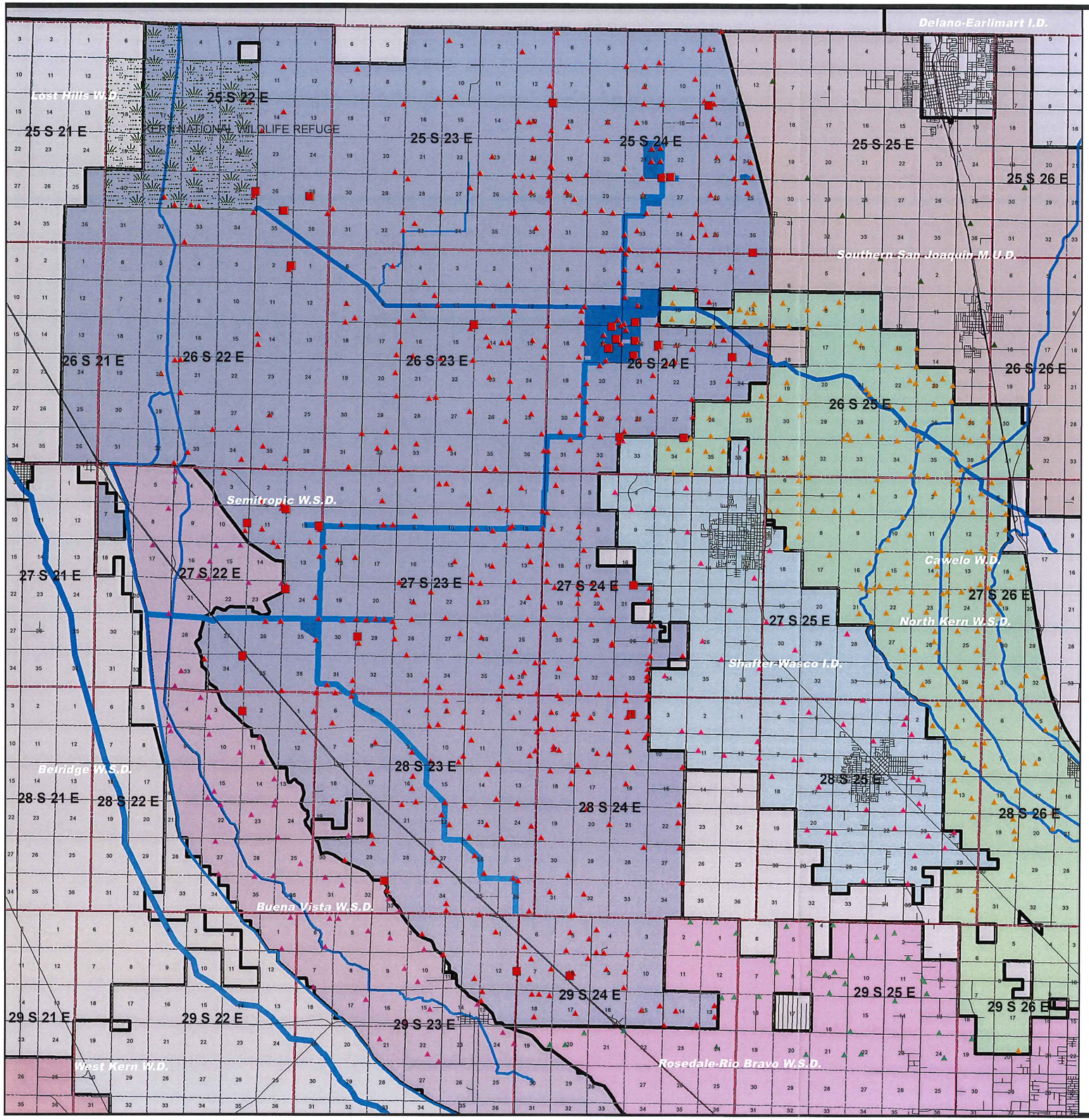
WATER LEVELS

Figure 3 shows the locations of wells used for water-level monitoring. Wells used in the monitoring program have been periodically modified as more information has been obtained, in order to enhance the utility of the monitoring program.

Lower Zone and Forebay

Water-Level Elevations and Direction of Groundwater Flow

The Spring 1995 water-level elevations indicated that water levels in wells tapping strata below the 300-foot clay in the SWSD closely matched those in the forebay area (approximately south of Seventh Standard Road and east of the Central Valley Highway or Wasco Avenue). Most groundwater inflow into SWSD from the forebay area to the east apparently comes from below the 300-foot deep confining bed. Groundwater beneath the 300-foot deep clay layer is confined beneath the District and to the east in much of the North Kern WSD. Thus water-level elevation contour maps have been prepared for the strata below the 300-foot confining bed



N

Figure 3
Location of Wells in Water-Level Network

Legend

- Monitor Wells

Well Locations

- BVWSD
- NKWSD
- RRBWSD
- SSJMUD
- SWID
- SWSD
- Water Agencies
- Canals

2 1 0 2 4 6 8

Miles

in the SWSD and for the adjacent upgradient forebay area to the east and south. A different designation (color) has been used for the water-level elevation contours in the forebay area than farther downgradient in the District.

Figures 4, 5, and 6 show water-level elevations and the direction of groundwater flow in the lower zone and forebay area for Spring 2015, 2016, and 2017. Water-level elevations for specific wells used in preparing the contours are also provided.

In Spring 2015, there was a large cone of depression beneath the north and central parts of the District. Water-level elevations were more than 30 feet below sea level in this depression. The lowest water levels were more than 90 feet below sea level near the north end of the District. These were the deepest spring levels yet monitored. There was a lack of water-level measurements in the northwest and northeast parts of the study area. Water-level elevations along Highway 43 north of Shafter ranged from near sea level to the south to more than 70 feet below mean sea level to the north. The highest water-level elevations (more than 80 feet above mean sea level) were in the southeast part of the study area.

In Spring 2016, there also an extensive north-south trending cone of depression, where water-level elevations were below sea level. The lowest water-level elevations were more than 120 feet below sea level, east of the Wildlife Refuge. To the east, north

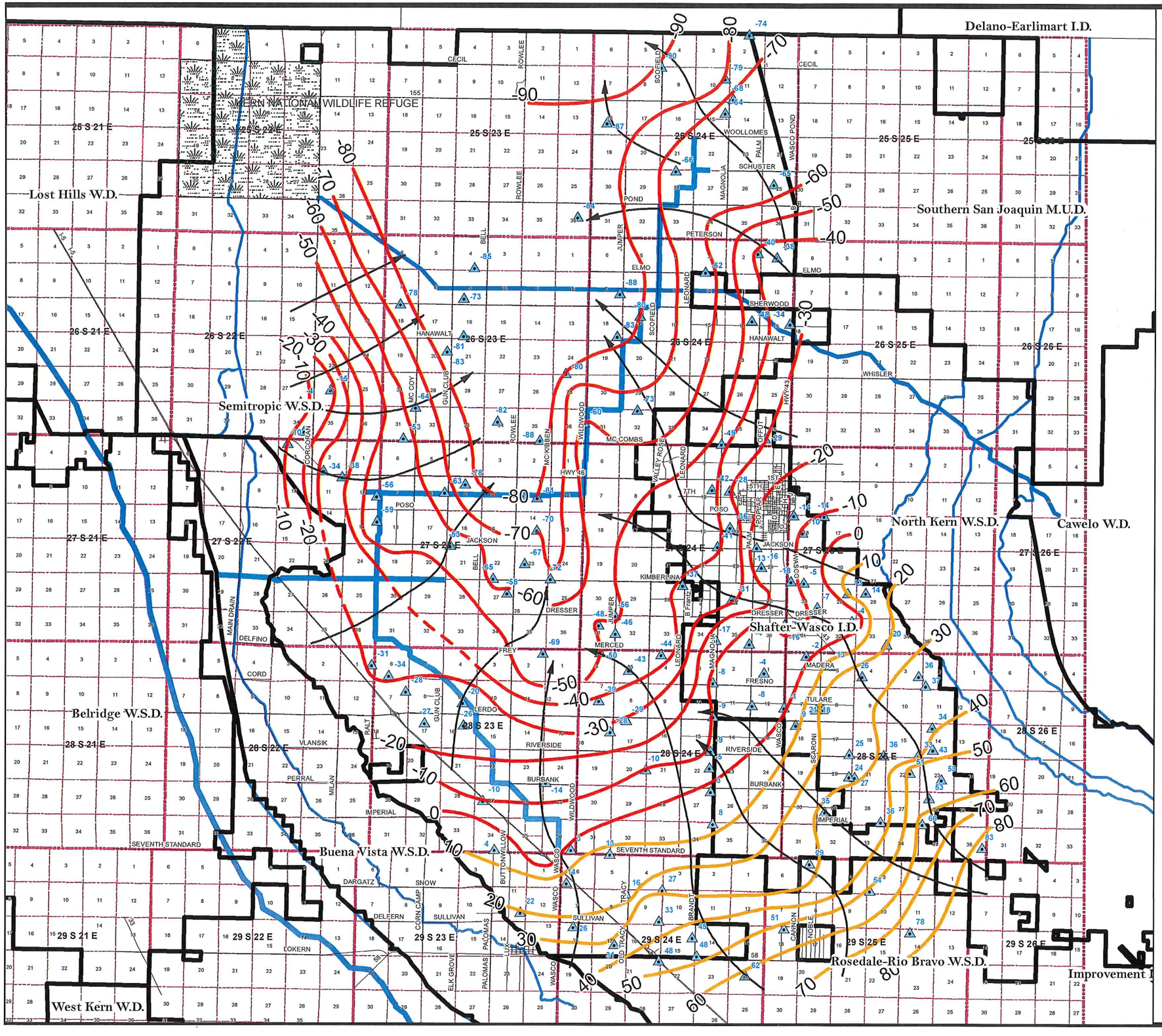


Figure 4

Water-Level Elevations and Direction of Groundwater Flow for the Forebay Area and Lower Zone (Spring 2015)

Legend

- Well & Water-Level Elevation (Ft. Relative to M.S.L)
- Direction of Groundwater Flow
- Water-Level Elevation Contours(Ft. Relative to M.S.L) for Forebay Area.
- Water-Level Elevation Contours(Ft. Relative to M.S.L) for Lower Zone.

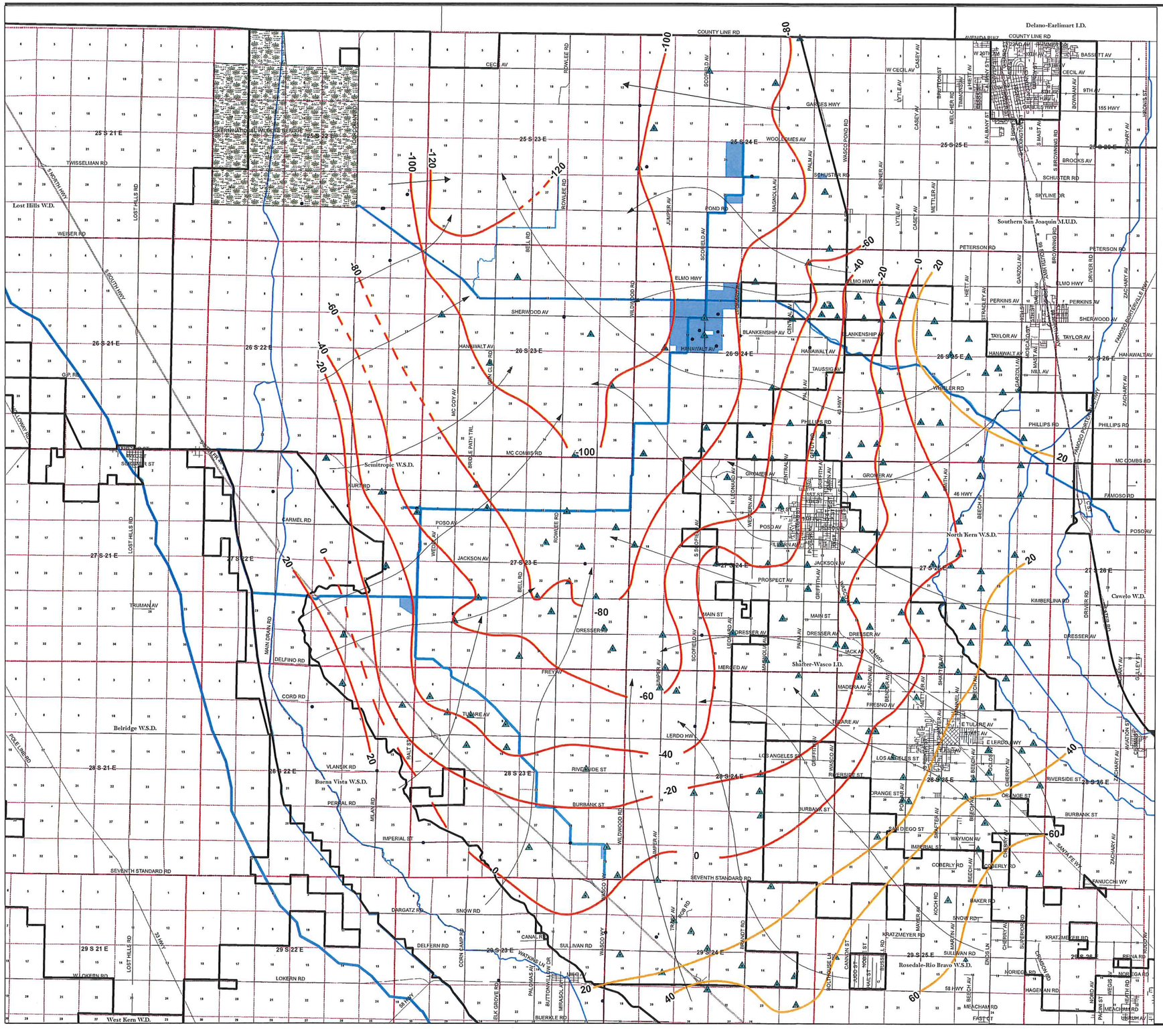
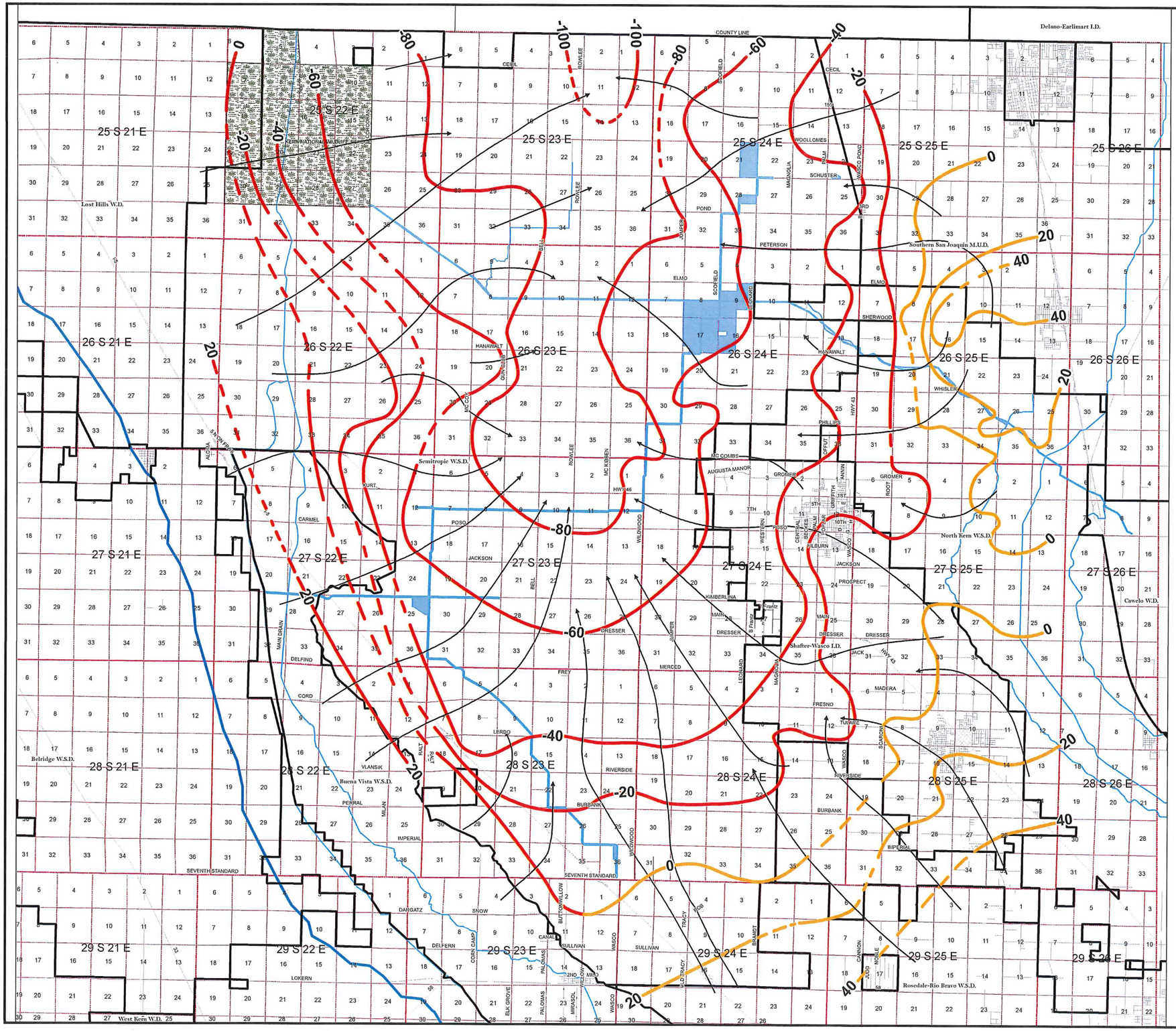


Figure 5

Water-Level Elevations and Direction of Groundwater Flow for the Forebay Area and Lower Zone (Spring 2016)

Legend

- Well Location
- Direction of Groundwater Flow
- 80 — Water-Level Elevation Contours(Ft. Relative to M.S.L) for Forebay Area.
- -20 — Water-Level Elevation Contours(Ft. Relative to M.S.L) for Lower Zone.



N

FIGURE 6-

Water-Level Elevations and Direction of Groundwater Flow for the Forebay Area and Lower Zone (Spring 2017)

Legend

- Well Location
- Direction of Groundwater Flow
- 80 — Water-Level Elevation Contours(Ft. Relative to M.S.L) for Forebay Area.
- -20 — Water-Level Elevation Contours(Ft. Relative to M.S.L) for Lower Zone.

1 0.5 0 1 2 3 4

Miles

of Wasco and Highway 43, water-level elevations ranged from about 30 to 80 feet below sea level. The highest water-level elevations, exceeding 160 feet above sea level, were in the northeast and southeast part of the study area. The direction of groundwater flow in the deep zone was into the SWSD, except along the north boundary of the District in the area east of the Wildlife Refuge, where groundwater flowed out of the District.

In Spring 2017, there was a less pronounced cone of depression beneath the north part of the District. Water-level elevations were about 20 feet below sea level near the south edge of this depression and about 100 feet below sea level near the north edge of the District. Along Highway 43 north of Shafter, water level elevations were about 20 to 40 feet below sea level. The highest water-level elevations exceeded 40 feet above sea level and were beneath the northeast and southeast parts of the study area. The direction of groundwater flow in the deep zone was almost entirely into the District.

Water-Level Changes

Figure 7 shows the water-level changes in the forebay area and lower zone between Spring 1995 and Spring 2017. No water-level rises were indicated during this period. Water levels fell from about 40 feet to 100 feet beneath most of the Semitropic WSD.

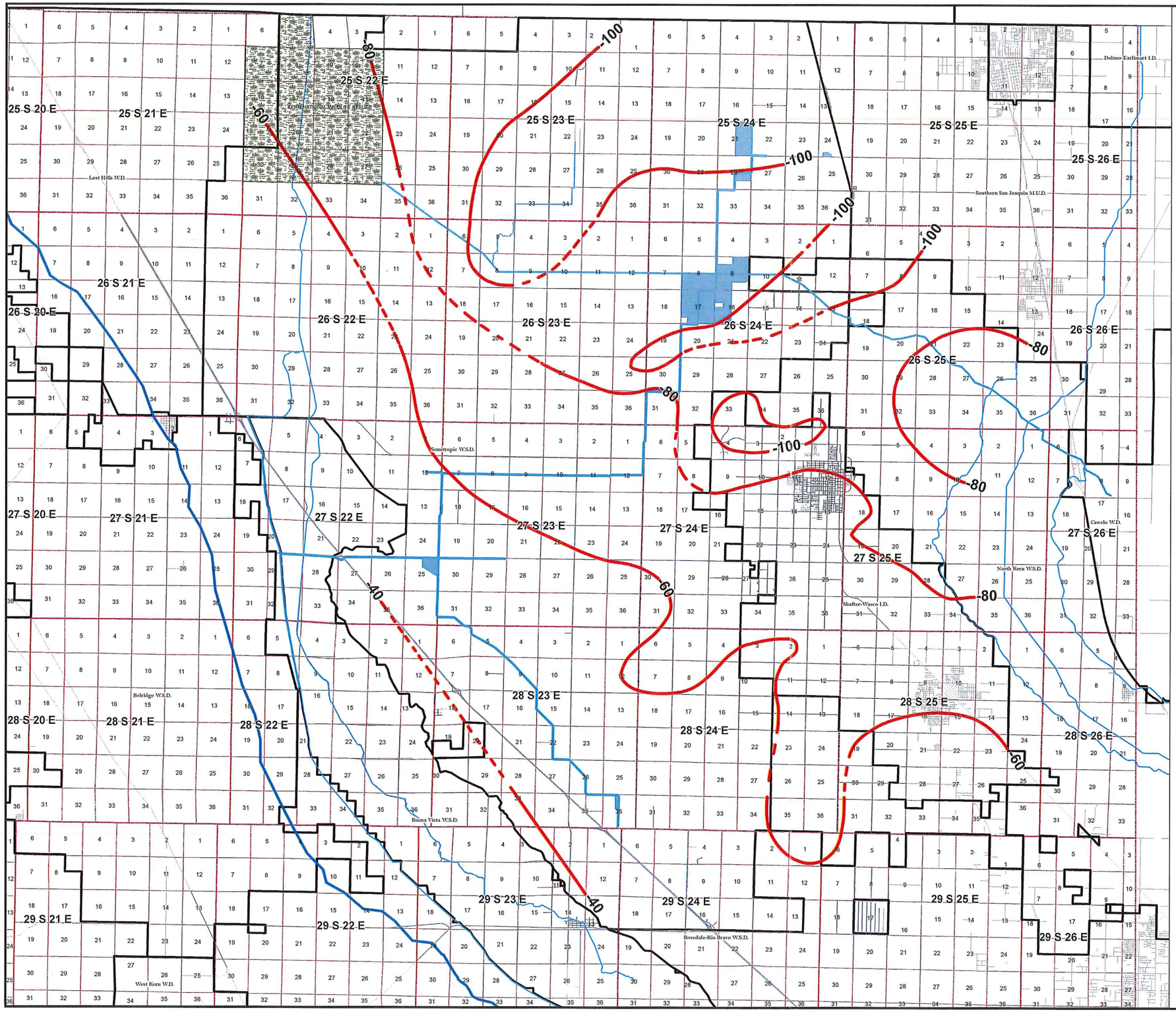


Figure 7
Water-Level Changes For The Forebay Area & Lower Zone (Spring 1995 - 2017)

Legend

- ▲ Well Location
- – Water-Level Decline
- -40 ~ Contour of Water-level Change (Feet)

The amount of decline in the SWSD generally increased to the north. The largest water-level declines were beneath T25S/R23E, T25S/R24E, T26S/R23E, and T26S/R24E, which correspond to the northerly systems and the north part of the central systems.

Appendix B contains water-level hydrographs for wells in the area. GEI Consultants provided long-term hydrographs for 49 lower zone wells in the SWSD. Records for some of these extend back to about 1970, and most extend back to about 1990-96. Transducer measurements are available for 12 of the District lower zone monitor well sites since 2006. The SWSD prepares hydrographs for these, and records for these (including manual measurements) extend back to 1990-91. In addition, the District has installed transducers in a number of other wells and hydrographs are provided for these. There are now about 50 wells in the SWSD with transducers.

No water-level hydrographs covering 2015-17 were available for the Southern San Joaquin MUD. GEI Consultants provided water-level hydrographs for 47 wells in the North Kern WSD. KDSA printed out DWR long-term water-level hydrographs for 11 wells in the Shafter-Wasco I.D. Buena Vista WSD provided water-level hydrographs for four lower zone wells in the study area, and these extend back to the early 1990's. KDSA printed out DWR long-term water-level hydrograph for eight wells in the Rosedale-Rio Bravo WSD in the forebay area, and some of these records extend back to about 1980.

2015-17. Water levels in the lower zone fell during this two-year period in most parts of the SWSD south of Whisler Road. North of Whisler Road, there were large areas where water levels rose. 2015 was a year of extensive recovery pumping, whereas 2016 was a year when the amounts of banked and recovered water were almost the same. Poso Creek flowed substantially during Winter and Spring 2016-17. The largest water-level declines (exceeding 15 feet) were primarily in the B-369 and Wegis systems. The largest rises (more than 20 feet) were in the North, P-1030, and Delta systems, in the northeast part of the District.

In the North Kern WSD water levels in many wells rose from 20 to 34 feet north of Highway 46 during the two year period. These wells were generally close to Poso Creek. There was not enough hydrographs to describe conditions farther south. In the Shafter-Wasco I.D., water levels in the forebay area were stable or fell up to 28 feet during this two-year period. The water-level declines were greater between Seventh Standard Road and Kimberlina Road. The smallest declines (less than 10 feet) were generally in the area north of Kimberlina Road. In the Rosedale-Bravo WSD, water levels in the forebay area were stable or fell up to 25 feet during the two-year period. In the Buena Vista WSD, water levels in one well fell during the two year period, whereas water levels slightly rose in the other three wells tapping the lower zone.

Long-Term. In this report a number of hydrographs that were termed "short-term" in previous biennial reports are grouped under long-term, as many of these hydrographs now extend for more than two decades. A typical water-level hydrograph for the lower zone in the SWSD is shown in Figure 8. Well T25S/R22E-27J is located west of Corcoran Road and north of Pond Road, in the northwest part of the District. The casing in this well is perforated from 497 to 800 feet in depth. Water-level records for this well extend from 1970 to 2011. Seasonal water-level declines have ranged from about 30 to about 130 feet. The water levels in this well were falling through 1977. Since then, water levels rose through 1984, then were relatively stable through 1991, and rose after 1994. In Spring 2004, depth to water was near the shallowest of record (near the 1988 and 1996 levels). However, the water level fell substantially after Spring 2008 to the lowest level of record (more than 360 feet deep) in late 2013. By Spring 2017, the water level had recovered to a depth of about 290 feet.

Water-level trends from Spring 1995-Spring 2017 were evaluated for 18 wells in or near the North Kern WSD. Hydrographs for most of the wells indicated rising water levels through Spring 1997, falling water levels from Spring 1997 to Spring 2005, rising water levels through Spring 2007, substantial declines by

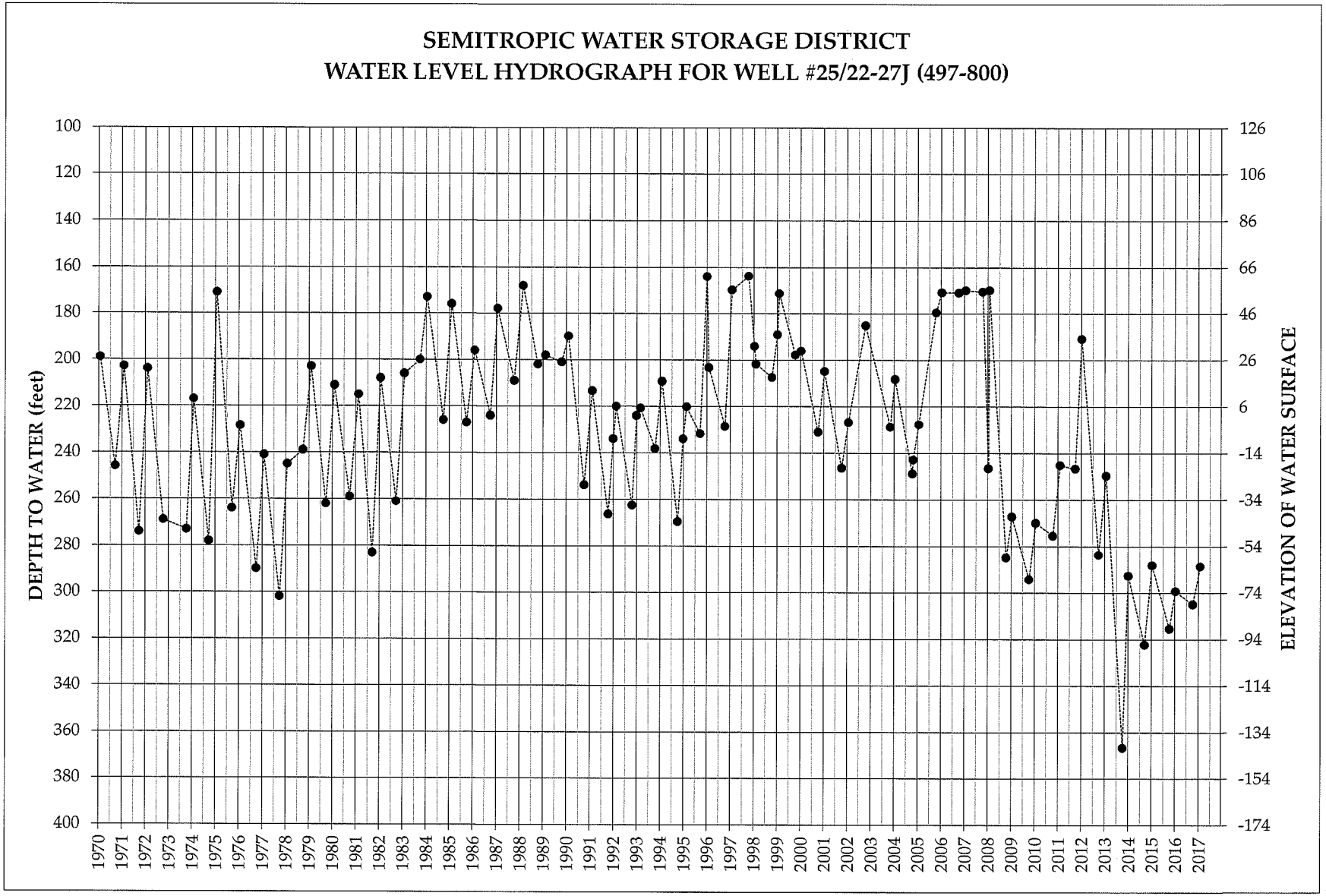


FIGURE 8-TYPICAL WATER-LEVEL HYDROGRAPH FOR THE LOWER ZONE

Spring 2008, then rising or stable water levels through Spring 2011. Water levels then fell through early 2016.

Water-level trends for 1995-2017 could not be evaluated in the Southern San Joaquin Municipal Utility District because wells with 1995 water level measurements were not measured in 2017.

Water-level trends for 1995-2017 were evaluated for about a dozen wells in the Shafter-Wasco I.D. Water levels had fallen through 1992-94 during the prolonged drought. Water levels then rose through 2001, then fell through 2005. Water levels then rose through 2007, declined significantly by Spring 2008, and then rose or were stable through 2011. After 2011, water levels in these wells fell through early 2016, then had slightly recovered by early 2017. Water-level trends for 1995-2017 were evaluated for five wells in the Rosedale-Rio Bravo WSD. Water levels in these wells rose through 2001, then fell through 2005, the rose through 2007, then fell through early 2015. Well T29S/R24E-21A is located in Rose-dale-Rio Bravo WSD, near Interstate 5 and Highway 58. Water-level measurements for this well extend from 1981 to 2017 (Figure 9). Seasonal fluctuations have normally been about ten feet. Over the long-term, the water level has risen during wet periods (i.e. the mid-1980's) and fallen during droughts (1989-93 and 2007-16). The shallowest water levels were

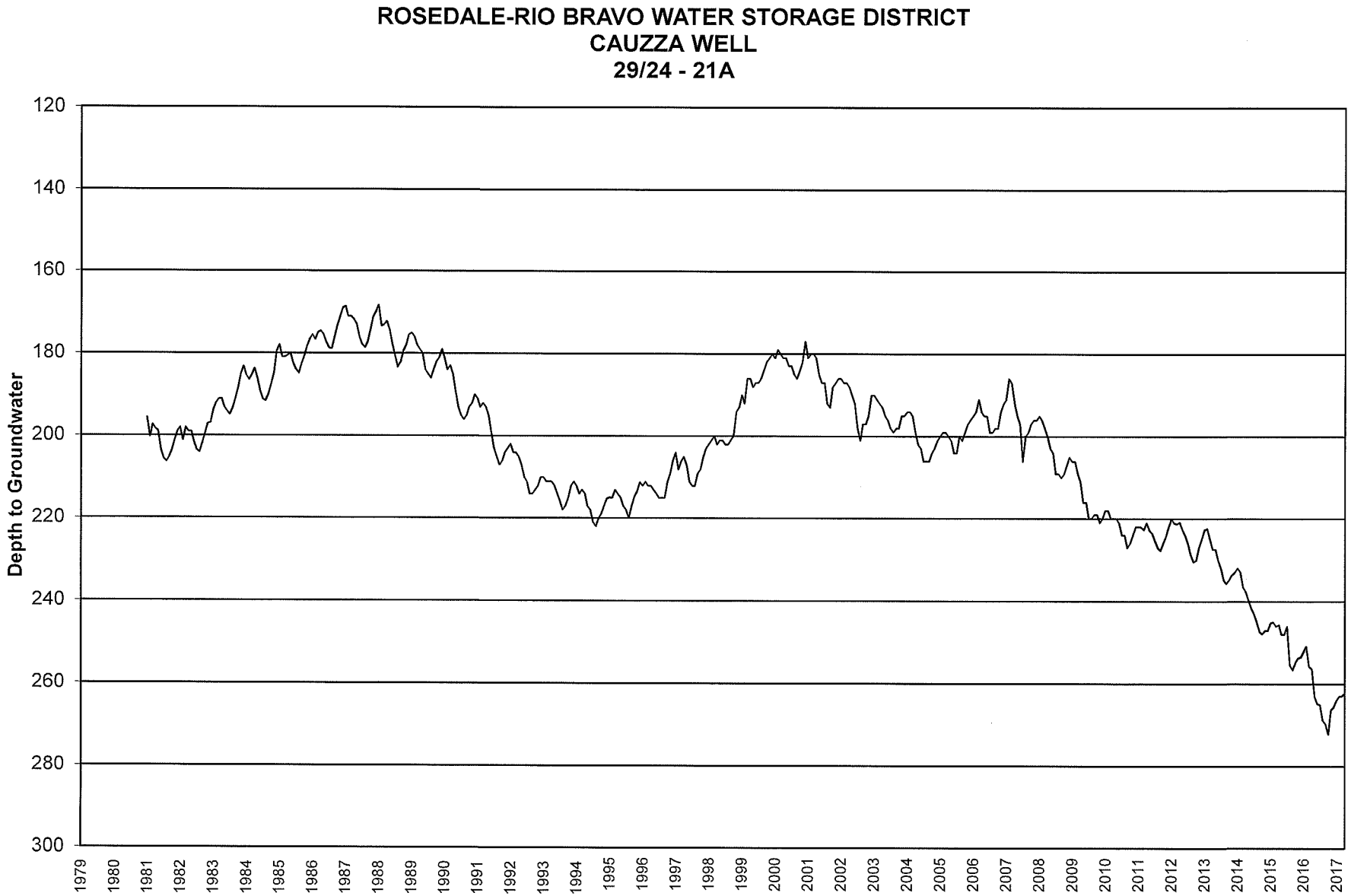


FIGURE 9-TYPICAL WATER-LEVEL HYDROGRAPH FOR THE FOREBAY AREA

in the late 1980's near the end of a wet period and the deepest were in the mid-1990's and during 2009-2016. The water-level rises from 1997-2001 and declines after Spring 2007 were partly due to water banking activities of the Kern Fan projects. Overall, the water level in this well has fallen over the long term, particularly since 2007.

Transducer Measurements for Westerly SWSD Wells. Frequent water-level measurements are available for these wells since 1995. Water levels in S-2, located near Jackson Avenue, have ranged from about 160 to 270 feet deep. The shallowest water levels were in 2006 and the deepest water levels were in late 2015 and early 2016. The water-level decline between Spring 2013 and Spring 2016 was about 70 feet, which was more than that between Spring 2007 and Fall 2008 (58 feet). Water levels in this well were relatively stable through 2007 and then declined until 2016-17, when they partly recovered. S-3 is located about one mile west and two miles south of S-2. Depth to water in this well has ranged from about 190 to 255 feet. The shallowest water levels were in 1999 and early 2007. The deepest water levels were in late 2015 and early 2016. Overall, the water level fell between 2007 and 2009, was relatively stable through 2013, and then fell thereafter. S-4 is located about one and a half miles south of S-3. Depth to water has ranged from about 175 to 245

feet. The shallowest water levels were in early 2001 and in early 2007. The deepest water levels were in 2014-16. Water levels in this well were relatively stable prior to 2007, and then fell through 2008, were stable through 2013, then fell until 2016-17. S-5 is located three miles east and half a mile north of S-3. Depth to water in this well has ranged from about 180 to 320 feet. The shallowest water levels were in early 2001 and early 2007. The deepest water levels were in 2015-16. Water levels in this well were relatively stable prior to 2007, declined through early 2009, then recovered through 2012, then fell through 2016, before slightly recovering. Water levels in this well are more indicative of confined conditions and more pumpage from the lower aquifer, as reflected by greater water-level variations than in the S-series wells that are farther north.

Transducer Measurements for Easterly SWSD Monitor Wells. S-6 is located at Peterson Road, about half a mile west of the Central Valley Highway. Depth to water has ranged from about 170 to more than 370 feet. The shallowest water levels were during 1996-2001 and in Spring 2007 and the deepest during 2008-10 and 2014-16. Water levels in this well were relatively stable prior to 2007, then declined through 2009, then recovered through 2011, then fell through 2014, and were then relatively stable. S-7B is located

about three miles south of S-6 and one mile west of Highway 43. Depth to water has ranged from about 158 to 290 feet. The shallowest water levels were in early 2006 and early 2007. The deepest water levels were in 1995, 2008-2009, and during 2013-17. Over the long-term, water levels in this well have been relatively stable since 1995. S-8A is located four miles west of Highway 43 and two miles north of Highway 46. Depth to water has ranged from about 195 to almost 420 feet. The shallowest water levels were during 1998-2001, and during early 2007. The deepest water levels were in Summer 2008, 2009, 2014, and 2015. Water levels in this well were relatively stable prior to 2007, fell through 2009, rose through 2011, then fell through 2015. The deepest water levels of record were during the Summer of 2014 and 2015. After 2015, water levels rose about 80 feet. S-9A is located half a mile south of Merced Avenue and three and a half miles west of the Central Valley Highway. Depth to water has ranged from about 230 feet to 340 feet. The shallowest water levels were in 2000-01 and Spring 2007. The deepest water levels were in late Fall 2005, the Summers of 2008-10, and in 2014-17. Water levels in this well were relatively stable prior to 2007, fell through 2009, rose through 2011, fell through early 2014, and then were relatively stable. Water levels in all of these wells are indicative of confined conditions.

Transducer Measurements for Northwesterly SWSD Wells. S-10A is

located near Pond Road and Corcoran Road. Depth to water has ranged from about 180 to 340 feet. The shallowest water levels were in 2000-01 and early 2007. The deepest water levels were in the Summers of 2008-10 and in 2014-17. Water levels in this well were apparently relatively stable until 2007, fell through 2009, rose through 2011, fell through 2014, and then partly recovered by early 2017. S-11 is located about half a mile east and one and a half miles south of S-10A. Depth to water has ranged from about 180 to 333 feet. The deepest water levels were during 2007-2010 and 2013-16. Water levels in this well were relatively stable prior to 2007, rose through 2011, fell through 2016, then partly recovered by early 2017. Water levels in these wells appear to be influenced by SWSD banking activities and also by pumping from irrigation wells that are used for the newly developed orchards in the area.

Transducer Measurements for Southerly SWSD Well. MW-948L3 is located about half a mile north of Sullivan Road near I-5. Depth to water has ranged from about 195 to 290 feet. The shallowest water levels were during 2000, early 2001, and in early 2007. The deepest water levels were in Summer of 2007-10 and in 2014-16. Water levels in this well fell during 2007-09, stabilized through 2012, then fell during 2013-16. Water levels in this well had slightly recovered by early 2017.

Transducers Measurements for Spreading Works. Transducer hydrographs are available for four deep monitor wells M03, M04, M07, and M08. All of these hydrographs cover 2010-17 (Appendix B). The shallowest water levels (about 230 feet deep) during this period were in late 2011-early 2012. The next shallowest (about 260 to 300 feet) were in January 2013. The deepest water levels (about 440 to 450 feet were in Summer 2015. Water levels in these wells correspond to pumping patterns for wells in the vicinity.

Transducers Measurements for Other Production Wells. Transducer measurements are available for four joint owned wells tapping the lower zone. Records for two of these (T25S/R24E-22P and T27S/R22E-11A) extend for more than one year. Records for the other two (T27S/R22E-11A and 12J) extend from 2007 to 2017. Well T25S/R24E-22P (PP 1041 DGW) indicated a significant response to pumpage. The shallowest water levels (about 310 feet deep) were in January 2017 and the deepest (about 470 feet deep) were in April-May, 2016. This well is located near District Spreading Works, about three miles north of the main District Spreading Works. Wells T27S/R27E-11A is located in the west part of the District, and is a composite wells (perforated from 150 to 446 feet in depth). The water-level elevations for this well are indicative of the lower zone. The shallowest water level (about 250 feet deep) was in late 2007, and

the deepest was in part of 2015-17 (about 310 feet deep).

Well T27S/R27E-12J is located about two and a half miles north of the SWSD Intake Canal. The shallowest water level (about 145 feet) was in early 2013 and the deepest (about 175 feet deep) was in Spring 2016.

Well T29S/R23E-12J is located near the southwest corner of the District. The shallowest water levels (about 165 feet deep) were in early 2016 and the deepest (about 200 to 205 feet deep) were in Summer 2014. Water levels in this well correspond highly to local pumping patterns. This well is perforated from 105 to 504 feet in depth and this is a composite well. Its water-level elevations are indicative of being between those for the upper aquifer and lower aquifer.

Upper Zone

Water-Level Elevations and Direction of Groundwater Flow

Figures 10, 11, and 12 show water-level elevations and the direction of groundwater flow in the upper zone for Spring 2015, 2016, and 2017. In Spring 2015, water-level elevations in the upper zone exceeded 200 feet over a large area near and west of the west boundary of the SWSD, and beneath the northeast part of the District. There was an apparent cone of depression beneath the District's Pond-Poso Spreading Works (Spreading Works). Groundwater in the upper zone

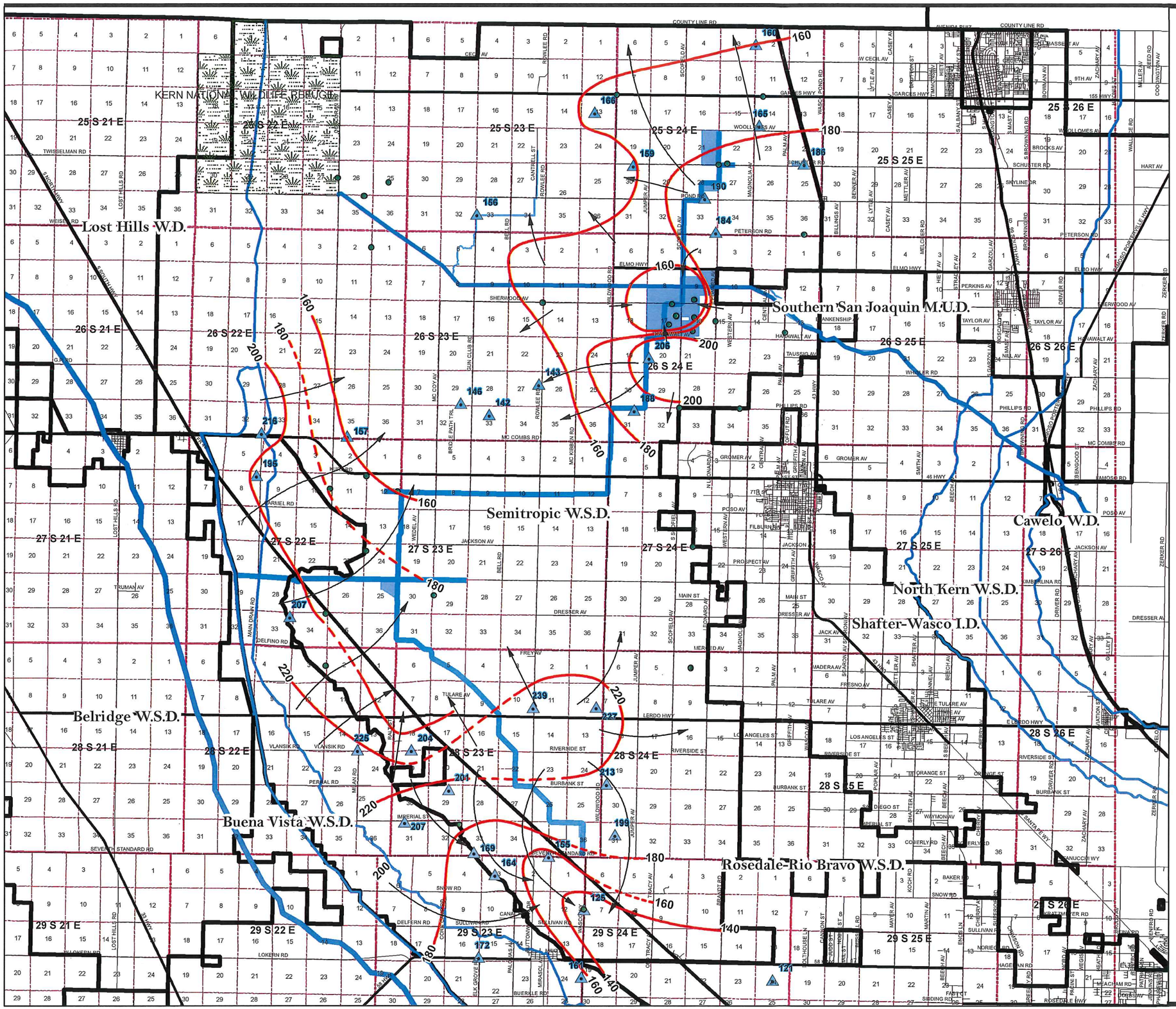
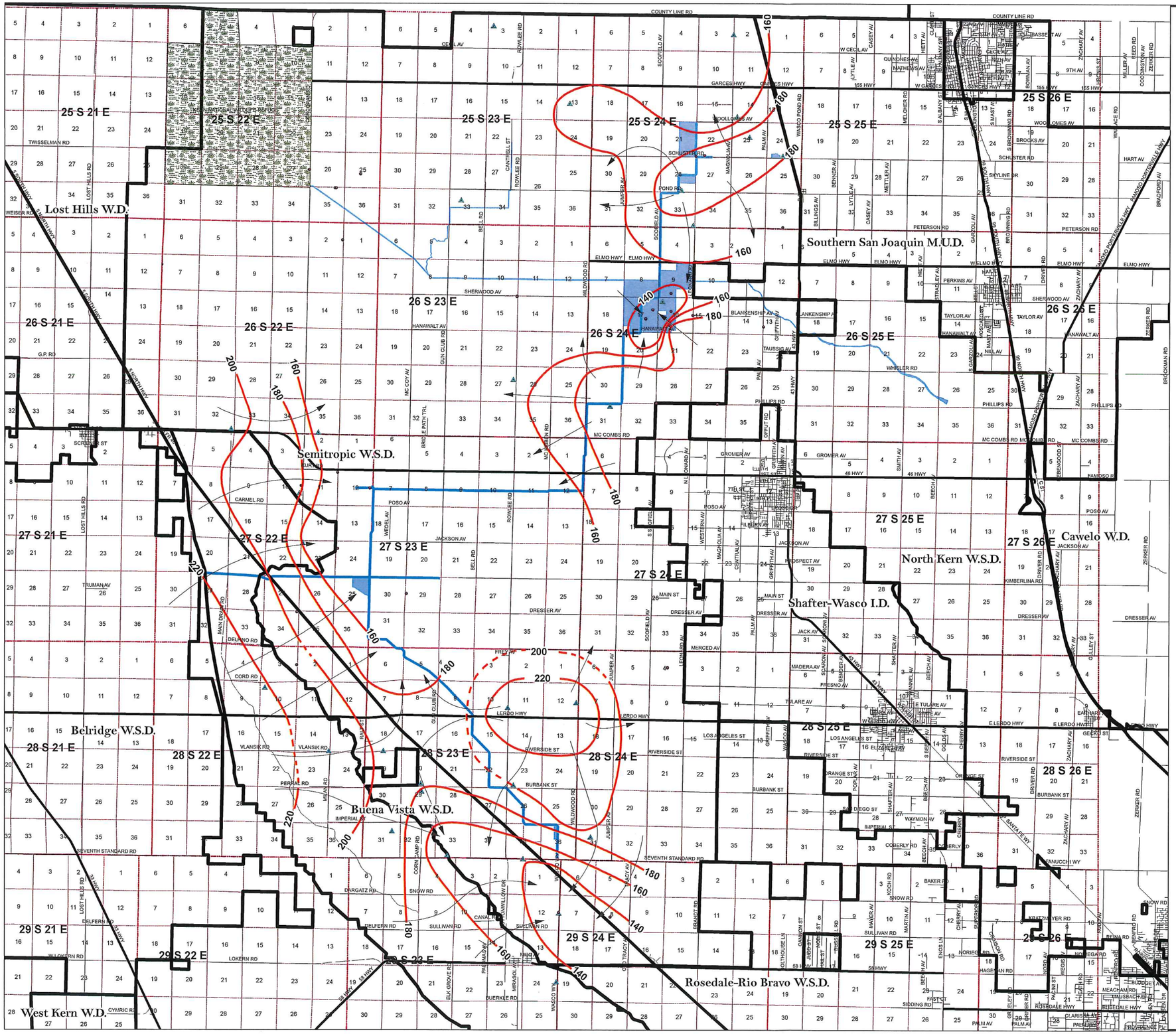


Figure 10

Water-Level Elevations And Direction of Groundwater Flow For the Upper Zone (Spring 2015)

Legend

- 227 — Well & Water-Level Elevation (Feet above MSL)
- Direction of Groundwater Flow
- 100 — Contour of Water-level Elevation (Feet above MSL)



N

Figure 11

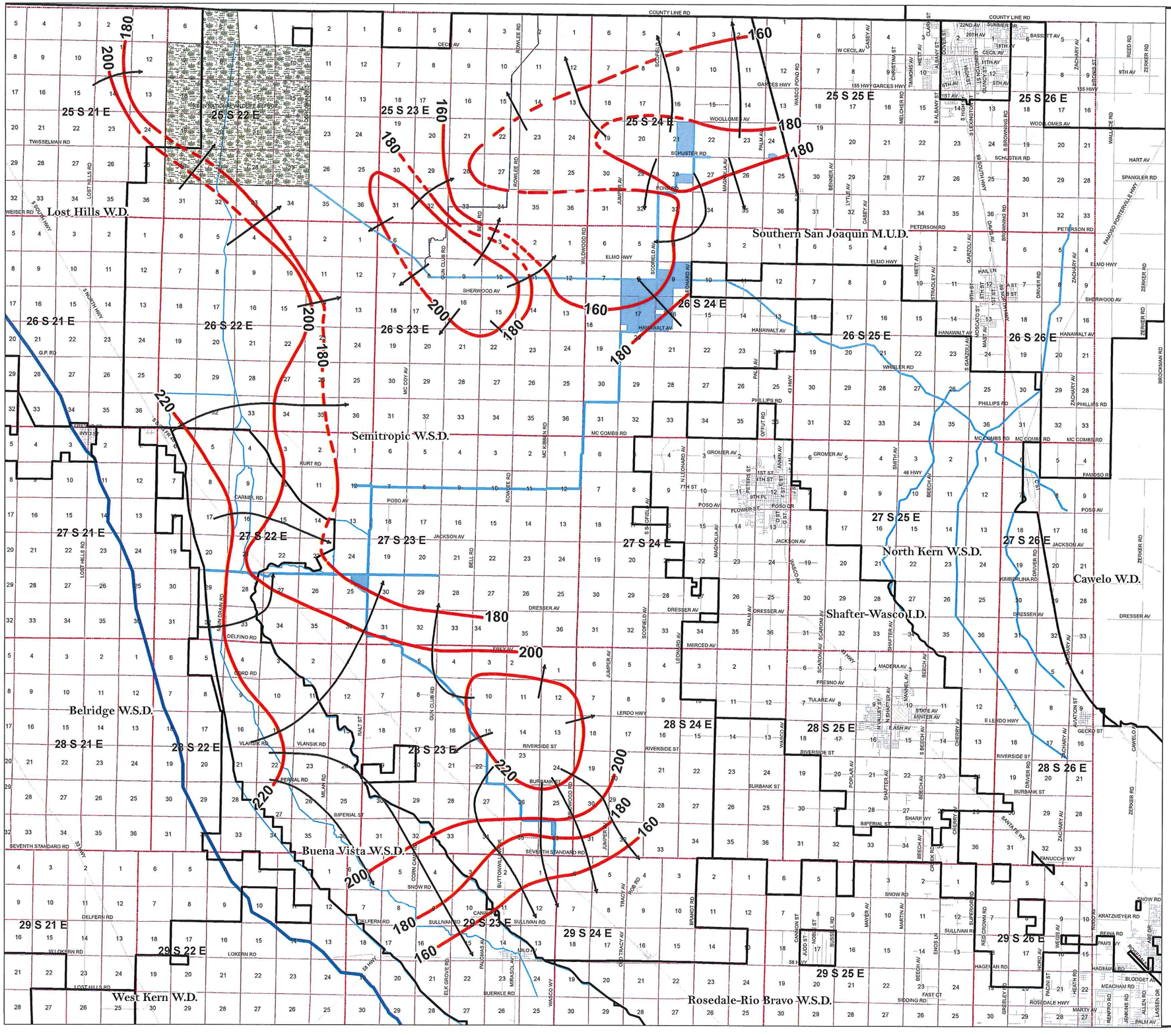
Water-Level Elevations And Direction of Groundwater Flow For the Upper Zone (Spring 2016)

Legend

- Well Location
- Direction of Groundwater Flow
- 160 Contour of Water-level Elevation (Feet above MSL)

1 0.5 0 1 2 3 4

Miles



N

Figure 12

Water-Level Elevations And Direction of Groundwater Flow For the Upper Zone (Spring 2017)

Legend

- Well Location
- 160 Contour of Water-level Elevation (Feet above MSL)
- Direction of Groundwater Flow

1 0.5 0 1 2 3 4
Miles

flowing out of the District to the north and south, and into the District from the west and possibly the northeast.

Generally similar water-level elevations were present in Spring 2016 as in 2015. A recharge ridge southwest of Pond was present, and near the District's Spreading Works was still evident. An apparent cone of depression was present beneath the Spreading Works. Groundwater in the upper zone was flowing into the District from the west, and out of the District to the north and south.

In Spring 2017, the same overall trends were present as in Spring 2012. However, there was apparently a recharge mound beneath the southeast part of the Spreading Works. Groundwater continued to flow into the SWSD from the west in the area north of Seventh Standard Road. Groundwater flowed out of the District to the north and south.

Water-Level Changes

2015-17. In most of the SWSD, water levels in the upper aquifer rose during this period, except in two areas, one of which was north of Wasco, and the other was east of Wildwood Avenue and south of Imperial Street. Water-level declines were usually less than 20 feet and were primarily in the CE, Delta, and Beta systems. Water-level rises in most wells ranged from 20 to 40 feet. One area of rising water levels was in the North, Alpha system, and the P667 systems. Another was in the Wegis, B-369, and B-21 systems. Another area of rising water levels

was in the P-823, CW, and Z Systems. Farther north, water levels rose up to 20 feet. Poso Creek streamflow appeared to be associated with significant recharge in Range 23E, west of Wildwood Avenue.

In the Buena Vista WSD, water levels in most wells south of Carmel Road were stable during 2015-17. Water-level declines were generally the greatest in the part of the area north of Whisler Road, and were usually less than 20 to 30 feet.

Long-Term. Comparison of the Spring 1995 and Spring 2017 water-level elevation maps for the upper zone indicates a predominance of water-level rises usually ranging from about 13 to 33 feet. The largest rises (exceeding 25 feet), were near Poso Creek and the SWSD Spreading Ponds. Water-level rises ranging from about 10 to 20 feet were present in most of T25S. Water-level rises of less than 10 feet were common along the west edge of the SWSD and in much of the adjoining BVWSD. There were water-level declines of from 5 to 10 feet in several wells, but these appear to be anomalous.

The Buena Vista WSD provided water-level hydrographs for four monitor wells which tap the upper zone, and the records extend back to the early to mid-1990's. Overall, these hydrographs indicate relatively stable levels over the long-term. For DMW-1, the water levels rose from 1992 through 1998, were relatively stable from 1999 through 2006, fell from 2006-2008, were relatively stable from 2008-2013, then feel during 2015-16. For DMW-2, trends through 2008

were similar to those for DMW-1. Water levels in DMW-2 rose between 2009 and 2012, then fell during 2013. Water levels in this well were relatively stable through 2016, then rose in 2017. Water levels in DMW-3 rose during 1992-1997, then were relatively stable through 2006. Water levels fell during 2006-09, then recovered by 2010. Water levels in this well were relatively stable through 2013. Water-level measurements for this well were incomplete after 2013. Water levels in DMW-5 rose from 1992-1998, then slightly fell during 1998 to 2002. Water levels were relatively stable through 2006, then fell during 2007-08. Water levels rose during 2009-10, then fell through 2016. Water levels rose significantly in 2017.

Figure 13 is a typical water-level hydrograph for a well tapping the upper zone in the central part of the SWSD. Well T27S/R24E-33A is located near Leonard and Dresser Avenues, southwest of Wasco. The casing in this well is perforated from 230 to 374 feet in depth. Although some perforations in this well are below the 300-foot clay, the water-level fluctuations were usually typical of the upper zone. Prior to 2007, seasonal fluctuations were usually less than 20 feet. The overall trend has been rises during wet periods (the mid-1980's), and declines during droughts (1988-1993, 2007-09, and 2012-15). Water levels in this well rose between Spring 1995 and Spring 2001, and then were relatively constant through 2006, before falling about 60 feet between early 2007 and early 2009. The water level then rose

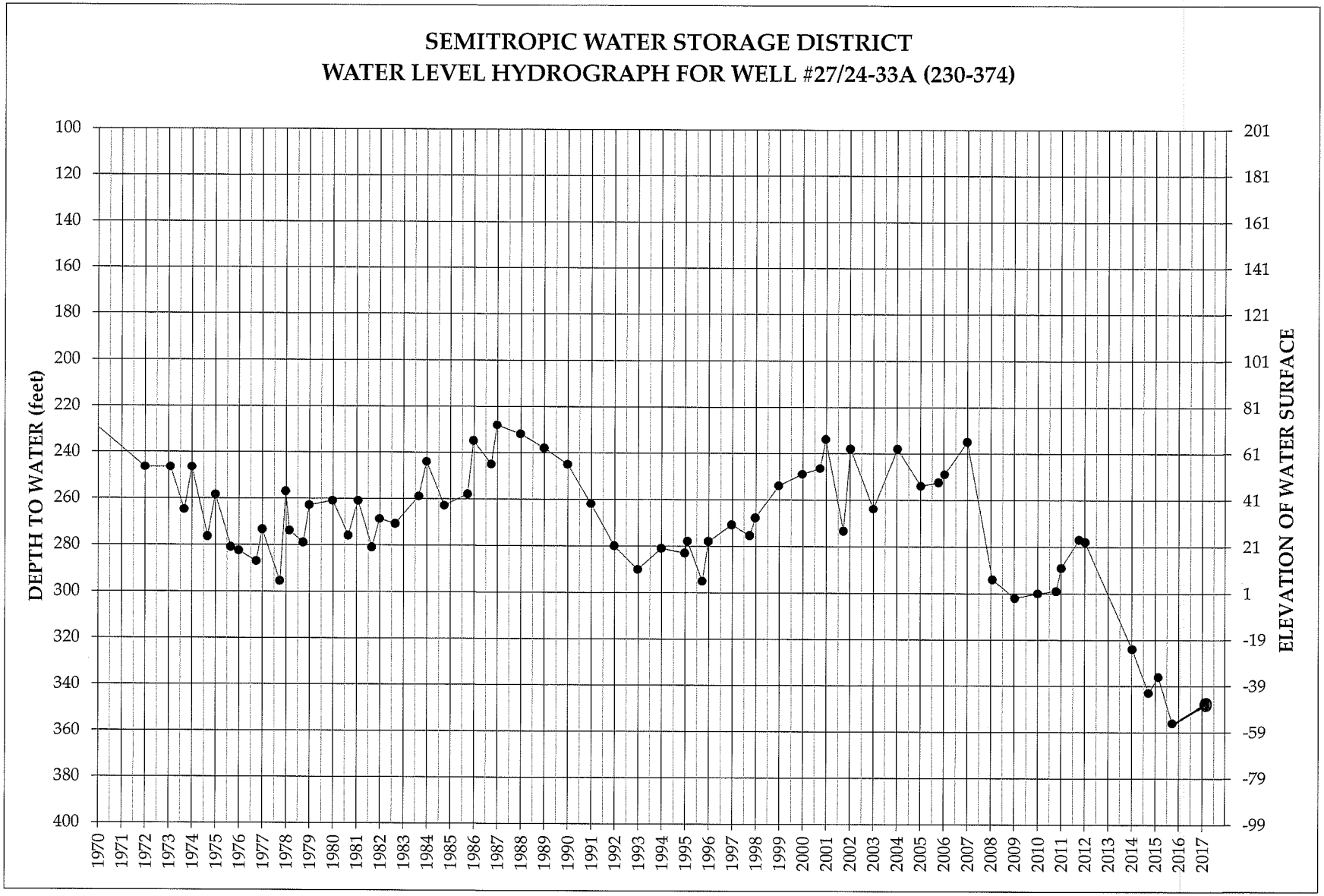


FIGURE 13-TYPICAL WATER-LEVEL HYDROGRAPH FOR THE UPPER ZONE

about 20 feet by early 2012, and then fell another 80 feet by the end of 2015. The water level then began to rise through early 2017.

Transducer Measurements. Transducer measurements are available for SWSD monitor well S-1, located south of Highway 46 and west of Corcoran Road. Depth to water in this well has ranged from about 15 to 50 feet. Measurements for this well indicate that the shallowest water levels were during 1997-2000 and in 2006. After 2006 and through 2009, the water level in this well fell almost 20 feet, apparently due to increased pumping in this area. After early 2010, the water level rose about 10 feet through 2012, then fell through early 2016. Water levels were relatively stable through 2012, but fell significantly during 2012-14.

Transducer measurements are available for the upper aquifer for four cluster monitor wells sites (M03, M04, M07, and M08) in the District Spreading Works. At each site there are three upper aquifer monitor wells, the depths of 50 feet, 90 feet, and 300 feet. Records are available for 2010-17. Only the deepest of these wells (the 300 foot depths) have consistently shown water. Depth to water in most of these wells has usually ranged from about 90 to 130 feet deep. Water levels in these wells respond more to recharge than to pumping. They have also been consistently shallower than water levels in the nearby lower aquifer monitor well. The water levels in the 300-foot

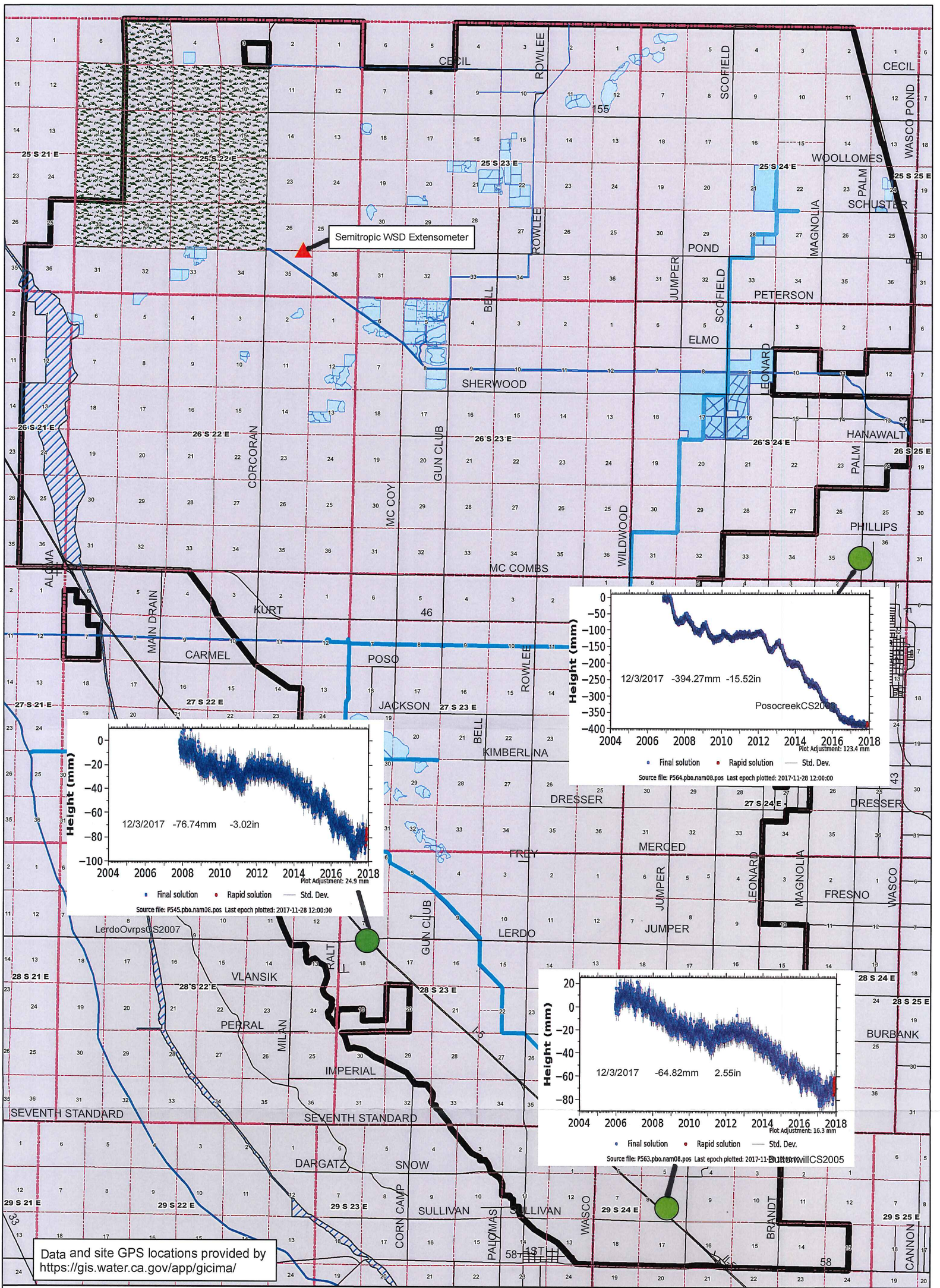
deep monitor wells have ranged from about 140 to 260 feet higher than in the lower aquifer well. Water has generally only been present in the 500 feet and 900 feet deep was during recharge cycles.

LAND SUBSIDENCE

For this report, information on land subsidence was obtained for four stations (Figure 14). One is an extensiometer installed and operated by the SWSD at a site near Pond Road and one mile east of Corcoran Road. This recorder has operated sporadically. Between August 2014 and the end of 2016, about three inches of subsidence when recorded. At the other three sites, total subsidence (associated with compaction of fine grained deposits in the intervals tapped by water supply wells) ranged from about two and a half inches to 15 inches during 2007-16. The greatest subsidence was for the recorder at the Wasco Airport. The lower rates of subsidence were at two stations along I-5. These two stations are near the south edge of the 300-foot, where less land subsidence is expected. The rate of subsidence at the Wasco Airport site increased markedly during 2013-16, associated with more pumpage from the lower zone during that period compared to previously.

GROUNDWATER QUALITY

Both water supply wells and monitor wells have been periodically



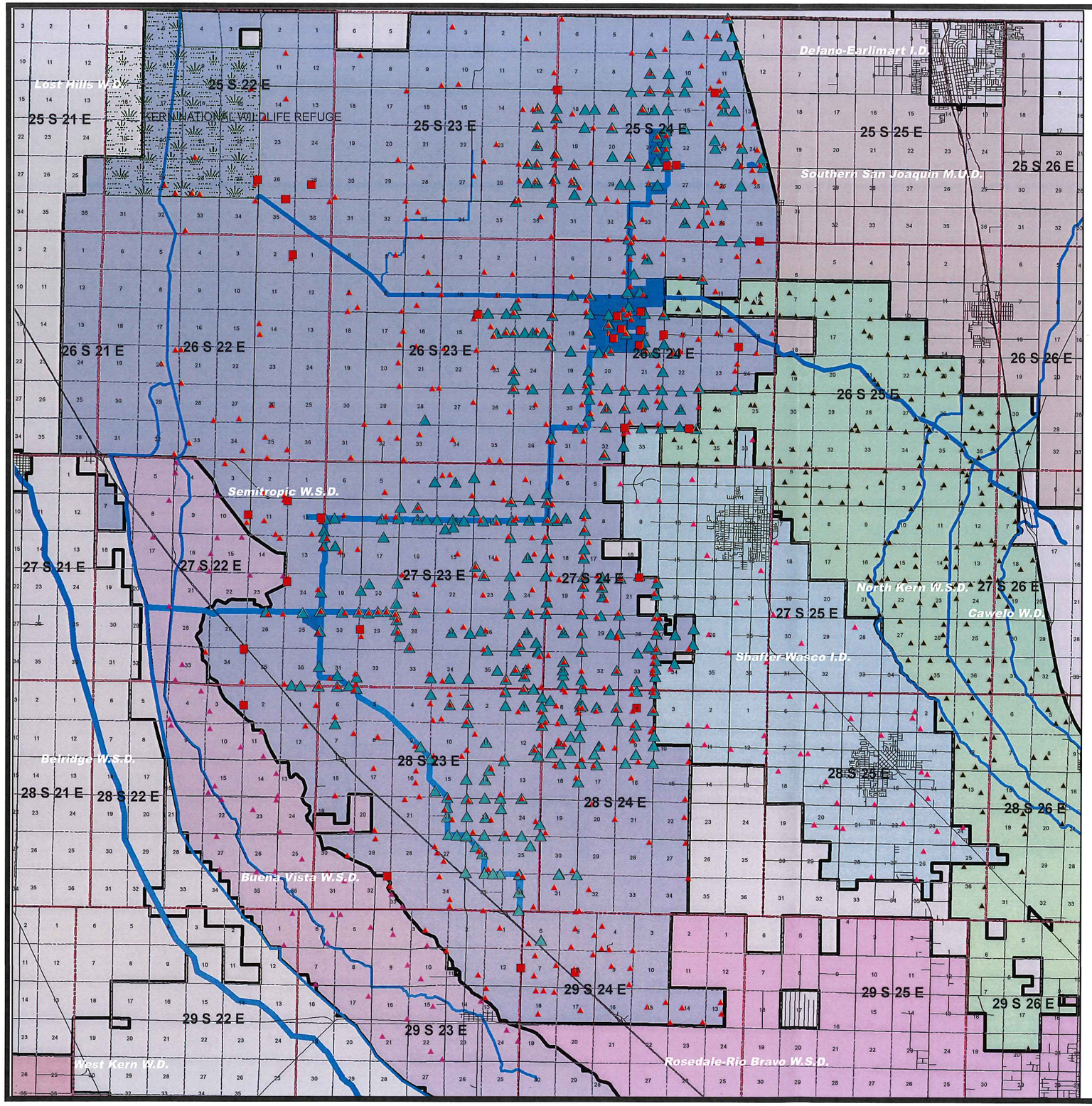
Legend

- ▲ Semitropic WSD Extensometer
- ● GICIMA Extensomete

Figure 14
Location of Land Subsidence Monitoring Stations

sampled as part of this monitoring program. Figure 15 shows the locations of wells in the SWSD which have been sampled as part of this program. Each entity that conducts well sampling arranges for the chemical analyses for the area within its jurisdiction. The Shafter-Wasco I.D., Rosedale-Rio Bravo WSD, and Southern San Joaquin MUD did not conduct groundwater sampling during 2015-17 as part of this program. During wet periods, most of the water supply wells in SWSD are not in operation and are generally not sampled. Extensive water sampling in SWSD was done in 2009, 2013, and 2016, associated with years of high recovery well pumping.

Total dissolved solids (TDS) was selected for initial evaluations, particularly because of a concern about possible enhanced migration of high salinity groundwater from the west due to banking activities. Nitrate was selected because a fairly large area of shallow high nitrate groundwater is present in part of and east of the SWSD. This was considered one of the most important inorganic chemical constituents in terms of drinking water quality. Arsenic became a greater concern when the maximum contaminant level (MCL) for drinking water was lowered from 50 to 10 ppb. Uranium is also of concern because of localized high activities in groundwater in some parts of the area. Hexavalent chromium was also mapped for this report, because of the development of a new MCL for this constituent and the presence of high concentrations in some wells in the District.



N

Figure 15
Location of Wells in Water Quality Network

Legend

- BVWSD
- NKWSD
- SWID
- SWSD
- Monitor Wells
- Semitropic Connected Wells
- Kern County Water Agencies

2 1 0 2 4 6 8

Miles

There are generally significant differences in concentrations of TDS and constituents such as nitrate between the shallow and deep groundwater in the study area. For salinity (TDS), separate maps are thus prepared for the shallow and deep groundwater. For nitrate, low concentrations are present in the deep groundwater, and where concentrations are high, they are usually for wells tapping shallower groundwater. Arsenic concentrations are generally higher in the deeper groundwater, as compared to in the shallow groundwater. Uranium activities are expected to be higher in the shallow groundwater, which is often oxidized.

Total Dissolved Solids

Shallow Groundwater

Figure 16 shows TDS concentrations in shallow groundwater, generally above a depth of about 300 feet, in the study area for February-November, 2016. It should be noted that "shallow" as used herein, refers to water-producing strata below a depth of about 50 feet, and not to groundwater within 50 feet or less of the land surface, such as in part of the Buena Vista WSD. The shallowest groundwater can be of much higher salinity than the underlying groundwater. TDS concentrations in the shallow groundwater have generally been less than 500 mg/l in most of the central part of the SWSD. The TDS concentrations in shallow groundwater exceeded 1,000

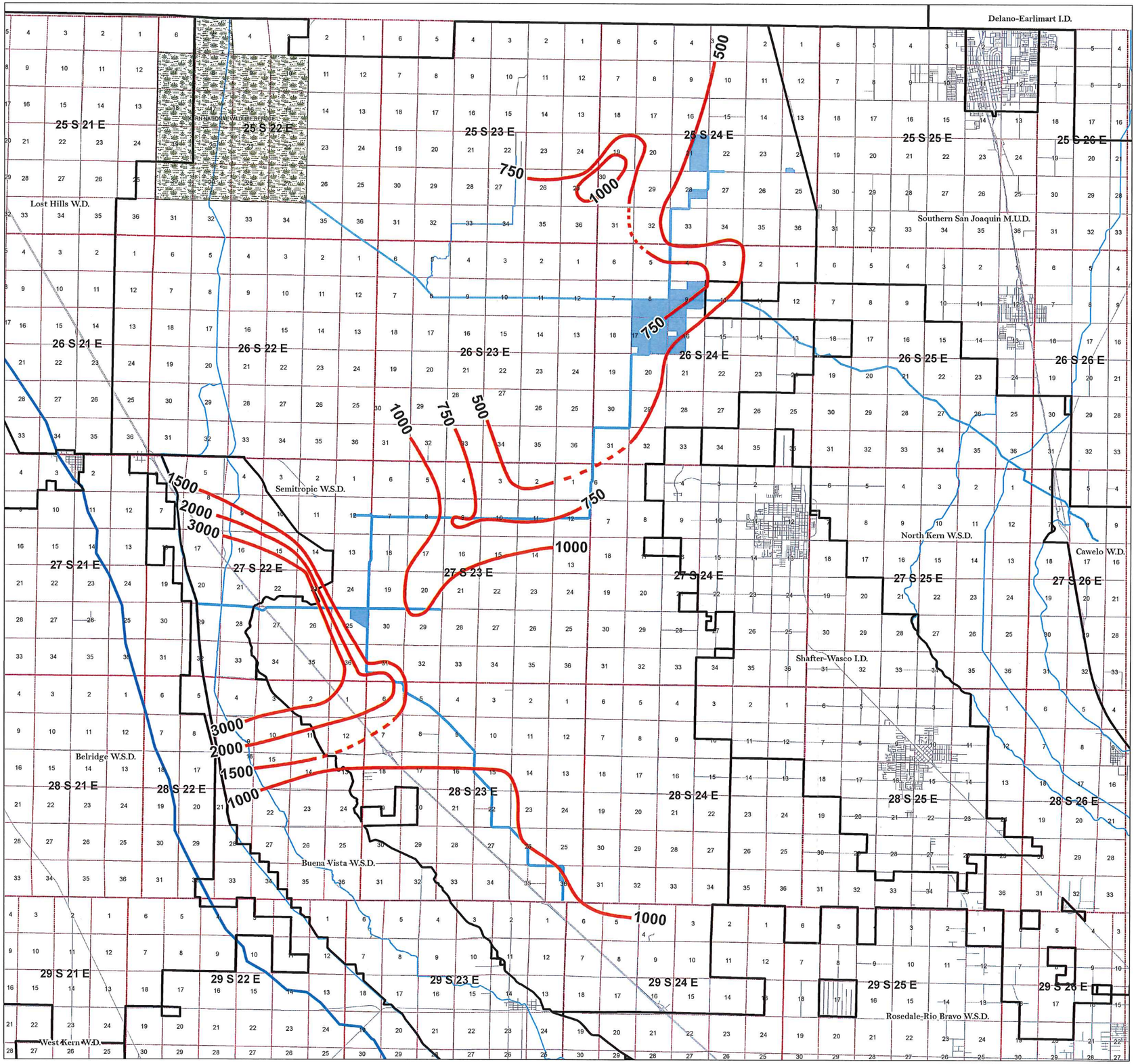


FIGURE 16-

Total Dissolved Solids in Shallow Groundwater (February - November, 2016)

Legend

▲ Location of Well sample site

200 ~ Contour of Total Dissolved Solids Concentration (mg/L)

mg/l beneath the westernmost part of the study area, except beneath most of the Buena Vista WSD south of Seventh Standard Road. In the area north of Buttonwillow, the boundary of this higher salinity groundwater becomes progressively farther west to the north. The highest TDS concentrations exceeded 3,000 mg/l in 2016. In the area south of Highway 46 and west of T24E, TDS concentrations decreased to the northeast, to less than 500 mg/l north of Highway 46. There was an area northwest of the SWSD Spreading Works where TDS concentrations exceeded 750 mg/l.

Several high salinity areas have been delineated by previous well sampling programs in the east part of the study area. Most of the information was derived from Kern County Water Agency water quality maps, as provided in annual reports. TDS concentrations exceeded 1,500 mg/l in the shallow groundwater beneath several areas. The northerly area was primarily north of Pond Road and south of Cecil Avenue, southwest of Delano. The western half of this area was in the SWSD and the eastern half in the Southern San Joaquin MUD. The second area was primarily beneath Wasco, and extended south to near Merced Avenue. This high TDS area was bounded by low salinity (less than 500 mg/l TDS) groundwater to the west, south, and north. The third high TDS area was located along the Central Valley Highway, primarily between Merced Avenue and Seventh Standard Road. This area was elongated from northwest to southeast, and was primarily

in the Shafter-Wasco Irrigation District. The southerly high TDS area was bounded by low TDS groundwater to the southwest, north, and northeast. As of 2016, there were remnants of the high TDS concentrations in the northerly area, but sampling results were limited due to a lack of wells tapping the upper zone in the eastern part of the study area.

Changes in Salinity in Westerly Monitor Wells. Appendix C contains electrical conductivity hydrographs for the eight Buena Vista WSD monitor wells tapping the upper zone along the west boundary of the study area. Analyses for DMW-1, located southeast of Lost Hills, indicate an increasing trend for electrical conductivities between 1992 and 2009. After 2009, the electrical conductivities decreased and then stabilized after 2011. The lowest TDS concentration (about 1,500 mg/l) was in 1994, and the highest concentration (about 2,700 mg/l) was in 2010. Analyses for DMW-2, located about two miles south of Highway 46 and west of the Eastside Canal, indicate a slight TDS increase during 1992-2000, except for one anomalous sample, then a significant decrease during 2001-03. Then the conductivities slightly increased through 2008, and were relatively stable through 2010. TDS concentrations then increased by 2012, and stayed relatively constant thereafter. The lowest TDS concentration (about 2,000 mg/l was in 1992 and the highest (about 7,000 mg/l) was

in 2000.

Analyses for DMW-3 indicate a significant increase in electrical conductivity during 2002-03. This well is located about three miles north of Lerdo Highway and east of the Eastside Canal. Electrical conductivities of water from this well were relatively stable from 2004-10. TDS concentrations then decreased by 2012 to near values prior to 2003, and remained relatively stable. The lowest TDS concentration (about 1,800 mg/) was in 1992 and the highest concentration (about 6,300 mg/l) was in 2007. Analyses for DMW-4, located about one mile north of Lerdo Highway and west of the Eastside Canal, indicate increasing electrical conductivities through 1995, followed by relatively constant values through 1999. Electrical conductivities then increased through 2001, then decreased, and were relatively stable through 2009. TDS concentrations then increased to the highest concentrations yet monitored in 2015. The lowest TDS concentration (about 1,600 mg/l) was in 1992 and the highest (about 4,200 mg/l) was in 2015.

Analyses for DMW-5, which is located about one mile south of Lerdo Highway and west of the Eastside Canal, indicate increasing electrical conductivities during 1991-95. After 1995, the conductivities slightly increased through 2004 and then were stable through 2013. The lowest TDS concentration (about 300 mg/l) was in 1996 and the highest concentration (about 1,300 mg/l) was in 2015.

This well is in an area of relatively low salinity groundwater in the upper zone, between Lerdo Highway and Seventh Standard Road. Analyses for DMW-6 indicate large fluctuations in TDS concentrations before 1997, and increasing concentrations through 2006. Since that time, electrical conductivities have decreased. The lowest TDS concentrations were about 200 to 250 mg/l in 1994-95, in 2012, and in 2014-16. The highest TDS concentration (about 1,200 mg/l) was in 2006. This well is also in the area of low salinity groundwater in the upper zone.

DMW-7 and 8 are located between Seventh Standard Road and Highway 58. Records for DMW-7 indicate relative stable electrical conductivities through 2000. The conductivities increased during 2001 and then gradually decreased to near the pre-existing concentrations by 2005. Since then, the concentrations increased through 2008, and then decreased. The lowest concentrations (about 300 mg/l) were in 1935-97 and in 2006. The highest TDS concentration (about 1,250 mg/l) was in 2008. The electrical conductivities in water from DMW-8 decreased from 1994 to 1999, and has been relatively stable since then. This may be associated with recharge from water-banking projects on the Kern Fan. The lowest TDS concentrations (about 250 mg/l) were during 1999-2007.

The overall trend during 1998-2016 for the northwestern part of the Buena Vista WSD was increasing electrical conductivities in water

from most of the monitor wells. South of Seventh Standard Road, electrical conductivities in water from two Buena Vista WSD monitor wells generally stayed about the same during this period.

The five westerly monitor wells in the SWSD were sampled annually during Summer 1994-95 and 1998-2003. Analyses indicate that TDS concentrations in water from the northerly of these wells (S-1) generally increased during this period. Updated information is not available.

Deep Groundwater

Figure 17 shows TDS concentrations in the deep groundwater for February-November 2016. Little information is available on the TDS concentrations in deep groundwater in the area west of the Main Drain, because of the lack of deep wells in this area. In 2016, TDS concentrations were less than 500 mg/l in the deeper groundwater beneath most of the District, except near the central west edge. TDS concentrations were less than 200 mg/l in a large area northwest of Wasco, near Wasco, and to the east in part of the NKWSD. This was similar pattern to that in 2013.

Nitrate

Figure 18 shows nitrate concentrations in the groundwater, based on sampling during February-November, 2016. Nitrate concentrations beneath the westerly part of the study area were

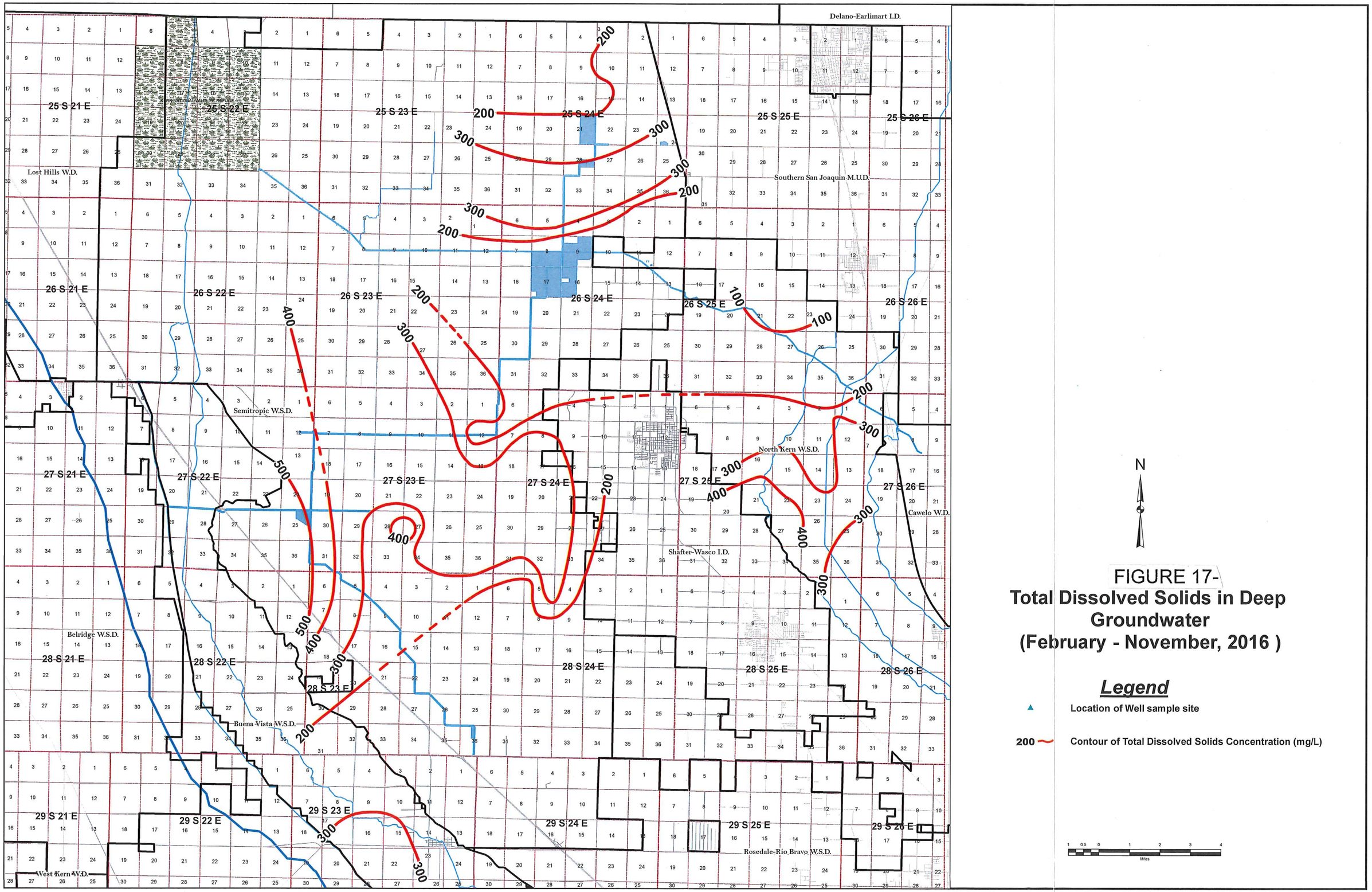


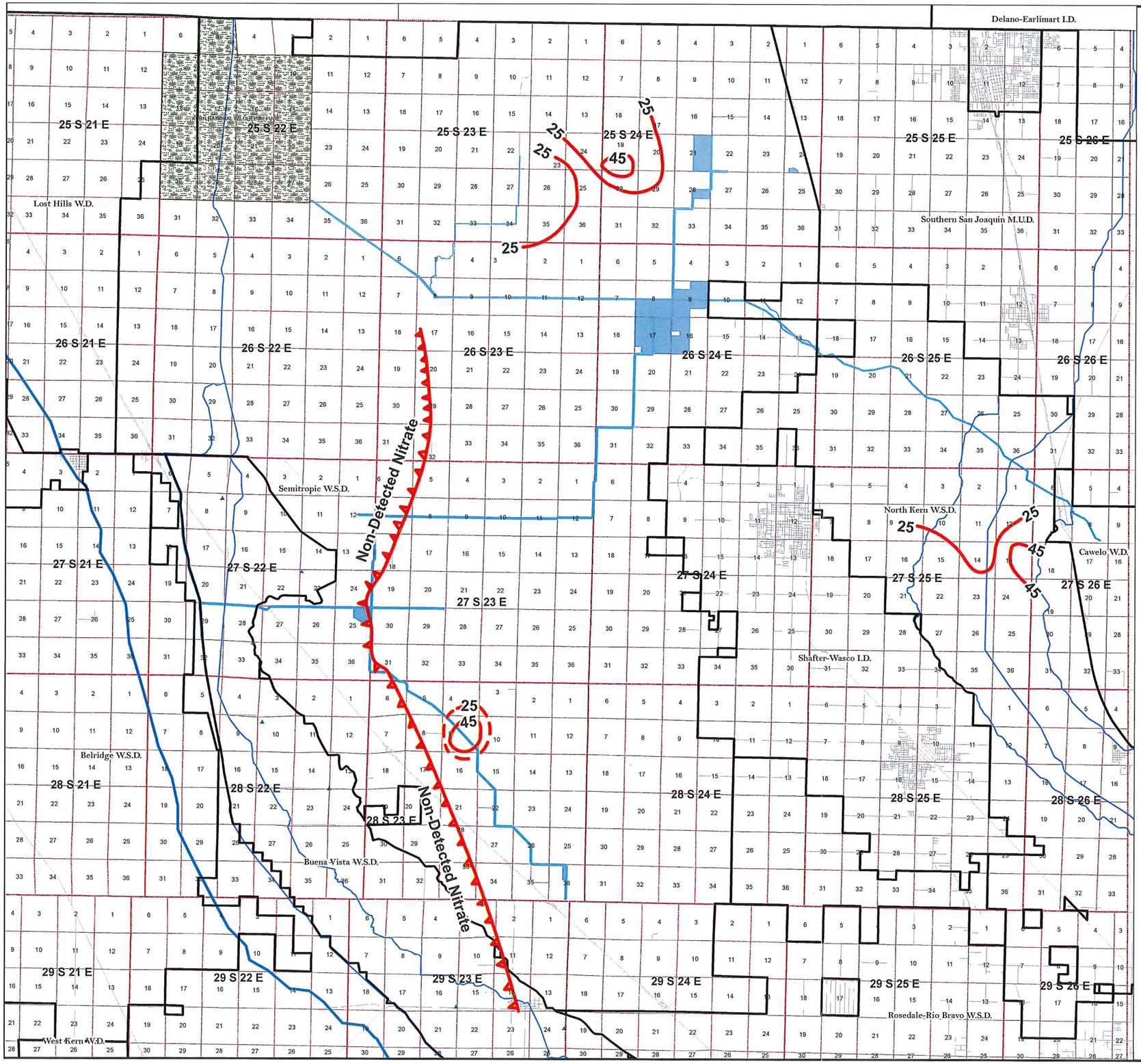
FIGURE 17-

Total Dissolved Solids in Deep Groundwater (February - November, 2016)

Legend

▲ Location of Well sample site

200 ~ Contour of Total Dissolved Solids Concentration (mg/L)



N

FIGURE 18-

Nitrate Concentrations in Groundwater (February - November, 2016)

Legend

- Location of Well sample site
- 45 Contour of Nitrate Concentration (mg/l)

2 1 0 2 4 6 8

Miles

non-detectable in 2016, in about the same area as shown by the results of sampling in 2007 and 2013, as reported in previous biennial reports. Most of this area was west of Gun Club Road and north of Lerdo Highway, and southwest of I-5 farther to the south. The areas of non-detectable nitrate concentrations are indicated to be where reducing or anaerobic conditions are prevalent in the groundwater.

The only identified part of the study area where nitrate concentrations in the shallow groundwater were known to exceed the MCL in 2016 were in three relatively small areas. One was northwest of the SWSD recharge ponds along Poso Creek and another was about seven miles east of Wasco. The third was near Lerdo Highway and Gun Club Road, near the west edge of the District. There is a lack of documentation of the high nitrate concentrations that were formerly monitored in the east part of the area, due to a lack of sampling of wells that tap the upper zone in recent years.

Arsenic

Arsenic concentrations were determined in water from a number of supply wells and monitor wells in the SWSD during February-November, 2016 (Figure 19). The MCL for arsenic in drinking water is 10 ppb. Analyses for arsenic for the 2016 sampling weren't available for the northwest part of the District. The lowest arsenic concentrations in groundwater in 2013 were generally beneath the east part of the

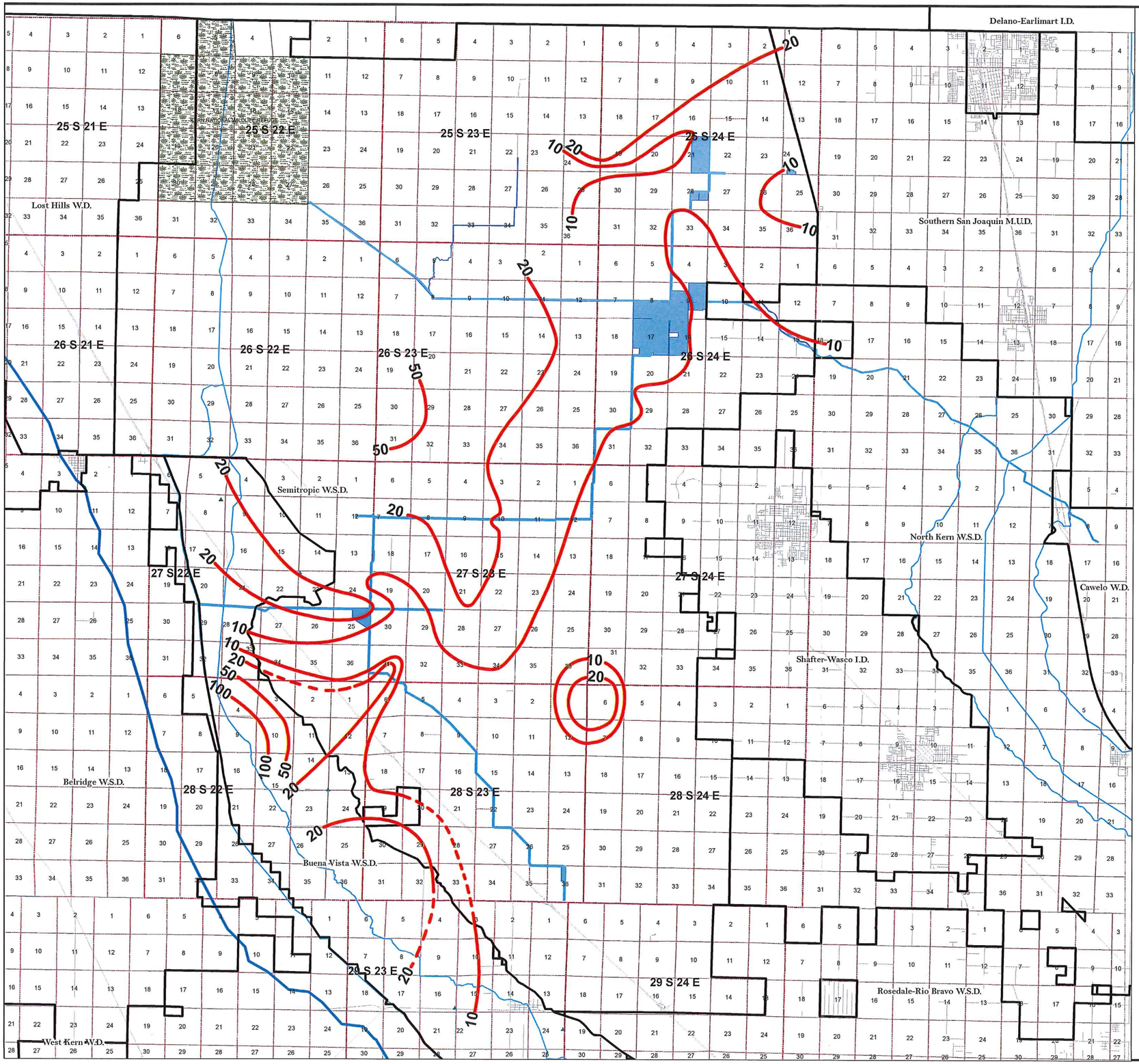


FIGURE 19-

Arsenic Concentrations in Groundwater (February - November, 2016)

Legend

▲ Location of Well sample site

20 Contour of Arsenic Concentration (ppb)

2 1 0 2 4 6 8

Miles

District, usually in the area south of T25S. In contrast, the highest arsenic concentrations in 2016 were in groundwater to the southwest, where they exceeded 20 ppb, and in some cases 100 ppb. The area where arsenic concentrations exceeded the MCL was relatively large. Results of previous sampling indicated that arsenic concentrations were generally somewhat higher in groundwater beneath the northwest part of the District, where the 300-foot clay is present. Also, arsenic concentrations generally increased toward the old Tulare lake-bed, a regional trend previously noted in the San Joaquin Valley by the U.S. Geological Survey. Most of the data points shown in Figure 19 are for the deep groundwater, and lower arsenic concentrations are indicated to be present in the shallow groundwater.

Hexavalent Chromium

Hexavalent chromium concentrations for samples collected during February-November, 2016 are shown in Figure 20. The proposed MCL for hexavalent chromium is 10 parts per billion (ppb), and implementation of the MCL is on hold due to litigation. There was an area northwest of Wasco where hexavalent chromium concentrations exceeded 10 ppb MCL. This area was generally in approximately the same area as where arsenic concentrations exceeded the MCL in 2016. Otherwise, hexavalent chromium concentrations were generally less than the MCL.

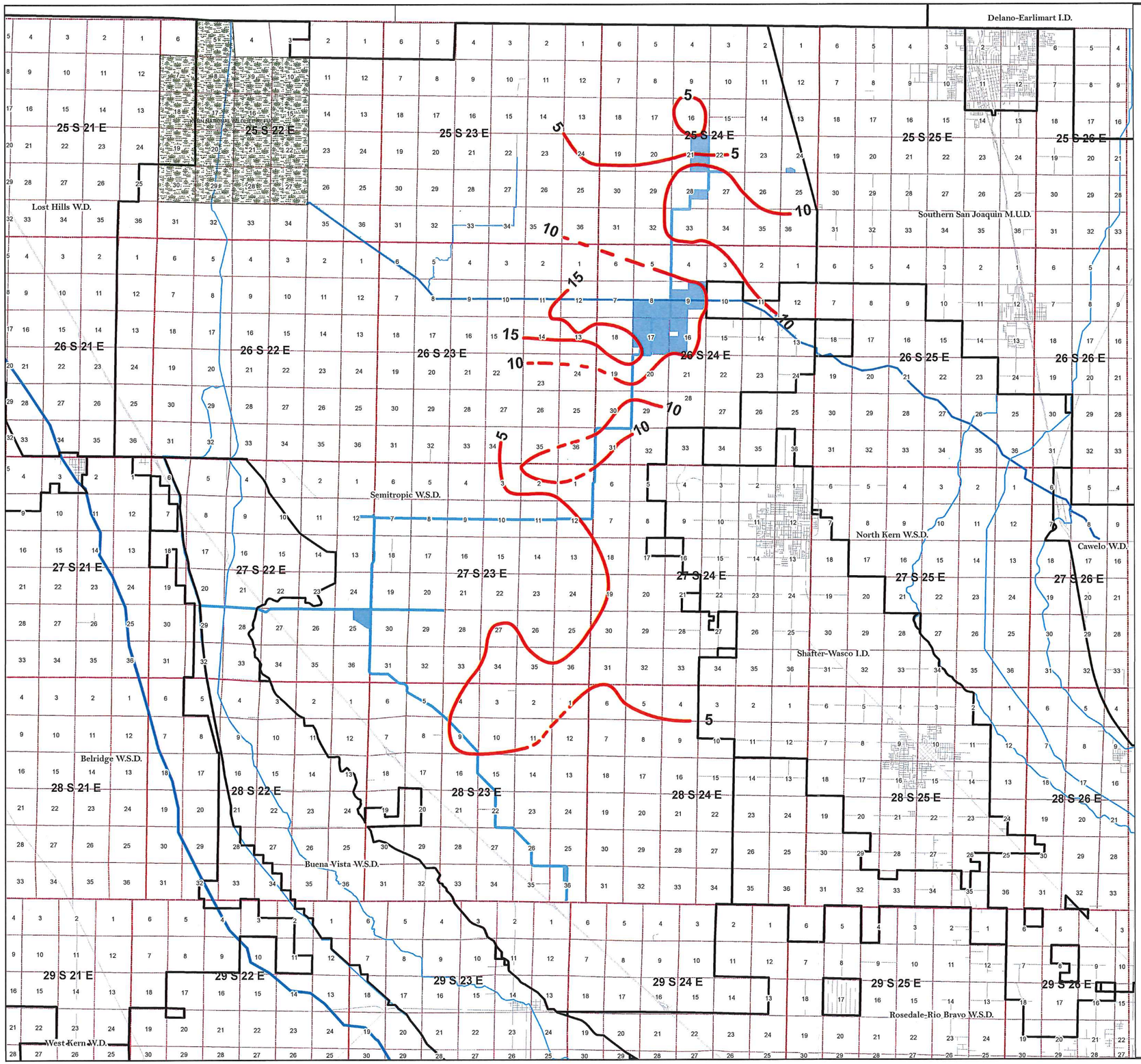


FIGURE 20-

Hexavalent Chromium in Groundwater (February - November, 2016)

Legend

▲ Location of Well sample site

15 ~ Contour of Hexavalent Chromium Concentration (ppb)

2 1 0 2 4 6 8

Miles

Uranium

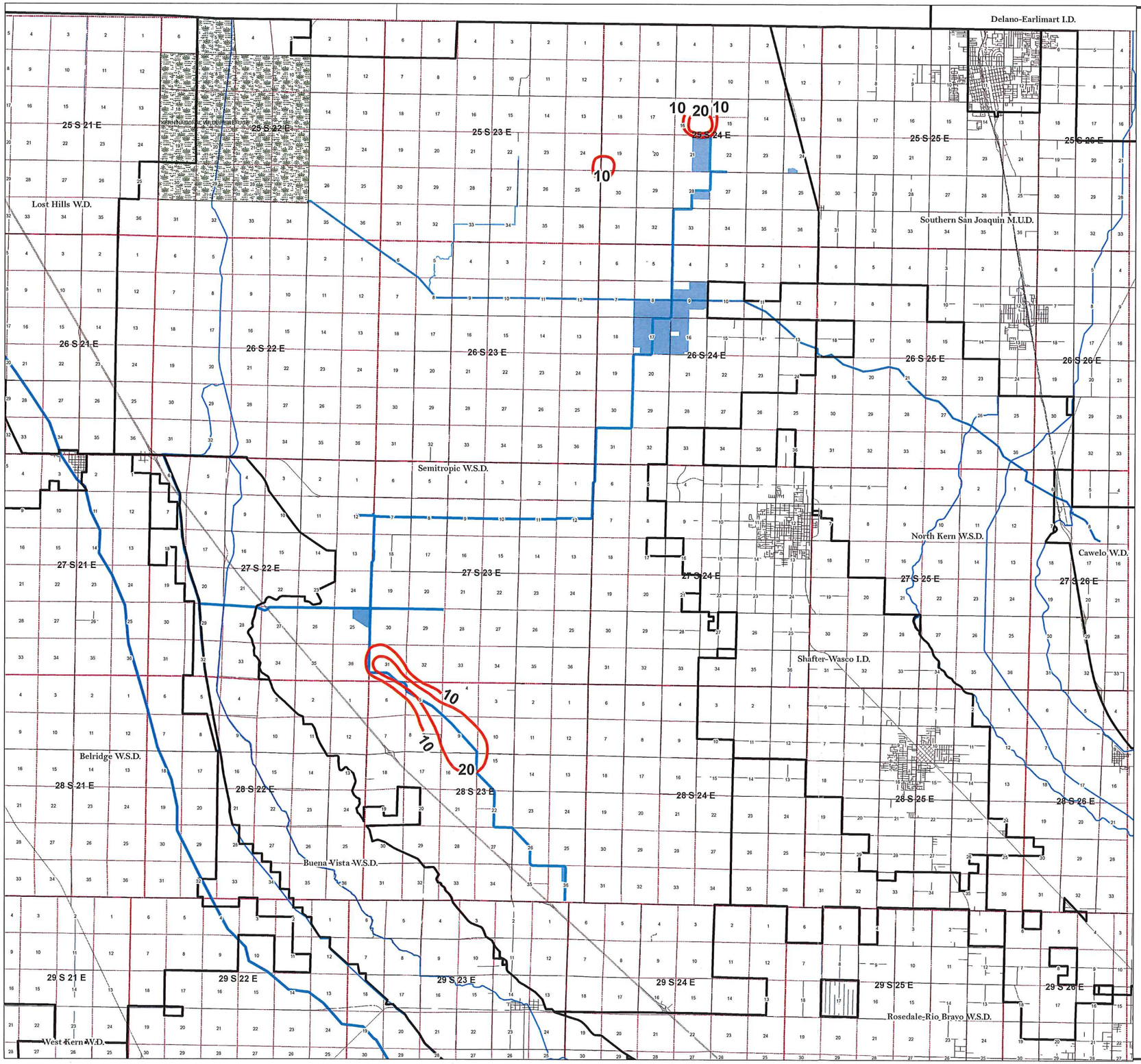
Figure 21 shows uranium activities in water from wells sampled during February-November, 2016. The MCL for uranium in drinking water is 20 picocuries per liter. Uranium activities were less than 10 picocuries per liter beneath most of the SWSD. However, uranium activities exceeded 20 picocuries per liter in two relatively small areas. One was about five miles north of the SWDS Poso spreading ponds. The second area was in the north part of T28S/R22E.

