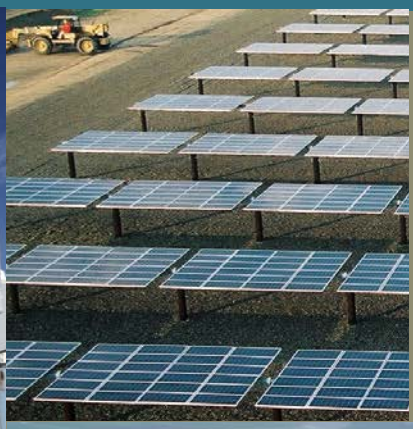
Semitropic Water Storage District Groundwater Sustainability Agency 2020 Groundwater Sustainability Plan

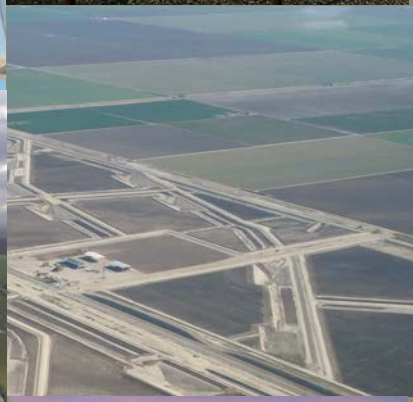
Kern County, CA













Semitropic Water Storage District • 1101 Central Ave., PO Box 8043 • Wasco, CA 93280

Semitropic Water Storage District Groundwater Sustainability Agency 2020 Groundwater Sustainability Plan

Kern County, CA

Submitted to:
Semitropic Water Storage District
1101 Central Avenue
Wasco, CA 93280

Submitted by:
GEI Consultants, Inc.
5001 California Ave., Suite 120
Bakersfield, CA 93309
661.327.7601

December 2019

This Page Left Blank Intentionally

Table of Contents

EXECUTIVE SUMMARY ..... **I**

1. INTRODUCTION **1**

1.1 General Information 1
1.2 Semitropic Information 1
1.2.1 District Information *1*
1.2.2 SGMA Authority *2*
1.3 GSP Implementation Costs 3
1.3.1 Costs Generated by GSP Implementation *3*
1.3.2 GSP Implementation Funding *3*
1.4 Description of Plan Area 4
1.4.1 Plan Area Setting *4*
1.4.2 Existing Plans in Plan Area *11*
1.4.3 Plan Elements from CWC Section 10727.4 ..... *13*
1.5 Notice and Communication 15
1.5.1 Participating Agencies *15*
1.5.2 Beneficial Uses and Users *15*
1.5.3 Public Meetings *16*
1.5.4 Comments Received *18*
1.6 GSP Organization 19

2. BASIN SETTING **21**

2.1 Reference to Umbrella GSP and Local Sources of Data 21
2.1.1 Local Refinements to the Umbrella Setting *21*
2.2 Hydrogeologic Conceptual Model (HCM) 21
2.2.1 Basin Regional Setting *21*
2.2.2 Lateral and Vertical Boundaries of Groundwater for SWSD *24*
2.2.3 Principal Aquifers and Aquitards *25*
2.2.4 Mapped Topography *53*
2.2.5 Surficial Geology *54*
2.2.6 Soils *57*
2.2.7 Natural Recharge, Direct Recharge Areas, and Potential Recharge Areas *61*
2.2.8 Surface Water Bodies *64*
2.2.9 Source and Point of Delivery for Imported Water Supplies *64*
2.2.10 Data Gaps in the Hydrogeologic Conceptual Model *69*
2.3 Current and Historical Groundwater Conditions 69
2.3.1 Groundwater Elevation Contour Maps *70*
2.3.2 Hydrographs *77*
2.3.3 Change in Groundwater Storage *81*
2.3.4 Seawater Intrusion *81*
2.3.5 Groundwater Quality Issues *81*
2.3.6 Land Subsidence *104*
2.3.7 Interconnected Surface Water Systems *118*
2.3.8 Potential Groundwater Dependent Ecosystems *118*

2.4 WATER BUDGET 128
2.4.1 Subbasin Coordinated Water Budgets 128
2.4.2 Semitropic Area Water Budget 129
2.5 EXISTING MONITORING PROGRAMS 132
2.5.1 Existing Water Level Monitoring 132
2.5.2 Existing Land Subsidence Monitoring 134
2.5.3 Existing Groundwater Quality Monitoring 136
2.6 MANAGEMENT AREAS WITHIN SWSD 139
2.7 EXISTING WATER RESOURCE PROGRAMS 139
2.7.1 Management Plans 140
2.7.2 Conjunctive Use Programs 145