OTHER ACTIVITIES AFFECTING THE WATER BUDGET

Appendix D contains information on surface water deliveries, intentional recharge, crop consumptive use, and estimated pump-age (where available) for the SWSD and adjoining entities for 2015 and 2016. Following is a summary of this information.

Southern San Joaquin MUD

The average delivery of surface water by the District was 108,100 acre-feet per year from 1965-2016. The delivery was 1,395 acre-feet in 2015, or 99 percent below average, and 2,272 acre-feet in 2016, or 98 percent below average. Groundwater pumpage in the District is not measured or estimated.



N

FIGURE 21-

Uranium Activities in Groundwater (February - October 2016)

Legend

▲ Location of Well sample site

20 ~ Contour of Uranium Activity (pCi/l)

2 1 0 2 4 6 8

Miles

North Kern Water Storage District

The average long-term delivery of surface water by the District was 167,700 acre-feet per year during 1954-2016. Deliveries in 2015 were 14,400 acre-feet (including in-district canal losses), 5,100 acre-feet of which were for intentional recharge. Deliveries in 2016 were 58,700 acre-feet (including in-district canal losses), of which about 14,400 acre-feet were for intentional recharge. Deliveries of surface water for these two years were thus 9, and 35 percent, respectively, of the long-term average. None of the District wells are in the study area. Pumpage from private wells is not measured or estimated. A crop survey was performed for only 2016, but consumptive use for the one year was not determined.

Rosedale-Rio Bravo WSD

There were no surface water diversions into the District in 2015. The surface water diversion into the District was about 4,500 acre-feet in 2016, of which about 4,300 acre-feet were delivered to intentional recharge facilities in the District. The average surface water diversion from 1962 to 2016 was about 66,000 acre-feet per year. Thus the estimated surface water diversions in 2015 were 0 percent and in 2016 were about seven percent of the long-term average. The estimated groundwater pumpage in the District was 139,000 acre-feet in

2015 and about 123,000 acre-feet in 2016. The crop consumptive use in the District was determined to be about 76,500 acre-feet in 2015 and about 78,400 acre-feet in 2016, based on crop surveys conducted in those years.

Shafter-Wasco Irrigation District

The average farm delivery of surface water by the District from 1988 to 2016 was about 50,700 acre-feet. There was no surface water delivery in 2015 (0 percent of the average), and 38,500 acre-feet was delivered in 2016 (76 percent of the average). Groundwater pumpage in the District was not measured or estimated for this period. Crop surveys were performed, but consumptive use of crops for the two years was not determined.

Buena Vista WSD

The average surface water supply by the District was 132,300 acre-feet per year from 1970-2016. Surface water supplies were 370 acre-feet in 2015 (less than one percent of the average), and 69,700 acre-feet in 2016 (53 percent of the average). The estimated groundwater pumpage in the District was 97,900 acre-feet in 2015, and 48,300 acre-feet in 2016. The average crop consumptive use in the District from 1970 to 2016 was 106,700 acre-feet. The estimated crop consumptive use was 98,200 acre-feet in 2015 and 99,100 acre-feet in 2016.

Semitropic WSD

From 1976 through 2016, the District's total surface water inflows averaged about 166,000 acre-feet annually. During the two years which are the subject of this report, annual surface water inflow varied by an order of magnitude; from 10,800 acre-feet in 2015 to 118,900 acre-feet in 2016. Following is a table which summarizes the annual surface water inflows, along with annual estimates of consumptive use and groundwater pumping for 2015-16.

Water Supplies, Water Use, and Groundwater Pumping
(acre-feet)

		2015	2016
Surface Water Inflow		10,800	118,900
Banked Water (net)		4,500	29,600
ET of Applied Water		326,700	325,900
Applied Water:			
	(e=90%)	363,000	362,100
	(e=80%)	408,400	407,400
Deliveries to Irrigation		52,200	140,600
Pumpage:			
On-Farm			
	(e=90%)	310,800	221,500
	(e=80%)	356,200	266,800
District		175,600	62,200
Total			
	(e=90%)	486,400	283,700
	(e=80%)	531,800	329,000

The estimated annual consumptive use or evapotranspiration ("ET") of applied water was based on the District's annual crop survey and

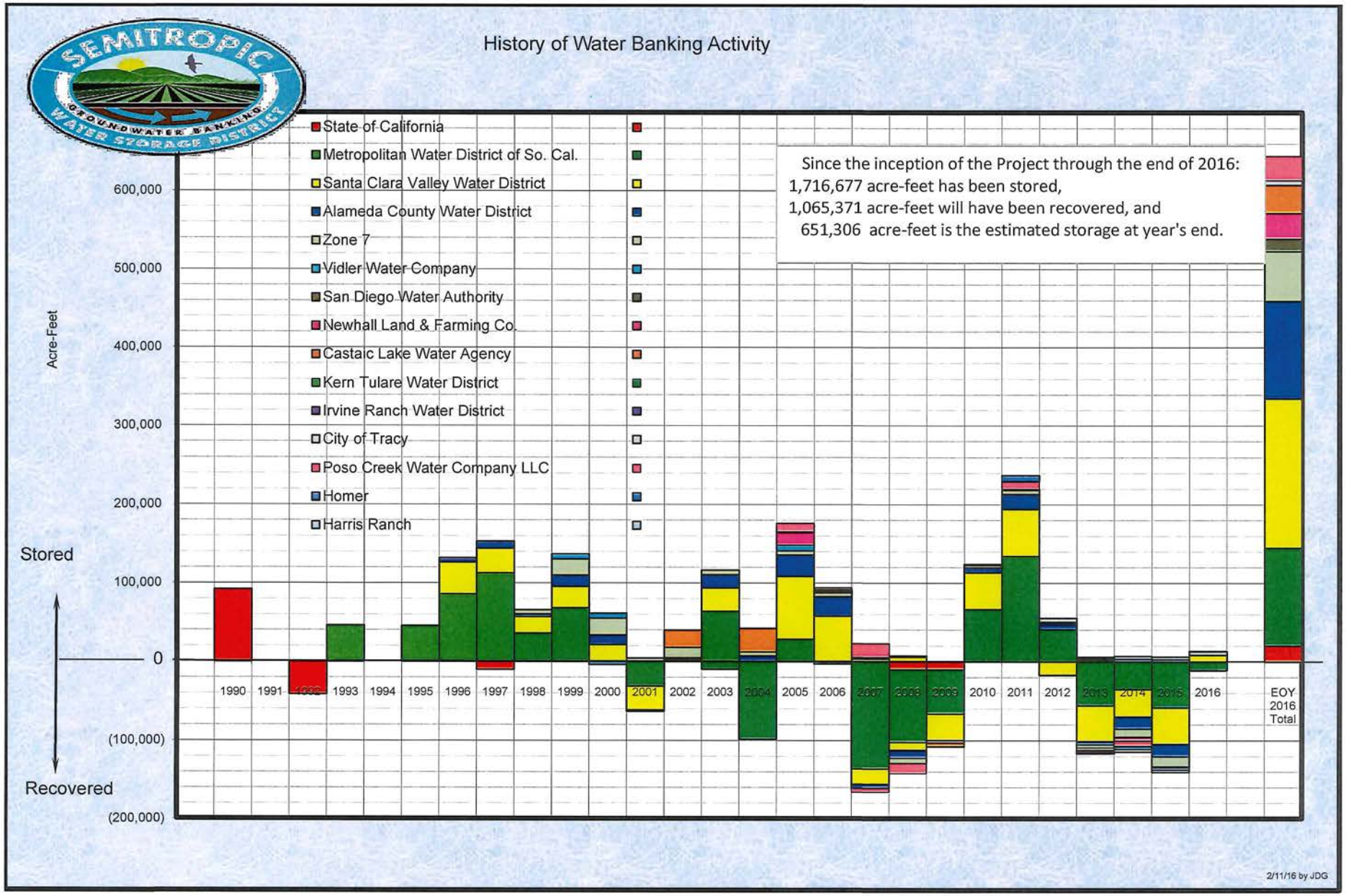
unit values of the consumptive use of applied water from Burt (2005)[1]. Assuming that the average irrigation efficiency ("e") ranges from 80 to 90 percent, the estimated applied water and pumpage are expressed as ranges. District deliveries to irrigation include surface water and District-pumped groundwater. Accordingly, on-farm pumping is estimated as the difference between the applied water and District deliveries to irrigation. District pumping includes pumping for in-District delivery and use as well as for delivery into the California Aqueduct when returning banked water to banking partners.

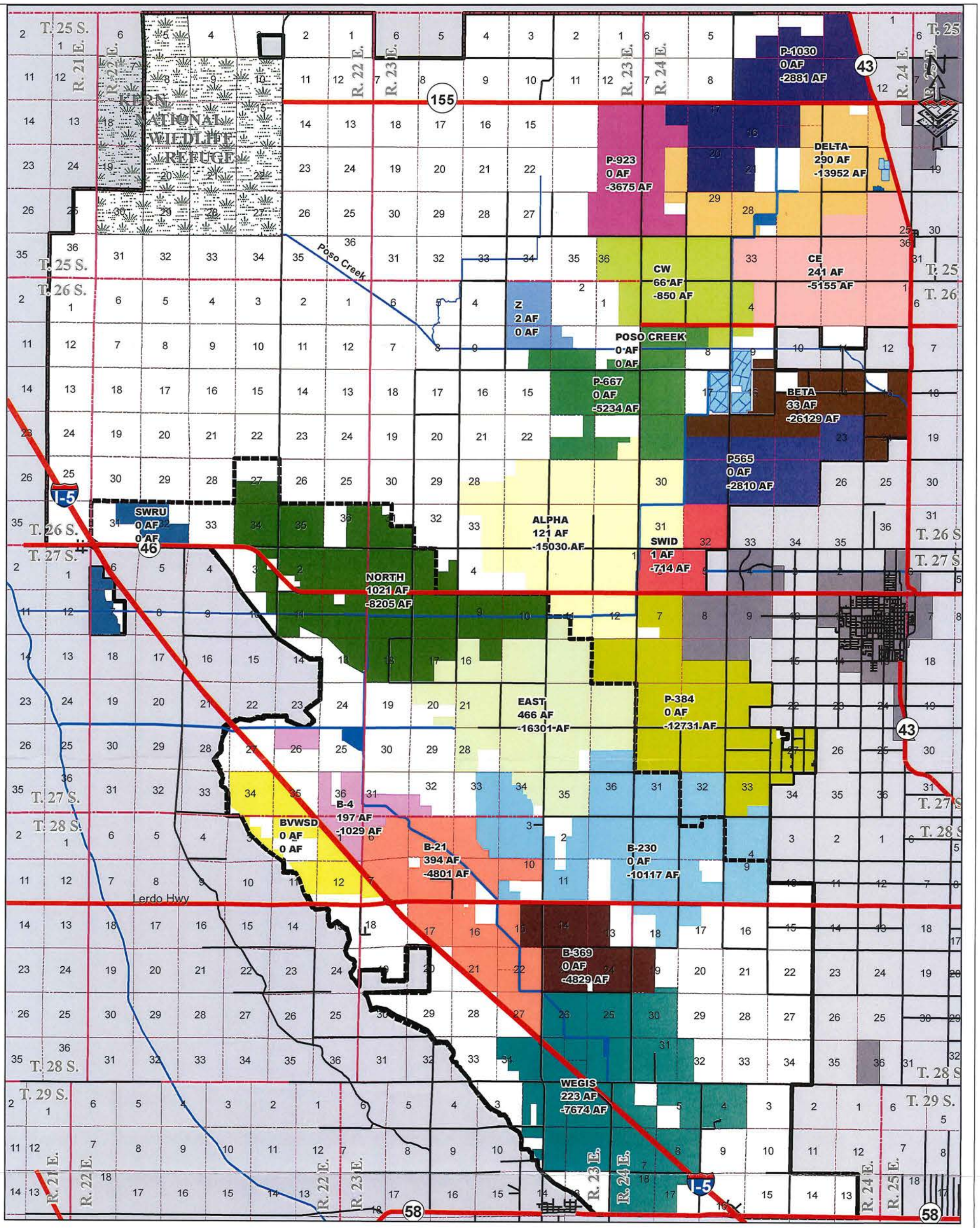
1 Charles M. Burt, Ph.D., P.E., August 18, 2005, "Expert Report on Friant Service Area". The unit values are indicated to be averages for 1999-2003; ET Zone 15; with adjustments for bare spots and decreased vigor.

APPENDIX A

WATER-BANKING OPERATIONS

History of Water Banking Activity





SEMITROPIC WATER STORAGE DISTRICT

DISTRIBUTION OF 2015 BANKING WATER
3,055 ACRE-FEET STORED
(-142,117 ACRE-FOOT RECOVERED)

0 0.5 1 2 3 4 5 Miles

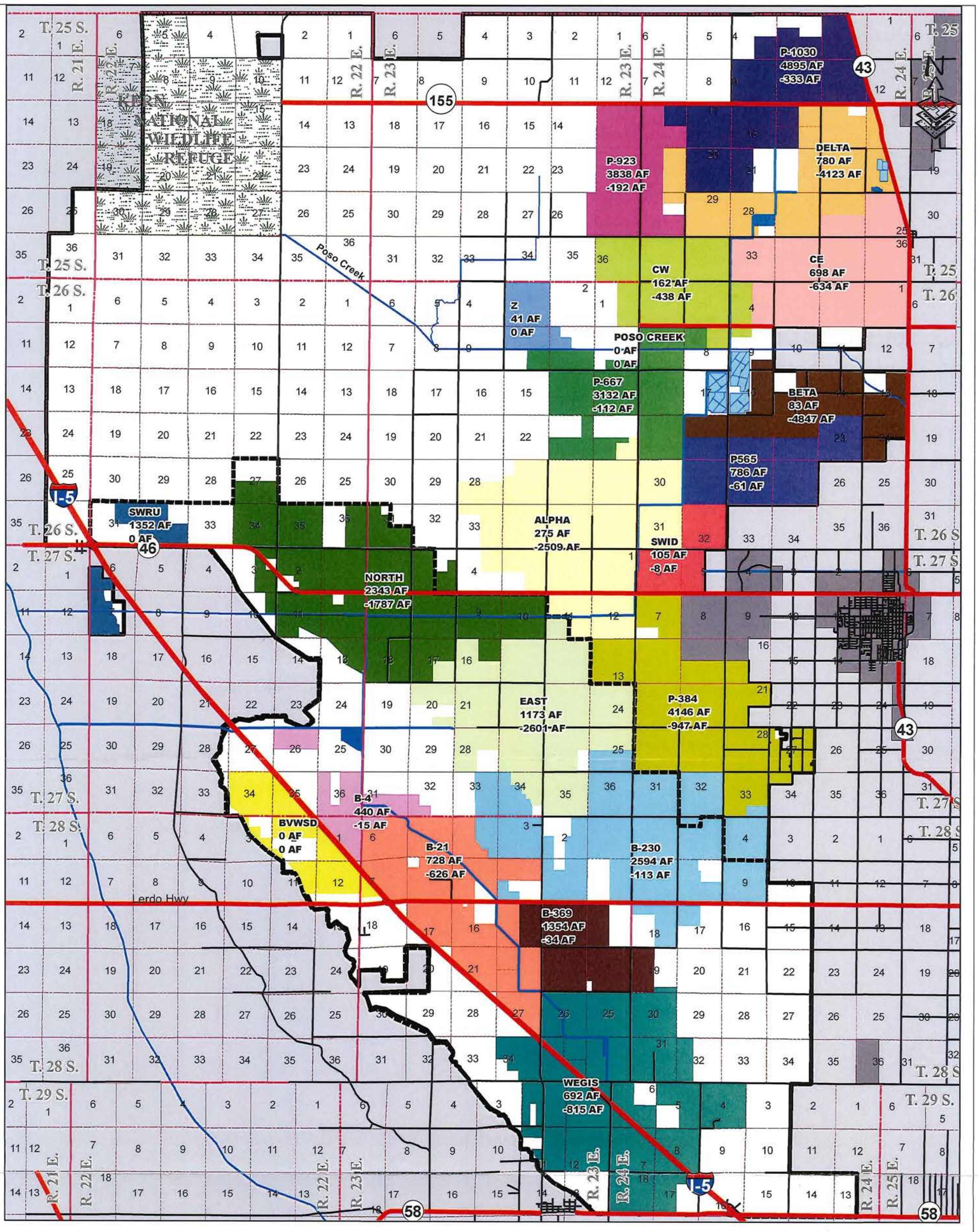
Sept 2017

Legend

- DistrictBoundary
- Improvement District Boundary
- Transportation
- Canals, Pipelines, and Aqueduct
- Distribution System

SEMITROPIC GROUNDWATER BANKING WATER STORAGE DISTRICT

\\GIS Projects\System Routes\DistributionBankingWater2015 Sept 12, 2017



SEMITROPIC WATER STORAGE DISTRICT

DISTRIBUTION OF 2016 BANKING WATER
29,617 ACRE-FEET STORED
(-20,195 ACRE-FOOT RECOVERED)

0 0.5 1 2 3 4 5 Miles

Sept 2017

Legend

- DistrictBoundary
- Improvement District Boundary
- Transportation
- Canals, Pipelines, and Aqueduct
- Distribution System

SEMITROPIC GROUNDWATER BANKING WATER STORAGE DISTRICT

\GIS Projects\System Routes\DistributionBankingWater2016 Sept 12, 2017

APPENDIX B

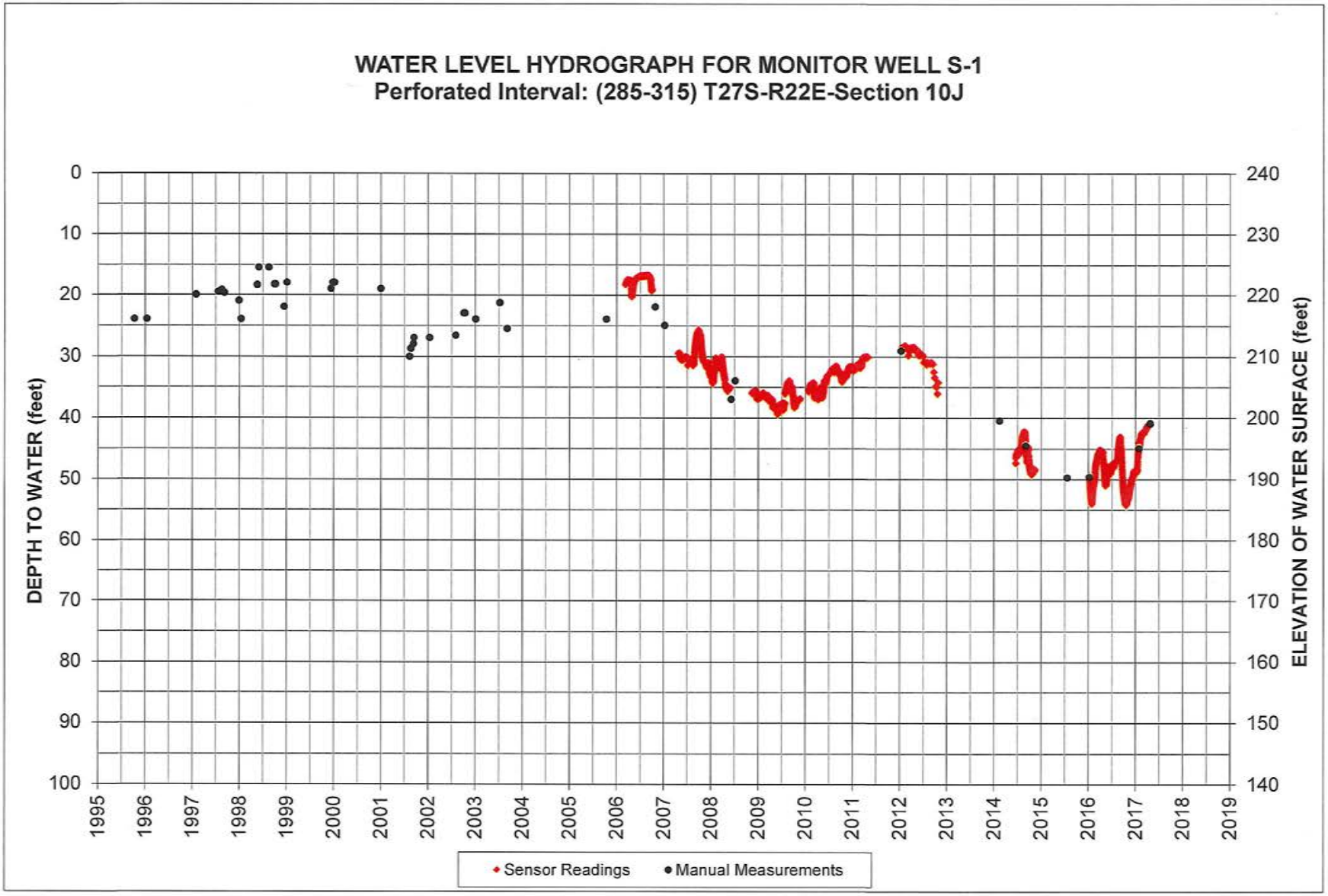
WATER-LEVEL HYDROGRAPHS

SEMITROPIC WATER STORAGE DISTRICT

Monitor Wells

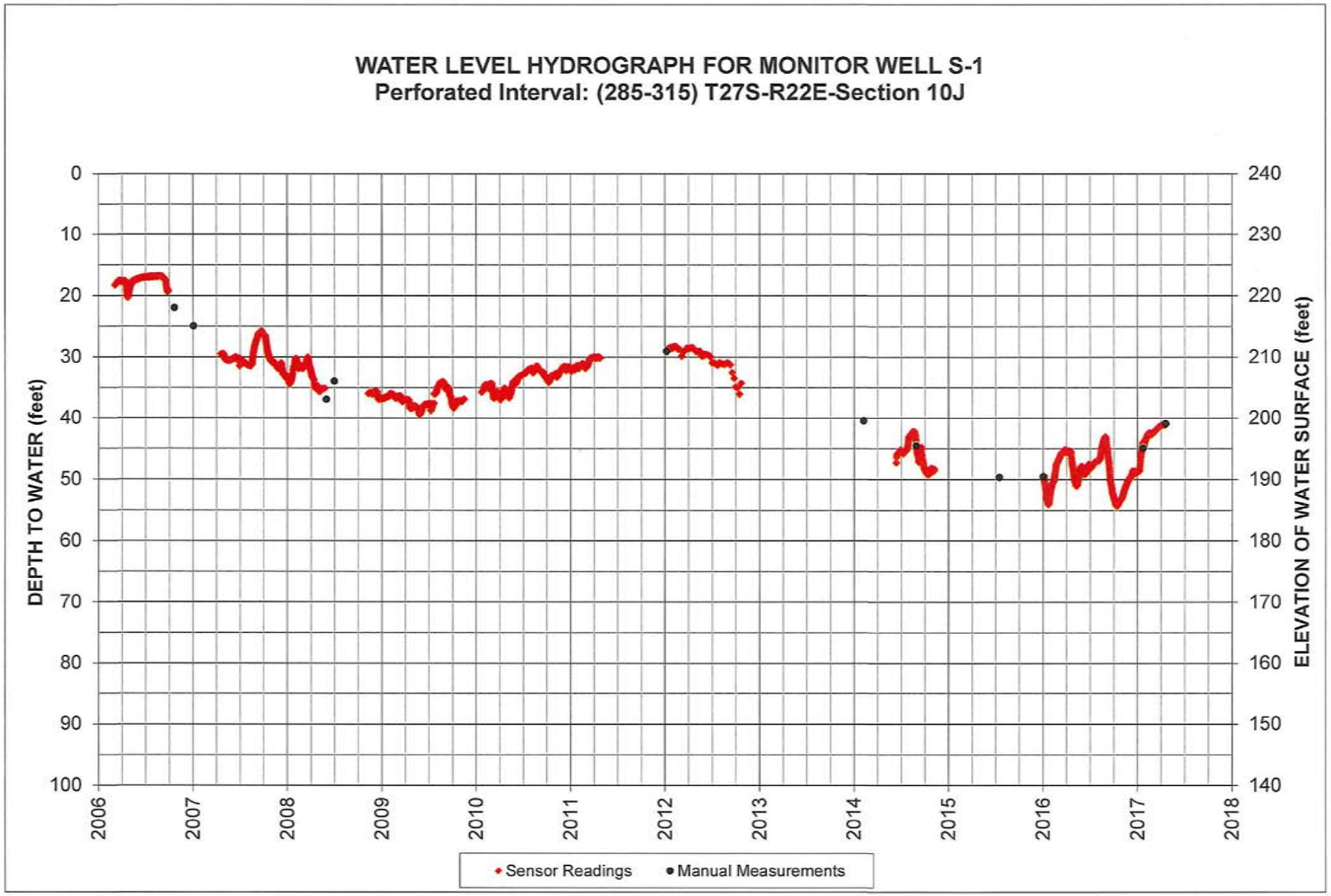
Well Characteristics

Well No.	Location T-R-S	Type of Well Monitoring -or- Production	Installed Transducer Serial Number	Year Well Constructed	RP Elevation (ft MSL)	Boring Depth (ft)	Completed Depth (ft)	Perforated Interval (ft)	Annular Seal Interval (ft)	Casing		Water Level Sounder Measurement Frequency	Sampling Pump	Sampling Frequency
										Diameter (in)	Material			
948L02	29S-24E-8L02	Monitor Well	105000	1992	295		625	525 - 625		6		6-12		2
948L03	29S-24E-8L03	Monitor Well	104970	1992	295		440	360 - 440		6		6-12		2
S-1	27S-22E-10J	Monitor Well	104935	1994	240	422	340	285-315		5.761	Sch.80 PVC	2		1
S-2	27S-22E-24D	Monitor Well	104939	1994	235	500	448	370-410		5.761	Sch.80 PVC	2		1
S-3	27S-22E-34A	Monitor Well	104942	1994	262	500	300	240-270		5.761	Sch.80 PVC	2		1
S-4	28S-22E-3H	Monitor Well	104996	1994	248	501	445	390-420		5.761	Sch.80 PVC	2		1
S-5	27S-23E-29M	Monitor Well	104999	1994	242	500	430	380-410		5.761	Sch.80 PVC	2		1
S-6	25S-24E-36Q	Monitor Well	104958	1995	282	450	431	381 - 431	0 - 356	6	3/16-in. Steel	2	X	
S-7A	26S-24E-13N	Monitor Well	104957	1995	297	700	600	550 - 600	0 - 520	6	1/4-in. Steel	2	X	1
S-7B	26S-24E-13N	Monitor Well	104959	1995	297	380	380	330 - 380	0 - 310	6	3/16-in. Steel	2		
S-8A	26S-24E-33D	Monitor Well	104956	1995	276	700	687	637 - 687	0 - 600	6	1/4-in. Steel	2	X	1
S-8B	26S-24E-33D	Monitor Well	104941	1995	276	432	432	392 - 432	0 - 362	6	3/16-in. Steel	2		
S-9A	28S-24E-4L	Monitor Well	104978	1995	297	700	690	660 - 690	0 - 640	6	1/4-in. Steel	2	X	1
S-9B	28S-24E-4L	Monitor Well	104998	1995	297	407	407	357 - 407	0 - 322	6	3/16-in. Steel	2		
S-10A	25S-22E-35B	Monitor Well	104968	1999	222		900	420 - 460 490 - 700 740 - 890		4		2		
S-10B	25S-22E-35B	Monitor Well	no transducer	1999	222		1270	1,250 - 1,260		4		2		
S-10C	25S-22E-35B	Monitor Well	no transducer	1999	222		1100	1,080 - 1,090		4		2	X	1
S-11	26S-22E-2J	Monitor Well	104937	2001	222	900	700	550 - 700		6 & 8	1/4-in. Steel	2		
S-12	25S-22E-25L	Monitor Well	104962	2001	217	940	740	510 - 740		6 & 8	1/4-in. Steel	2		
S-13A	25S-24E-18D	Monitor Well	no transducer	2003	222	695	690	660 - 690	0 - 630	6	1/4-in. Steel	2	X	1
S-13B	25S-24E-18D	Monitor Well	no transducer	2003	222	430	435	390 - 430	0 - 370	6	3/16-in. Steel	2	X	
S-14A	26S-24E-16J	Monitor Well	no transducer	2003	274	715	710	670 - 710	0 - 640	6	1/4-in. Steel	2	X	1
S-14B	26S-24E-16J	Monitor Well	no transducer	2003	274	485	480	430 - 480	0 - 410	6	3/16-in. Steel	2	X	
S-15A	27S-24E-16P	Monitor Well	no transducer	2003	295	605	600	550 - 600	0 - 520	6	1/4-in. Steel	2	X	1
S-15B	27S-24E-16P	Monitor Well	no transducer	2003	295	455	450	400 - 450	0 - 380	6	3/16-in. Steel	2	X	
S-16A	26S-24E-27Q	Monitor Well	100993	2003	295	675	670	620 - 670	0 - 590	6	1/4-in. Steel	2	X	1
S-16B	26S-24E-27R	Monitor Well	114335	2003	295	415	410	370 - 410	0 - 350	6	3/16-in. Steel	2	X	
26S-23E-15A1	26S-23E-15A1	Monitor Well	101667	1974	229.3		350	310-350	0-80	6.625 (O.D.)				
26S-23E-15A2	26S-23E-15A2	Monitor Well	104977	1974	229.8		237	80-237	0-25	6.625 (O.D.)				



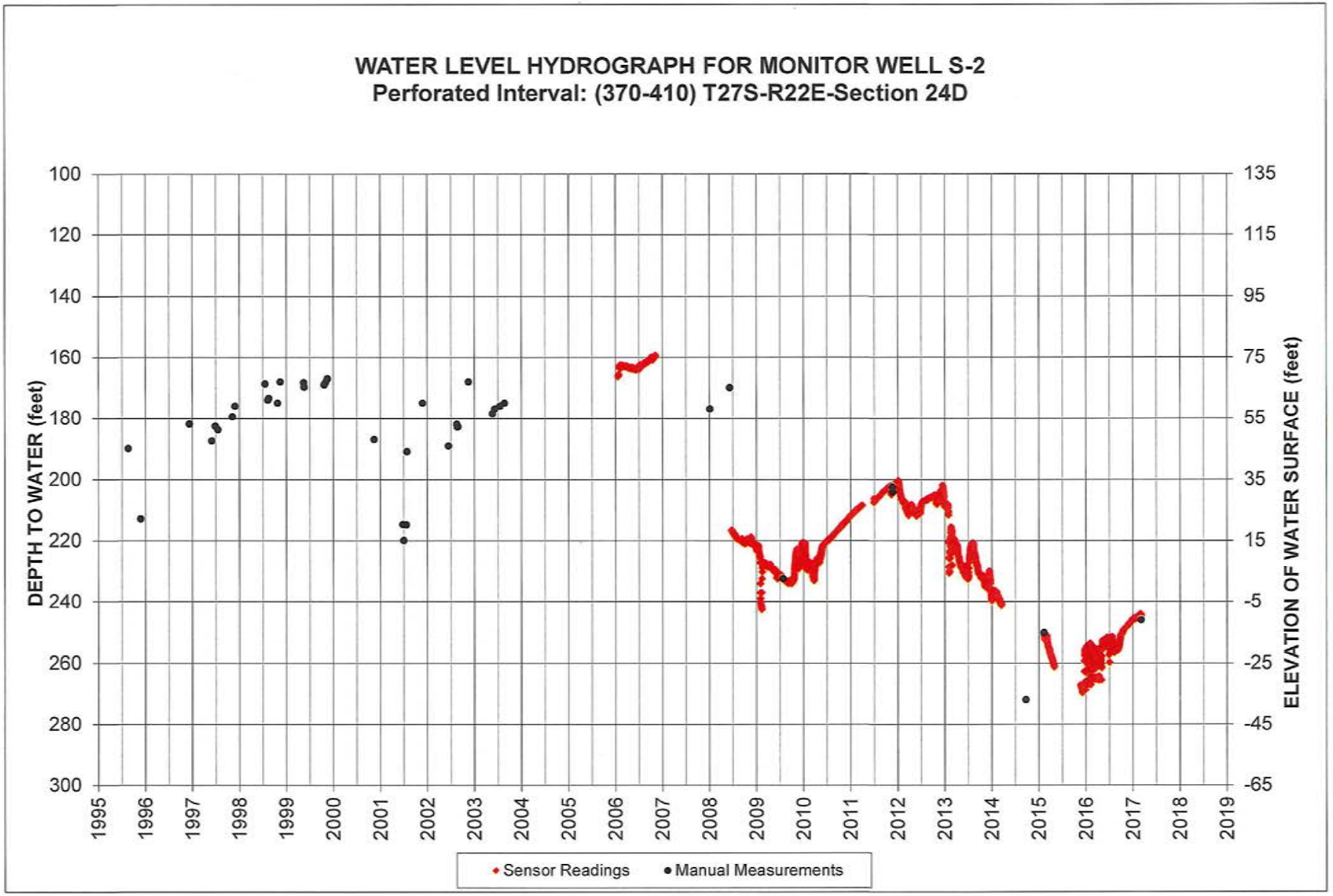
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



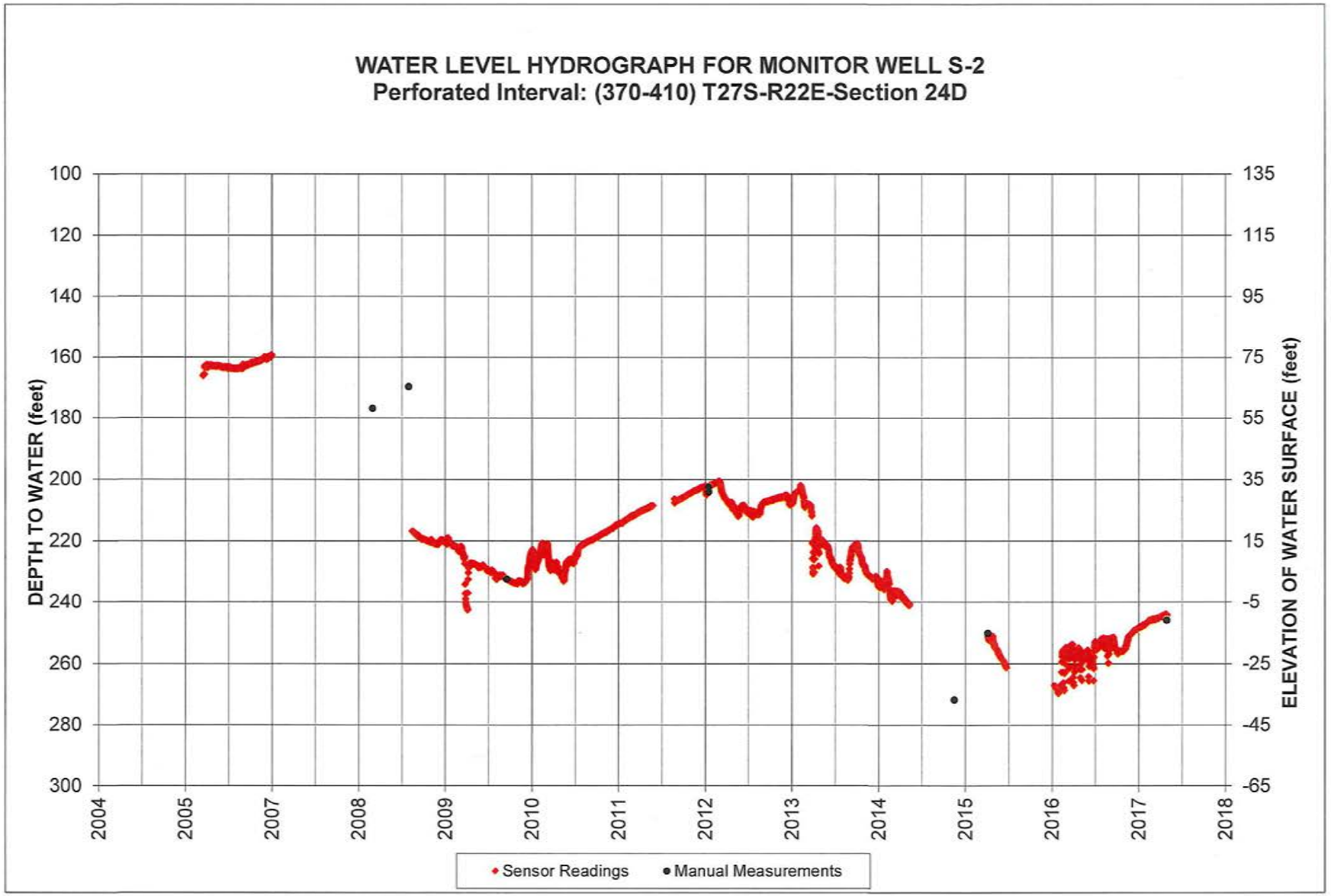
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



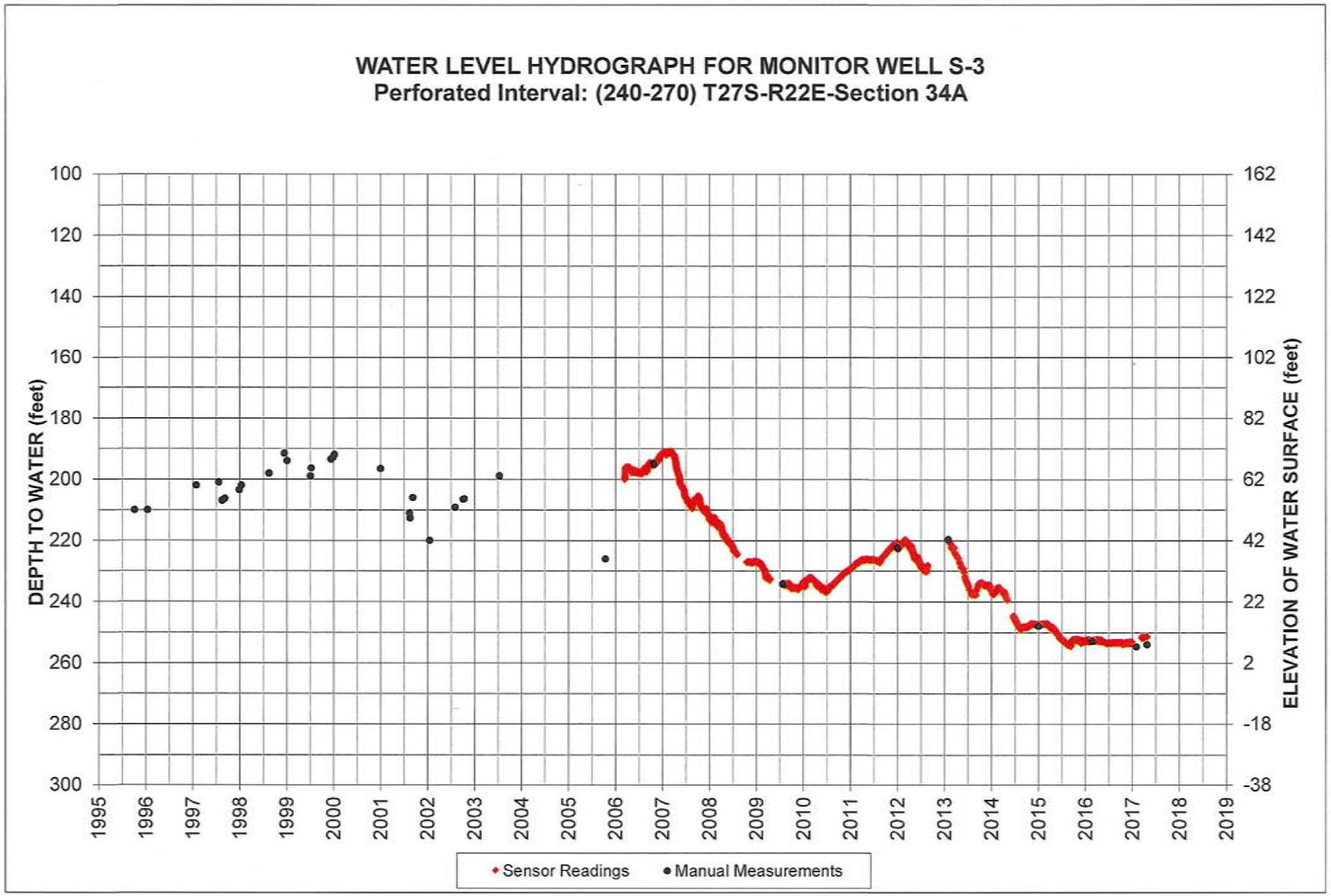
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



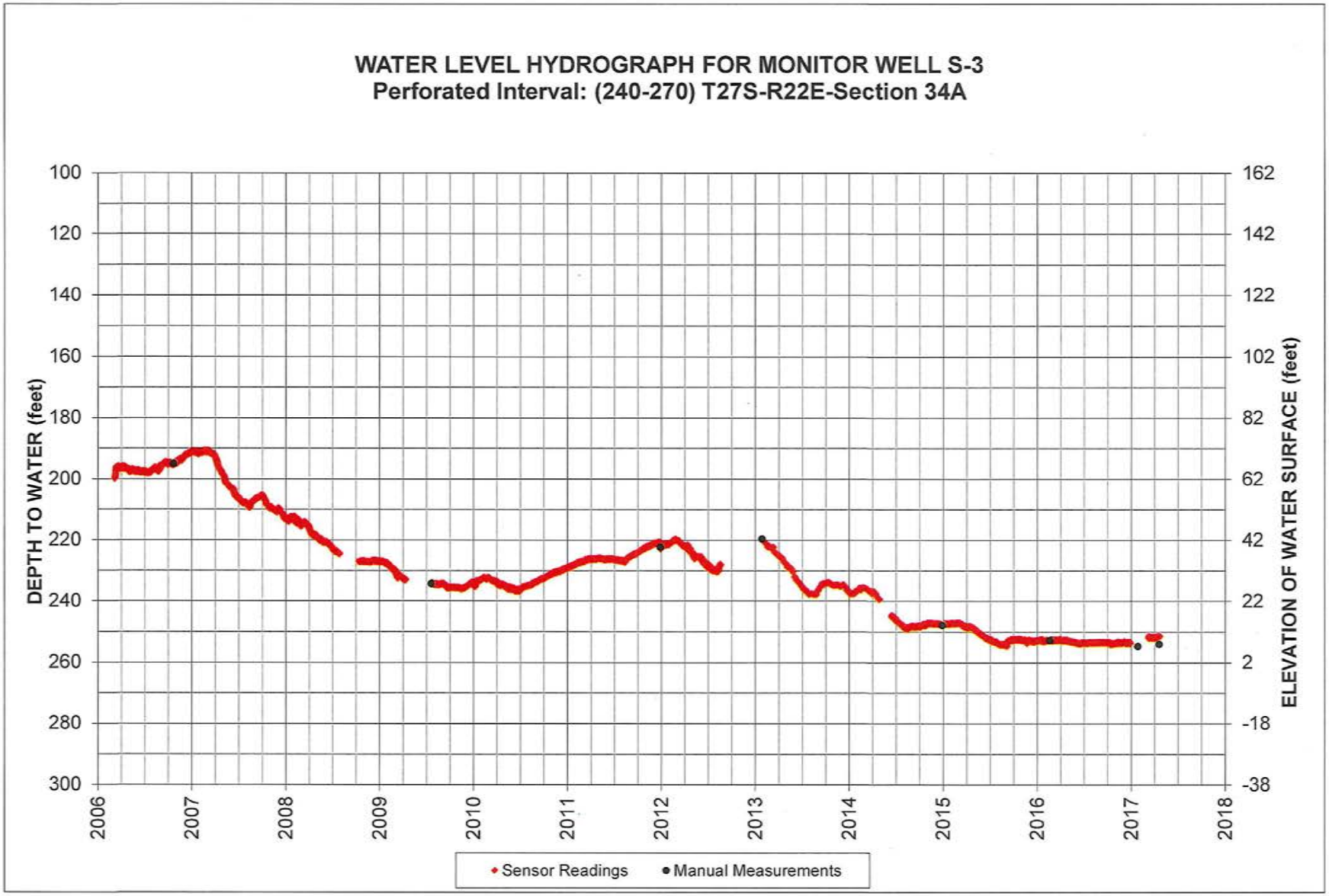
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



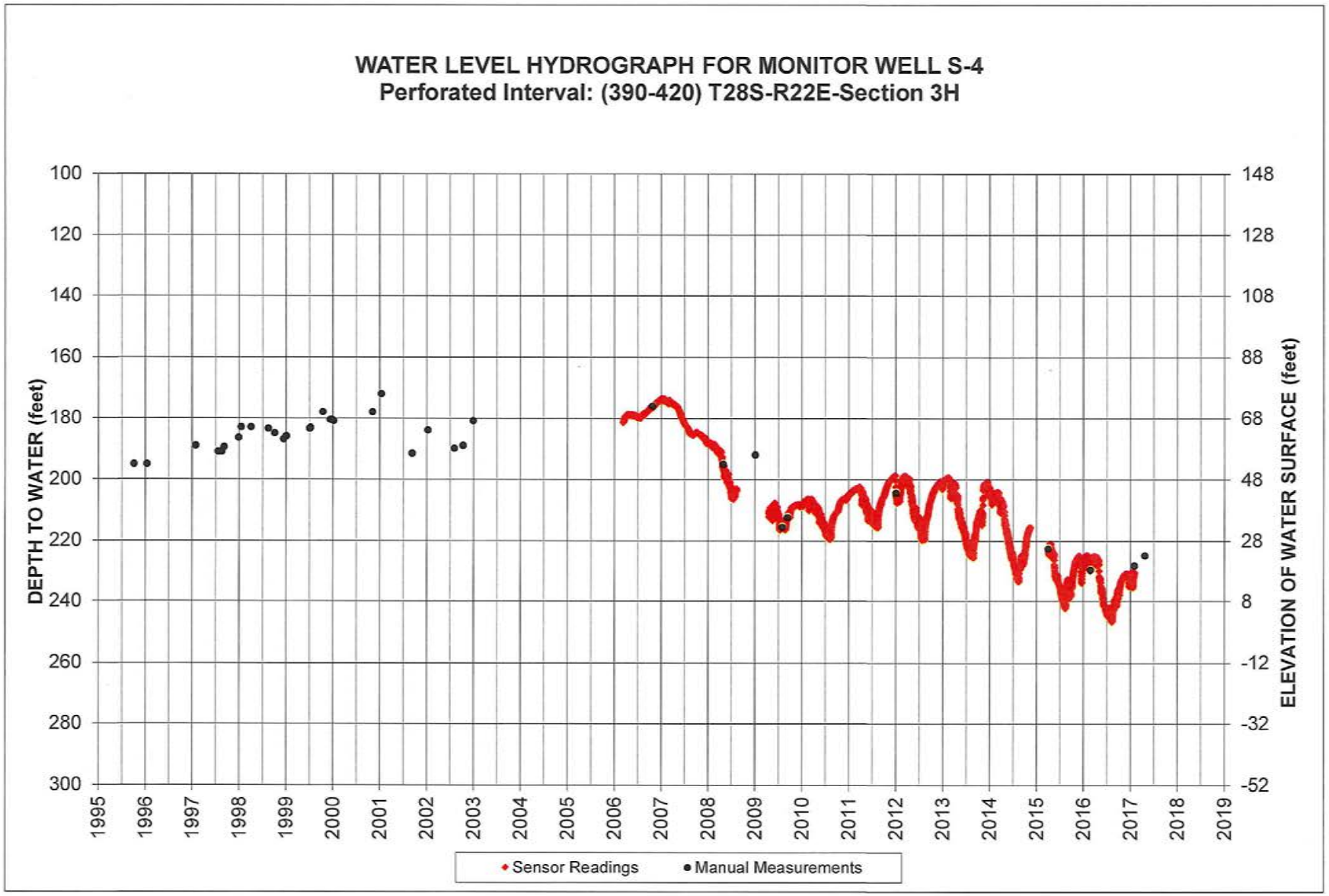
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



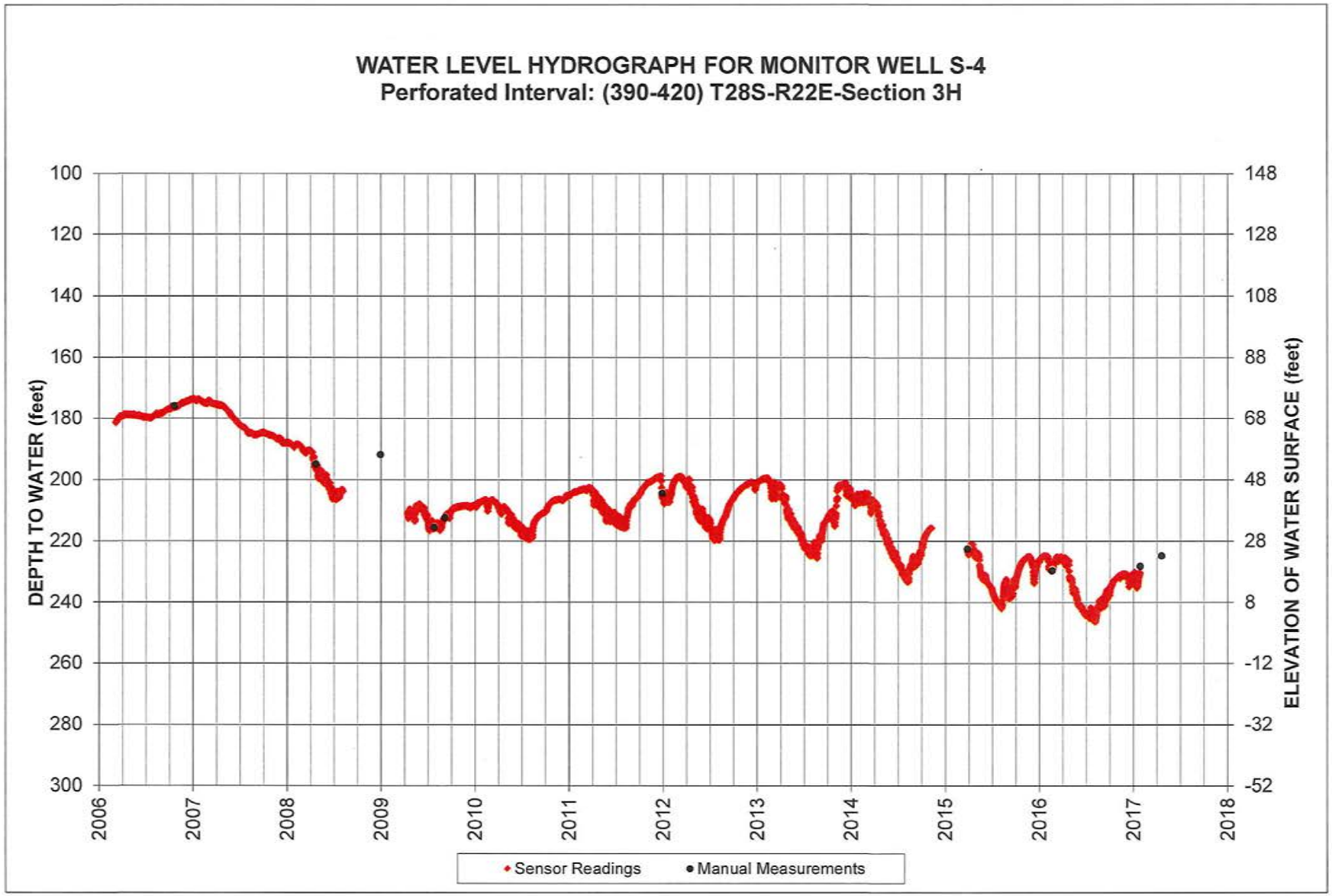
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

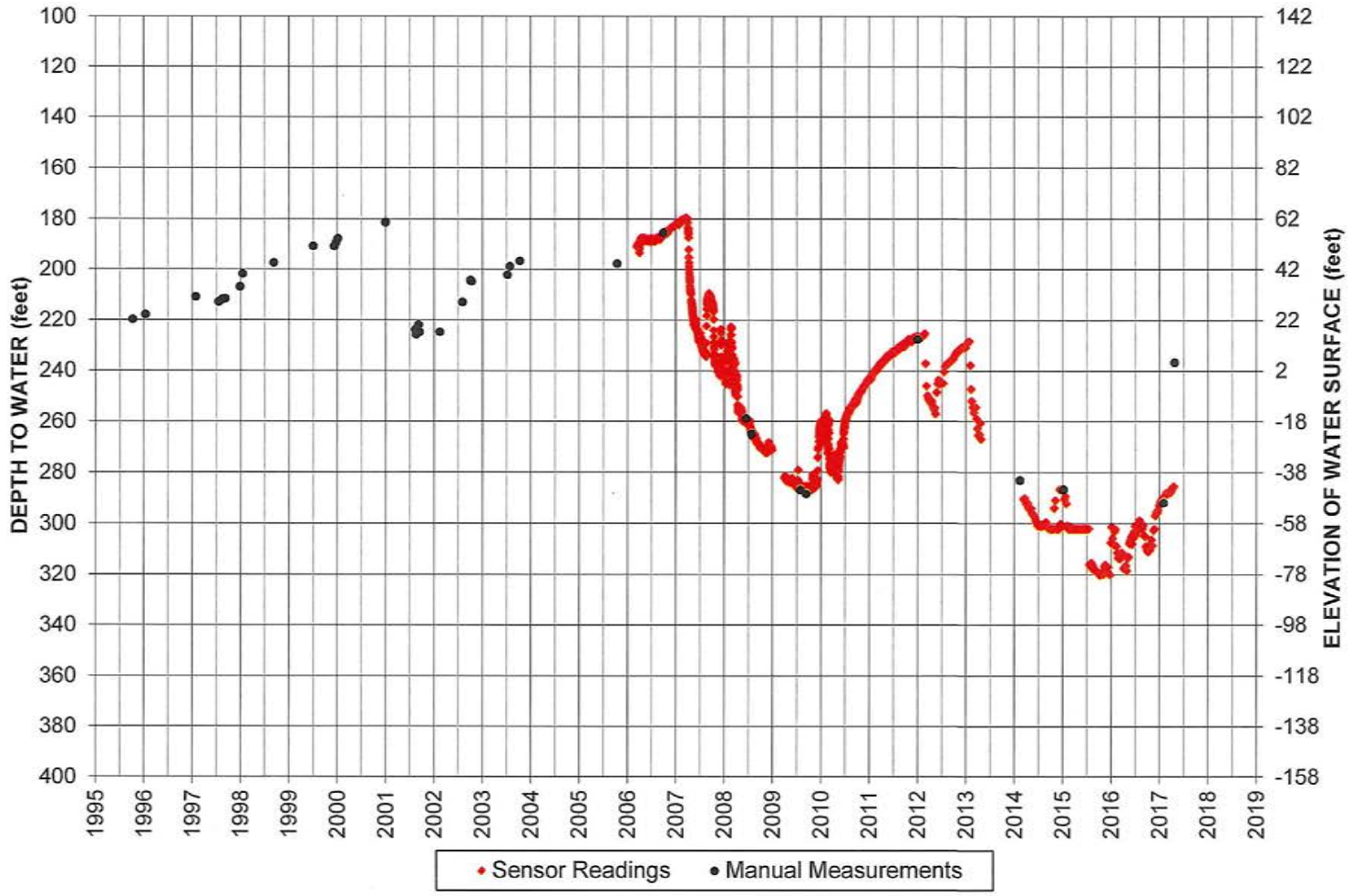
5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017

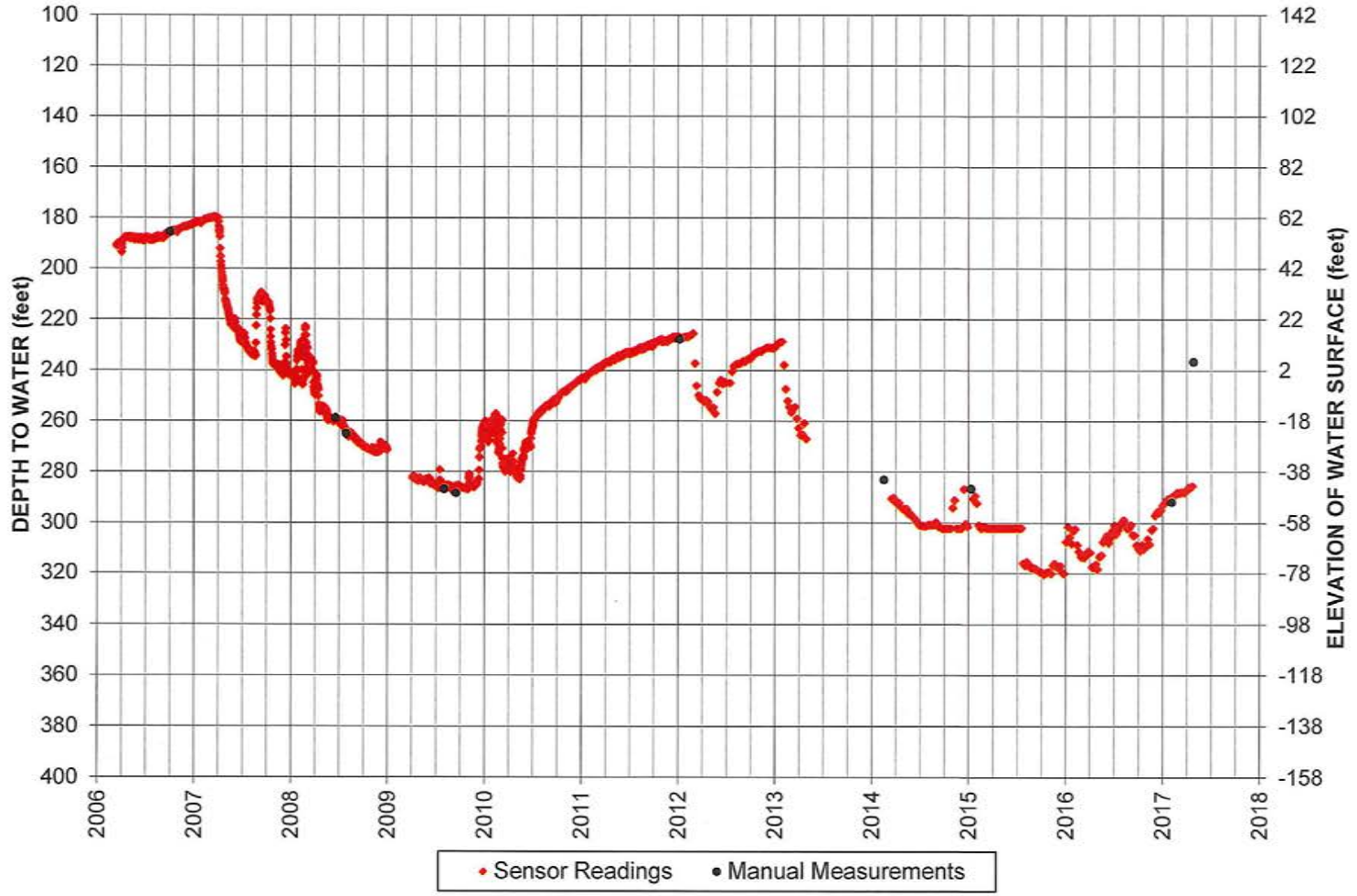
WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-5
Perforated Interval: (380-410) T27S-R23E-Section 29M



Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017

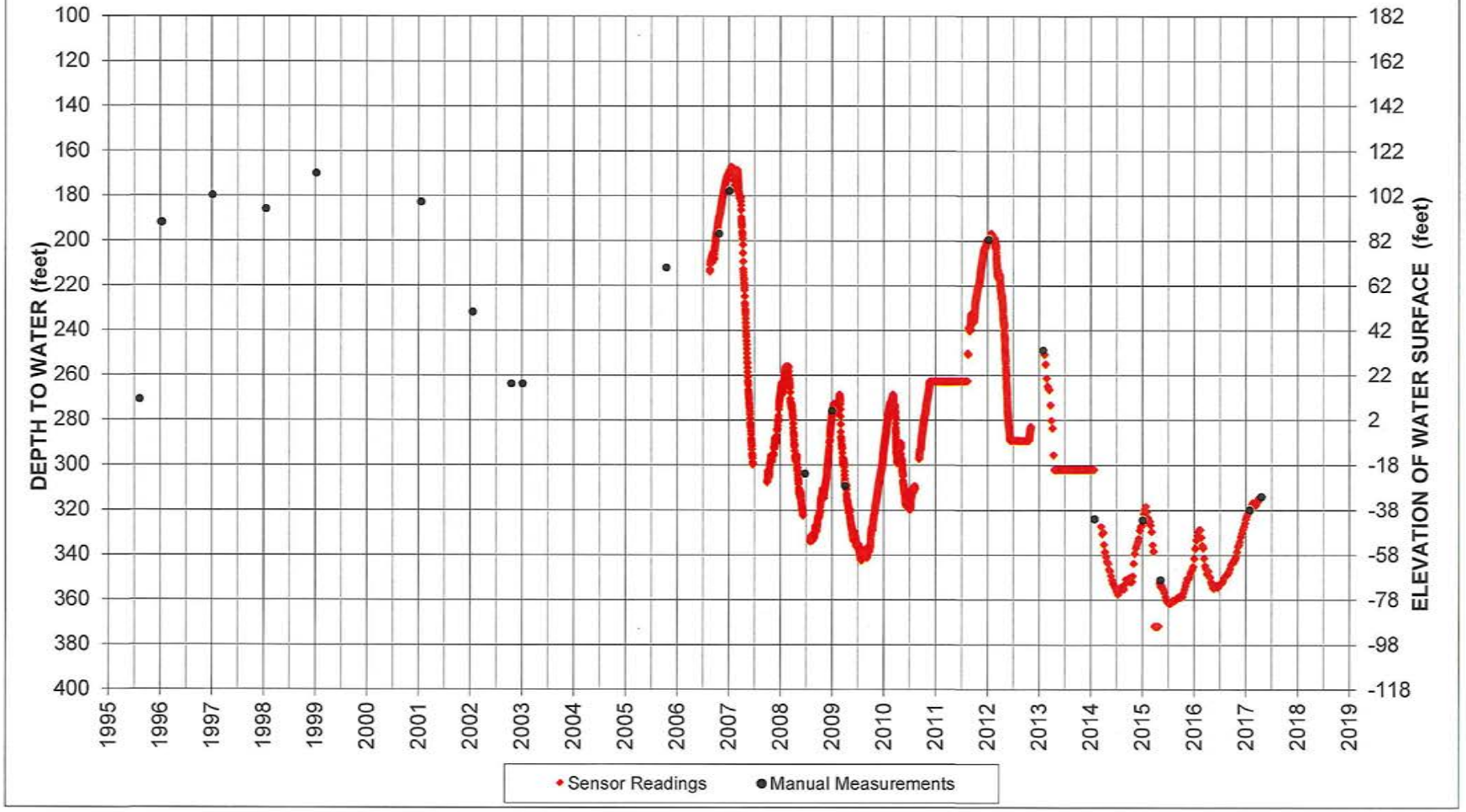
WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-5
Perforated Interval: (380-410) T27S-R23E-Section 29M



Semitropic Water Storage District
(Manual data from the KCWA)

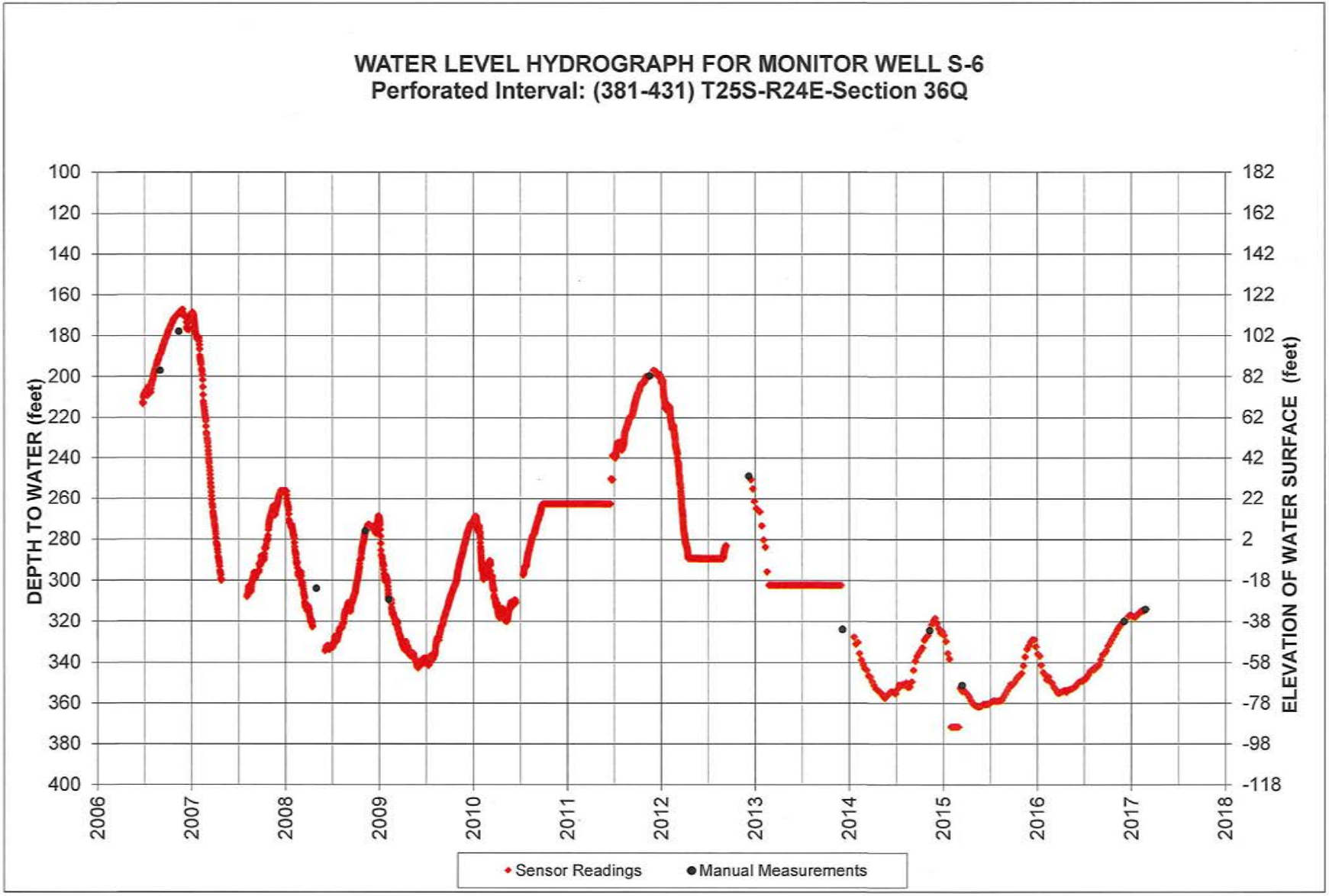
5/8/2017

WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-6
Perforated Interval: (381-431) T25S-R24E-Section 36Q



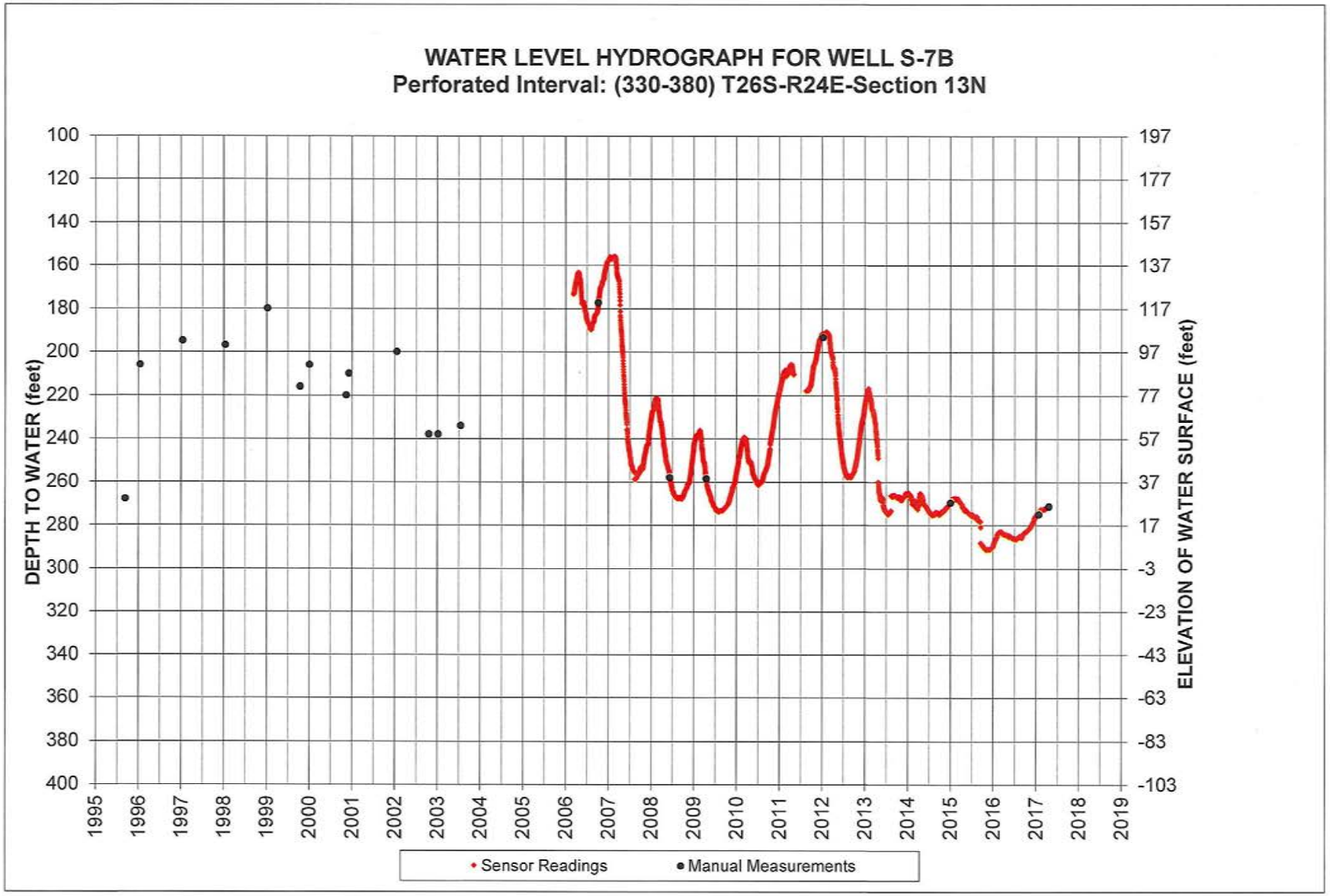
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



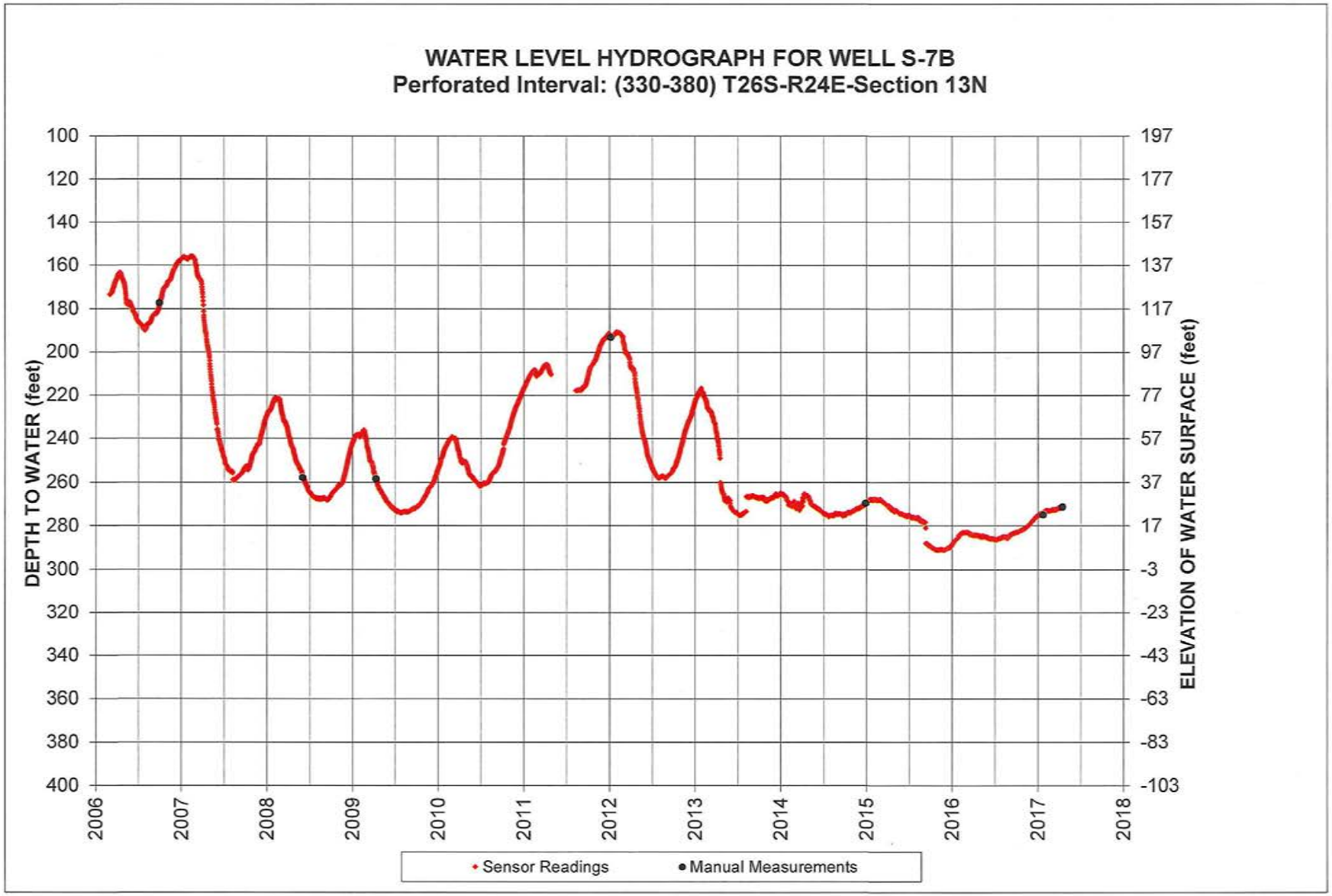
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



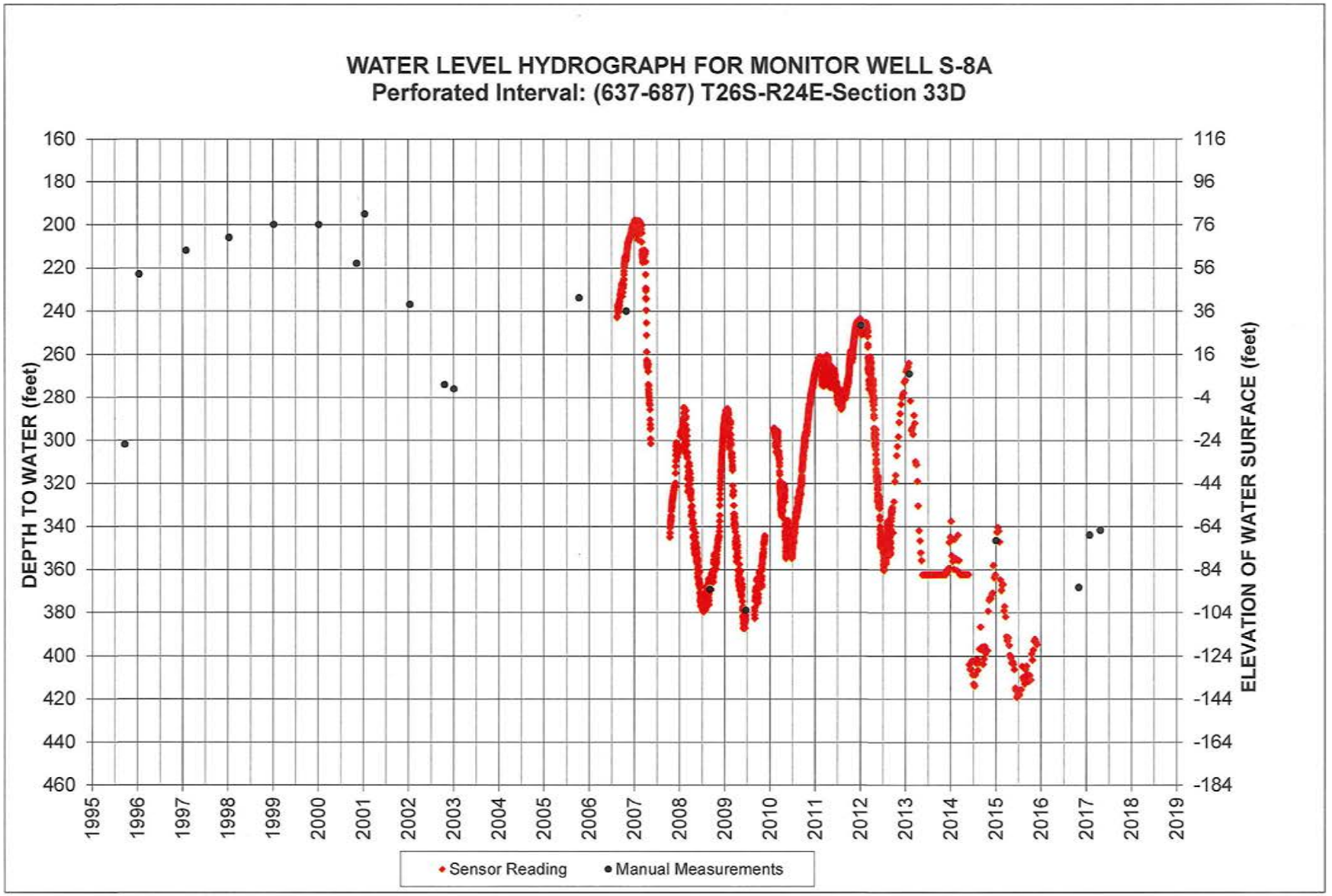
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



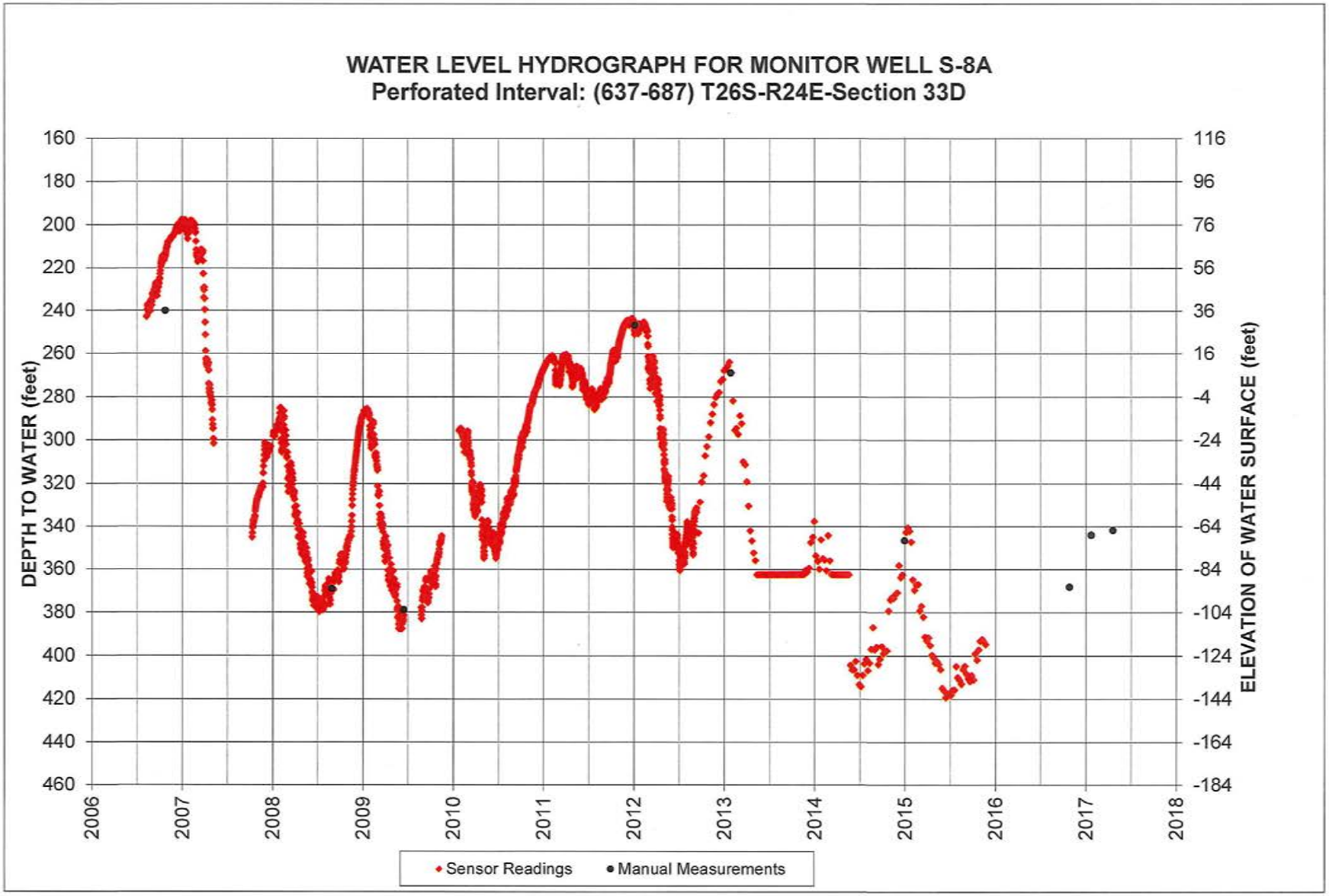
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



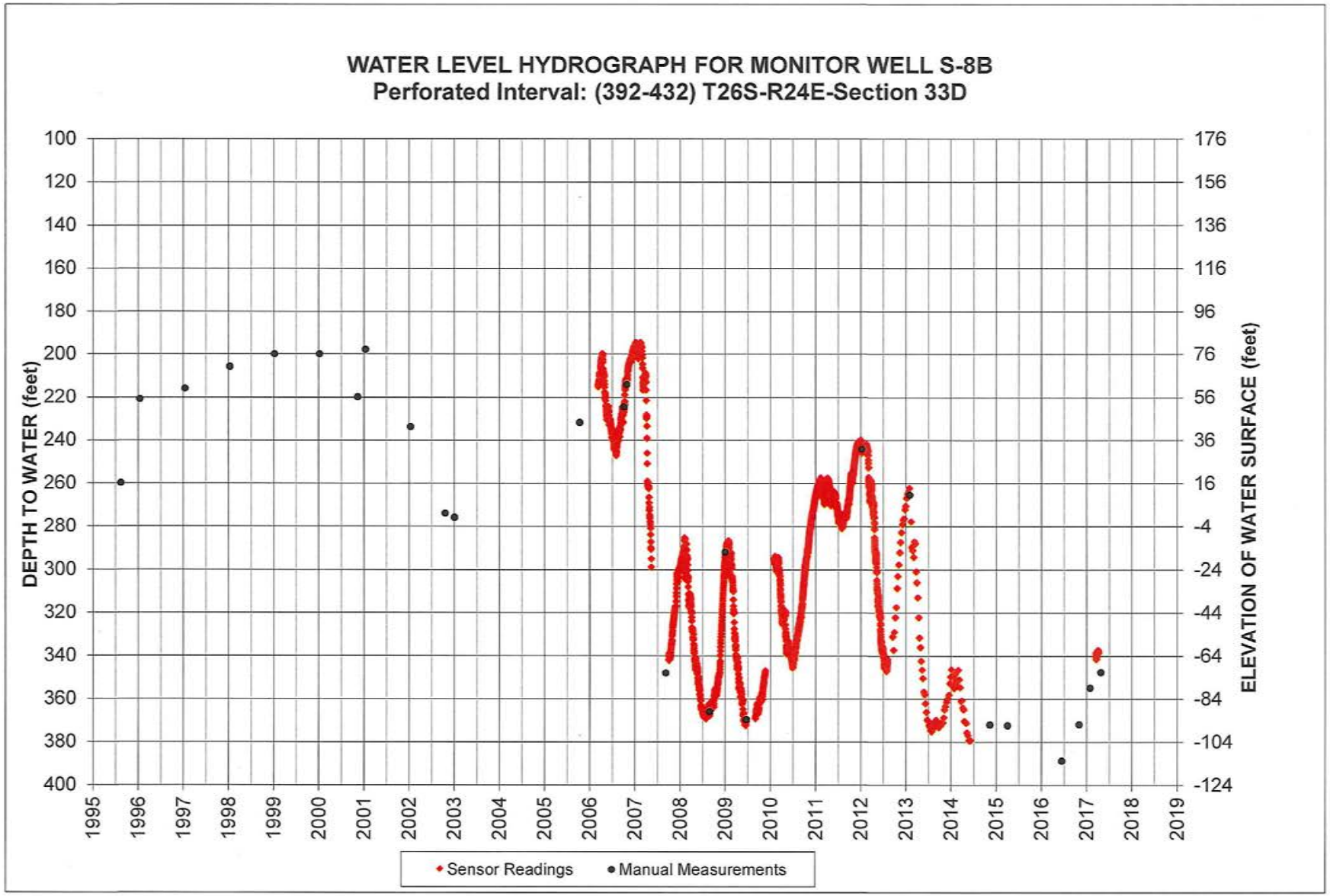
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



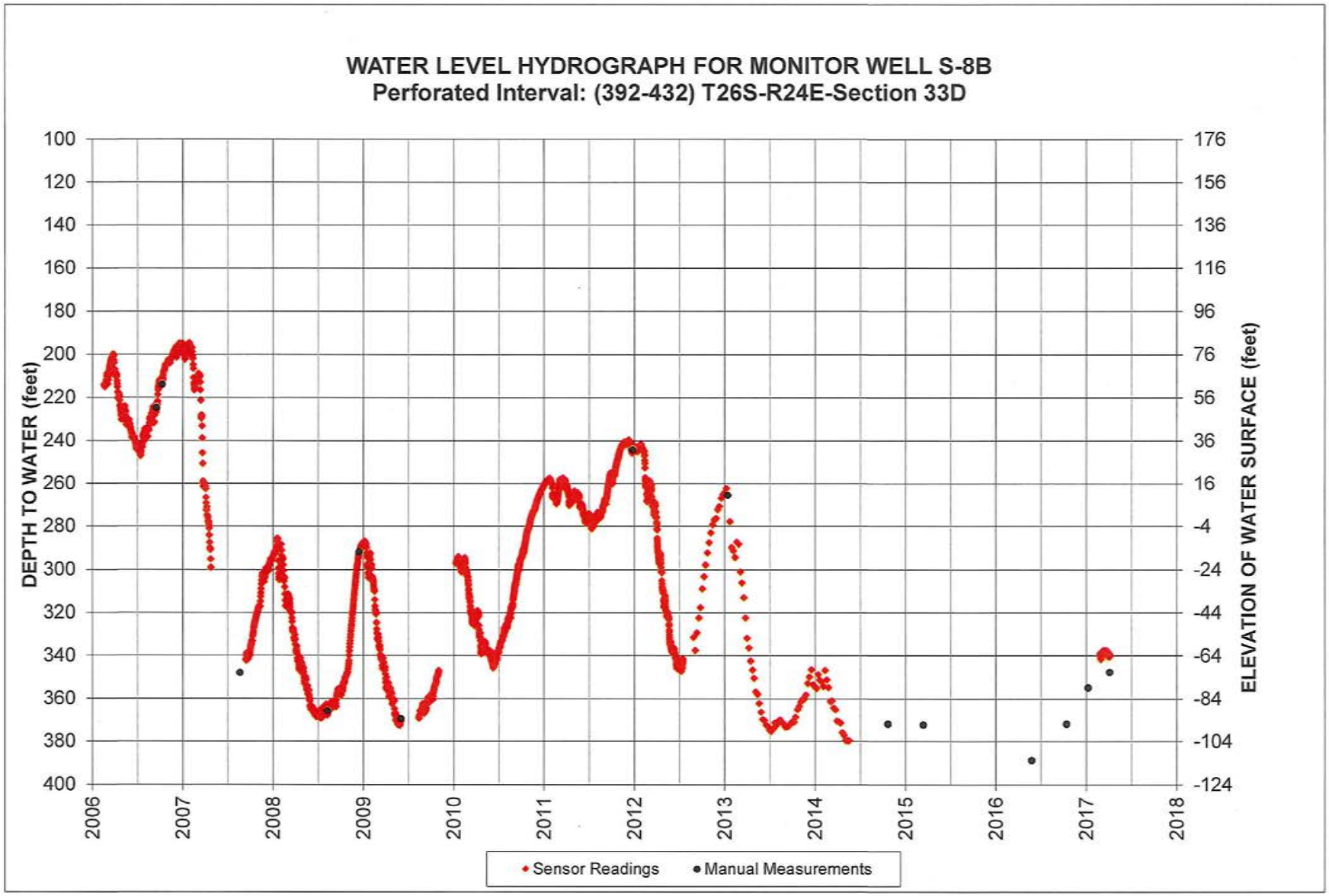
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

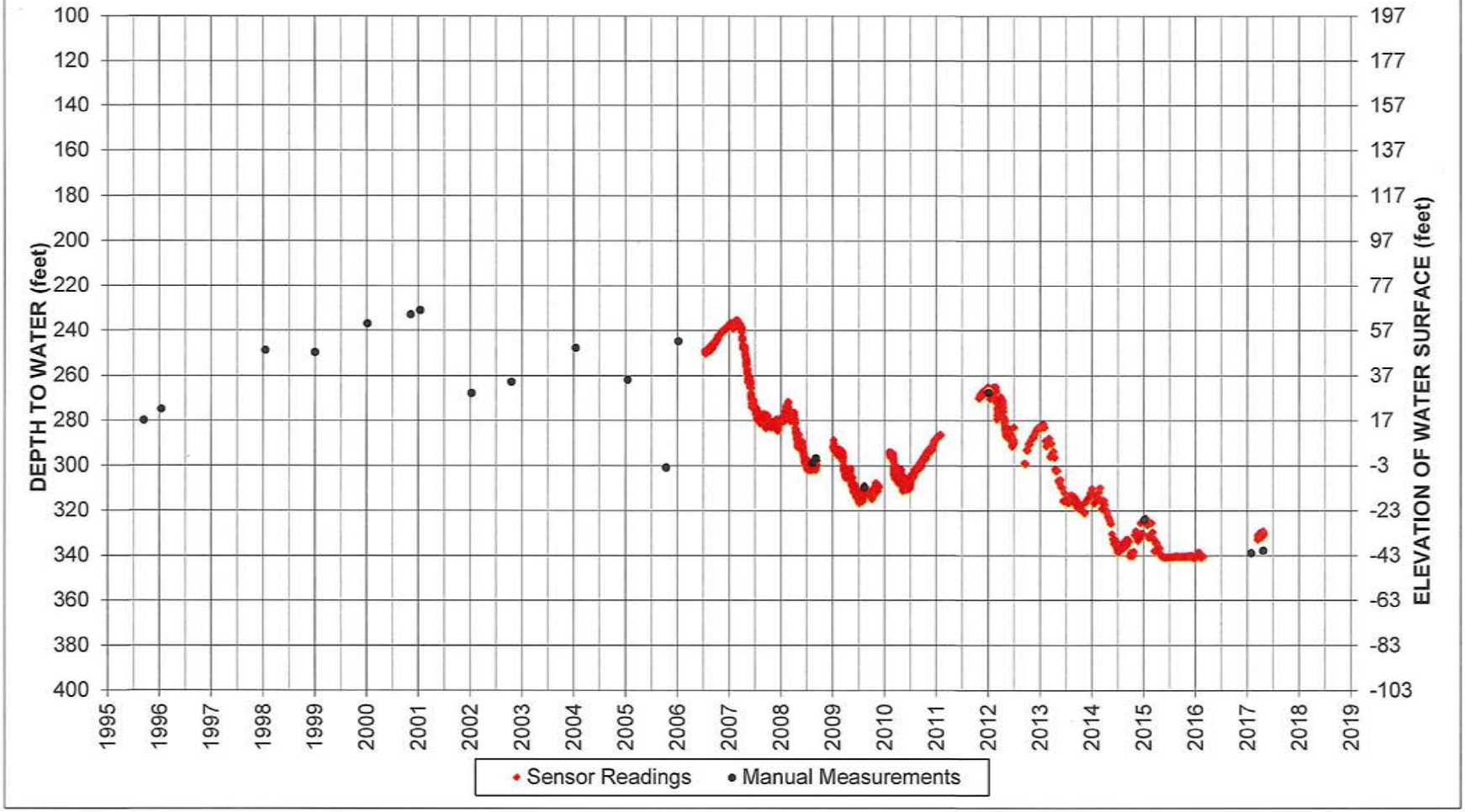
5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017

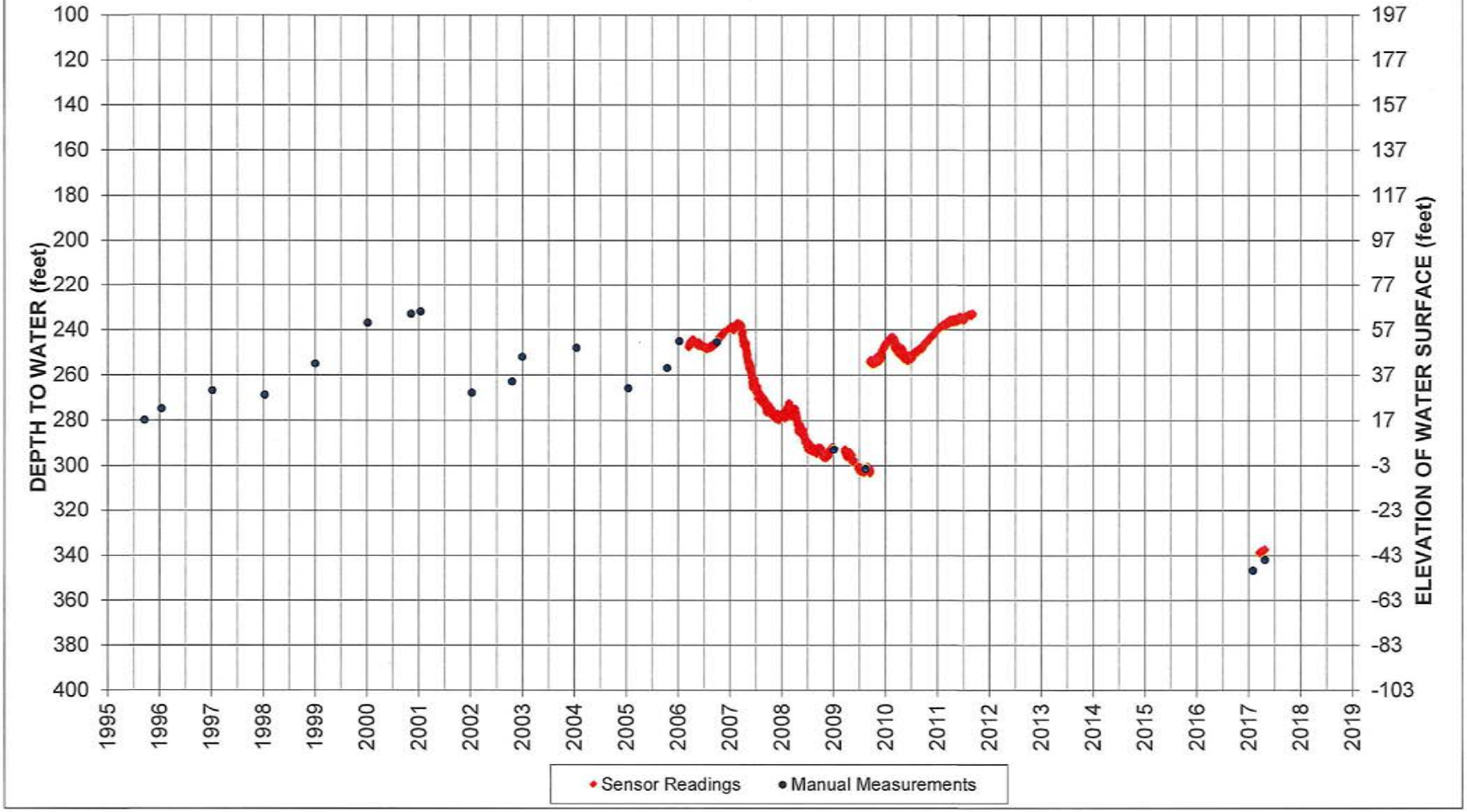
WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-9A
Perforated Interval: (660-690) T28S-R24E-Section 4L



Semitropic Water Storage District
(Manual data from the KCWA)

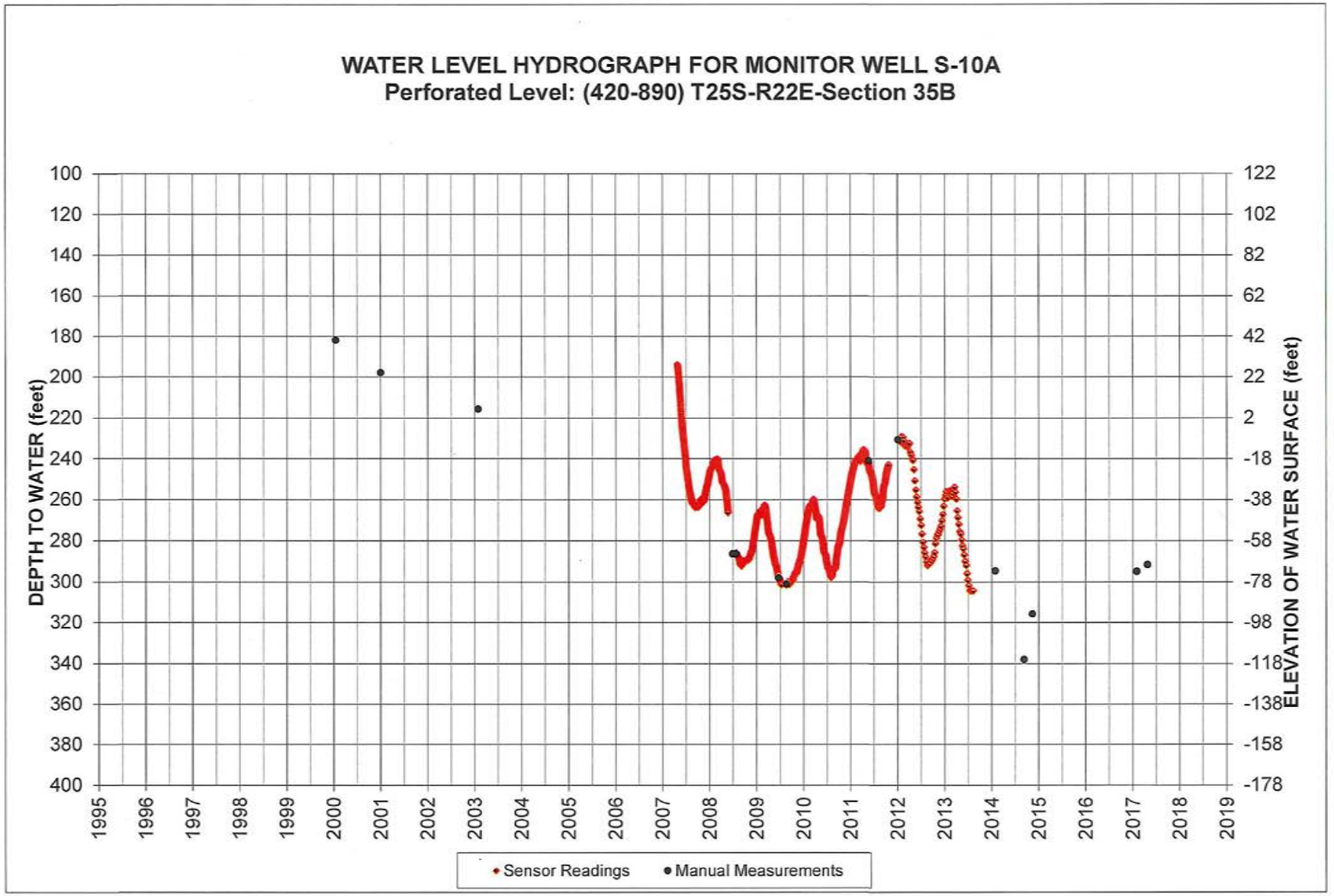
5/8/2017

WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-9B
Perforated Interval: (357-407) T28S-R24E-Section 4L



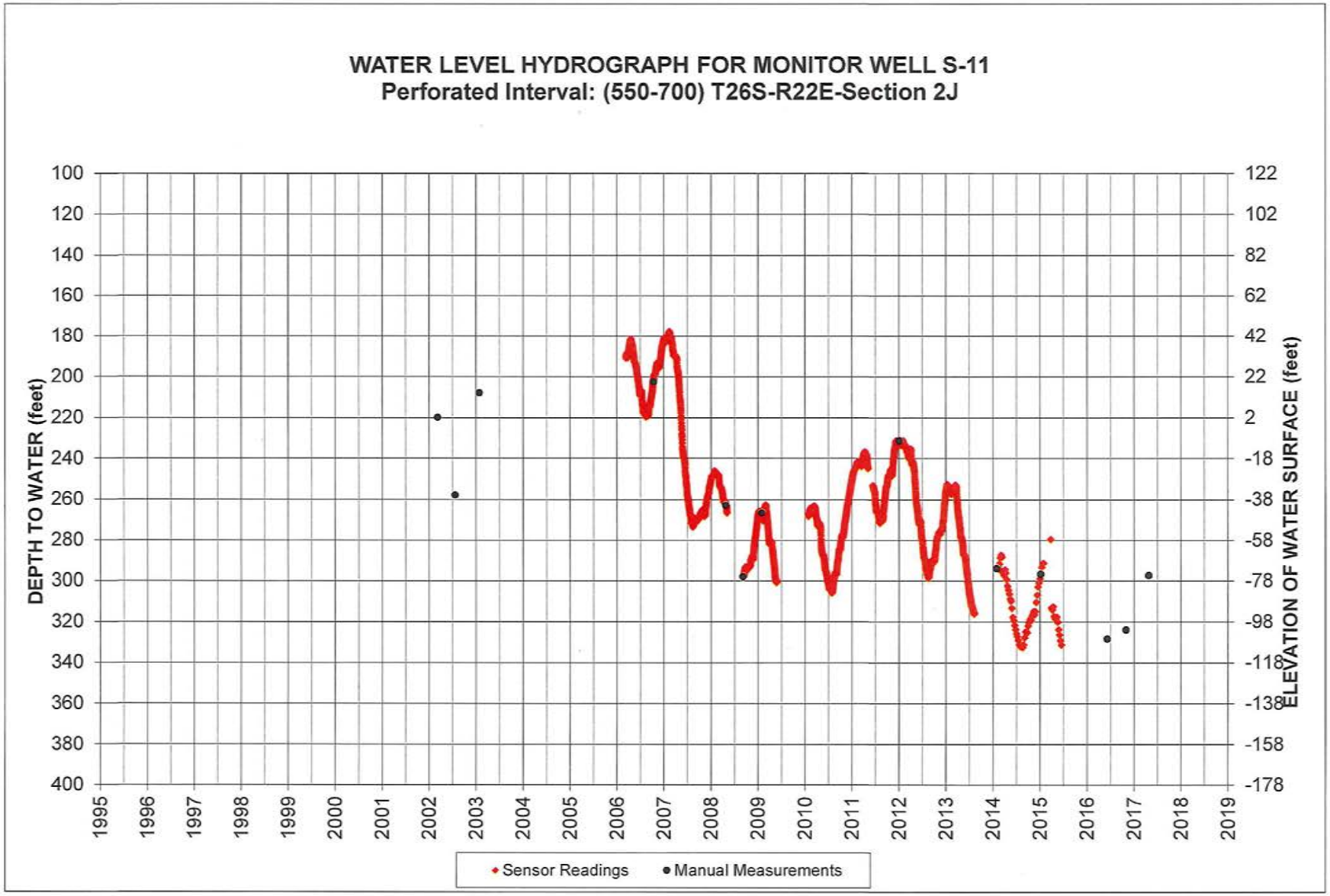
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



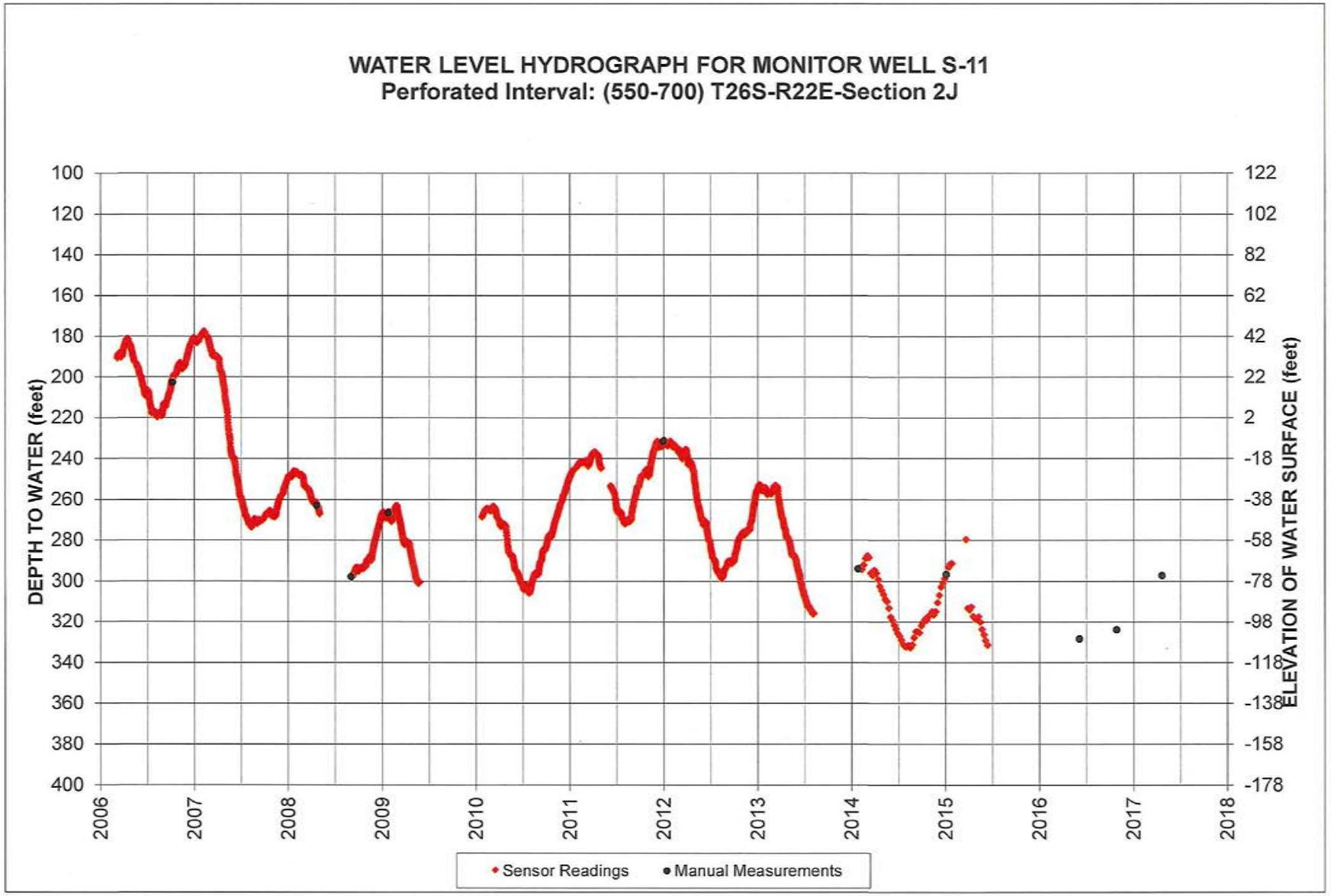
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

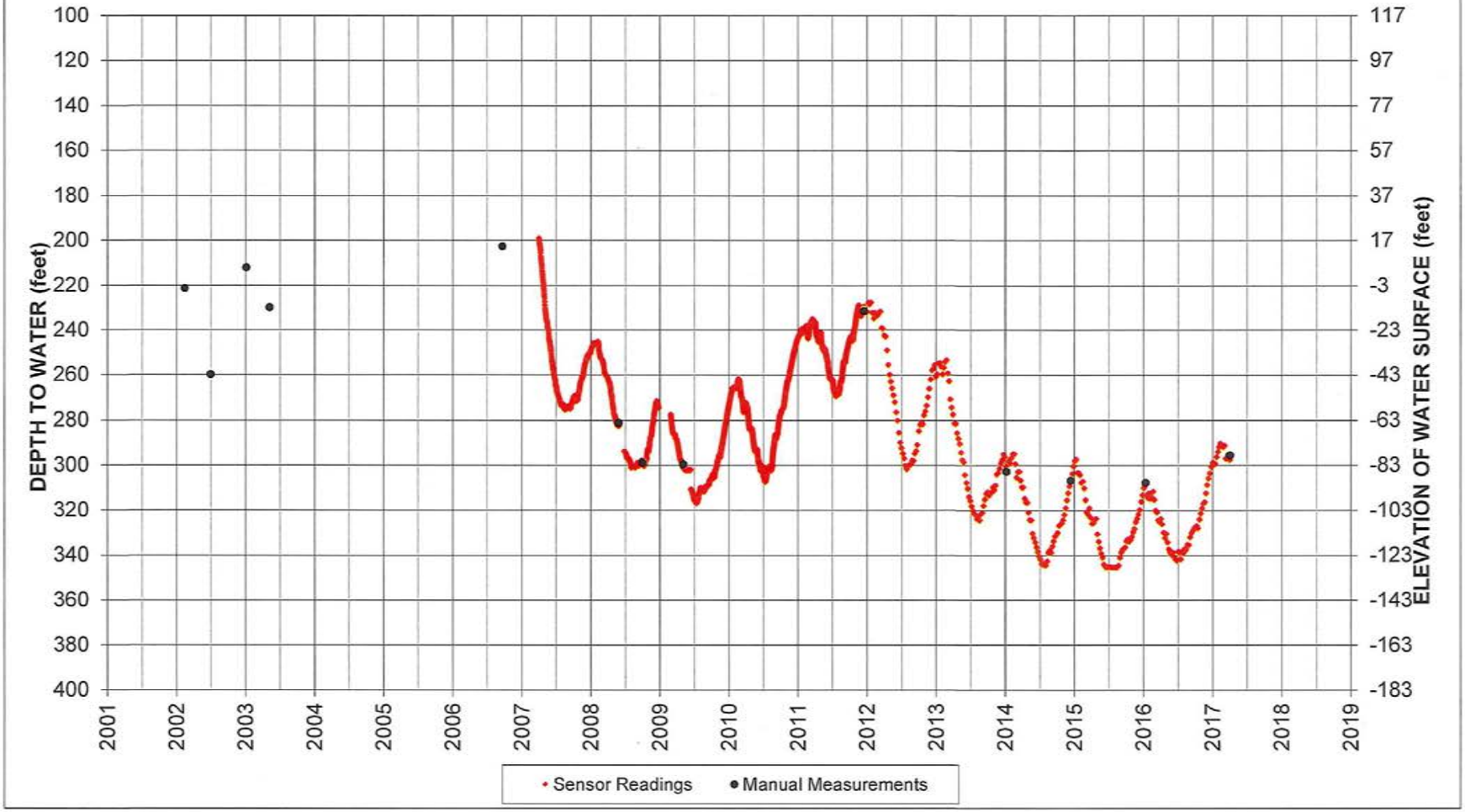
5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

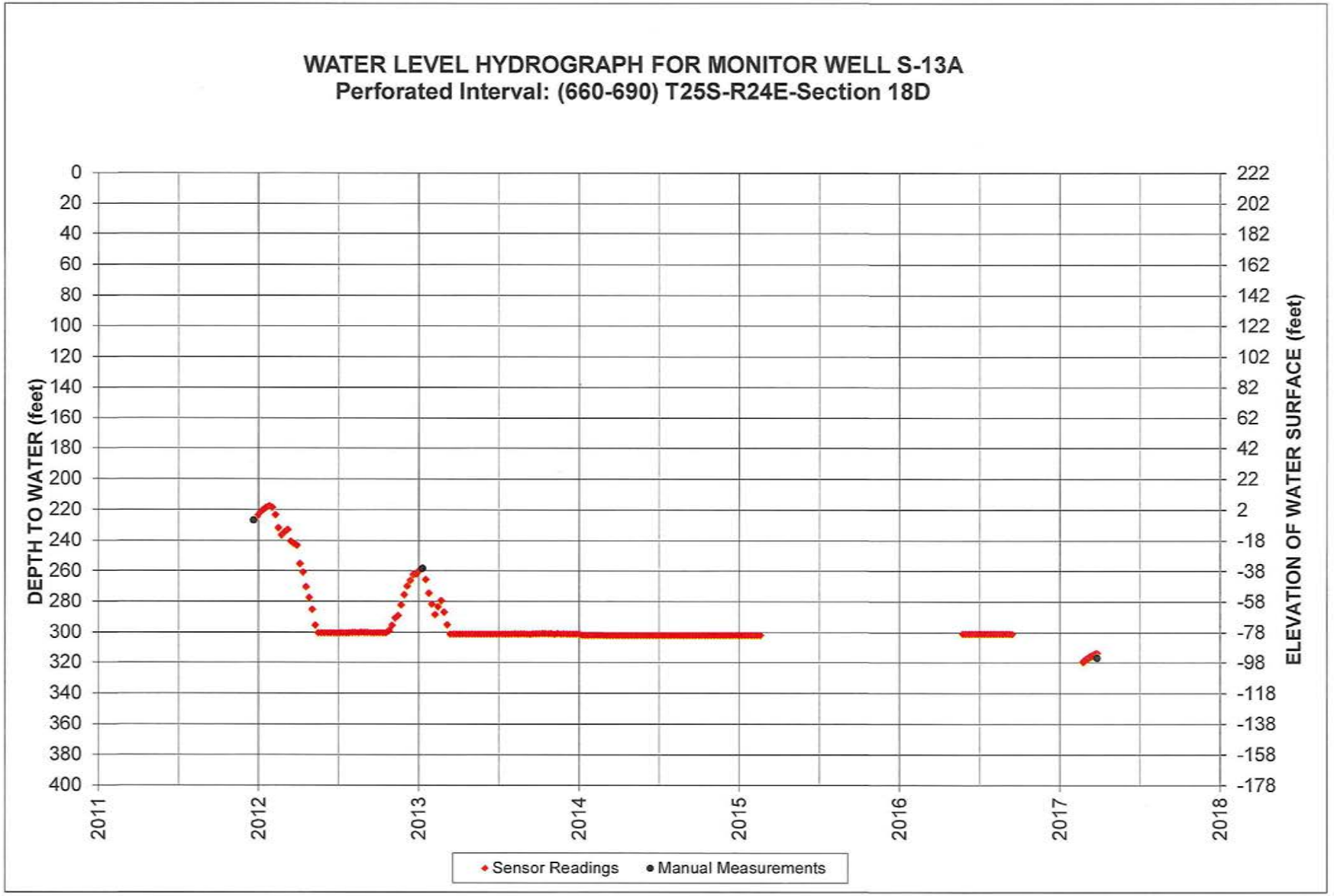
5/8/2017

WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-12
Perforated Interval: (510-740) T25S-R22E-Section 25L



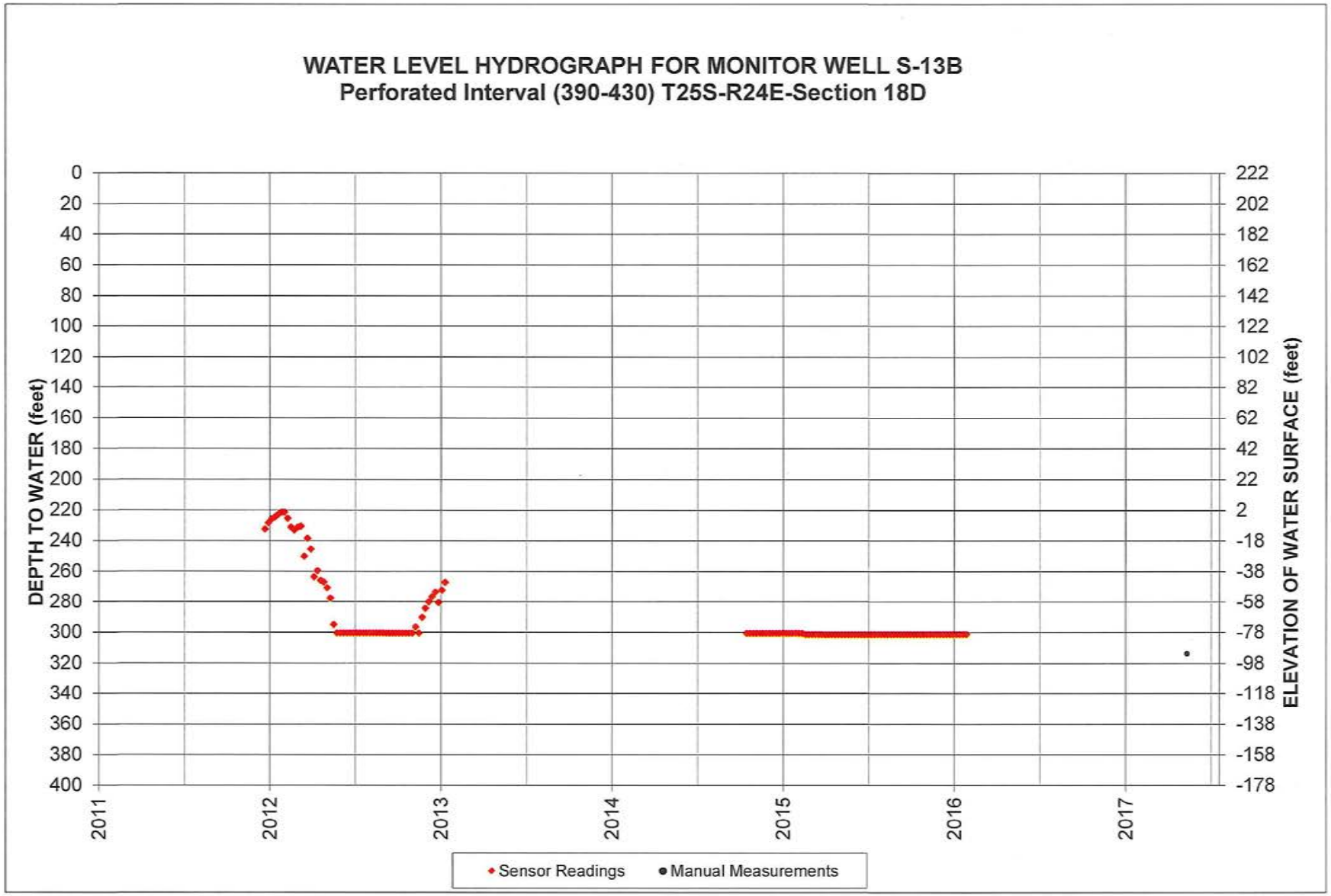
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



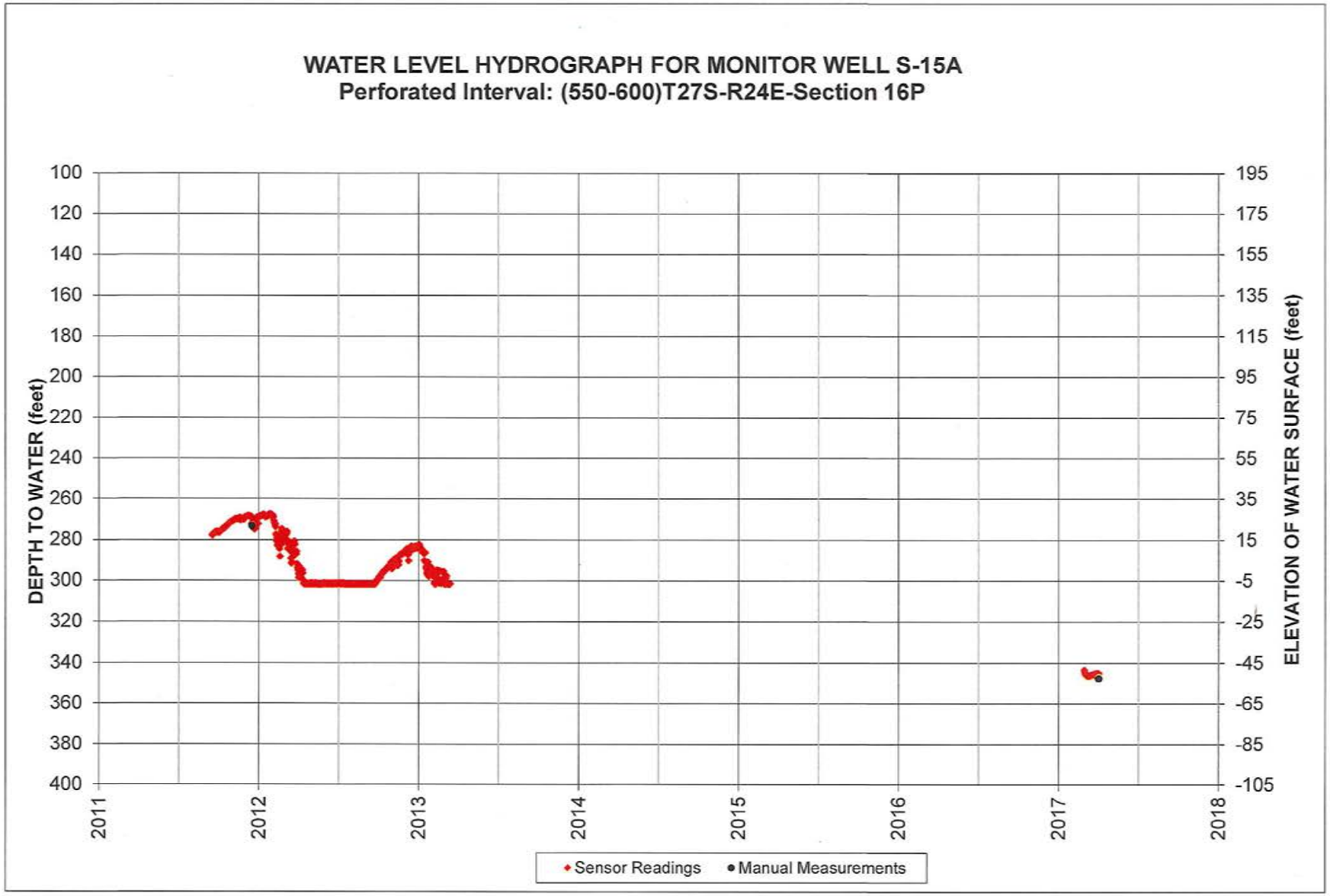
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

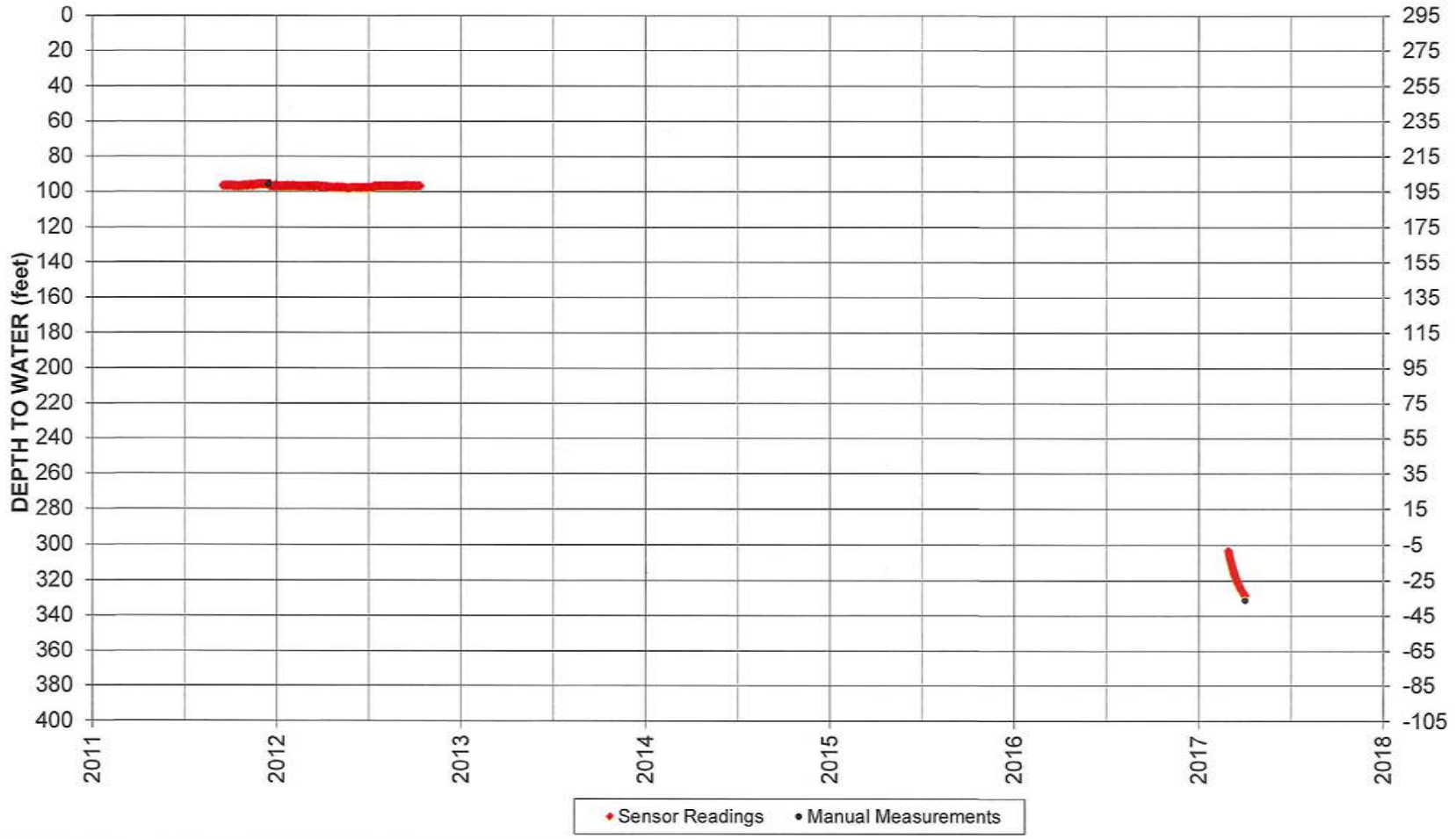
5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017

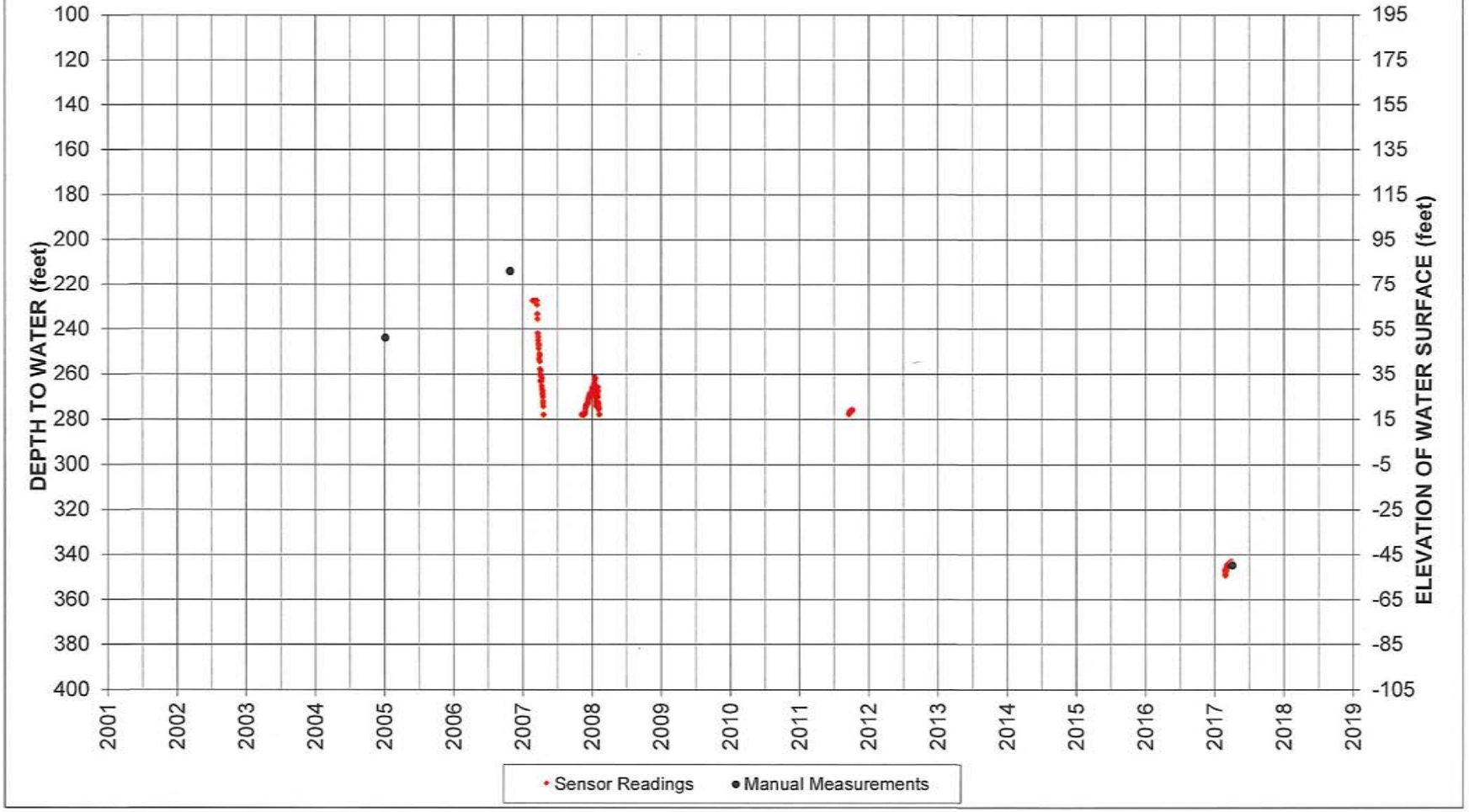
WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-15B
Perforated Interval: (400-450)T27S-R24E-Section 16P



Semitropic Water Storage District
(Manual data from the KCWA)

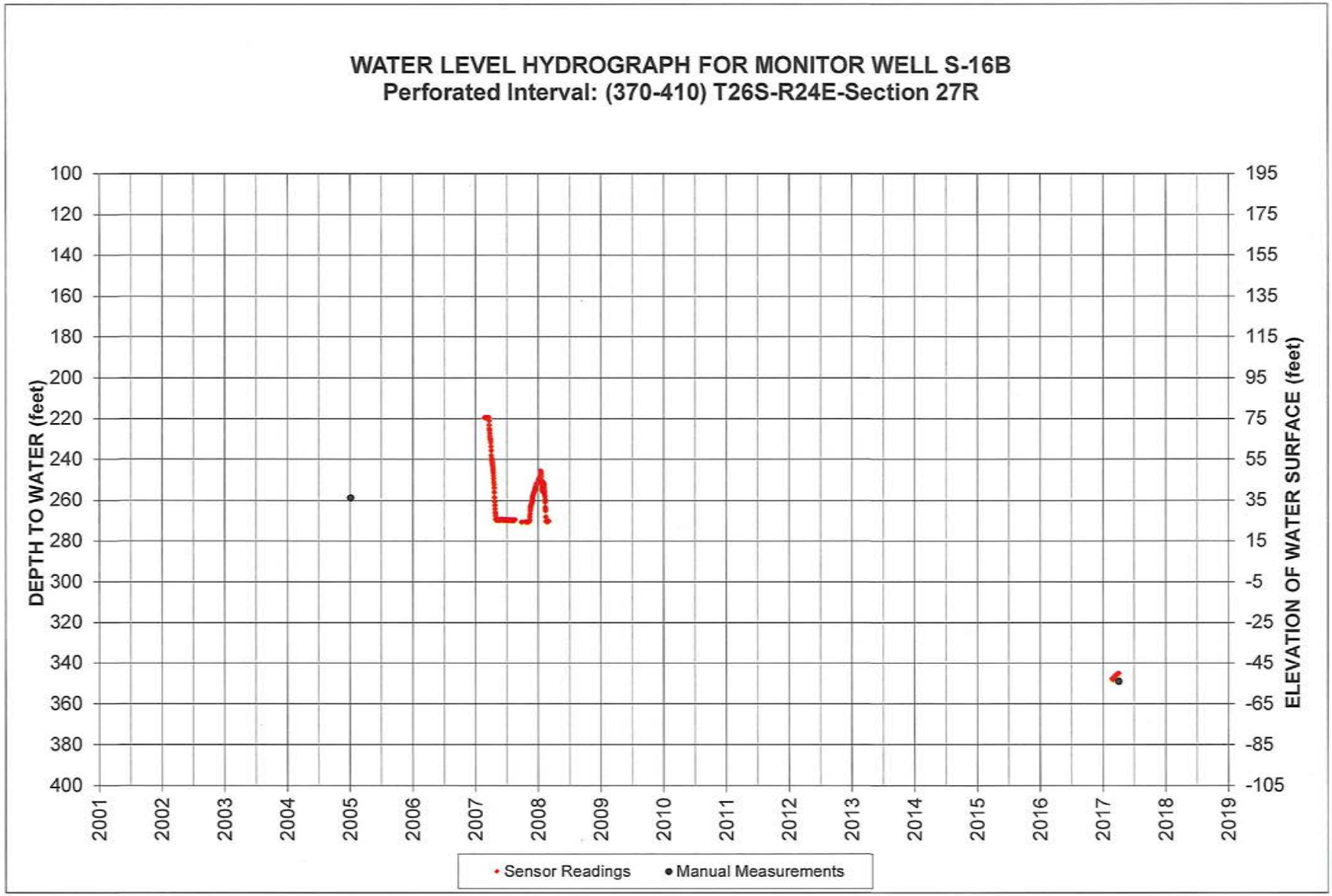
5/8/2017

WATER LEVEL HYDROGRAPH FOR MONITOR WELL S-16A
Perforated Interval: (620-670) T26S-R24E-Section 27Q



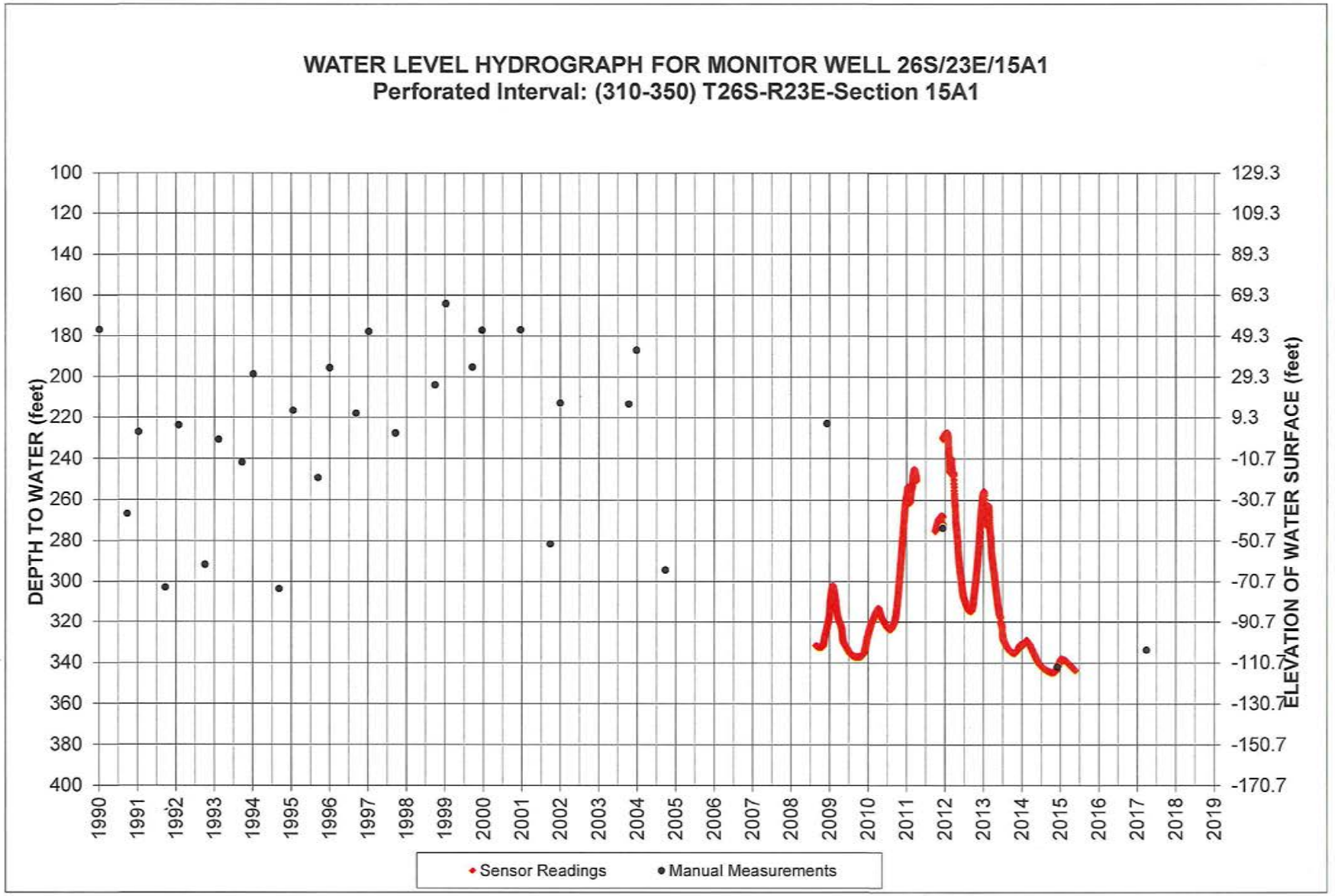
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



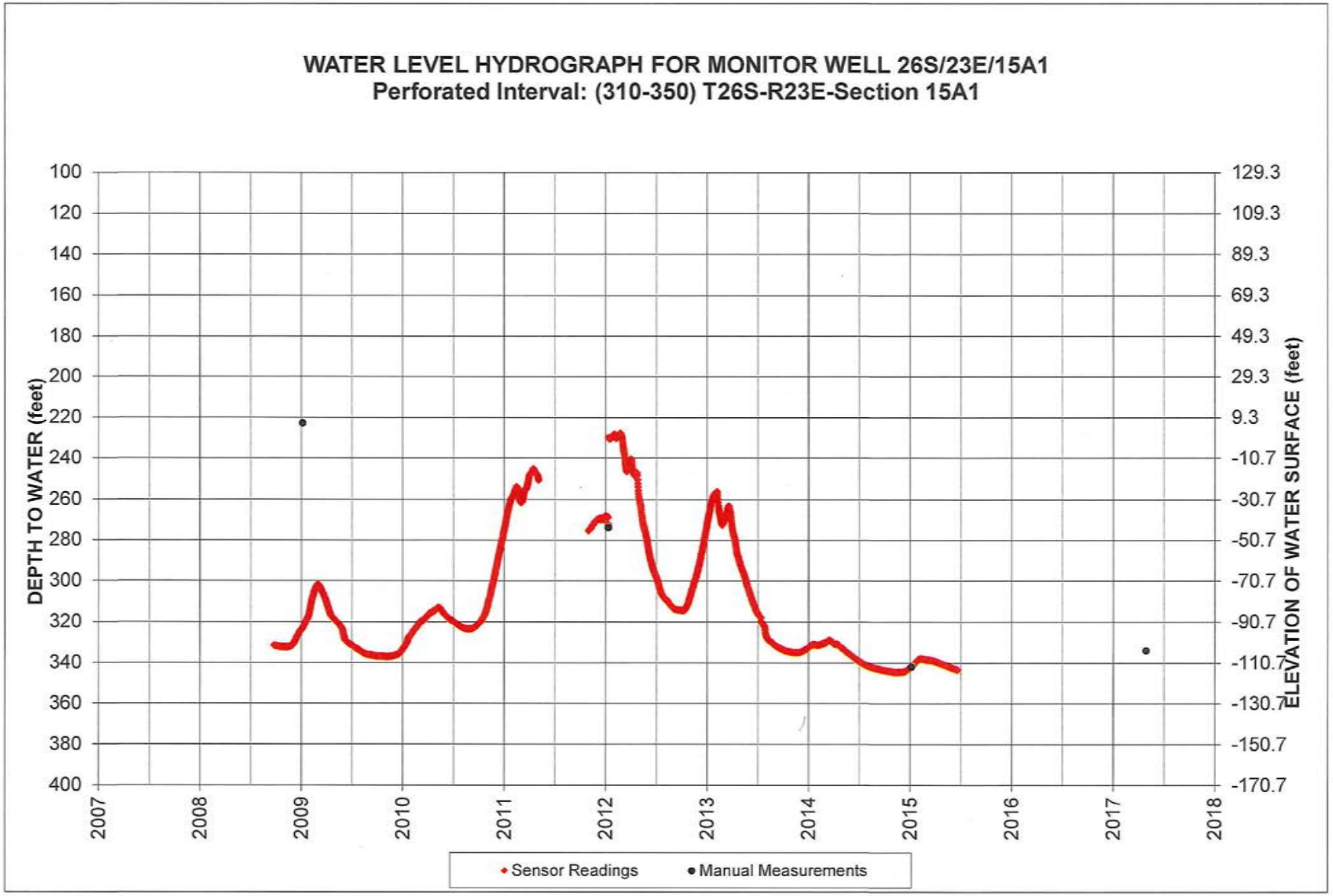
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



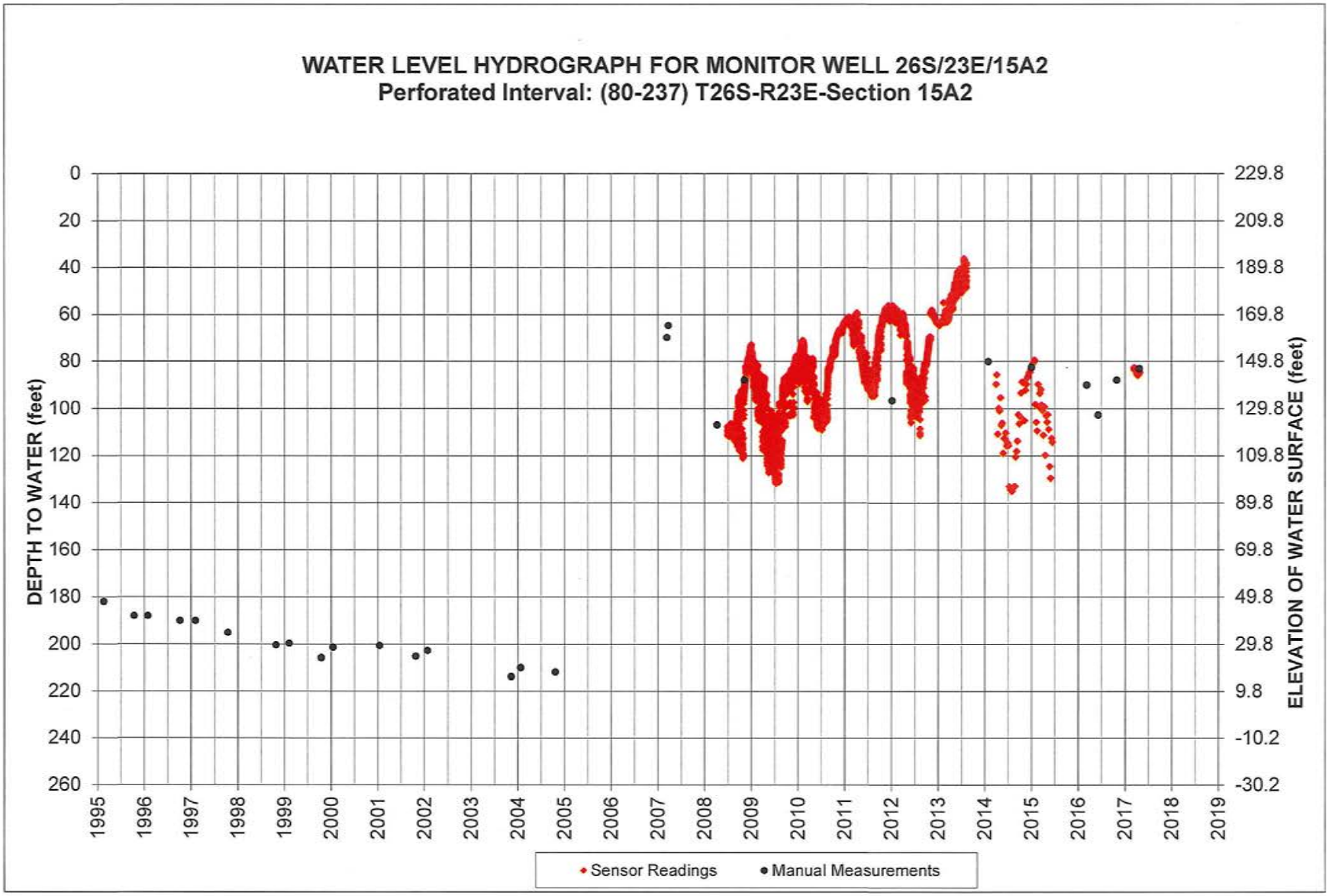
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



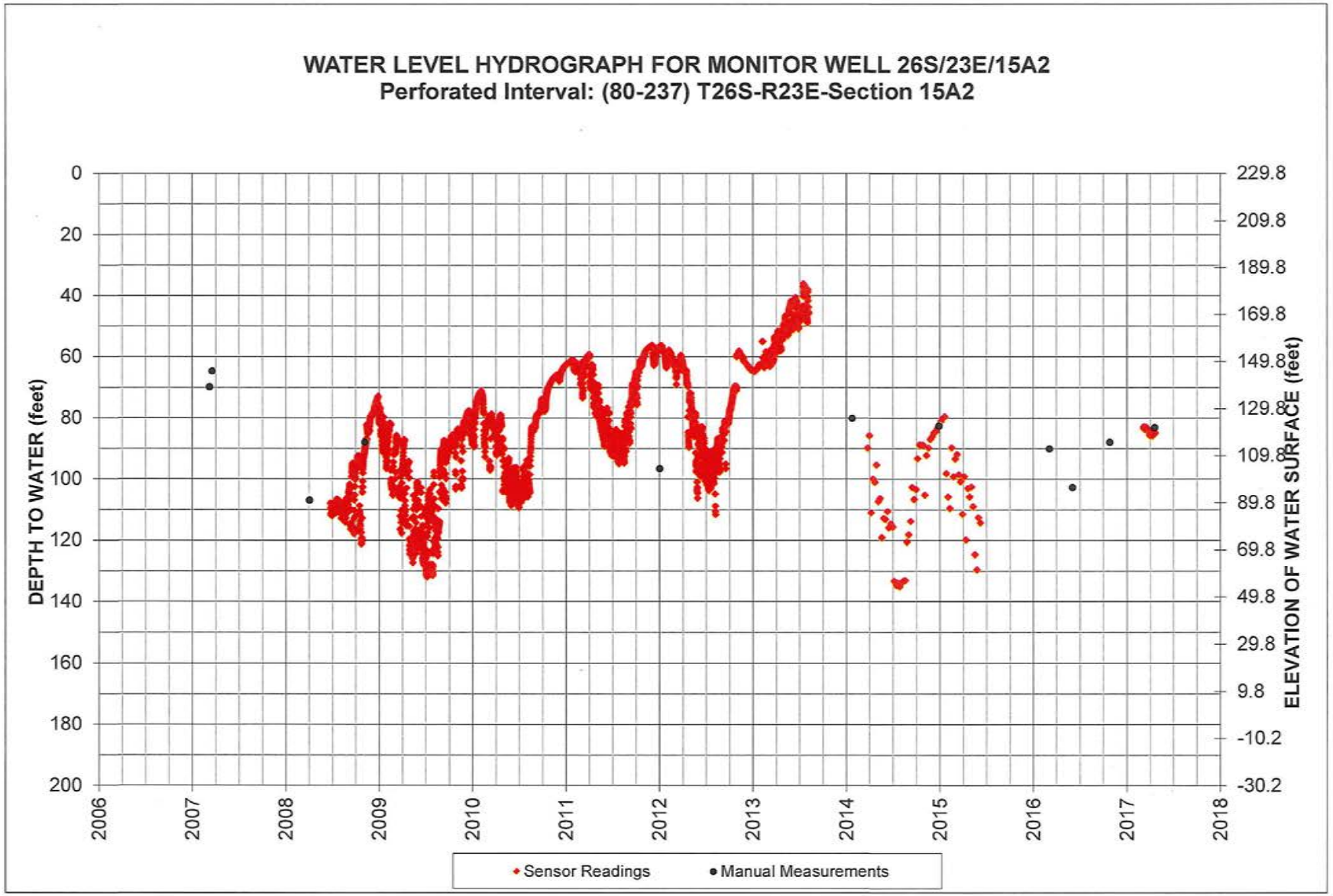
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



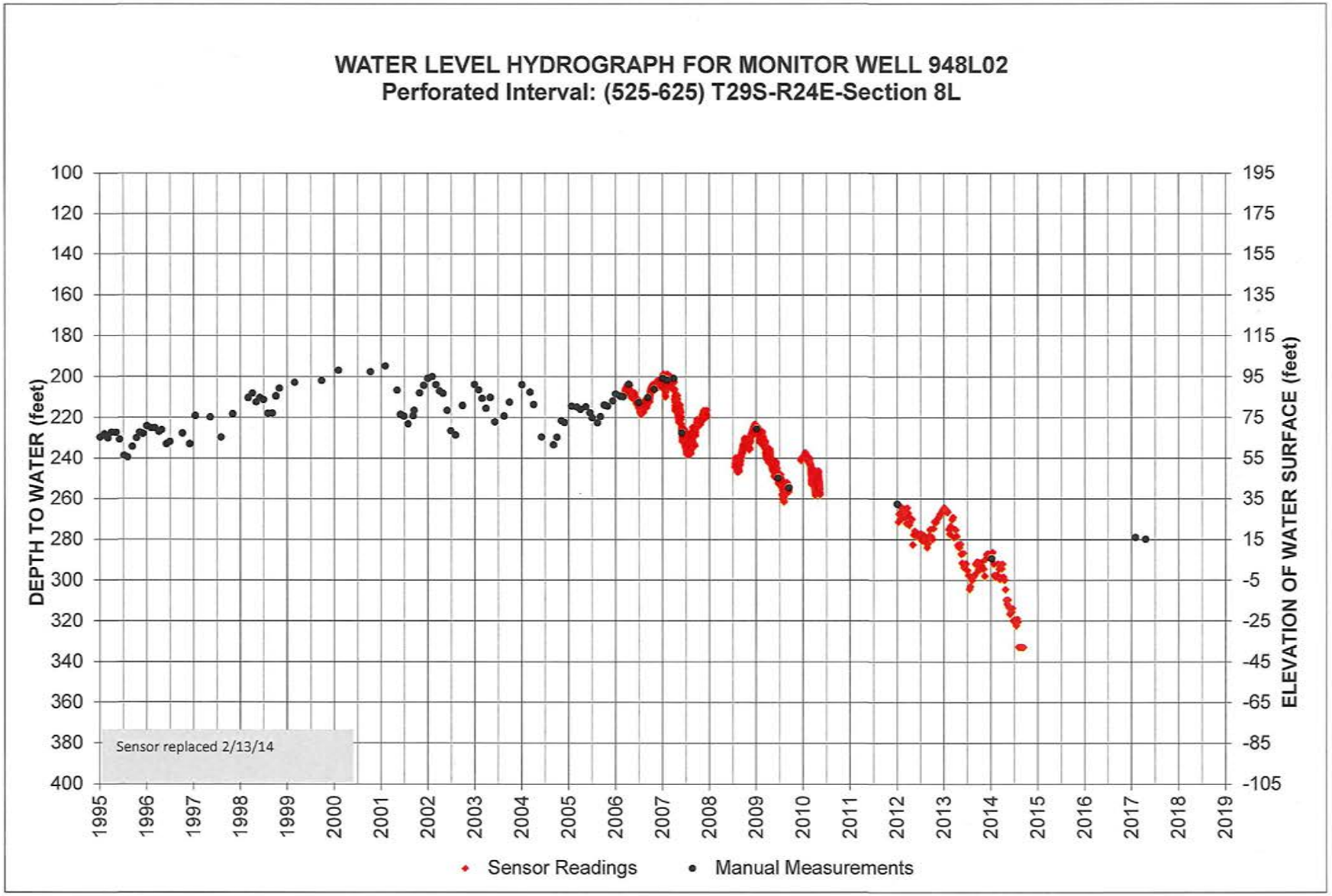
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



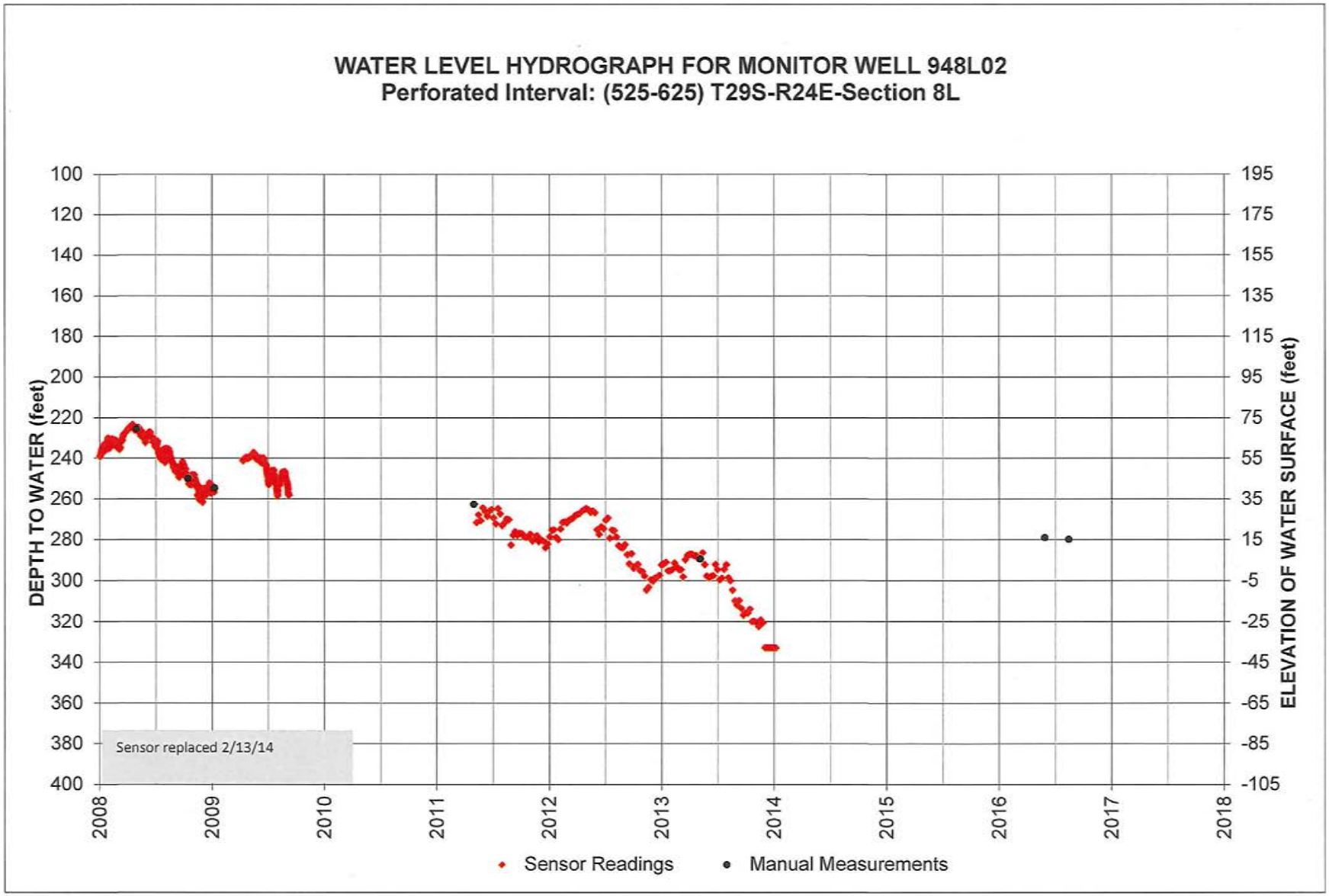
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



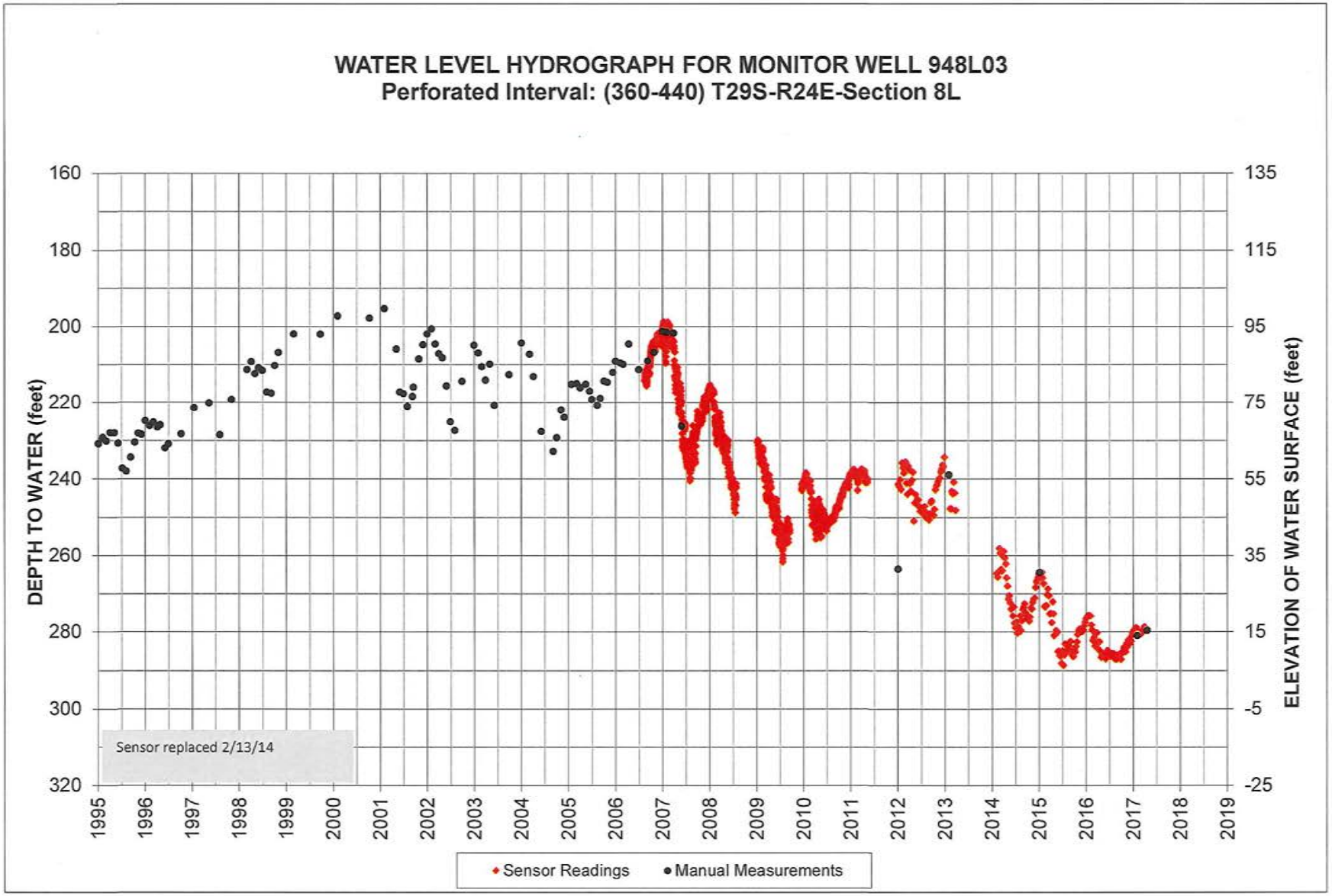
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



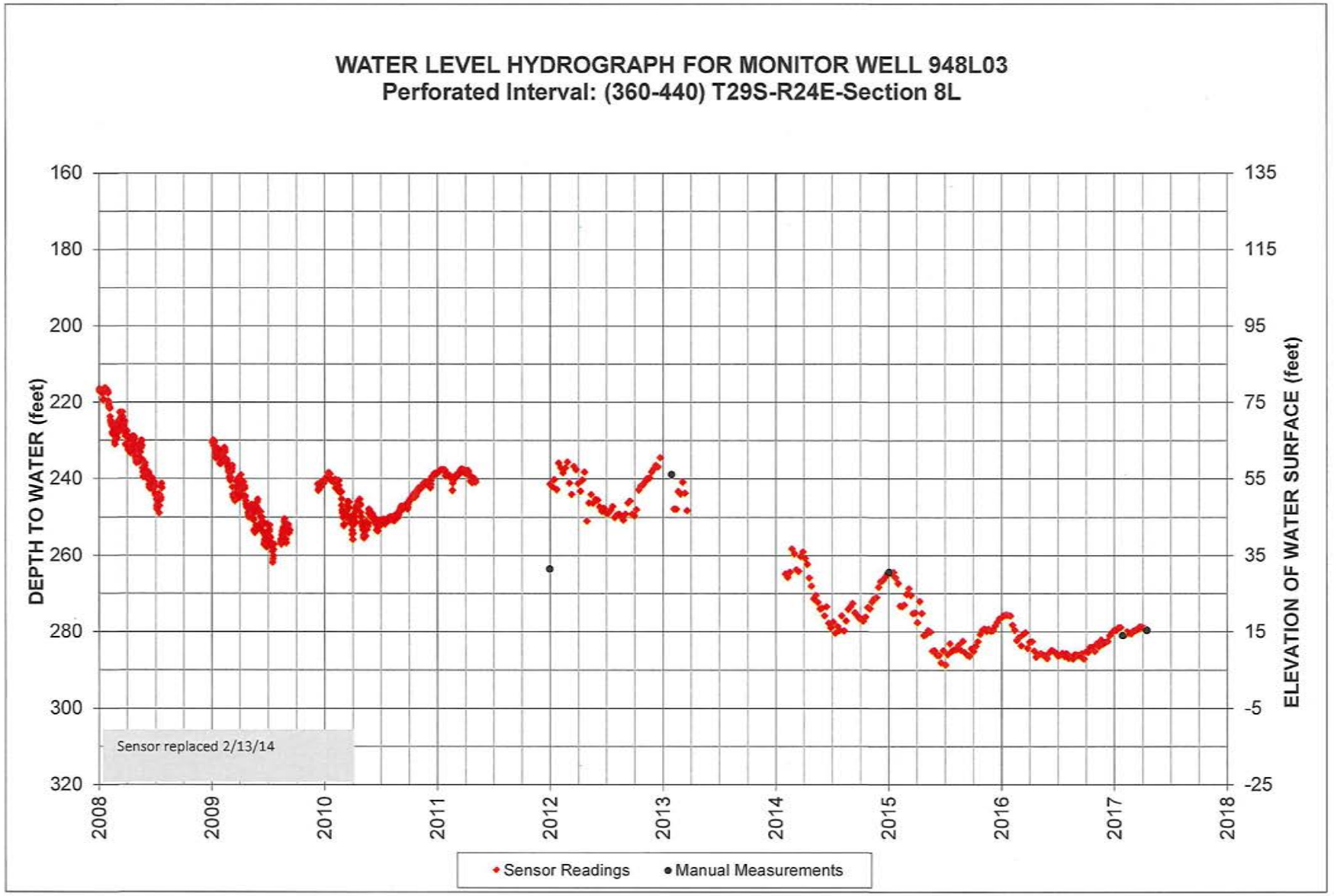
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



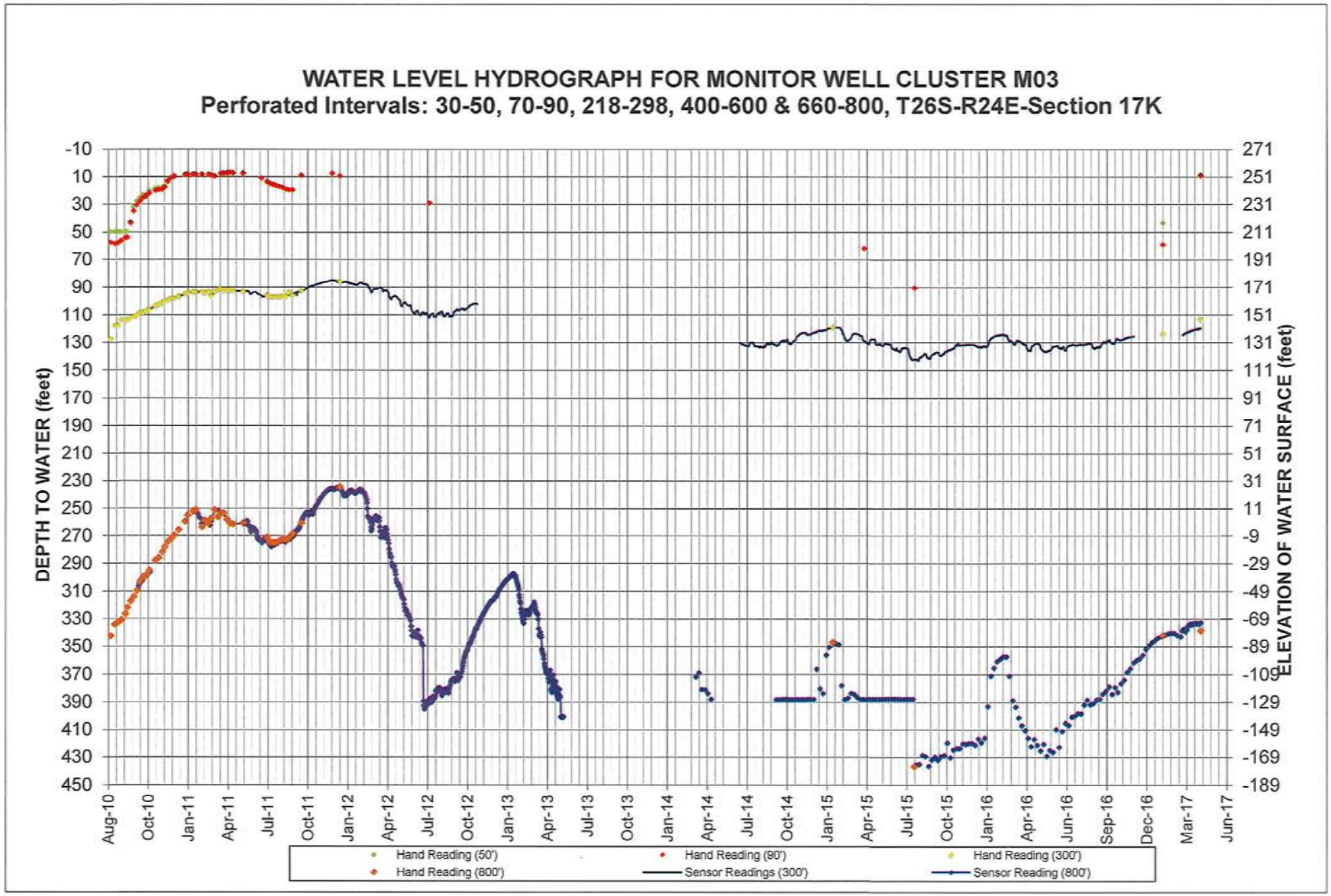
Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

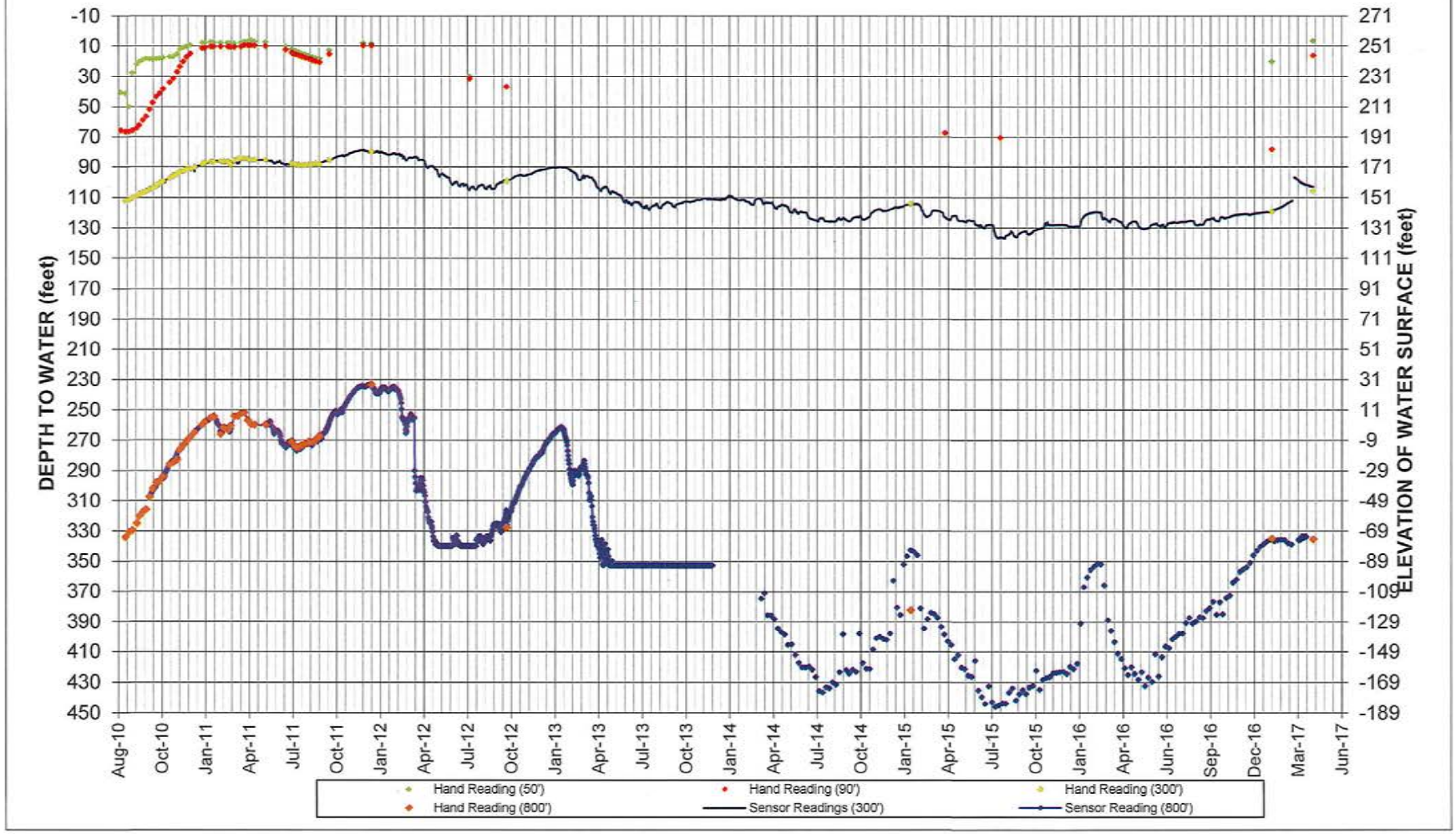
5/8/2017



Semitropic Water Storage District

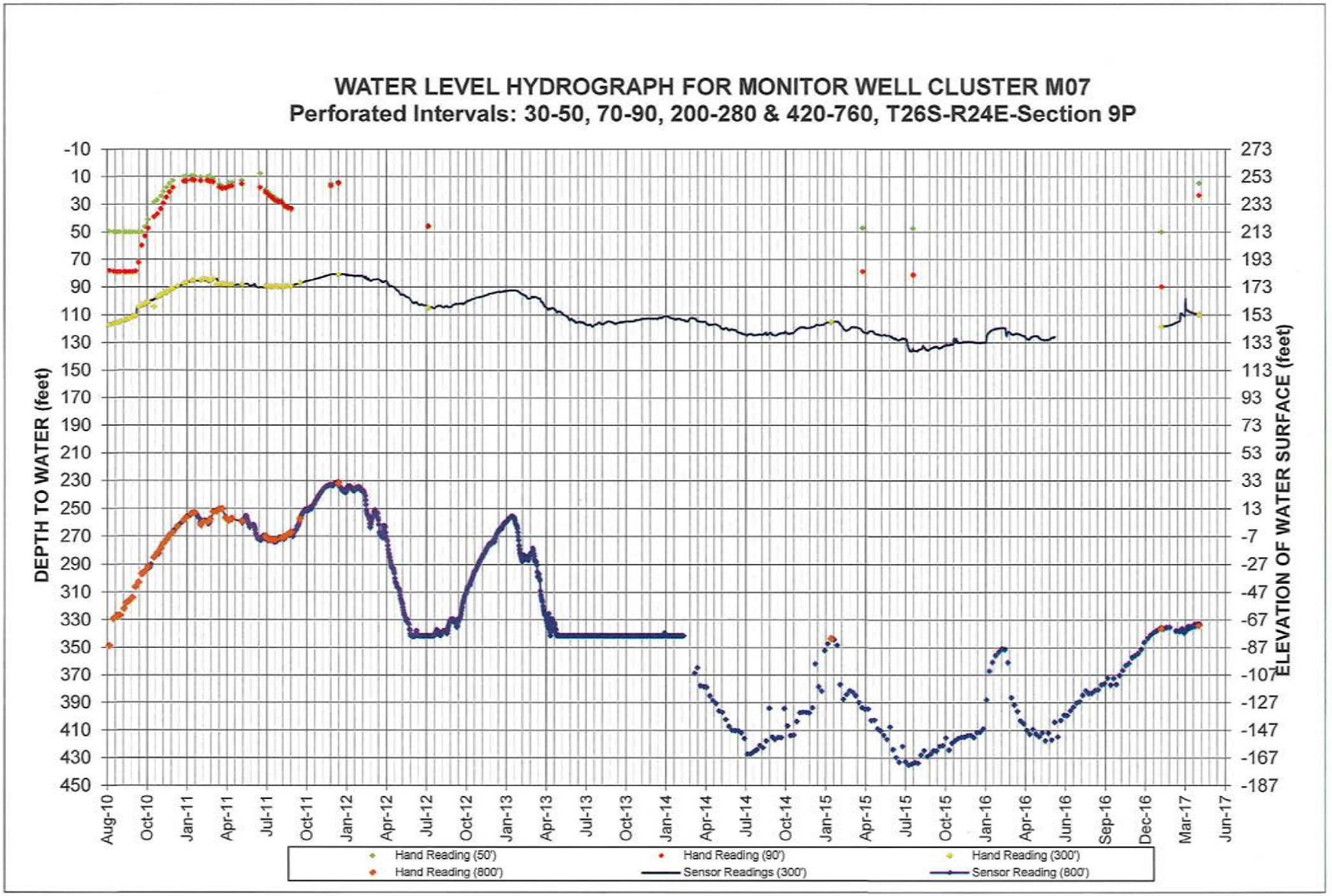
5/8/2017

WATER LEVEL HYDROGRAPH FOR MONITOR WELL CLUSTER M04
Perforated Intervals: 30-50, 70-90, 197-277 & 420-780, T26S-R24E-Section 17H



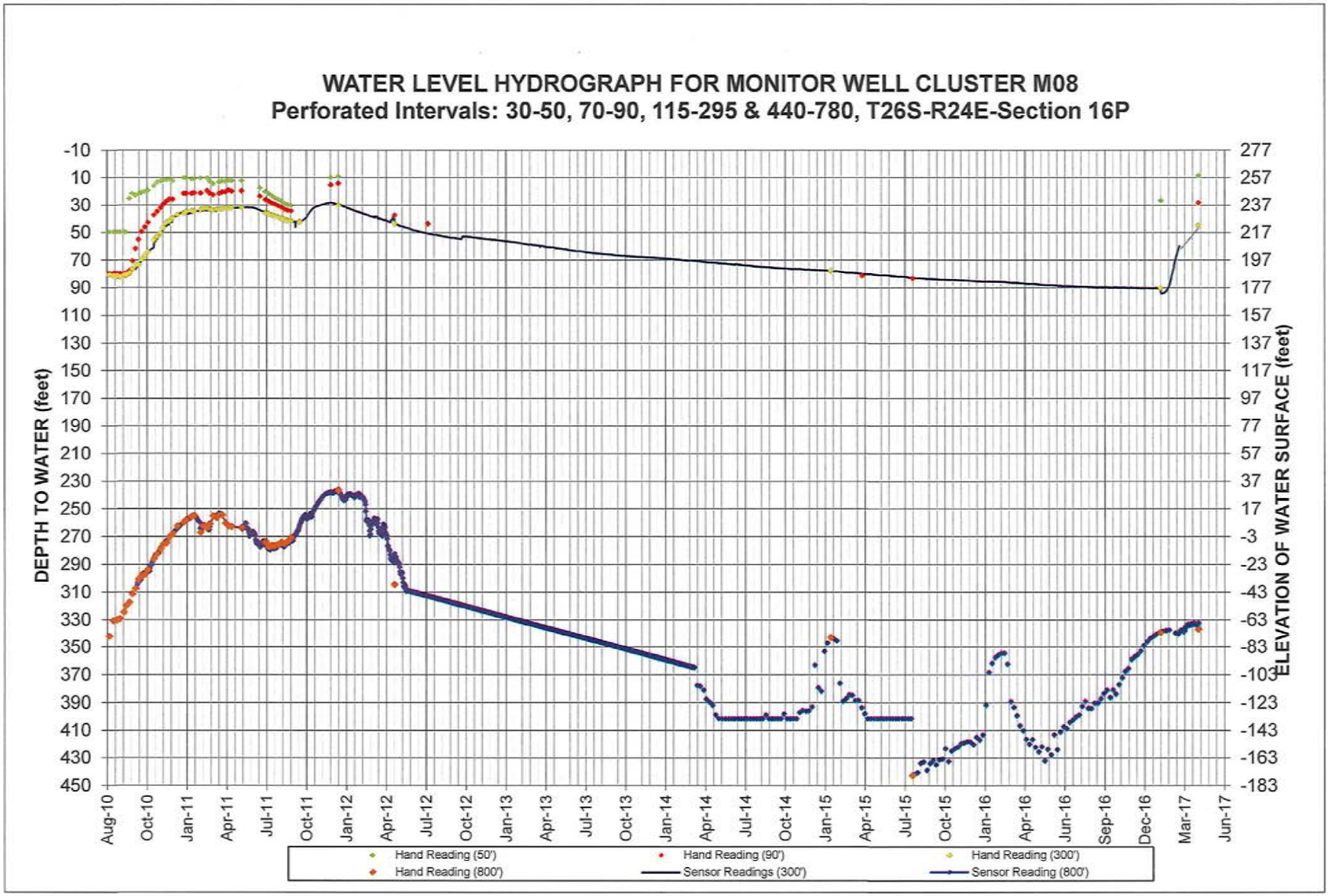
Semitropic Water Storage District

5/8/2017



Semitropic Water Storage District

5/8/2017



Semitropic Water Storage District

5/8/2017

Supply Wells

SEMITROPIC WSD

WELLS

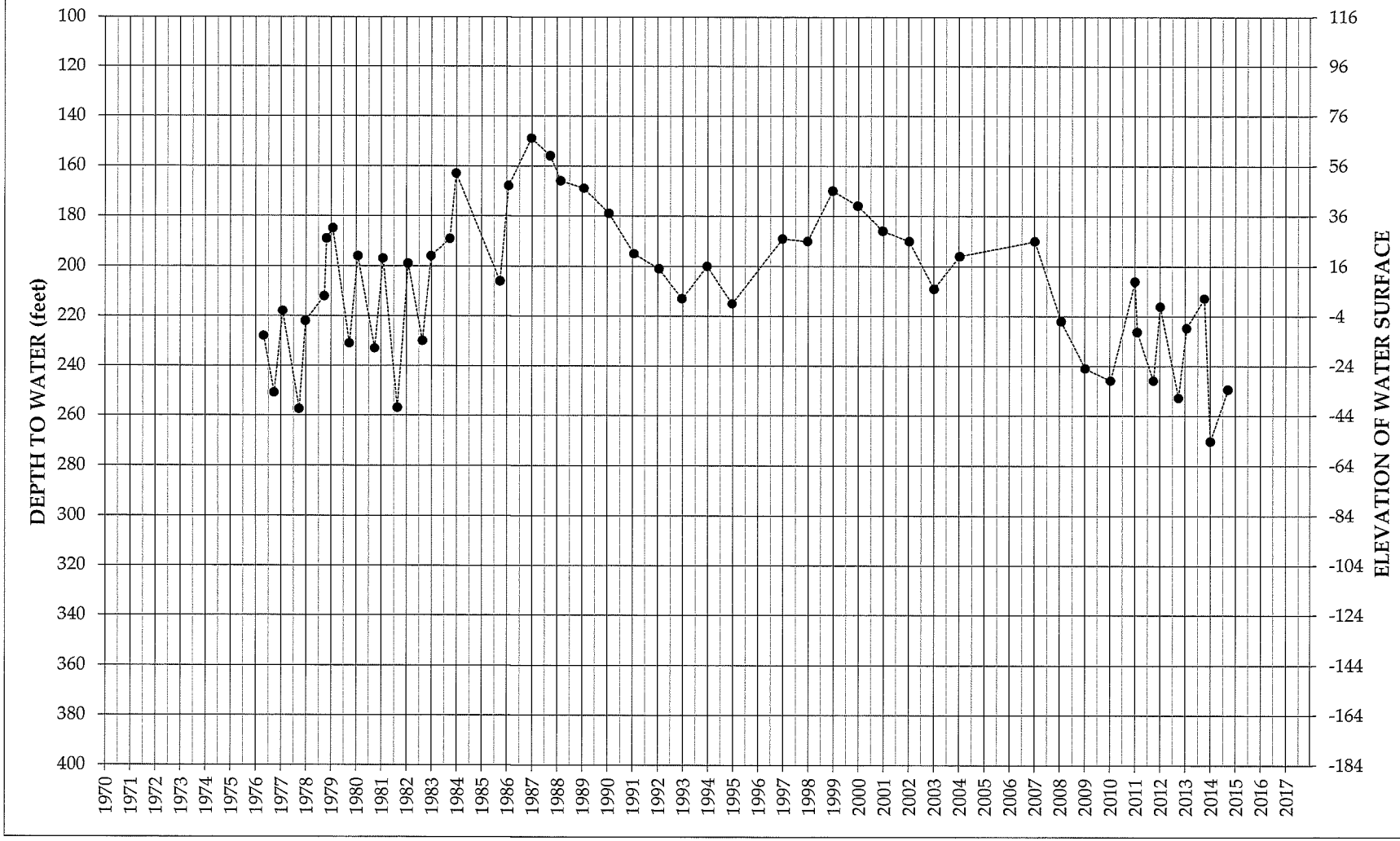
HYDROGRAPHS

Well Number		Perforated Interval		Well Type
		from	to	
25/22-15A		230	320	Private
25/22-27J		497	800	Private
25/23-3E				Private
25/23-22Q	(a)			Private
25/23-24R		499	1200	Private
25/24-2B		400	700	Private
25/24-25F		500	1200	Private
25/24-36R		404	1005	Private
26/22-14E		299	544	Private
26/22-34L	(b)	200	400	Private
26/22-35P	QM (2012 &2015)			Private
26/23-13R		450	807	Private
26/23-21Q	(b)	350	702	Private
26/24-8R		410	820	Private
26/24-9N		470	840	District
26/24-17B	(a)	450	790	District
26/24-17G		450	810	District
26/24-17R				Private
26/24-18R				Private
26/24-19R				Private
26/24-20C	(a)	440	830	District
26/24-20M		440	820	District
26/24-23R		300	472	Private
26/24-27H		450	805	Private
26/24-29D	(a)	460	830	District
26/24-29M	(a)	410	910	District
26/24-31B				District
26/24-31E	(a)			District
27/22-12G	(a)	219	416	Private
27/22-13R				District
27/22-24H				District
27/22-24R				District
27/22-25D	(a)	242	516	District

27/22-25J		262	565	District
27/23-4H02		300	600	Private
27/23-10J		442	633	District
27/23-12A				District
27/23-15G01		371	602	Private
27/23-16N		300	600	Private
27/23-20R				District
27/23-26P	(a)	350	750	Private
27/23-28A	(a)	200	625	Private
27/23-29C				District
27/23-30A		204	484	District
27/23-33J		300	840	Private
27/24-5H		260	730	Private
27/24-6F		400	700	Private
27/24-16P		350	716	Private
27/24-20K	(a)	300	700	Private
27/24-31D01				Private
27/24-33A		230	374	Private
28/22-1H				Private
28/23-7H		300	495	Private
28/23-11R		288	510	Private
28/23-16G		240	416	Private
28/23-22F		413	645	District
28/23-26F		420	690	District
28/23-27A				District
28/23-34K	(a)	226	459	Private
28/23-35A	(a)	400	670	District
28/24-4C				Private
28/24-10R				Private
28/24-28A		204	504	Private
28/24-32N	(a)	68	420	Private
29/23-12J		150	504	Private

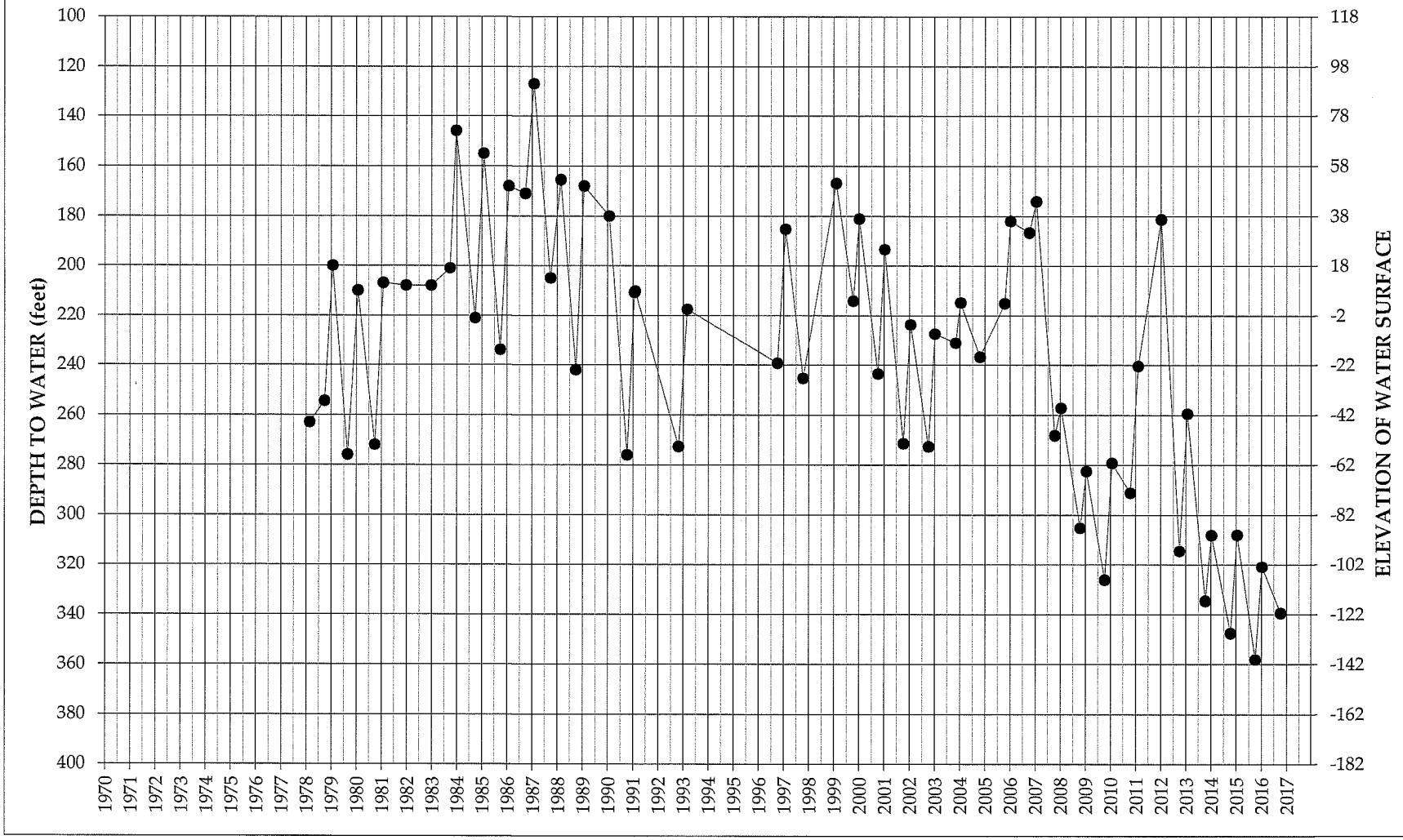
(a) Not included for lack of "recent" or anomalous data.
QM – Questionable Measurements.

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/22-15A (230-320)



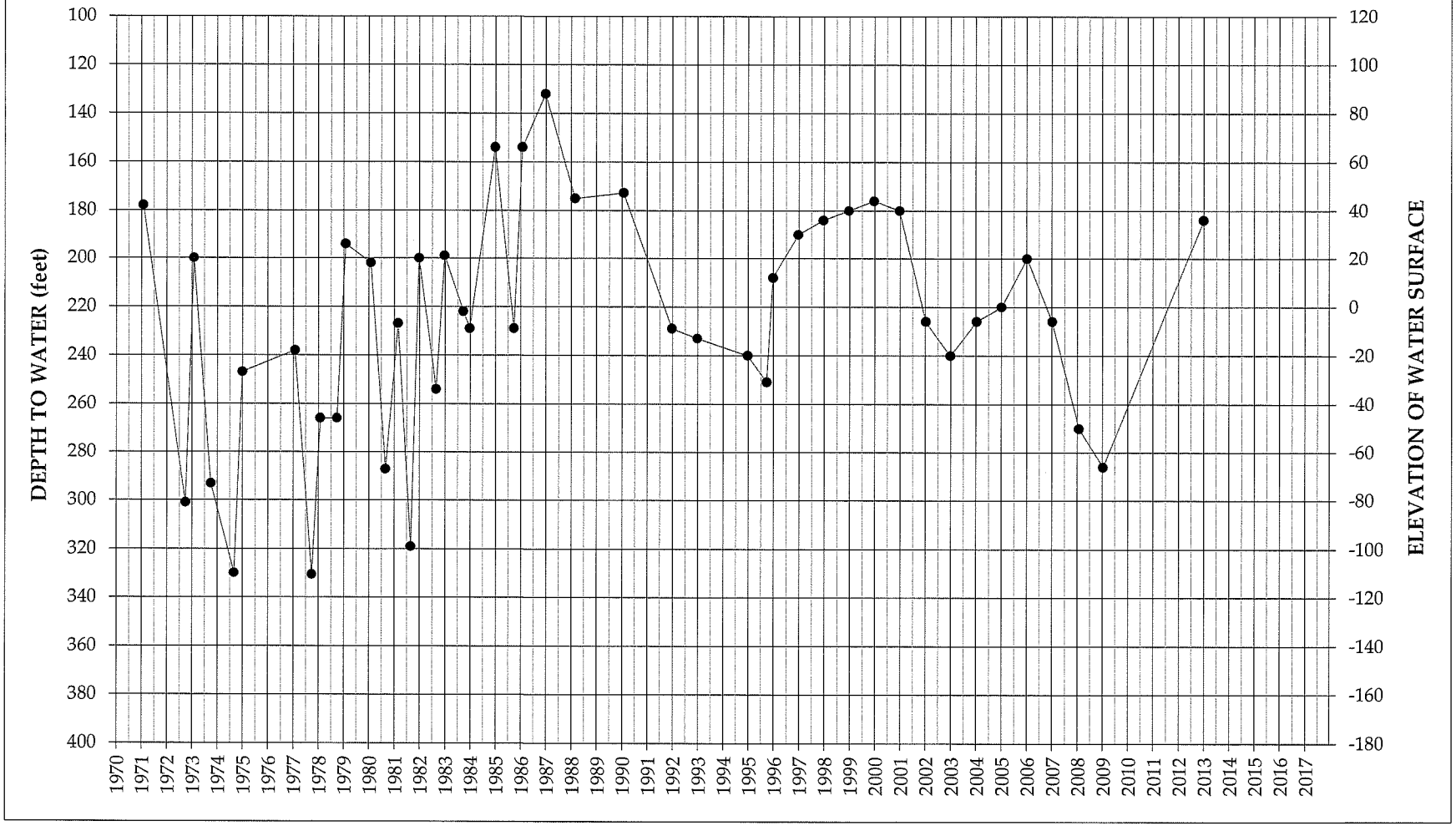
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/23-3E



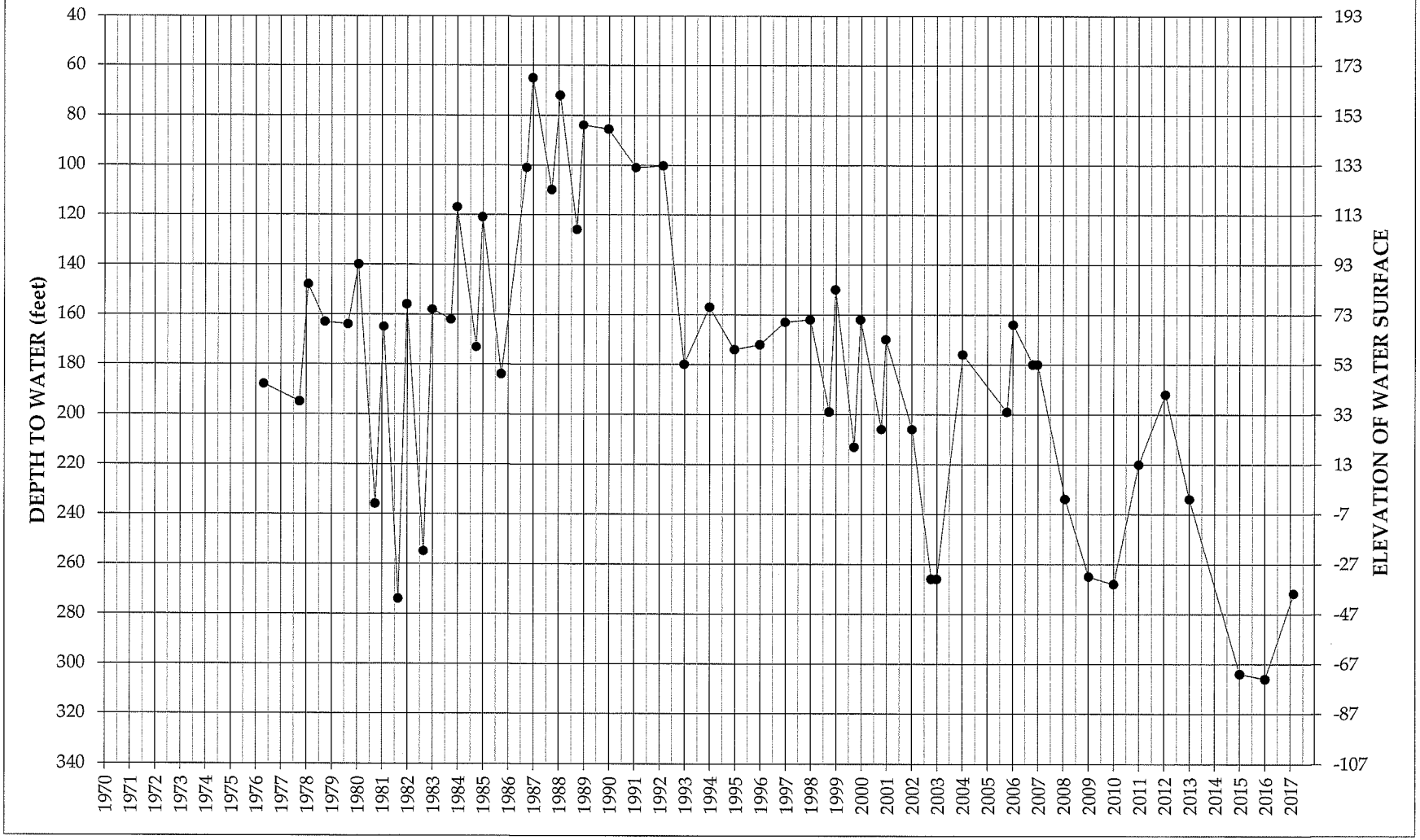
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/23-24R (499-1200)

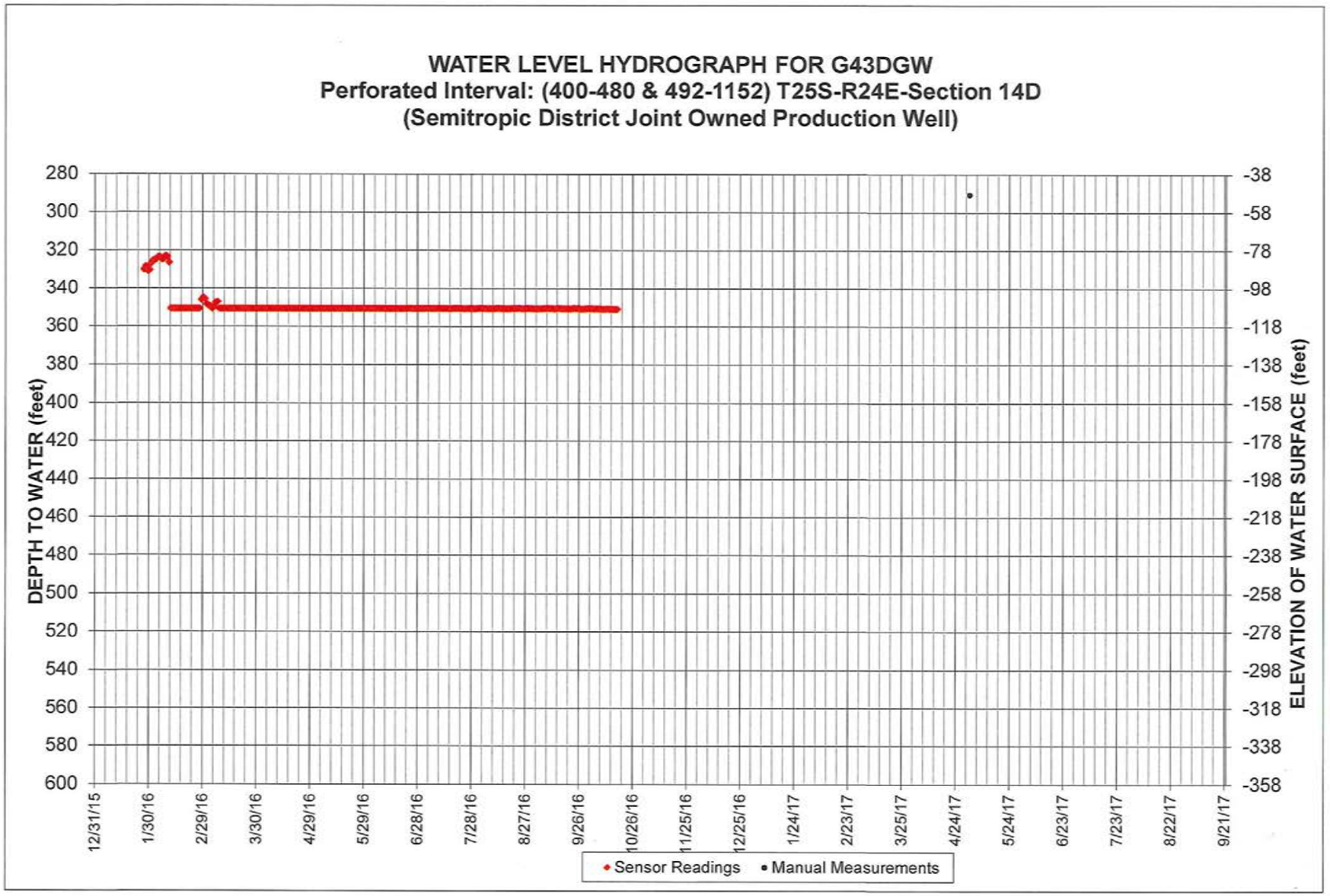


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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/24-2B (400-700)

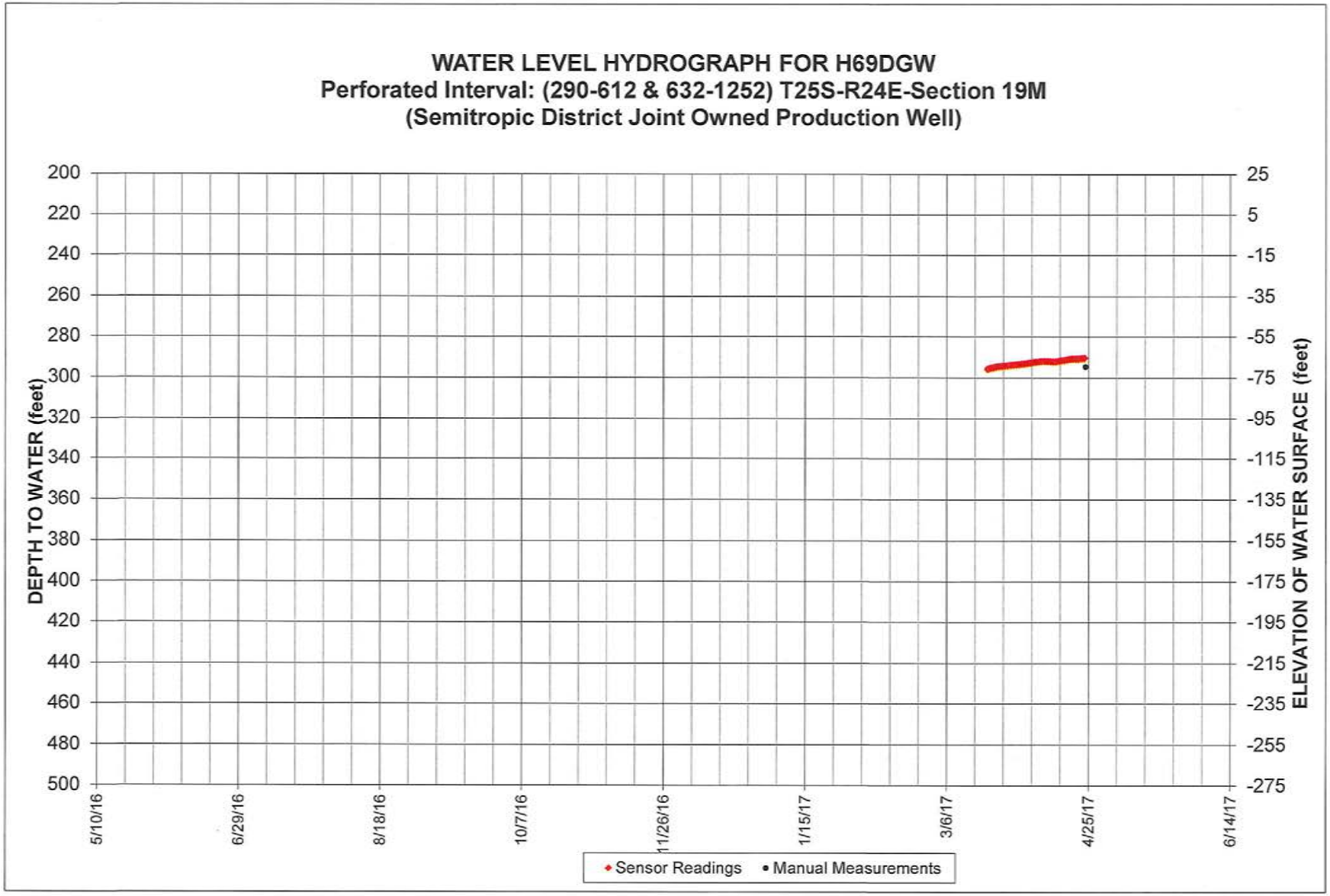


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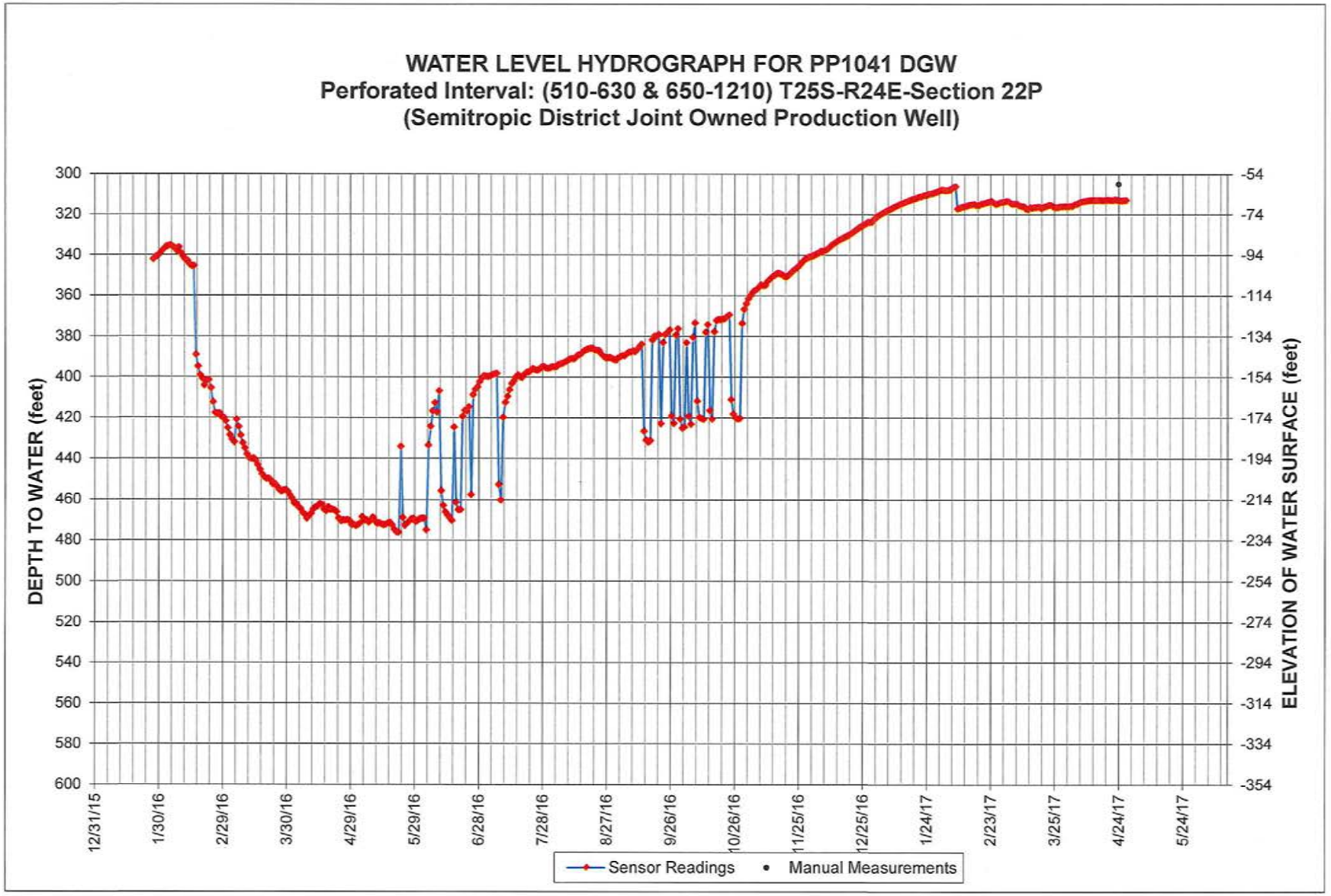
Semitropic Water Storage District
(Manual data from the KCWA)

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Semitropic Water Storage District
(Manual data from the KCWA)

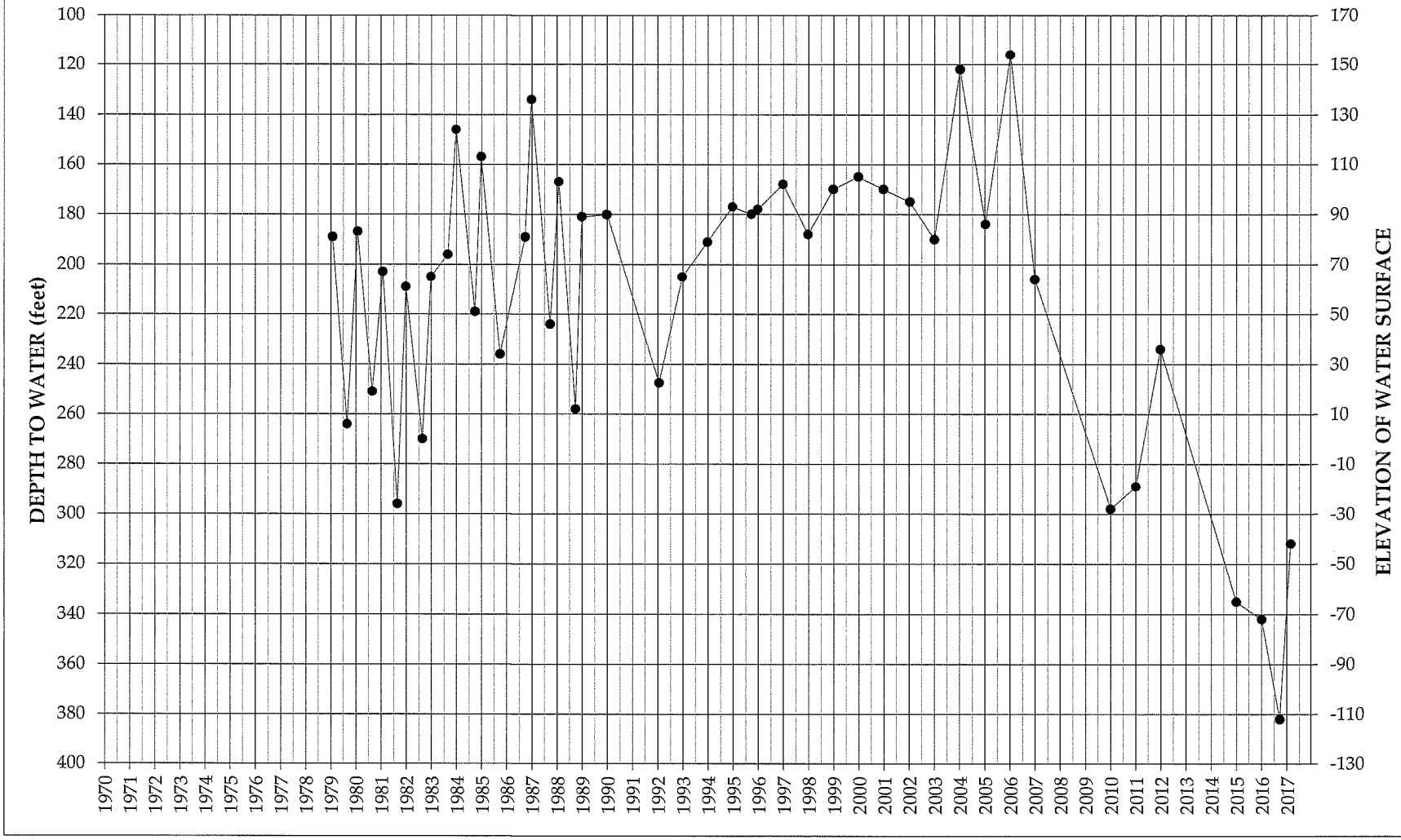
5/8/2017



Semitropic Water Storage District
(Manual data from the KCWA)