3. SUSTAINABLE MANAGEMENT CRITERIA 147

3.1 SUSTAINABILITY GOALS 147
3.2 UNDESIRABLE RESULTS 147
3.2.1 Undesirable Results for Chronic Lowering of Groundwater Levels 148
3.2.2 Undesirable Results for Reduction of Groundwater Storage 149
3.2.3 Undesirable Results for Degraded Water Quality 150
3.2.4 Undesirable Results for Land Subsidence 151
3.3 MINIMUM THRESHOLD 152
3.3.1 The Chronic Lowering of Groundwater Levels 157
3.3.2 Groundwater Storage 159
3.3.3 Subsidence 159
3.3.4 Degraded Water Quality 160
3.4 MEASURABLE OBJECTIVES AND INTERIM MILESTONES 160
3.4.1 The Chronic Lowering of Groundwater Levels 161
3.4.2 Groundwater Storage 162
3.4.3 Subsidence 162
3.4.4 Degraded Water Quality 162
3.5 POTENTIAL EFFECTS BEYOND GSP AREA 163

4. GSP MONITORING NETWORK 165

4.1 MONITORING NETWORK OBJECTIVES 165
4.1.1 Water Level Monitoring as a Key Sustainability Indicator 165
4.2 MONITORING PROGRESS TOWARD MEASURABLE OBJECTIVES 166
4.2.1 Potential Impacts to Beneficial Uses and Users of Groundwater 166
4.2.2 Monitoring Network for Water Budget Components 167
4.3 MONITORING NETWORK DESIGN AND SUSTAINABILITY INDICATORS 169
4.3.1 Monitoring Frequency Design 170
4.3.2 Spatial Density Design 170
4.3.3 Rationale for Design 170
4.3.4 Chronic Lowering of Groundwater Levels and Reduction of Groundwater Storage 171
4.3.5 Seawater Intrusion 175
4.3.6 Degraded Water Quality 175
4.3.7 Land Subsidence 176
4.3.8 Depletion of Interconnected Surface Water 178
4.4 MONITORING PROTOCOLS AND REPORTING STANDARDS 178
4.4.1 Groundwater Level Monitoring Network Protocol and Standards 179

4.4.2 Water Quality Monitoring Network Protocol and Standards 182
4.4.3 Land Subsidence Monitoring Network 184
4.5 Monitoring Network Improvement Plan 185
4.5.1 Water Level, Groundwater Storage, and Water Quality Monitoring Network Assessment 185
4.5.2 Land Subsidence Network Assessment 185

5. PROJECTS AND MANAGEMENT ACTIONS 187

5.1 Management Actions Processes 187
5.1.1 Goals and Objectives 187
5.1.2 Circumstances for Implementation 188
5.1.3 Public Noticing 188
5.1.4 Permitting and Regulatory Process 188
5.1.5 Implementation Timetable and Status 189
5.1.6 Expected Benefits 189
5.1.7 Source and Reliability of Water Outside SWSD 189
5.1.8 Legal Authority Required 190
5.1.9 Estimated Costs and Funding 190
5.2 Management Actions Descriptions 190
5.2.1 Existing Projects and Management Actions 193
5.2.2 Future Projects and Management Actions 194
5.2.3 Management Action 1: Landowner Water Budgets 195
5.2.4 Management Action 2: Tiered Pricing Structure 202
5.2.5 Management Action 3: District Fallowing Program 202
5.3 Implementation 202