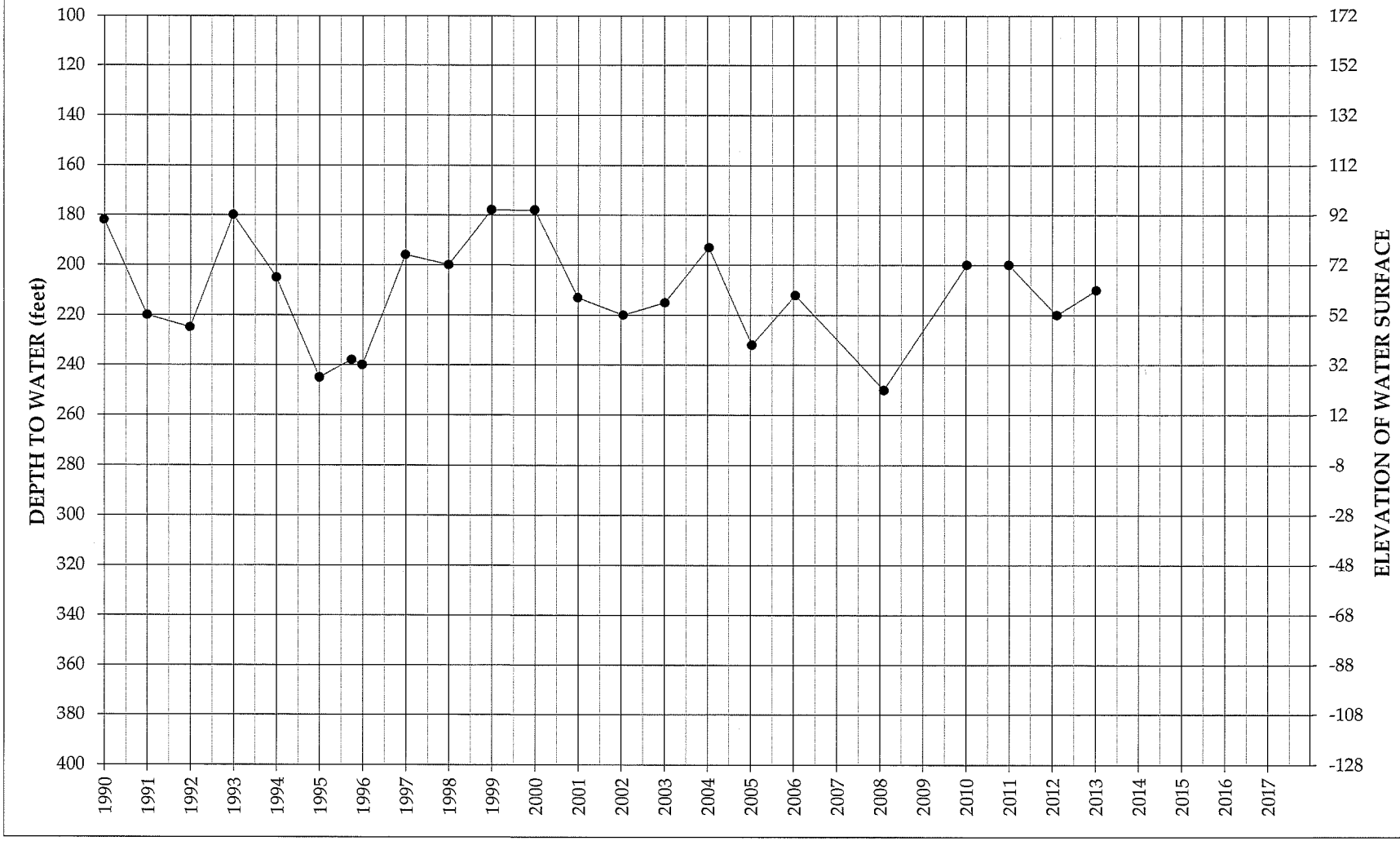
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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/24-25F (500-1200)



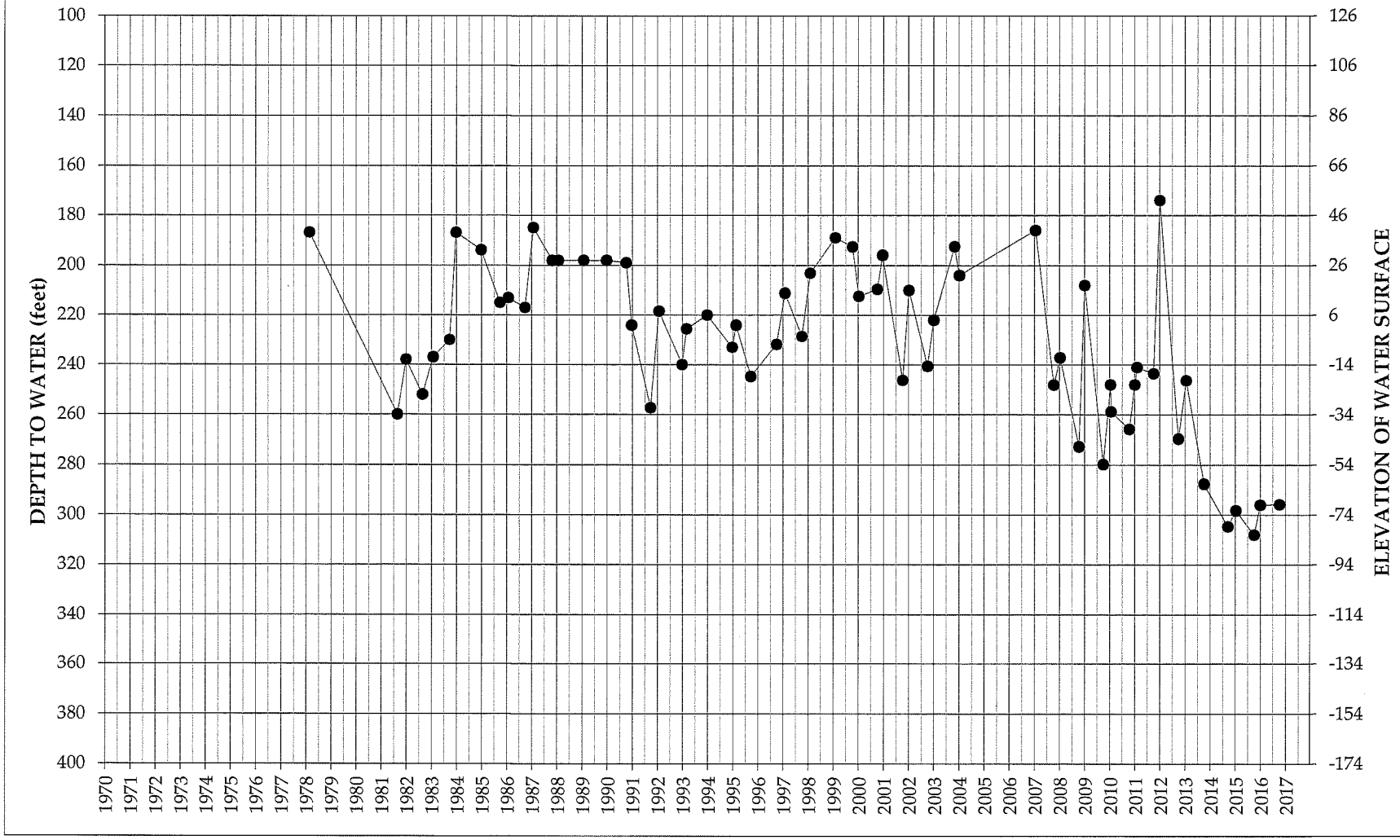
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #25/24-36R (404-1005)



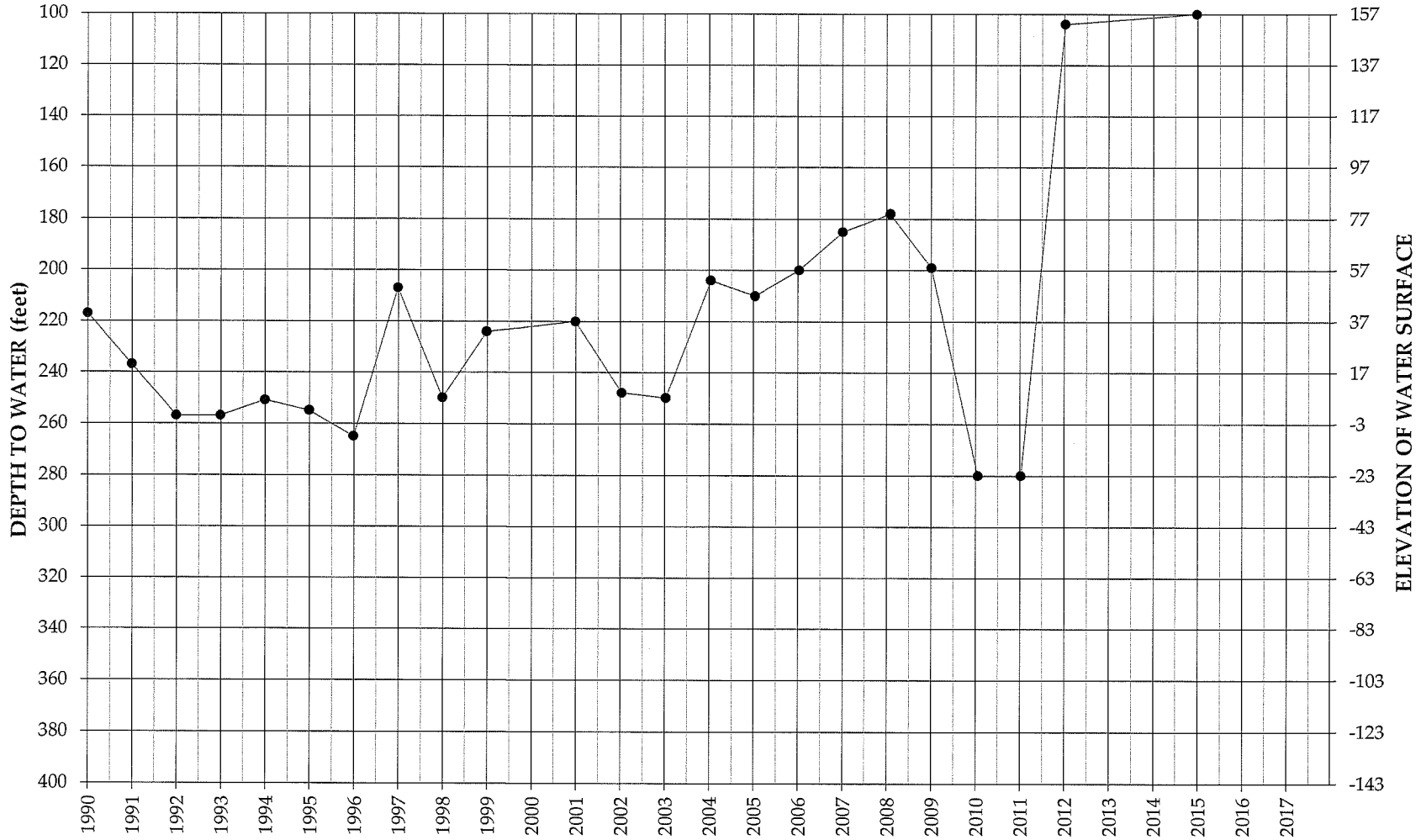
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/22-14E (299-544)



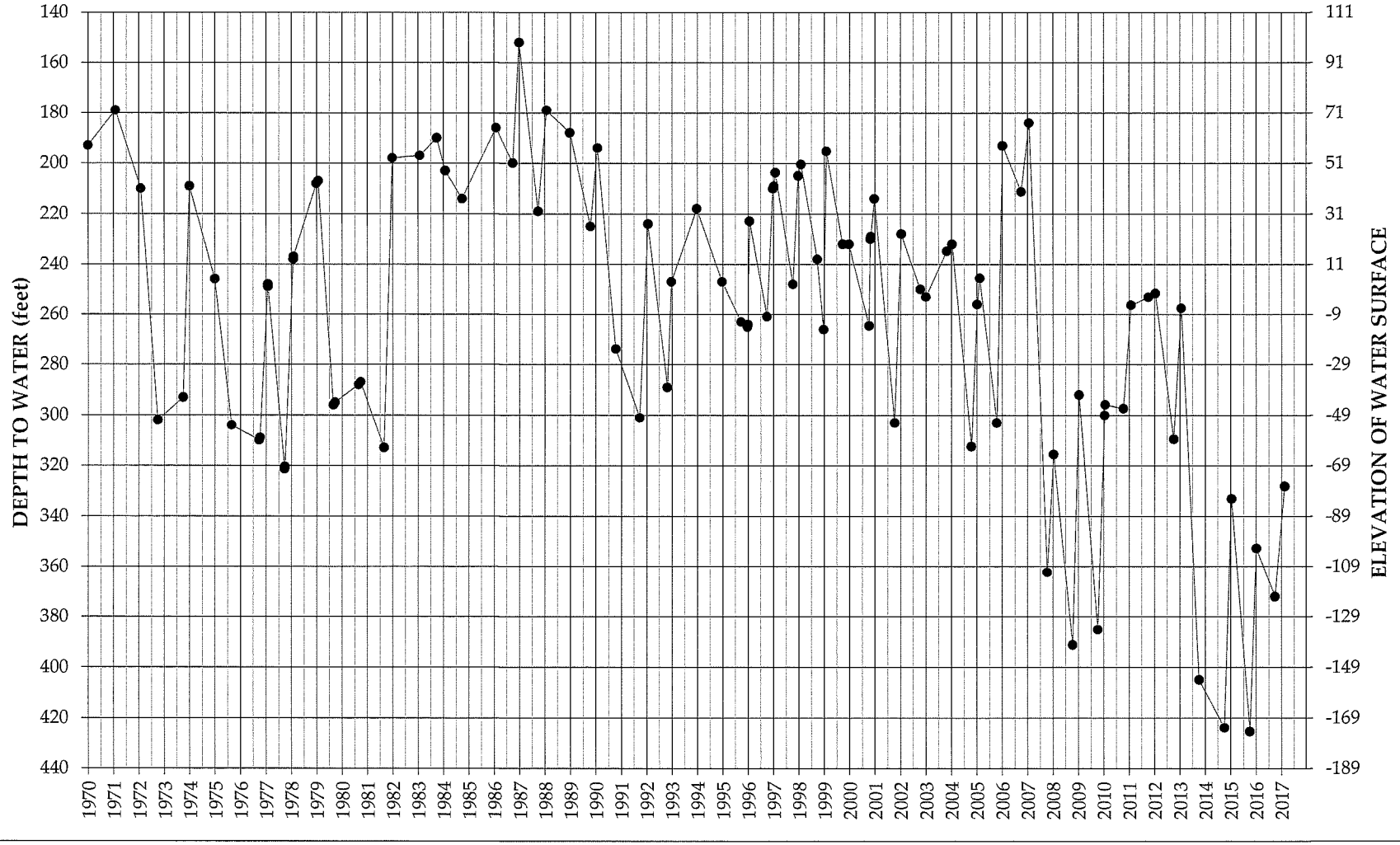
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/22-35P



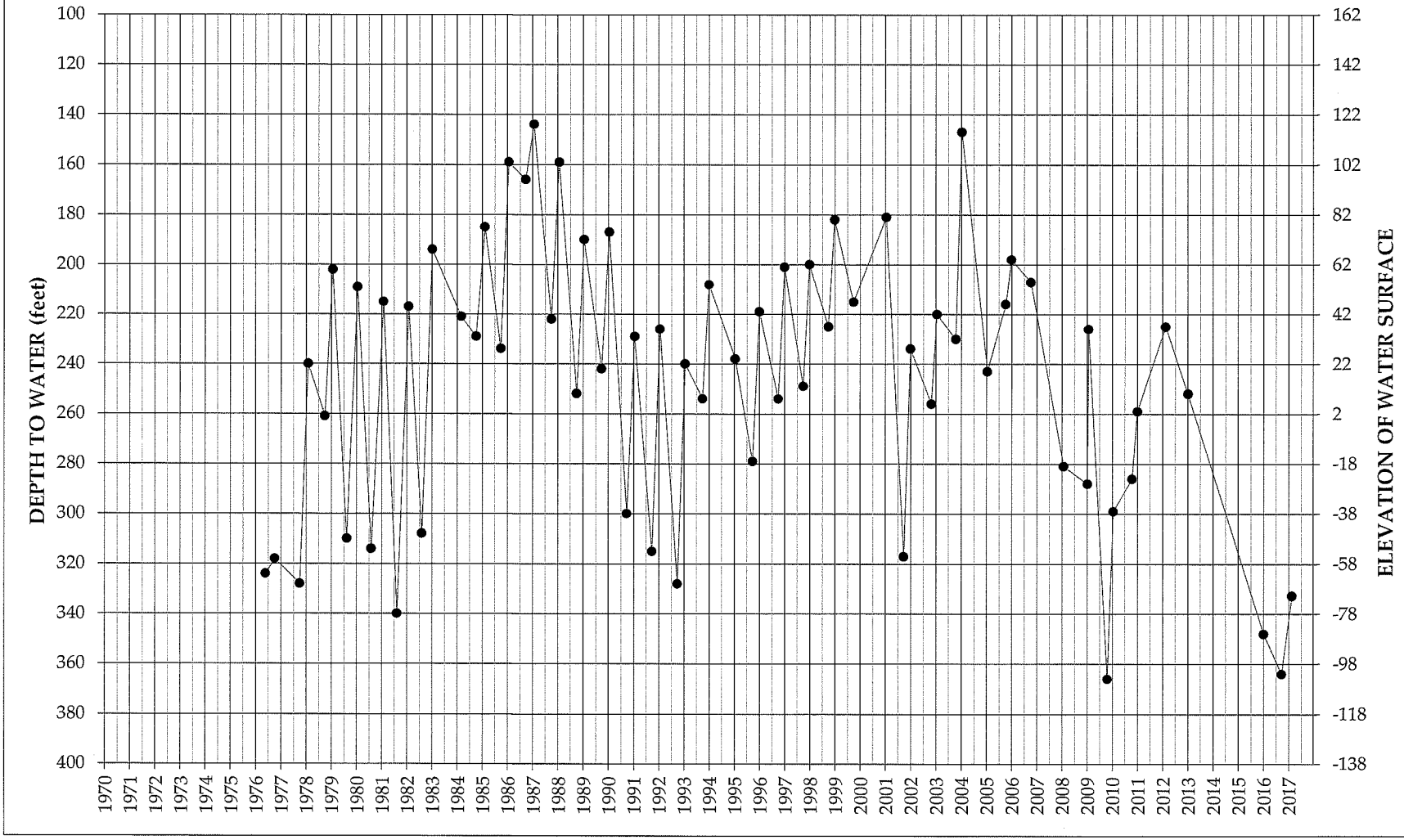
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/23-13R (450-807)



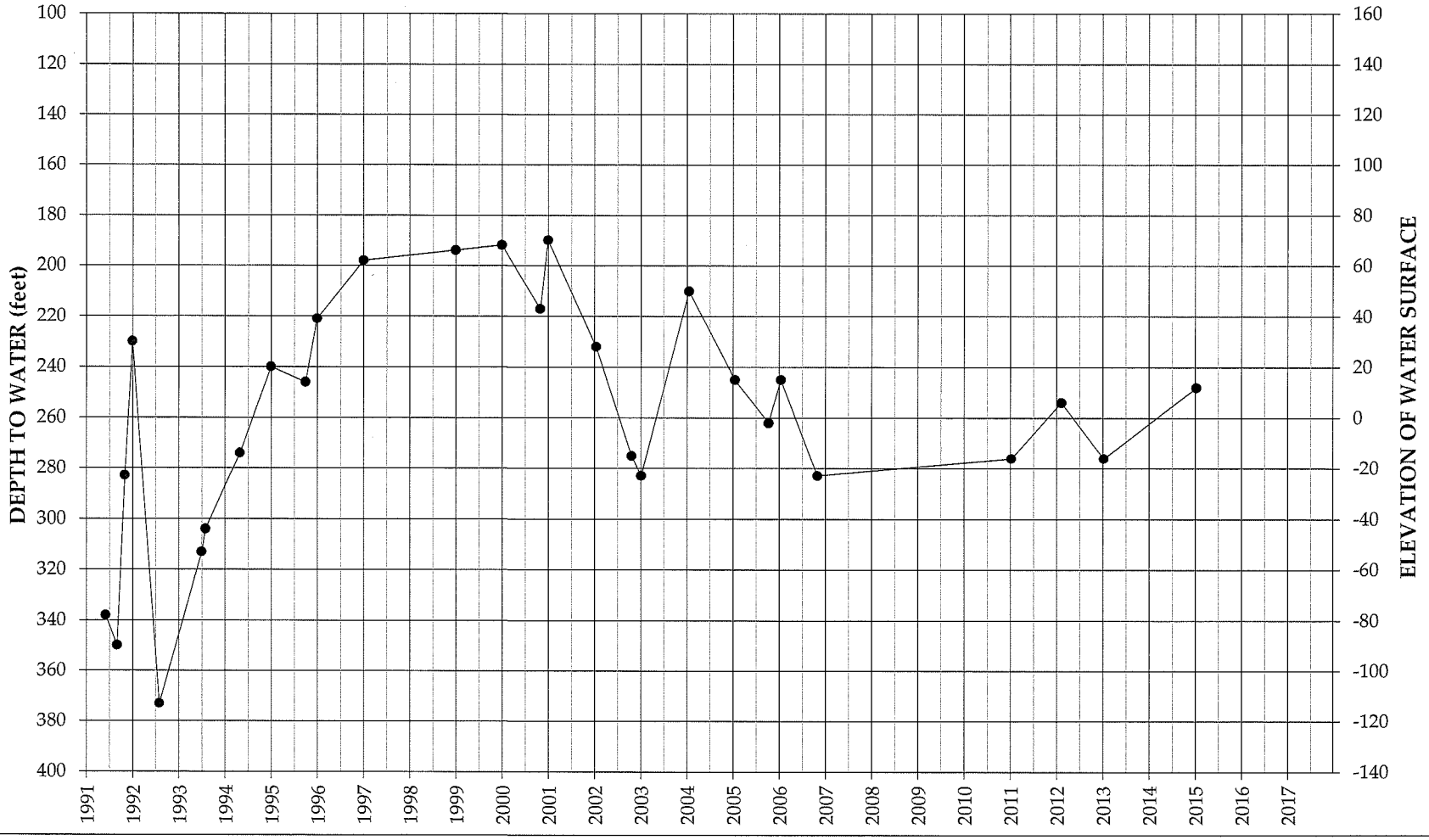
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-8R (410-820)



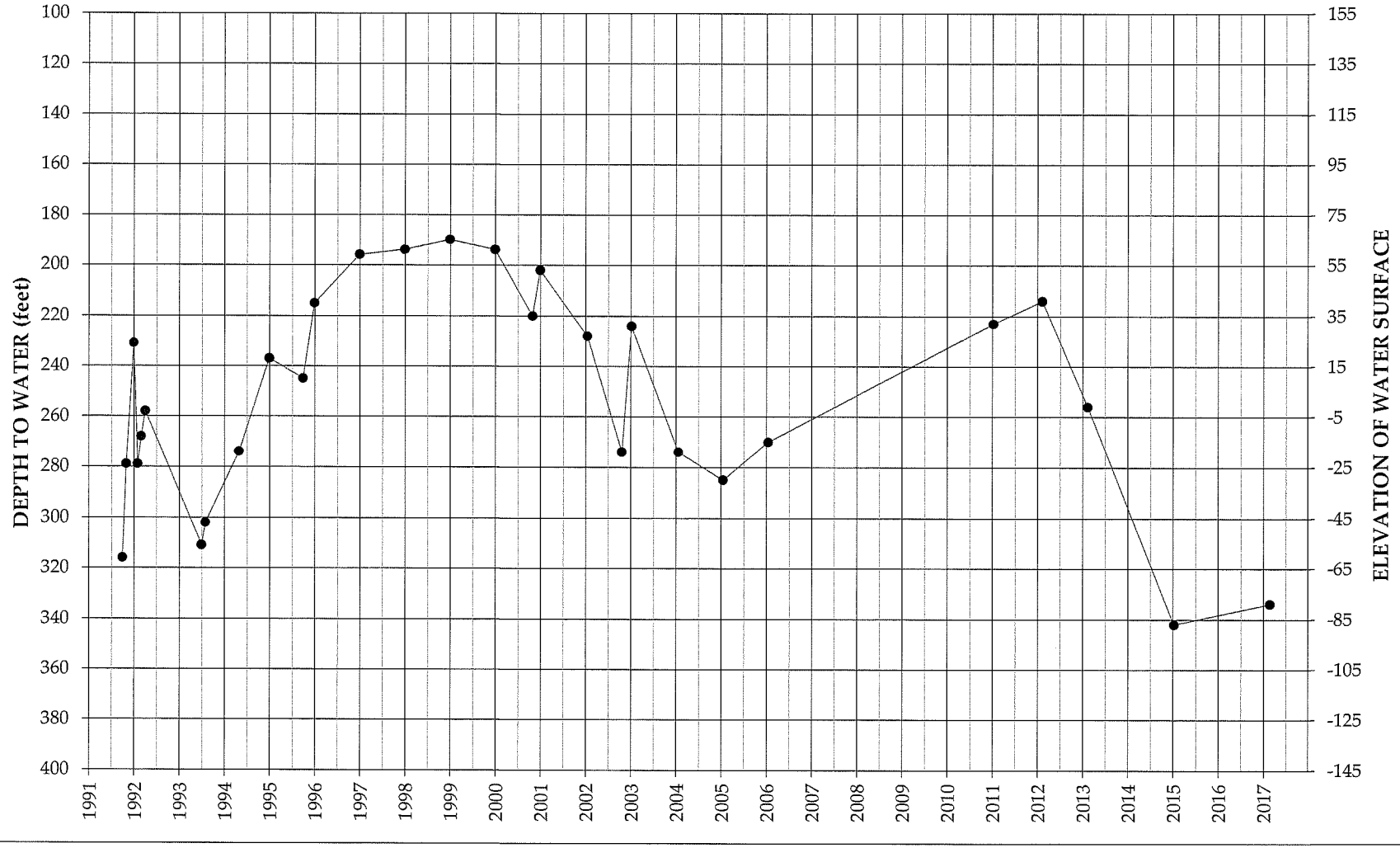
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER WELL HYDROGRAPH FOR WELL #26/24-9N (470-840)



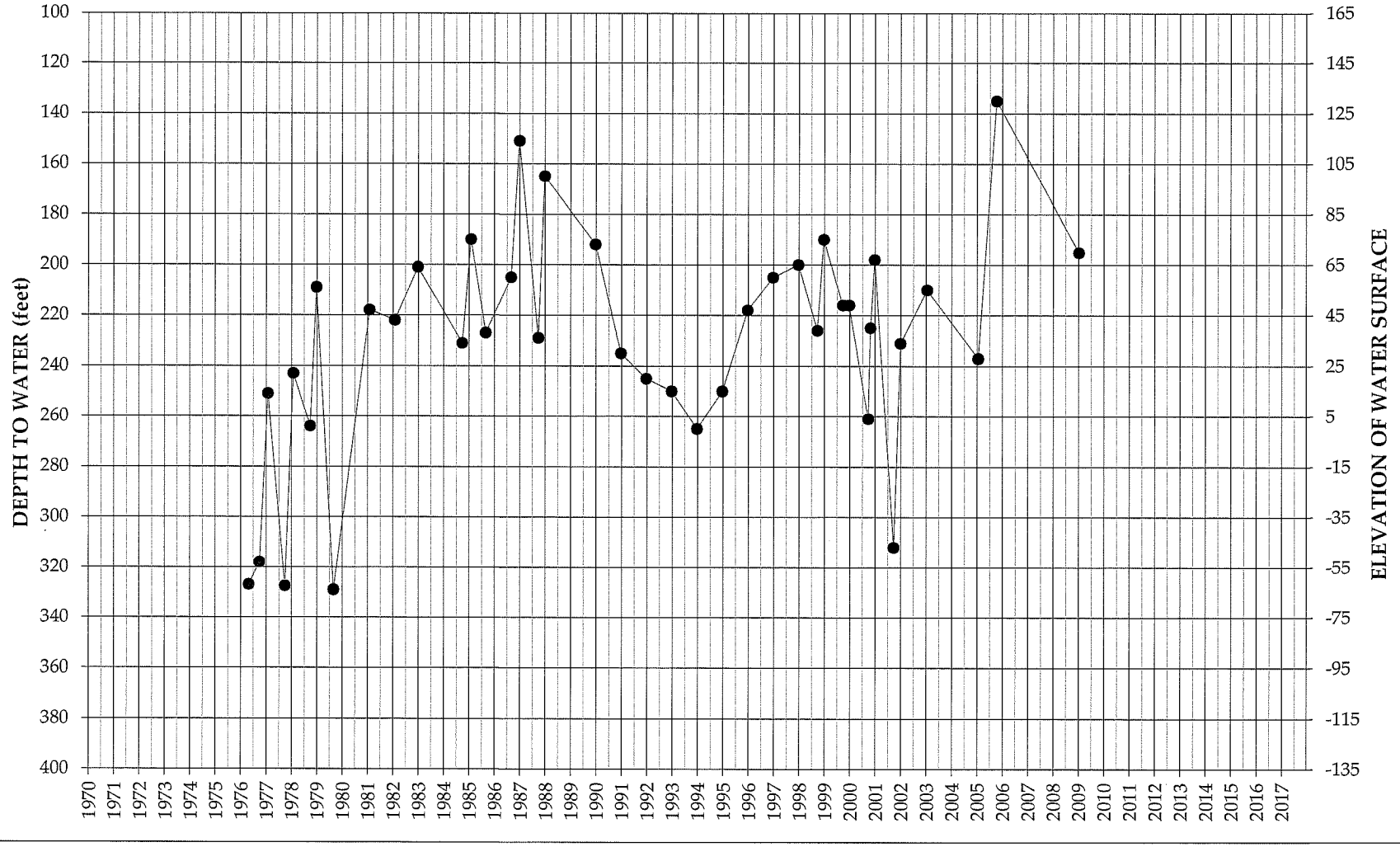
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-17G (450-810)



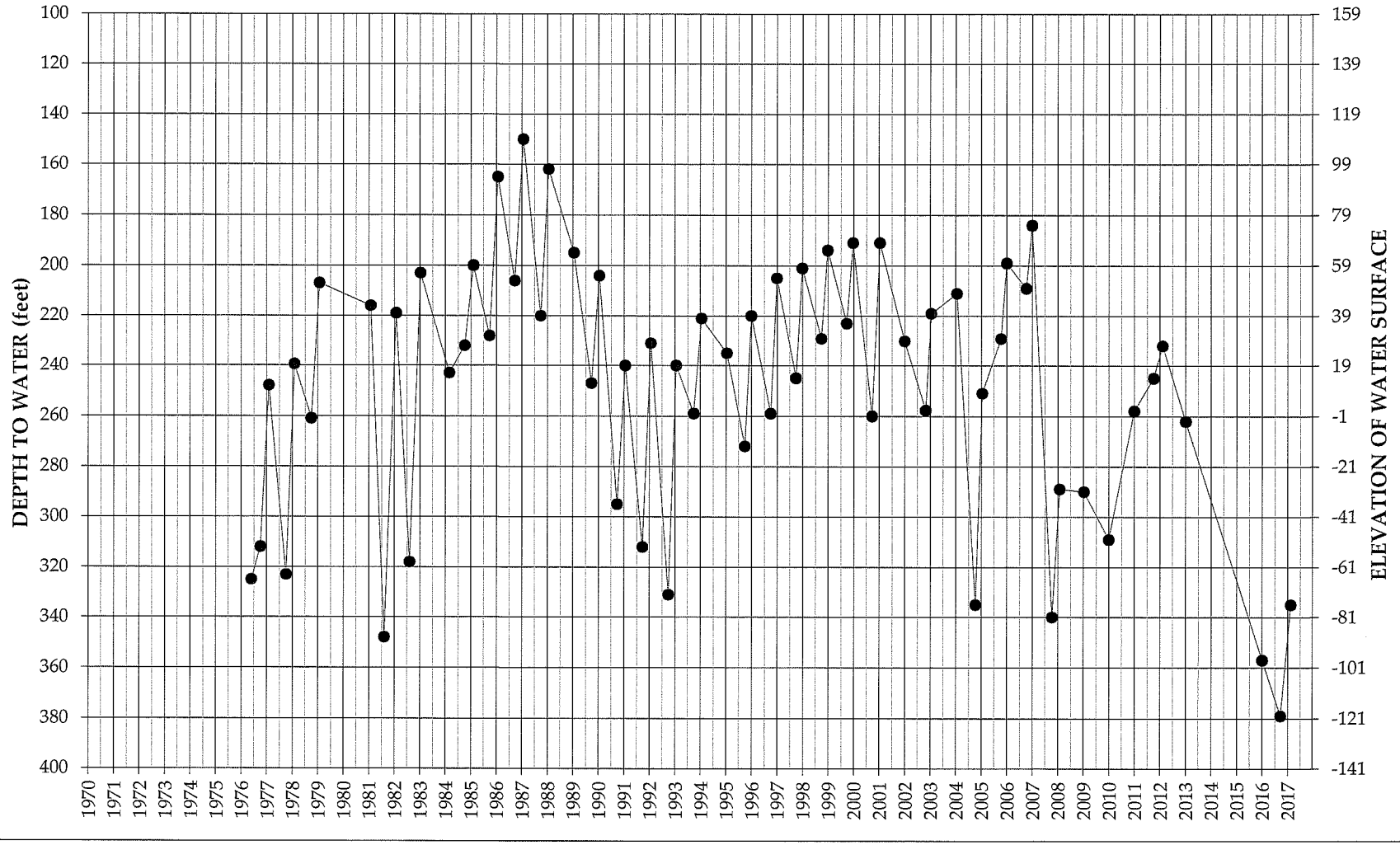
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-17R



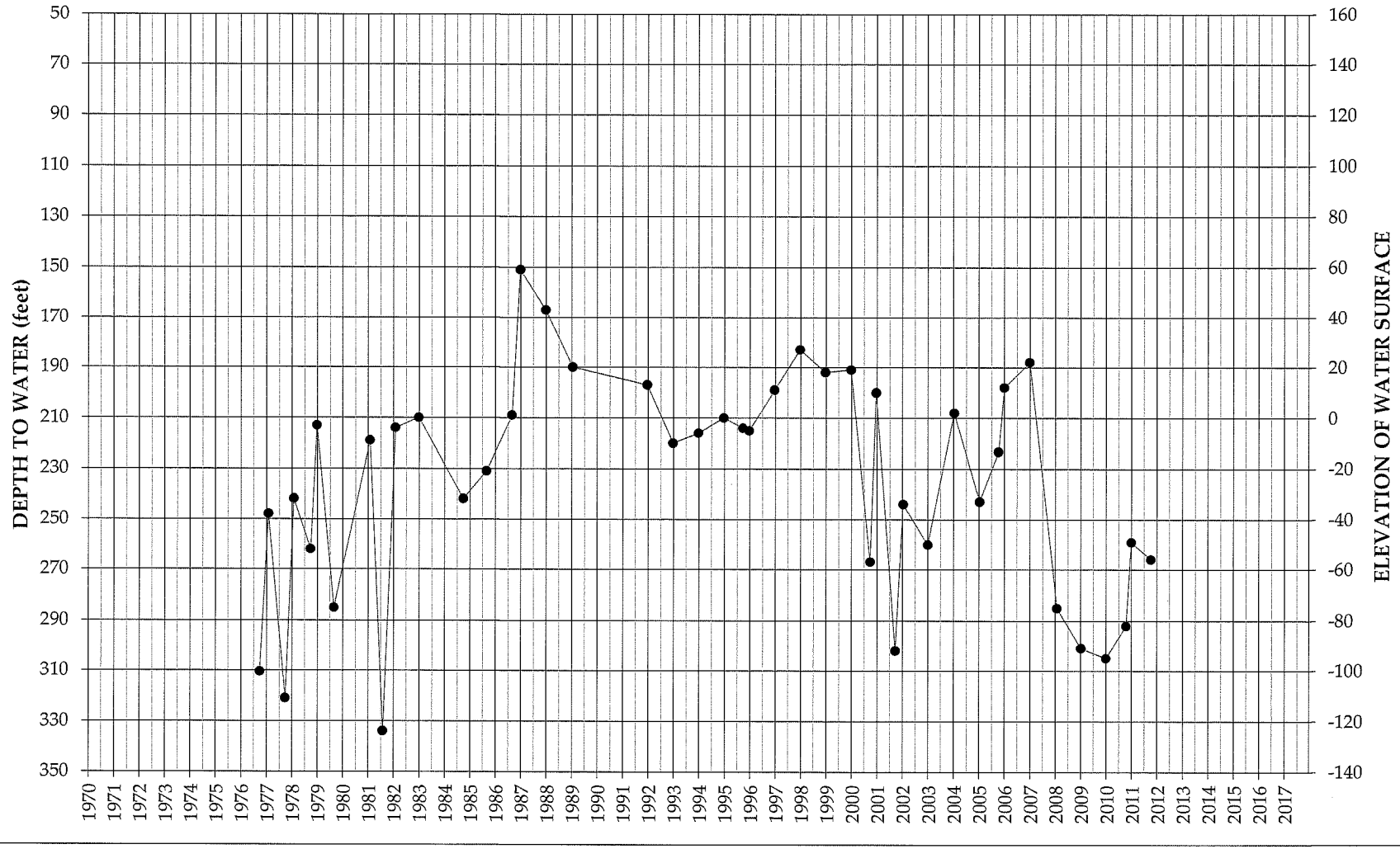
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-18R



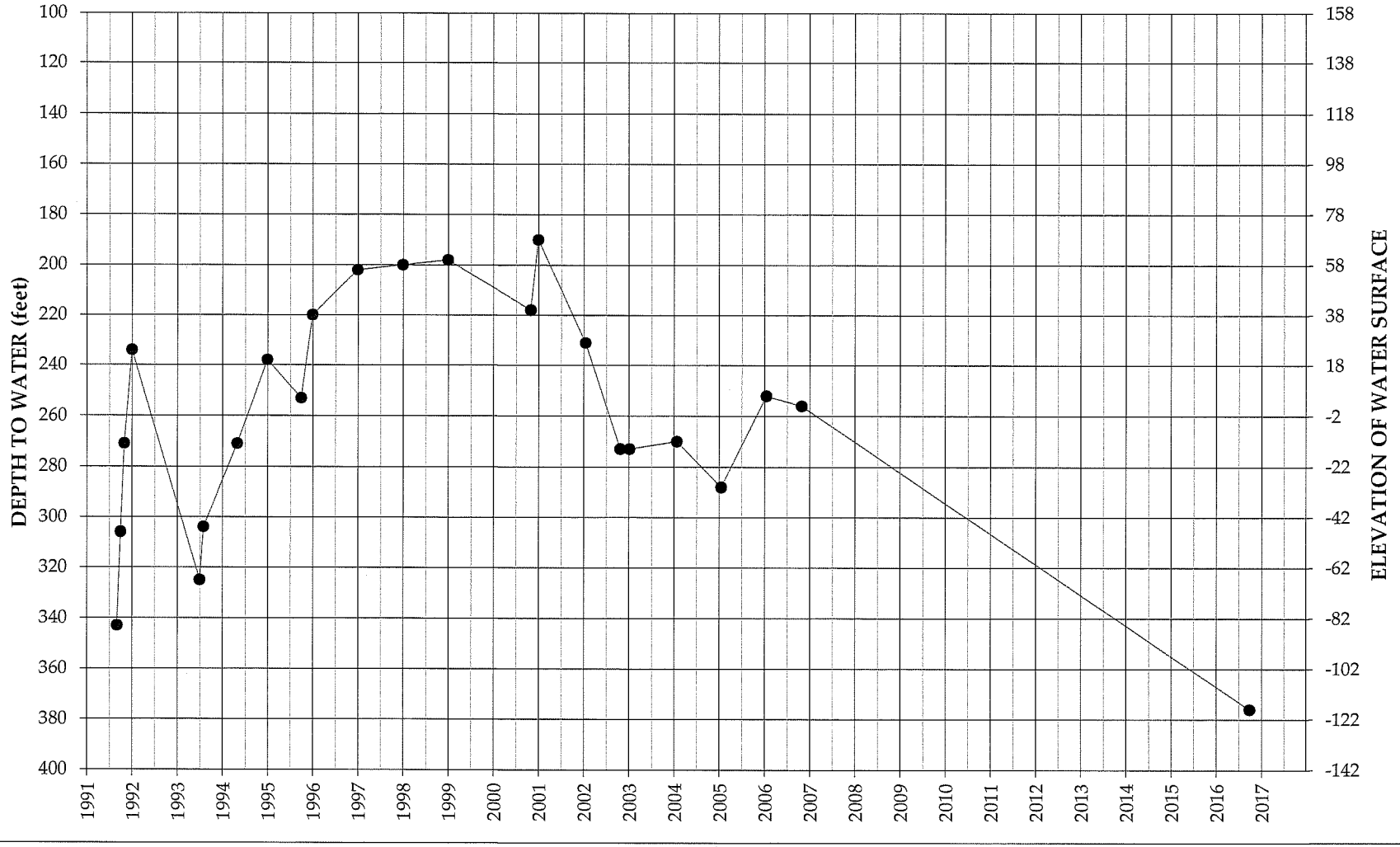
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-19R



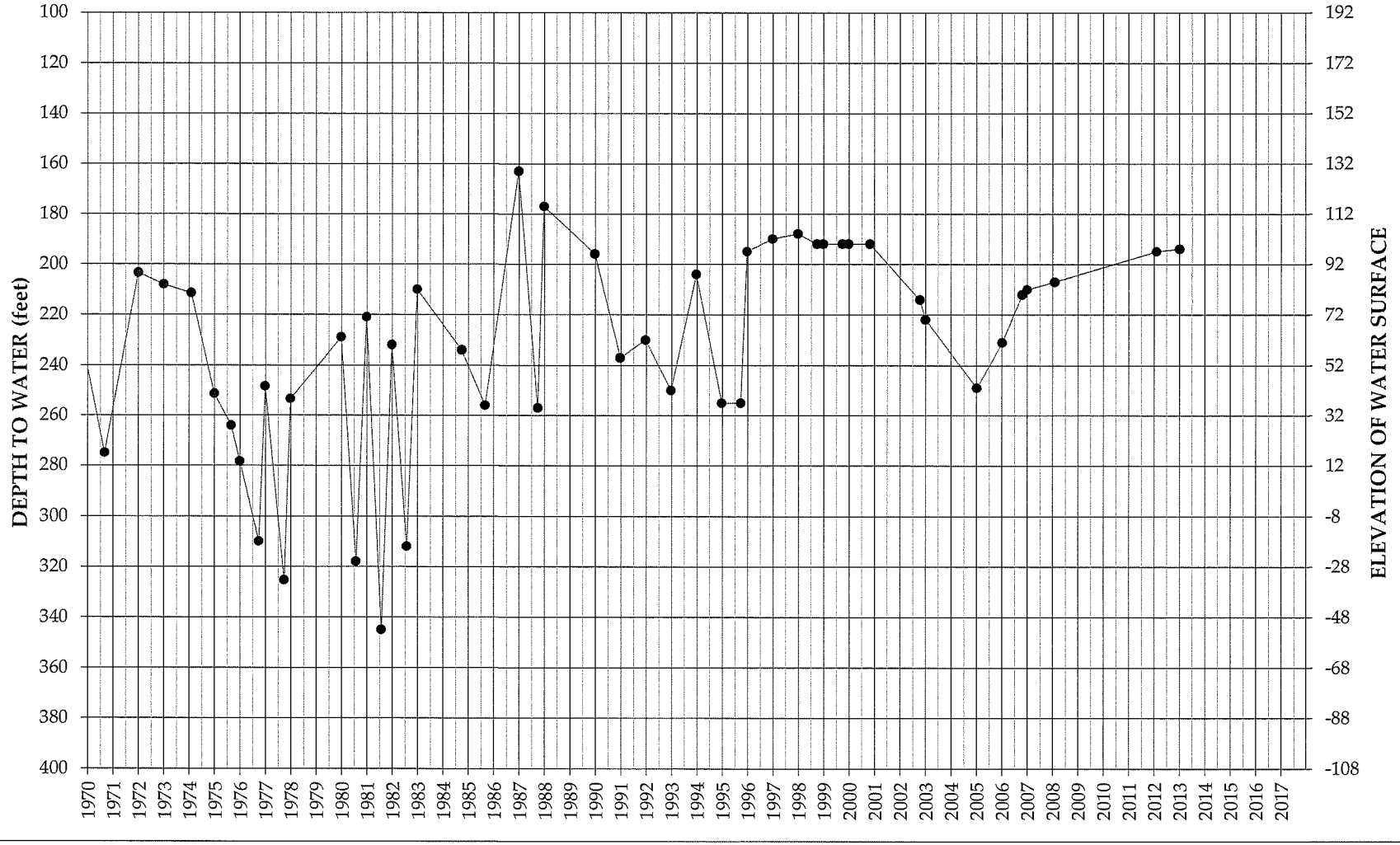
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Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-20M (440-820)

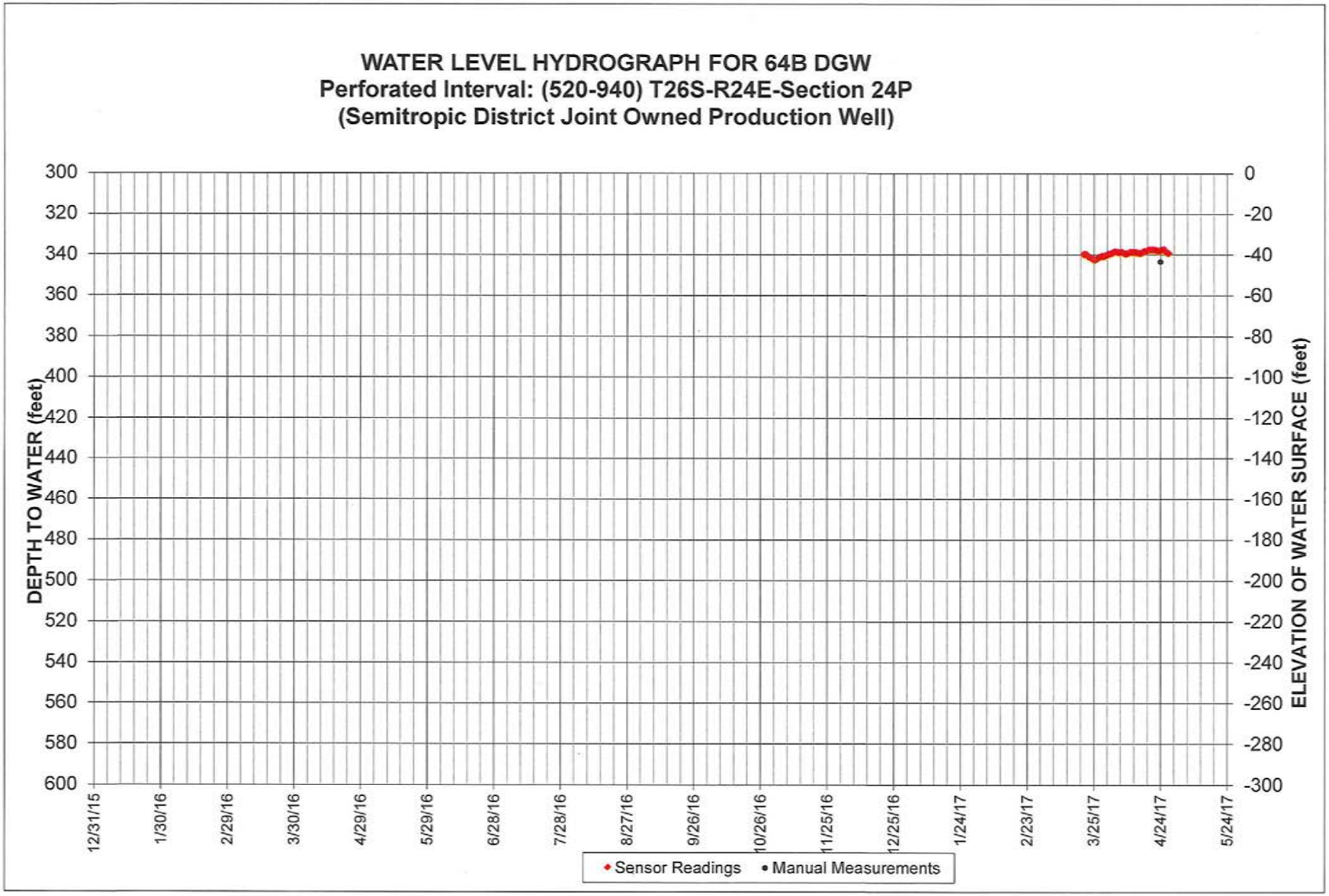


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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-23R (300-472)



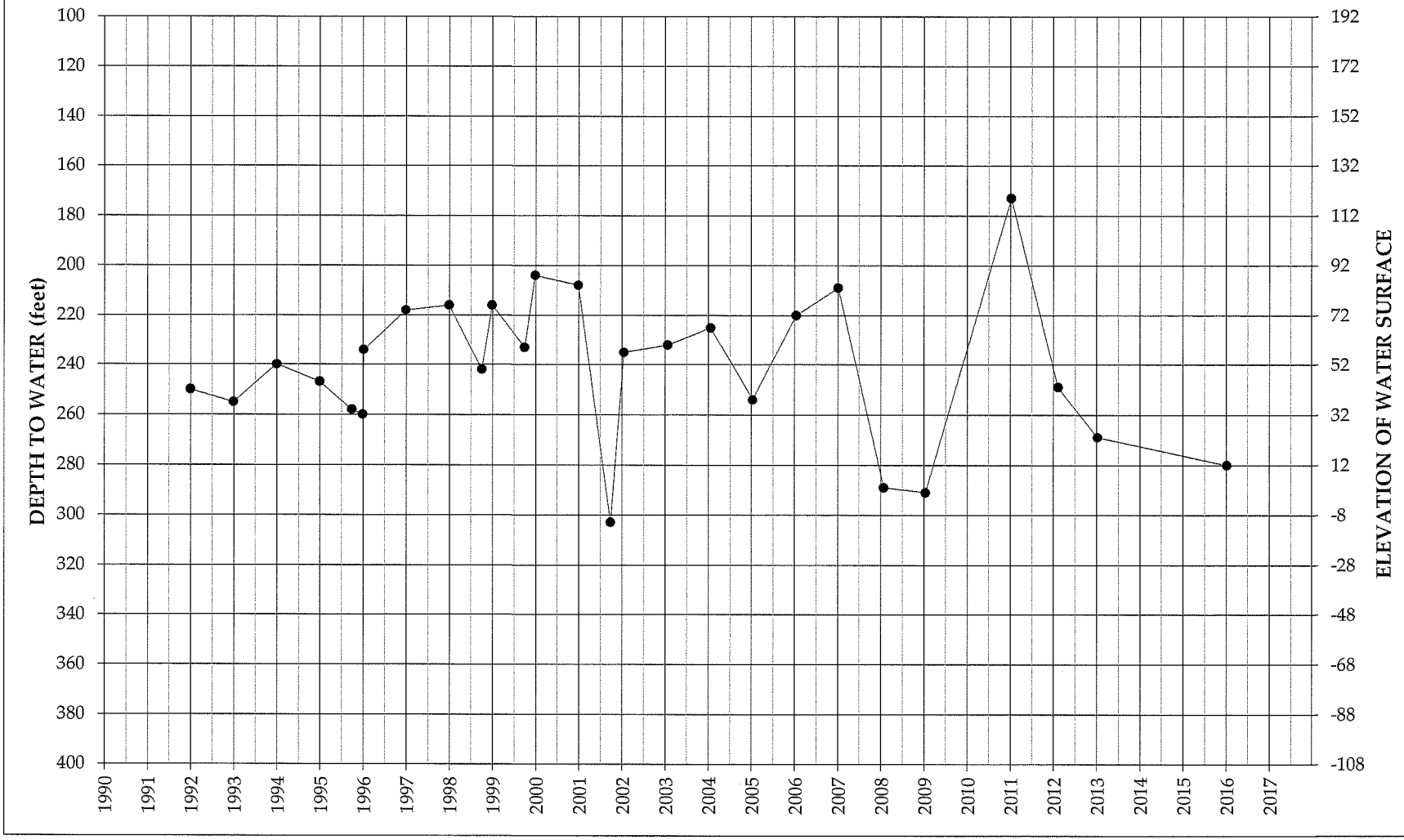
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Semitropic Water Storage District
(Manual data from the KCWA)

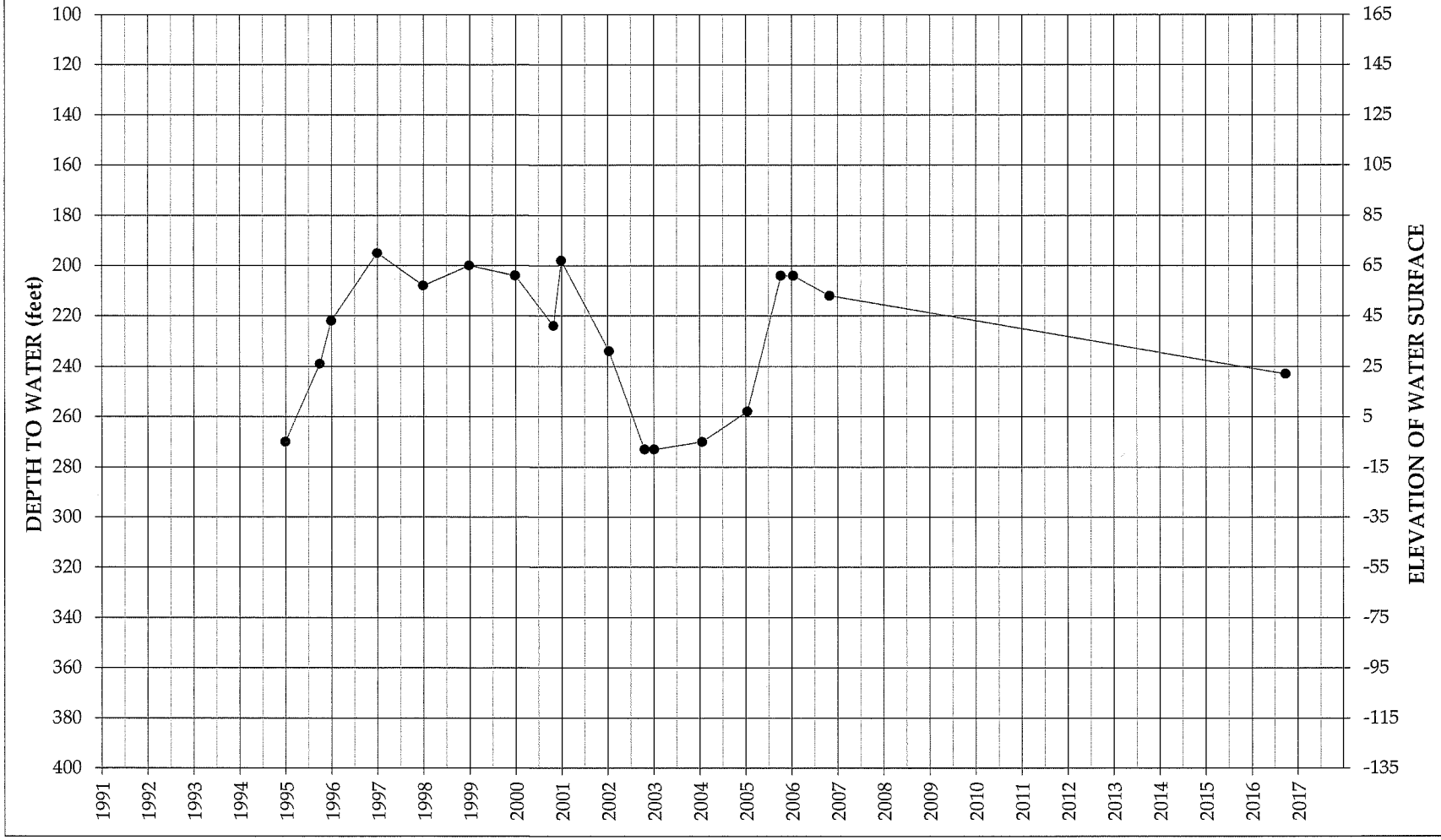
5/8/2017

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-27H (450-805)

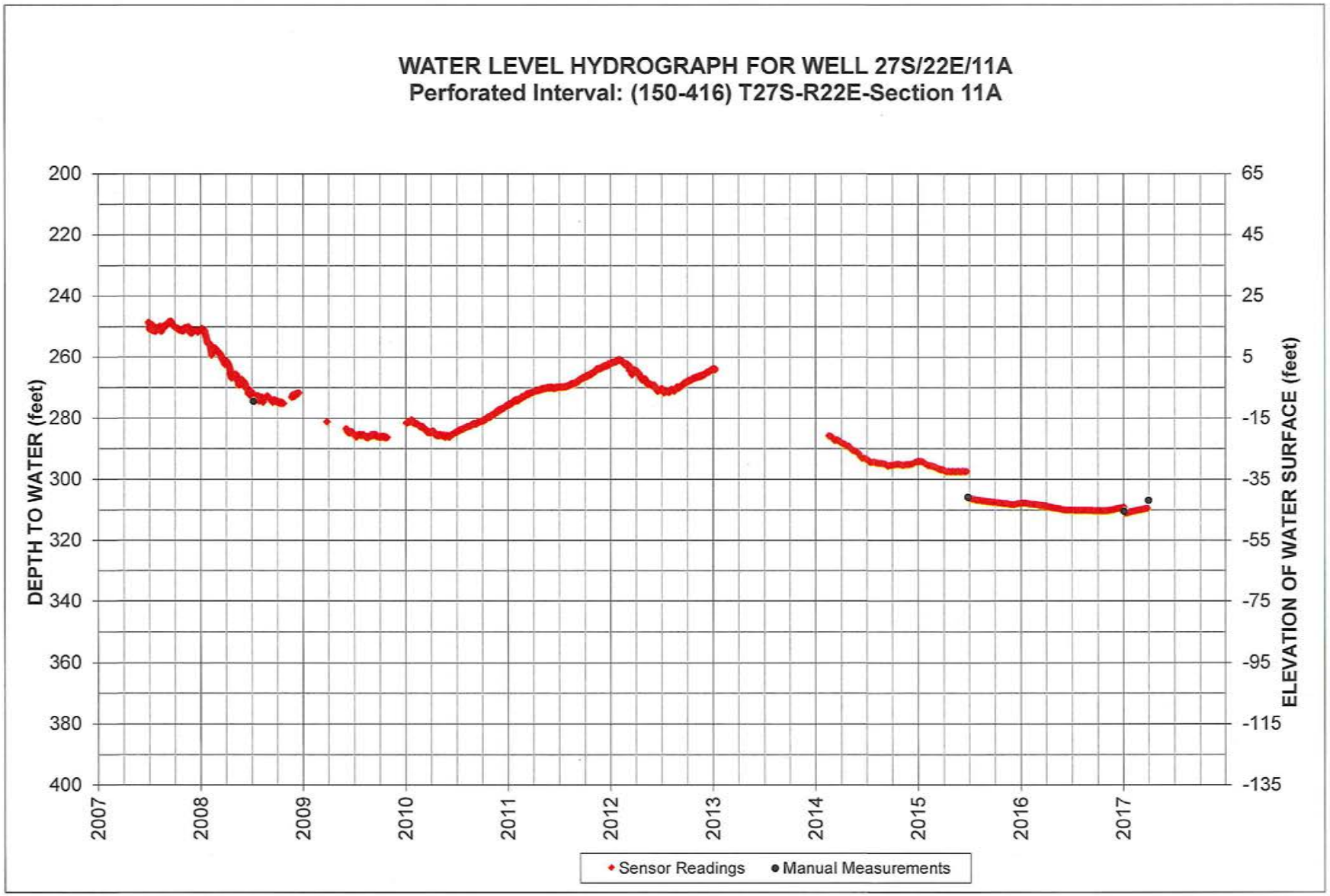


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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-31B

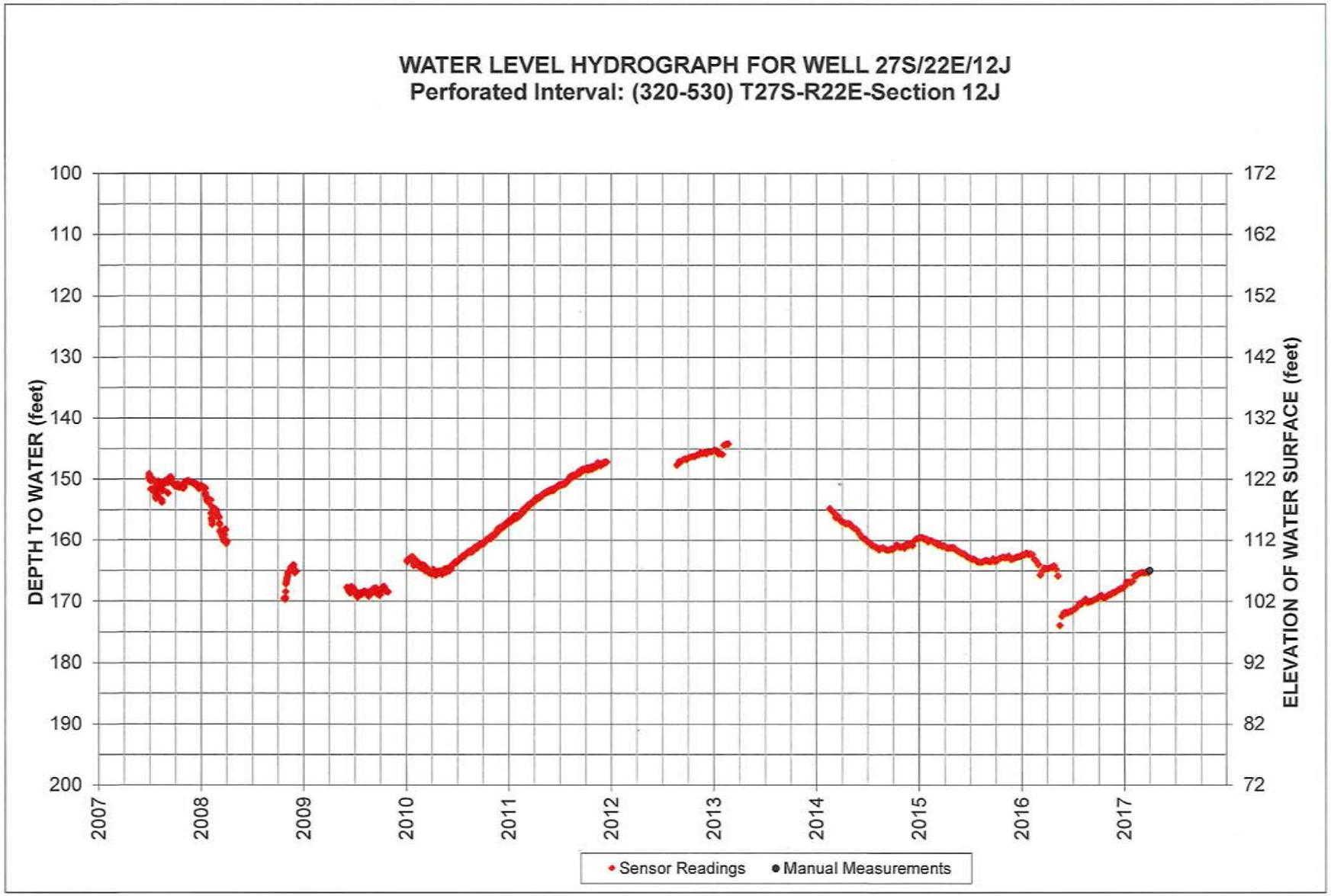


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Semitropic Water Storage District
(Manual data from the KCWA)

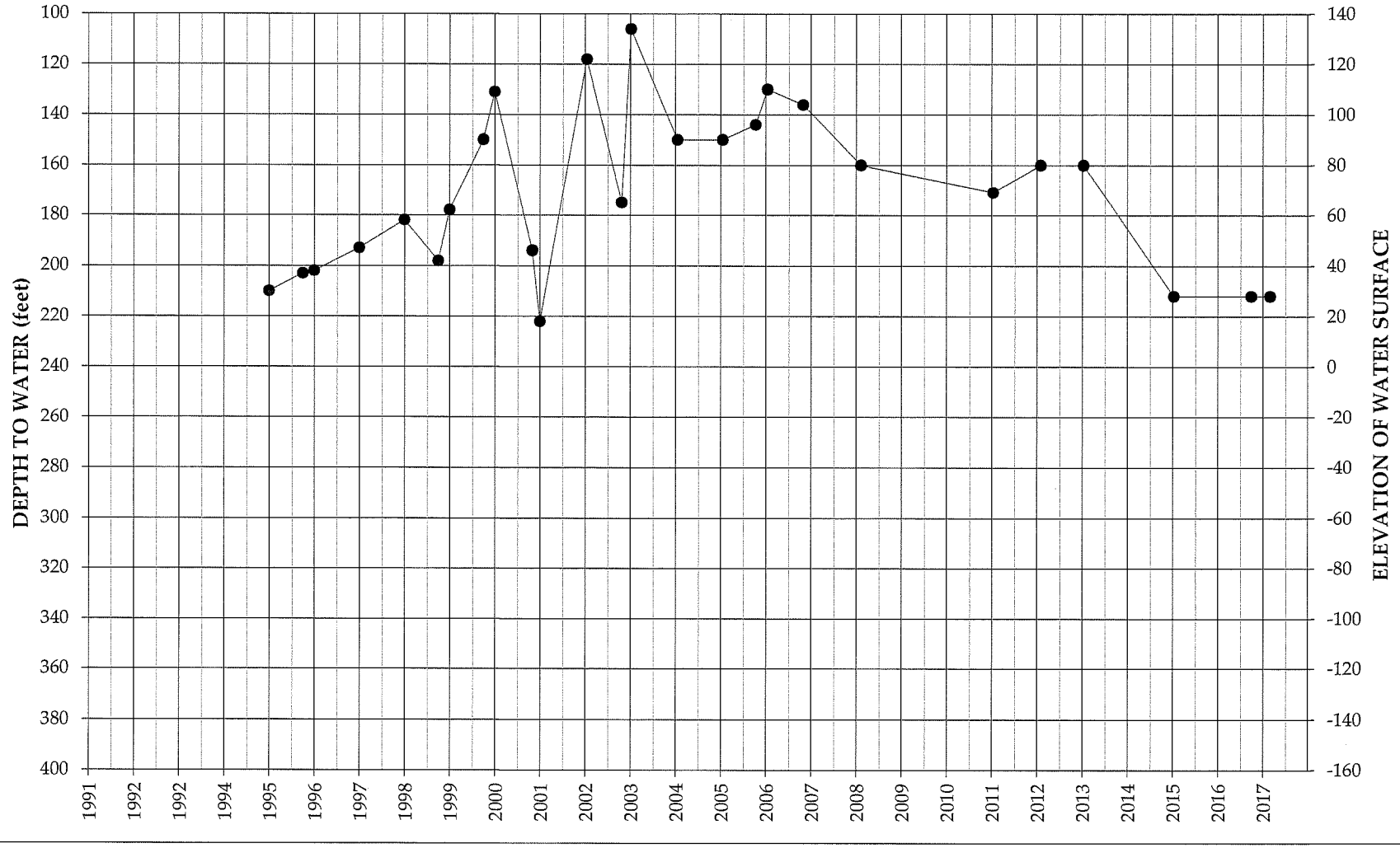
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Semitropic Water Storage District
(Manual data from the KCWA)

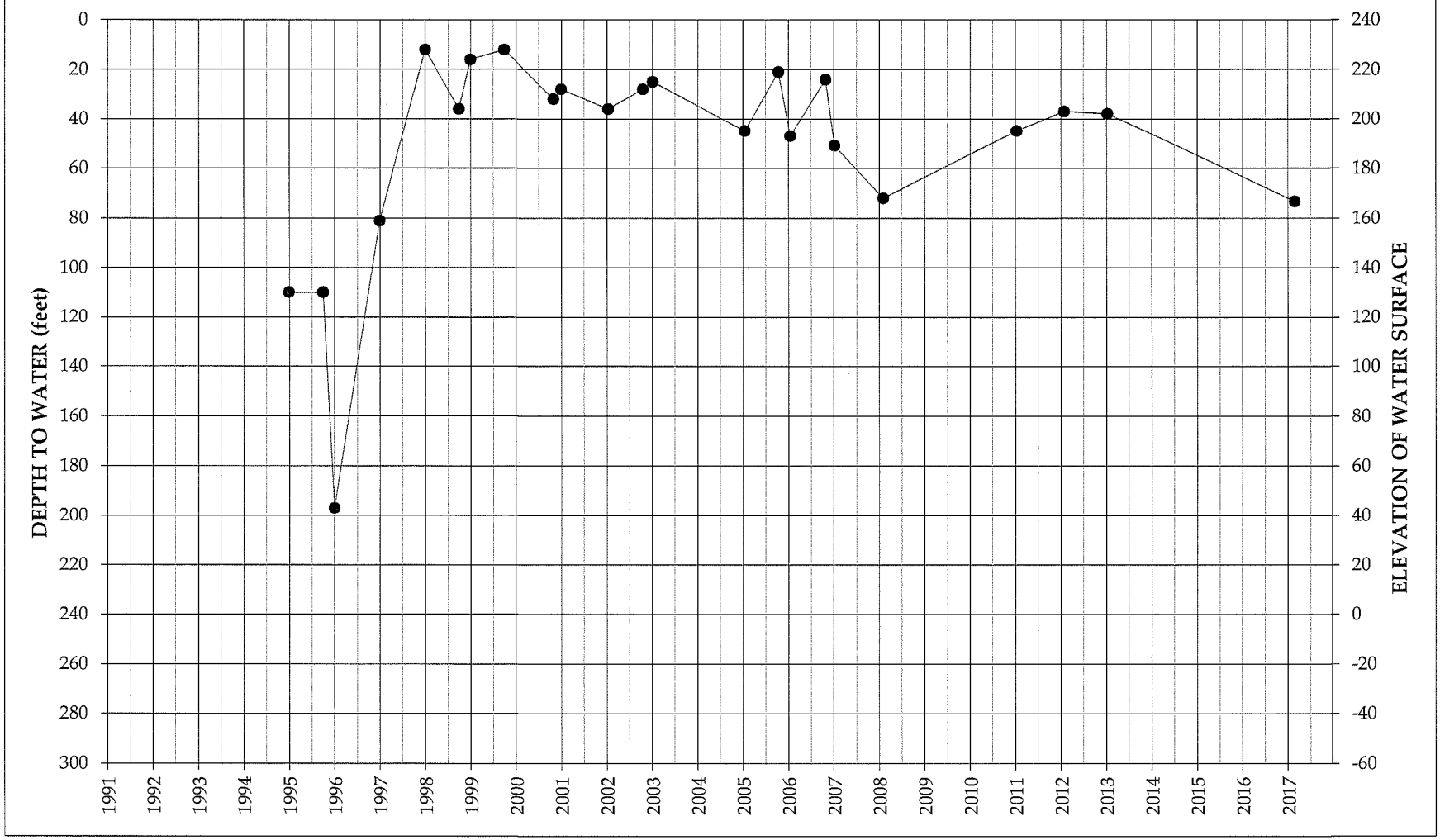
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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/22-13R



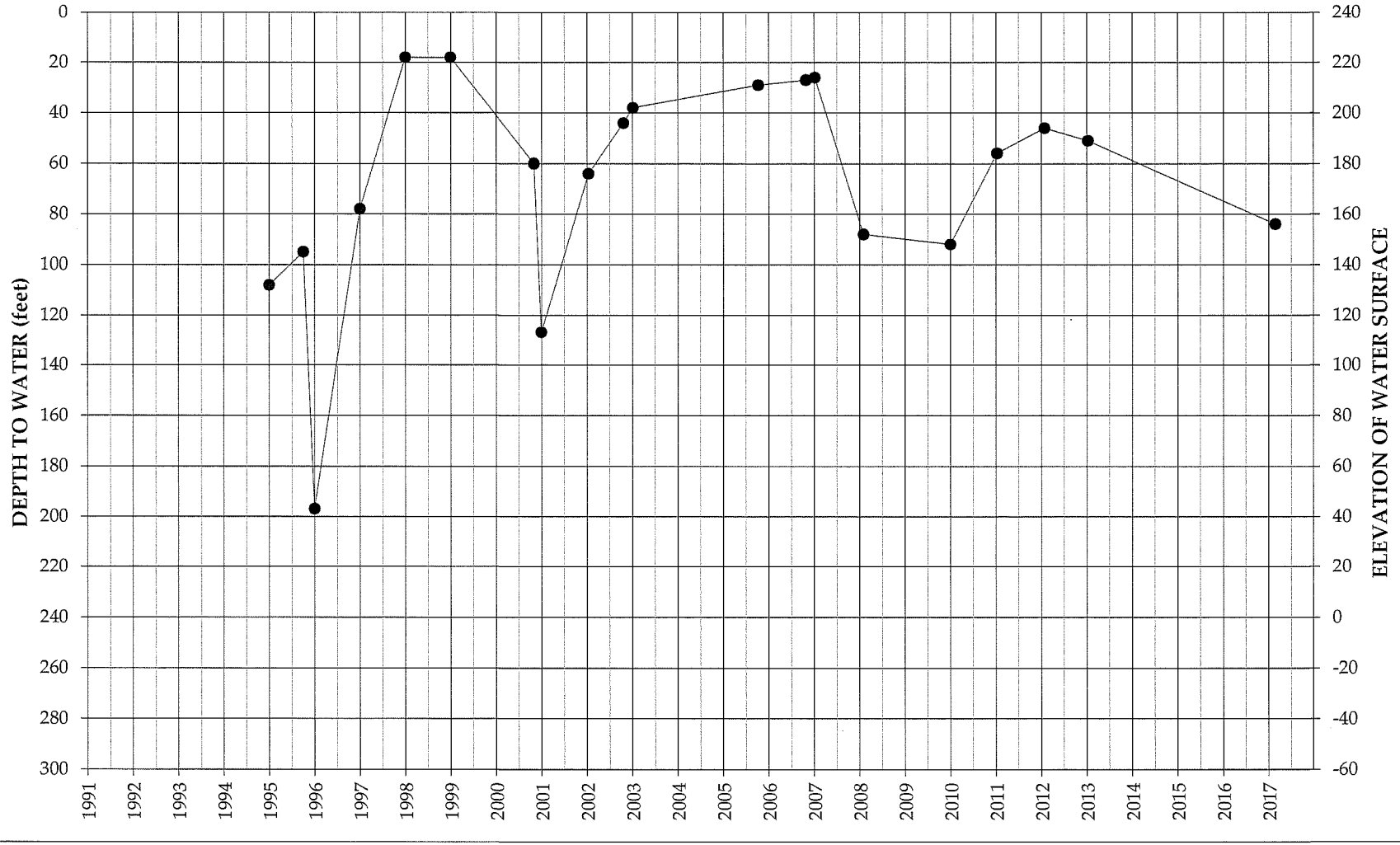
GEI Consultants
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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/22-24H



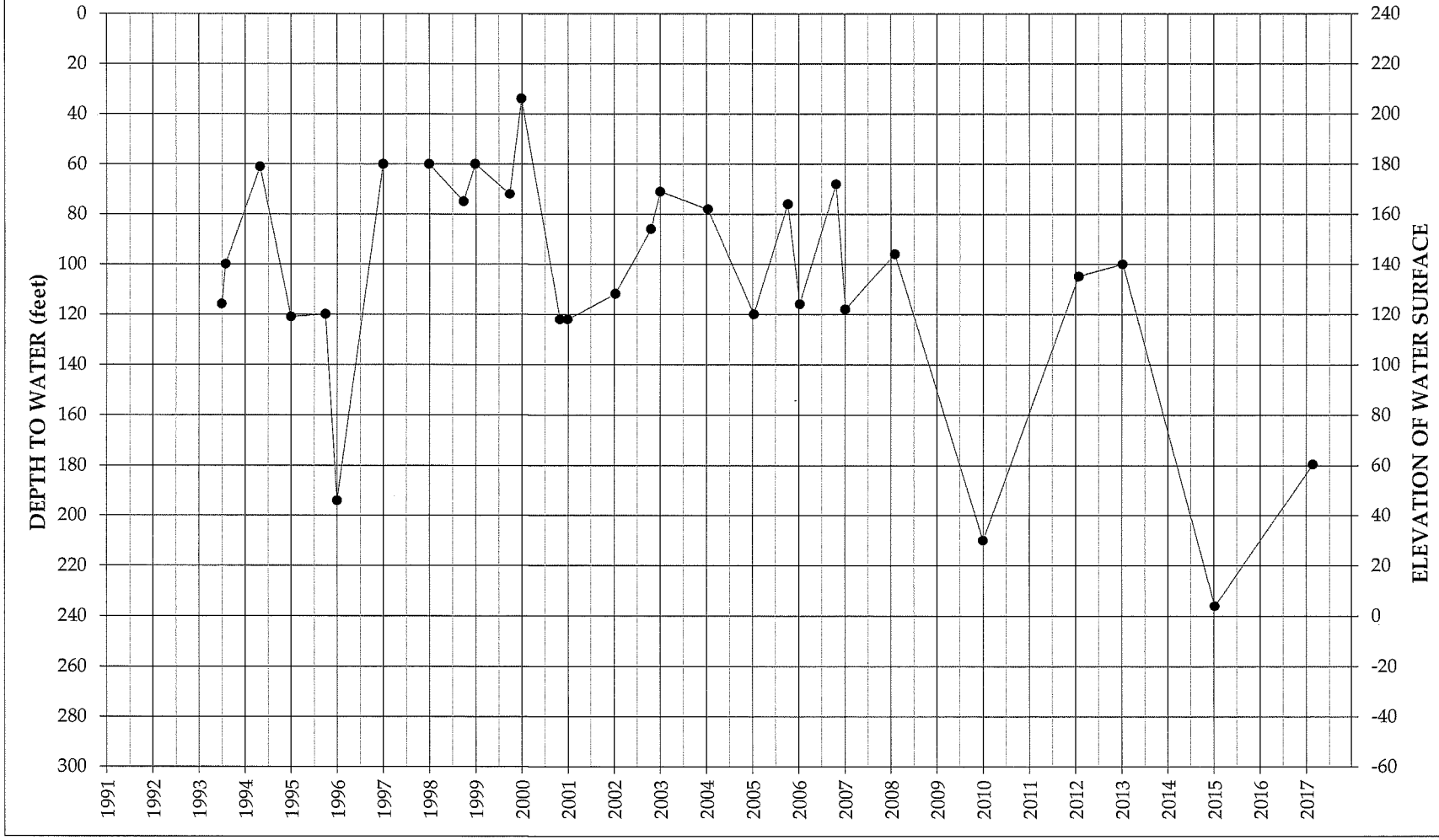
GEI Consultants
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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/22-24R



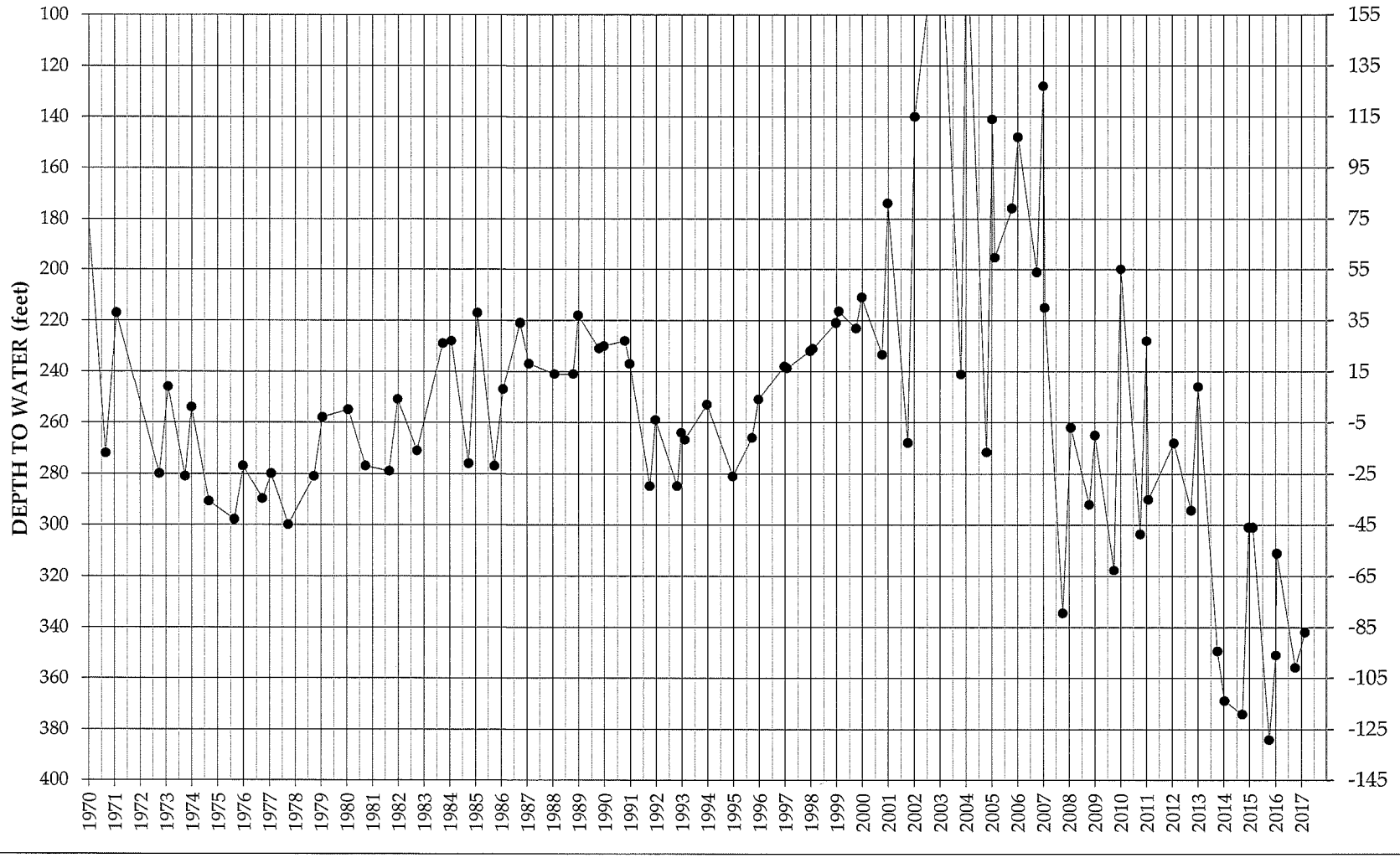
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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/22-25J (262-565)



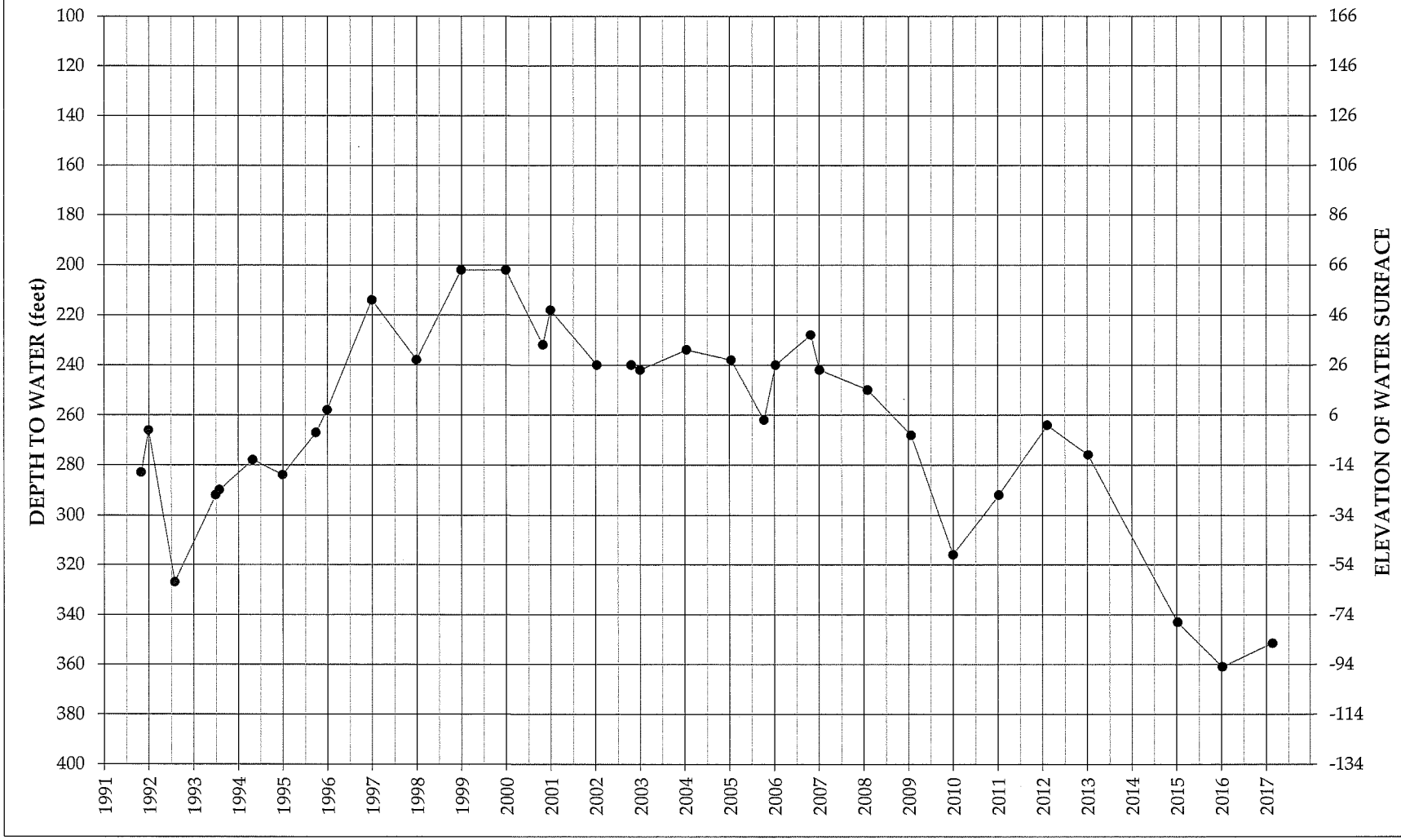
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-4H02



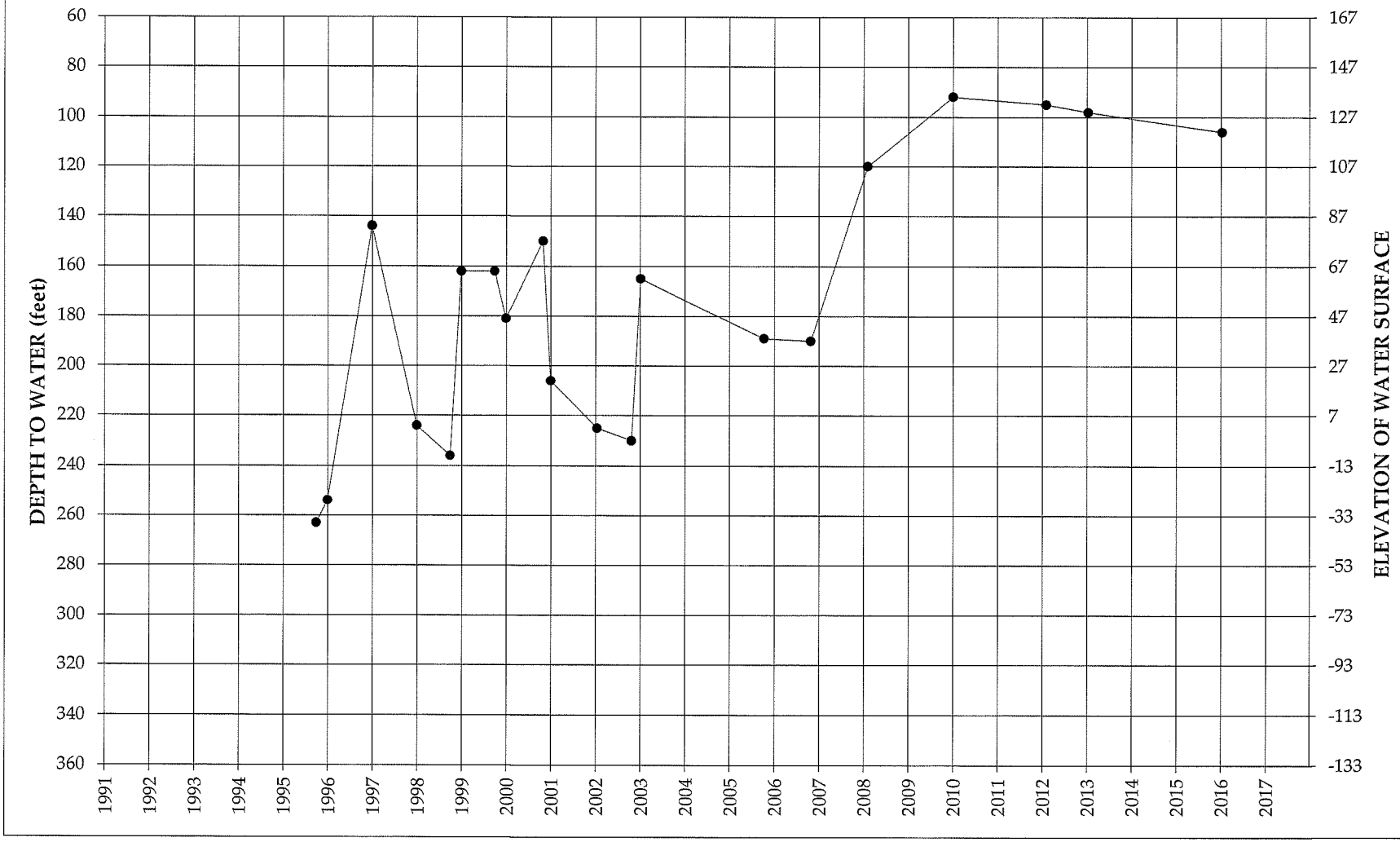
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-10J (442-633)



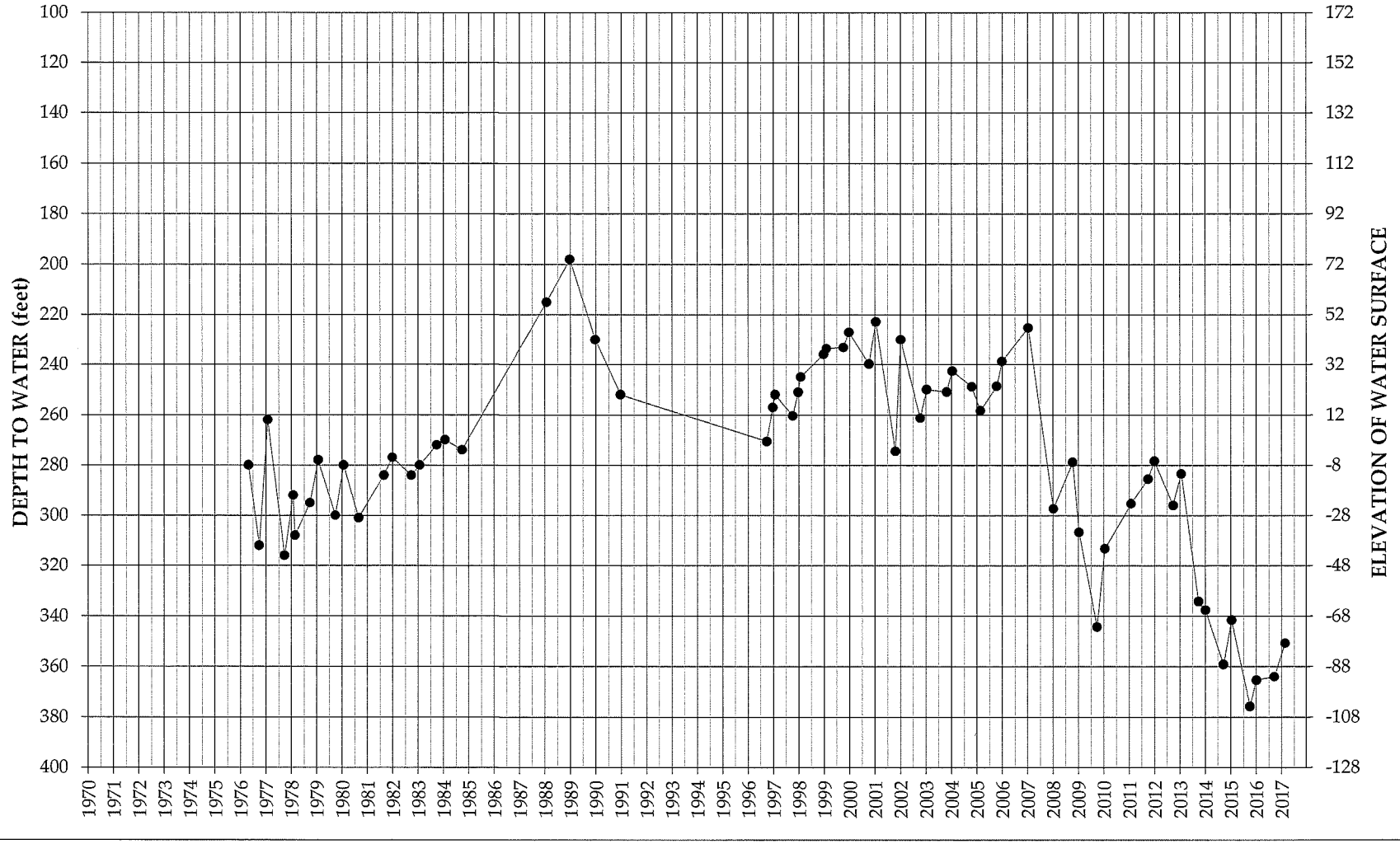
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-12A



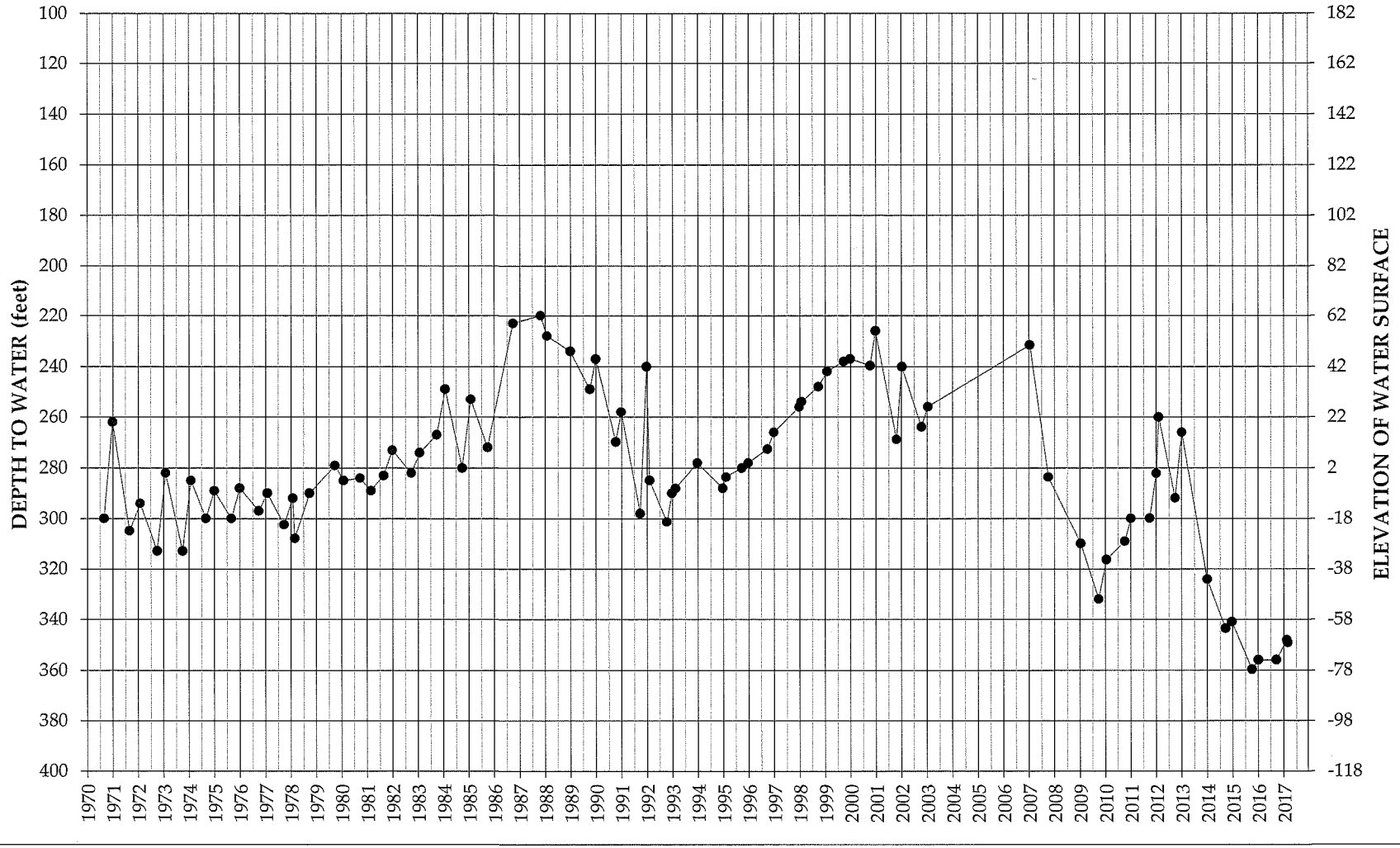
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-15G01



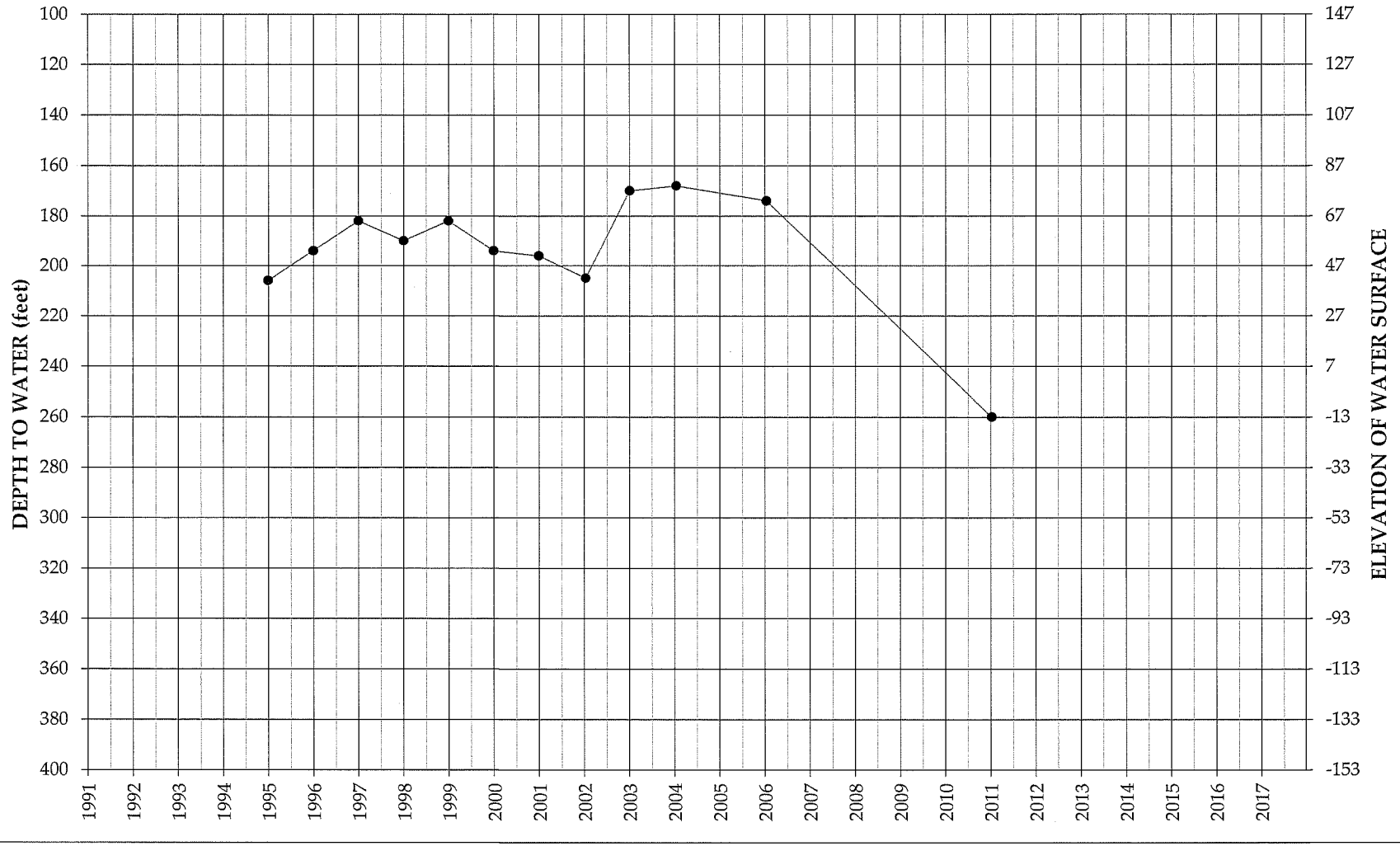
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-16N (300-600)

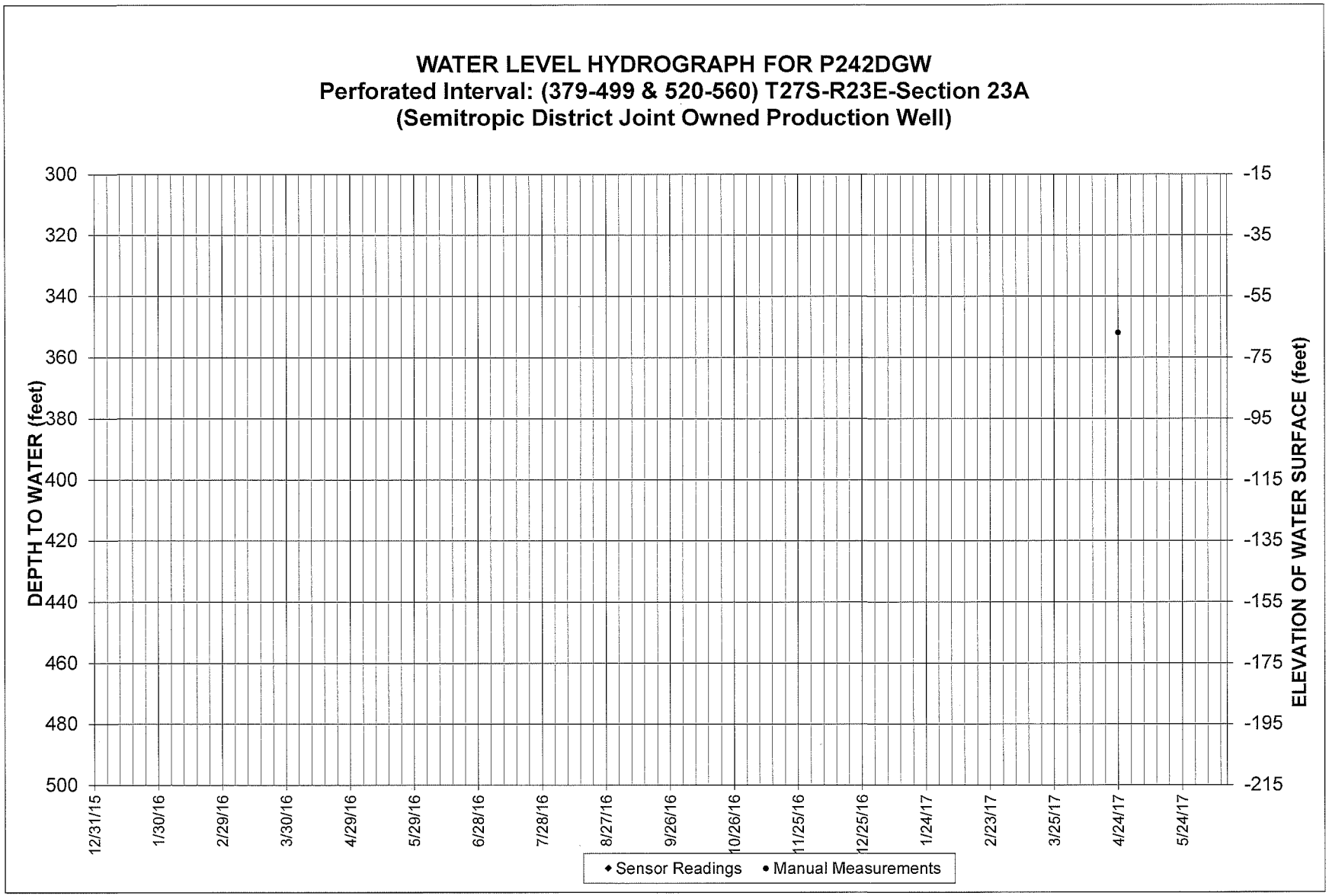


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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-20R



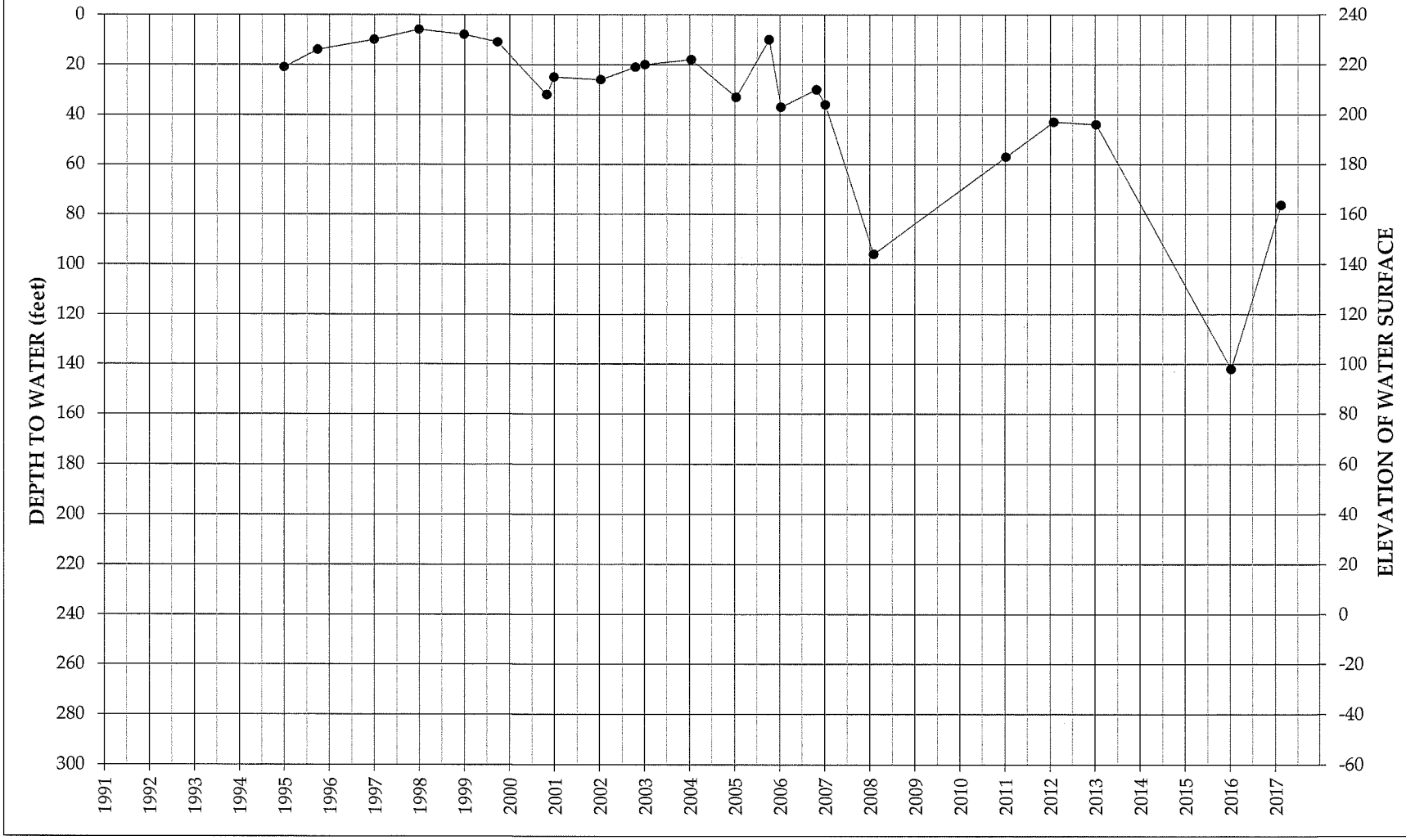
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Semitropic Water Storage District
(Manual data from the KCWA)

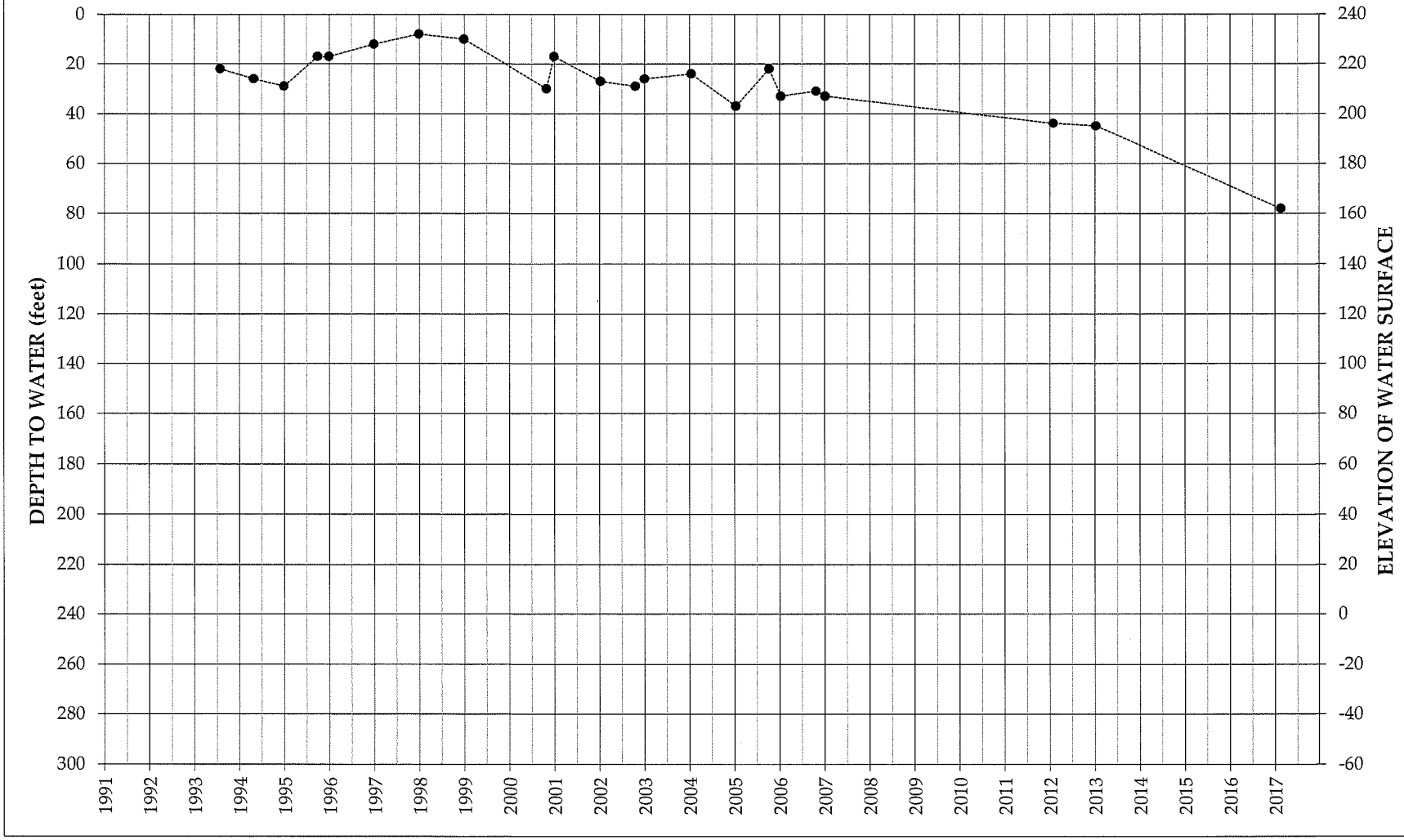
5/8/2017

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-29C



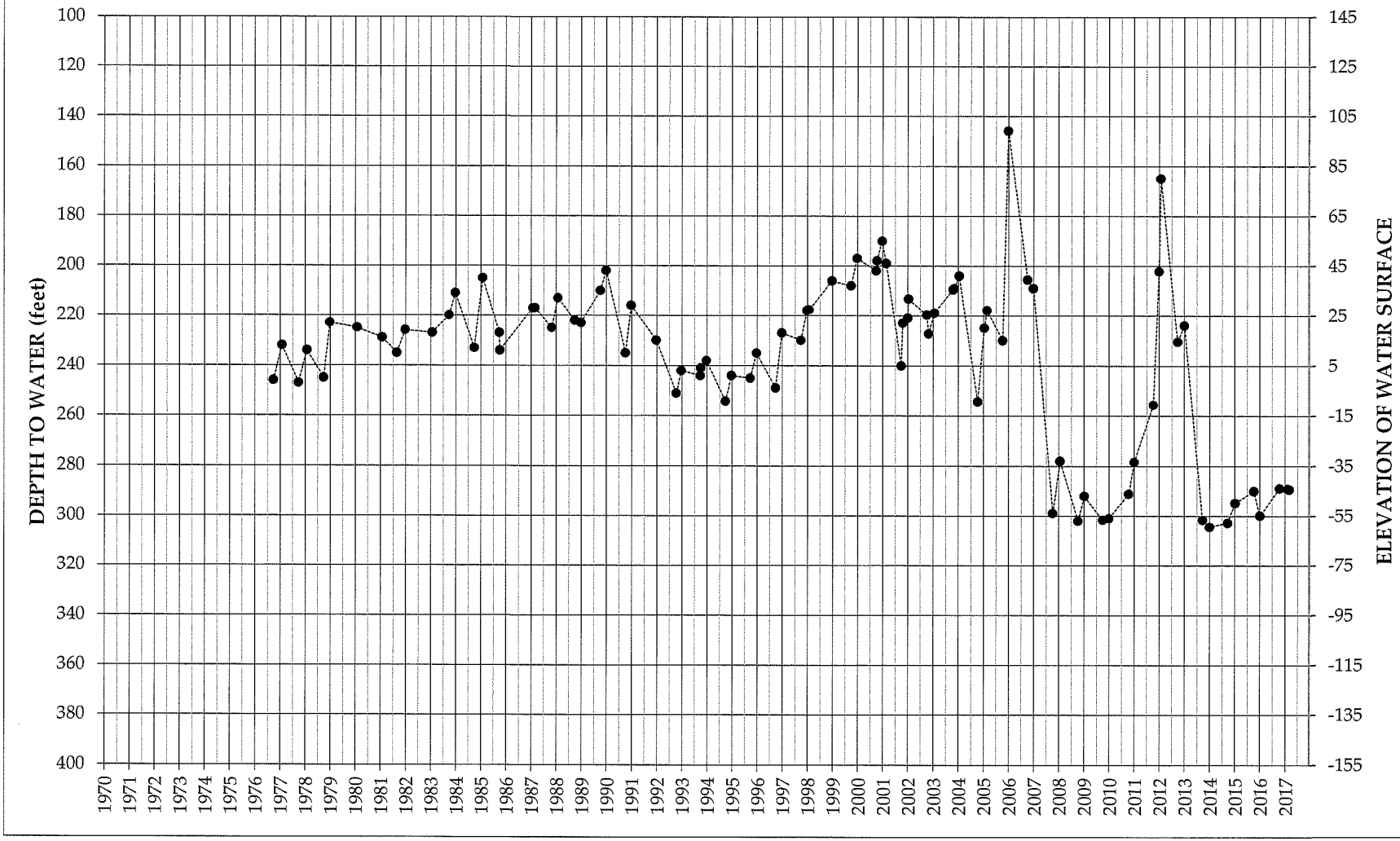
GEI Consultants
Bookman-Edmonston Division

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-30A (204-484)



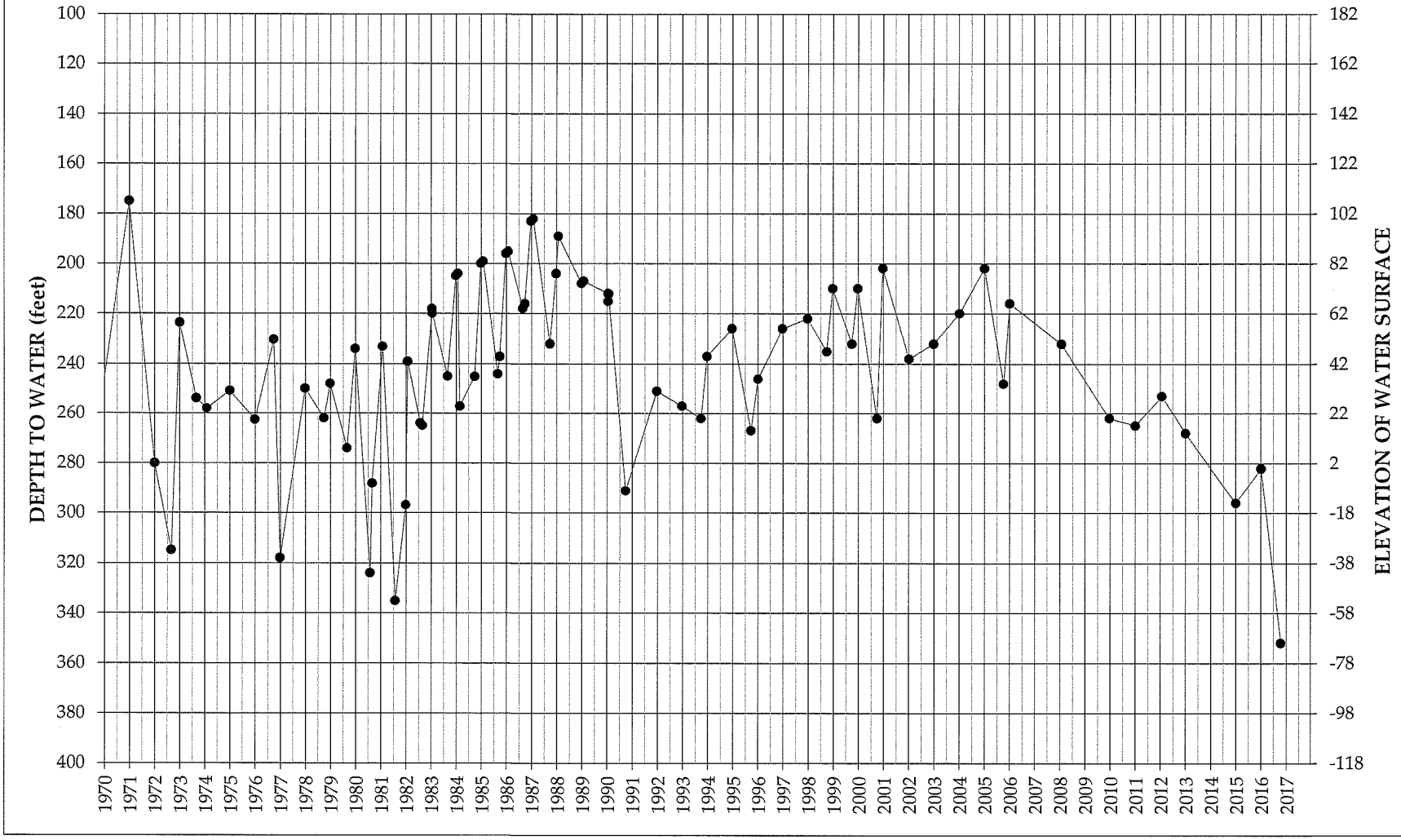
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/23-33J (300-840)



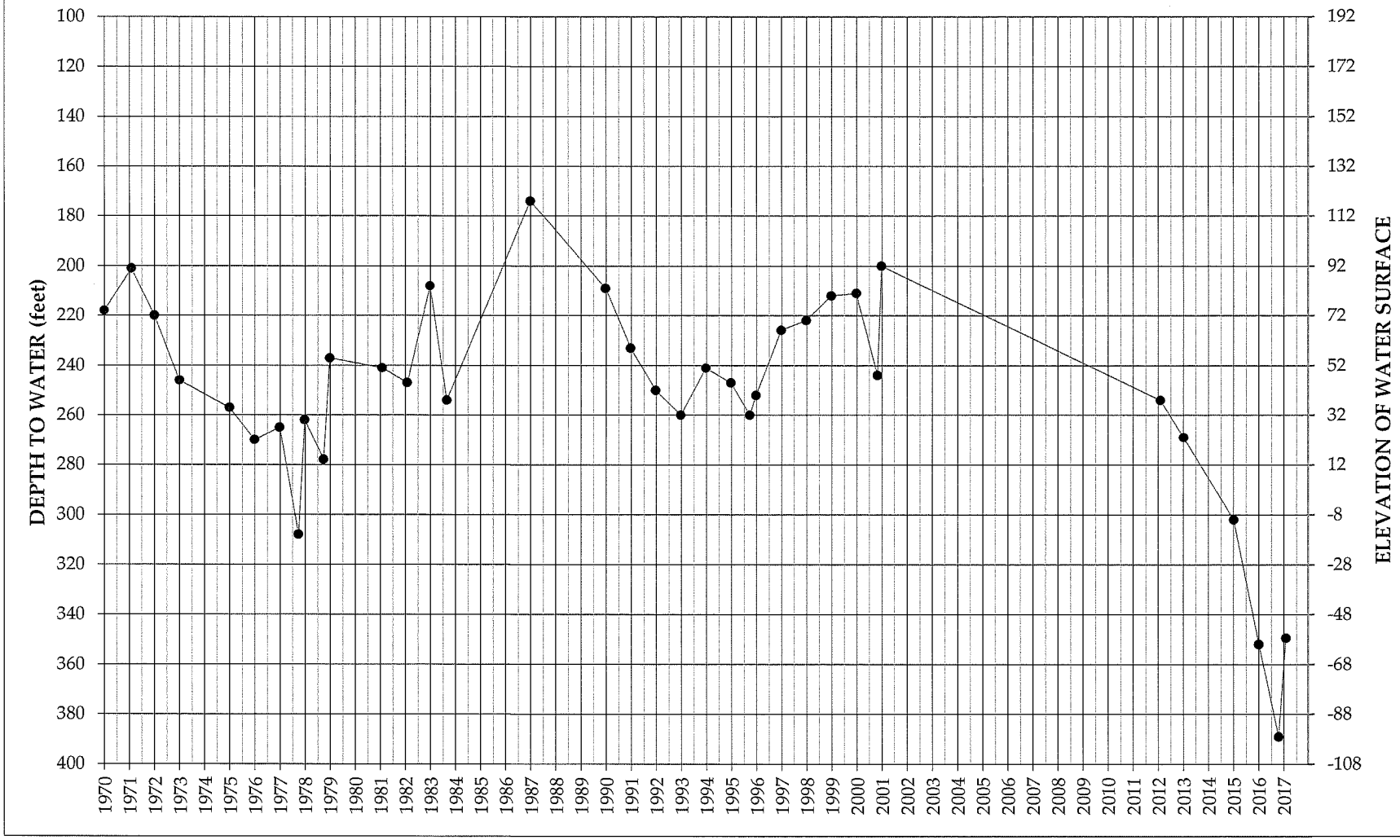
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/24-5H (260-730)



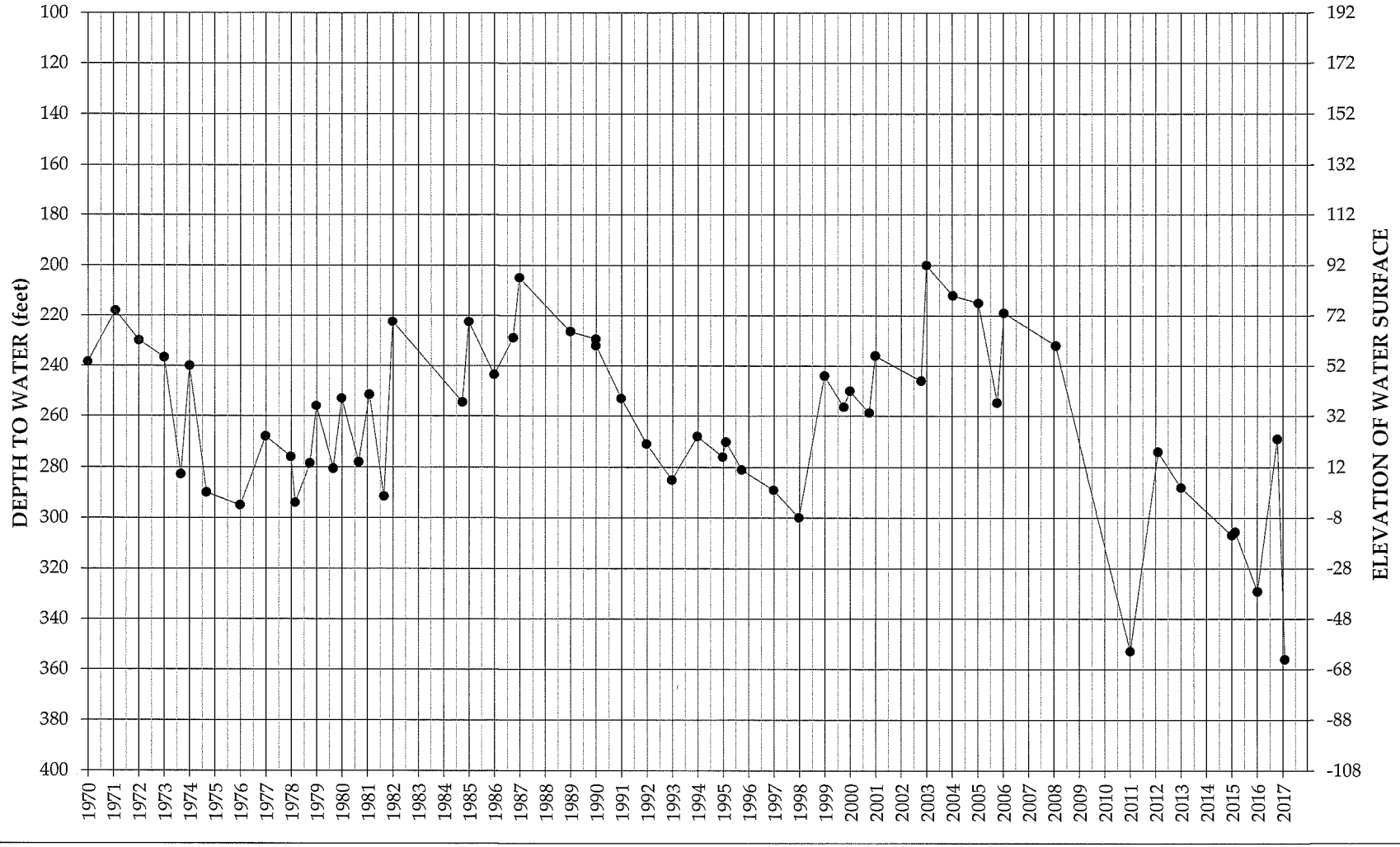
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/24-6F

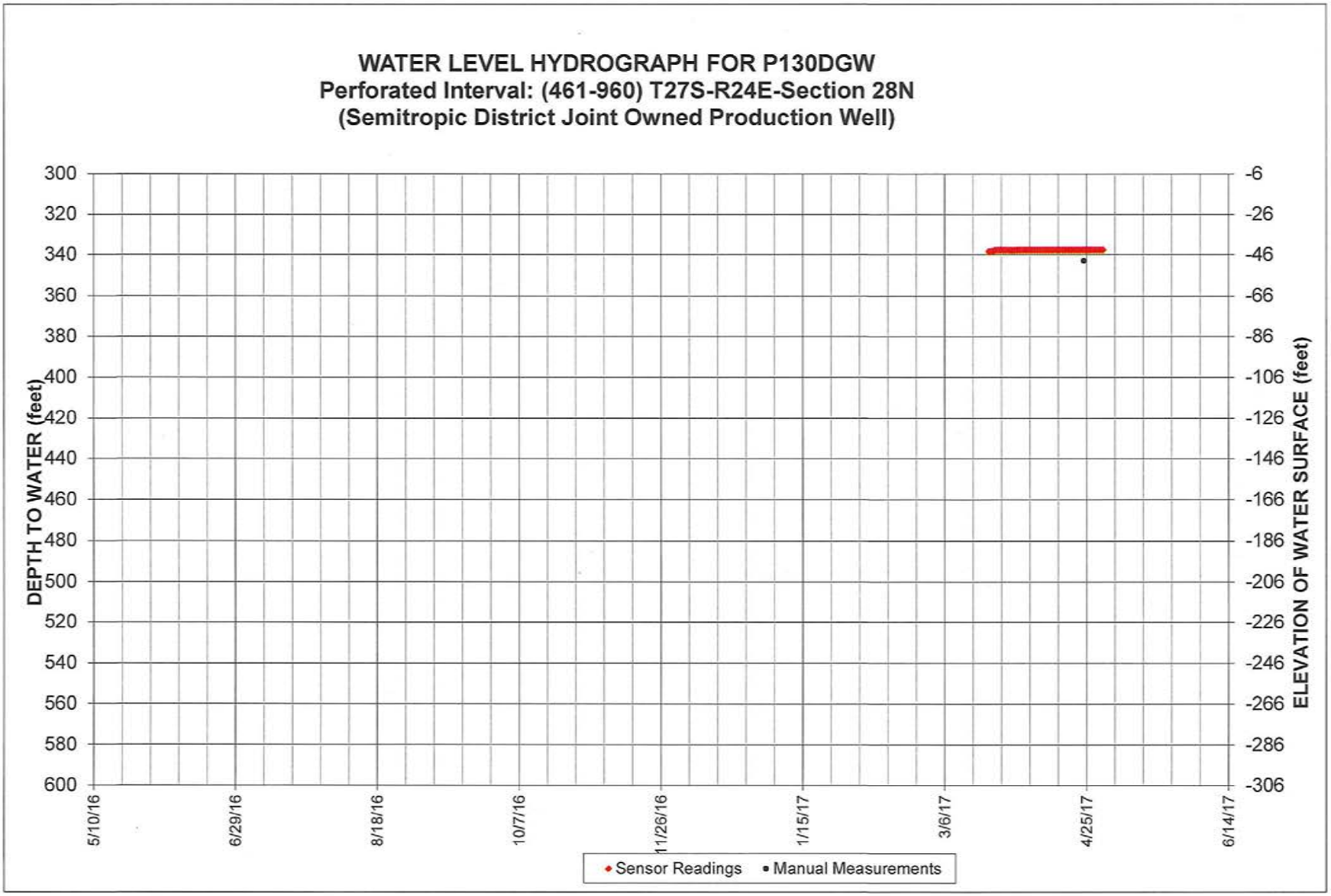


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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/24-16P (350-716)



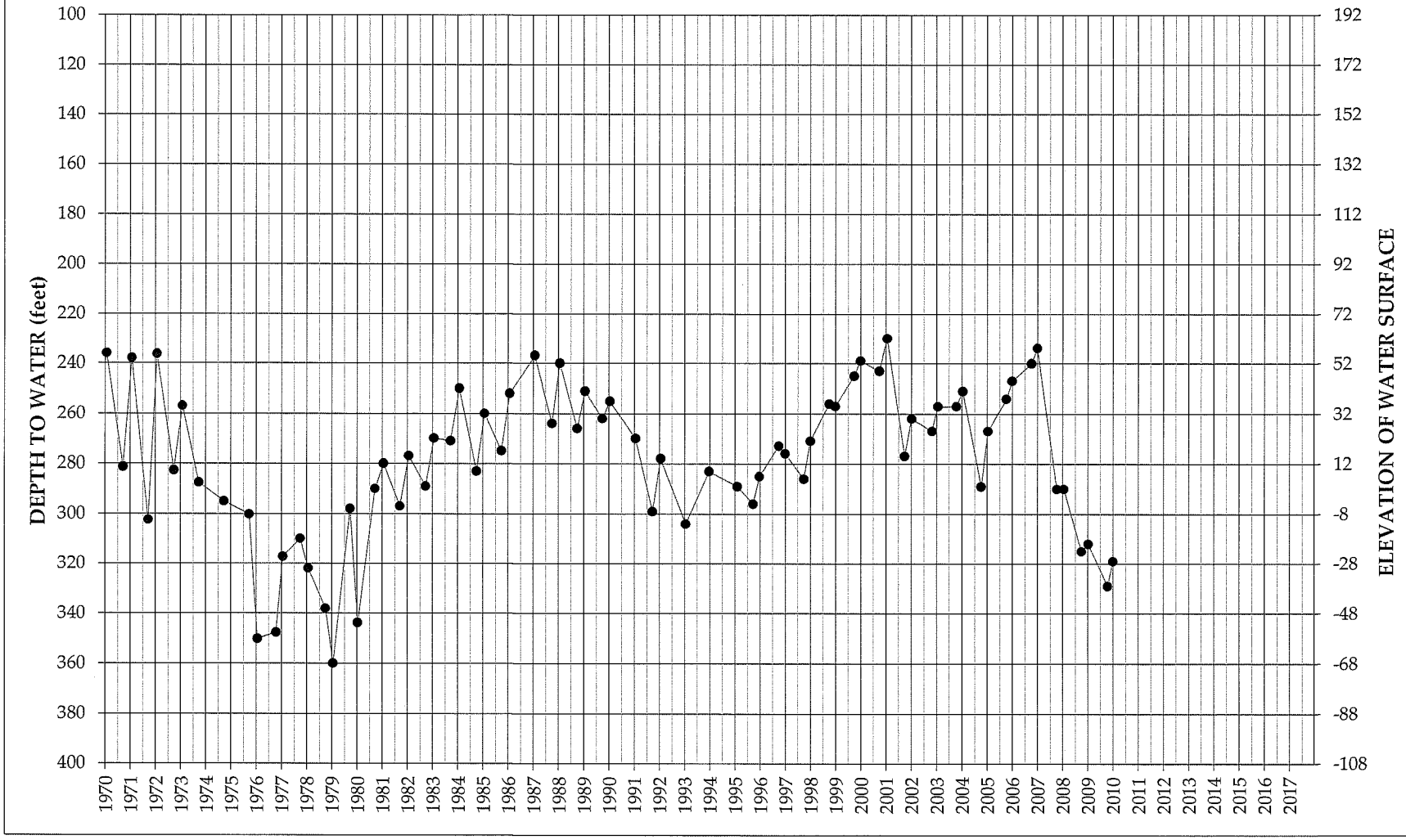
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Semitropic Water Storage District
(Manual data from the KCWA)

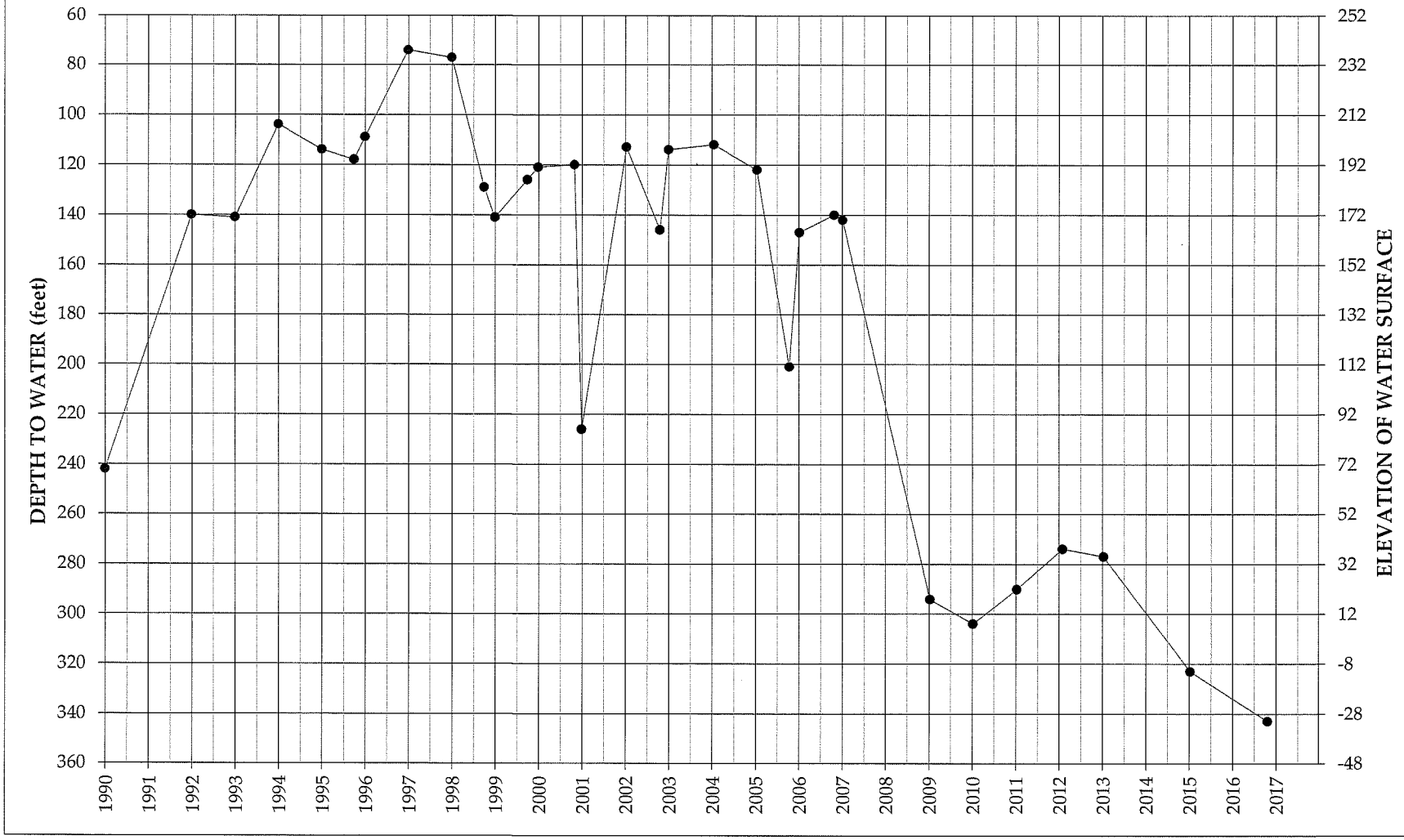
5/8/2017

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/24-31D01



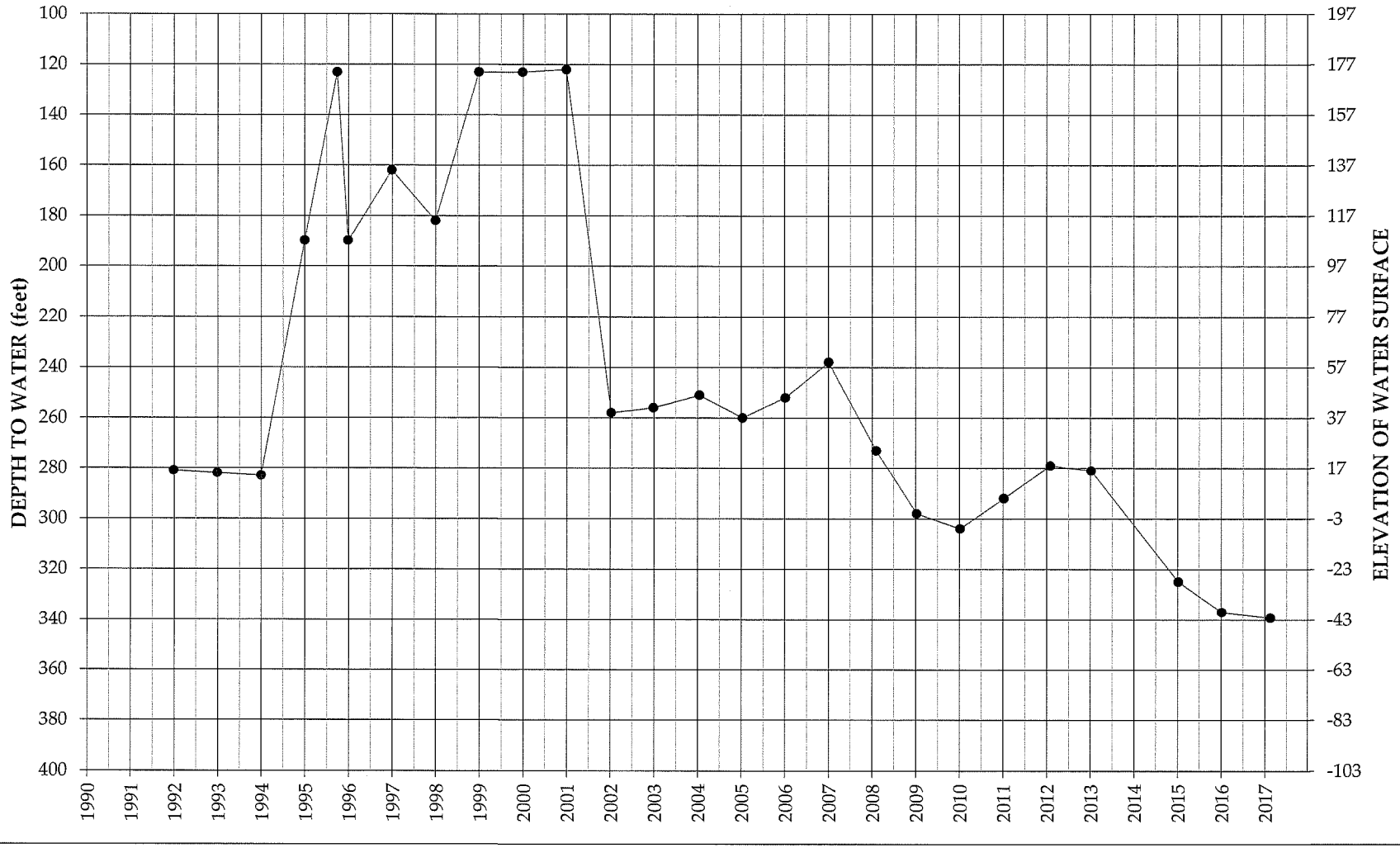
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/22-1H



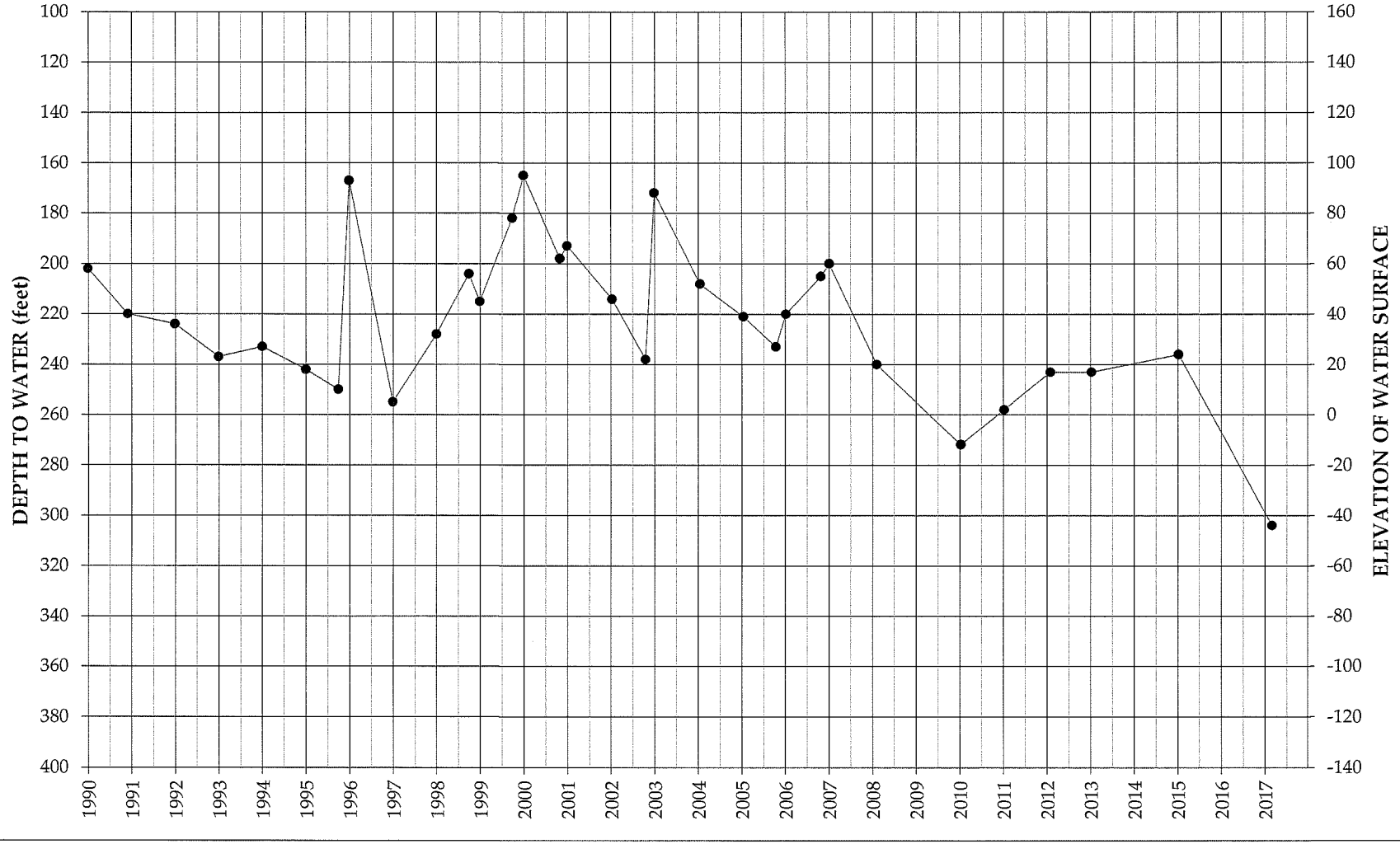
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-7H (300-495)



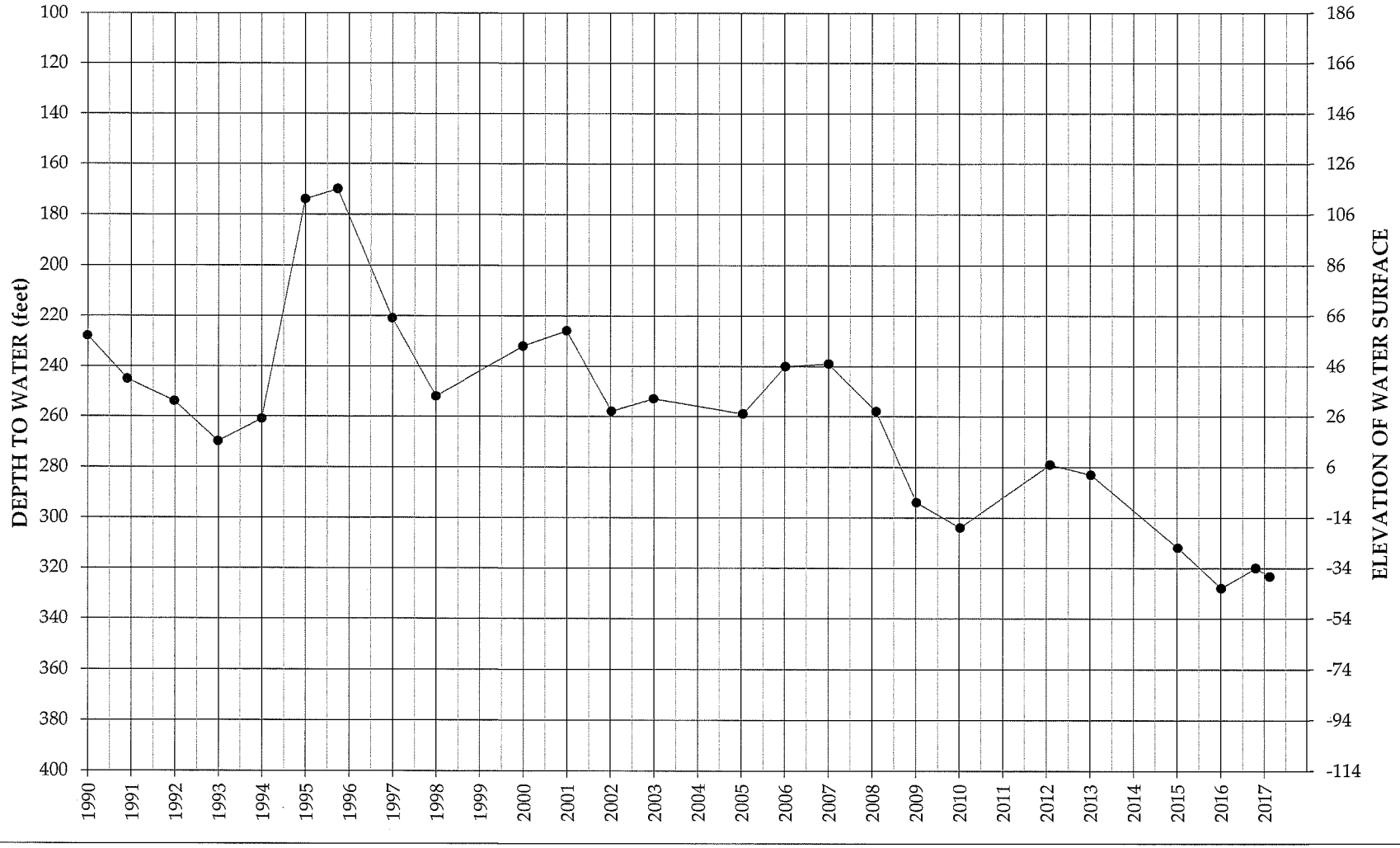
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-11R (288-510)



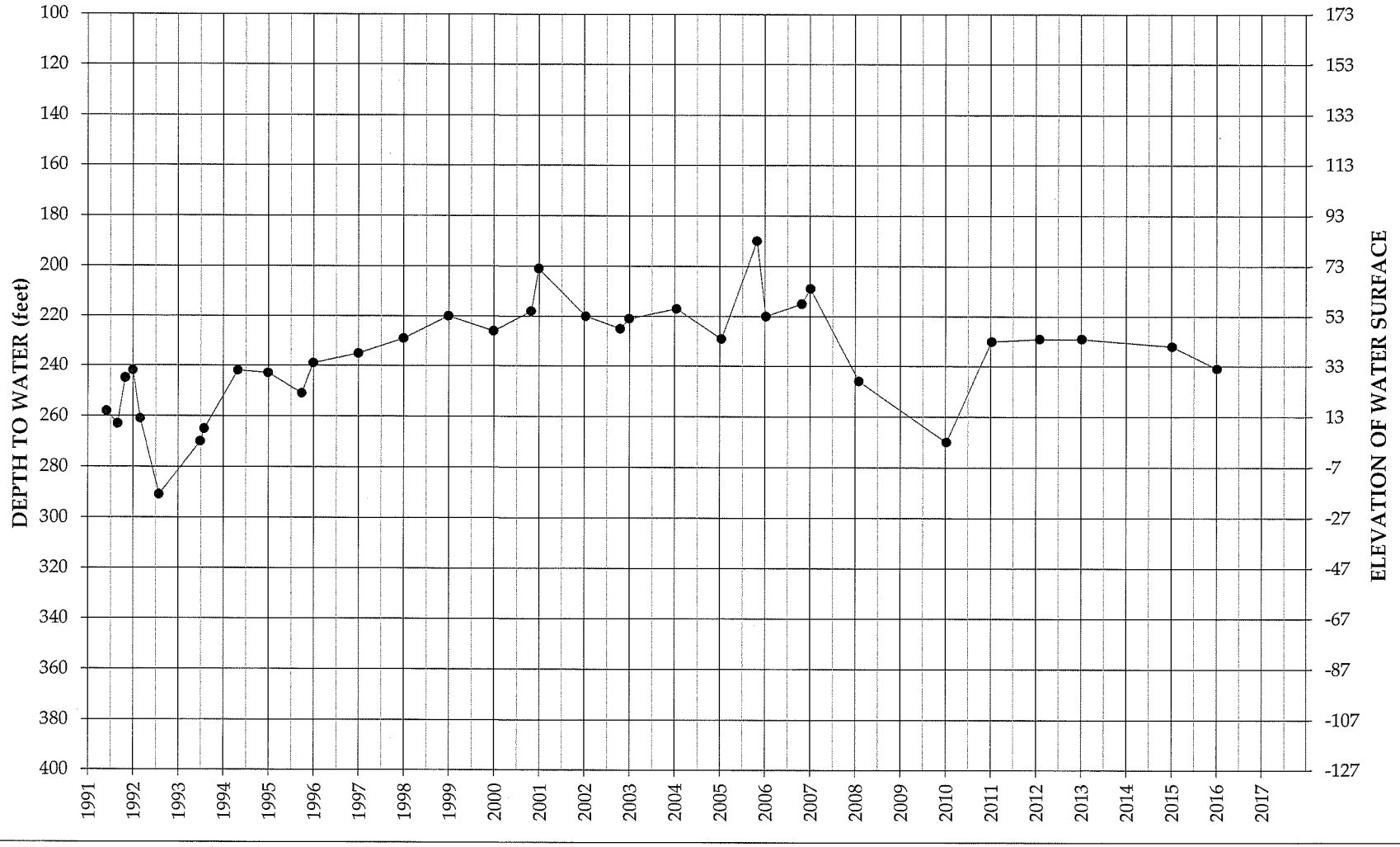
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-16G (240-416)



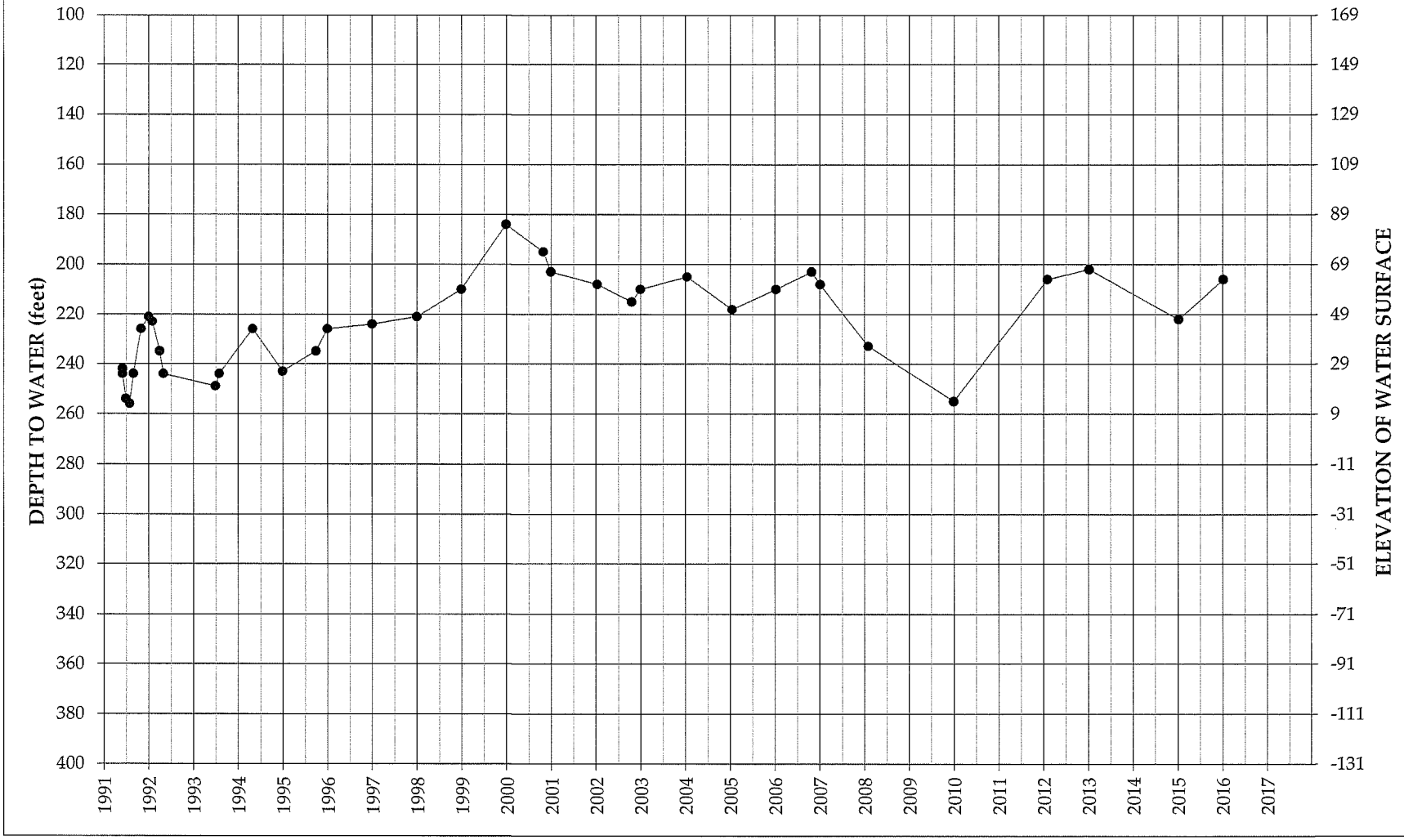
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-22F (413-645)



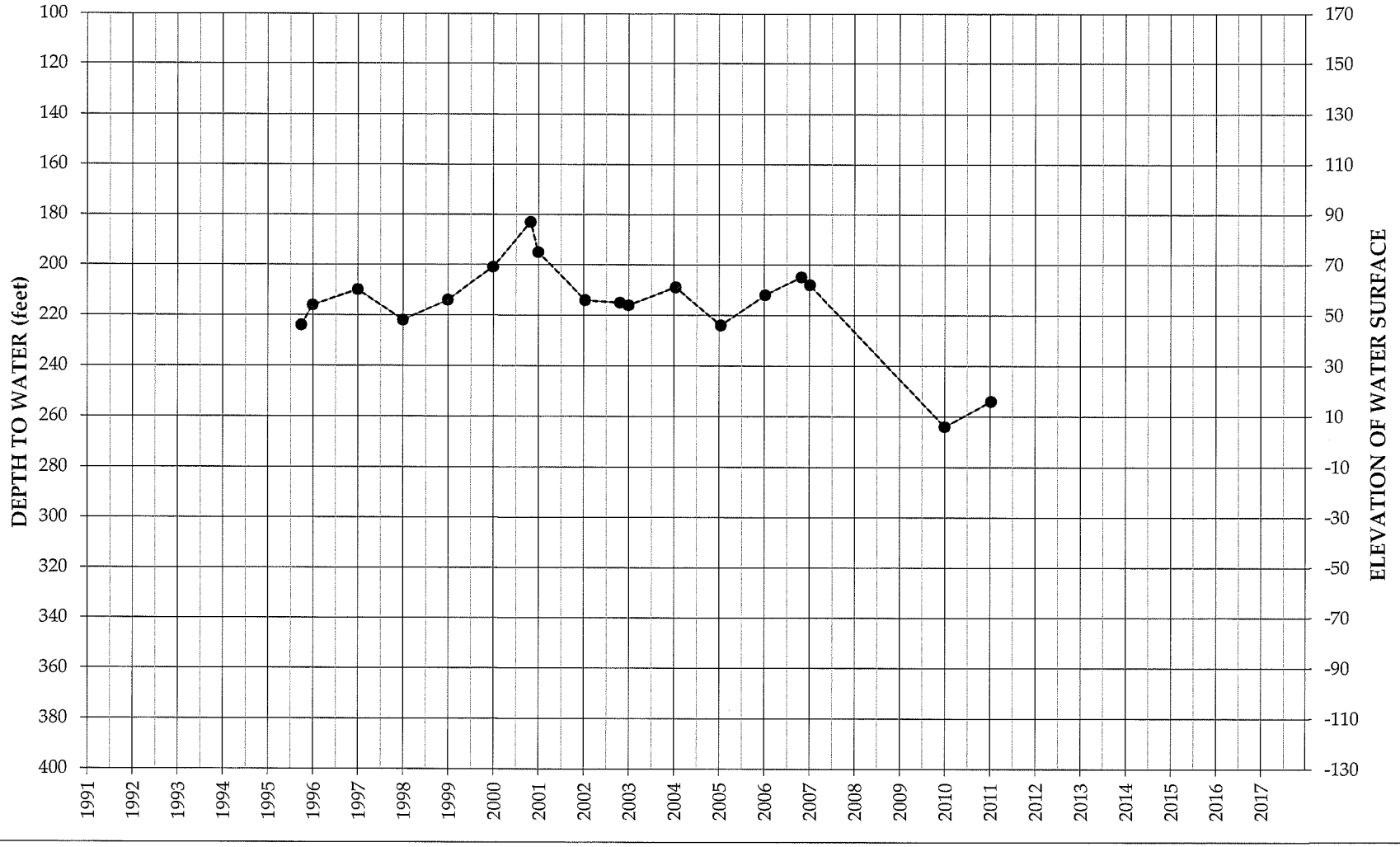
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-26F (420-690)



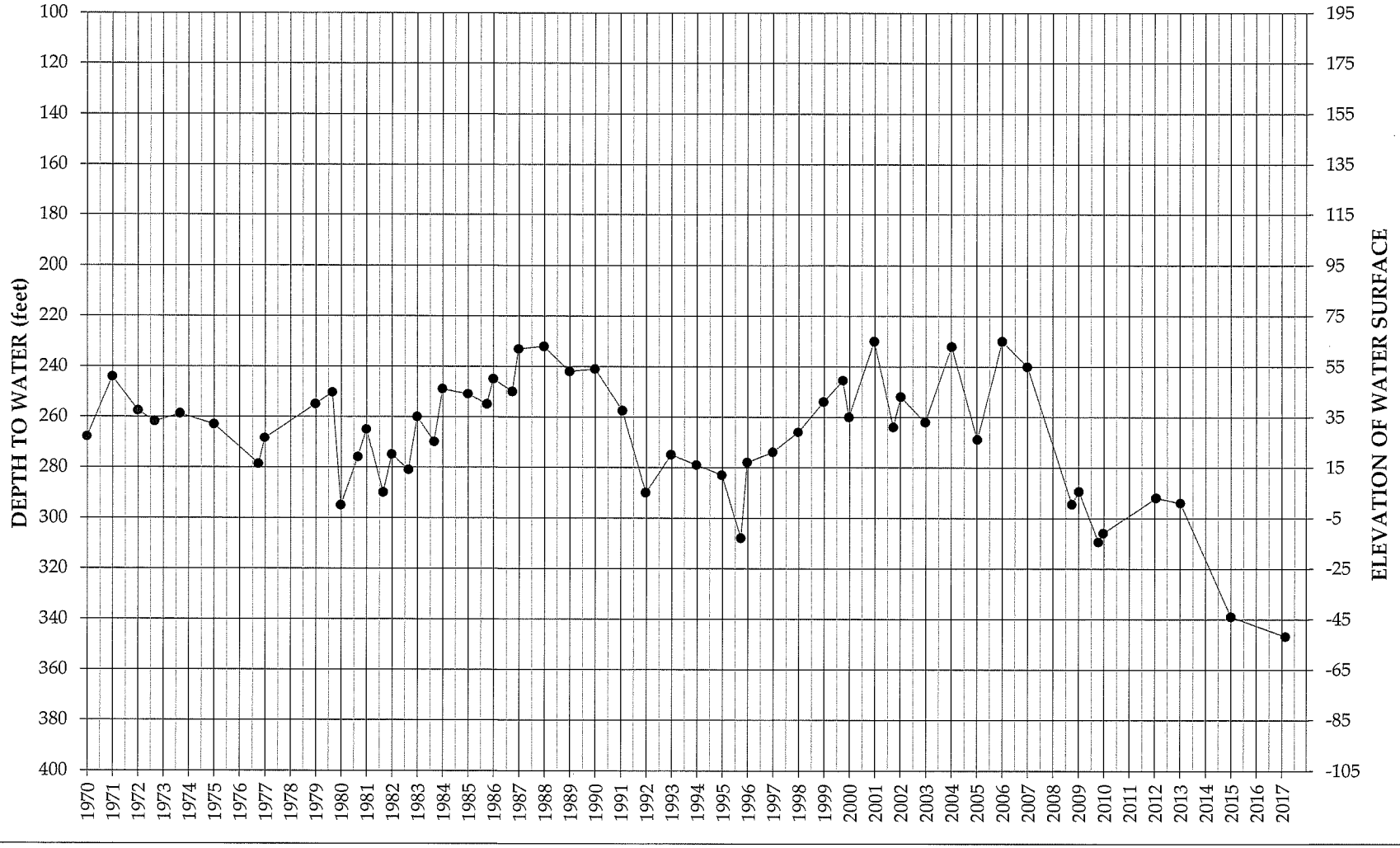
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/23-27A



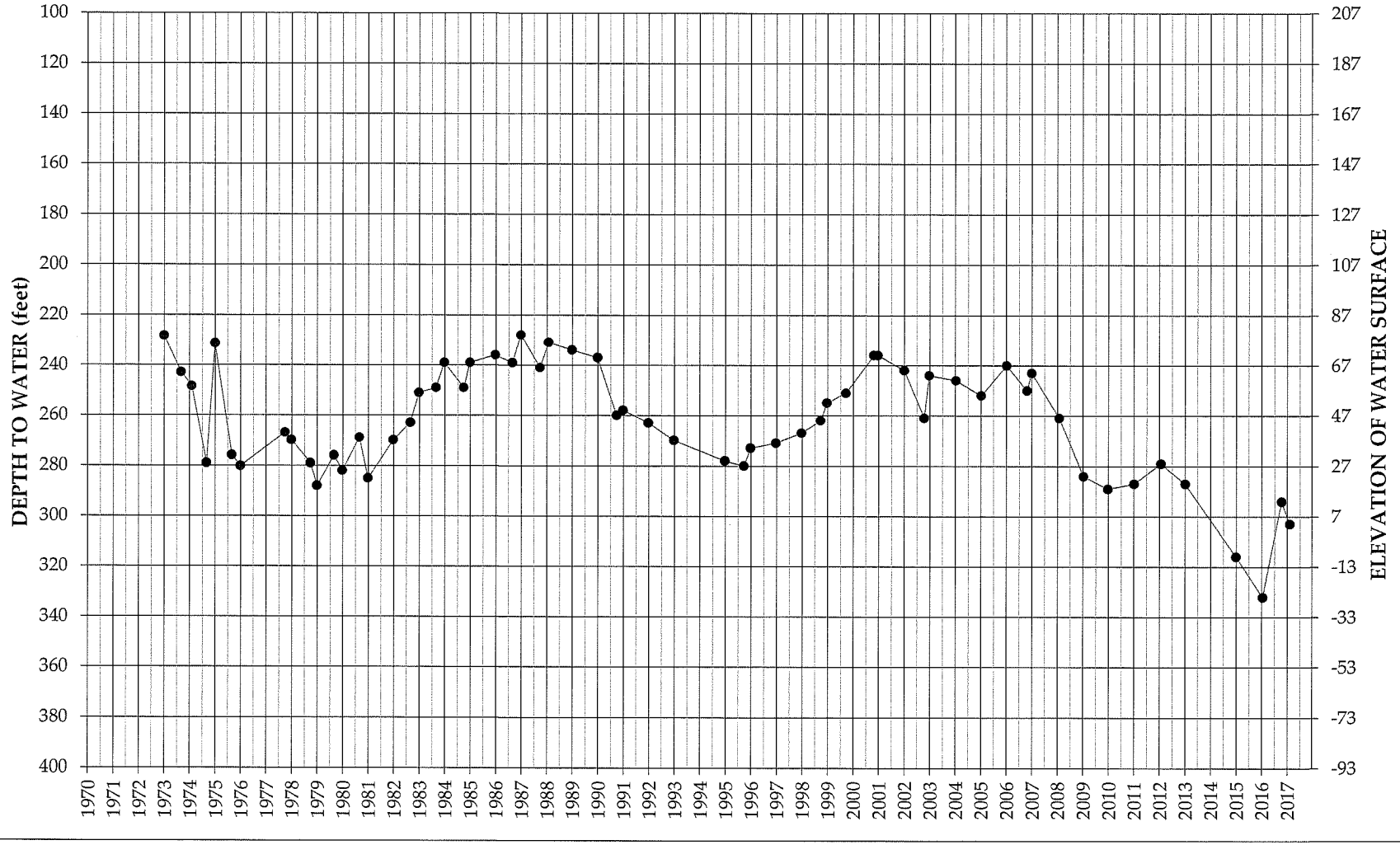
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/24-4C



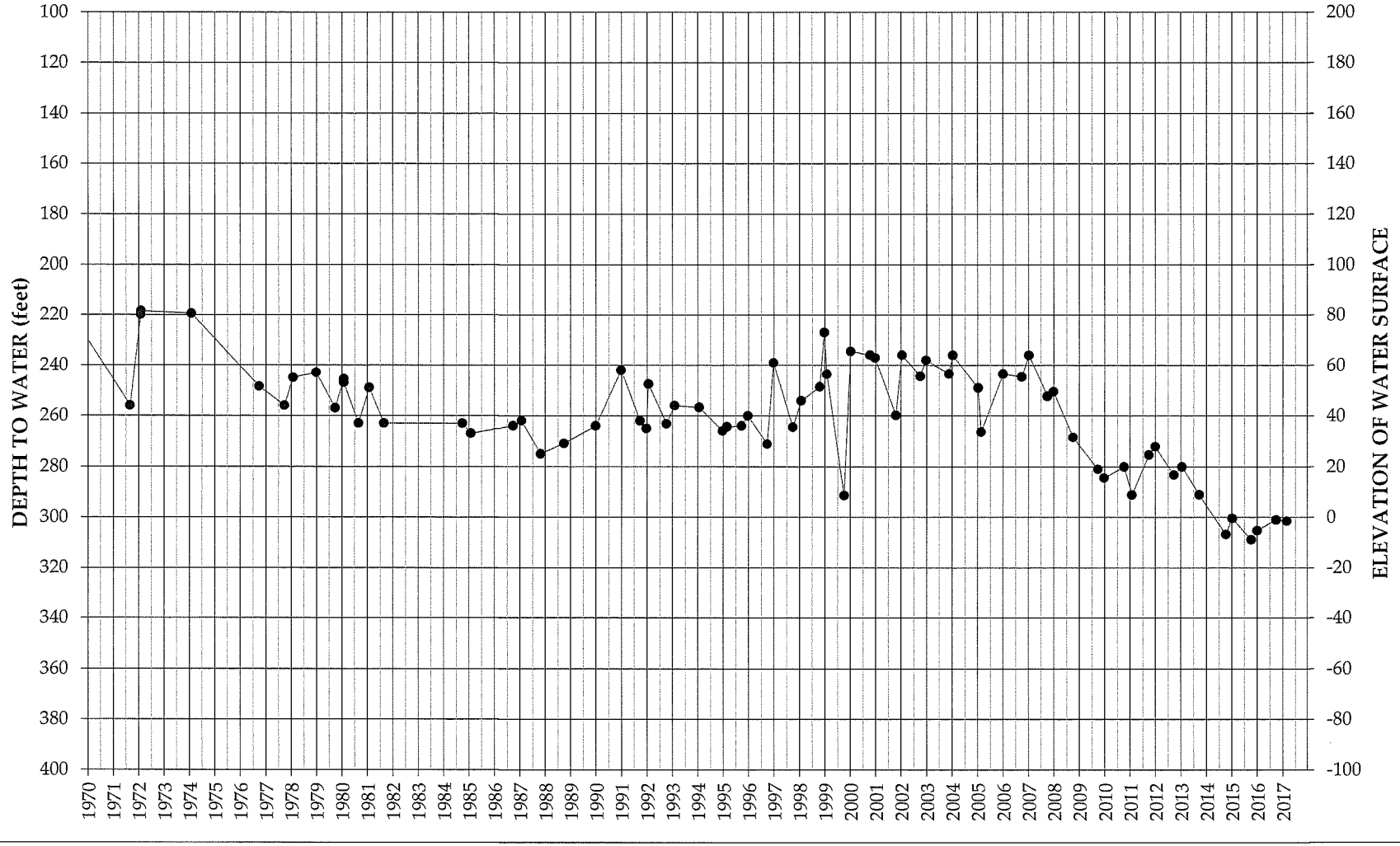
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/24-10R



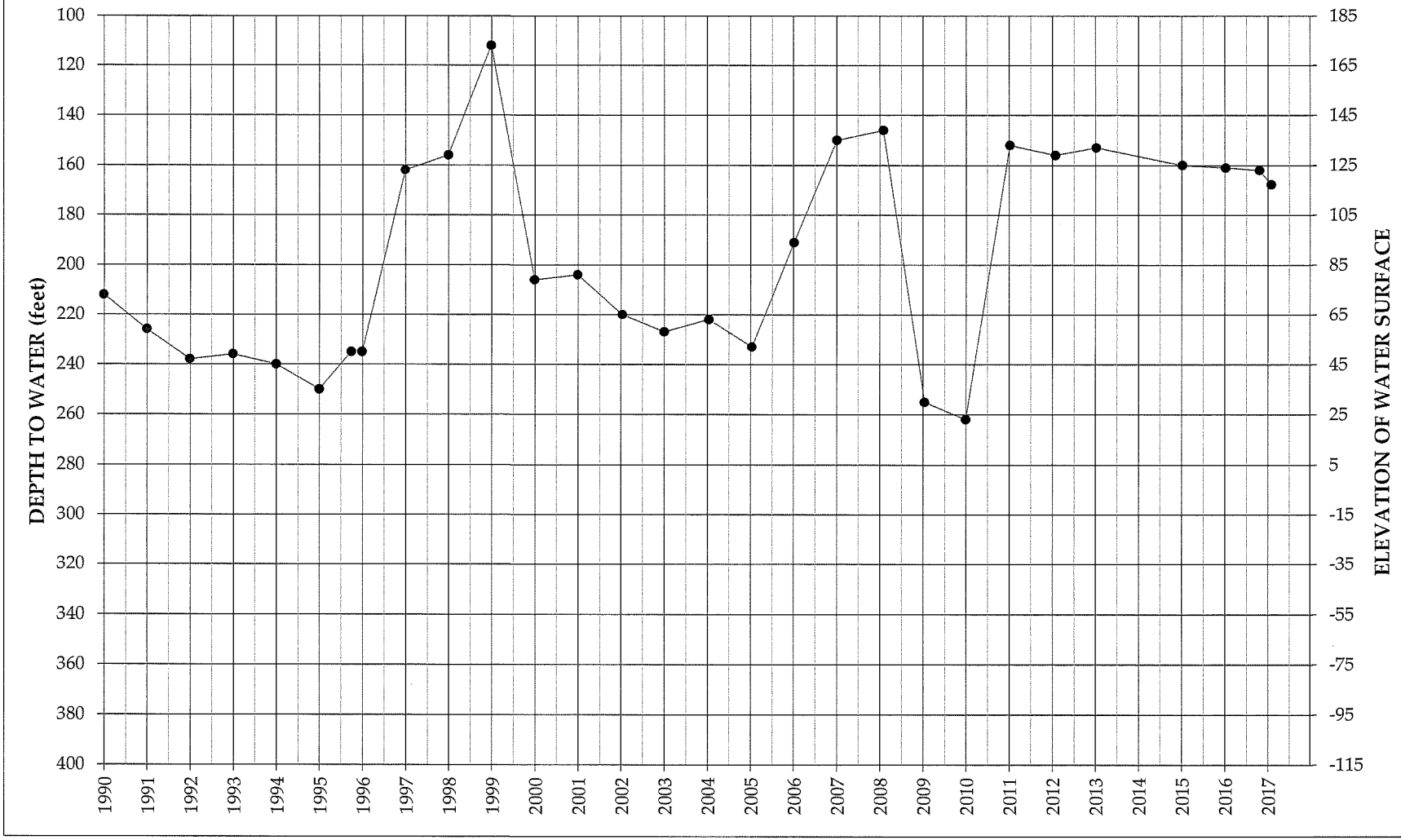
GEI Consultants

SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/24-28A (204-504)

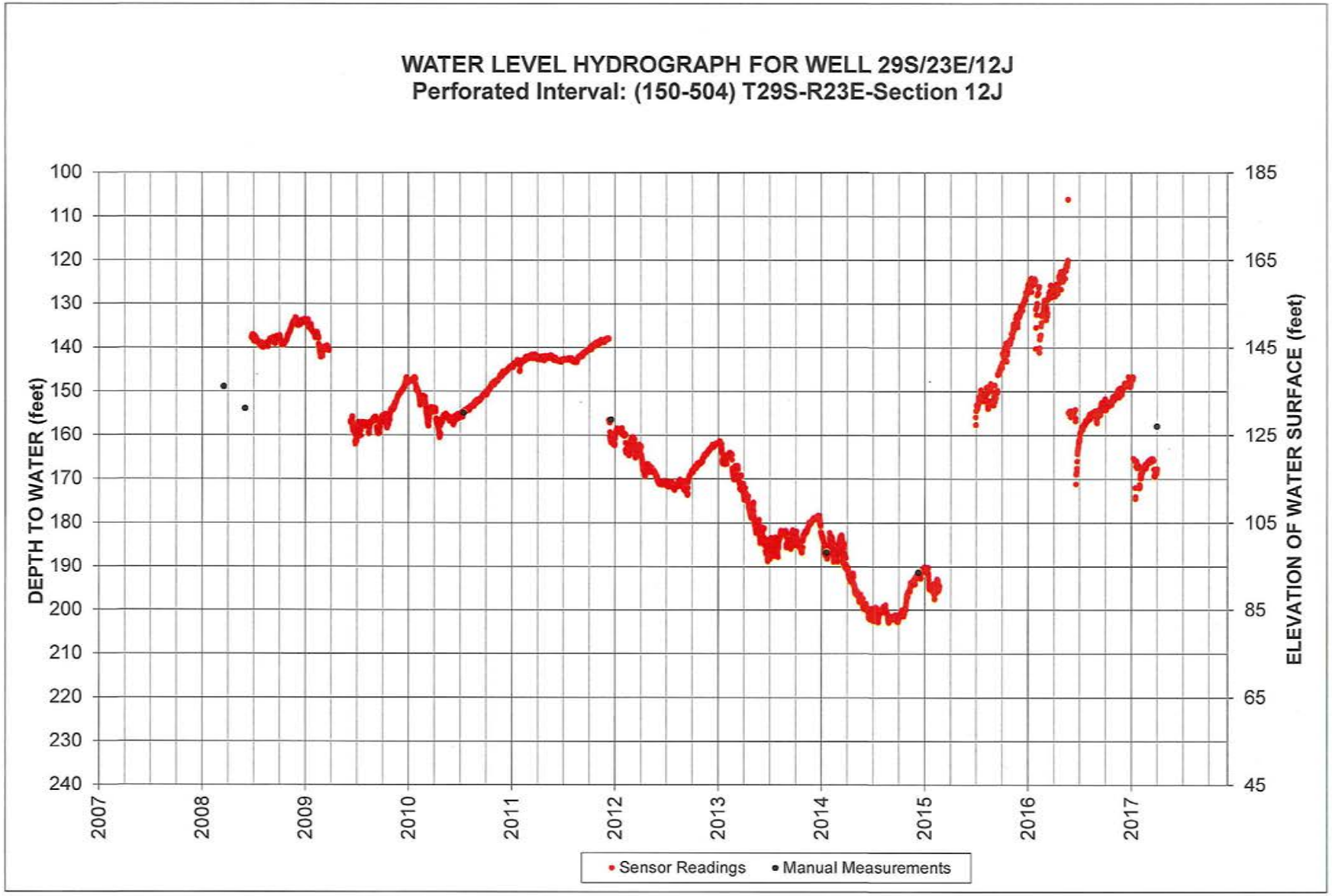


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SEMITROPIC WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #29/23-12J (150-504)



GEI Consultants



Semitropic Water Storage District
(Manual data from the KCWA)

5/8/2017



WATER-LEVEL HYDROGRAPH FOR WELL T29S/R24E-9F



WATER-LEVEL HYDROGRAPH FOR WELL T29S/R24E-9H

NORTH KERN WATER STORAGE DISTRICT

North Kern WSD

WELLS

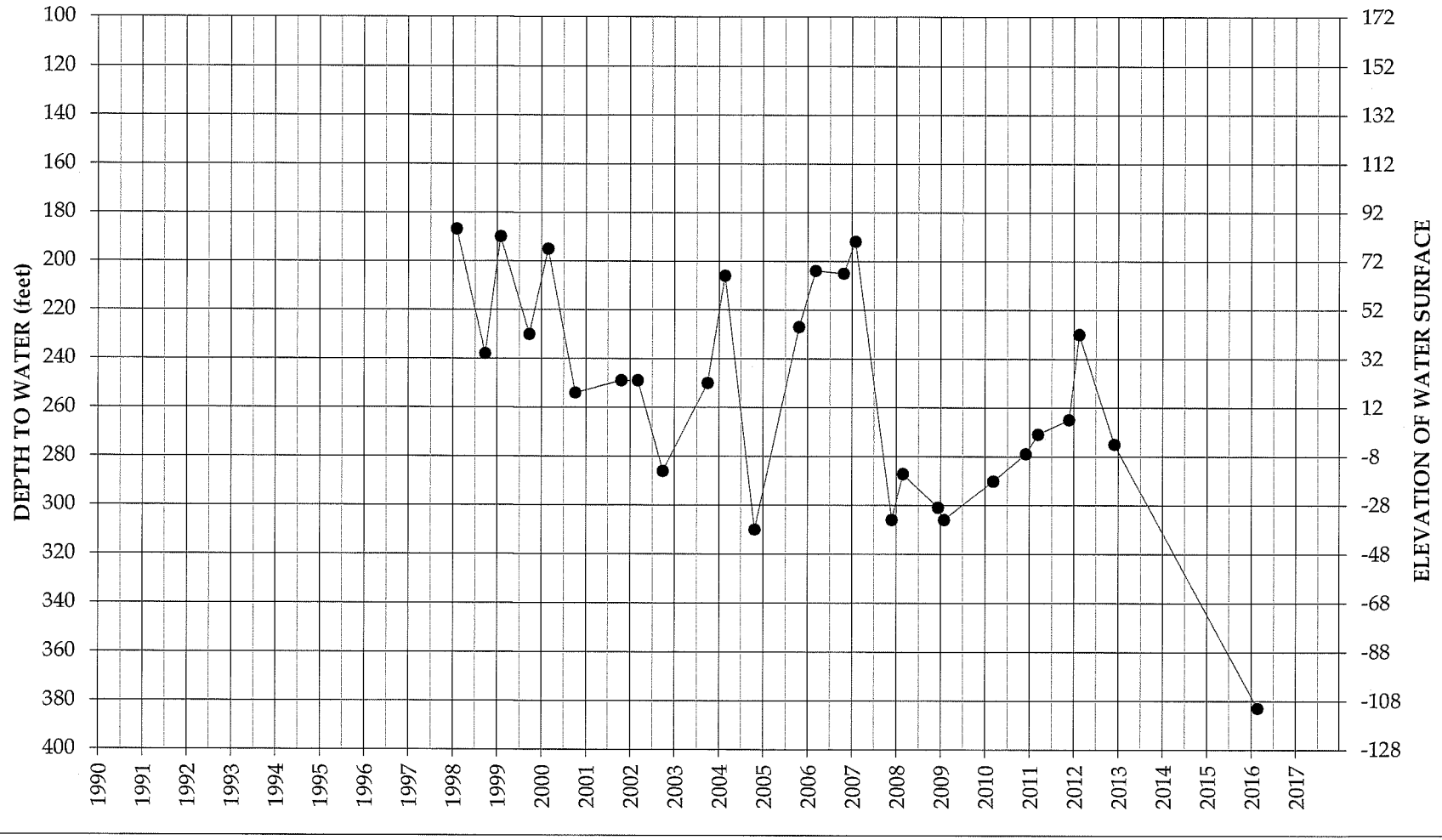
HYDROGRAPHS

Well Number		Perforated Interval from	to	Well Type
26/24-10F				Private
26/24-11P				Private
26/24-12R				Private
26/24-25F				Private
26/24-26P				Private
26/24-34P				Private
26/24-35F	(a)			Private
26/24-36J				Private
26/25-07R				Private
26/25-08P				Private
26/25-09R				Private
26/25-15R				Private
26/25-16R				Private
26/25-19R				Private
26/25-21K		340	900	District
26/25-22H				Private
26/25-23R				Private
26/25-25R				Private
26/25-26N		400	800	District
26/25-27B				District
26/25-28Q		340	800	District
26/25-30H		340	800	District
26/25-31R				Private
26/25-34R		340	800	District
26/25-35B		340	800	District
26/25-36E		336	800	District
27/25-01N		336	800	District
27/25-03H		340	800	District
27/25-03J	(a)			Private
27/25-04H				Private
27/25-05H				Private
27/25-06N				Private
27/25-07L	(a)			Private
27/25-10J				Private
27/25-10L		342	800	District
27/25-12F	(a)			Private
27/25-14G	(a)			Private
27/25-15J				Private

27/25-16H				District
27/25-21K	(a)			Private
27/25-22J				Private
27/25-23C		341	803	District
27/25-24C				Private
27/25-25J				Private
27/25-26K				Private
27/25-27C				Private
27/25-34A				Private
27/25-35L				Private
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28/25-01C				Private
28/25-02A				Private
28/25-12Q				Private
28/25-13F				Private

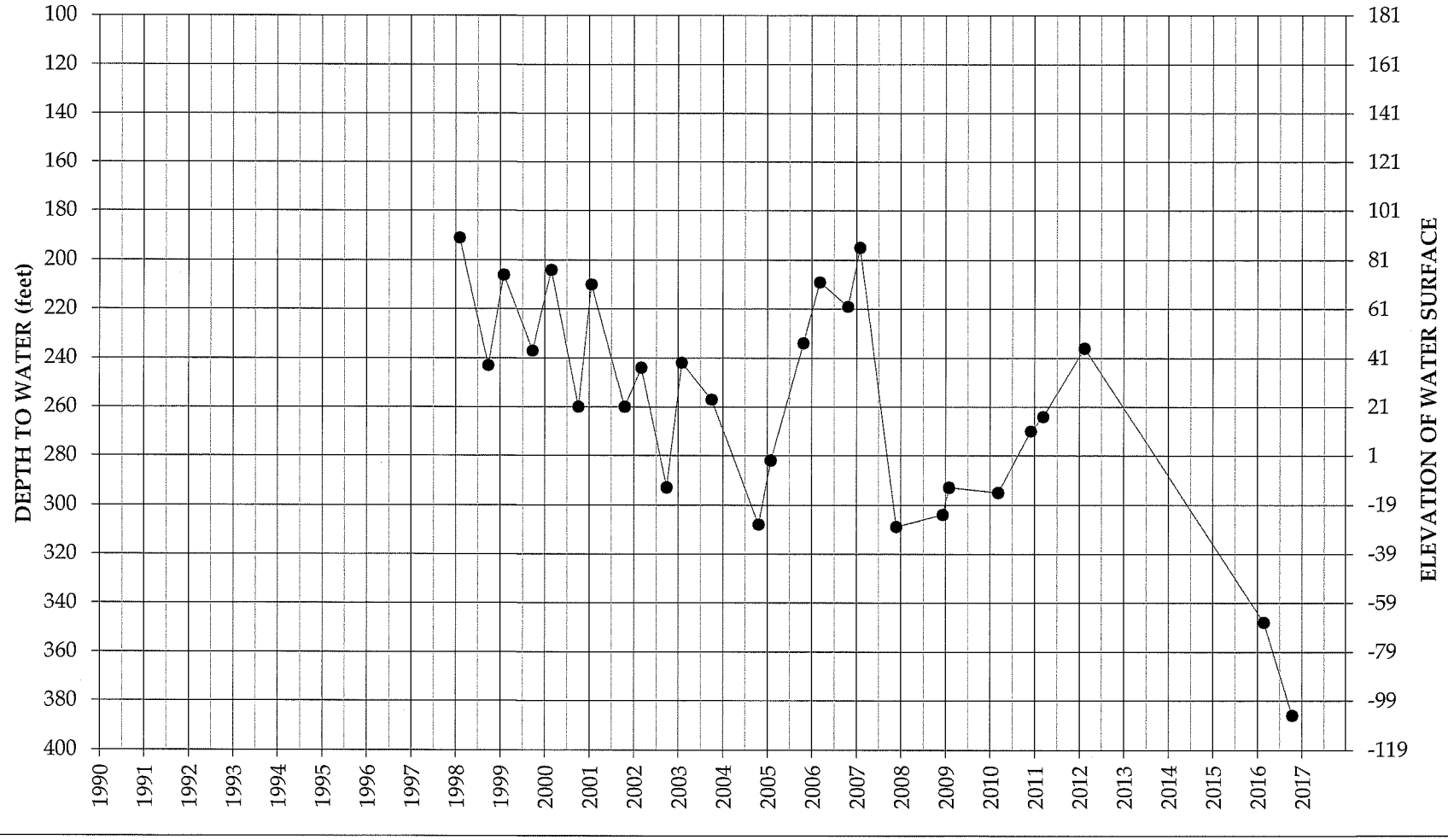
(a) Not included for lack of "recent" or anomalous data.

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-10F



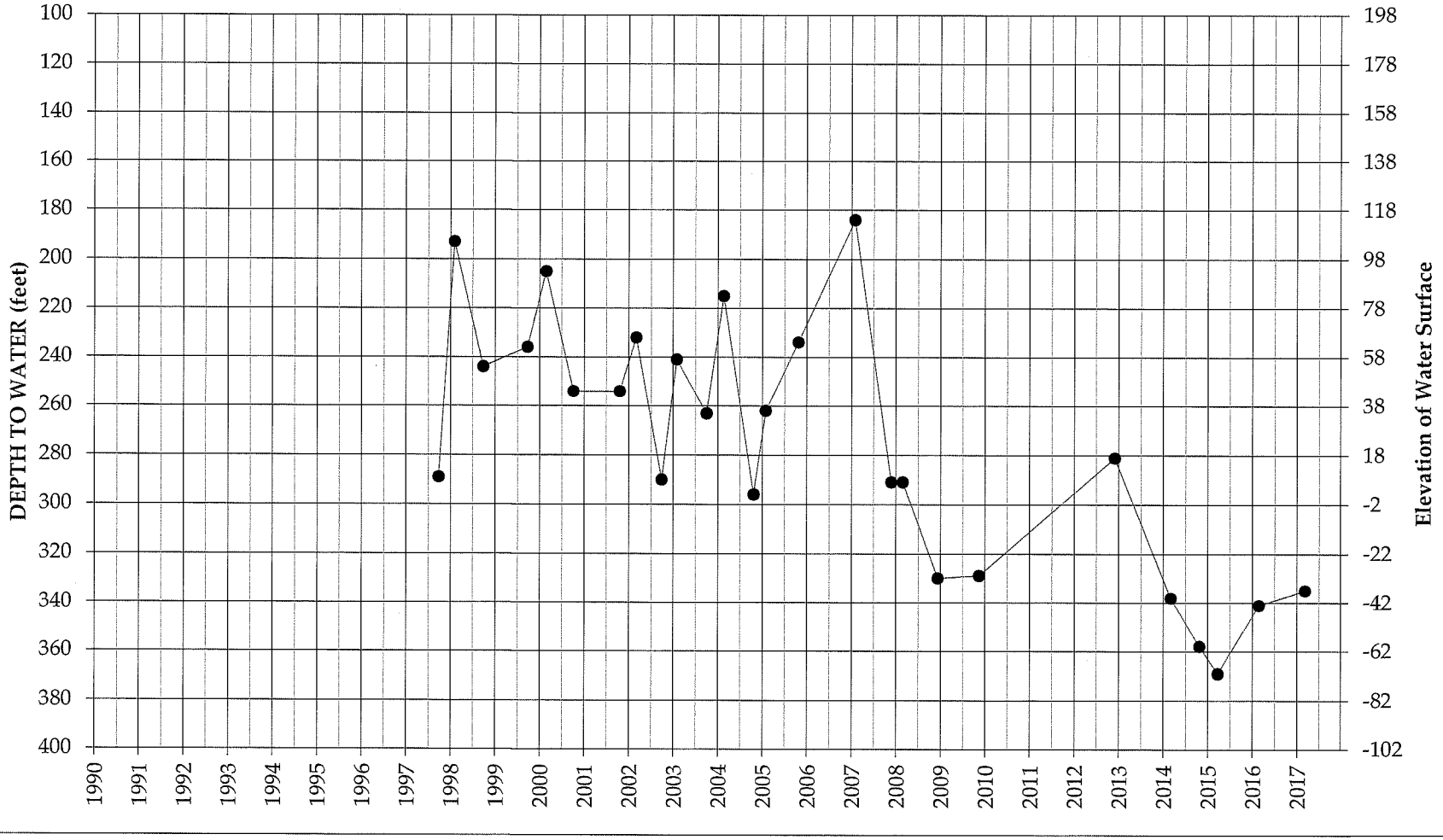
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-11P



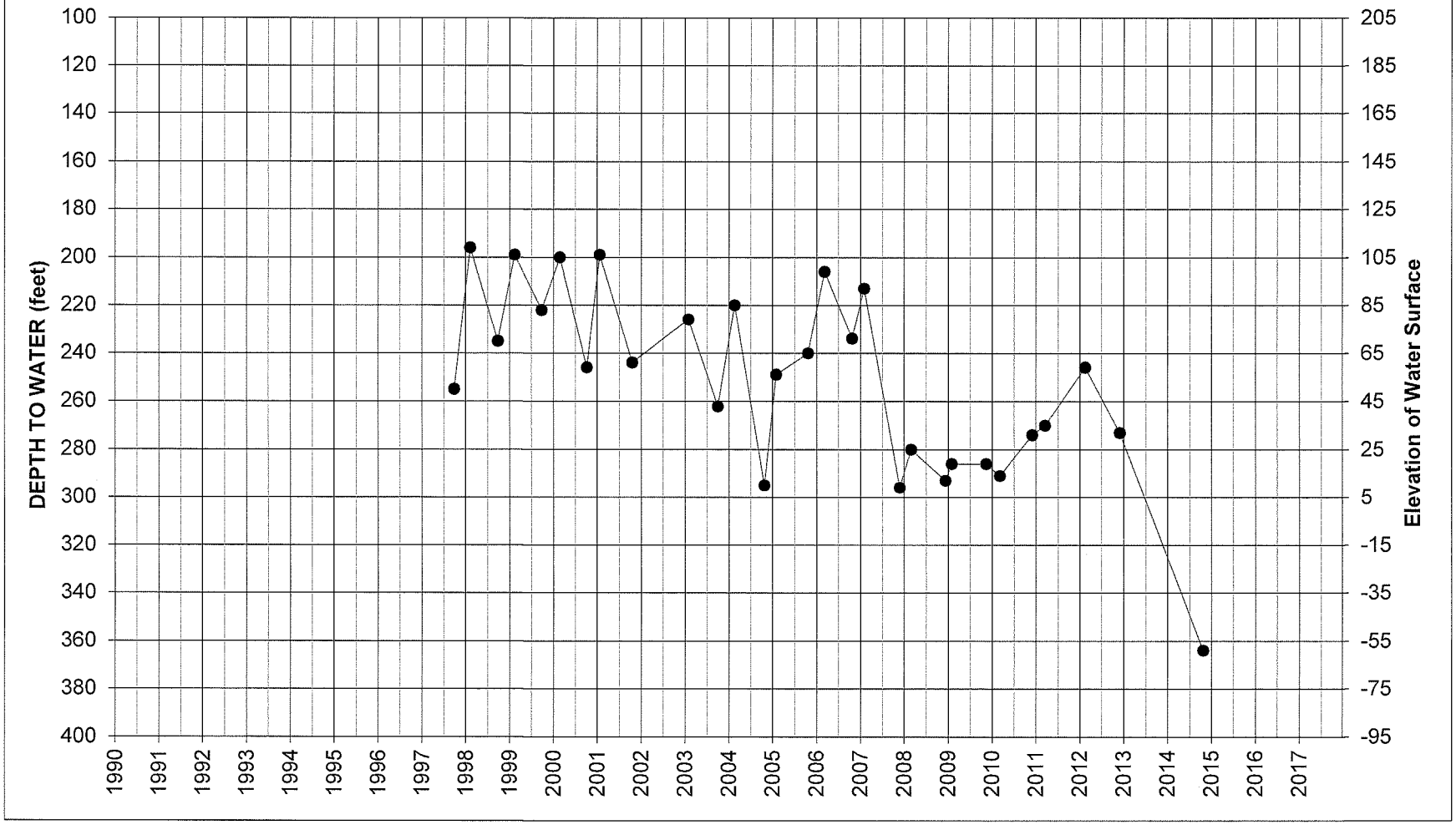
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-12R



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Bookman-Edmonston Division

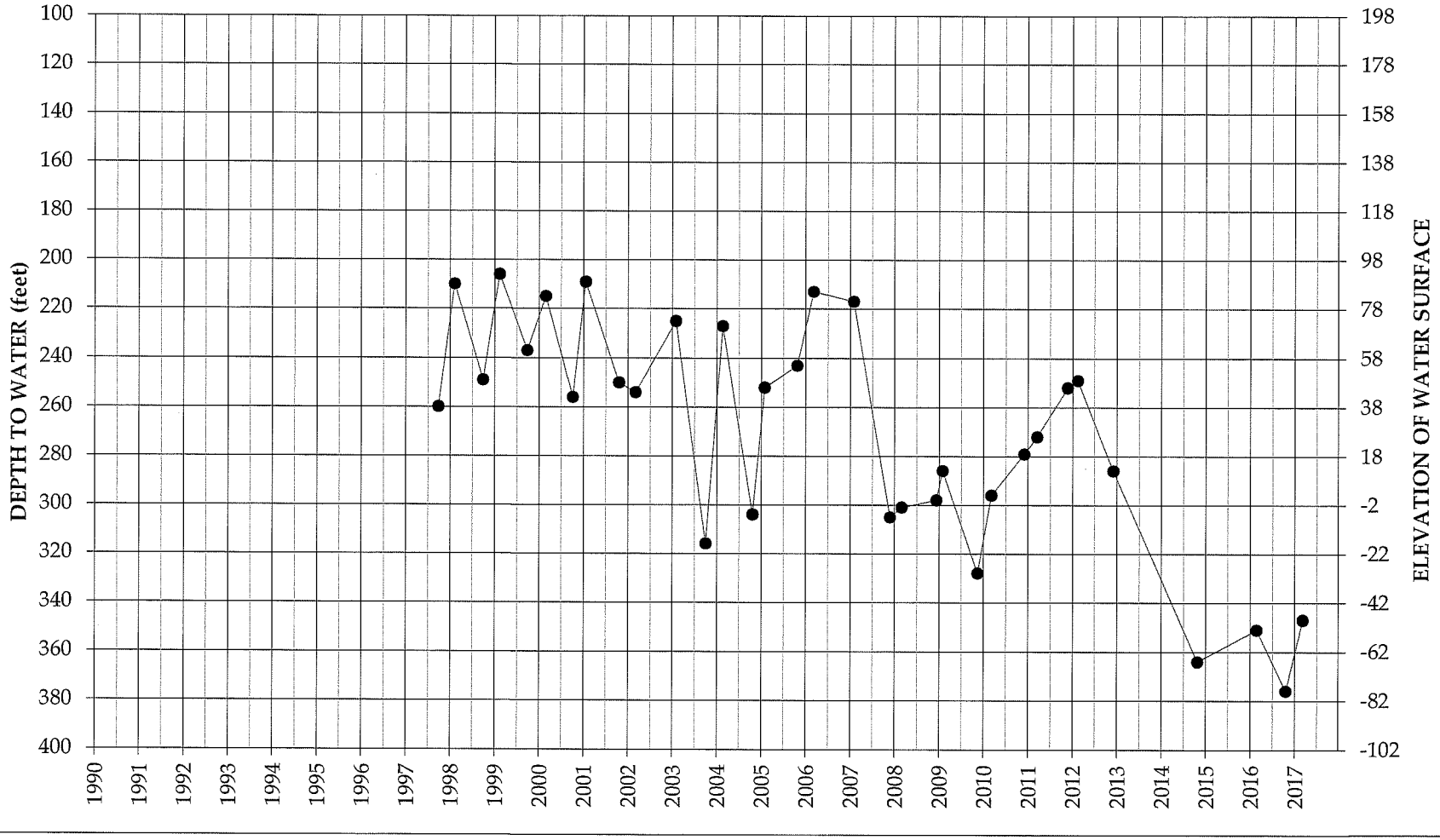
NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-25F



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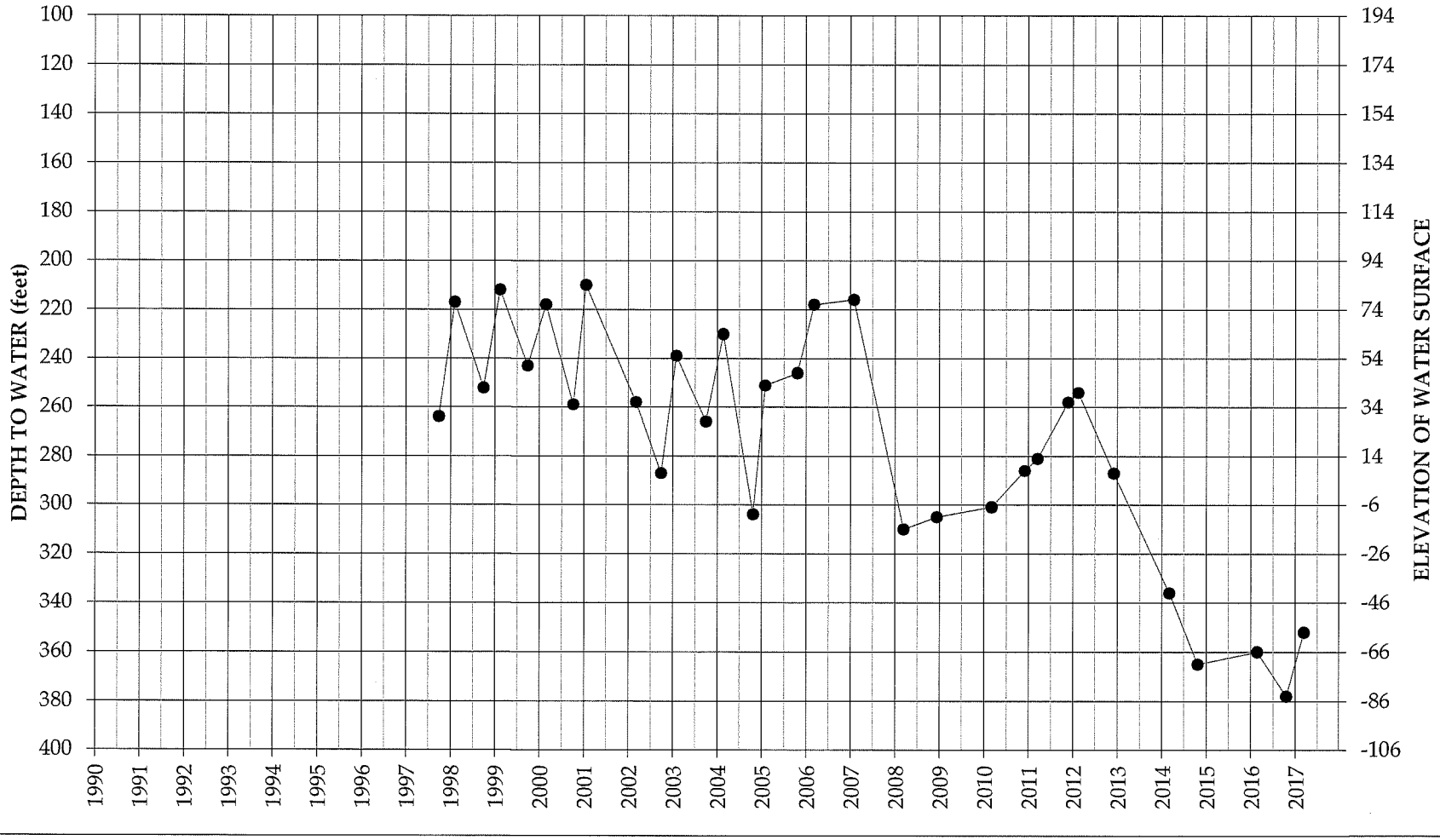
June 2010

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-26P



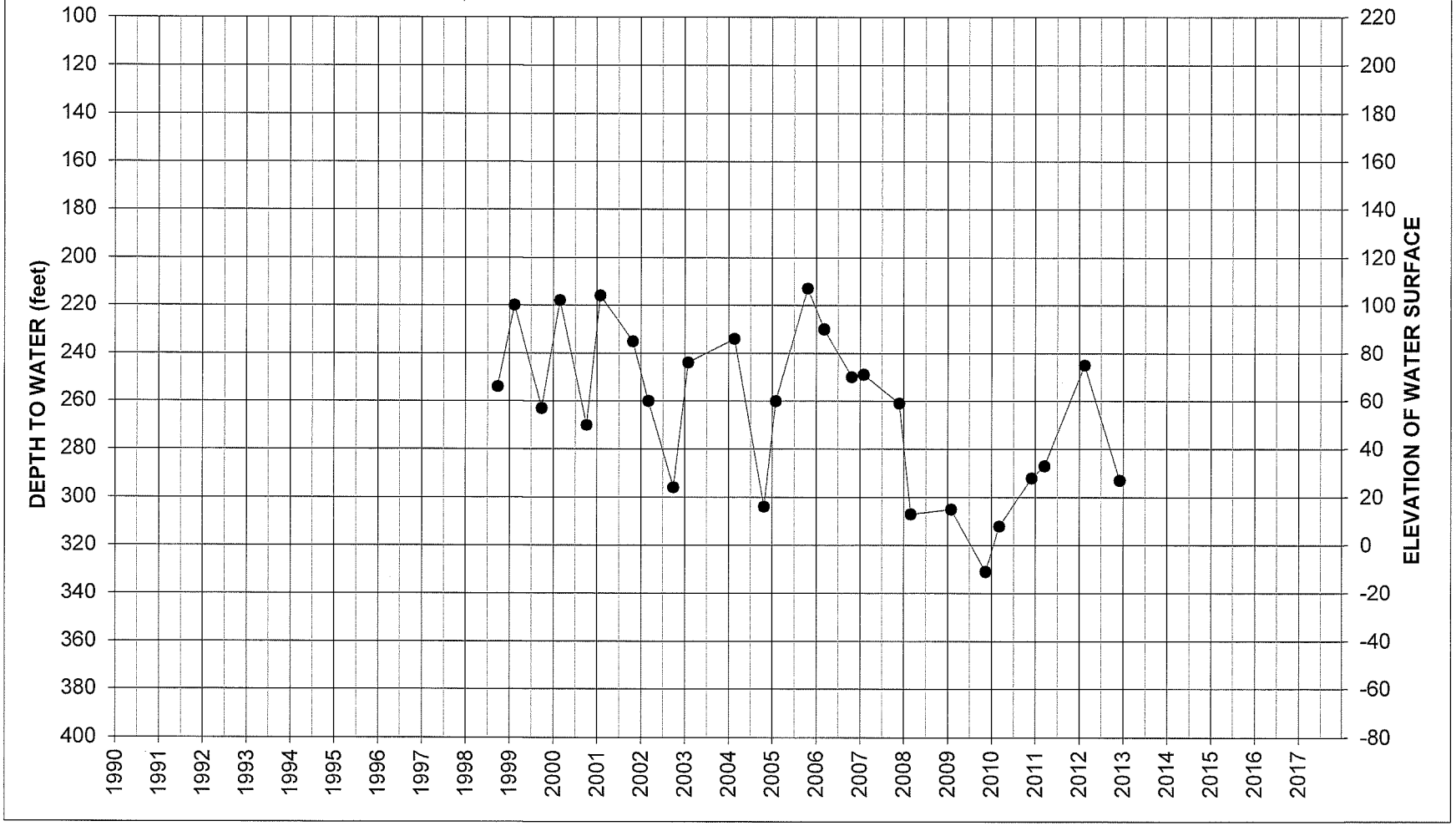
GEI Consultants
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-34P



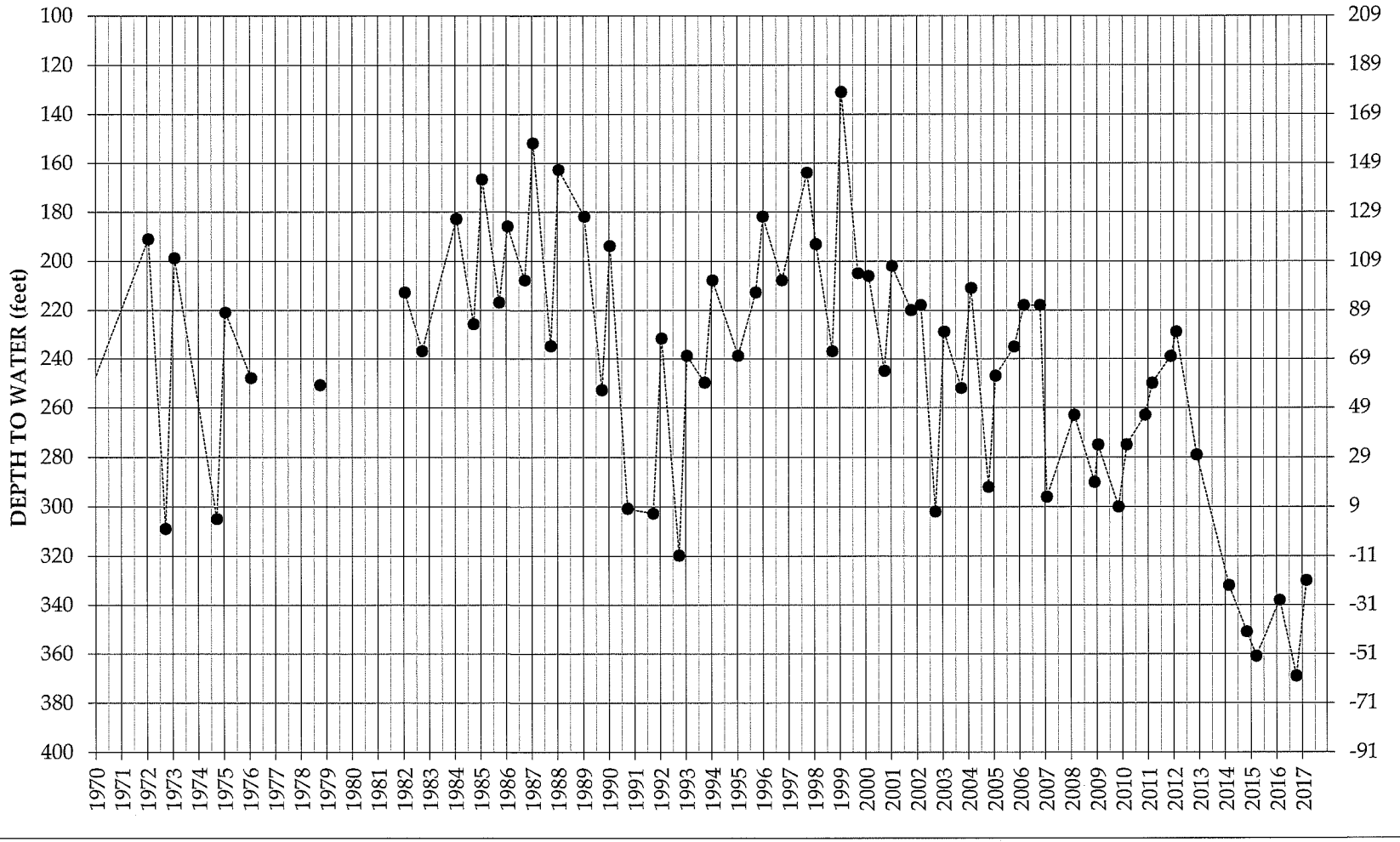
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/24-36J