6. REFERENCES AND TECHNICAL STUDIES 209

APPENDICES 217

List of Tables

Table 1-1. Kern Groundwater Authority Member Agencies
Table 1-2. Estimated Costs for GSP Implementation
Table 1-3. Public Meetings and Outreach
Table 1-4. GSP Organization
Table 2-1a. Local Aquifer Parameters
Table 2-1b. Local Aquifer Parameters
Table 2-2. Public Water Systems within SWSD
Table 2-3. List of Constituents and Standards
Table 2-4. Representative Wells in Relation to Aquifer
Table 2-5. Summary of Sodium Prevalence within SWSD
Table 2-6. Summary of Arsenic Prevalence within SWSD
Table 2-7. Summary of Arsenic Prevalence Among Public Water Systems
Table 2-8. Summary of TCP Prevalence Among Public Water Systems
Table 2-9. Summary of Nitrate Concentrations Public Water Systems
Table 2-10. Subsidence Results
Table 2-11. NCAAG Plant Rooting Depth
Table 2-12. SWSD Water Supplies for Current Conditions
Table 2-13. SWSD Water Supplies for 2030 Climate Conditions
Table 2-14. SWSD Net Water Budget for Current Conditions
Table 2-15. Summary of Monitoring Committee
Table 2-16. Summary of Land Subsidence Monitoring in Study Area
Table 2-17. Types of Monitoring Programs Implemented within the District
Table 2-18. Constituents Monitored as Part of the Current Monitoring Program
Table 2-19. PWS within the Semitropic Service Area
Table 3-1. Summary of Minimum Thresholds and Measurable Objectives
Table 4-1. Potential Impacts of Overdraft with Corresponding Monitoring
Table 4-2. Weather Stations within the Vicinity
Table 4-3. Monitoring Wells and Corresponding Sustainable Management Criteria
Table 4-4. Monitoring Network Well Density per 100 Square Miles (approximate)
Table 4-5. Summary of Land Subsidence Monitoring in Study Area
Table 4-6. Monitoring Schedule
Table 5-1. Proposed List of Projects and Management Actions for Semitropic GSA
Table 5-2. Example Water Budget for Contract Lands
Table 5-3. Example Water Budget for Groundwater Service Area GPSC Lands
Table 5-4. Example Water Budget for Groundwater Service Area GPSC

List of Figures

Figure 1-1. SWSD Jurisdictional Area
Figure 1-2. Land Use within SWSD
Figure 1-3. SWSD Areas Receiving Surface Water
Figure 1-4. Well Density (Domestic Wells)
Figure 1-5. Well Density (Production Wells)
Figure 1-6. Well Density (Public Wells)
Figure 2-1. Central Valley Hydrologic Regions-Tulare Lake Region
Figure 2-2. Conceptual Block Diagram Looking North from Kern River
Figure 2-3. Base of Freshwater by Page (1973) and Non-USDWs
Figure 2-4. Base of 10,000 ppm TDS Gillespie et. al. (2017) and Non-USDWs
Figure 2-5. Groundwater Subbasin Conceptual Profile
Figure 2-6. General Aquifer Zones of SWSD
Figure 2-7. Approximate Thickness and Extent of E-Modified Corcoran Clay
Figure 2-8. Geologic Map (Bartow, 1991)
Figure 2-9. Cross Section A-A'
Figure 2-10. Cross Section B-B'
Figure 2-11. Cross Section C-C'
Figure 2-12. Cross Section D-D'
Figure 2-13. Cross Section E-E'
Figure 2-14. Cross Section F-F'
Figure 2-15. Geologic Map Index Map (CGS, 2010)
Figure 2-16. Topographic Map
Figure 2-17. Geologic Map (Page, 1986)
Figure 2-18. Hydrologic Soil Groups
Figure 2-19. Soils (USDA SSURGO)
Figure 2-20. Areas of District Recharge
Figure 2-21. Soil Agricultural Groundwater Banking Index
Figure 2-22. Surface Water Features from National Hydrography Dataset.
Figure 2-23. Source and Points of Delivery for Imported Water Semitropic WSD
Figure 2-24. Generalized Groundwater Flow in Kern County Subbasin
Figure 2-25. Groundwater Elevations Upper Zone (Spring 2015)
Figure 2-26. Groundwater Elevations Lower Zone (Spring 2015)
Figure 2-27. Representative Shallow Groundwater Contours
Figure 2-28. Water Year Index (1995 to 2017)
Figure 2-29. General Hydrograph Trends by Year
Figure 2-30. Public Water Systems Identified within SWSD
Figure 2-31. Land Use within SWSD
Figure 2-32. Representative Wells for Water Quality Evaluation
Figure 2-33. SWSD Max Sodium Concentrations in Representative Wells Not Screened Entirely Below Corcoran Clay
Figure 2-34. SWSD Sodium versus Water Level in Upper Zone
Figure 2-35. SWSD Max Sodium Concentrations in Representative Wells in Lower Zone
Figure 2-36. SWSD Sodium versus Water Level in Lower Zone West of Spreading Ground
Figure 2-37. Sodium versus Water Level in Lower Zone South of Spreading Ground