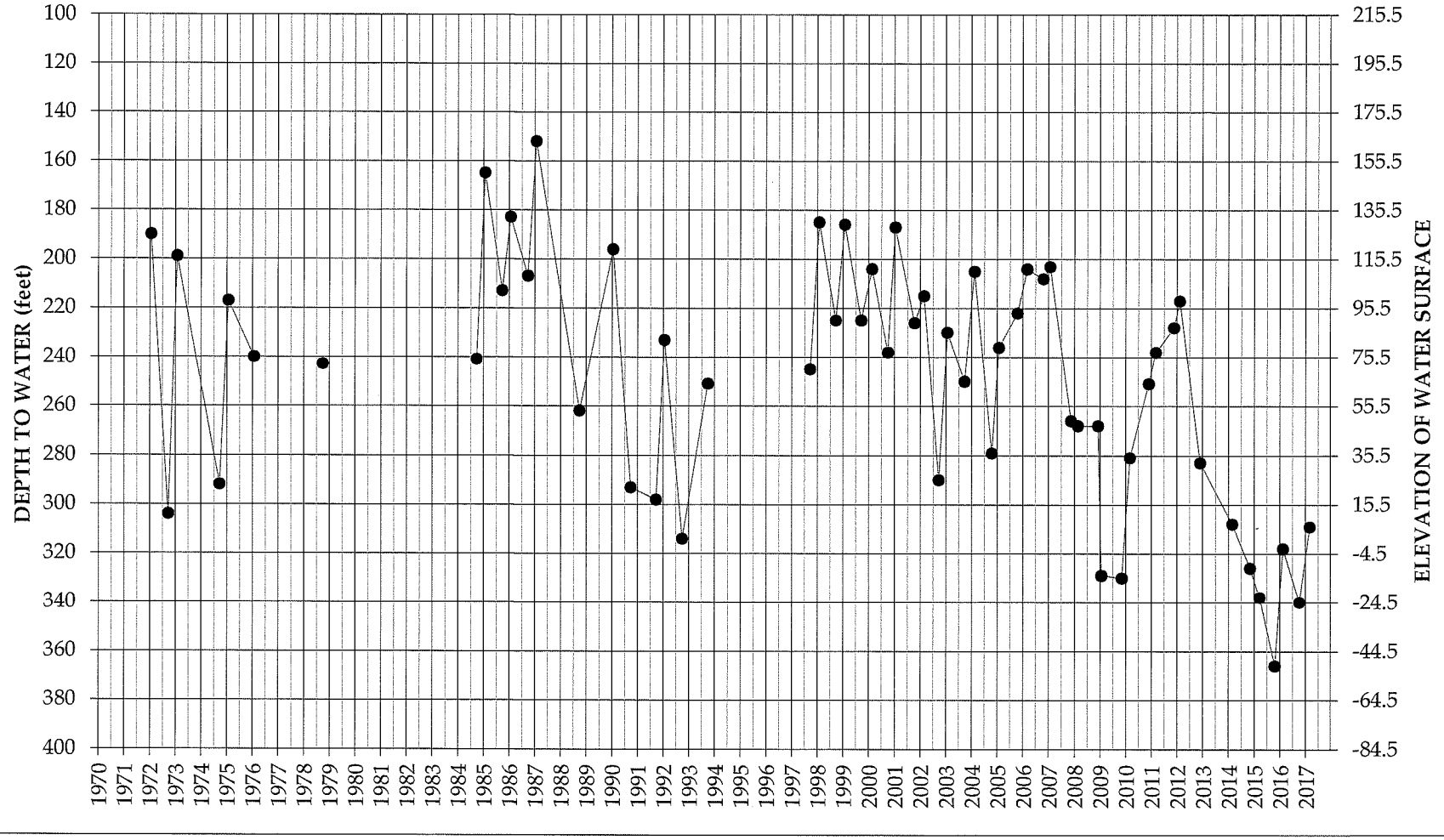
GEI Consultants
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-07R



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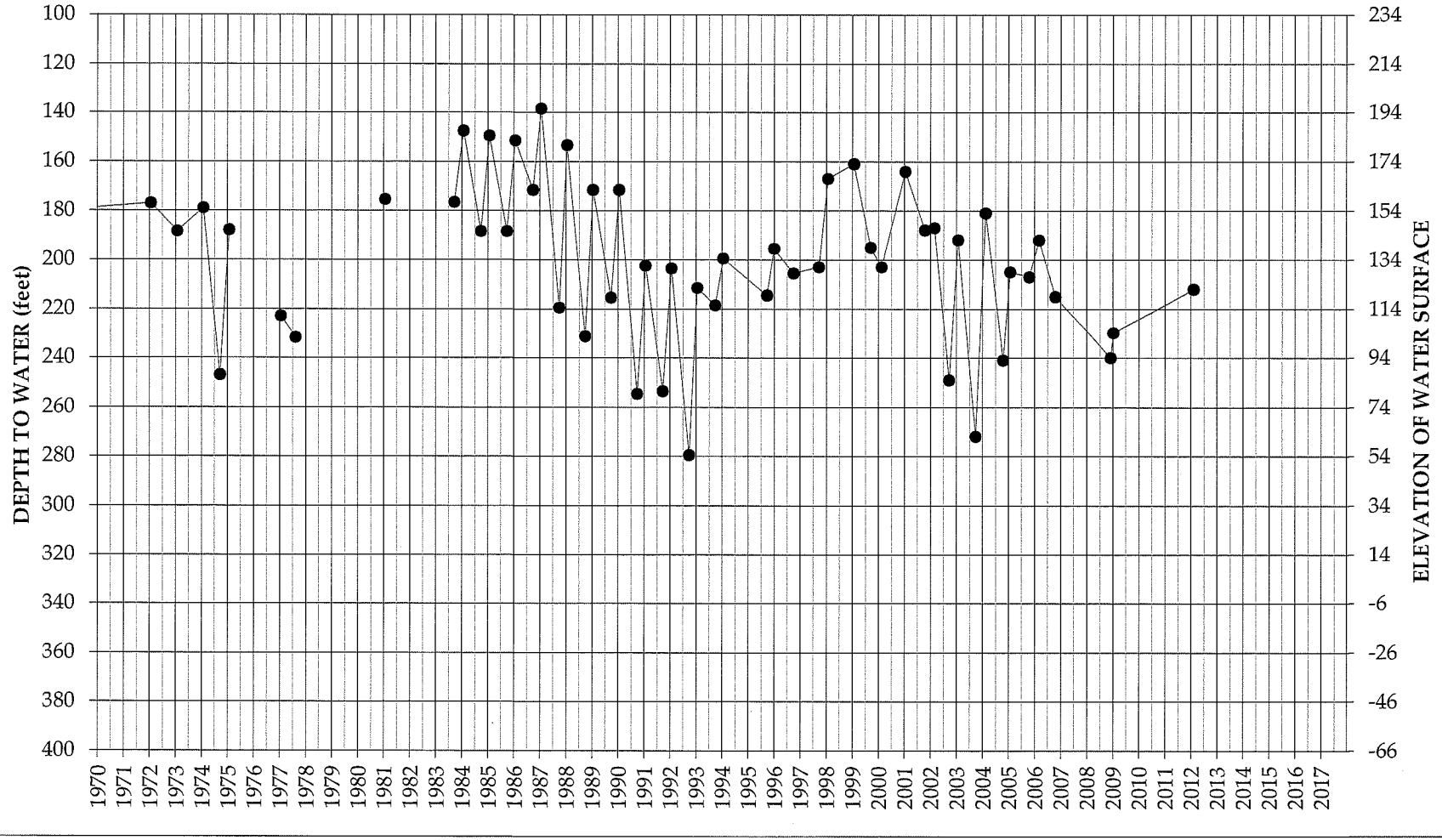
NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-08P



GEI Consultants
Boolerman-Edmonston Division

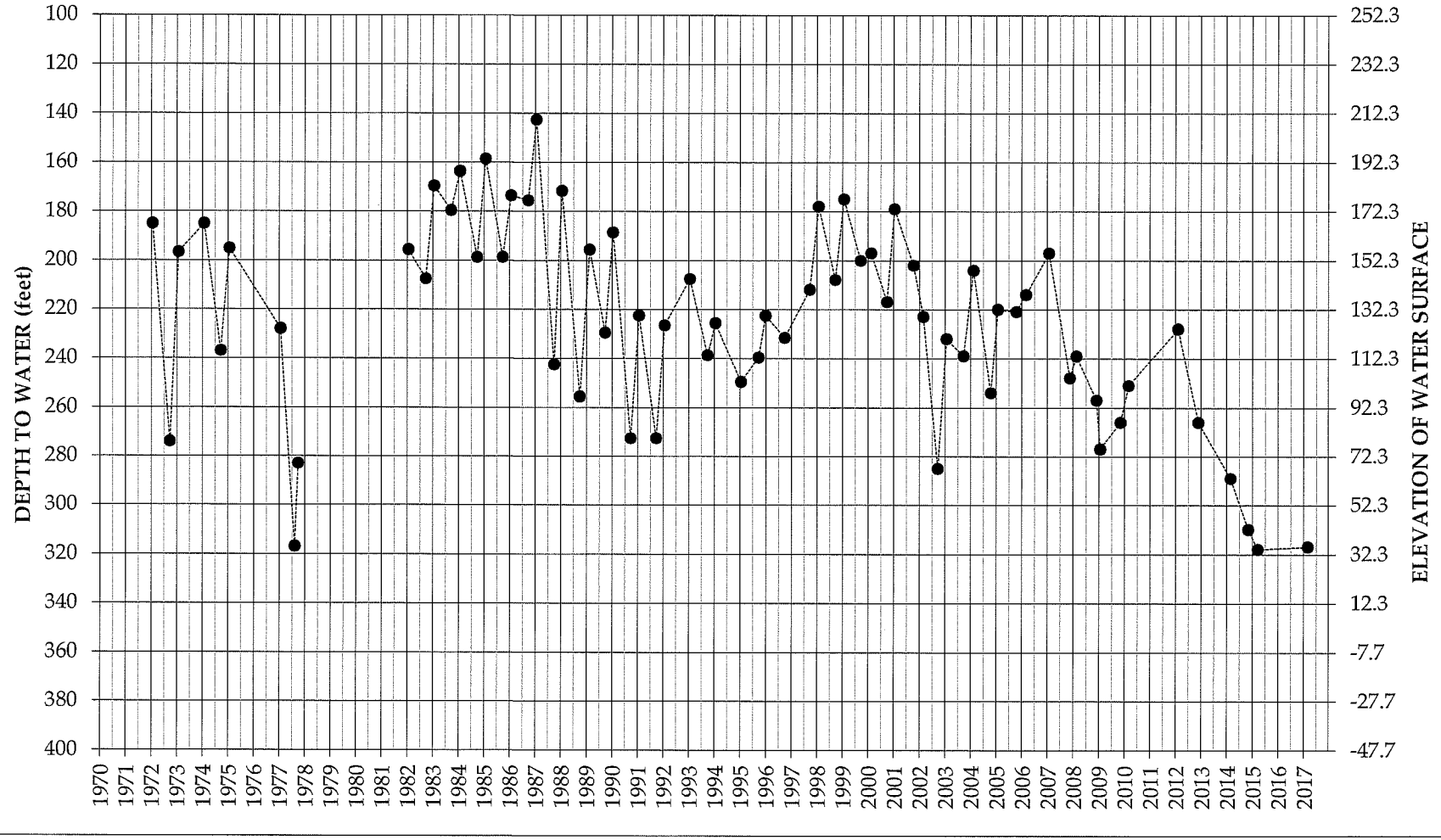
June 2010

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-09R



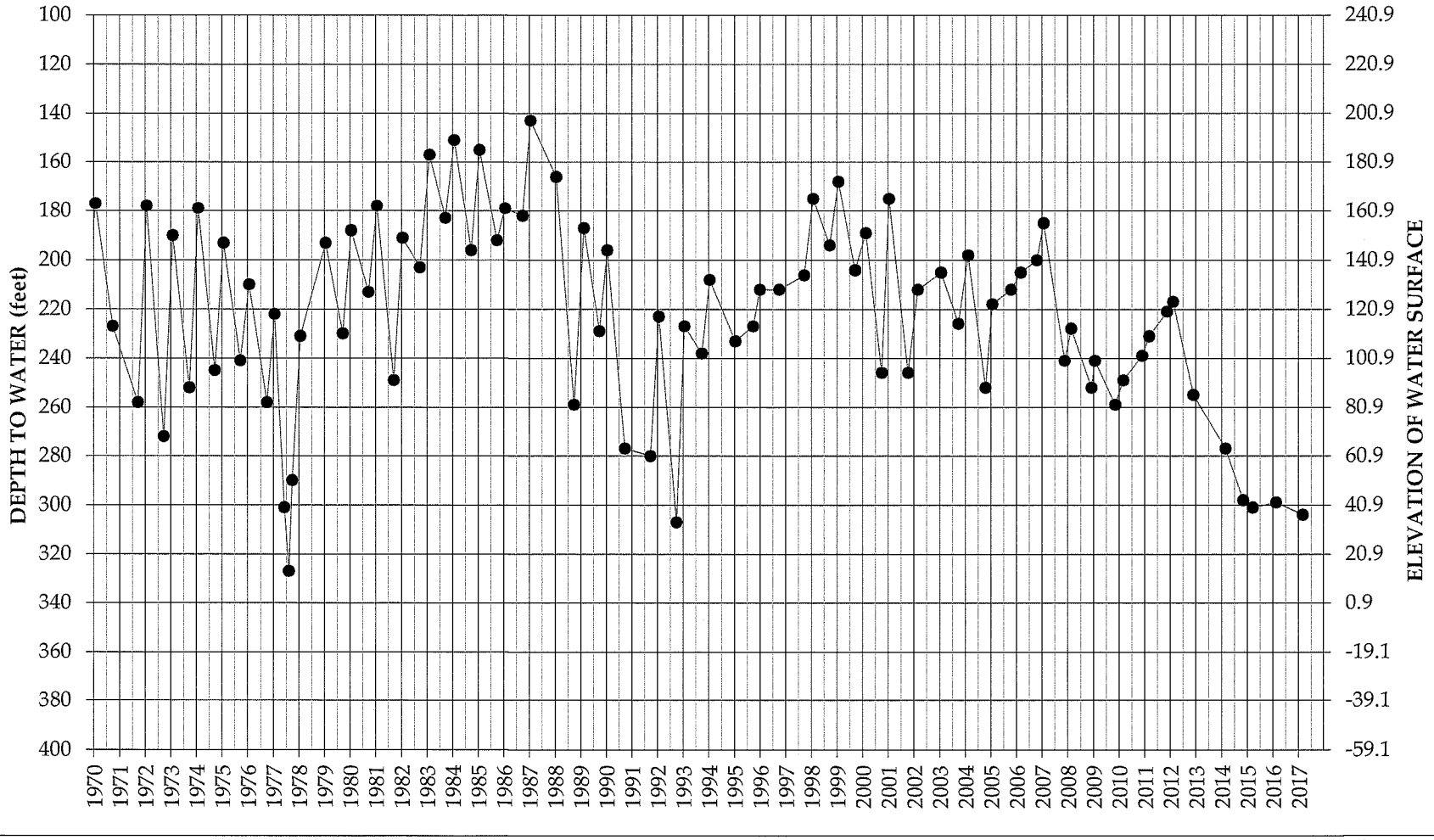
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-15R



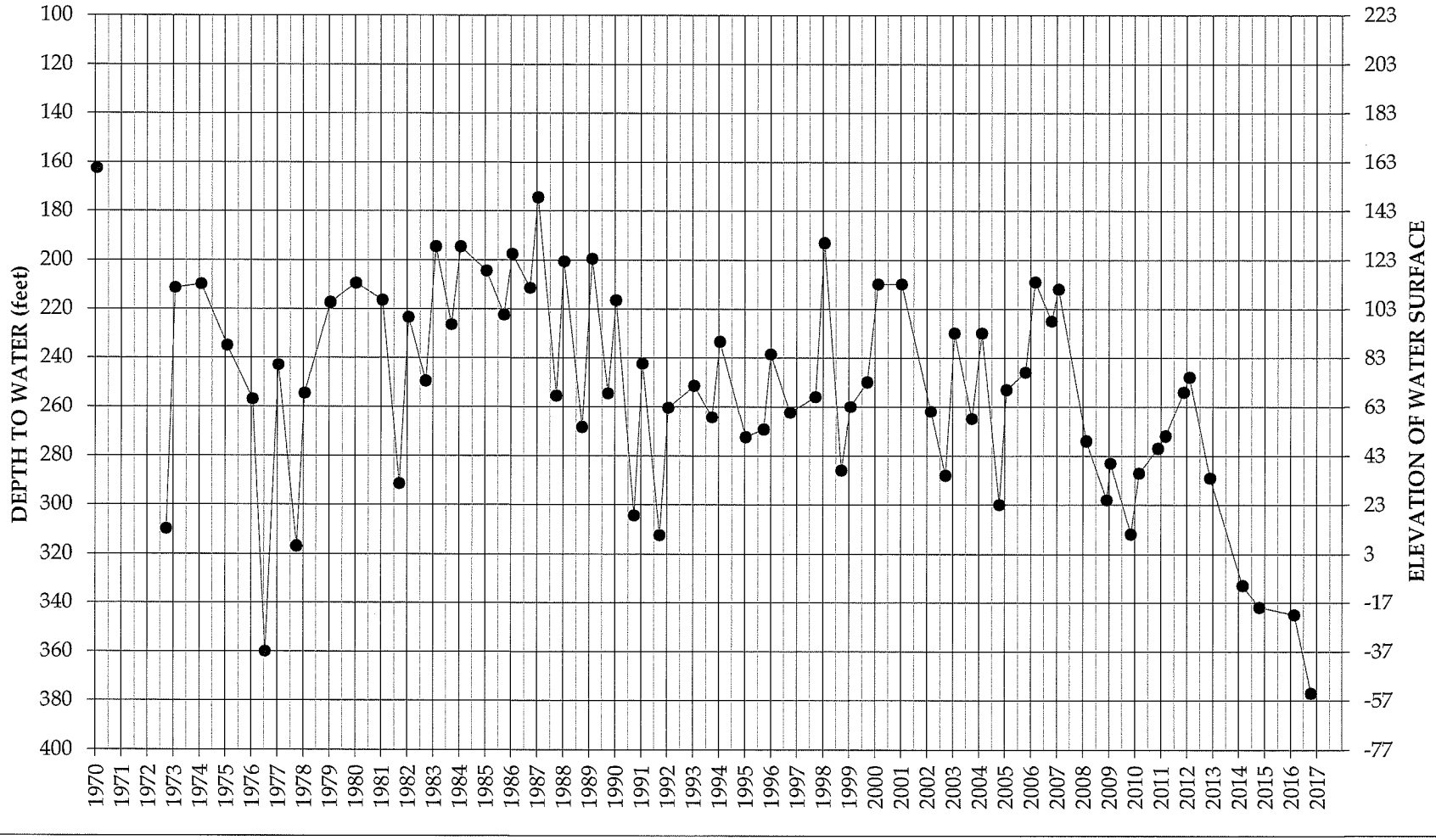
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-16R



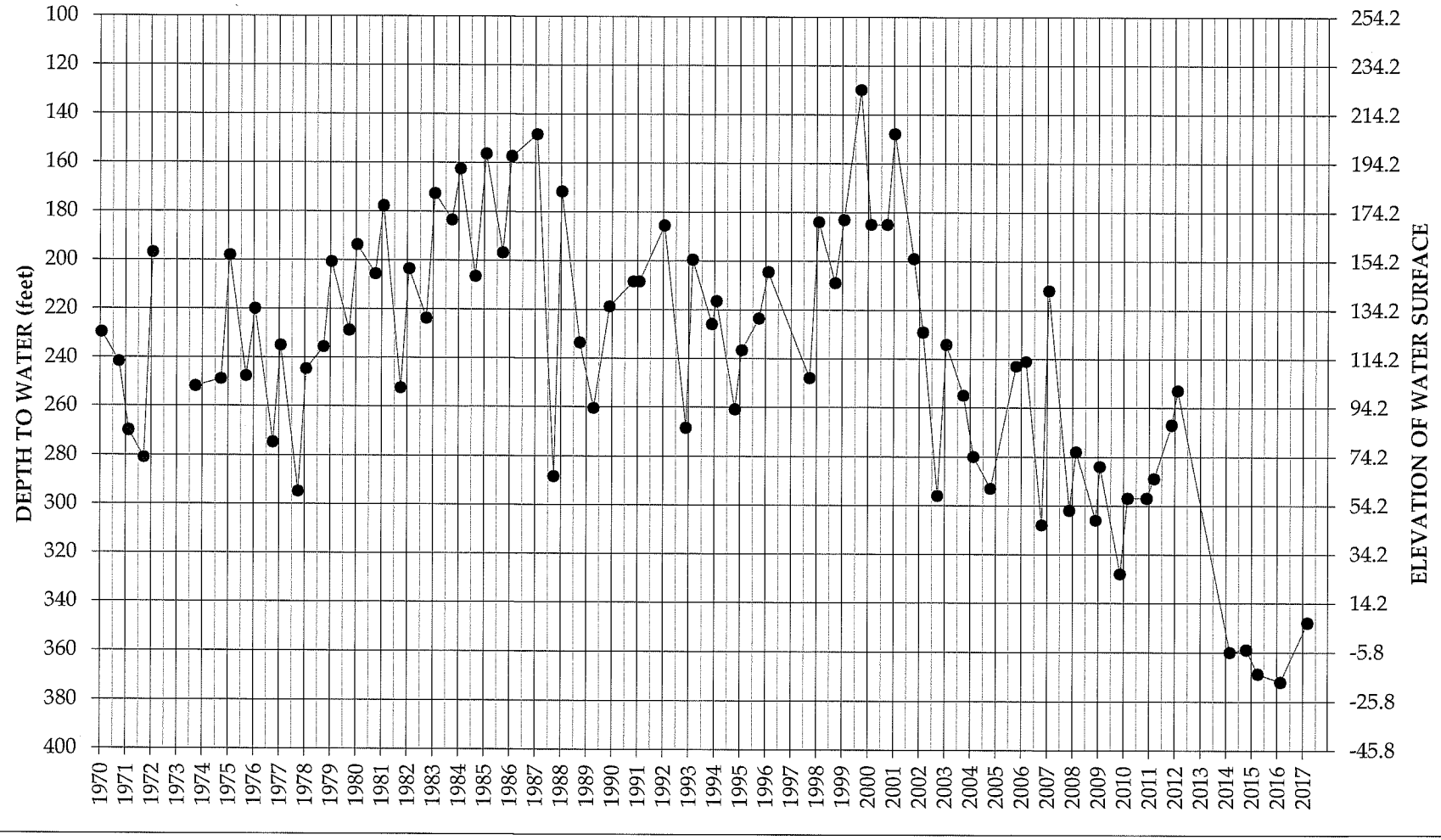
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-19R



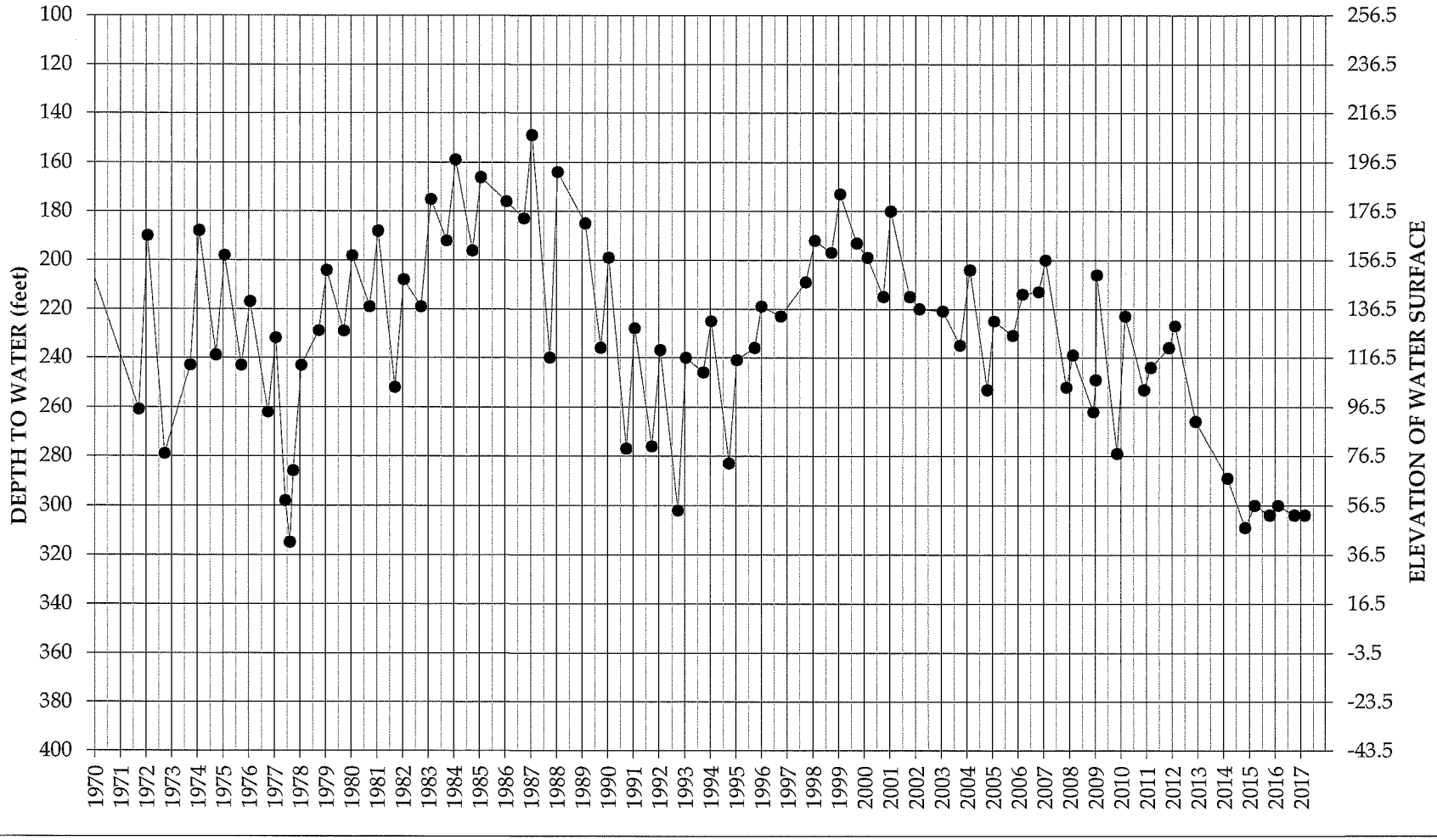
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-21K (340-900)



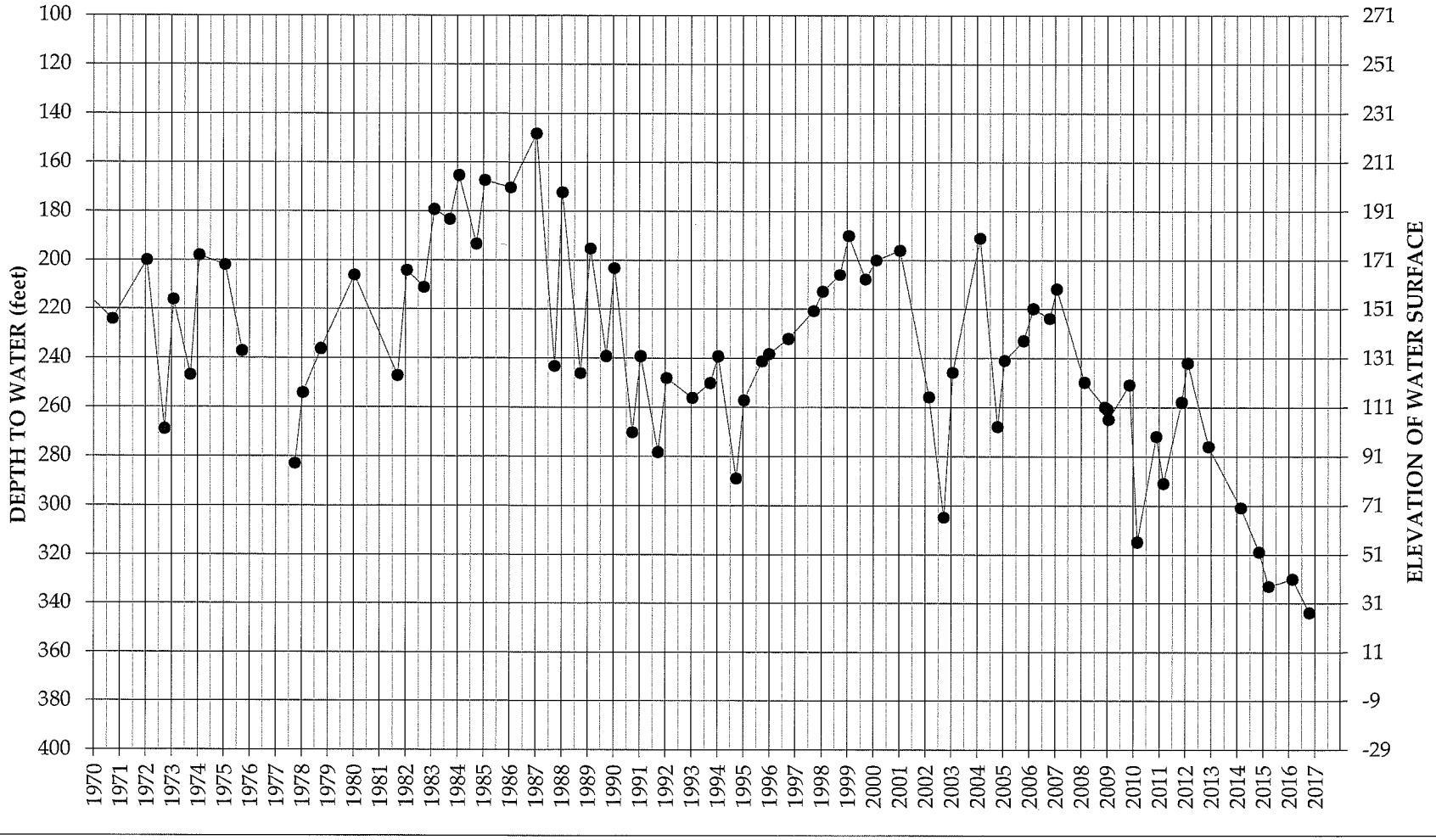
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-22H



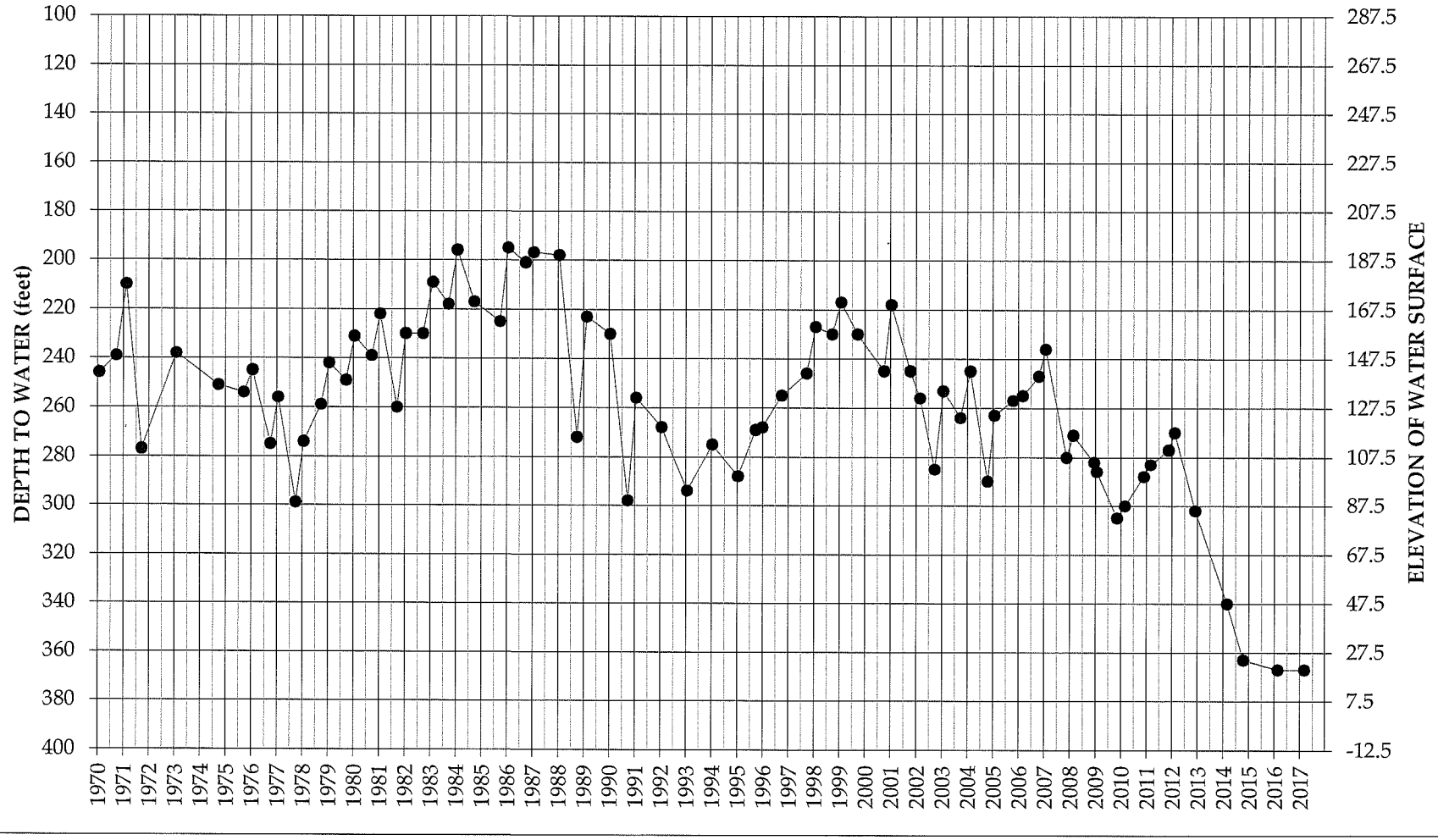
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-23R



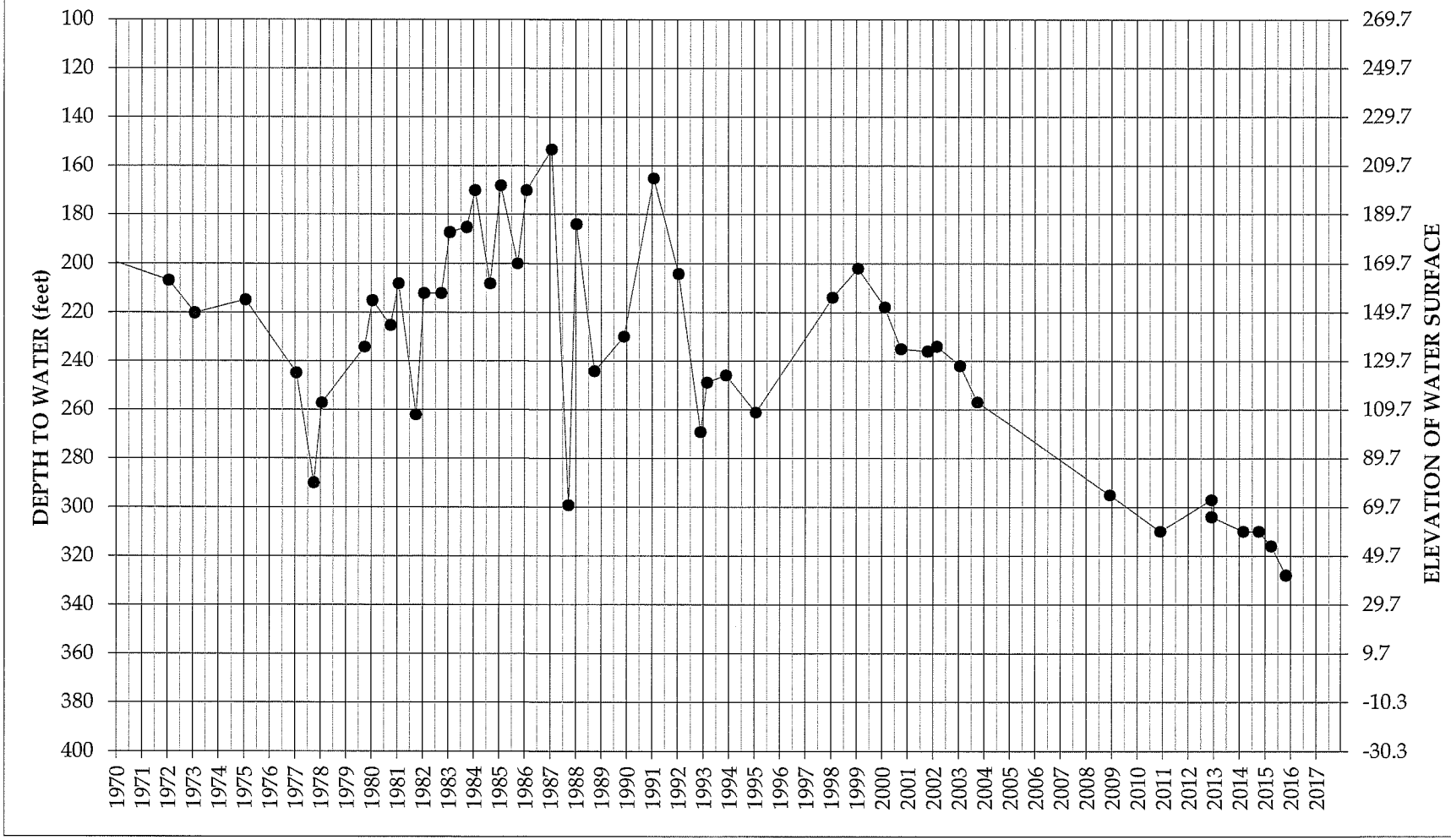
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-25R



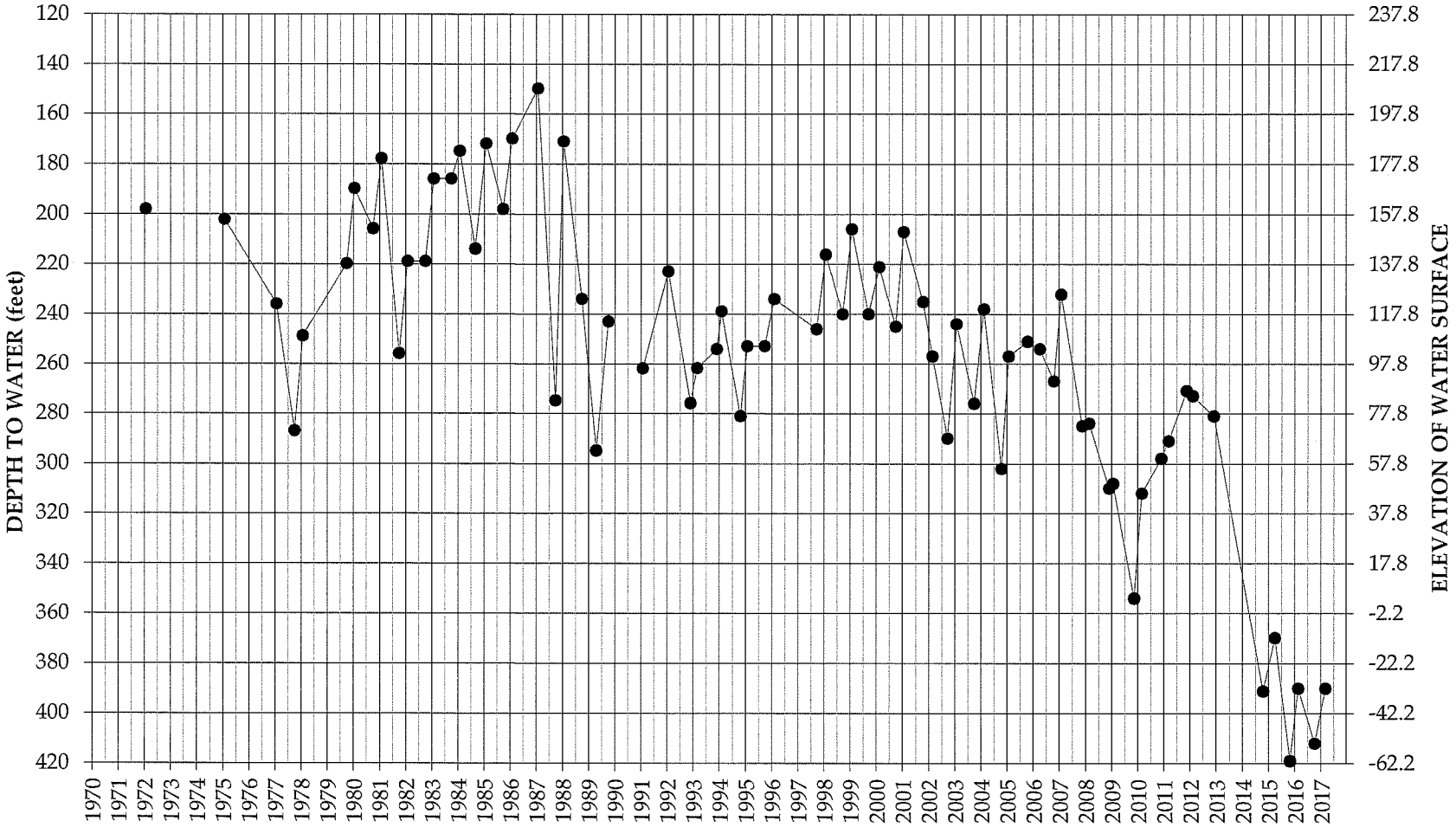
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-26N (400-800)



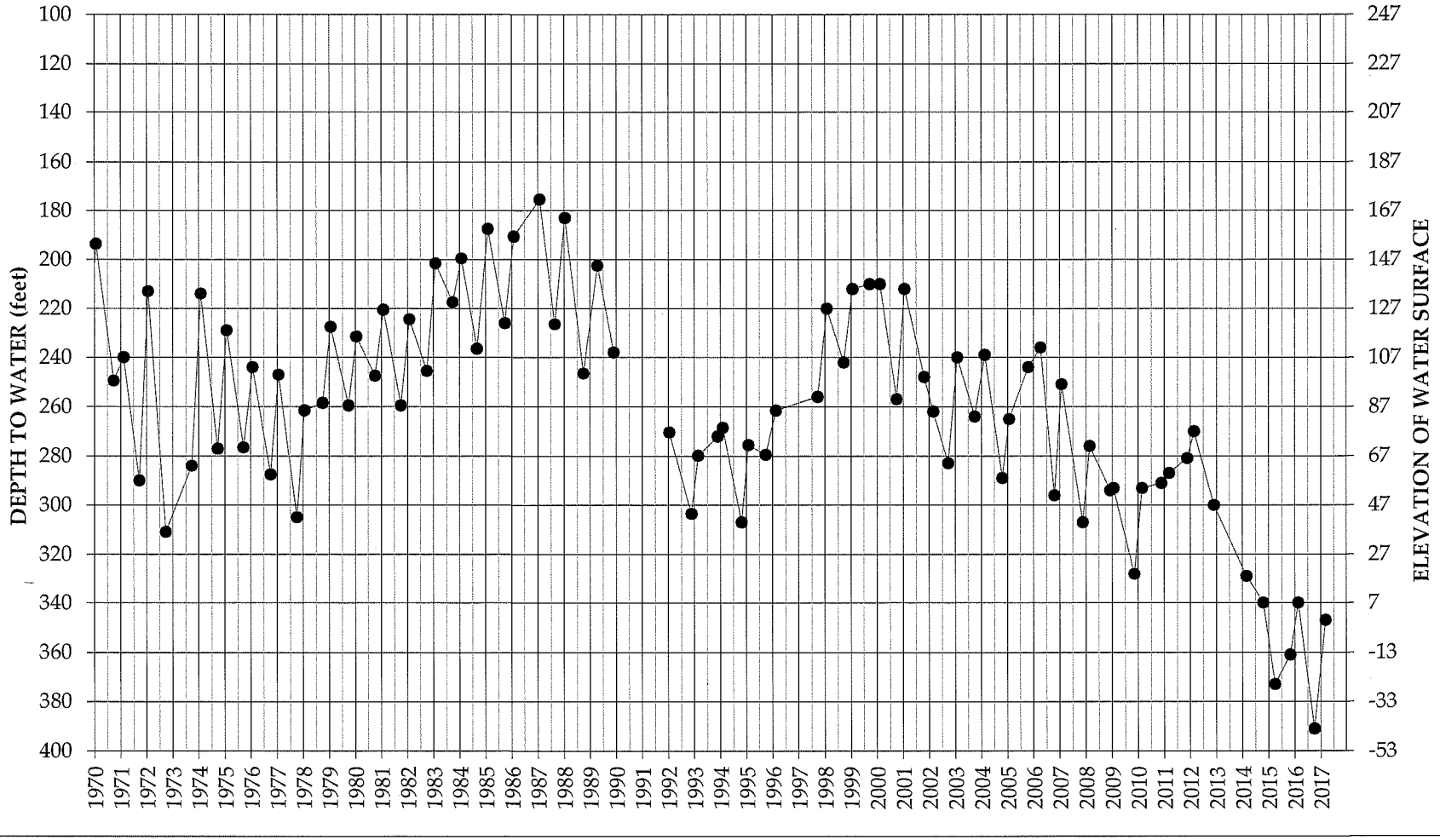
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-27B



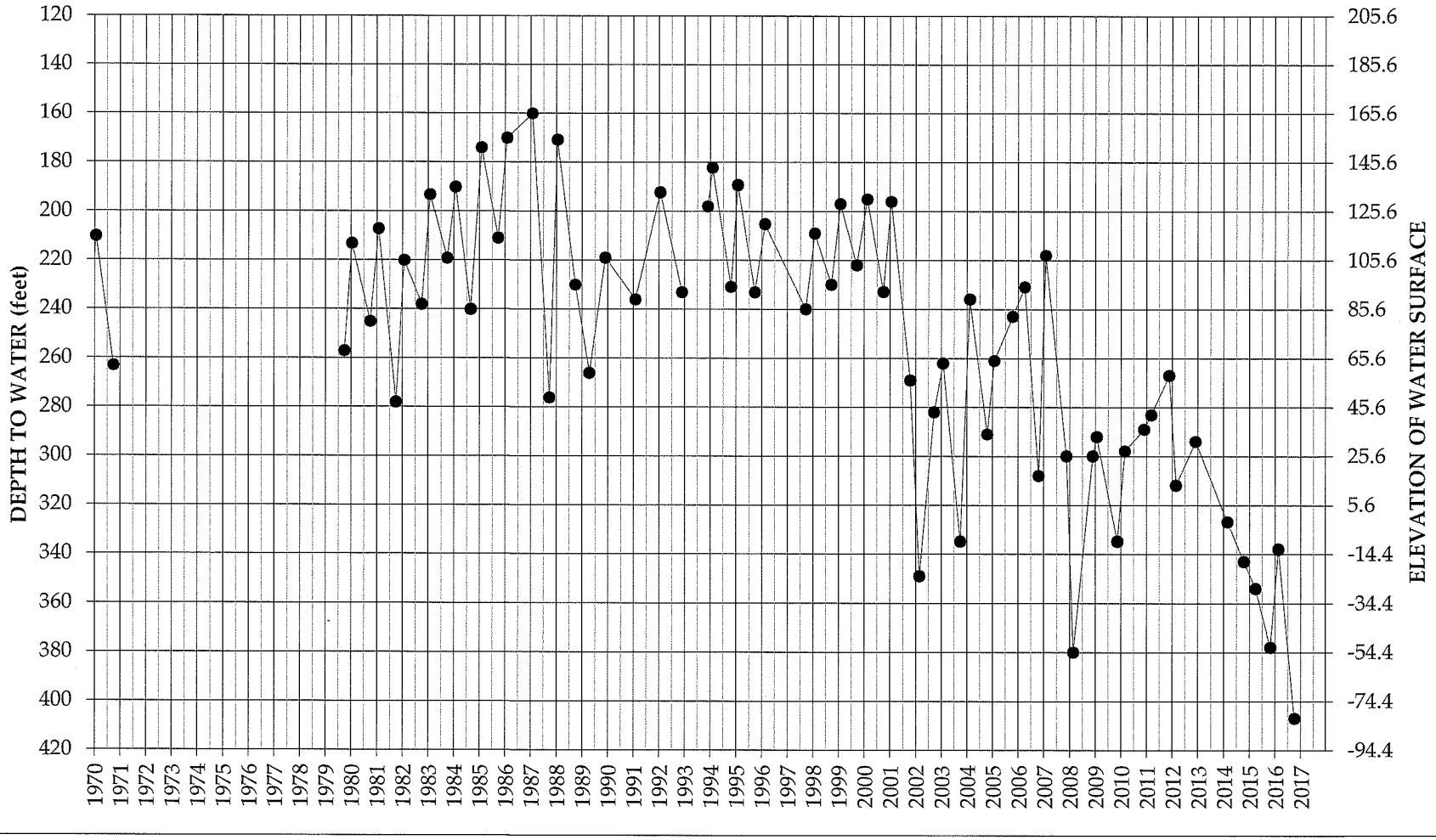
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-28Q (340-800)



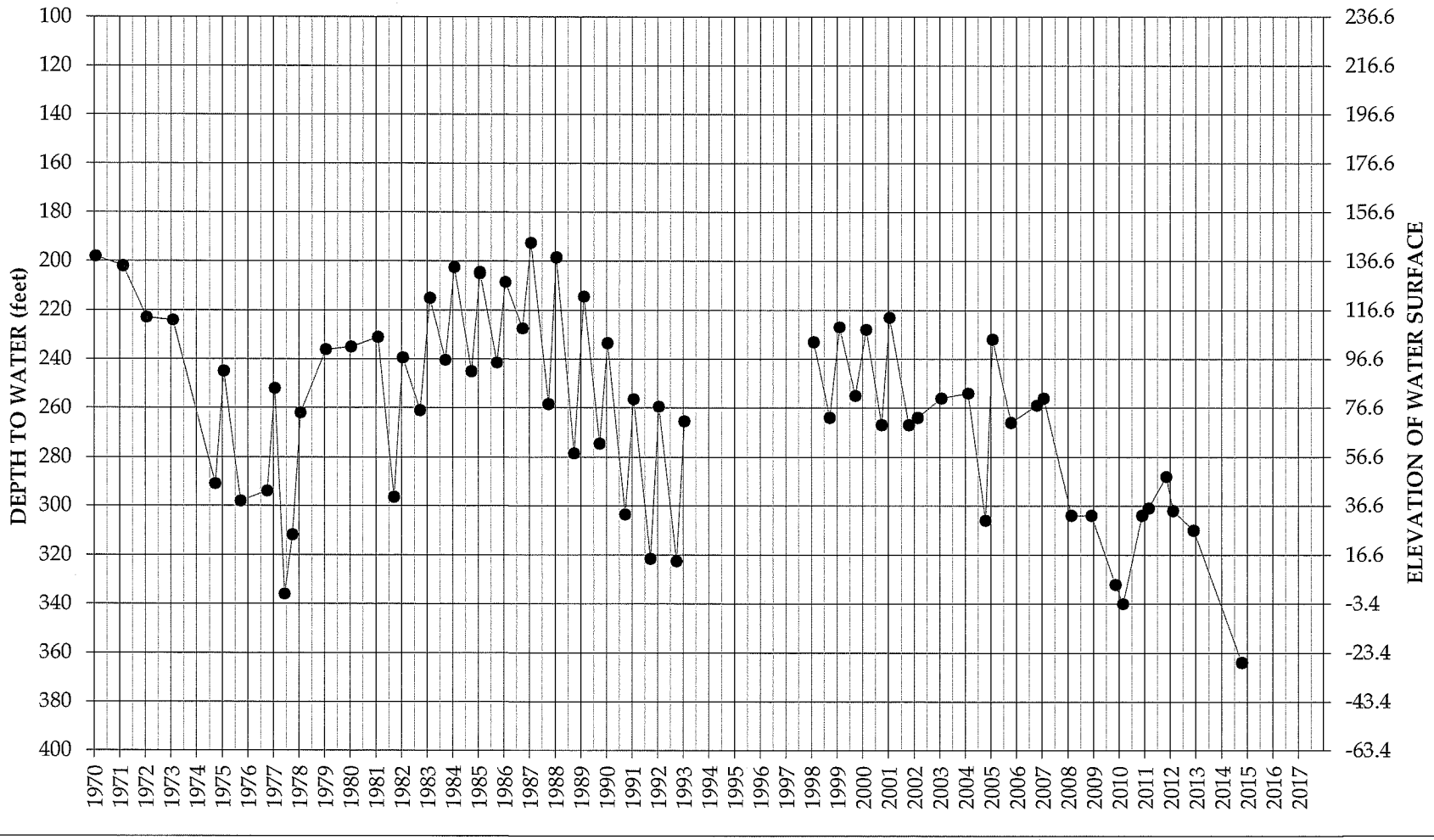
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-30H (340-800)



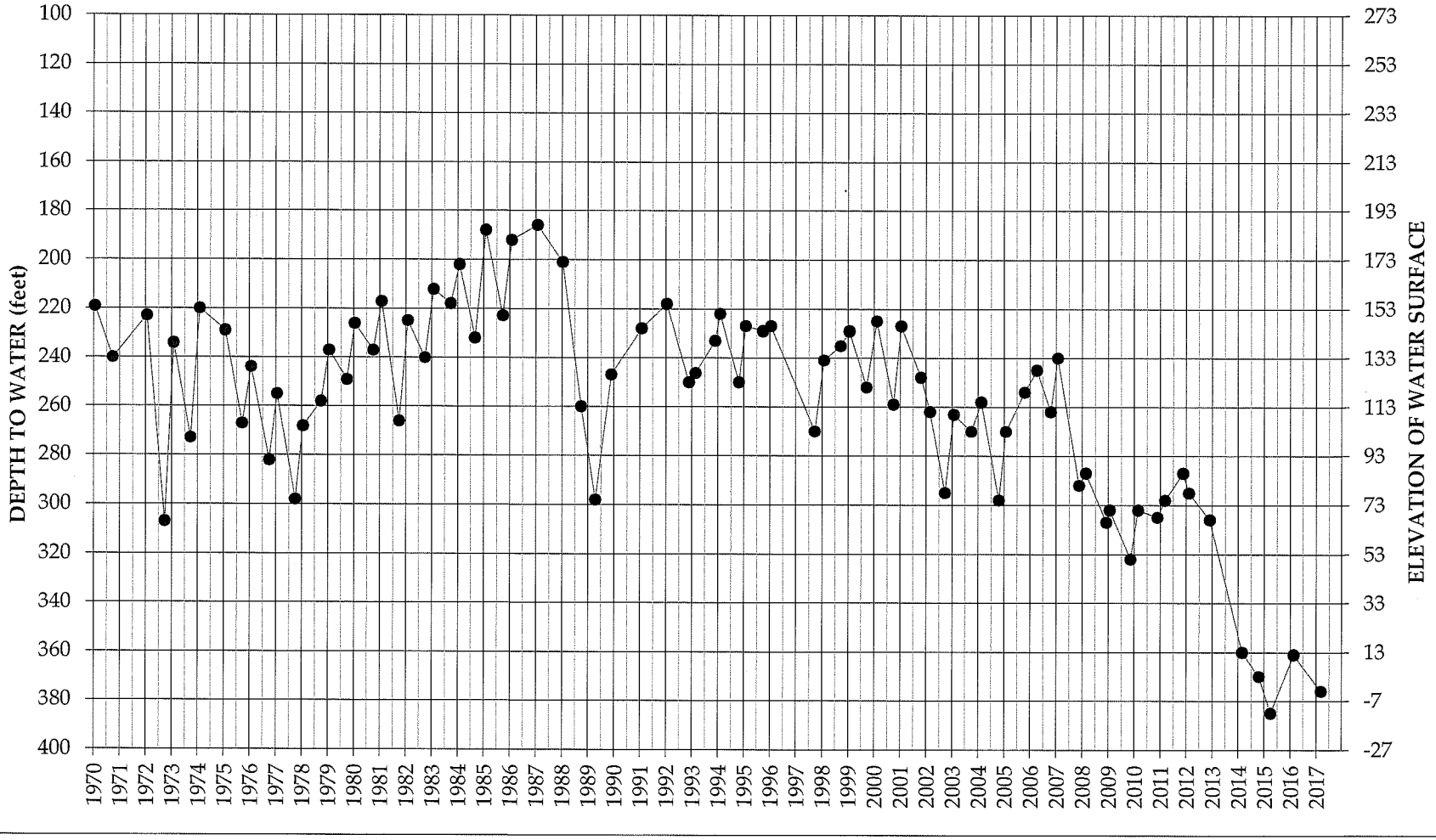
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-31R



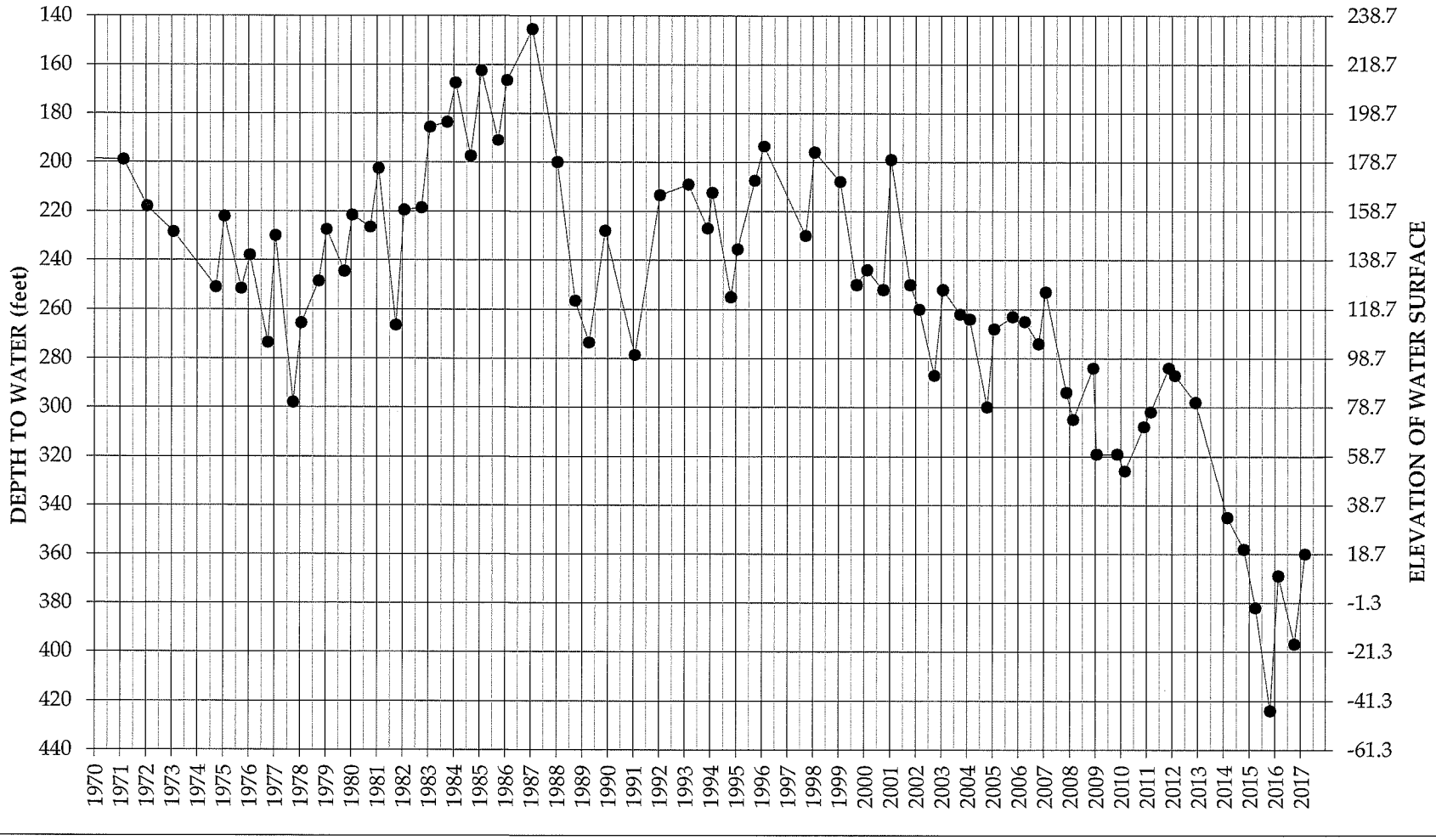
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-34R (340-800)



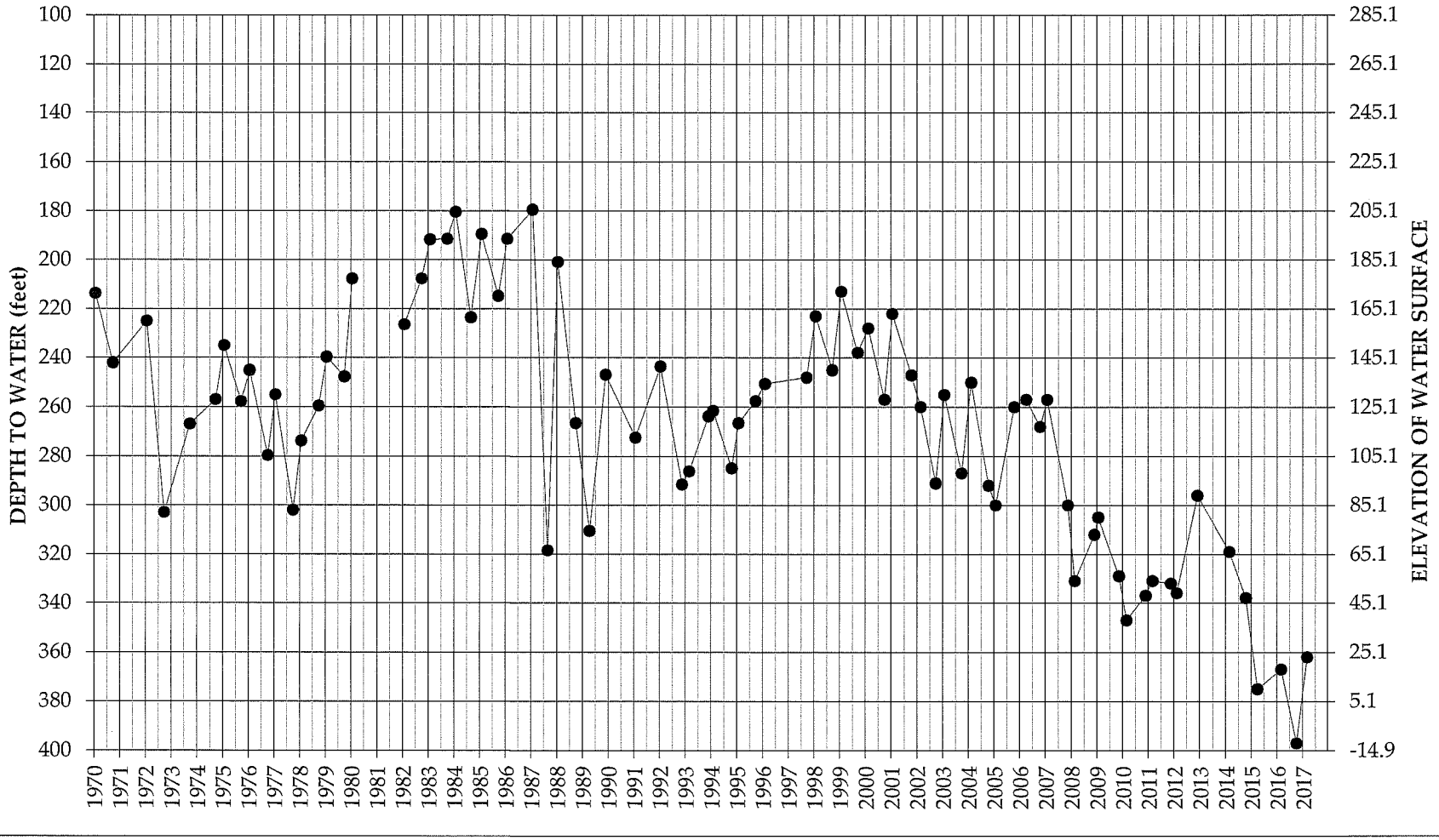
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-35B (340-800)



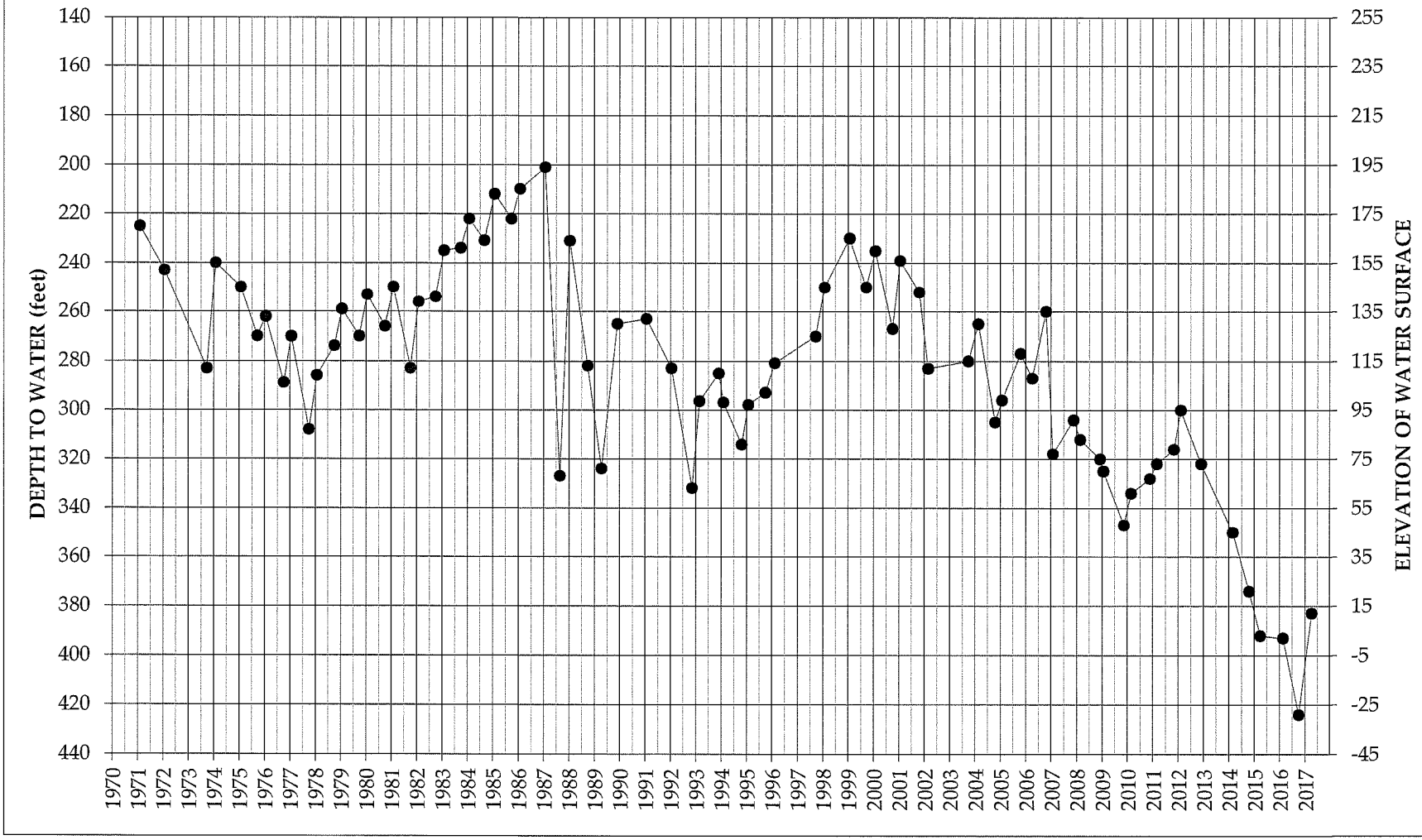
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #26/25-36E (336-800)



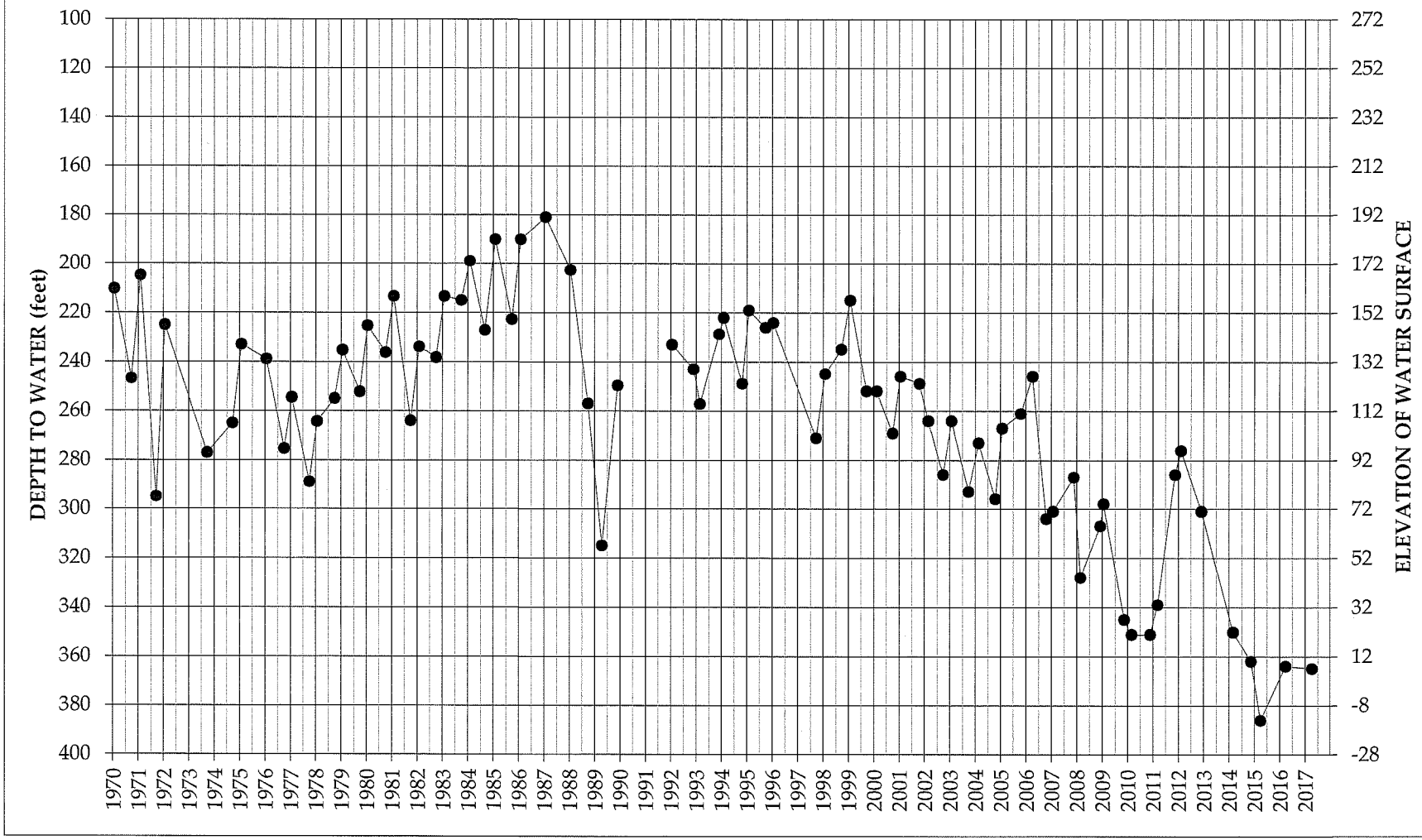
GEI Consultants
Bookman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-01N (336-800)



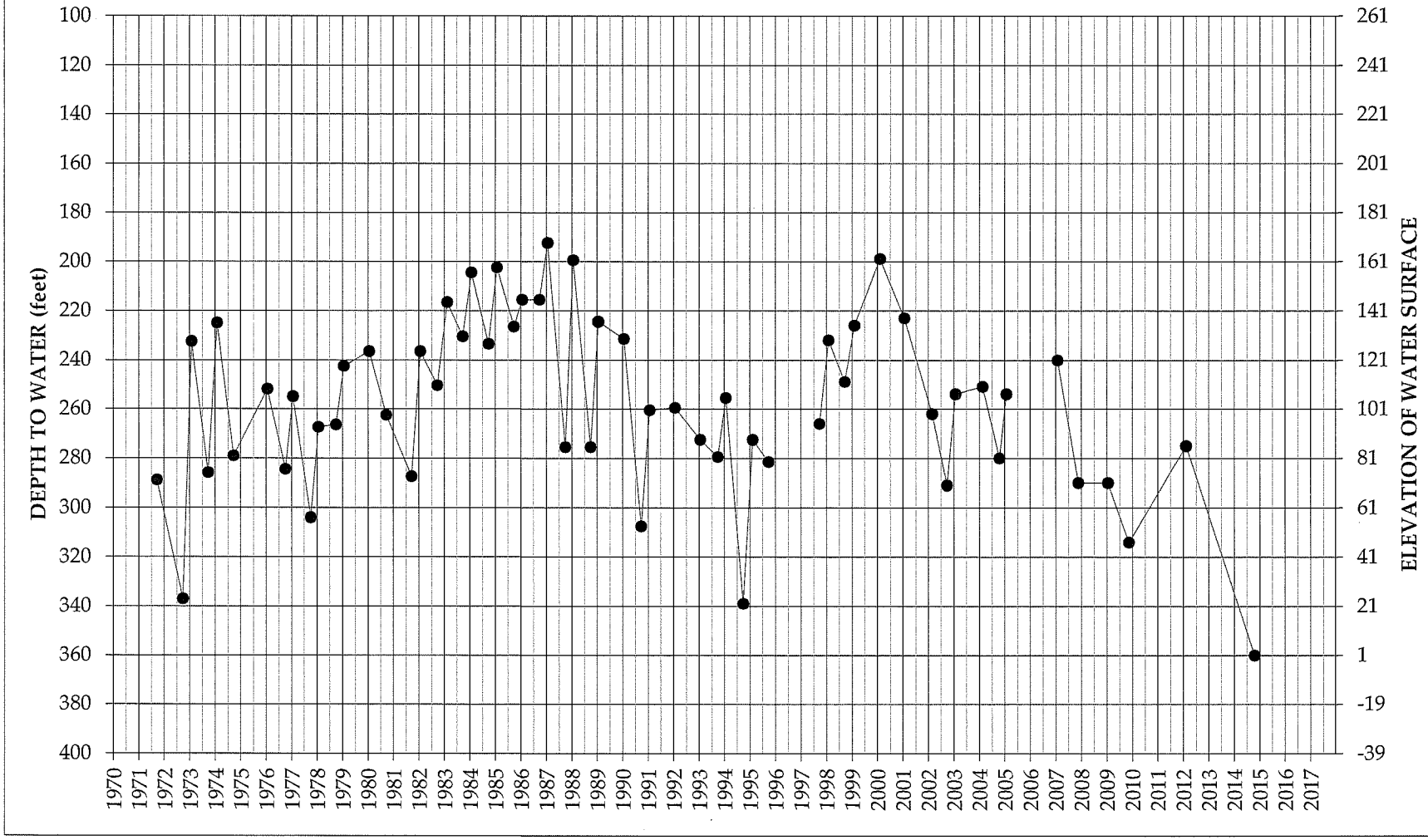
GEI Consultants

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-03H (340-800)



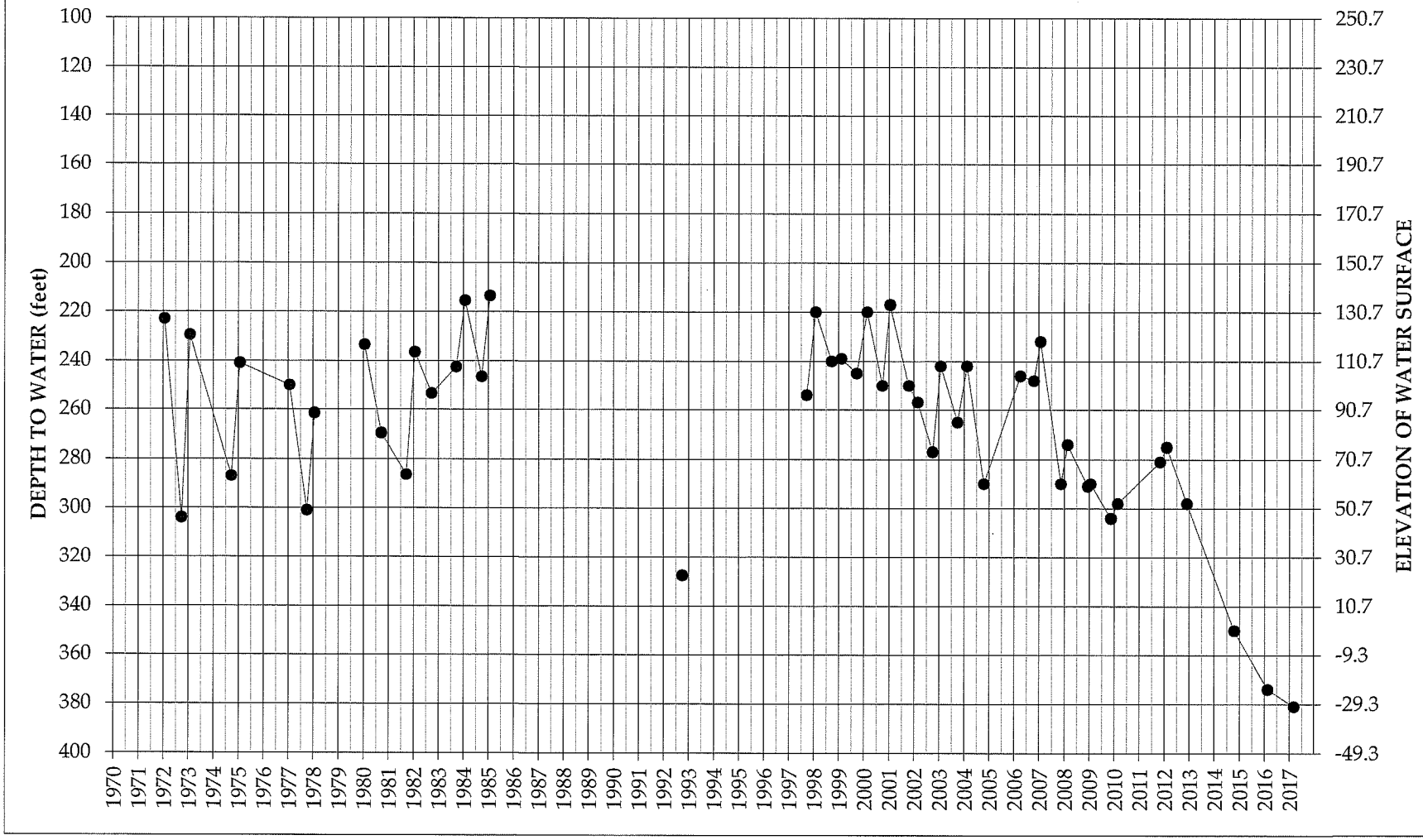
GEI Consultants

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-04H



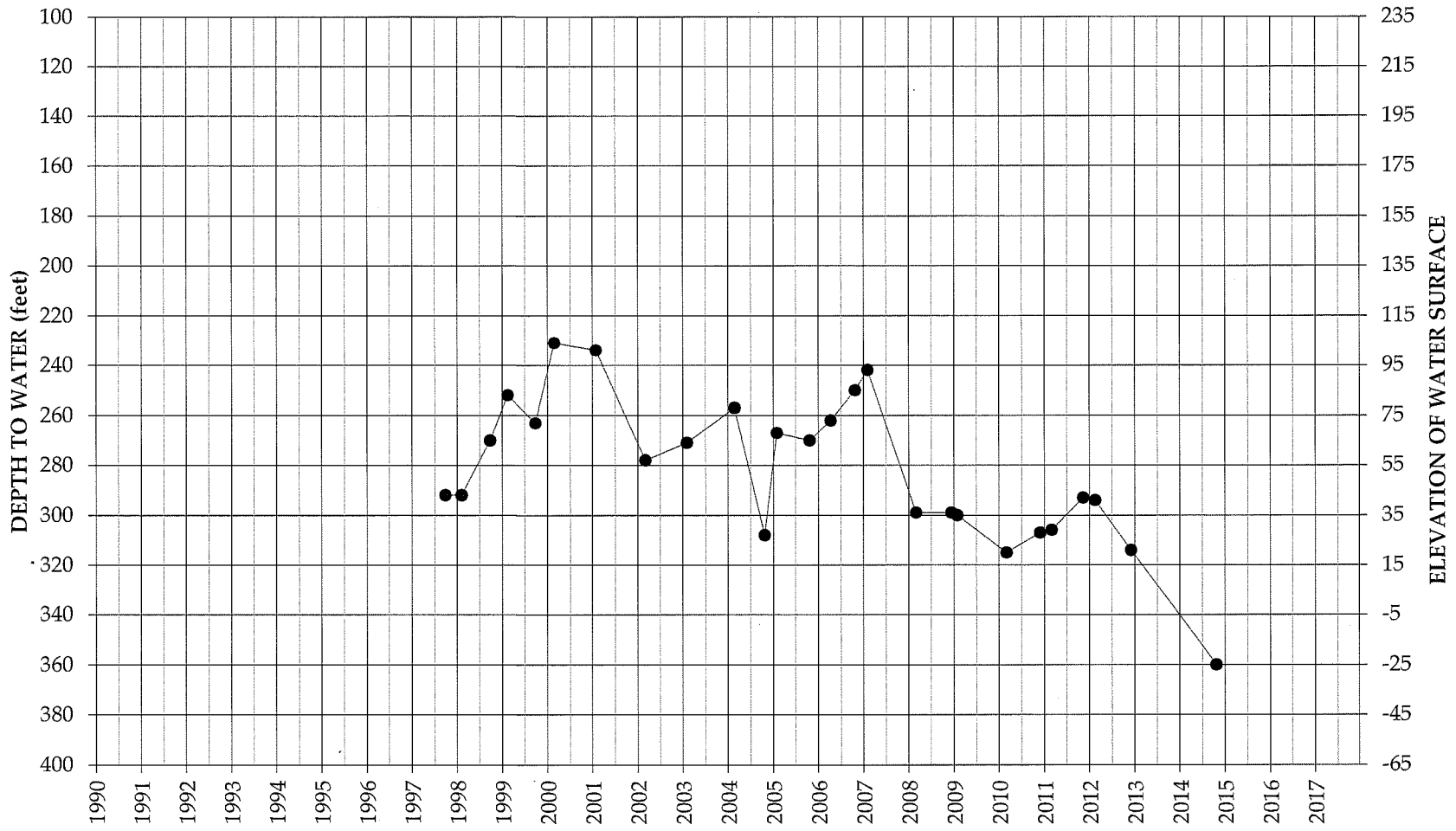
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-05H



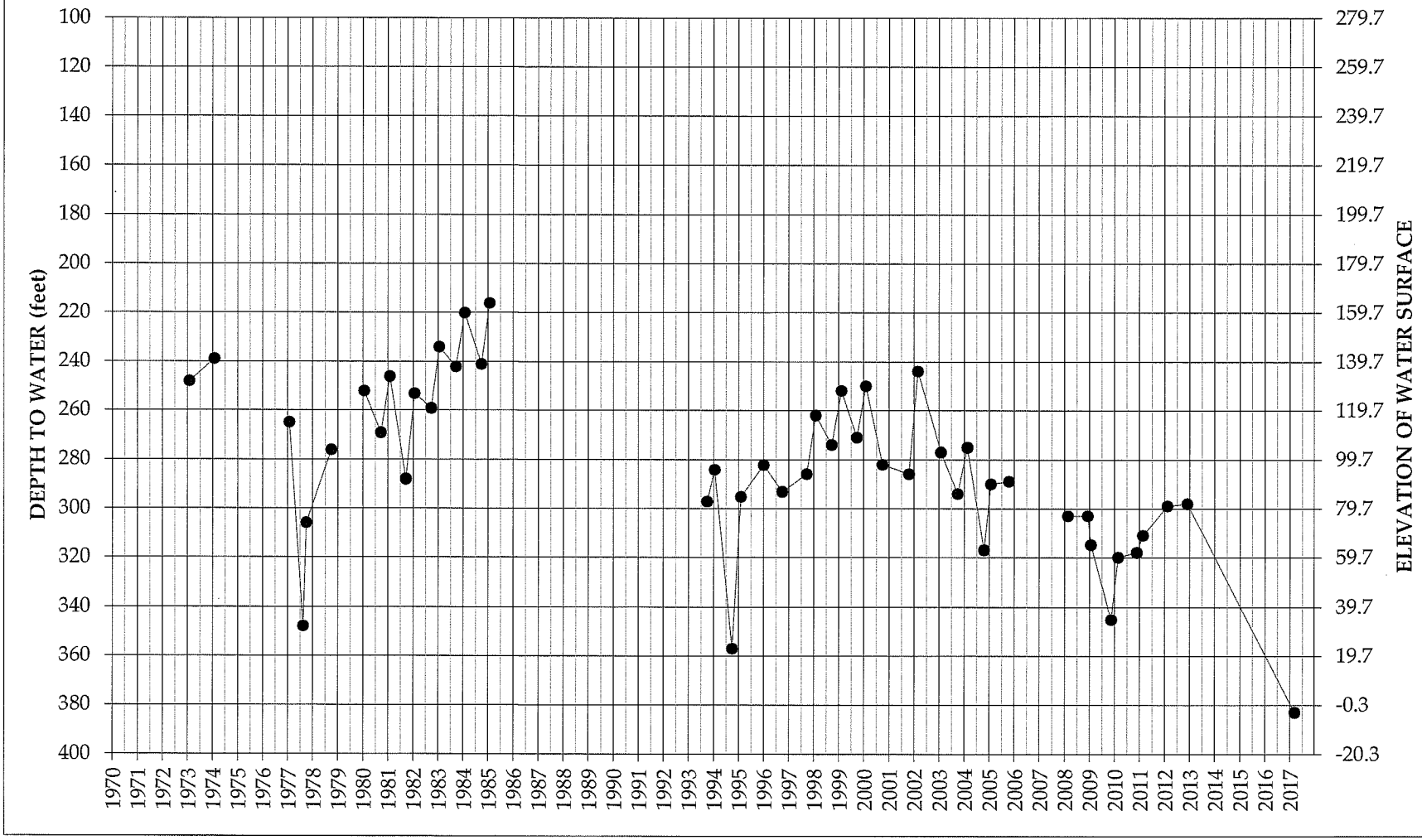
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-06N



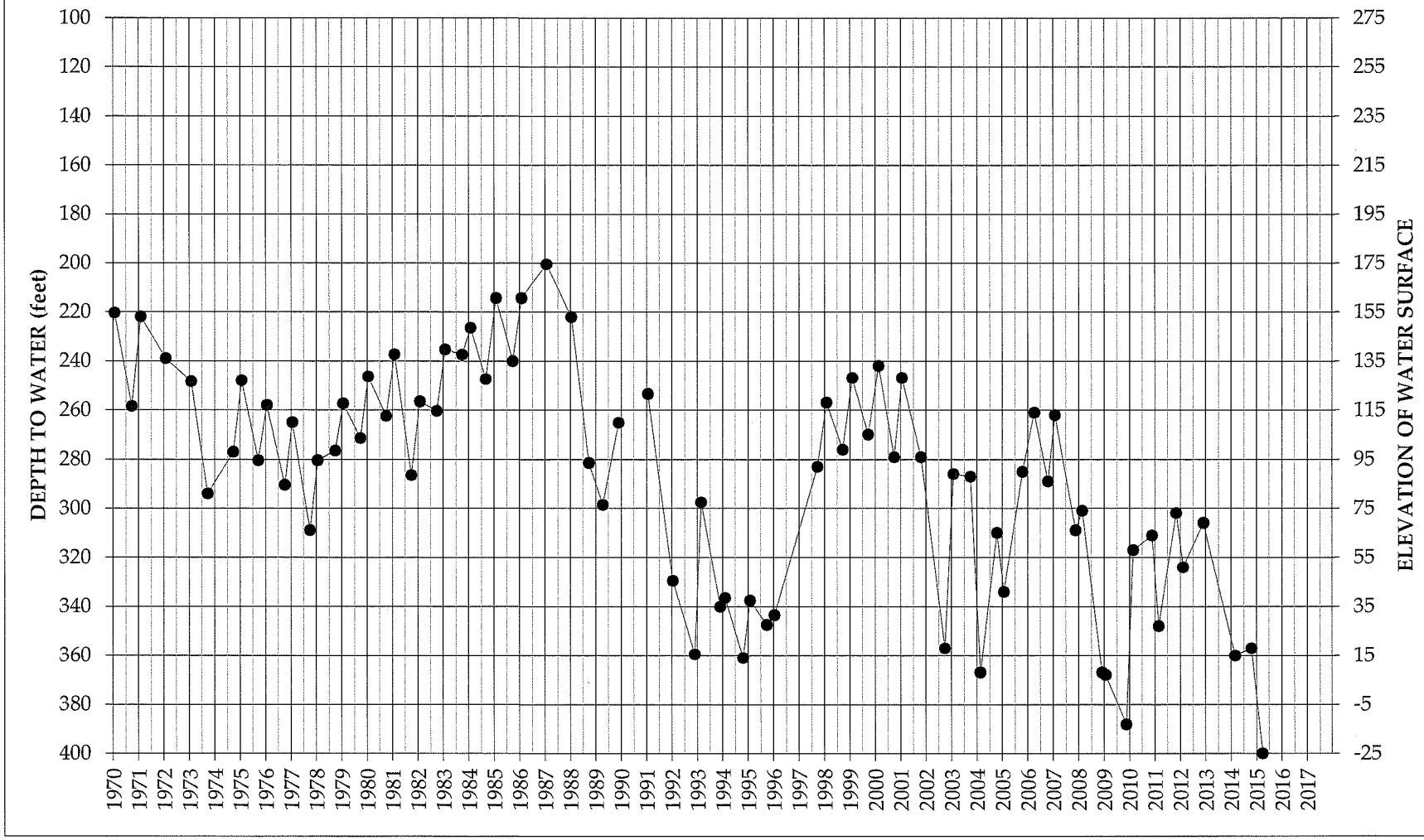
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-10J



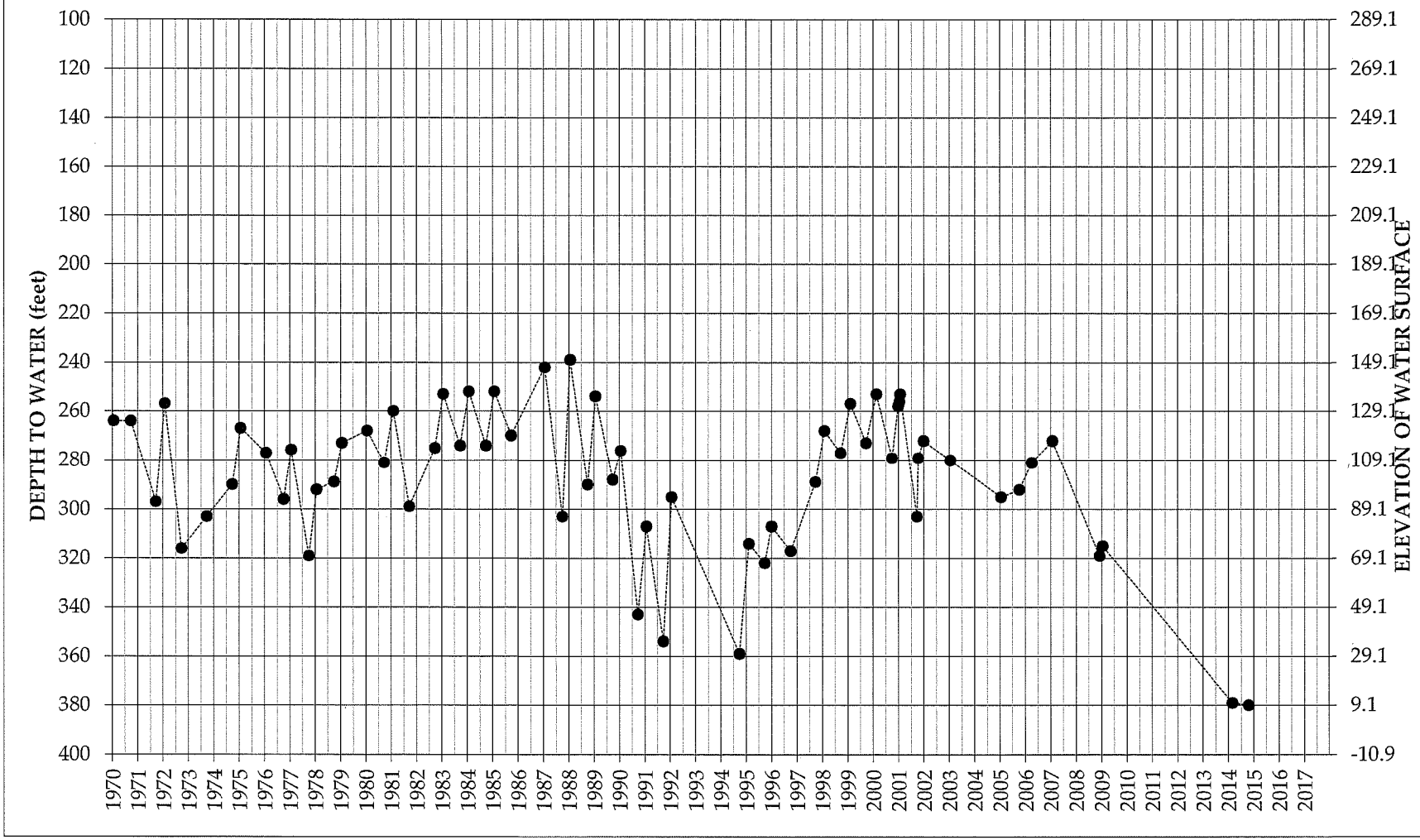
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-10L (342-800)



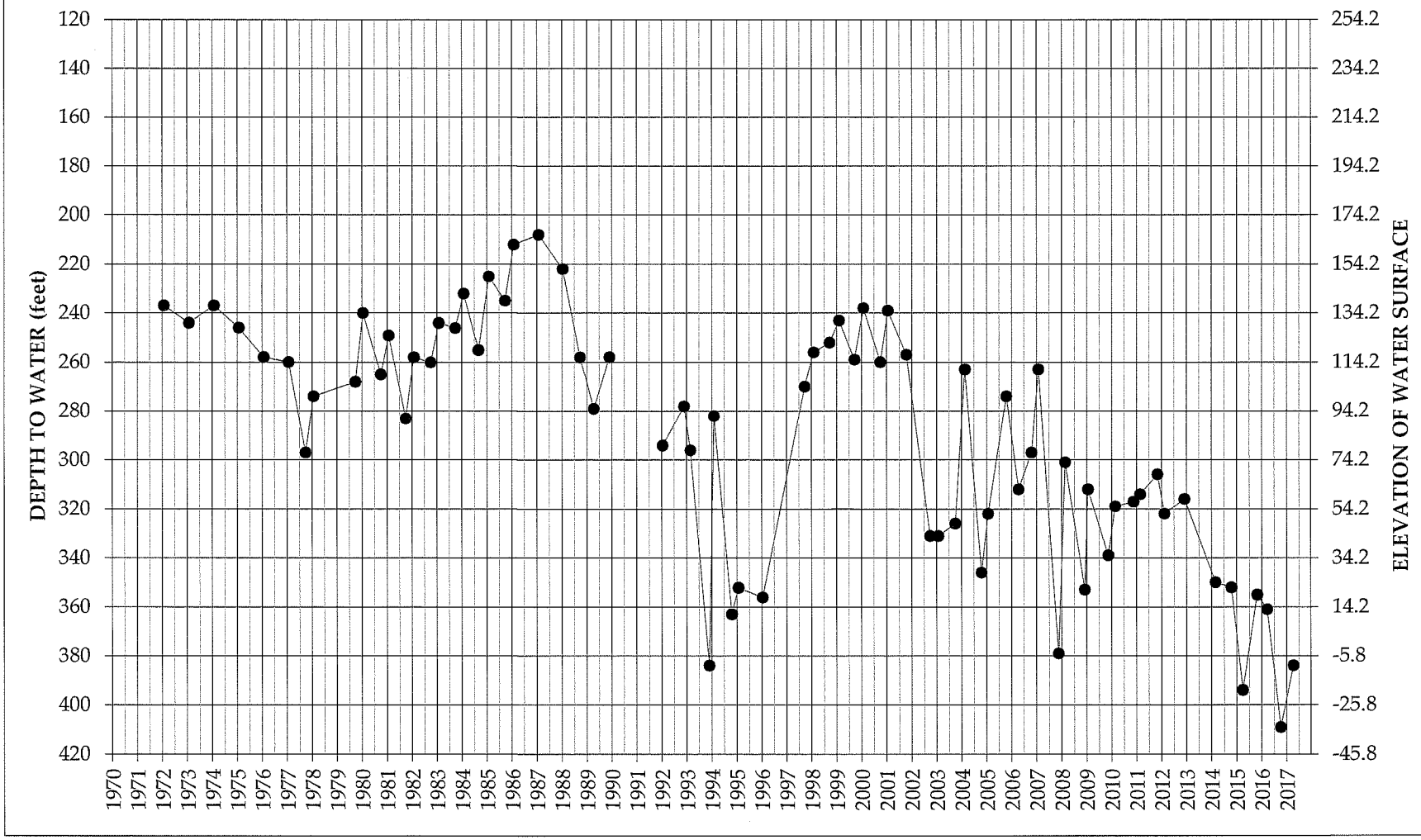
GEI Consultants

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-15J



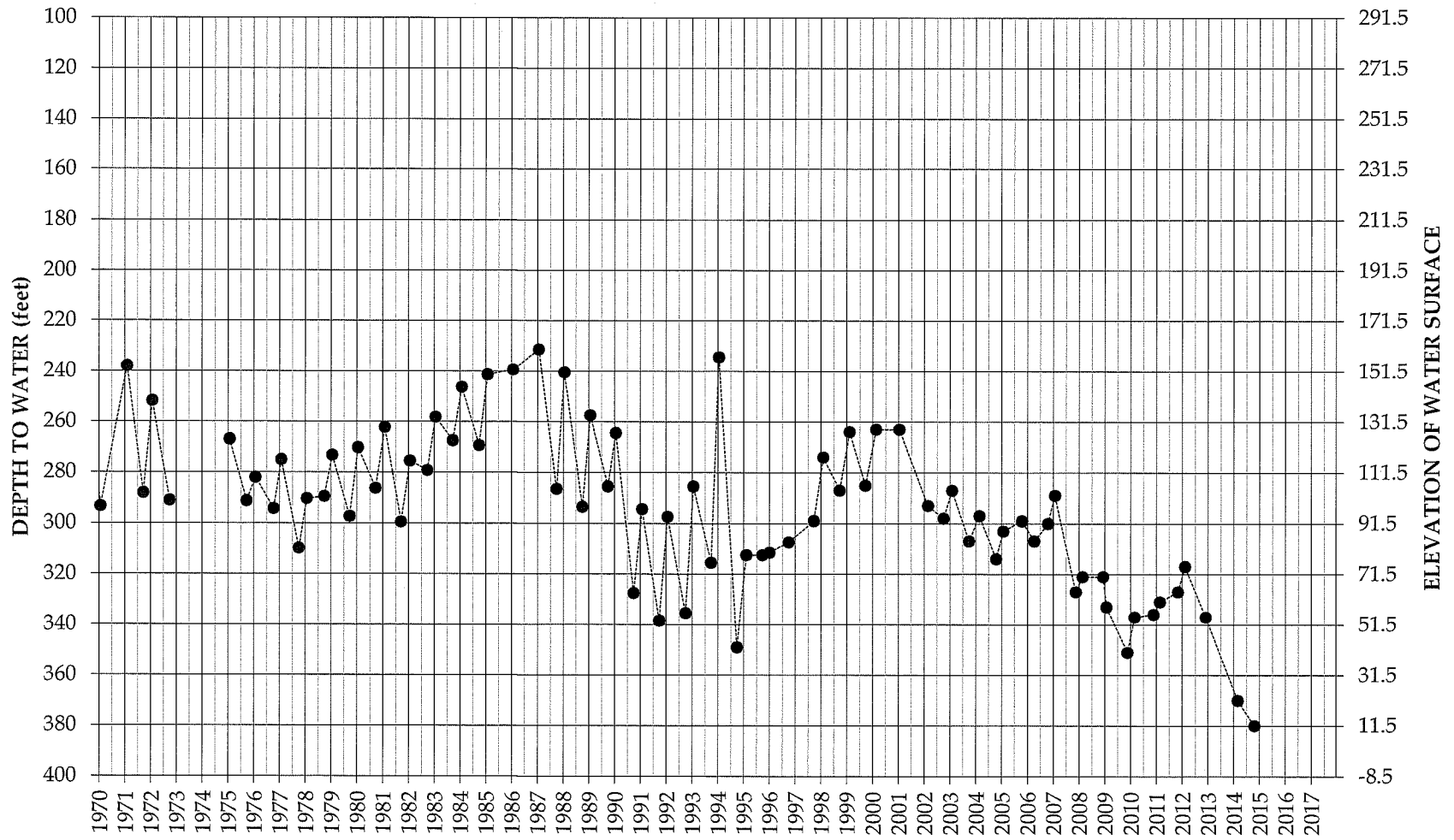
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-16H



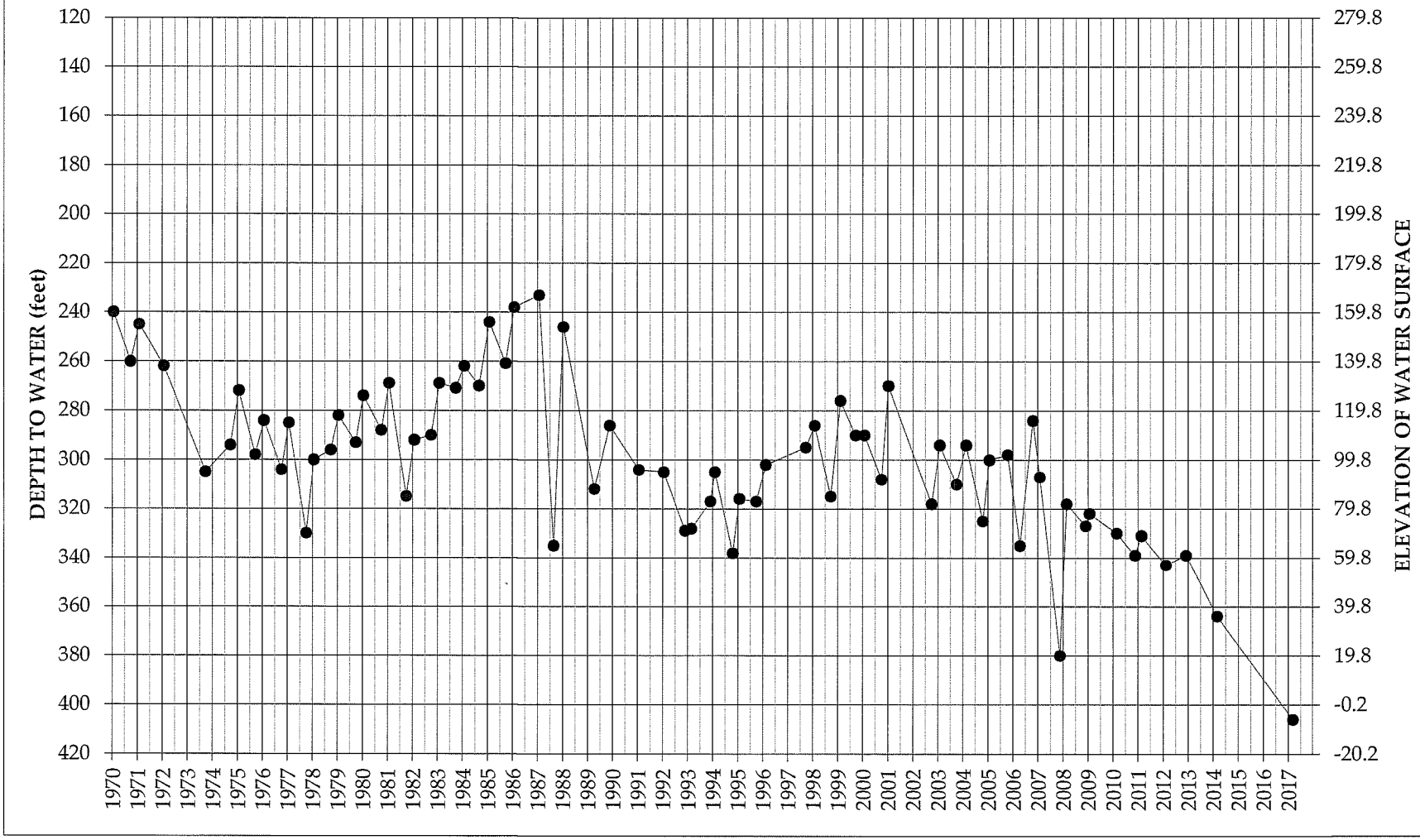
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-22J



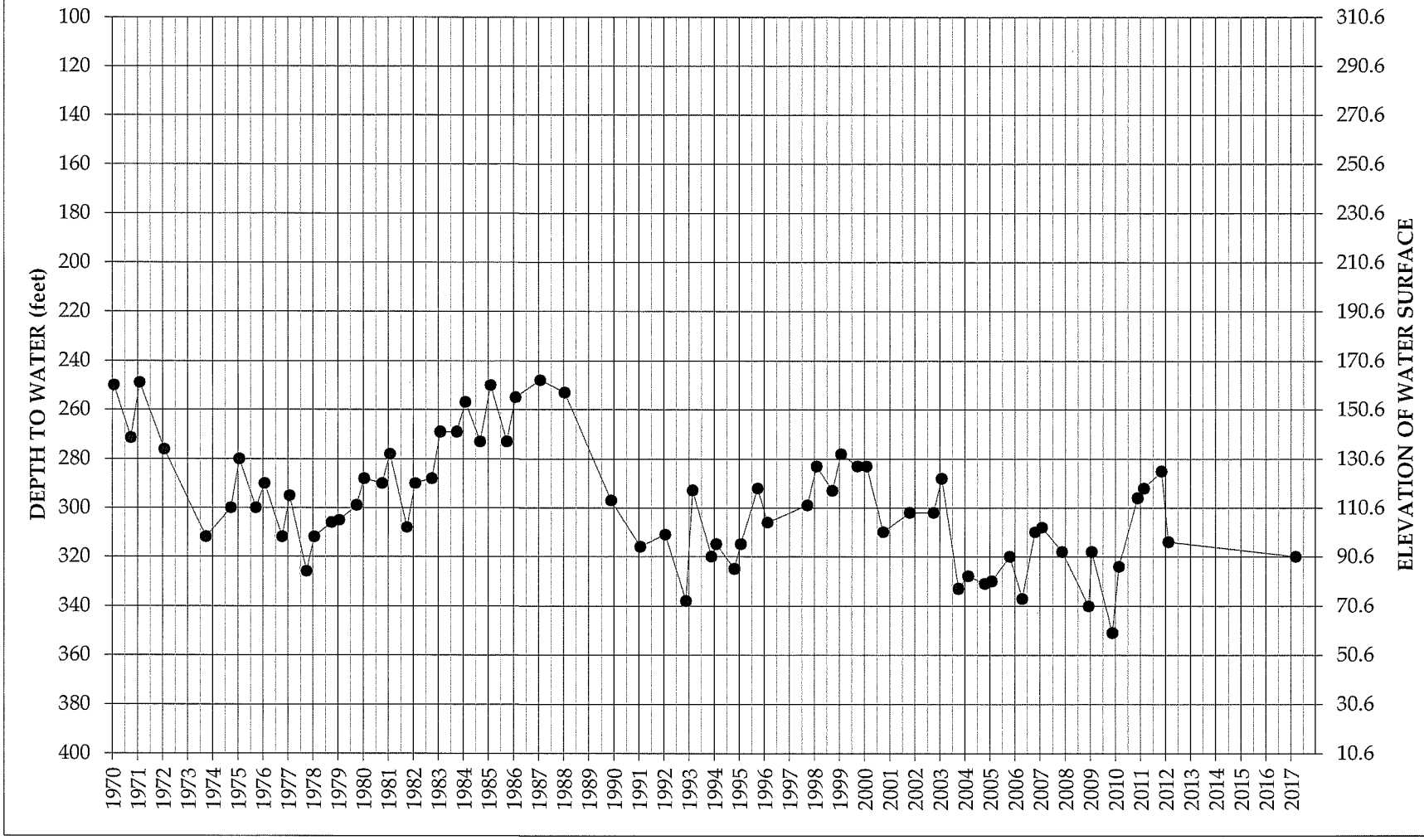
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-23C (341-803)



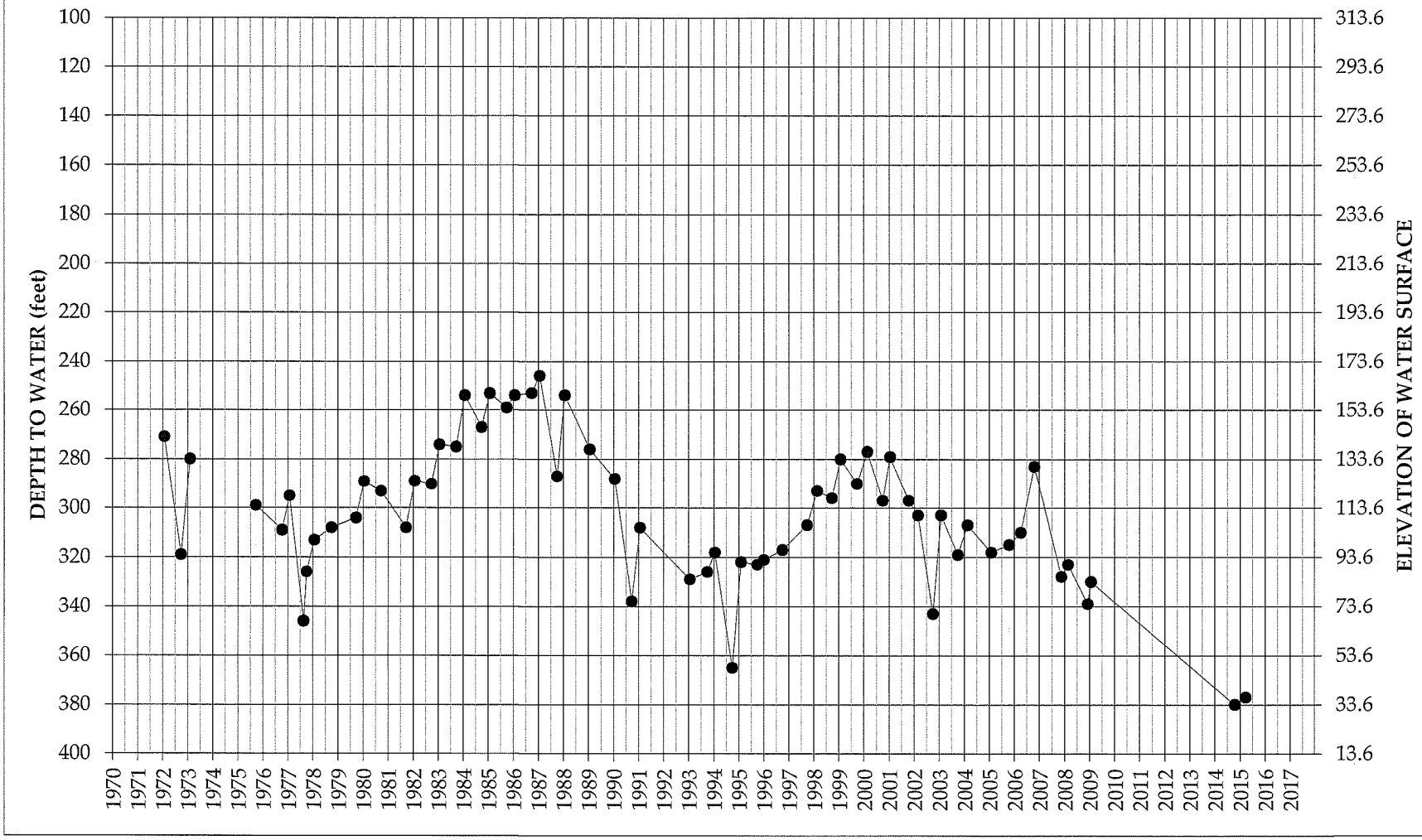
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-24C



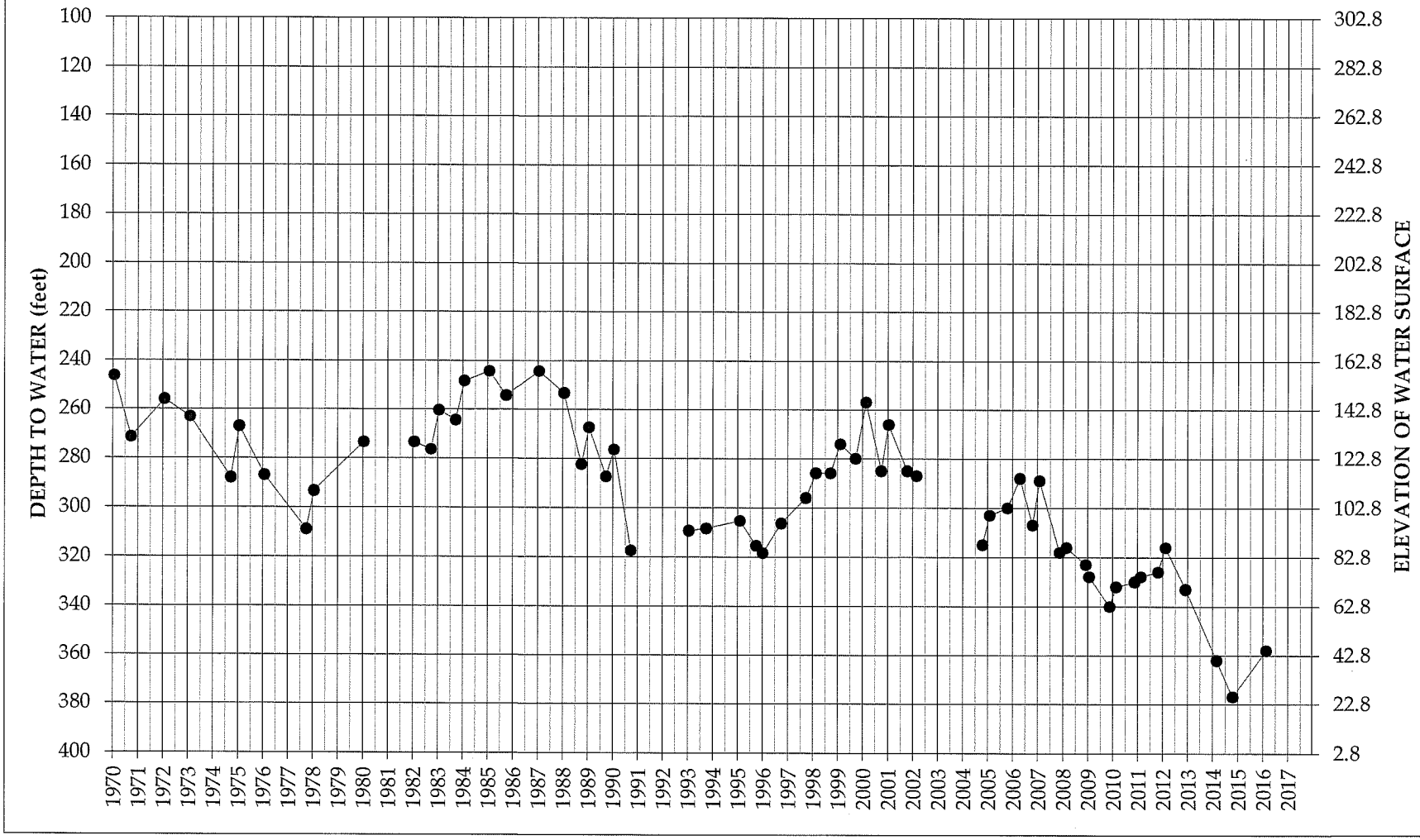
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-25J



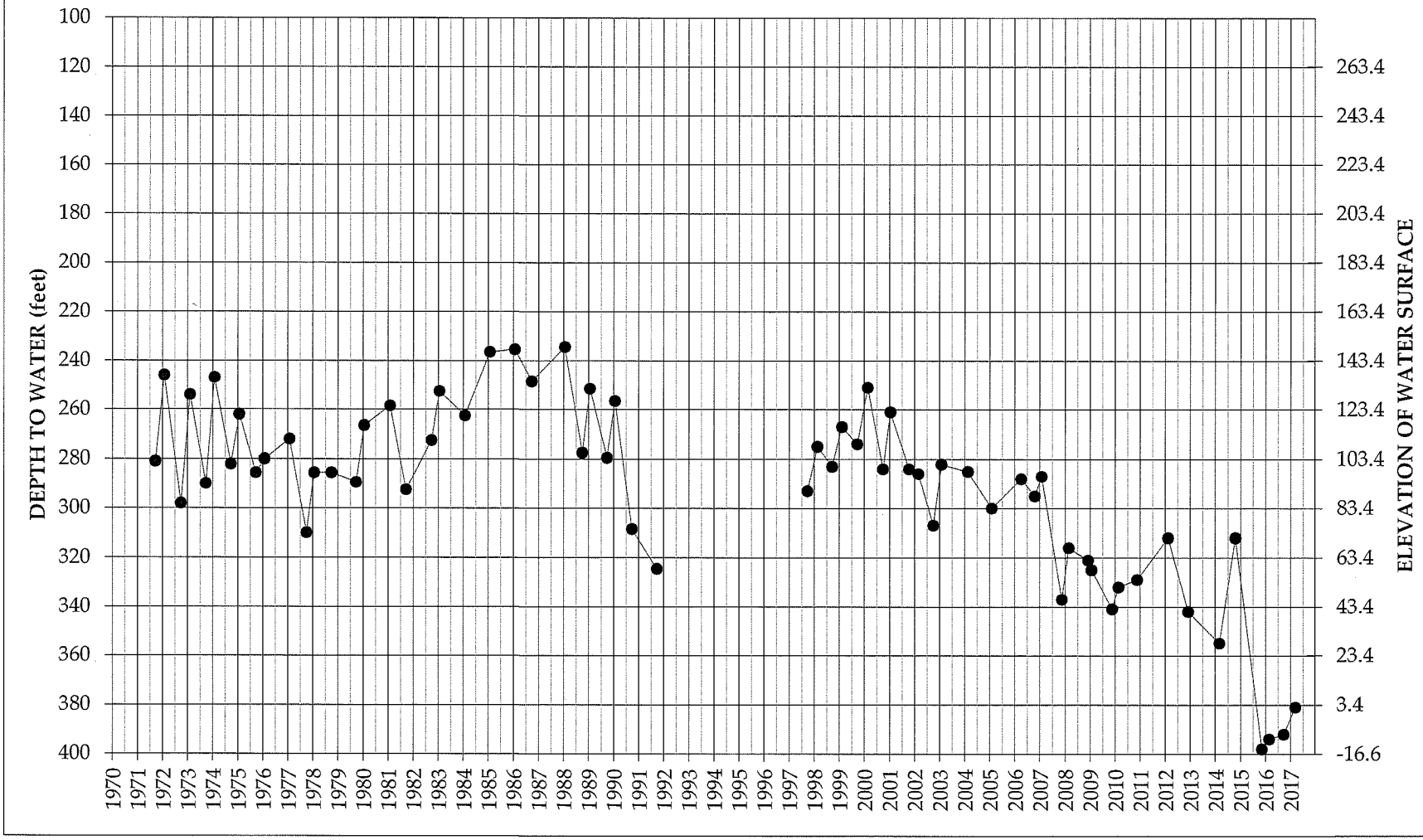
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-26K



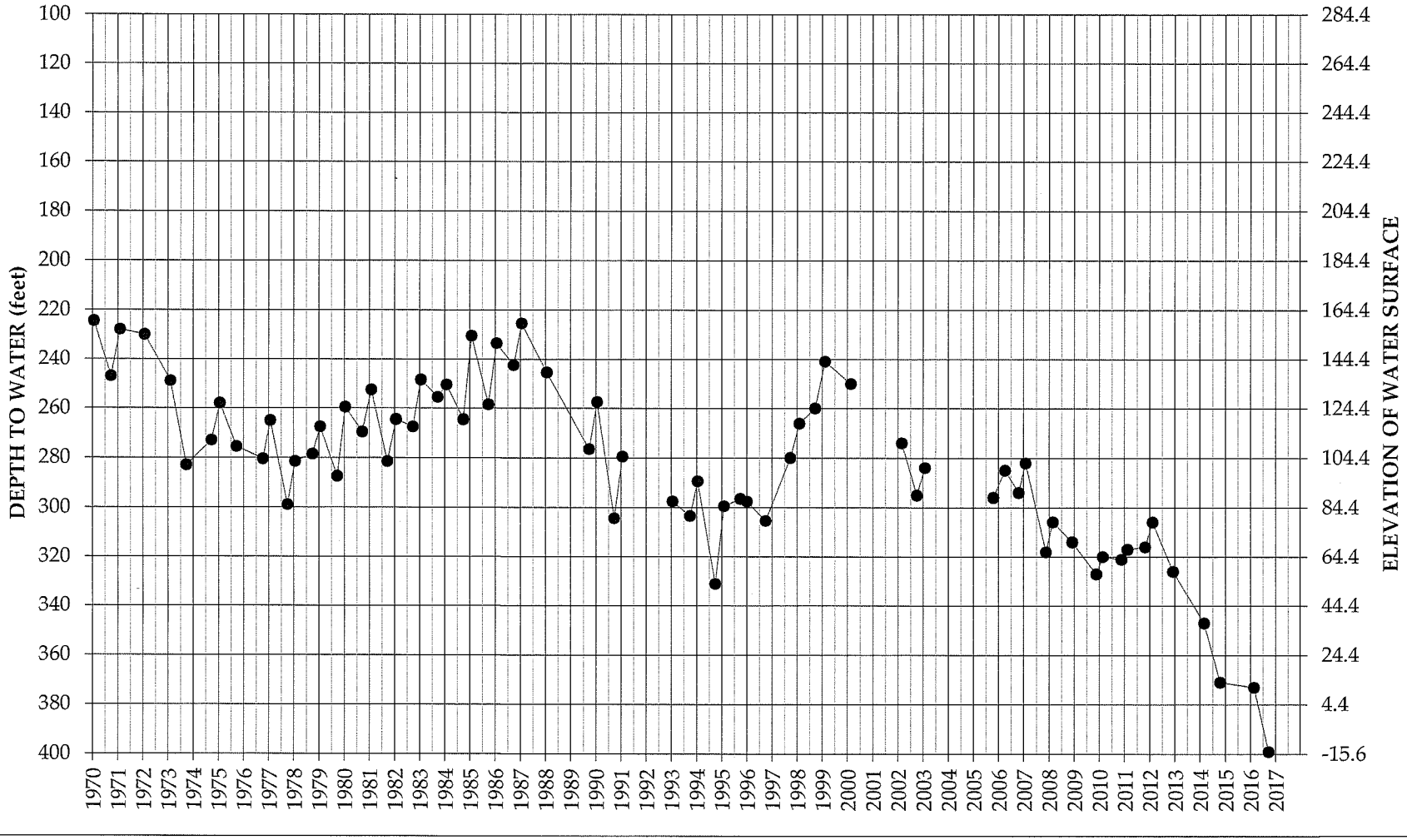
GEI Consultants
Boolman-Edmonston Division

NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-27C



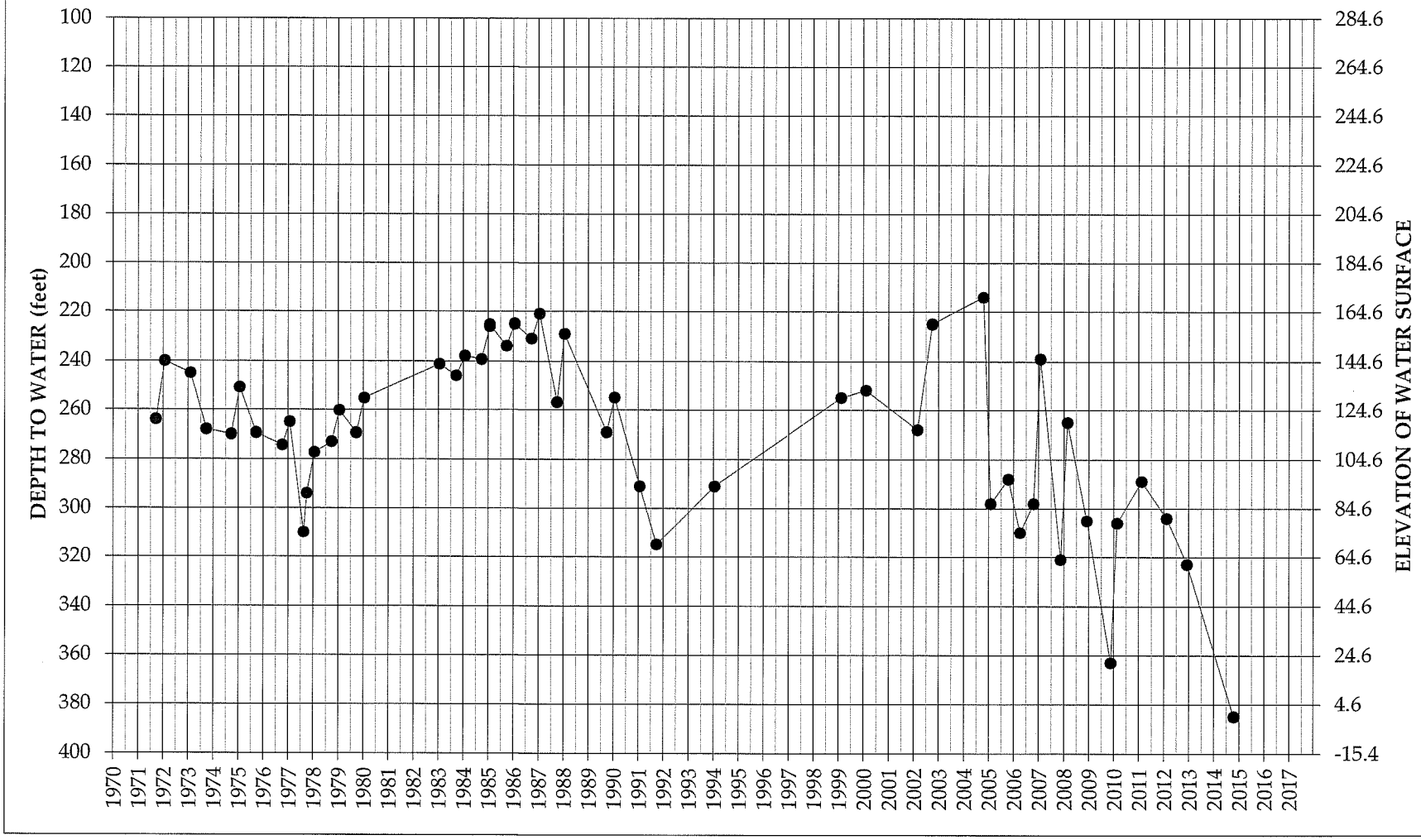
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-34A



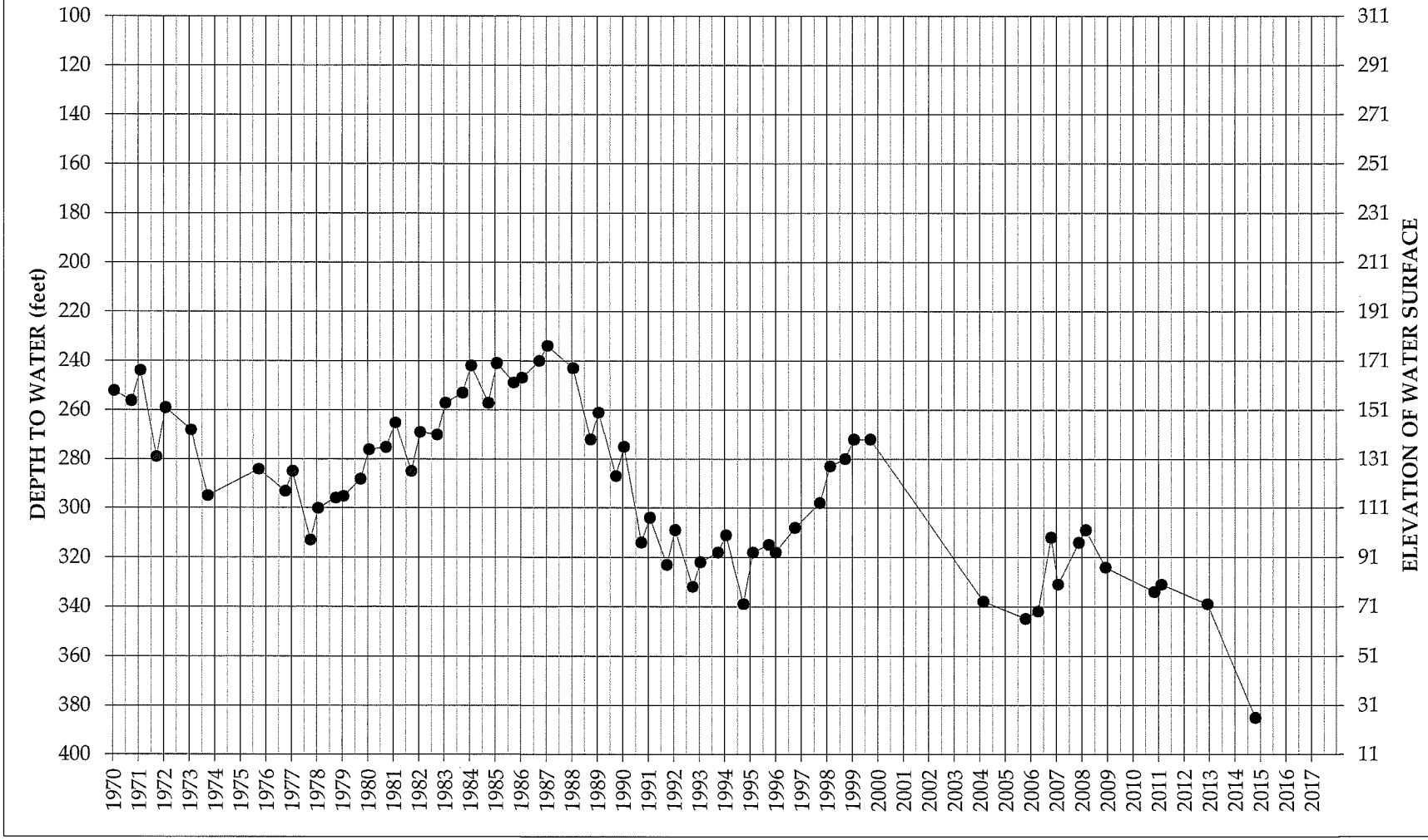
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-35L



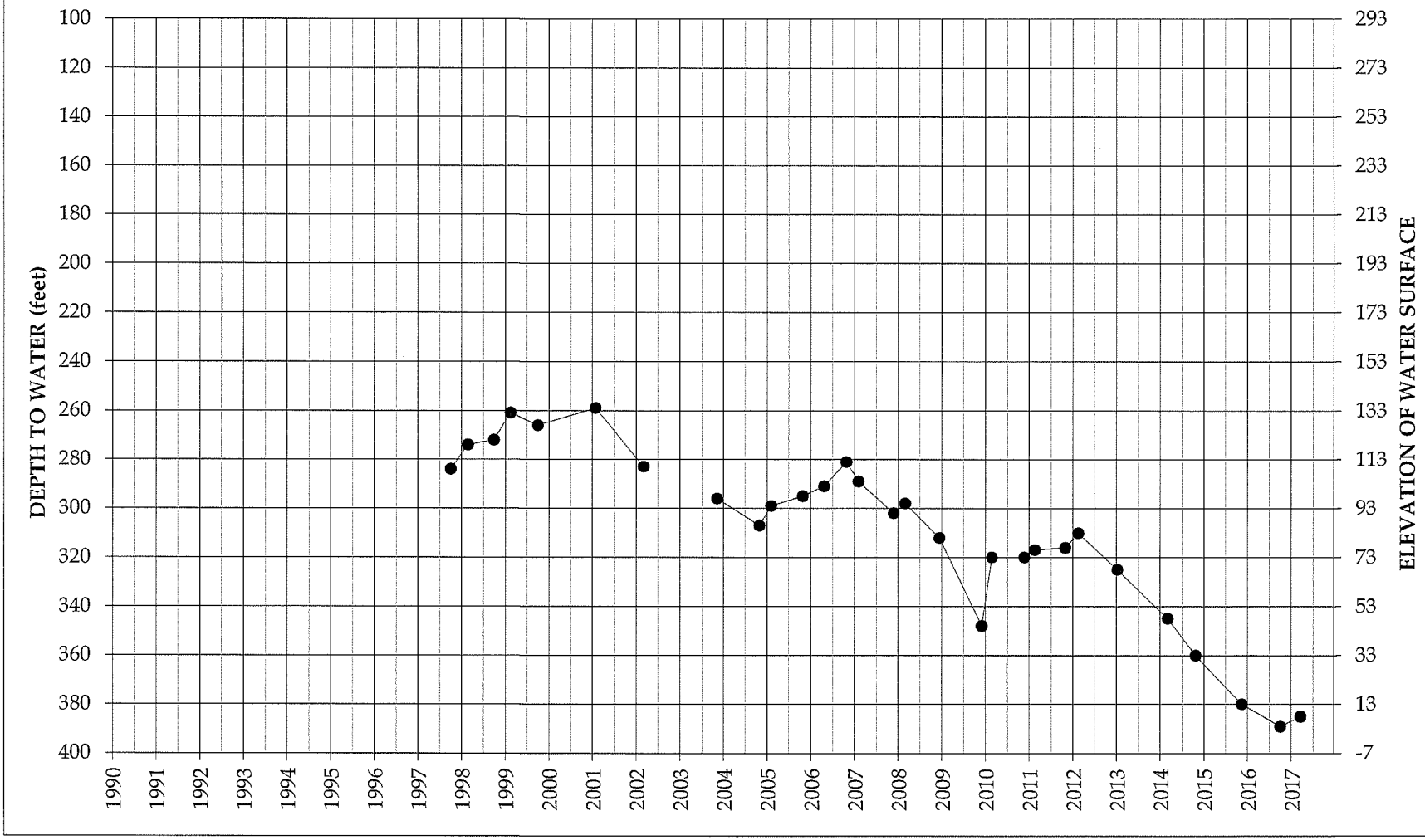
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #27/25-36J



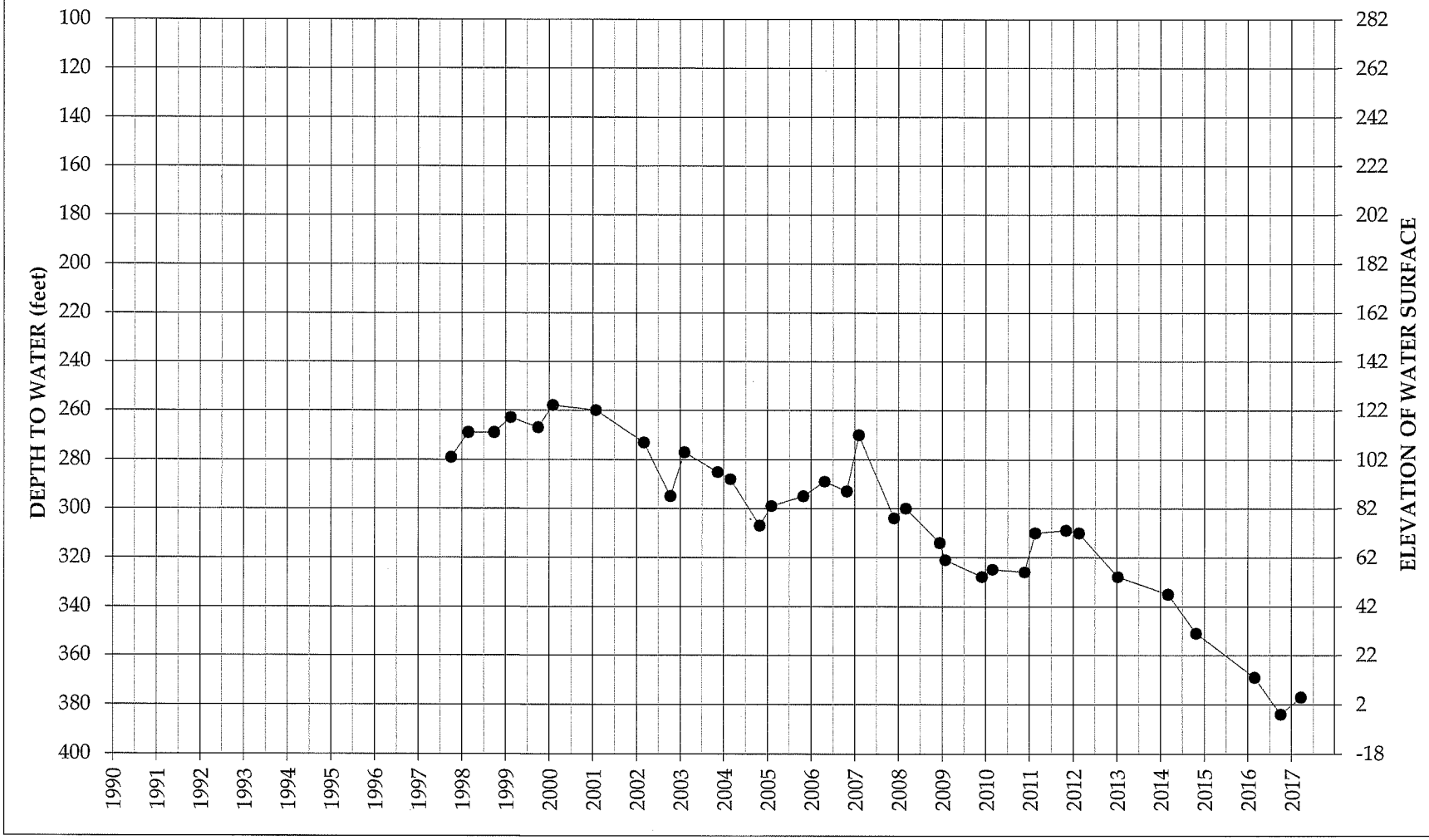
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/25-01C



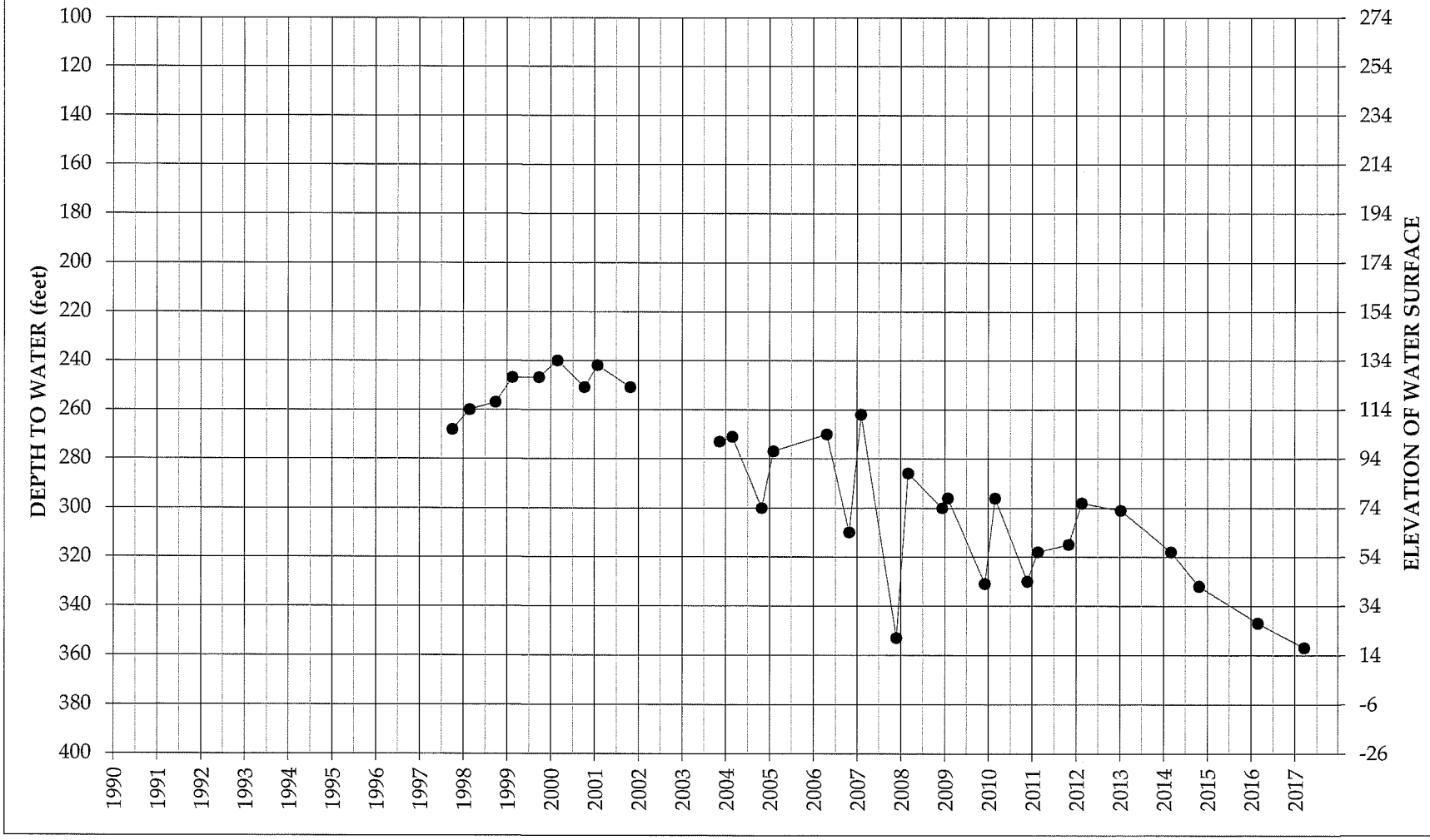
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/25-02A



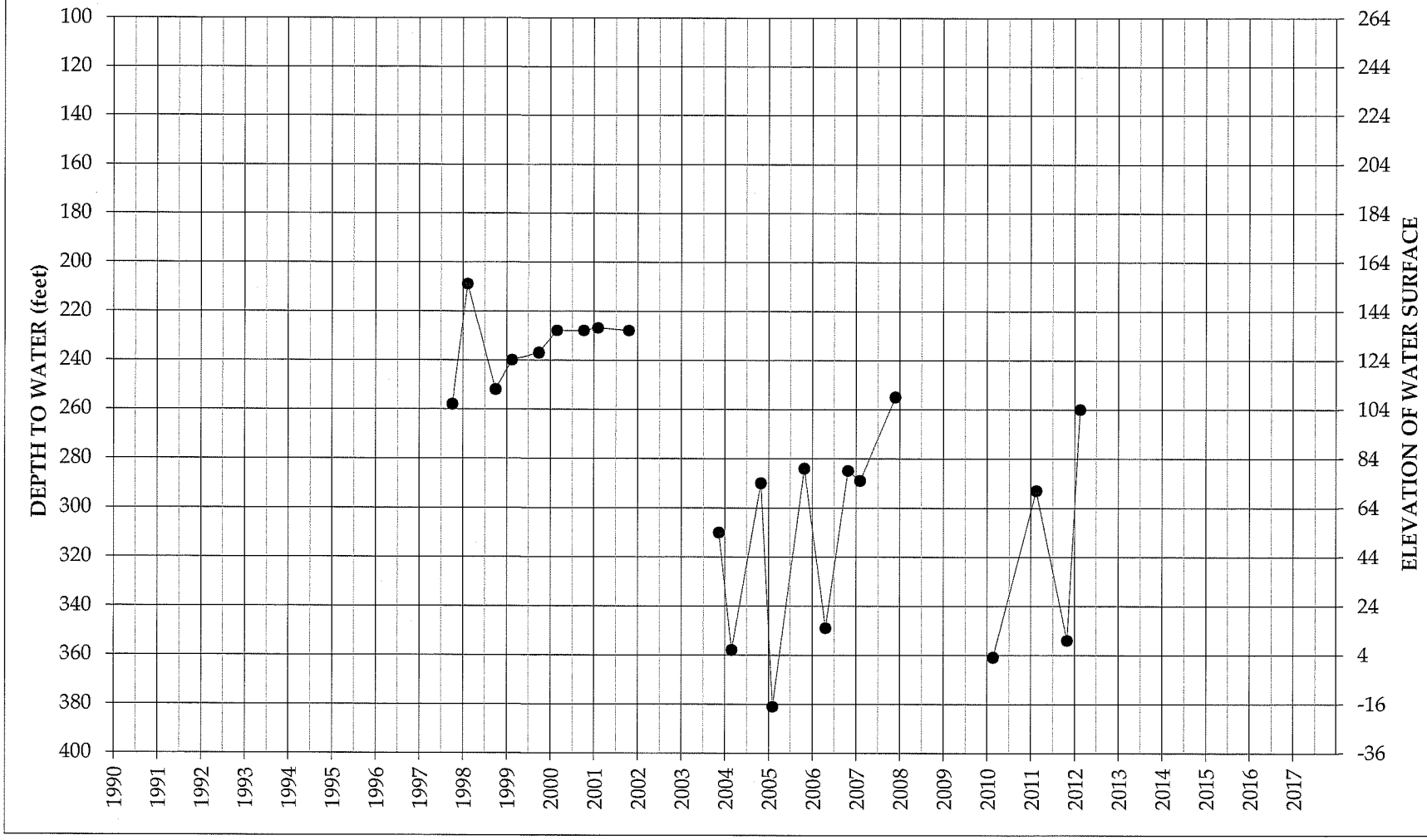
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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/25-12Q



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NORTH KERN WATER STORAGE DISTRICT
WATER LEVEL HYDROGRAPH FOR WELL #28/25-13F

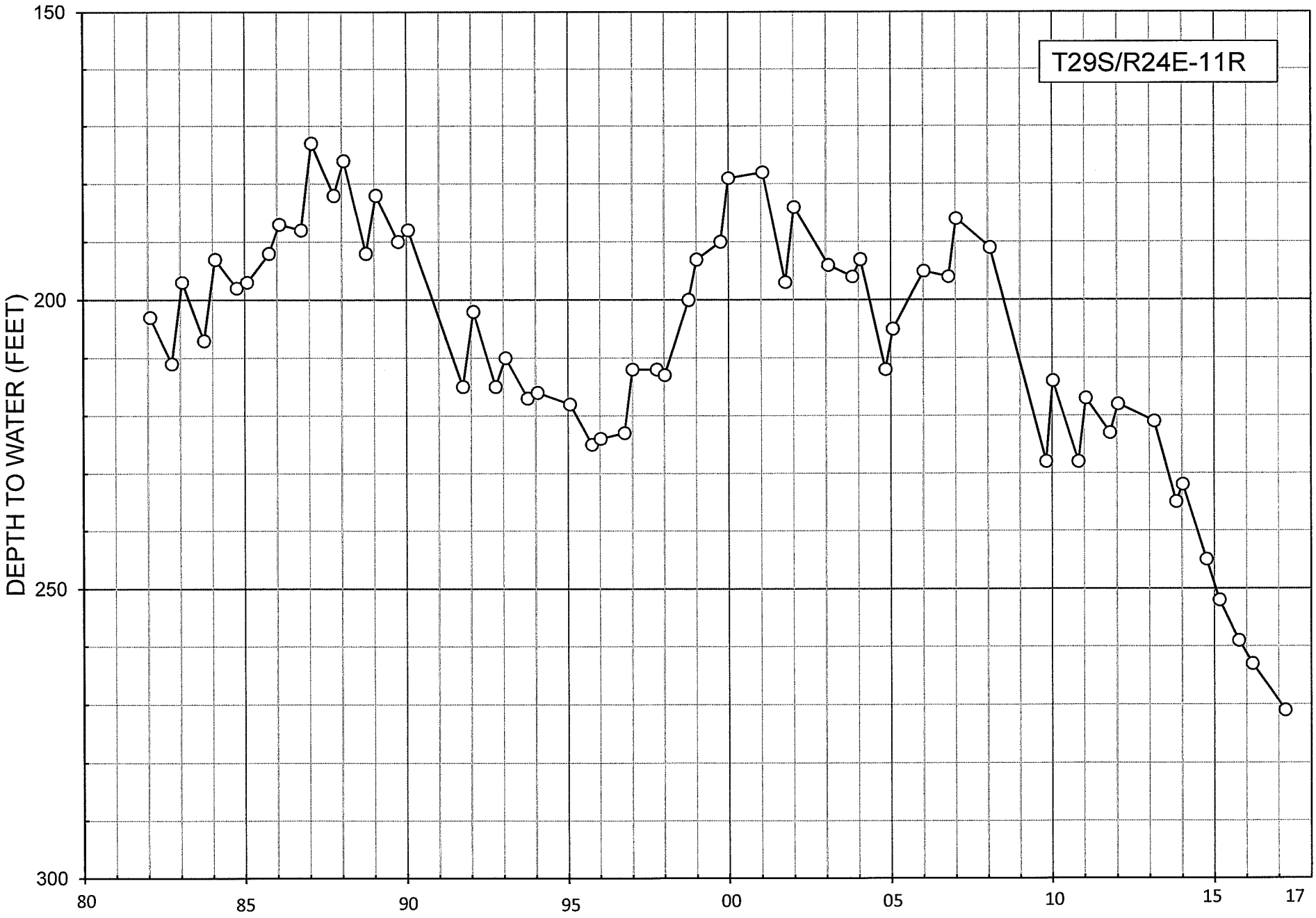


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ROSEDALE-RIO BRAVO WATER
STORAGE DISTRICT



WATER-LEVEL HYDROGRAPH FOR WELL T29S/R24E-2J



WATER-LEVEL HYDROGRAPH FOR WELL T29S/R24E-11R

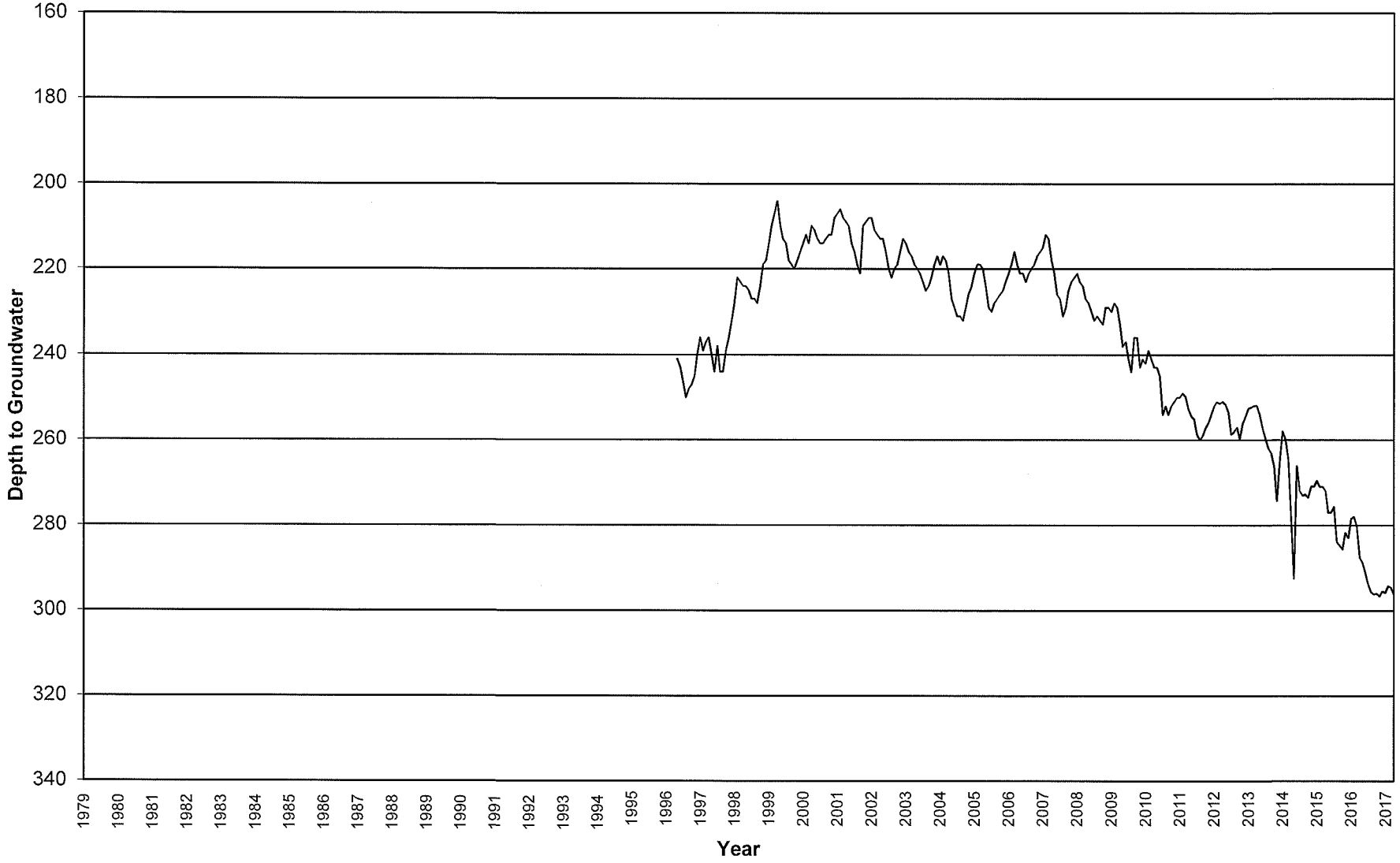


WATER-LEVEL HYDROGRAPH FOR WELL T29S/R24E-13A

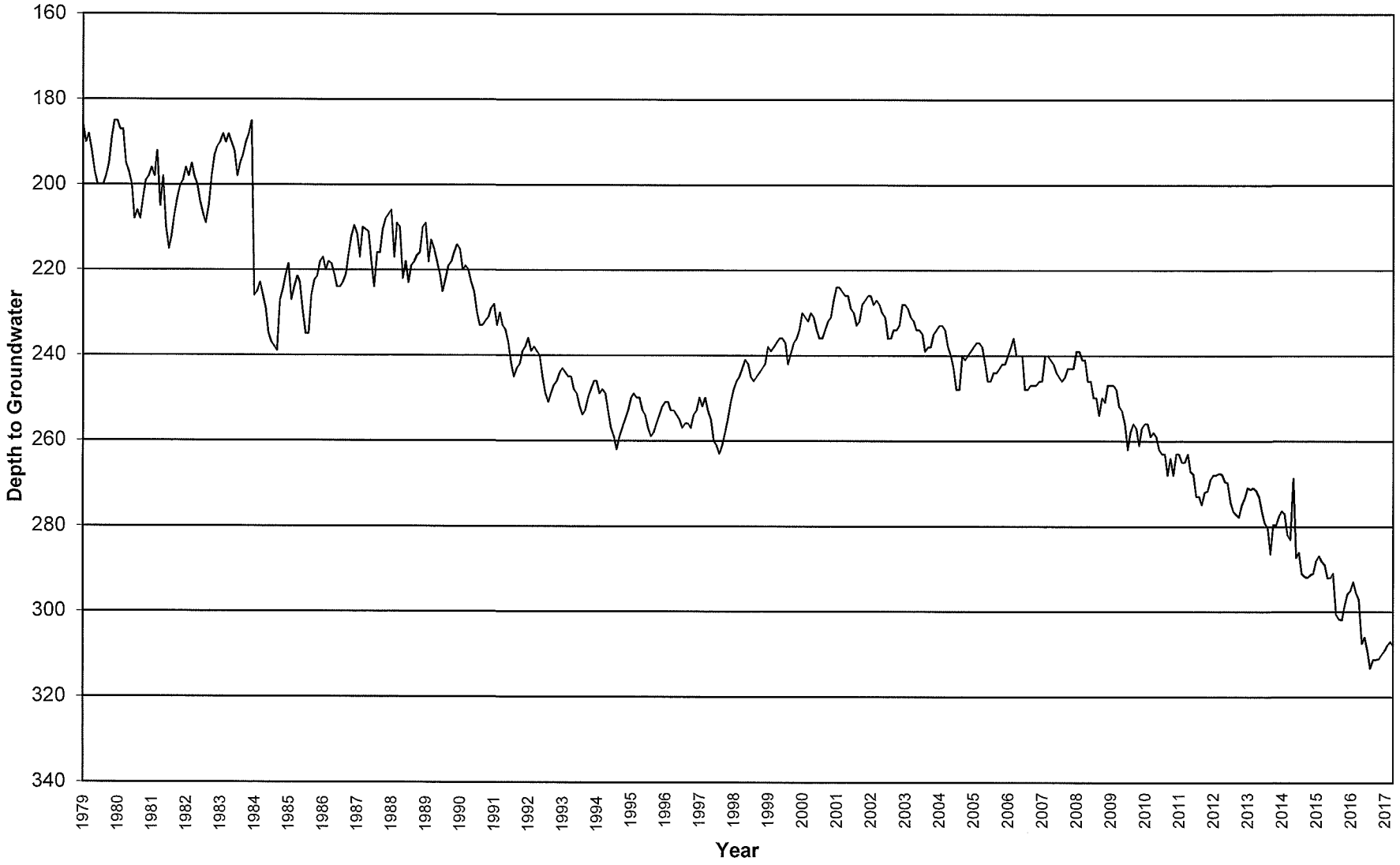


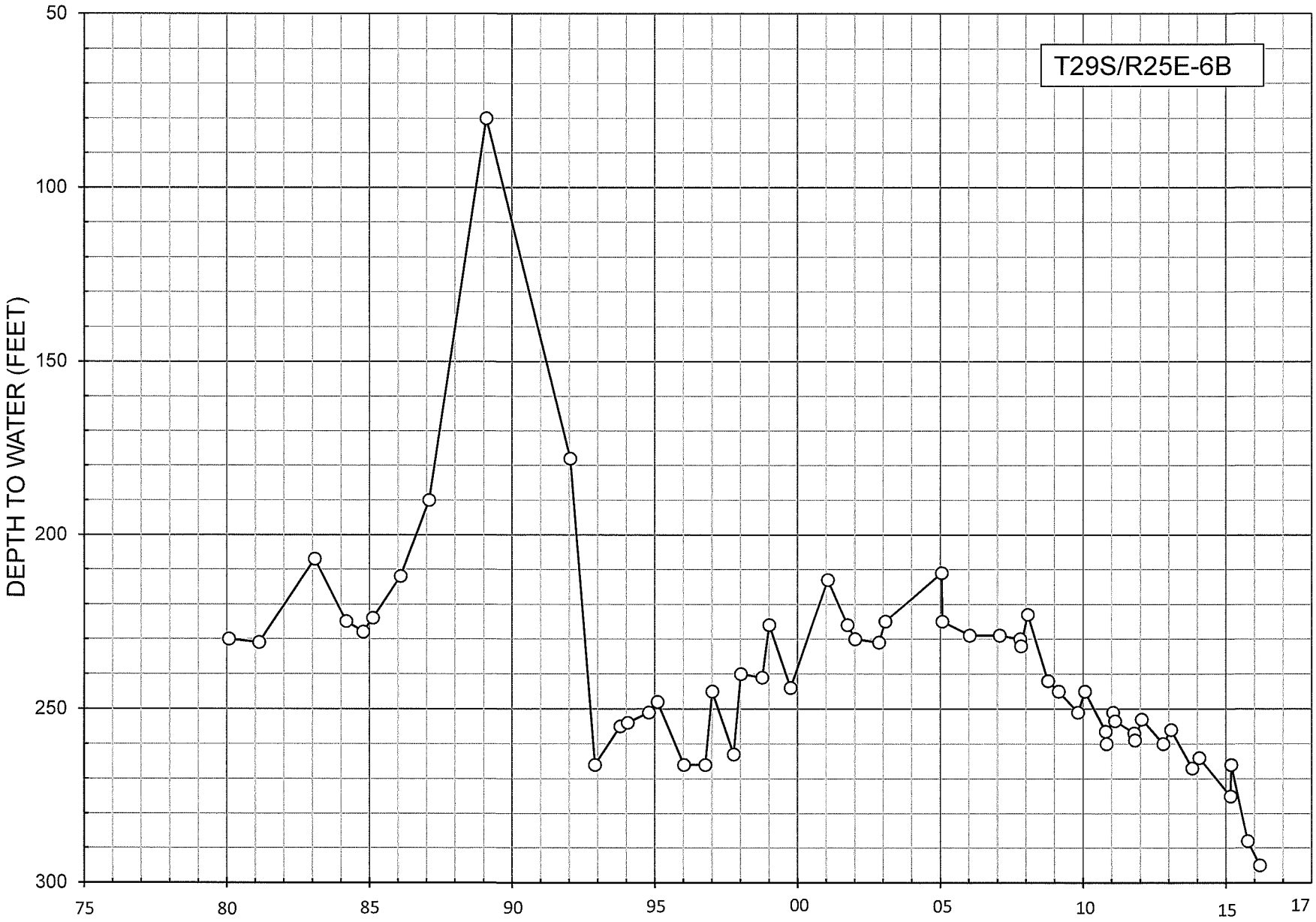
WATER-LEVEL HYDROGRAPH FOR WELL T29S/R24E-24P

ROSEDALE-RIO BRAVO WATER STORAGE DISTRICT
L.R. STOUT WELL
29/25 - 3N1

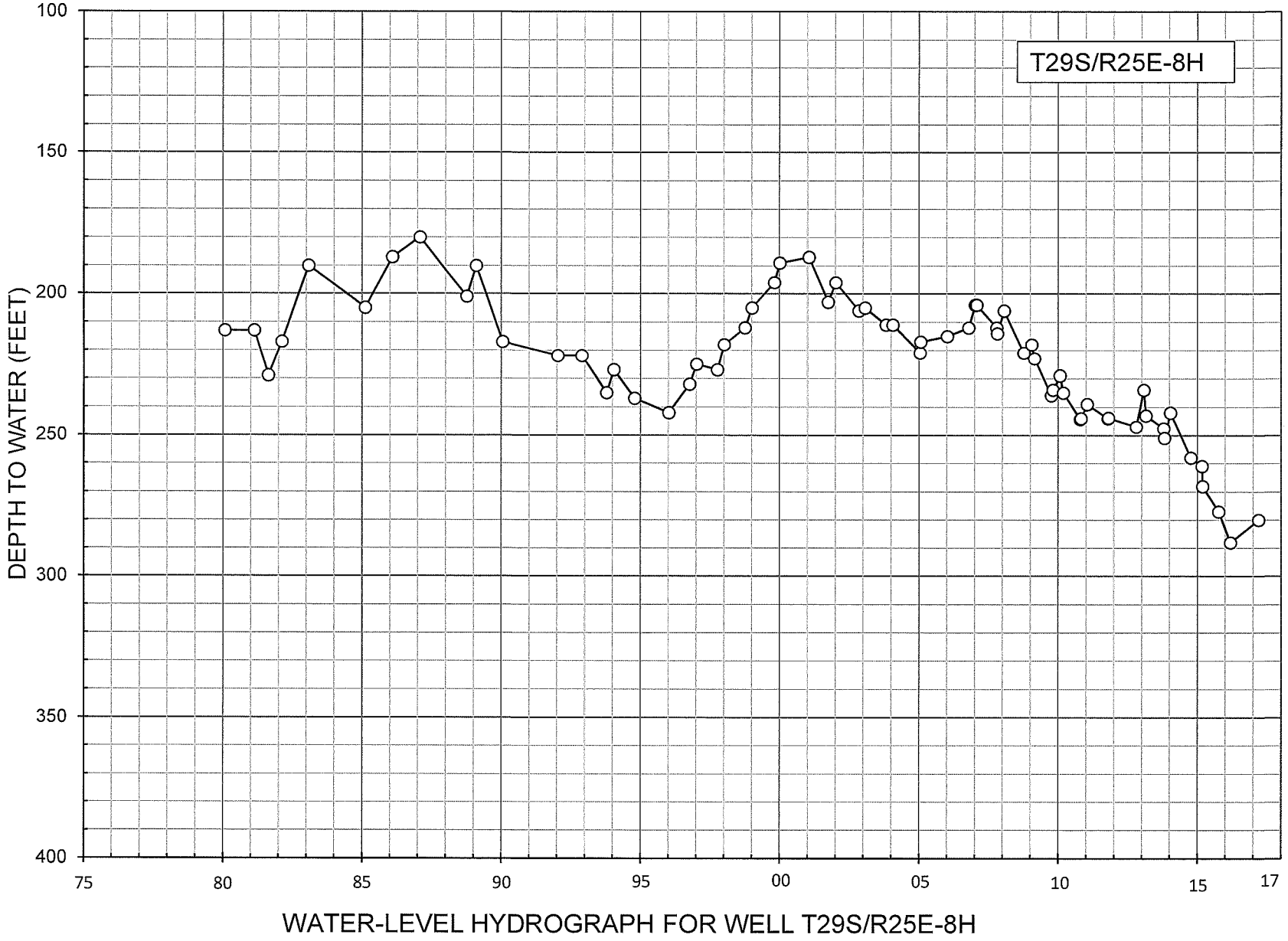


ROSEDALE-RIO BRAVO WATER STORAGE DISTRICT
HAAG WELL
29/25 - 5C (28/25 - 31)

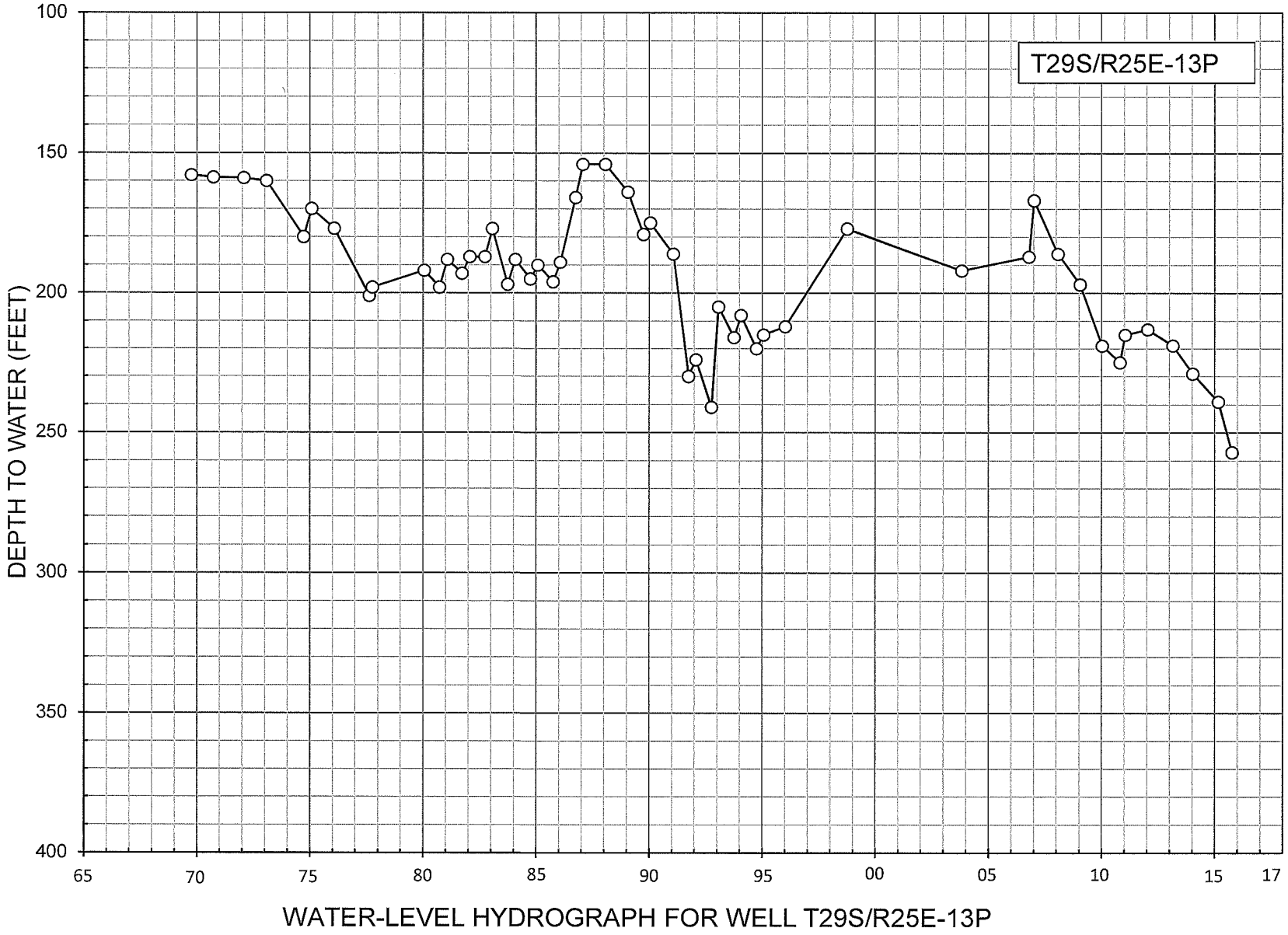




WATER-LEVEL HYDROGRAPH FOR WELL T29S/R25E-6B

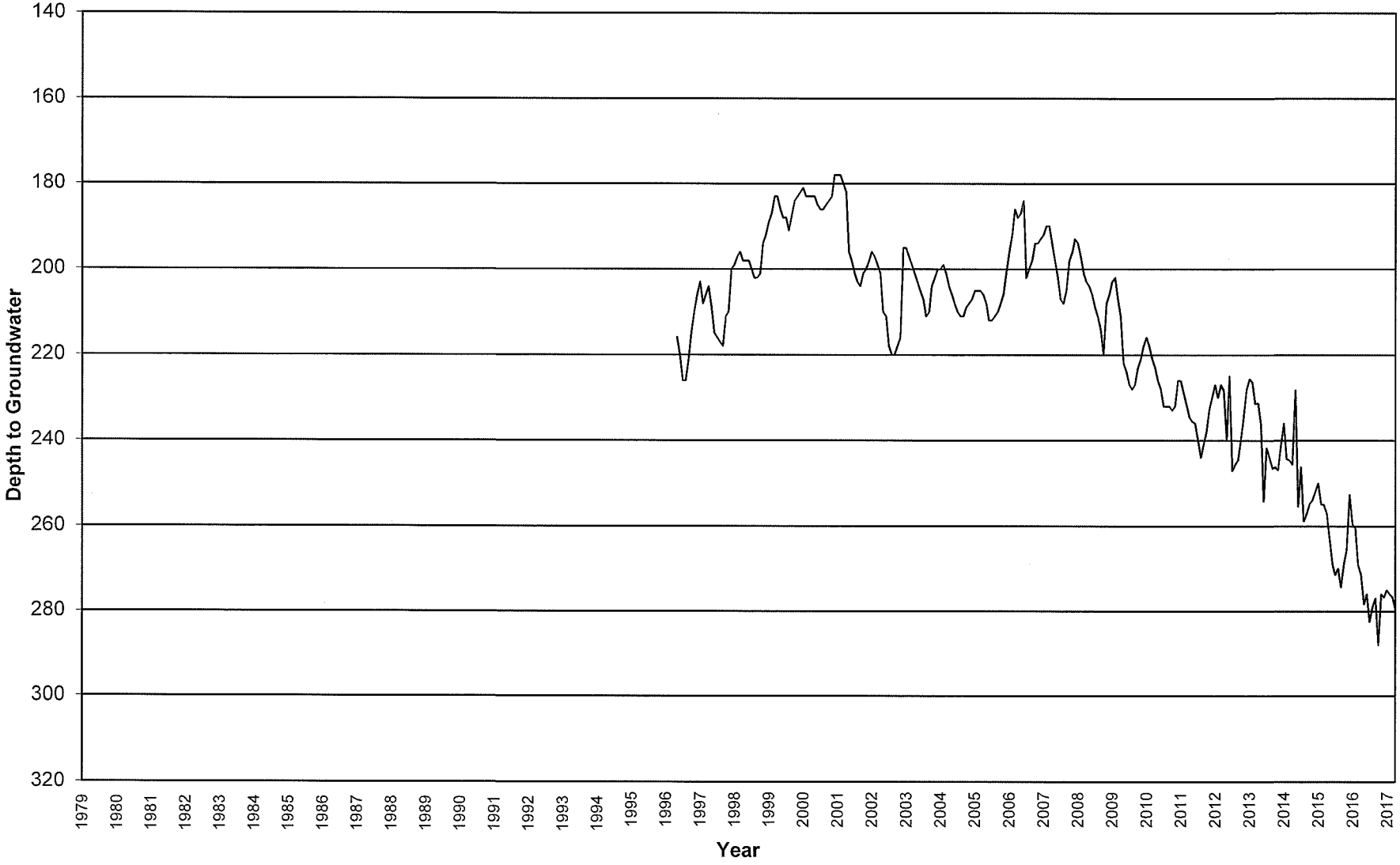


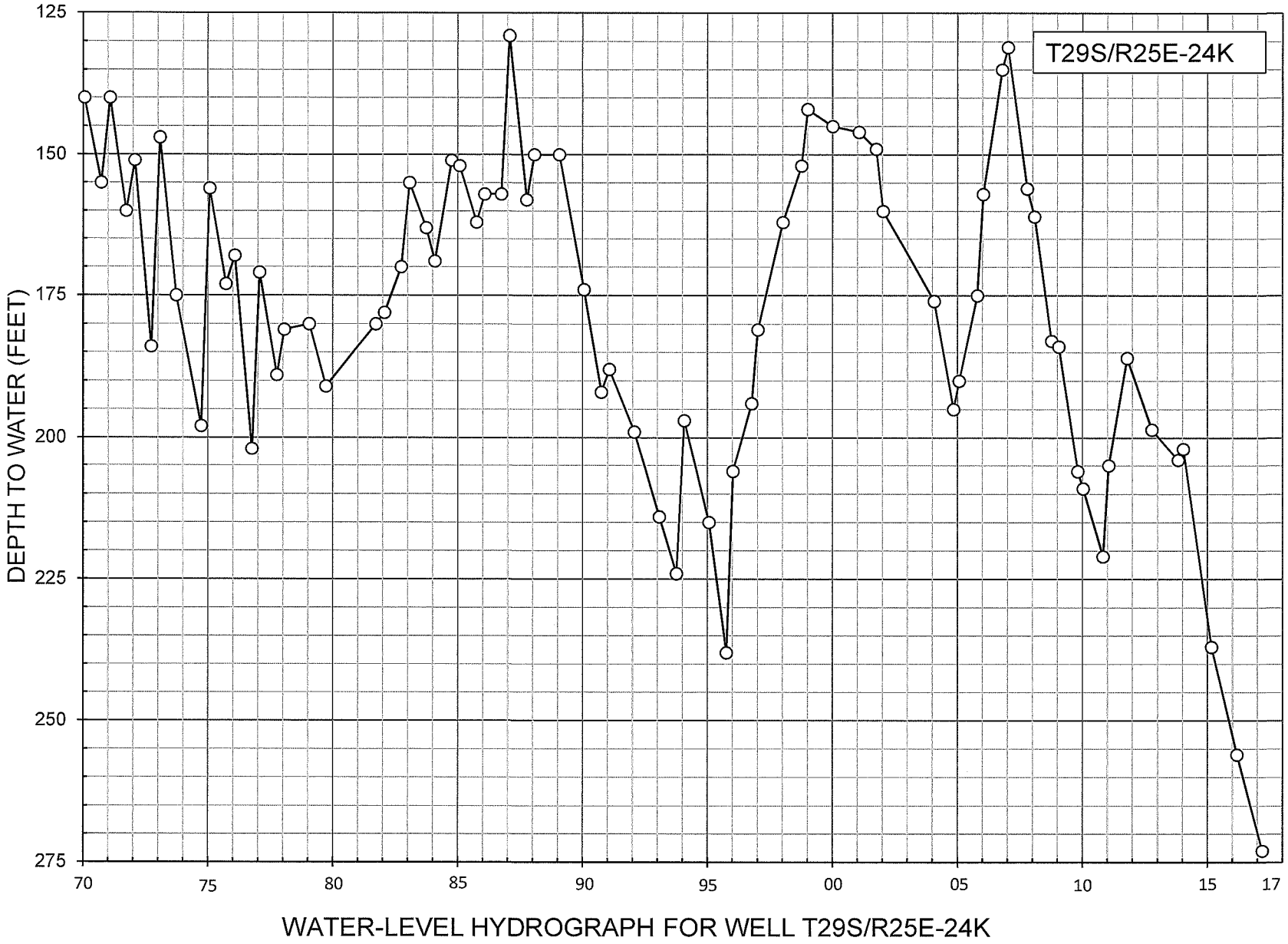
WATER-LEVEL HYDROGRAPH FOR WELL T29S/R25E-8H



WATER-LEVEL HYDROGRAPH FOR WELL T29S/R25E-13P

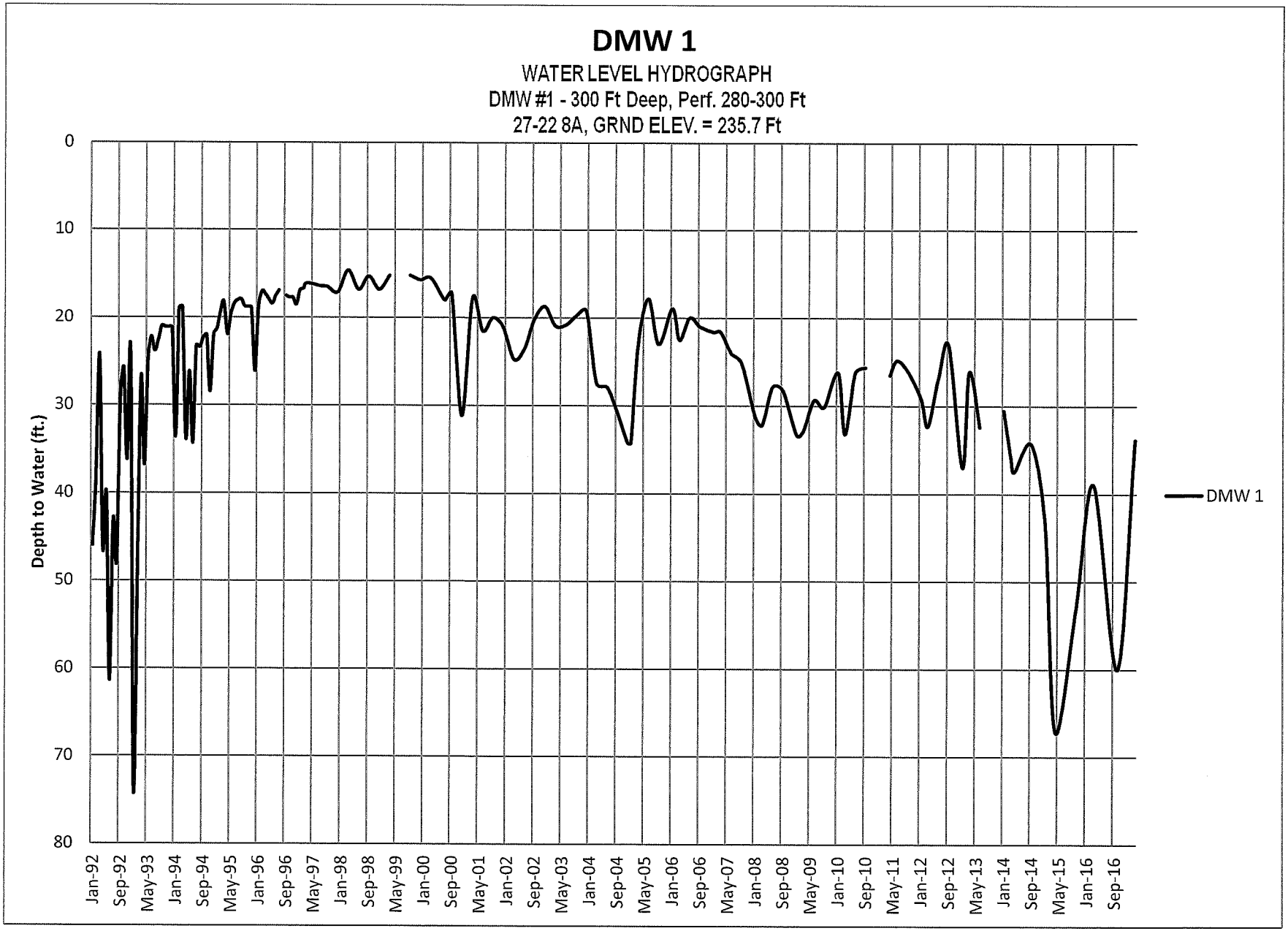
ROSEDALE-RIO BRAVO WATER STORAGE DISTRICT
SECTION 18 WELL
29/25 - 18A1

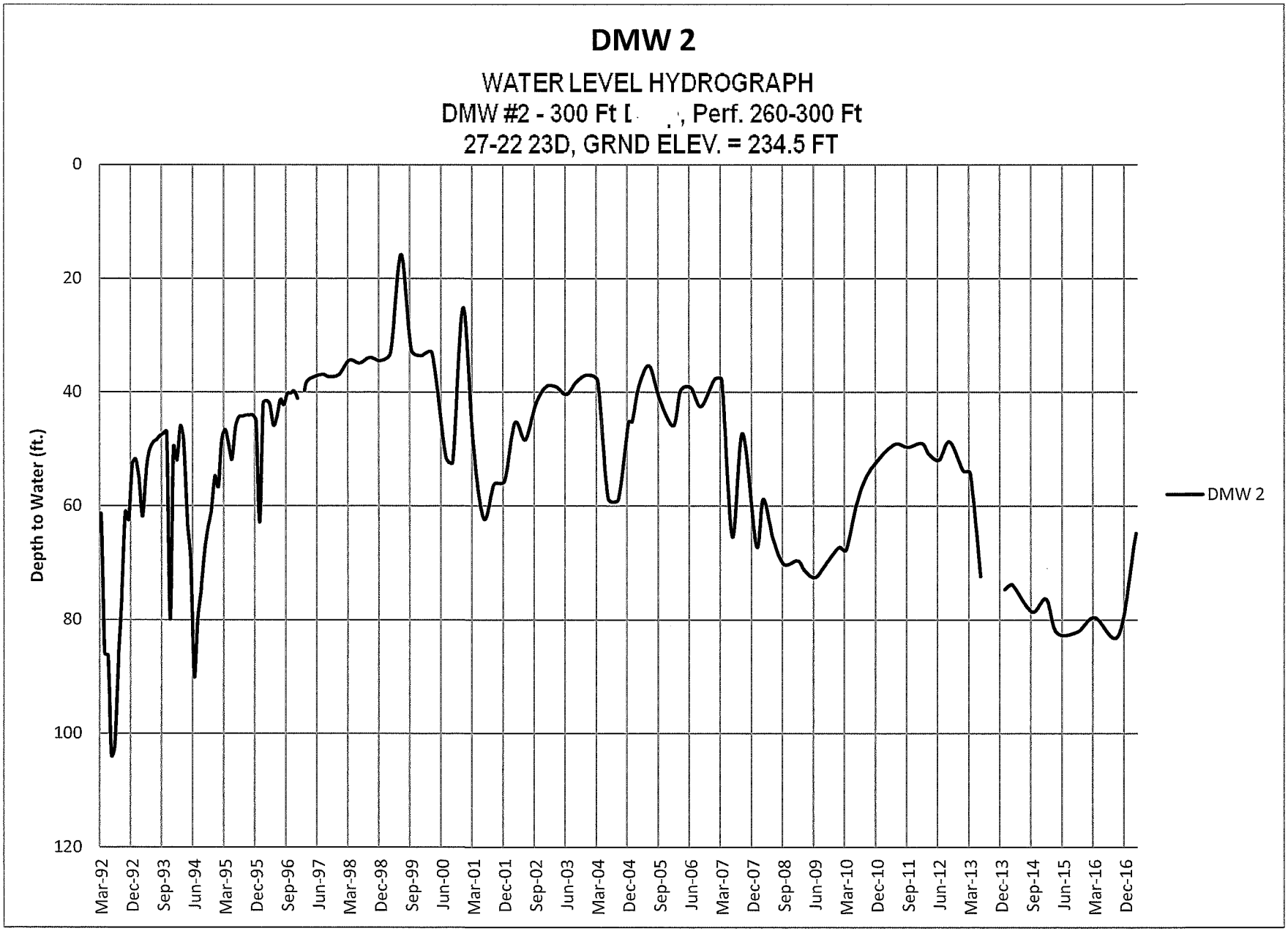


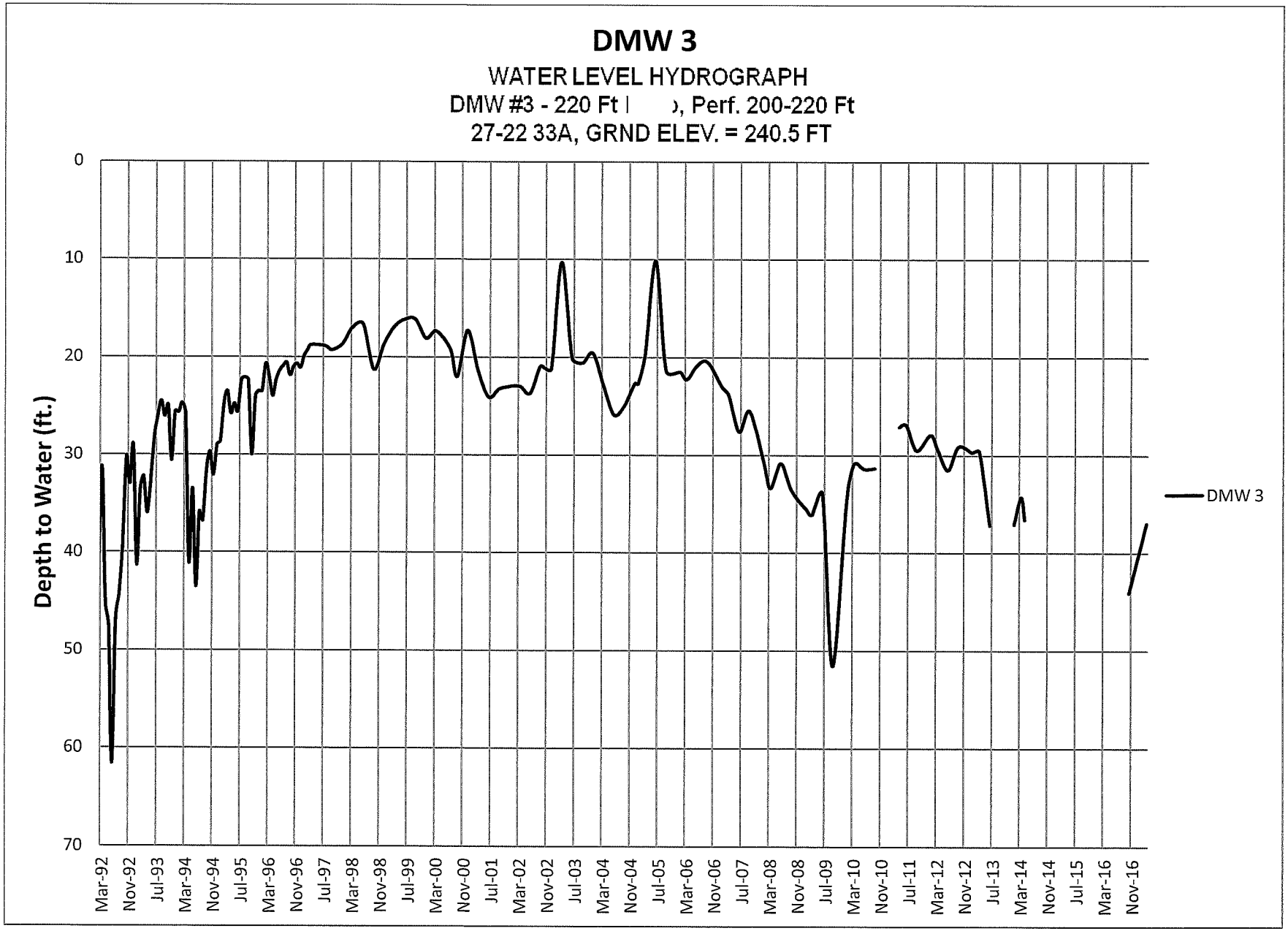


WATER-LEVEL HYDROGRAPH FOR WELL T29S/R25E-24K

BUENA VISTA WATER STORAGE DISTRICT

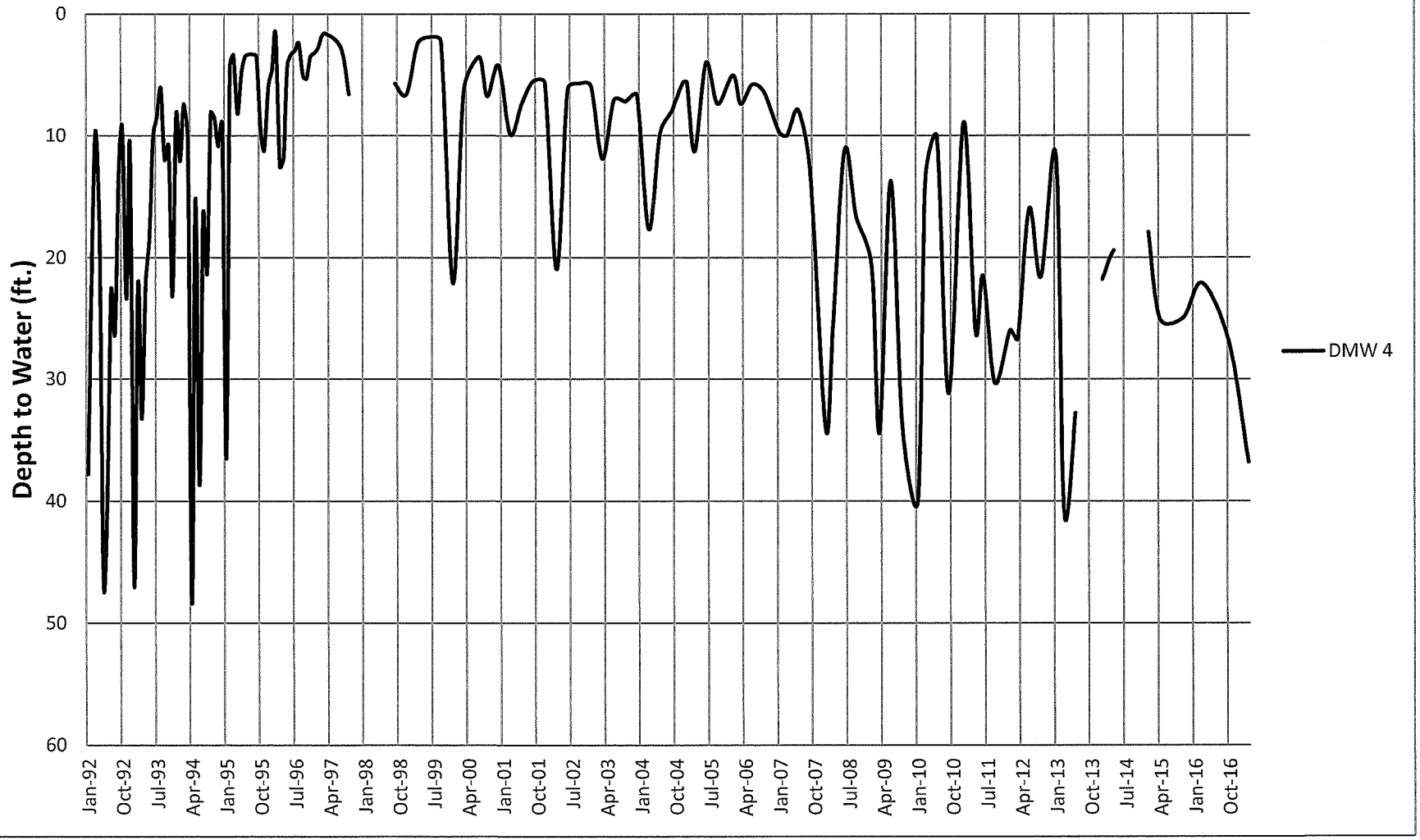

DMW 1
WATER LEVEL HYDROGRAPH
DMW #1 - 300 Ft Deep, Perf. 280-300 Ft
27-22 8A, GRND ELEV. = 235.7 Ft
Depth to Water (ft.)
0
10
20
30
40
50
60
70
80
Jan-92
Sep-92
May-93
Jan-94
Sep-94
May-95
Jan-96
Sep-96
May-97
Jan-98
Sep-98
May-99
Jan-00
Sep-00
May-01
Jan-02
Sep-02
May-03
Jan-04
Sep-04
May-05
Jan-06
Sep-06
May-07
Jan-08
Sep-08
May-09
Jan-10
Sep-10
May-11
Jan-12
Sep-12
May-13
Jan-14
Sep-14
May-15
Jan-16
Sep-16
DMW 1

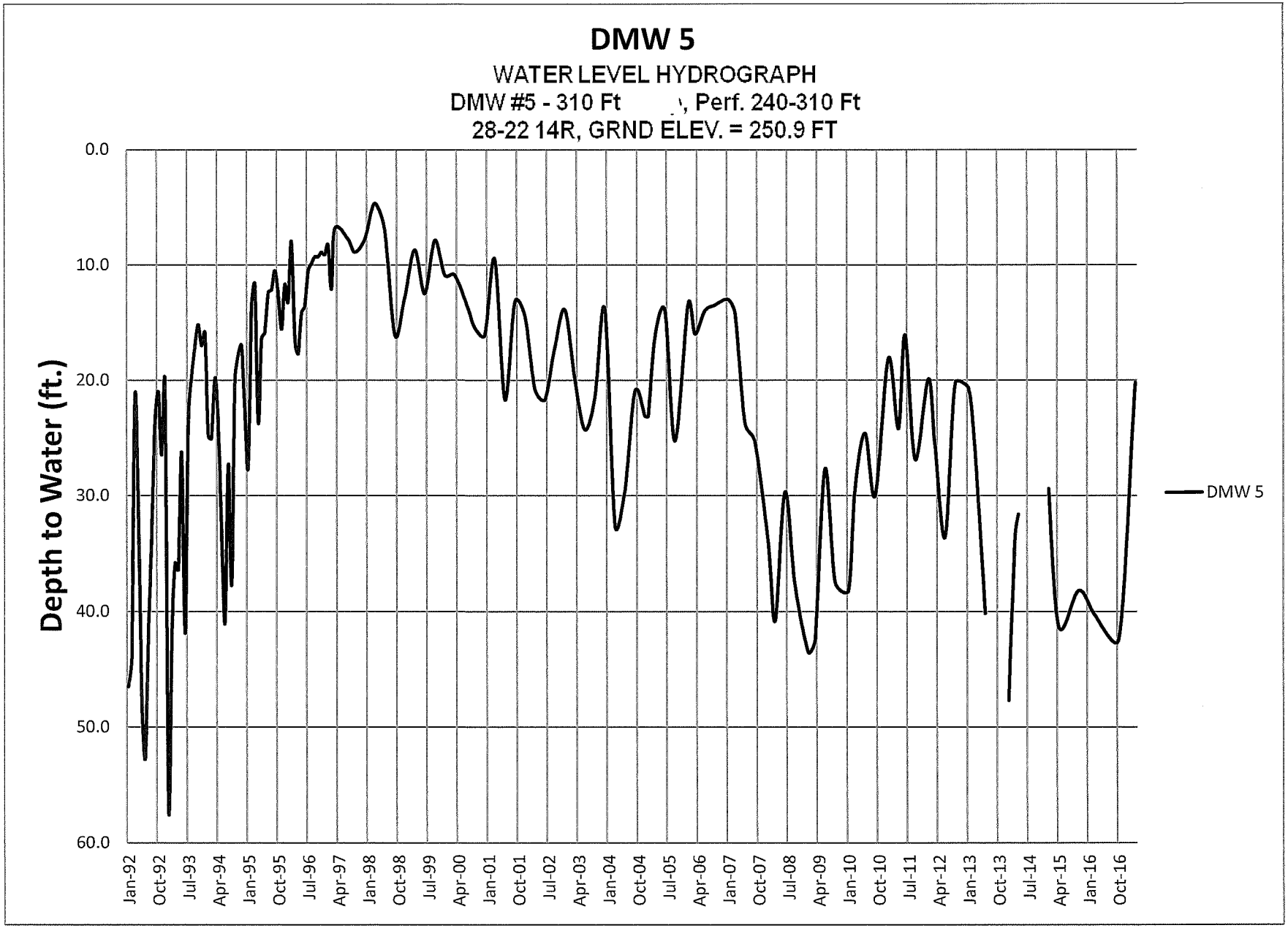

DMW 2
WATER LEVEL HYDROGRAPH
DMW #2 - 300 Ft D , Perf. 260-300 Ft
27-22 23D, GRND ELEV. = 234.5 FT
Depth to Water (ft.)
0
20
40
60
80
100
120
Mar-92
Dec-92
Sep-93
Jun-94
Mar-95
Dec-95
Sep-96
Jun-97
Mar-98
Dec-98
Sep-99
Jun-00
Mar-01
Dec-01
Sep-02
Jun-03
Mar-04
Dec-04
Sep-05
Jun-06
Mar-07
Dec-07
Sep-08
Jun-09
Mar-10
Dec-10
Sep-11
Jun-12
Mar-13
Dec-13
Sep-14
Jun-15
Mar-16
Dec-16
DMW 2

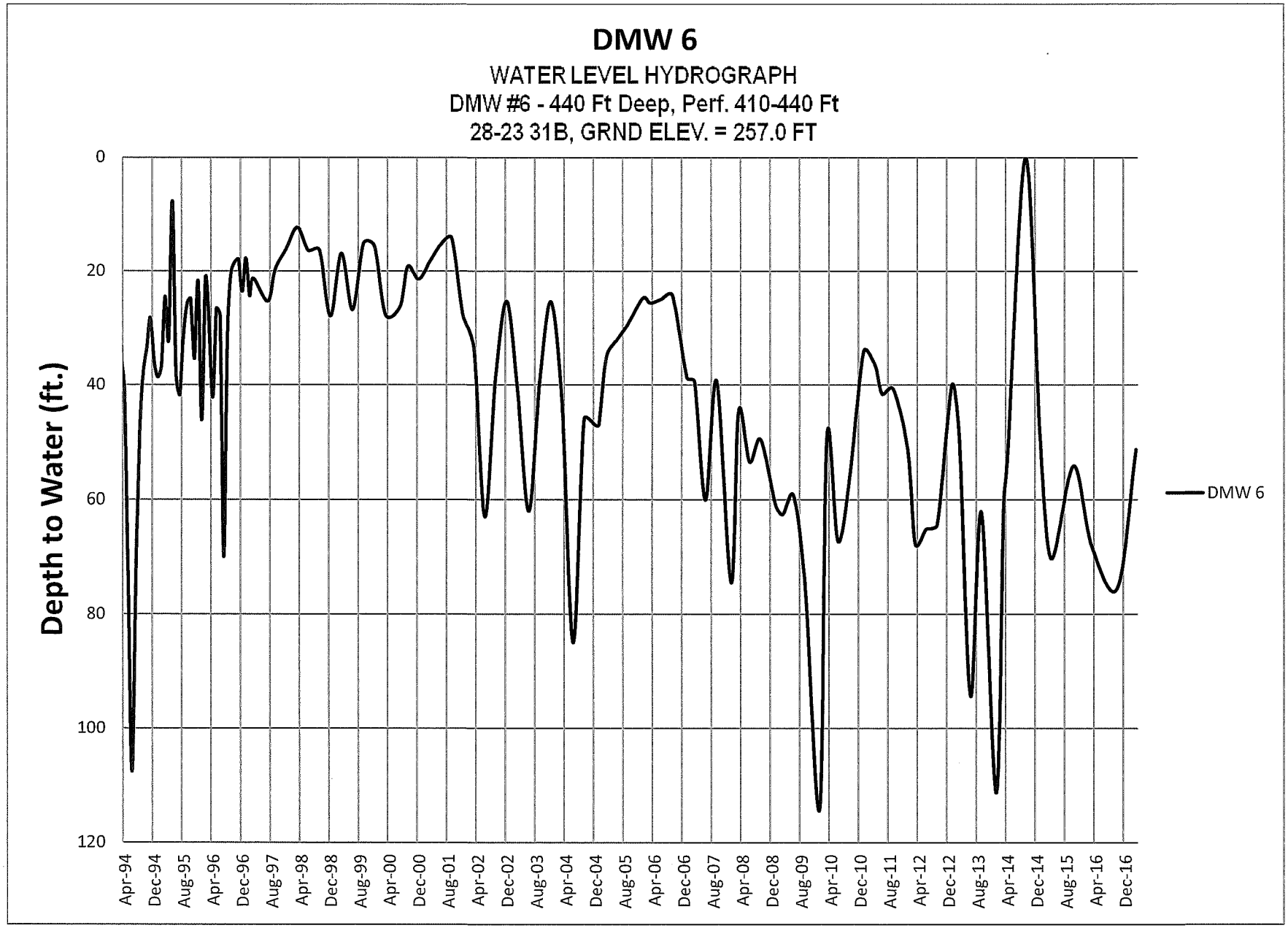

DMW 3
WATER LEVEL HYDROGRAPH
DMW #3 - 220 Ft I), Perf. 200-220 Ft
27-22 33A, GRND ELEV. = 240.5 FT
Depth to Water (ft.)
0
10
20
30
40
50
60
70
Mar-92
Nov-92
Jul-93
Mar-94
Nov-94
Jul-95
Mar-96
Nov-96
Jul-97
Mar-98
Nov-98
Jul-99
Mar-00
Nov-00
Jul-01
Mar-02
Nov-02
Jul-03
Mar-04
Nov-04
Jul-05
Mar-06
Nov-06
Jul-07
Mar-08
Nov-08
Jul-09
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Jul-15
Mar-16
Nov-16
DMW 3

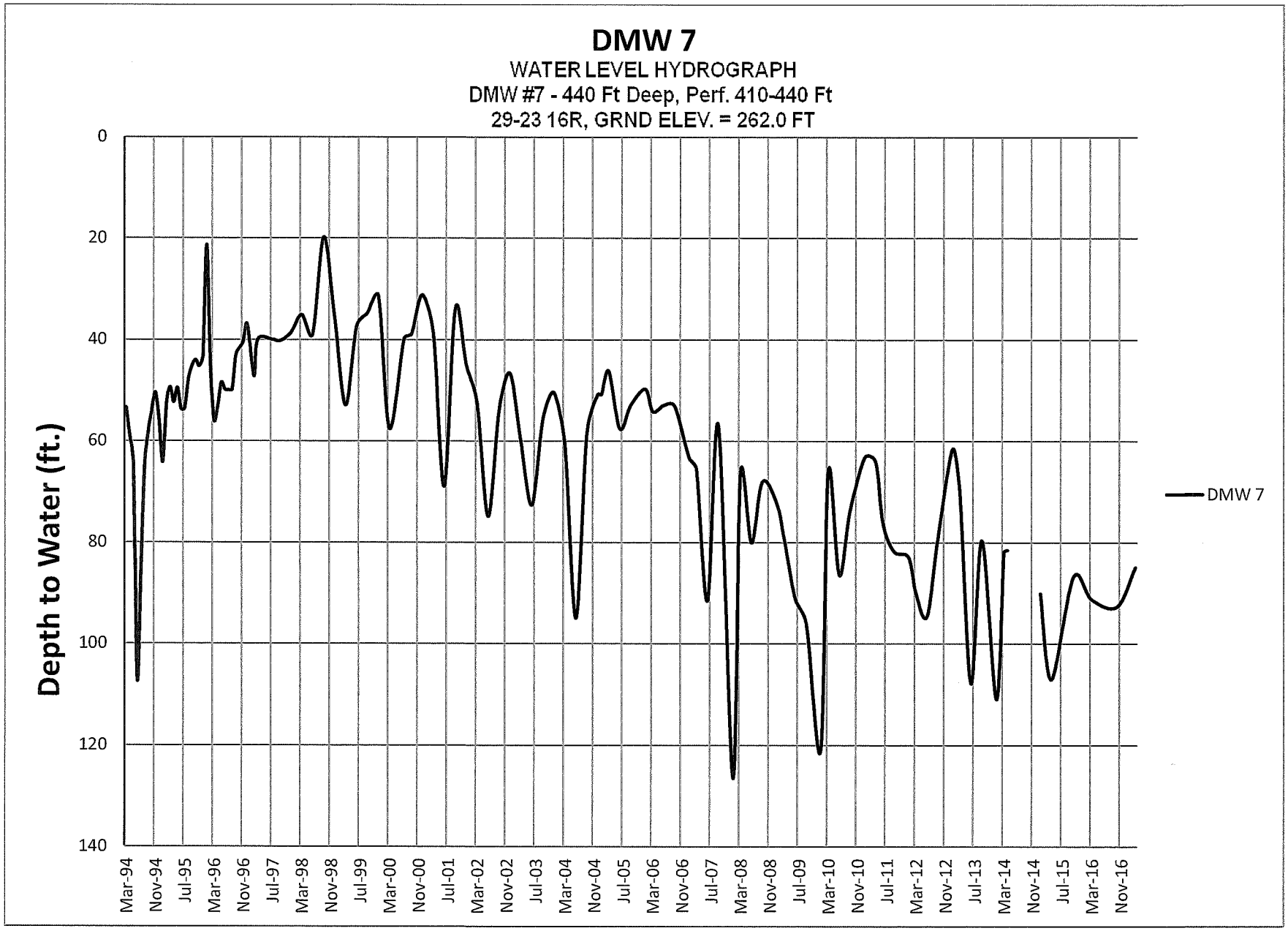
DMW 4

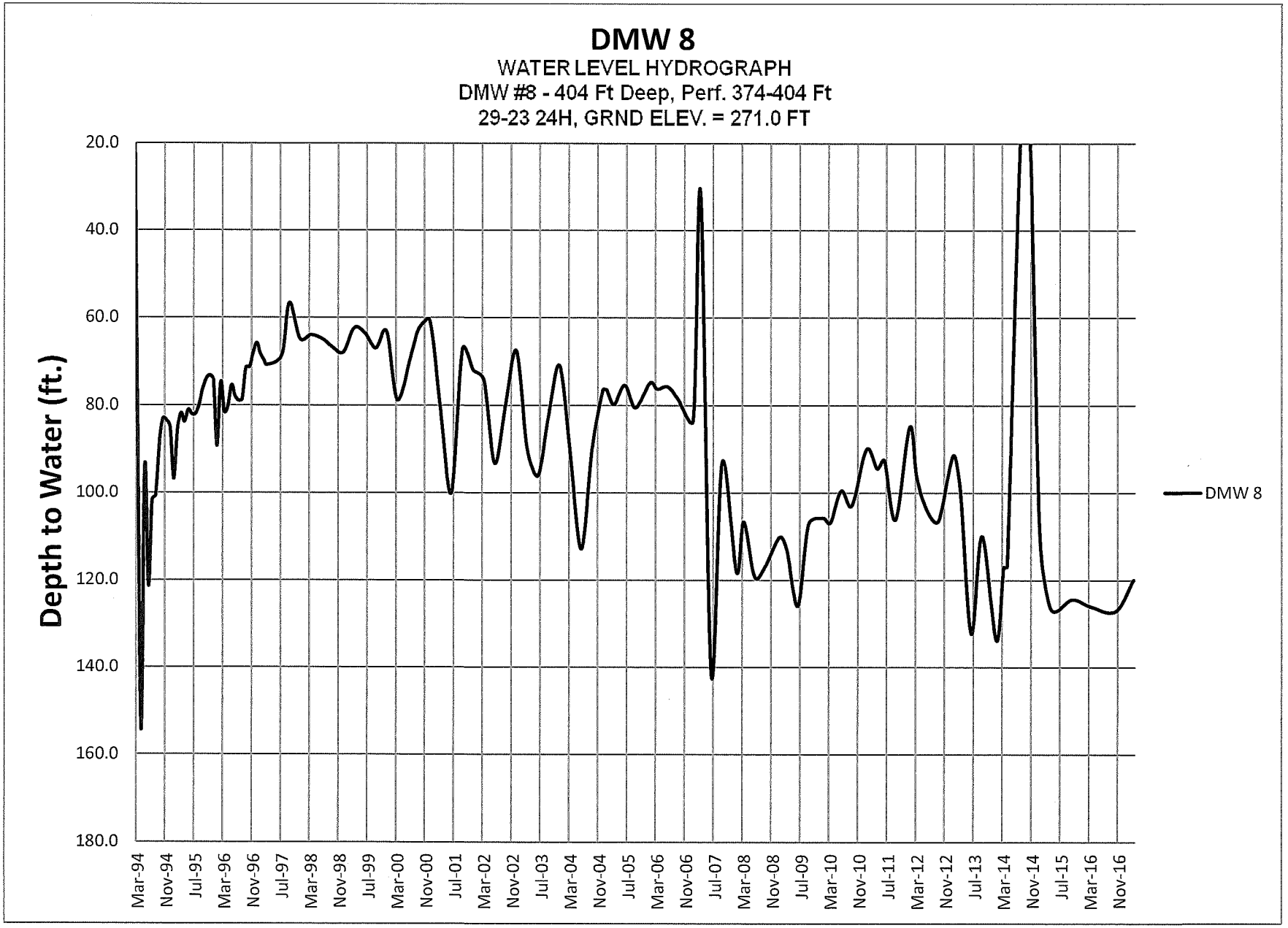
WATER LEVEL HYDROGRAPH
DMW #4 - 374 Ft Deep, Perf. 334-374 Ft
28-22 10D, GRND ELEV. = 242.8 FT



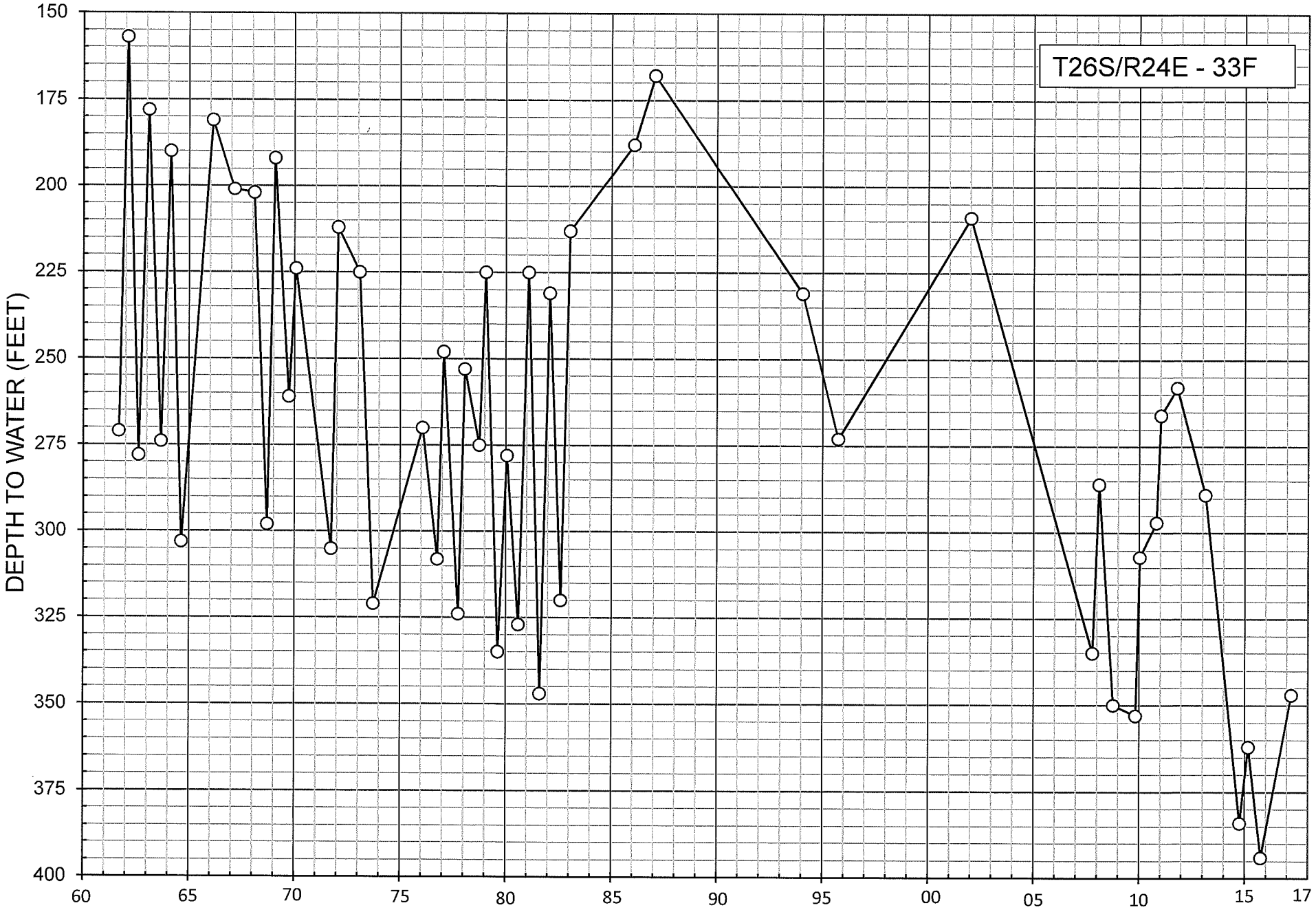

DMW 5
WATER LEVEL HYDROGRAPH
DMW #5 - 310 Ft , Perf. 240-310 Ft
28-22 14R, GRND ELEV. = 250.9 FT
Depth to Water (ft.)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Jan-92
Oct-92
Jul-93
Apr-94
Jan-95
Oct-95
Jul-96
Apr-97
Jan-98
Oct-98
Jul-99
Apr-00
Jan-01
Oct-01
Jul-02
Apr-03
Jan-04
Oct-04
Jul-05
Apr-06
Jan-07
Oct-07
Jul-08
Apr-09
Jan-10
Oct-10
Jul-11
Apr-12
Jan-13
Oct-13
Jul-14
Apr-15
Jan-16
Oct-16
DMW 5


DMW 6
WATER LEVEL HYDROGRAPH
DMW #6 - 440 Ft Deep, Perf. 410-440 Ft
28-23 31B, GRND ELEV. = 257.0 FT
Depth to Water (ft.)
0
20
40
60
80
100
120
Apr-94
Dec-94
Aug-95
Apr-96
Dec-96
Aug-97
Apr-98
Dec-98
Aug-99
Apr-00
Dec-00
Aug-01
Apr-02
Dec-02
Aug-03
Apr-04
Dec-04
Aug-05
Apr-06
Dec-06
Aug-07
Apr-08
Dec-08
Aug-09
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Apr-12
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Apr-14
Dec-14
Aug-15
Apr-16
Dec-16
DMW 6

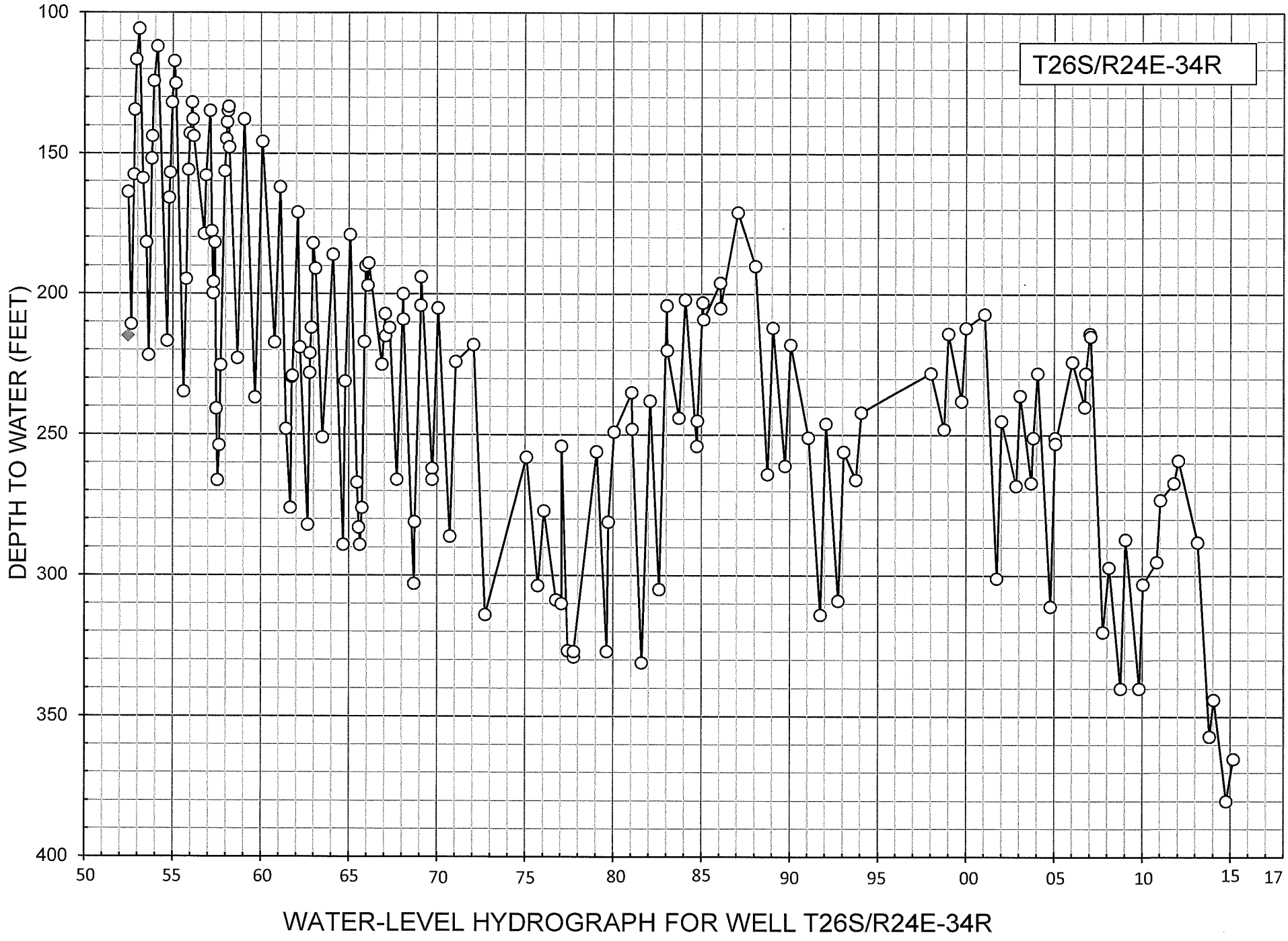

DMW 7
WATER LEVEL HYDROGRAPH
DMW #7 - 440 Ft Deep, Perf. 410-440 Ft
29-23 16R, GRND ELEV. = 262.0 FT
Depth to Water (ft.)
0
20
40
60
80
100
120
140
Mar-94
Nov-94
Jul-95
Mar-96
Nov-96
Jul-97
Mar-98
Nov-98
Jul-99
Mar-00
Nov-00
Jul-01
Mar-02
Nov-02
Jul-03
Mar-04
Nov-04
Jul-05
Mar-06
Nov-06
Jul-07
Mar-08
Nov-08
Jul-09
Mar-10
Nov-10
Jul-11
Mar-12
Nov-12
Jul-13
Mar-14
Nov-14
Jul-15
Mar-16
Nov-16
DMW 7


DMW 8
WATER LEVEL HYDROGRAPH
DMW #8 - 404 Ft Deep, Perf. 374-404 Ft
29-23 24H, GRND ELEV. = 271.0 FT
Depth to Water (ft.)
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
Mar-94
Nov-94
Jul-95
Mar-96
Nov-96
Jul-97
Mar-98
Nov-98
Jul-99
Mar-00
Nov-00
Jul-01
Mar-02
Nov-02
Jul-03
Mar-04
Nov-04
Jul-05
Mar-06
Nov-06
Jul-07
Mar-08
Nov-08
Jul-09
Mar-10
Nov-10
Jul-11
Mar-12
Nov-12
Jul-13
Mar-14
Nov-14
Jul-15
Mar-16
Nov-16
DMW 8

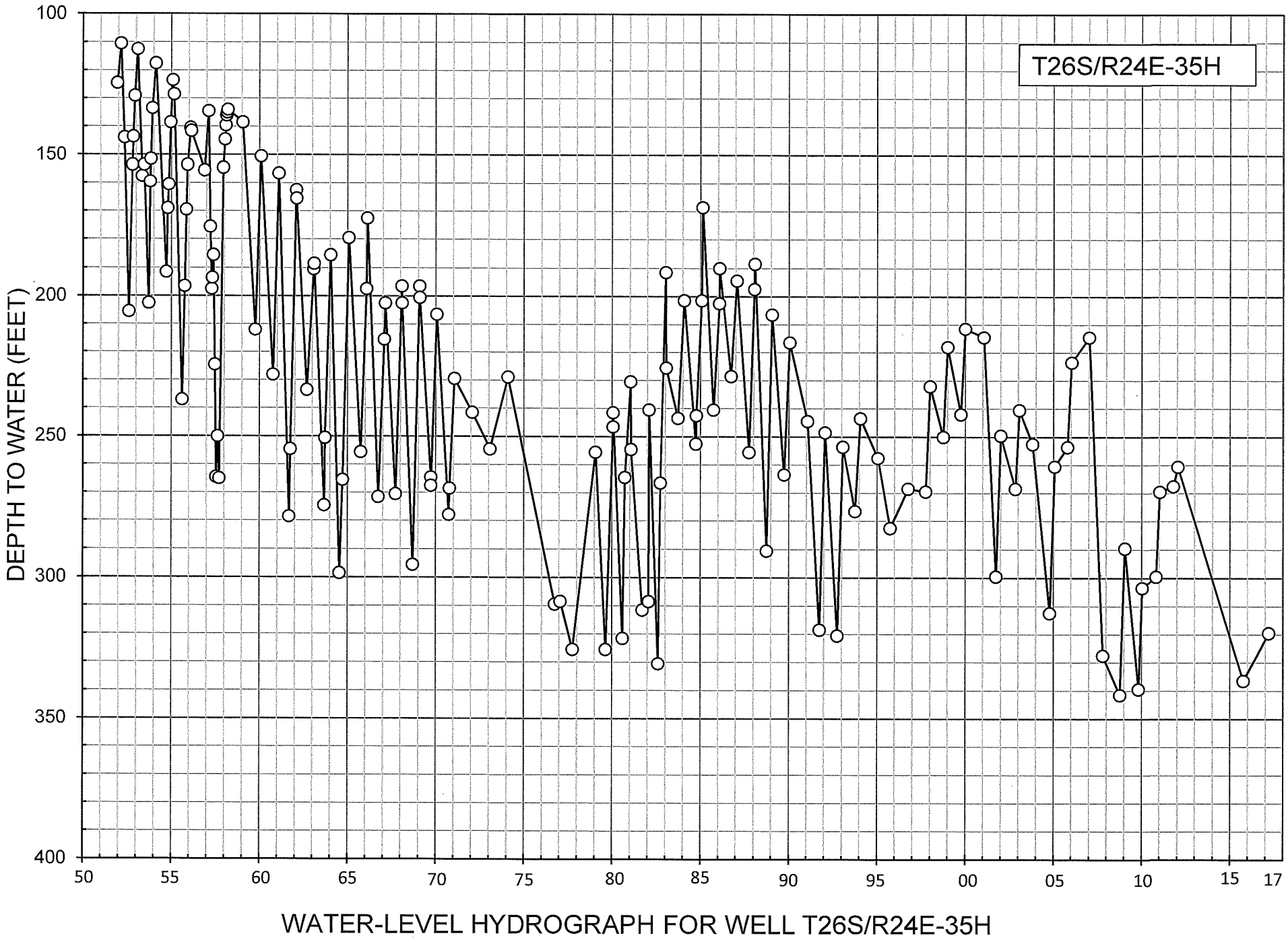
SHAFTER-WASCO IRRIGATION DISTRICT



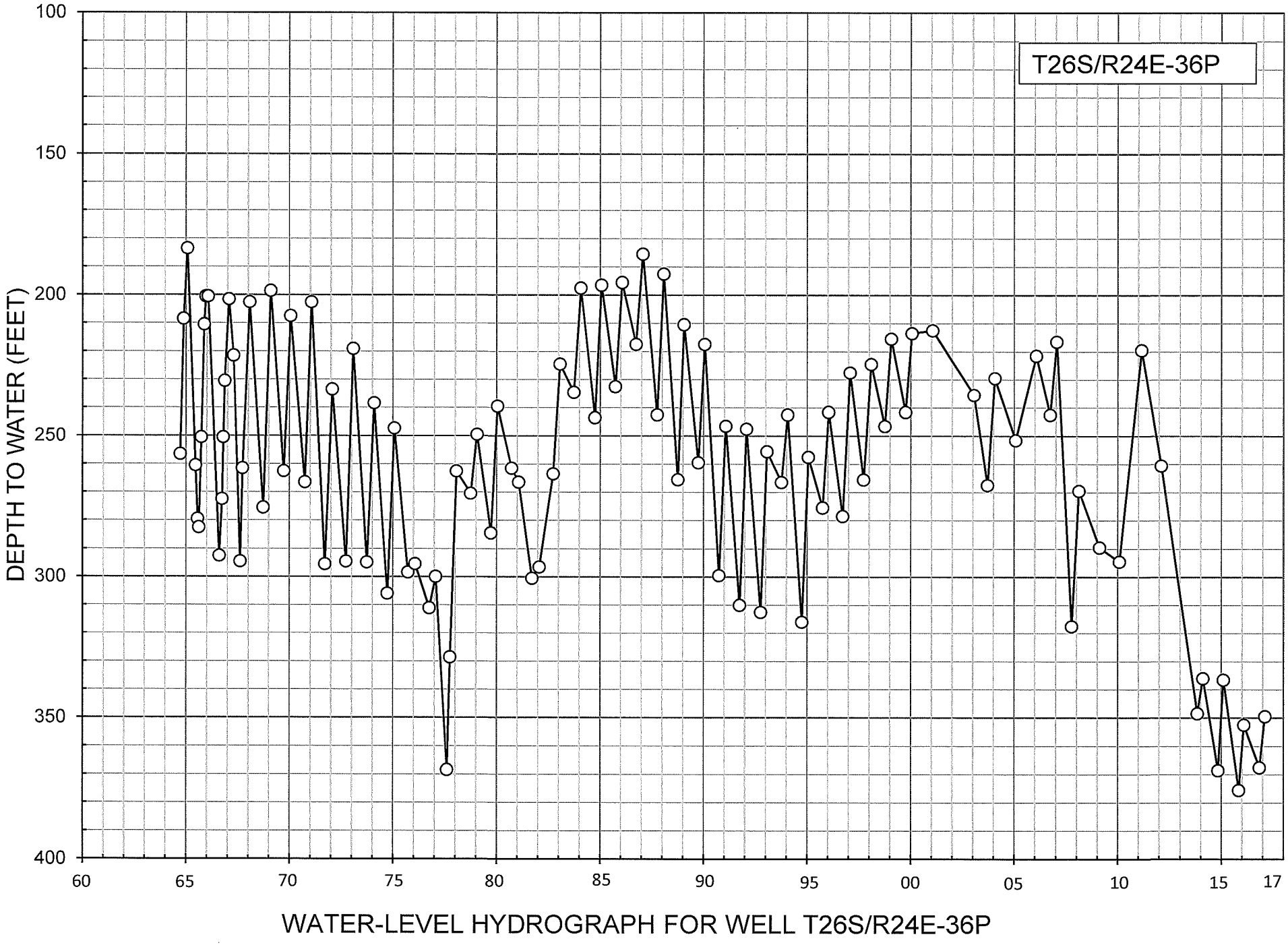
WATER-LEVEL HYDROGRAPH FOR WELL T26S/R24E-33F



WATER-LEVEL HYDROGRAPH FOR WELL T26S/R24E-34R



WATER-LEVEL HYDROGRAPH FOR WELL T26S/R24E-35H



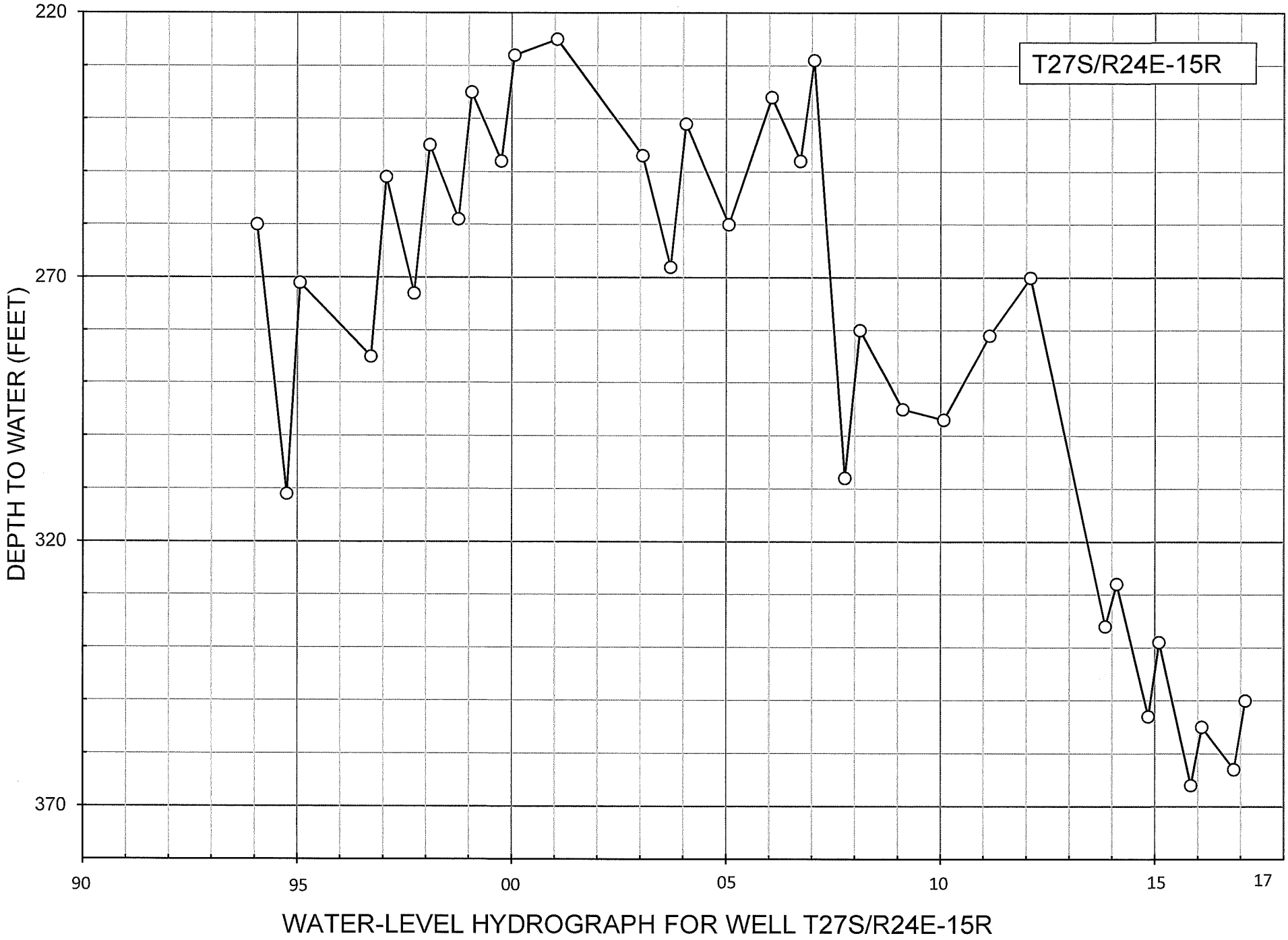
WATER-LEVEL HYDROGRAPH FOR WELL T26S/R24E-36P



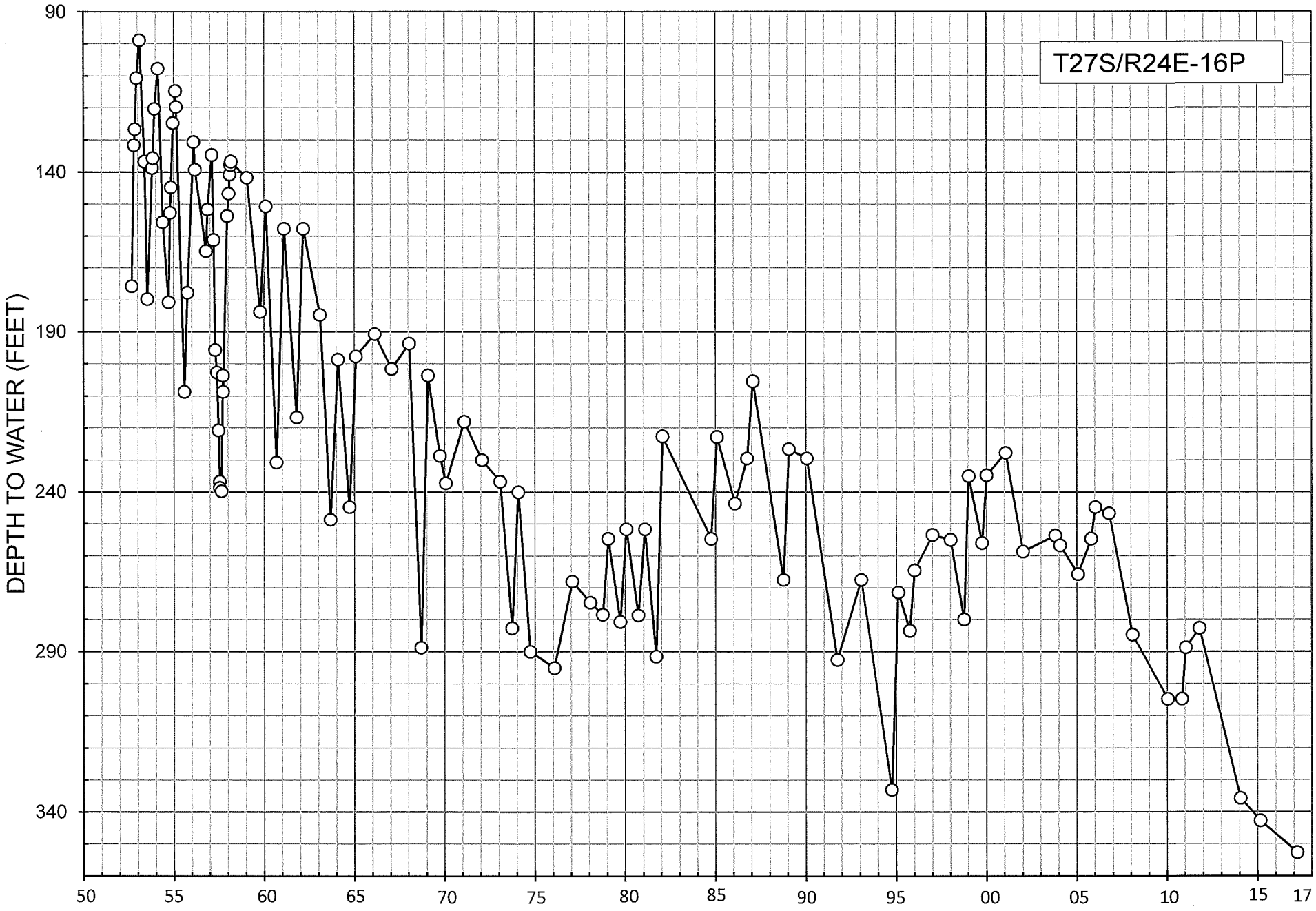
WATER-LEVEL HYDROGRAPH FOR WELL T27S/R24E-4P



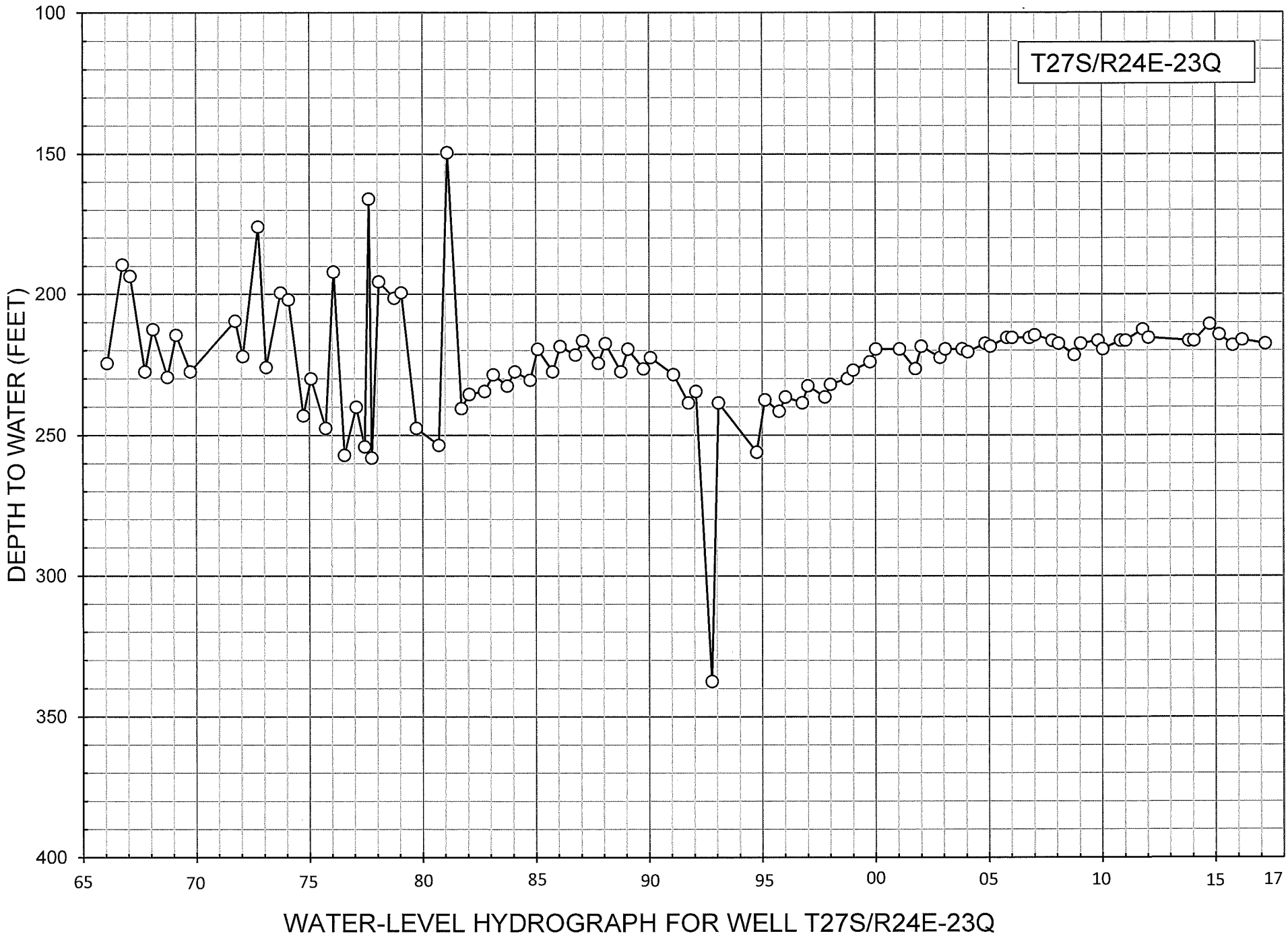
WATER-LEVEL HYDROGRAPH FOR WELL T27S/R4E-10G



WATER-LEVEL HYDROGRAPH FOR WELL T27S/R24E-15R



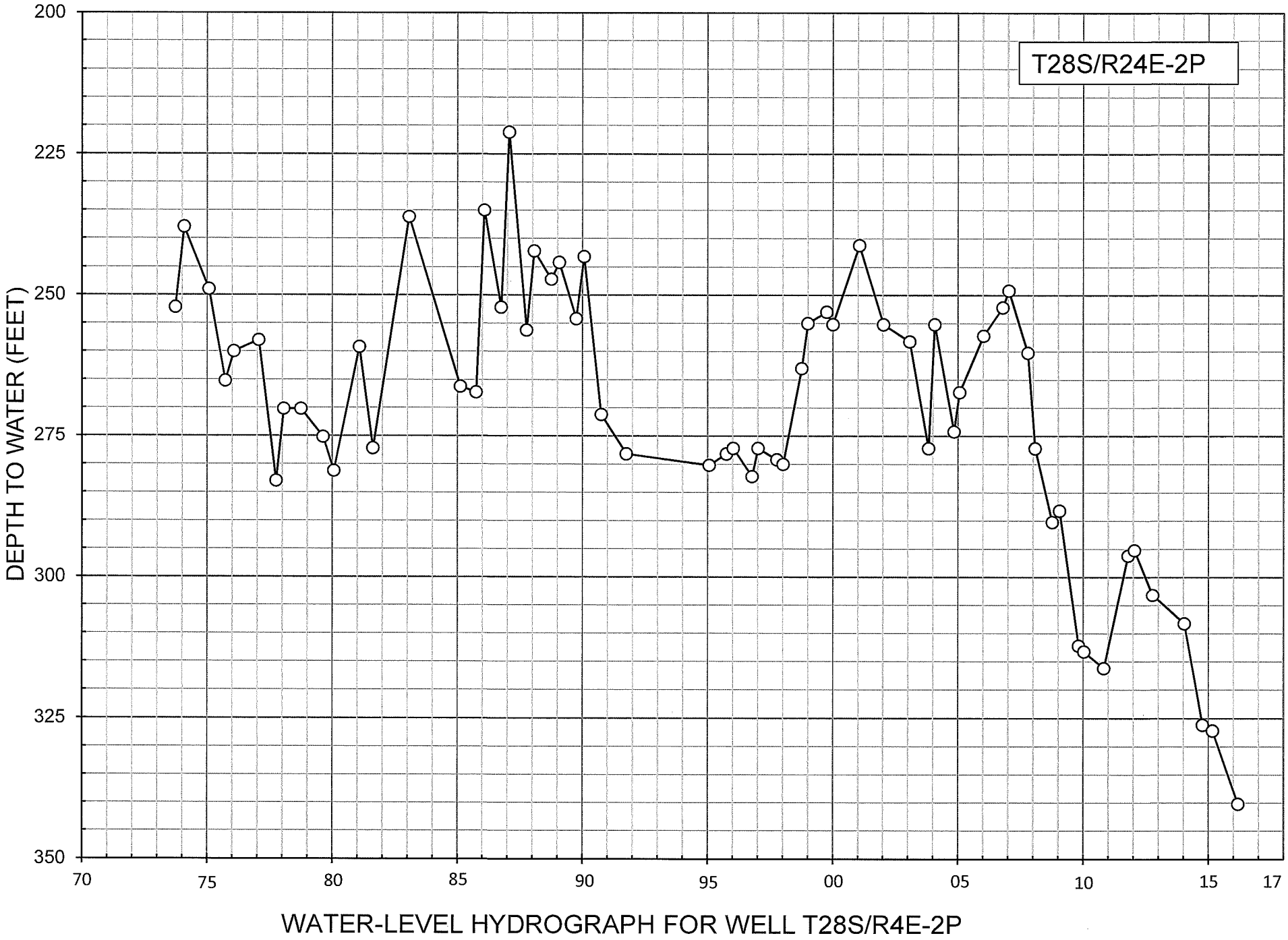
WATER-LEVEL HYDROGRAPH FOR WELL T27S/R24E-16P



WATER-LEVEL HYDROGRAPH FOR WELL T27S/R24E-23Q



WATER-LEVEL HYDROGRAPH FOR WELL T27S/R24E-34F



WATER-LEVEL HYDROGRAPH FOR WELL T28S/R4E-2P

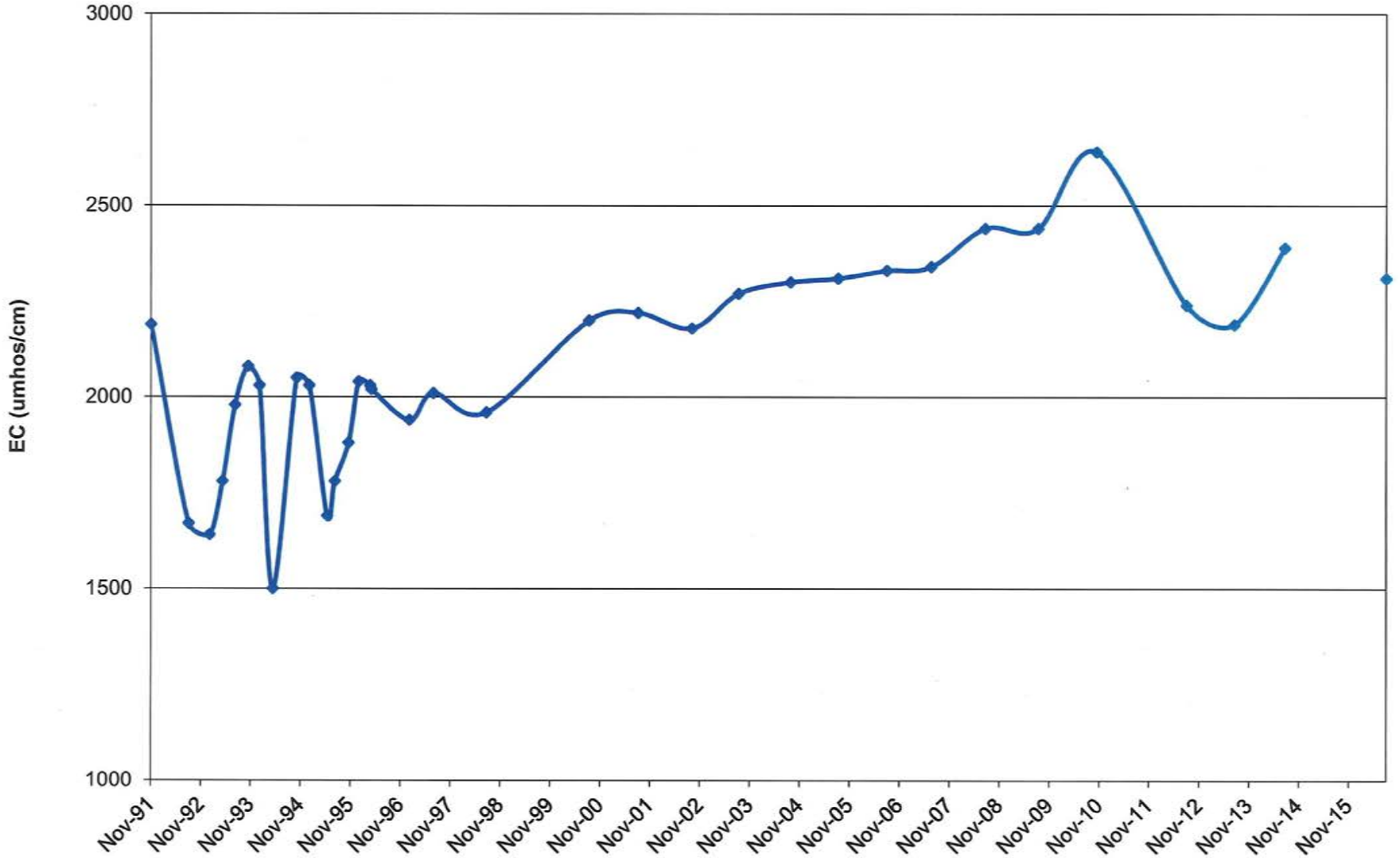
APPENDIX C

WATER QUALITY HYDROGRAPHS

BUENA VISTA WATER STORAGE DISTRICT

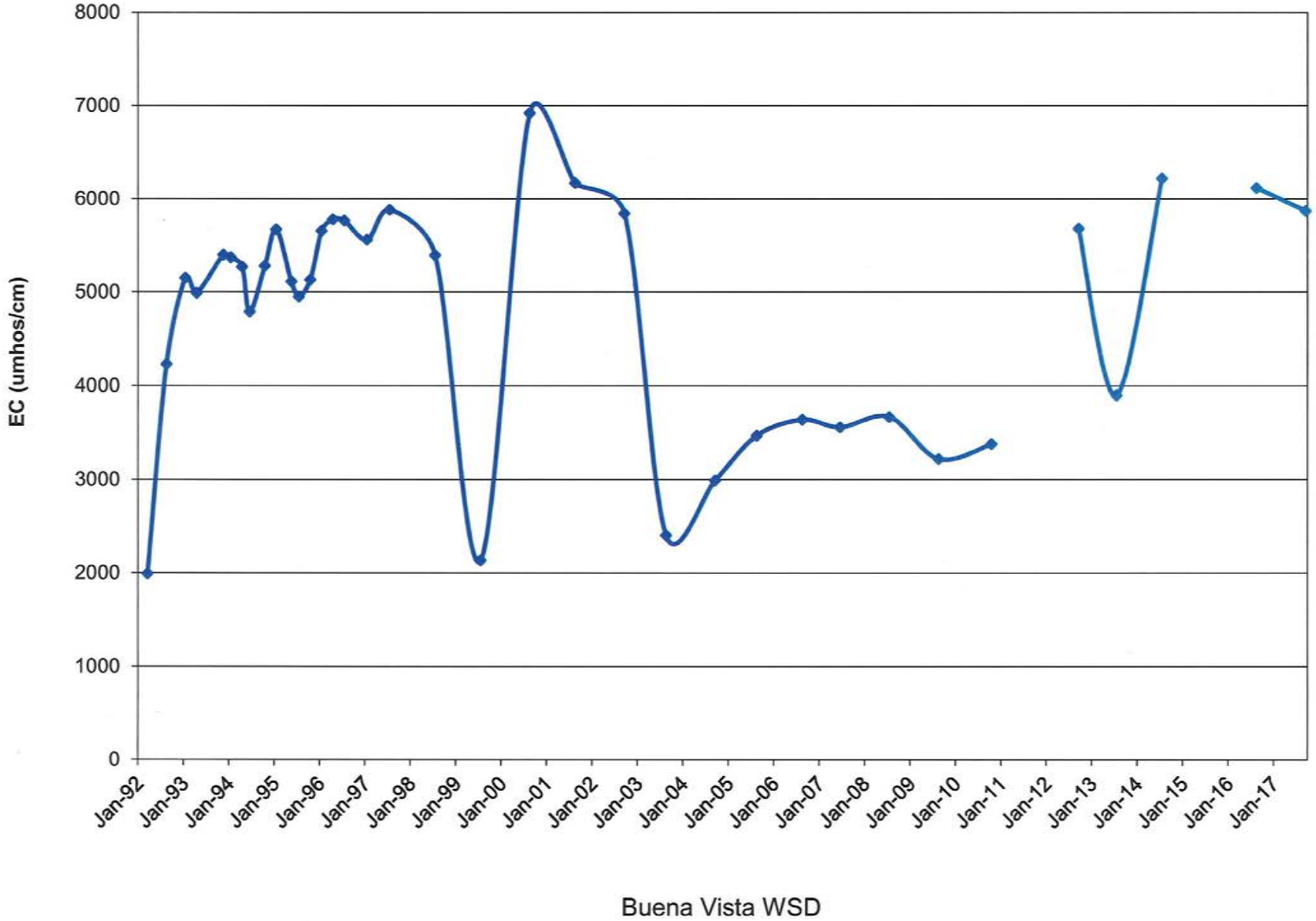

Monitor Wells
Well 1
Well 2
Well 3
Well 4
Well 5
Well 6
Well 7
Well 8
Wells 11A & 11B
Wells 10A & 10B
Wells 12A & 12B
Lerdo Hwy
7th Standard Rd
Lokern Rd
Lokern
McKittrick
Brandt Rd
Stockdale
N
Miles
2
BUENA VISTA WATER STORAGE DISTRICT
https://bvh2o.com/
Path: \\BVSVR-DC1\Company\GIS Maps\Maps Completed\BV Monitoring wells.mxd Time: 9:40:02 AM Date: 7/2/2012
© 2010 NAVTEQ © AND © 2012 Microsoft Corporation

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #1
Depth = 300 Ft, Perf. = 280-300 Ft
T27S R22E Sec. 8A



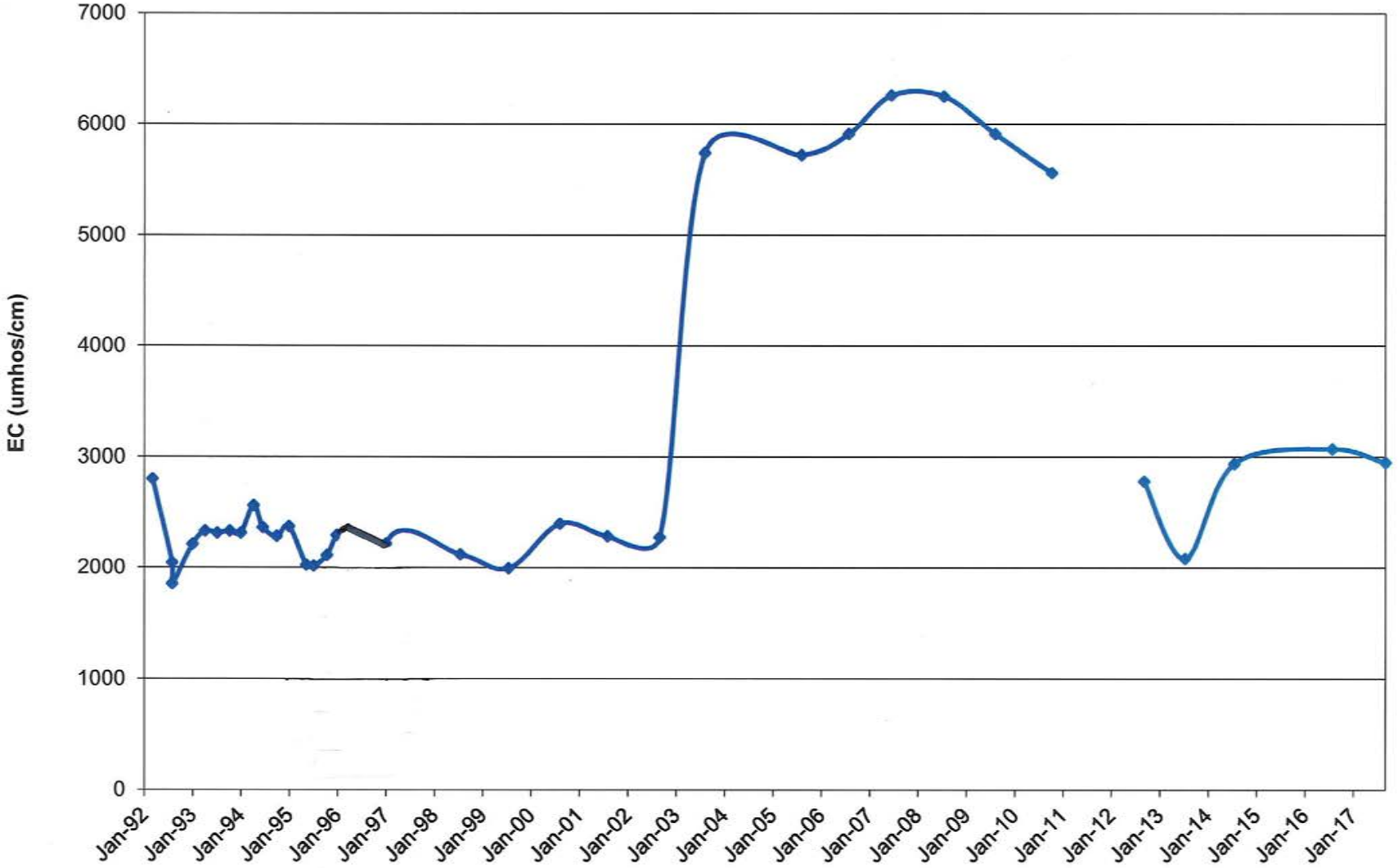
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #2
Depth = 300 Ft, Perf. = 260-300 Ft
T27S R22E Sec. 23D



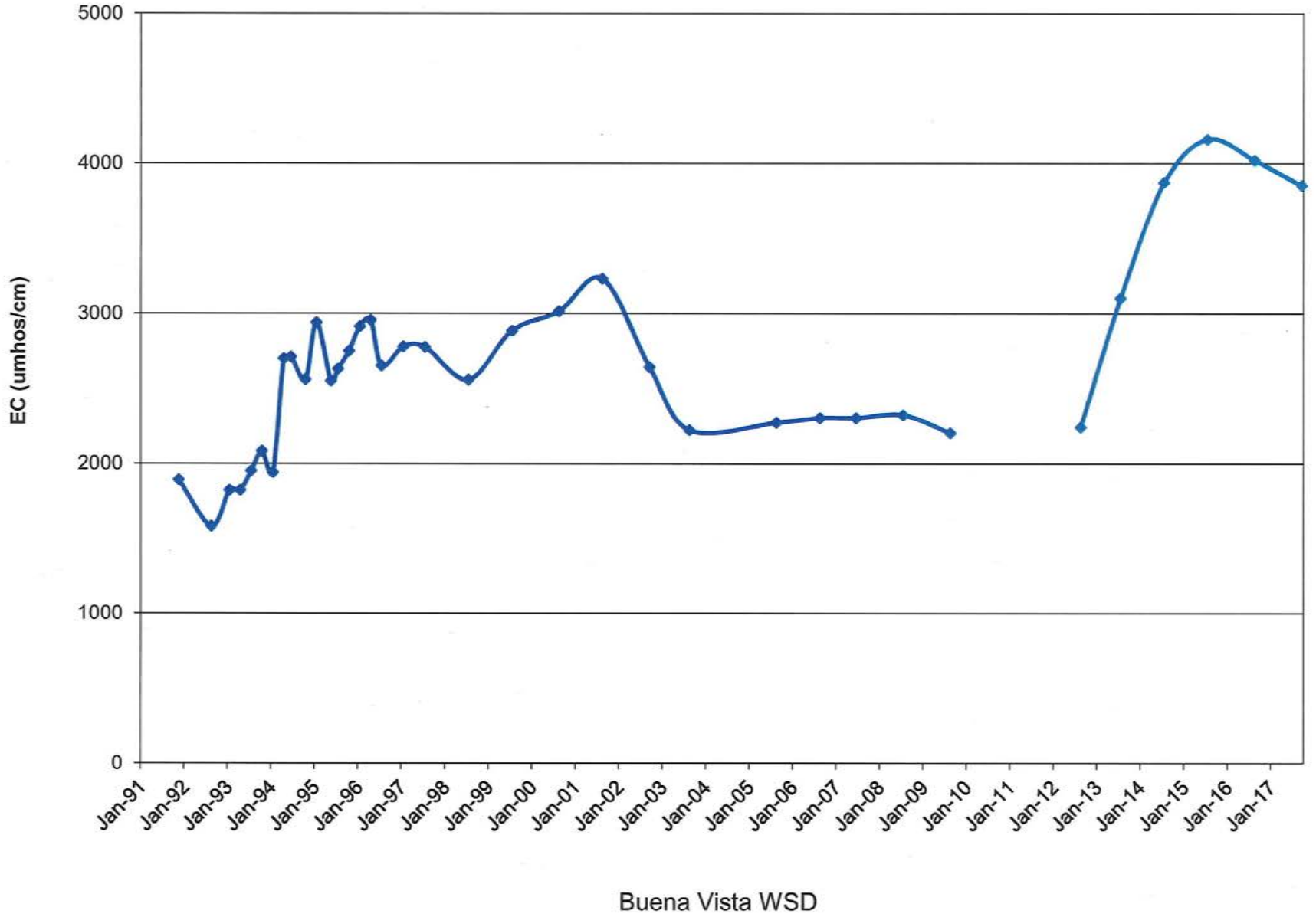
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #3
Depth = 220 Ft, Perf. = 200-220 Ft
T27S R22E Sec. 33A



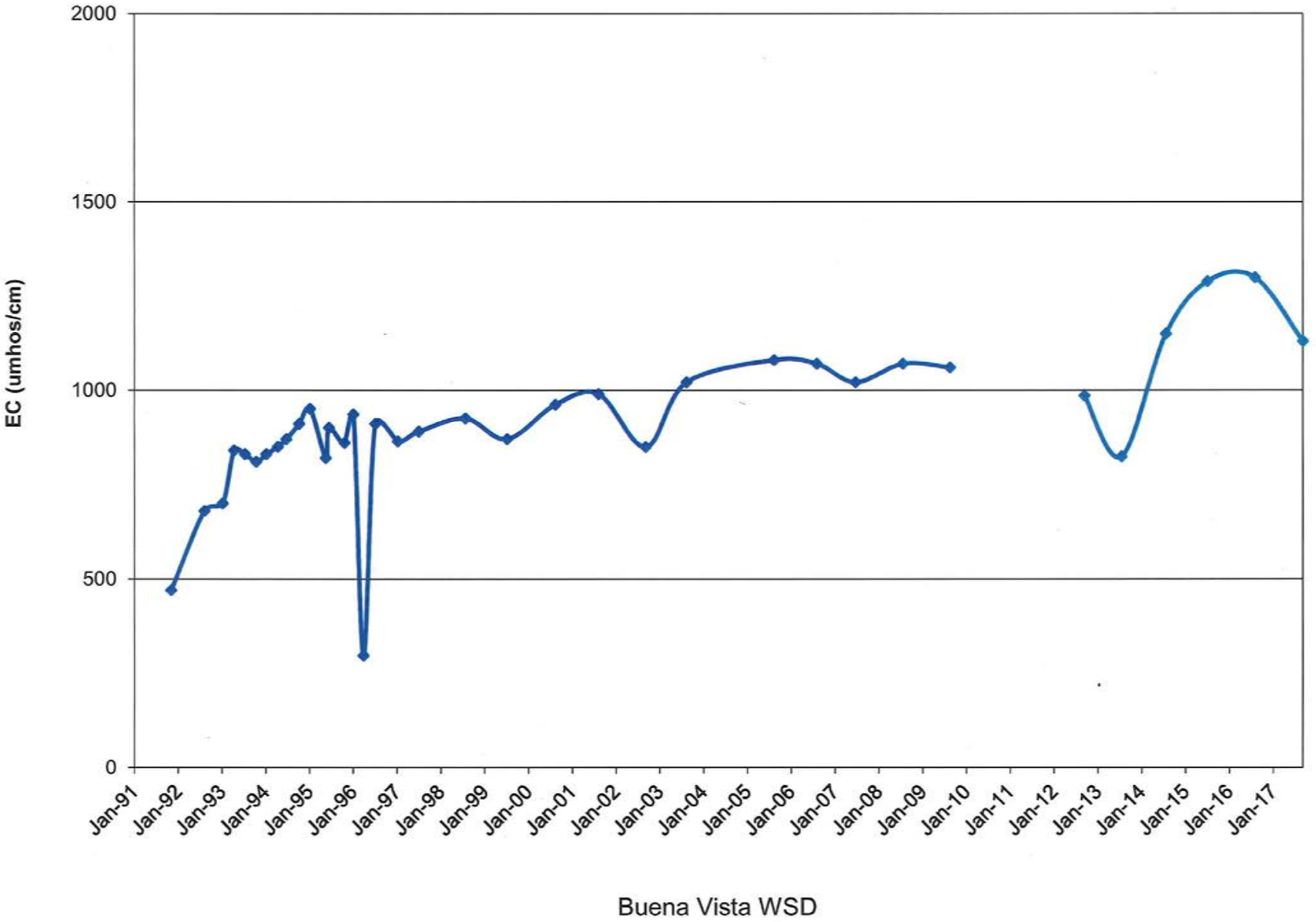
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #4
Depth = 374 Ft, Perf. = 334-374 Ft
T28S R22E Sec. 10D



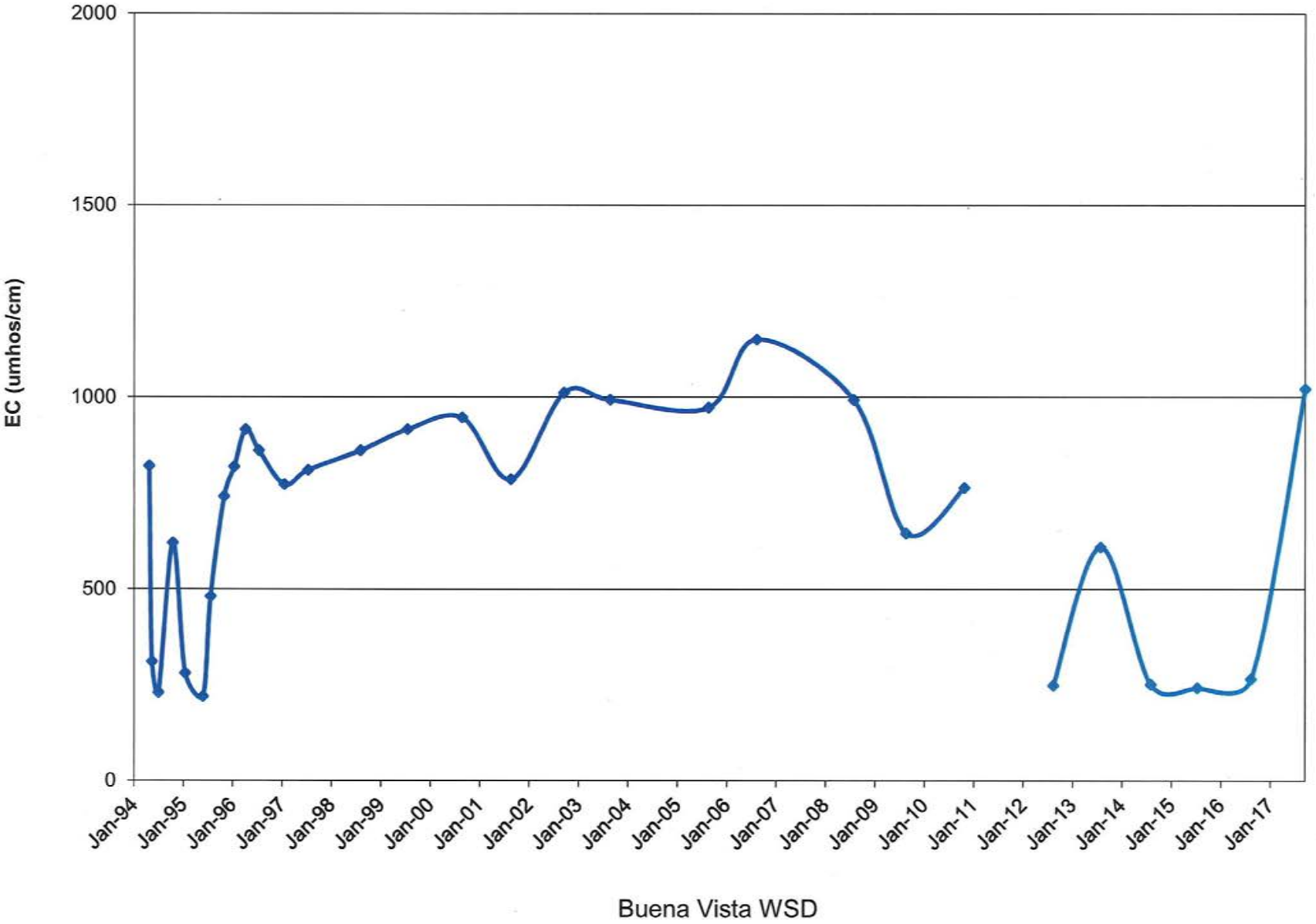
Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #5
Depth = 310 Ft, Perf. = 240-310 Ft
T28S R22E Sec. 14R

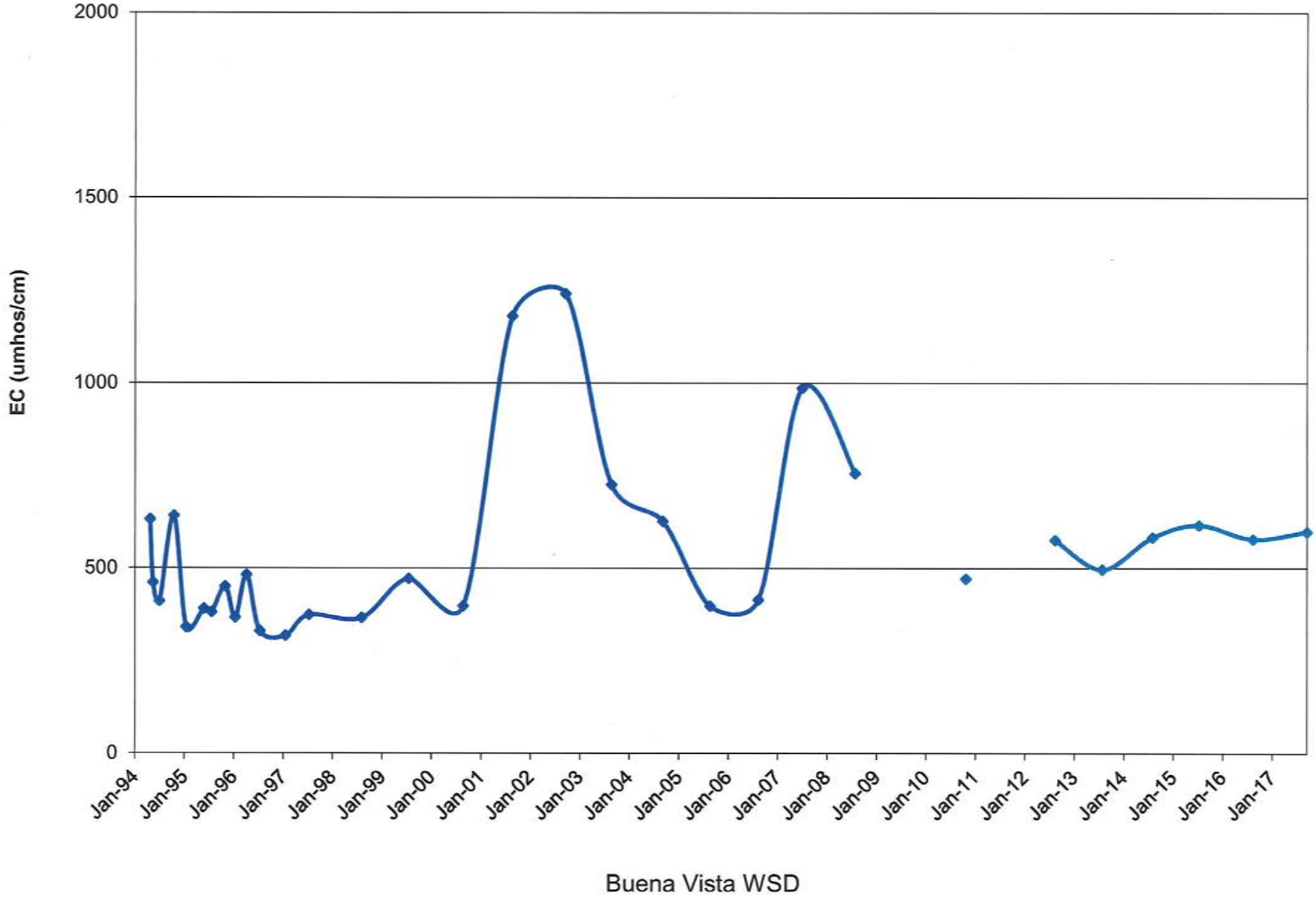


Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #6
Depth = 440 Ft, Perf. = 410-440 Ft
T28S R23E Sec. 31B

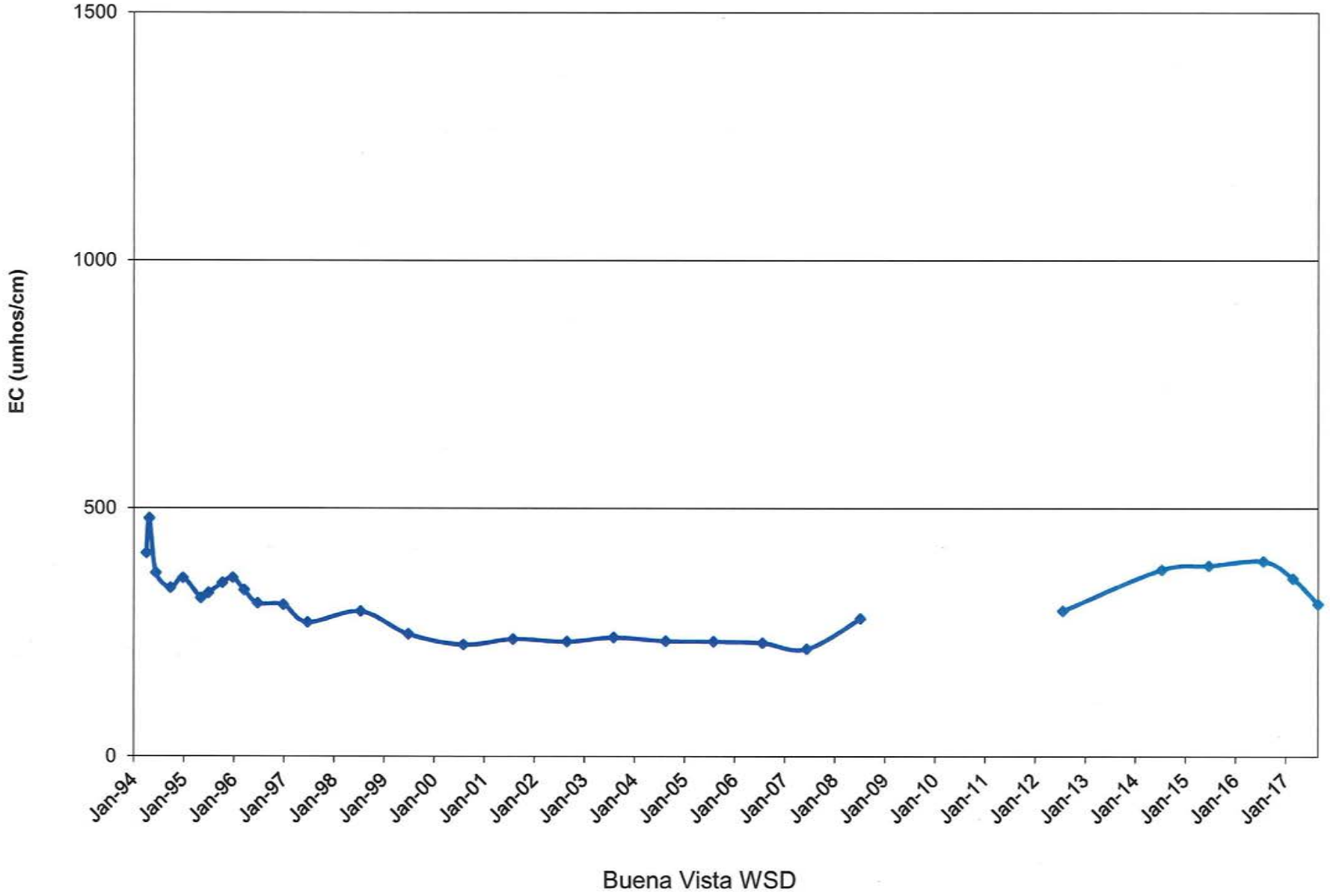


WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #7
Depth = 440 Ft, Perf. = 410-440 Ft
T29S R23E Sec. 16R



Buena Vista WSD

WATER QUALITY HYDROGRAPH
DEEP MONITOR WELL #8
Depth = 404 Ft, Perf. = 374-404 Ft
T29S R23E Sec. 24H



APPENDIX D

WATER-BUDGET INFORMATION

SEMITROPIC WATER STORAGE DISTRICT

Original Bank

Existing Contracts	Contract Storage Capacity (AF)	Firm Recovery Capacity (AF/Year)	Entitlement Exchange (AF/Year) Min - Max		Effective Date of Agreement/ Amendment
Metropolitan Water District of Southern California	350,000	31,500	0 - 46,550	35%	December 12, 1994 May 6, 2003
Santa Clara Valley Water District	350,000	31,500	0 - 46,550	35%	June 1, 1997 April 24, 2003
Alameda County Water District	150,000	13,500	0 - 19,950	15%	July 1, 1997 Sept 28, 2001 April 24, 2003
Zone 7 Water Agency	65,000	5,850	0 - 8,645	7%	January 28, 1998 February 26, 2003
Newhall Land and Farming Co.	55,000	4,950	0 - 7,315	6%	May 21, 2001 February 26, 2003
San Diego County Water Authority	30,000	2,700	0 - 3,990	3%	October 8, 1998 May 21, 2001 Sept. 28, 2001 February 26, 2003 July 1, 2005
Total Subscription	**1,000,000**	**90,000**		**100%**	
Program Capacity	**1,000,000**	**90,000**	**0 - 133,000**		

Stored Water Recovery Unit, Area A

Existing Contracts	Contract Storage Capacity (AF)	Firm Recovery Capacity (AF/Year)		Effective Date of Agreement/ Amendment
Zone 7 Water Agency	9,750	3,250	7%	January 12, 2005
Poso Creek Water Company, LLC	60,000	20,000	40%	April 23, 2007
San Diego County Water Authority	4,500	1,500	3%	July 1, 2008
City of Tracy	10,500	3,500	7%	November 16, 2010
Homer, LLC	15,000	5,000	10%	October 1, 2012
Harris Farms, Inc	10,500	3,500	7%	November 15, 2013
Shows Family Farms, LP	300	100	0%	Sept. 10, 2014
Mid Valley Ranch, LLC / Lazy Dog Orchard	3,600	1,200	2%	April 30, 2015
Castaic Lake Water Agency	15,000	5,000	10%	May 13, 2015
Metropolitan Water District (Increased Recovery)		8,200	16%	Interim Recovery Agreement, December 18, 2014
Total Subscription	**129,150**	**51,250**	**103%**	
Program Capacity	**150,000**	**50,000**		
Remaning Capacity	**20,850**	**(1,250)**		

Stored Water Recovery Unit, Area B

Existing Contracts	Contract Storage Capacity (AF)	Firm Recovery Capacity (AF/Year)	Effective Date of Agreement/ Amendment
San Diego County Water Authority	15,000	5,000	August 20, 2008
Total Subscription	**15,000**	**5,000**	
Program Capacity	**450,000**	**150,000**	
Remaning Capacity	**435,000**	**145,000**	

SUMMARY OF INFLOWS, GROUNDWATER PUMPING, DELIVERIES, AND OUTFLOWS

(values in acre-feet unless noted otherwise)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
(+) Diverted from CA Aqueduct	99,892	18,670	19,967	202,455	337,139	200,366	46,285	5,748	9,658	113,807
Semitropic No. 1 (Parshall Flume)	33,347	12,403	19,716	67,071	157,174	87,612	34,437	4,884	2,775	59,270
Semitropic No. 2 (Penstock)	66,225	6,267	0	65,826	51,604	53,453	10,746	0	42	3,561
Semitropic No. 3	320	0	251	69,558	128,361	59,301	1,102	864	6,841	50,976
(+) Diverted from Main Drain	5,353	1,469	731	3,539	9,061	3,942	202	0	43	441
(+) Inflow from P-565 Connection with North Kern	0	4,303	2,975	0	526	0	0	314	0	0
(+) Inflow from Diltz Intertie with Shafter-Wasco	0	2,162	3,061	0	539	601	0	1,443	1,147	4,671
(+) Poso Creek (Sec. 215 water)	0	0	0	0	5,785	0	0	0	0	0
(=) Subtotal Inflow to District	**105,245**	**26,604**	**26,733**	**205,994**	**353,050**	**204,909**	**46,487**	**7,505**	**10,848**	**118,919**
(+) District Wells	46,467	56,240	66,532	10,614	0	16	44,141	82,221	89,749	46,669
(+) Pumping Agreement Wells	71,332	82,233	65,136	0	0	0	60,911	57,860	74,381	2,705
(+) Shared Wells	0	0	0	0	0	0	10,620	4,483	11,493	12,881
(=) Subtotal Groundwater Supplies (In-District)	**117,799**	**138,473**	**131,668**	**10,614**	**0**	**16**	**115,672**	**144,564**	**175,623**	**62,255**
Total Water Supplies	**223,044**	**165,077**	**158,401**	**216,608**	**353,050**	**204,925**	**162,159**	**152,069**	**186,471**	**181,174**
(+) Contract	78,334	65,831	57,984	80,849	109,268	89,706	53,778	20,387	27,204	81,670
(+) Non-Contract	64,268	786	2,427	103,376	205,451	94,147	10,620	4,483	11,493	50,523
(+) SAW	310	5,087	5,418	400	0	4,594	7,870	9,874	10,042	6,199
(+) Emergency (& Trans)	2,746	822	1,650	963	1,251	3,577	2,915	2,924	3,432	2,208
(=) Deliveries to Farm Turnouts	**145,658**	**72,526**	**67,479**	**185,587**	**315,970**	**192,024**	**75,183**	**37,667**	**52,172**	**140,599**
(+) Deliveries to Spreading (PPSG)	712	92	2	12,853	18,953	212	0	0	22	0
(+) Deliveries to Duck Clubs	150	0	0	952	1,394	119	0	0	0	0
(+) Deliveries to KNWR ("Refuge")	0	26	23	20	493	0	0	1,697	666	0
(=) Subtotal Deliveries inside Semitropic	**146,519**	**72,644**	**67,504**	**199,413**	**336,811**	**192,355**	**75,183**	**39,364**	**52,860**	**140,599**
(+) CA Aqueduct Pump-In	55,492	84,062	78,067	116	0	0	64,651	91,302	109,580	14,516
Semitropic No. 2 (Penstock)	31,546	41,094	36,103	0	0	0	32,140	46,308	37,985	1,257
Semitropic No. 3	23,946	42,968	41,964	116	0	0	32,511	44,994	71,595	13,259
(+) Outflow via P-565 Connection with North Kern	0	0	0	0	0	0	0	0	0	0
(+) Outflow via Diltz Intertie with Shafter-Wasco	0	0	0	596	0	0	0	0	0	0
(+) Outflow via Belridge 1A	0	0	728	0	0	0	0	0	0	0
(=) Subtotal Outflow from District	**55,492**	**84,062**	**78,795**	**712**	**0**	**0**	**64,651**	**91,302**	**109,580**	**14,516**
Total Deliveries	**202,011**	**156,706**	**146,299**	**200,124**	**336,811**	**192,355**	**139,834**	**130,666**	**162,440**	**155,115**
Implied "Losses" (Supplies minus Deliveries)	**21,033**	**8,371**	**12,102**	**16,484**	**16,239**	**12,570**	**22,324**	**21,402**	**24,032**	**26,060**
	9%	5%	8%	8%	5%	6%	14%	14%	13%	14%

Source: Summary of flows into and out of SWSD from Dispatch program (Latis) and Deliveries from Semitropic's "Water Usage Recap Sheets".

ACRES OF IRRIGATED CROPS AND OTHER LAND USES
SEMITROPIC WATER STORAGE DISTRICT
(values in acres)

CROP	2015	2016
Alfalfa	18,378	16,337
Cotton	2,970	2,736
Duck Pond	10,332	10,737
Fruits	1,147	1,194
Grain/Pasture	17,826	17,185
Grapes	5,779	5,701
Nursery	468	418
Nut Crops	74,268	78,493
Vegetables	3,561	2,891
Unidentified Crop	1,267	2,117
Waste & Miscellaneous Land	11,934	11,788
Exempt lands	11,935	11,935
Undeveloped Native Vegetation	61,553	59,886
TOTALS	**221,420**	**221,420**

Source: District land use survey.

NORTH KERN WATER STORAGE DISTRICT

NORTH KERN WATER STORAGE DISTRICT

(values in acre-feet)

Calendar Year	Deliveries to Irrigation			District Well Production	Net Surface Supply	Deliveries to Spreading
	Class 1	Class 2	Total			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1995	76,904	47,969	124,873	0	367,136	202,581
1996	89,762	51,019	140,781	0	262,014	86,428
1997	78,857	56,800	135,657	0	272,997	106,187
1998	53,696	41,439	95,135	0	359,829	240,830
1999	75,250	34,873	110,123	0	171,869	30,645
2000	85,017	33,400	118,417	17,837	133,469	4,669
2001	84,346	22,164	106,510	60,582	75,408	0
2002	90,281	21,881	112,162	66,678	66,096	2,099
2003	83,433	24,432	107,865	20,647	110,236	897
2004	86,493	36,238	122,731	55,509	109,644	13,683
2005	84,018	54,735	138,753	0	288,879	104,884
2006	80,587	59,452	140,039	1,922	331,933	159,813
2007	83,103	50,850	133,953	99,760	87,325	30,151
2008	92,978	57,010	149,988	93,625	79,705	2,487
2009	91,711	55,948	147,659	100,029	85,962	13,083
2010	78,807	54,723	133,530	6,448	200,825	19,143
2011	75,723	61,809	137,532	0	387,207	203,179
2012	86,256	59,875	146,131	107,429	79,783	7,312
2013	84,521	47,712	132,233	140,551	229	1,029
2014	84,893	38,281	123,174	132,150	1,888	3,733
2015	76,258	38,497	114,755	110,596	8,789	5,087
2016	81,236	40,939	122,175	92,609	58,663	14,408
Avg (1995-2016)	**82,006**	**45,002**	**127,008**	**50,290**	**160,904**	**56,924**

Column Notes:

(2), (3), and (4) Includes surface water and District-pumped groundwater.

(5) Includes use of District wells to return previously banked water.

(6) Total surface supply less losses and deliveries outside District (deliveries outside District include pumped groundwater).

(7) Does not include incidental recharge from operation of the District's distribution system. Included in net surface supply.

North Kern Water Storage District

Annual Crop Surveys

(values in gross acres)

Crop Type	*2015*	*2016*
Alfalfa		642
Citrus		0
Corn		0
Cotton		281
Field Crops		0
Fruits		75
Grapes		6,000
Nursery		1,828
Nuts		40,114
Small Grains		363
Vegetables		1,149

Totals:	
All Crops	50,452
Perm. Crops	46,189

Note: No data for 2015.

NORTH KERN WATER STORAGE DISTRICT

Quantities in acre-feet

Year: 2015

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
NKWSD River Entitlement	+	0	55	0	0	0	0	0	0	0	0	0	1,298	1,353
Release	+ or -	1,977	935	800	0	0	20	0	0	0	0	4,236	~~3,373~~ 336	~~15,304~~ 15,341
ENTITLEMENT + OR - RELEASE	=	**1,977**	**990**	**800**	**0**	**0**	**20**	**0**	**0**	**0**	**0**	**4,236**	~~8,634~~	~~16,657~~ 16,694
From KRC & Irr. Company	+	0	0	0	0	0	0	0	0	0	0	0	3,671 35	35
From City of Bakersfield	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Isabella Reservoir Storage	+	177	107	153	0	0	1,801	1,472	157	0	0	197	149	4,213
From Improvement District No. 4	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Buena Vista WSD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Kern Delta WD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
To City of Bakersfield	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Improvement District #4	-	0	32	0	0	0	0	0	0	0	0	0	0	32
To Cawelo WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Kern Delta WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Into Isabella Reservoir Storage	-	510	208	154	0	0	0	0	0	0	0	805	2,428	4,105
Other	+ or -	0	0	0	38	0	0	0	0	123	0	0	~~32~~ 6	167
TOTAL DIVERTED FROM RIVER	=	**1,644**	**857**	**799**	**38**	**0**	**1,821**	**1,472**	**157**	**123**	**0**	**3,628**	~~6,397~~	~~16,936~~ 16,972
Loss to Seventh Standard Line	-	22	30	18	10	0	60	61	12	0	0	54	50	317
NKWSD Deep Well Production	+	1,636	4,706	11,478	12,405	15,503	15,227	12,934	11,665	11,804	11,772	922	544	110,596
Non-District Deep Well Production	+	0	26	337	6,073	6,016	6,770	7,563	5,827	2,632	226	8	0	35,478
Poso Creek Natural Flow	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Friant-Kern Inflow to Poso Creek	+	0	0	0	0	0	0	0	0	0	0	0	0	0
CRC Produced Water	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Cawelo to NKWSD	+	0	0	0	171	173	173	1,041	139	0	0	0	0	1,697
Semitropic WSD to NKWSD via FK/8-1	+	0	0	0	0	0	0	0	0	64	0	0	0	64
Rosedale Ranch Improvement District	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Semitropic WSD via Poso Creek	-	0	0	0	0	0	0	0	0	0	0	0	0	0
CVC Conduit "A" Inflow	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DISTRICT SUPPLY	=	**3,258**	**5,559**	**12,596**	**18,677**	**21,692**	**23,931**	**22,949**	**17,776**	**15,085**	**12,684**	**5,167**	~~7,317~~ 7,353	~~166,691~~ 166,727
Class 1 Irrigation Deliveries	+	173	1,600	5,407	8,493	11,286	11,865	12,143	9,437	7,944	6,198	1,531	181	76,258
Class 2 Irrigation Deliveries	+	107	952	3,195	4,449	5,599	6,724	5,304	4,290	3,717	3,174	944	42	38,497
NKWSD to K-T via FK Irrigation Deliveries	+	0	0	0	460	777	826	772	658	435	0	0	0	3,928
NKWSD to DEID via FK Irrigation Deliveries	+	1,209	130	0	0	0	0	0	0	428	192	0	0	1,959
Shafter-Wasco ID Irrigation Deliveries	+	18	436	186	145	191	295	294	564	304	200	208	208	3,049
OMW to K-Tulare	-	0	0	0	0	0	0	0	0	0	0	0	0	0
OMW to Cawelo	-	0	0	0	0	0	0	0	210	0	0	0	0	210
Westside Districts via FK-CVC	-	0	0	0	0	0	0	0	0	475	801	0	182	1,458
Cawelo to NKWSD to Paramount	-	0	0	0	0	0	0	1,035	139	0	0	0	0	1,174
NKWSD to Cawelo	-	345	345	205	0	0	0	0	0	0	0	0	0	895
Shafter-Wasco ID to NKWSD	+	0	0	0	46	45	42	0	38	64	6	4	4	249
Friant-Kern Canal Pump-In Deliveries	+	0	0	824	0	0	0	0	0	0	0	0	0	824
TOTAL IRRIGATION USE	=	**1,162**	**2,773**	**9,407**	**13,593**	**17,898**	**19,752**	~~18,513~~ 17,478	**14,638**	**12,417**	**8,969**	**2,687**	**253**	~~122,062~~ 121,027
District Spreading Ponds (Kern)	+	1,035	0	0	0	0	0	0	0	0	0	0	4,052	5,087
District Spreading Ponds (Other)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Poso Creek Spreading (Kern)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Poso Creek Spreading (Other)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DISTRICT SPREADING	=	**1,035**	**0**	**0**	**0**	**0**	**0**	~~0~~ 1,040	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL DISTRICT USE		**2,197**	**2,773**	**9,407**	**13,593**	**17,898**	**19,752**	~~18,513~~ 17,478	**14,638**	**12,417**	**8,969**	**2,687**	**4,305**	~~127,149~~ 126,114
Total NKWSD Canal Loss		1,061	2,786	3,189	5,084	3,794	4,179	~~4,436~~ 5,471	3,138	2,668	3,715	2,480	~~3,042~~ 3,048	~~39,542~~ 40,613
Into Reservoir Storage		510	208	154	0	0	0	0	0	0	0	805	2,428	4,105
Reservoir Evaporation Loss		111	126	184	230	292	343	236	53	0	0	75	104	1,754
From Reservoir Storage		177	107	153	0	0	1,801	1,472	157	0	0	197	149	4,213
END OF MONTH RESERVOIR STORAGE		**4,792**	**4,767**	**4,584**	**4,354**	**4,062**	**1,918**	**210**	**0**	**0**	**0**	**533**	**2,708**	

NORTH KERN WATER STORAGE DISTRICT

Quantities in acre-feet

Year: 2016

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
NKWSD River Entitlement	+	1,304	3,116	128	2,358	9,654	11,238	127	0	0	0	0	2,416	30,341
Release	+ or -	7,093	6,207	4,292	1,829	2,093	0	0	0	0	0	3,586	10,843	35,943
ENTITLEMENT + OR - RELEASE	=	**8,397**	**9,323**	**4,420**	**4,187**	**11,747**	**11,238**	**127**	**0**	**0**	**0**	**3,586**	**13,259**	**66,284**
From KRC & Irr. Company	+	0	0	0	0	376	373	0	0	0	0	0	69	818
From City of Bakersfield	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Isabella Reservoir Storage	+	846	0	585	411	210	383	5,514	4,300	1,364	0	246	396	14,255
From Improvement District No. 4	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Buena Vista WSD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
From Kern Delta WD	+	0	0	0	0	0	0	0	0	0	0	0	4	4
To City of Bakersfield	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Improvement District #4	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Cawelo WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
To Kern Delta WD	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Into Isabella Reservoir Storage	-	2,061	2,212	669	1,766	8,144	8,446	0	0	0	0	2,060	5,039	30,397
Other	+ or -	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DIVERTED FROM RIVER	=	**7,182**	**7,111**	**4,336**	**2,832**	**4,189**	**3,548**	**5,641**	**4,300**	**1,364**	**0**	**1,772**	**8,689**	**50,964**
Loss to Seventh Standard Line	-	61	58	50	59	61	60	61	61	32	0	38	47	588
NKWSD Deep Well Production	+	1,563	163	6,276	9,505	14,654	13,989	12,865	9,630	11,685	9,798	2,247	234	92,609
Non-District Deep Well Production	+	0	36	90	0	177	6,401	3,884	2,370	0	0	0	0	12,958
Poso Creek Natural Flow	+	0	0	0	256	0	0	0	0	0	0	0	0	256
Friant-Kern Inflow to Poso Creek	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Produced Water	+	468	222	768	952	978	926	946	1,113	708	597	10	6	7,694
Cawelo to NKWSD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
SWID to NKWSD via FK/8-1	+	0	0	0	1,686	0	0	1,000	0	0	0	423	0	3,109
Rosedale Ranch Improvement District	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Semitropic WSD via Poso Creek	-	0	0	0	0	0	0	0	0	0	0	0	0	0
CVC Conduit "A" Inflow	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DISTRICT SUPPLY	=	**9,152**	**7,474**	**11,420**	**15,172**	**19,937**	**24,804**	**24,275**	**17,352**	**13,725**	**10,395**	**4,414**	**8,882**	**167,002**
Class 1 Irrigation Deliveries	+	770	1,823	5,302	7,547	10,818	13,978	14,761	10,284	8,222	5,716	1,874	141	81,236
Class 2 Irrigation Deliveries	+	419	1,212	3,320	4,169	5,282	6,339	6,932	5,052	3,749	3,132	1,133	200	40,939
NKWSD to K-T via FK Irrigation Deliveries	+	0	0	0	0	0	0	0	0	0	0	0	0	0
NKWSD to DEID via FK Irrigation Deliveries	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Shafter-Wasco ID Irrigation Deliveries	+	33	178	208	8	19	40	77	27	26	54	270	14	954
NKWSD to Westside Districts via FK-CVC	+	1,622	196	0	0	0	0	0	0	0	0	0	0	1,818
OMW to K-Tulare	-	0	0	0	0	0	0	0	0	0	0	0	0	0
OMW to Cawelo	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Cawelo to NKWSD to Paramount	-	0	0	0	0	0	0	0	0	0	0	0	0	0
NKWSD to Cawelo	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Shafter-Wasco ID to NKWSD	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Friant-Kern Canal Pump-In Deliveries	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL IRRIGATION USE	=	**2,844**	**3,409**	**8,830**	**11,724**	**16,119**	**20,357**	**21,770**	**15,363**	**11,997**	**8,902**	**3,277**	**355**	**124,947**
District Spreading Ponds (Kern)	+	3,505	2,249	135	0	0	0	0	0	0	0	0	5,714	11,603
District Spreading Ponds (Other)	+	0	0	0	0	0	0	0	0	30	393	815	1,099	2,337
Poso Creek Spreading (Kern)	+	0	0	0	0	0	0	0	0	0	0	0	468	468
Poso Creek Spreading (Other)	+	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DISTRICT SPREADING	=	**3,505**	**2,249**	**135**	**0**	**0**	**0**	**0**	**0**	**30**	**393**	**815**	**7,281**	**14,408**
TOTAL DISTRICT USE		**6,349**	**5,658**	**8,965**	**11,724**	**16,119**	**20,357**	**21,770**	**15,363**	**12,027**	**9,295**	**4,092**	**7,636**	**139,355**
Total NKWSD Canal Loss		2,803	1,816	2,455	3,448	3,818	4,447	2,505	1,989	1,698	1,100	322	1,246	27,647
Into Reservoir Storage		2,061	2,212	669	1,766	8,144	8,446	0	0	0	0	2,060	5,039	30,397
Reservoir Evaporation Loss		161	182	178	192	307	766	848	619	393	271	186	164	4,267
From Reservoir Storage		846	0	585	411	210	383	5,514	4,300	1,364	0	246	396	14,255
END OF MONTH RESERVOIR STORAGE		**3,762**	**5,792**	**5,698**	**6,861**	**14,488**	**21,785**	**15,423**	**10,504**	**8,747**	**8,476**	**10,104**	**14,583**	

ROSEDALE-RIO BRAVO WATER
STORAGE DISTRICT

SUMMARY OF 2015 RRBWSD OPERATIONS

Quantities in Acre-feet

Est. Consumptive Use (2015 crop survey) =	76,500
Estimated Applied Water (75% Effic.) =	102,000
Estimated Diversions =	0
Banked Water Recovery =	37,000
Estimated Groundwater Pumping =	**139,000**
Total Deliveries to District =	0
Direct Recharge =	0
Applied Water - Consumptive Use =	25,500
Total Replenishment =	**25,500**
Replenishment Less Pumping =	**-113,500**

(Subsurface inflow/outflow not considered)

SUMMARY OF 2016 RRBWSD OPERATIONS

Quantities in Acre-feet

Est. Consumptive Use (2016 crop survey) =	78,400
Estimated Applied Water (75% Effic.) =	104,500
Estimated Diversions =	-200
Banked Water Recovery =	18,700
Estimated Groundwater Pumping =	**123,000**
Total Deliveries to District =	4,500
Direct Recharge =	4,300
Applied Water - Consumptive Use =	26,100
Total Replenishment =	**30,400**
Replenishment Less Pumping =	**-92,600**

(Subsurface inflow/outflow not considered)

RRBWSD Groundwater Program Operations Report 1995-2016

Table 1 - Water Supplies For Rosedale-Rio Bravo Water Storage District

	Water Supply (Inflows)																			
	1. District Contractual Water Rights				2. District Water Purchases						3. District Programs (see Table 3 for details)					4. District Natural Inflows				
	a	b	c	d	a	b	c	d	e	f	a	b	c	d	e	a	b	c	d	
Year	Kern River Regulated Supply	SWP Table A Supply	Kern River Credited yet Undelivered Supplies	Subtotal (a + b + c)	SWP Article 21	SWP Pools	CVP Section 215	Purchased Groundwater	Short-term Purchases & Exchanges	Subtotal (a+b+c+d+e)	Gross Deliveries for Programs	Total to Program Accounts	Total Returned from Program Accounts	Total Program Account Balances	Gross Program Share for RRBWSD	Gross Useable Rainfall[1]	Unregulated Flood Flows[2]	Safe Yield[3]	Subtotal (a + b + c)	Total Supplies[4]
1995	87,383	29,900	-	**117,283**	7,858	-	693	-	(4,908)	**3,643**	29,515	19,677	-	27,717	**9,838**	27,522	2,992	12,683	**43,198**	**173,962**
1996	56,305	29,900	-	**86,205**	-	-	-	-	(6,690)	**(6,690)**	51,796	34,531	-	62,248	**17,265**	22,146	-	12,683	**34,829**	**131,610**
1997	59,226	29,900	-	**89,126**	-	-	-	-	(8,894)	**(8,894)**	39,054	29,861	11,476	80,633	**9,193**	16,316	20,793	12,607	**49,716**	**139,141**
1998	74,383	29,900	-	**104,283**	-	-	2,361	-	12,368	**14,729**	690	460	5,590	75,503	**230**	38,380	39,065	12,607	**90,052**	**209,294**
1999	14,787	29,900	-	**44,687**	3,790	30,000	-	-	219	**34,009**	3,187	3,187	29,753	48,937	-	16,948	-	12,607	**29,555**	**108,251**
2000	10,758	7,874	-	**18,632**	3,254	16,872	-	-	(8,071)	**12,055**	48,279	32,186	5,000	76,123	**16,093**	13,979	-	12,604	**26,583**	**73,363**
2001	3,972	2,943	-	**6,915**	691	122	-	9,130	8,718	**18,661**	4,037	2,146	3,733	74,536	**1,808**	20,785	-	12,601	**33,385**	**60,770**
2002	5,135	20,648	-	**25,783**	968	631	-	-	148	**1,747**	-	-	21,523	53,013	-	12,374	-	12,552	**24,926**	**52,456**
2003	7,576	27,077	-	**34,653**	838	255	-	-	-	**1,093**	25,143	21,810	23,030	51,792	**3,333**	14,736	-	12,552	**27,287**	**66,367**
2004	3,342	19,550	16,682	**39,574**	3,034	157	-	100,000	223	**103,414**	313	280	17,938	34,134	-	17,105	-	12,550	**29,655**	**172,643**
2005	56,017	26,475	-	**82,492**	3,807	587	-	-	4,134	**8,528**	215,077	136,490	3,943	166,680	**67,897**	24,599	-	12,529	**37,128**	**196,045**
2006	27,643	30,335	113	**58,091**	1,868	-	3,949	-	676	**6,493**	73,816	59,693	417	225,957	**5,000**	18,920	21,809	12,518	**53,247**	**122,831**
2007	7,783	17,122	85	**24,990**	552	145	-	10,000	(9,472)	**1,225**	8,200	29,323	44,103	211,176	-	9,051	-	12,518	**21,569**	**47,784**
2008	-	10,695	6,650	**17,345**	-	28	-	2,223	-	**2,251**	-	-	17,421	193,755	-	9,658	-	12,518	**22,176**	**41,772**
2009	-	12,044	3,505	**15,549**	-	48	-	5,792	(842)	**4,998**	4,633	4,170	14,818	183,107	-	15,385	-	12,506	**27,891**	**48,438**
2010	14,965	13,906	19,322	**48,193**	-	100	-	-	6,221	**6,321**	116,925	81,876	8,250	256,732	**37,850**	38,338	-	12,555	**50,893**	**143,256**
2011	35,776	6,144	966	**42,886**	4,355	527	11,954	-	34,874	**51,710**	181,287	130,337	11,000	376,069	**51,753**	13,617	-	12,555	**26,172**	**172,521**
2012	7,328	19,418	2,053	**28,799**	-	67	-	-	(571)	**(504)**	40,475	34,911	30,999	379,982	**14,029**	13,400	-	12,555	**25,955**	**68,279**
2013	-	23,852	10,000	**33,852**	-	1,607	-	25,000	-	**26,607**	-	-	44,194	335,788	-	10,311	-	12,728	**23,039**	**83,498**
2014	-	6,460	10,000	**16,460**	-	191	-	7,902	-	**8,093**	-	-	49,978	285,810	-	12,182	-	12,728	**24,910**	**49,463**
2015	-	6,701	10,000	**16,701**	-	1	-	169	-	**170**	-	-	37,570	248,240	-	11,939	-	12,936	**24,875**	**41,746**
2016	-	17,678	10,000	**27,678**	-	277	-	-	157	**434**	8,298	9,209	26,753	230,696	**4,149**	21,600	-	12,936	**34,536**	**66,797**
Total	472,379	418,422	89,376	980,177	31,015	51,615	18,957	160,216	28,290	290,093	850,725	630,145	407,489	3,678,627	238,438	399,294	84,659	277,627	761,580	2,270,288
Average	29,524	19,019	7,448	44,554	2,820	3,036	4,739	20,027	2,829	15,268	50,043	37,067	20,374	167,210	18,341	18,150	21,165	12,619	34,617	103,195
Median	7,680	19,484	99	34,253	276	134	-	-	-	5,660	8,249	14,443	16,120	174,894	2,571	15,851	-	12,578	28,723	78,431

Notes: 1. Effective precipitation calculated per method developed as a part of groundwater mediation process.
2. Unregulated flood flows include deliveries of floodwater from the Kern River and the Friant system.
3. Safe yield calculated based on 0.3 acre-feet/acre for total District gross (assessed) acres less non-farmed District owned lands.
4. Total supplies = 1d + 2f + 3e + 4d. Supplies do not include water banked for 3rd parties.

Table 2 - Water Demands & Balance For Rosedale-Rio Bravo Water Storage District

	Water Demands (Outflows)									Supplies (Inflows)	Balance				
	1. District Consumption			2. Other								Cumulative Groundwater Balance (End of Year)			
	a	b	c	a	b	c	d	e				GLC Program			
Year	Crop Use[1]	Urban Use[2]	Subtotal	Transfers	District ODC Losses[3]	Kern Fan Project Losses[4]	District Project Losses[4]	Subtotal	Total Demands [Col 1a+2d]	Total Water Supplies (Table 1)	Annual Balance (Change In Storage)	ODC Balance	Exportable Balance[5]	Total Program Balance	RRBWSD District Balance
1995	84,252	6,497	**90,749**	-	3,838	474	1,181	**5,493**	**96,242**	173,962	77,720	77,720		**77,720**	**77,720**
1996	83,861	6,542	**90,403**	-	2,564	931	2,072	**5,567**	**95,970**	131,610	35,639	113,360		**113,360**	**113,360**
1997	87,179	6,587	**93,766**	-	2,481	413	1,103	**3,997**	**97,763**	139,141	41,378	154,738		**154,738**	**154,738**
1998	88,808	6,631	**95,439**	-	4,187	776	28	**4,990**	**100,430**	209,294	108,865	263,603		**263,603**	**263,603**
1999	89,842	6,874	**96,716**	-	1,468	-	-	**1,468**	**98,184**	108,251	10,067	273,669		**273,669**	**273,669**
2000	86,634	7,117	**93,751**	-	771	1,400	1,931	**4,102**	**97,853**	73,363	(24,490)	249,179		**249,179**	**249,179**
2001	83,575	7,360	**90,935**	-	96	123	50	**270**	**91,204**	60,770	(30,435)	218,744		**218,744**	**218,744**
2002	81,138	7,603	**88,741**	-	122	117	-	**239**	**88,979**	52,456	(36,524)	182,220		**182,220**	**182,220**
2003	81,916	7,725	**89,641**	-	376	556	400	**1,332**	**90,973**	66,367	(24,606)	157,614		**157,614**	**157,614**
2004	81,707	7,877	**89,584**	-	251	-	-	**251**	**89,835**	172,643	82,808	140,422	100,000	**240,422**	**240,422**
2005	82,486	8,308	**90,794**	-	2,382	2,180	7,171	**11,732**	**102,527**	196,045	93,518	233,940	100,000	**333,940**	**333,940**
2006	83,284	8,454	**91,738**	-	2,223	638	338	**3,199**	**94,937**	122,831	27,893	240,025	121,809	**361,834**	**361,834**
2007	76,112	8,797	**84,909**	-	271	-	-	**271**	**85,180**	47,784	(37,396)	202,629	121,809	**324,438**	**324,438**
2008	79,624	8,703	**88,327**	3,000	-	-	330	**3,330**	**91,657**	41,772	(46,885)	155,744	118,809	**274,553**	**274,553**
2009	84,177	8,809	**92,986**	3,000	-	-	330	**3,330**	**96,316**	48,438	(44,877)	110,867	115,809	**226,676**	**226,676**
2010	86,748	8,825	**95,573**	-	828	231	2,322	**3,381**	**98,954**	143,256	44,302	155,169	115,809	**270,978**	**270,978**
2011	83,319	8,518	**91,837**	-	2,021	1,537	3,643	**7,201**	**99,038**	172,521	73,483	210,299	134,162	**344,461**	**344,461**
2012	84,474	8,518	**92,992**	4,000	284	67	1,302	**5,653**	**98,645**	68,279	(26,365)	183,933	130,162	**314,095**	**314,095**
2013	85,441	8,539	**93,980**	16,500	-	-	1,815	**18,315**	**112,295**	83,498	(12,296)	171,637	88,662	**260,299**	**285,299**
2014	87,189	8,539	**95,728**	5,000	-	-	550	**5,550**	**101,278**	49,463	(46,814)	124,823	83,662	**208,485**	**233,485**
2015	85,569	9,044	**94,613**	9,500	-	-	1,045	**10,545**	**105,158**	41,746	(53,911)	70,912	74,162	**145,074**	**170,074**
2016	87,503	9,028	**96,531**	16,500	-	-	2,344	**18,844**	**115,375**	66,797	(32,078)	38,834	57,662	**96,496**	**121,496**
Total	1,854,838	174,894	2,029,732	57,500	24,162	9,443	27,955	119,060	2,148,792	2,270,288					
Average	84,311	7,950	92,261	8,214	1,510	726	1,553	5,412	97,672	103,195					
Median	84,215	8,381	92,411	-	330	120	798	4,049	97,808	78,431					

Notes:
1. Crop use calculated per method developed as a part of groundwater mediation process (Cal Poly method).
2. Urban consumptive use estimated based on 1.2 acre-feet/net acre.
3. Losses are assessed at 3% per MOU on surface water deliveries for District recharge not a part of other programs.
4. Losses for banked water and for surface diversions for District use associated with banking programs are assessed per MOU. See Tables 3 and 4.
5. 25,000 AF deleted from Exportable Balance per WK program and added to RRBWSD District Balance in 2013.

BUENA VISTA WATER STORAGE DISTRICT

YEAR	HISTORIC CROP PATTERN																
	COTTON (ACRES)	ALFALFA (ACRES)	GRAIN (ACRES)	BEETS (ACRES)	WETLANDS (ACRES)	TOMATOES (ACRES)	WALNUTS YOUNG (ACRES)	PISTACHIOS YOUNG (ACRES)	PISTACHIOS MATURE (ACRES)	Pomegrante YOUNG (ACRES)	Pomegrante Mature (ACRES)	Olives YOUNG (ACRES)	Grapes YOUNG (ACRES)	Cherries YOUNG (ACRES)	CORN SILLAGE (ACRES)	MISC. FIELD CROPS (ACRES)	TOTAL (ACRES)
2015	8,182	6,652	646	0	4,248	1,534	596	6,020	2,569	0	1,725	80	2,575	105	618	1,135	36,685
2016	8,662	5,568	511	0	4,248	1,850	530	5,962	3,462	0	1,818	80	3,135	105	866	1,298	38,095

YEAR	HISTORIC CROP PATTERN																
	COTTON (ACRES)	ALFALFA (ACRES)	GRAIN (ACRES)	BEETS (ACRES)	WETLANDS (ACRES)	TOMATOES (ACRES)	WALNUTS YOUNG (ACRES)	PISTACHIOS YOUNG (ACRES)	PISTACHIOS MATURE (ACRES)	Pomegrante YOUNG (ACRES)	Pomegrante Mature (ACRES)	Olives YOUNG (ACRES)	Grapes YOUNG (ACRES)	Cherries YOUNG (ACRES)	CORN SILLAGE (ACRES)	MISC. FIELD CROPS (ACRES)	TOTAL (ACRES)
2015	8,182	6,652	646	0	4,248	1,534	596	6,020	2,569	0	1,725	80	2,575	105	618	1,135	36,685
2016	8,662	5,568	511	0	4,248	1,850	530	5,962	3,462	0	1,818	80	3,135	105	866	1,298	38,095

SHAFTER-WASCO IRRIGATION DISTRICT

Shafter-Wasco Irrigation District

2015 Crop Year District Acreage Summary

CROP	CODE	TOTAL ACRES
Pasture	1	208
Garden	10 AD	5
Carrots	10 H	355
Cabbage	10 K	1
Watermelon	10 R	57
Onions	10 T	17
Potatoes	10 V	305
Strawberries	10C	2
Cherries	11 D	563
Plums	11 I	18
Persimmons	11 J	59
Grapes Table	14A	399
Grapes Raisin	14B	252
Grapes Wine	14C	561
Cotton Lint (American Pima	18	660
Cotton Lint-Upland (Acala)	18A	78
Alfalfa/Hay	2	1,870
Almonds	27 A	19,960
Walnuts	27 C	256
Pistachios	27 D	976
Nursery Stock	28	1,098
Corn	6 B	78
Wheat	6 E	655
Oats	6 F	53
Pumpkins	6 N	1
Blackeye Bean	6 T	229
Corn Silage	6BS	199
Safflower	6S	38
	TOTAL HARVESTED LAND:	**28,953**
No Crop	21 D	2,169
Commercial	31 C	1,746
Farmsteads	31 F	2,437
Waste-Misc	31 M	90
	TOTAL NON HARVESTED LAND :	**6,442**
	TOTAL CROP LAND:	**35,395**
Residential	31 R	3,371
	Total Residential :	**3,371**
	TOTAL DISTRICT LAND :	**38,766**

Shafter-Wasco Irrigation District

2016 Crop Year District Acreage Summary

CROP	CODE	TOTAL ACRES
Pasture	1	201
Garden	10 AD	5
Carrots	10 H	603
Onions	10 T	75
Potatoes	10 V	227
Strawberries	10C	2
Cherries	11 D	363
Plums	11 I	18
Persimmons	11 J	59
Grapes Table	14A	399
Grapes Raisin	14B	252
Grapes Wine	14C	461
Cotton Lint (American Pima	18	327
Cotton Lint-Upland (Acala)	18A	144
Alfalfa/Hay	2	1,450
Almonds	27 A	21,167
Walnuts	27 C	330
Pistachios	27 D	976
Nursery Stock	28	1,257
Corn	6 B	78
Wheat	6 E	583
Pumpkins	6 N	1
Blackeye Bean	6 T	290
Corn Silage	6BS	138
TOTAL HARVESTED LAND:		**29,406**
No Crop	21 D	1,866
Commercial	31 C	1,596
Farmsteads	31 F	2,437
Waste-Misc	31 M	90
TOTAL NON HARVESTED LAND :		**5,989**
TOTAL CROP LAND:		**35,395**
Residential	31 R	3,371
Total Residential :		**3,371**
TOTAL DISTRICT LAND :		**38,766**

SOUTHERN SAN JOAQUIN MUNICIPAL
UTILITY DISTRICT

Summary Report by Crop

Date: Saturday, February 28, 2015

Crop	Acreage
Alfalfa	2812.000 ac
Almonds	14354.500 ac
Berries,except Straw	61.000 ac
Cherries	273.000 ac
Cotton	135.000 ac
Fallow	709.600 ac
Grapefruit	10.000 ac
Grapes	5571.500 ac
Hay - Other	95.000 ac
Kiwi	48.000 ac
Lemons and Limes	10.000 ac
Mandarins	99.000 ac
Naval Oranges	3915.500 ac
Nothing	803.000 ac
Oats	260.000 ac
Other fruits	8.000 ac
Pasture	45.000 ac
Pecans	394.000 ac
Pistachios	4893.000 ac
Raisin Grapes	212.000 ac
Roses	158.000 ac
Safflower	155.000 ac
Silage	11.000 ac
Sudan	268.000 ac
Table Grapes	11045.000 ac
Tomatoes	156.000 ac
Valencia Oranges	721.500 ac
Vegetables,other	186.000 ac
Walnuts	361.000 ac
Wheat	611.000 ac
Wine Grapes	128.000 ac
Grand Total:	**48509.600 ac**

Summary Report by Crop

Date: Monday, February 29, 2016

Crop	Acreage
Alfalfa	1949.000 ac
Almonds	14364.500 ac
Berries,except Straw	61.000 ac
Cherries	273.000 ac
Cotton	135.000 ac
Fallow	1409.600 ac
Grapefruit	10.000 ac
Grapes	5877.930 ac
Hay - Other	95.000 ac
Kiwi	48.000 ac
Lemons and Limes	10.000 ac
Mandarins	99.000 ac
Naval Oranges	3924.500 ac
Nothing	879.000 ac
Oats	260.000 ac
Other fruits	8.000 ac
Pasture	45.000 ac
Pecans	394.000 ac
Pistachios	4893.000 ac
Raisin Grapes	212.000 ac
Roses	79.000 ac
Safflower	155.000 ac
Silage	11.000 ac
Sudan	268.000 ac
Table Grapes	11019.000 ac
Tomatoes	156.000 ac
Valencia Oranges	721.500 ac
Vegetables,other	186.000 ac
Walnuts	436.000 ac
Wheat	531.000 ac
Wine Grapes	128.000 ac
Grand Total:	**48638.030 ac**