Figure 2-38. SWSD Max Arsenic Concentrations
Figure 2-39. SWSD Arsenic and Water Level Relationship in Lower and Both Zones
Figure 2-40. SWSD Arsenic and Water Level Relationship in Upper Zone
Figure 2-41. SWSD Well Depth vs. Arsenic Level in Confined Aquifer
Figure 2-42. Conceptual Diagram of Subsidence
Figure 2-43. SWSD Subsidence Historical
Figure 2-44. SWSD Subsidence 2007-2010
Figure 2-45. SWSD Subsidence 2015-2016
Figure 2-46. SWSD Subsidence Rate 2007-2010
Figure 2-47. SWSD Subsidence Rate 2015-2016
Figure 2-48. NCCAG Vegetation
Figure 2-49. NCCAG Wetlands
Figure 2-50. Generalized Extensometer
Figure 2-51. SWSD Management Areas
Figure 3-1. Measurable Thresholds and Measurable Objectives
Figure 4-1. SWSD GSP Monitoring Well Network
Figure 5-1. Example Water Budget for Contract Lands Through the Implementation Period
Figure 5-2. Example Water Budget for Groundwater Service Area GPSC Lands Through the Implementation Period.
Figure 5-3. Example Water Budget Special GPSC (Duck Club) Lands Through the Implementation Period
Figure 5-4. Projected-Future Superposition Hydrograph: RMW-132-SWSD
Figure 5-5. Projected-Future Superposition Hydrograph: RMW-137-SWSD
Figure 5-6. Projected-Future Superposition Hydrograph: RMW-139-SWSD
Figure 5-7. Projected-Future Superposition Hydrograph: RMW-140-SWSD

List of Appendices

Appendix A. Comments
Appendix B. Hydrographs
Appendix C. Time-Series Subsidence
Appendix D. Land Subsidence Monitoring
Appendix E. Hydrogeologic Zones
Appendix F. References

List of Acronyms

Ag Goals……Agricultural Water Quality Goals
Bgs…….…….Below Ground Surface
BMPs……...……Best Management Practices
BVGSA…….....…….Buena Vista GSA
BVWSD……...……Buena Vista Water Storage District
CASGEM…….....California Statewide Groundwater Elevation Monitoring
CDFW……...…….California Department of Fish and Wildlife
CEQA……...……...….California Environmental Quality Act
CSA……California State Aqueduct
CGPS……..…….……..Continuous GPS
CIMIS…….…….. California Irrigation Management Information System
COC……...……Constituents of Concern
CUP……...……Conditional Use Permit
CVHM…….……..Central Valley Hydrologic Model
CVP…….Central Valley Project
CV-SALTS……..……..Central Valley Salinity Alternatives for Long-term Sustainaility
DBCP……..…….Dibrochloropropane
DMS…….……..Data Management System
DWR……California Department of Water Resources
EC…….…Electroconductivity
ESA……...European Space Agency
ET……...…..Evaportranspiration
FKC……Friant-Kern Canal
GAMA…….....Groundwater Ambient Monitoring and Assessment Program
GAR…….……..Groundwater Quality Assessmenr Report
GCP……..…….…….Groundwater Communication Portal
GDE……...……...…….Groundwater Dependent Ecosystemt
GIS……...…Geographic Information System
GMP……...……...Groundwater Management Plan
GPS…….…….…… Global Positioning System
GPSC……..General Project Sevice Charge
GSP…….…….……Groundwater Sustainability Plan
HZs……....Hydrogeologic Zones
ILRP……...…Irrigated Lands Regulatory Program
InSAR…… Inferometric Synthetic-Aperture Radar
IPA……Incremental Pumping Allowance
IRWMP……..…Integrated Regional Water Mangement Plan
ITRC…….Irrigation Training and Research Center
JPA…….……Joint Powers Agreement
JPL……...Jet Propulsion Laboratory
KCPHSD……..……Kern County Public Healh Sevices Department

KCS……Kern County Subbasin
KCWA……Kern County Water Agency
KFMC……Kern Fan Monitoring Committee
KGA……Kern Groundwater Authority
KNWR……Kern National Wildlife Refuge
KRWCA……Kern River Watershed Coalition Authority
KWB……Kern Water Bank
LADWP……Los Angeles Department of Water and Power
LHWD……Lost Hills Water District
MCL…… Maximum Contaminant Limit
MMU……Minimum Map Unti
N……Nitrate as Nitrogen
NASA……National Aeronautics and Space Administration
NCCAG……Natural Communities Commonly Associated with Groundwater
NEPA……National Environmental Policy Act
NHD……National Hydrography Dataset
NKWSD……North Kern Water Storage District
NPDES……National Pollution Discharge Elimination System
NRCS……National Resource Conservation Service
NTNC……Non-Transient Non-Community
NWI……National Wetland Inventory
PBO……Plate Boundary Observation
PGA…… Pacific Geotechnical Associates
pH……Acidity
PWS……Public Water System
RP……Reference Point
RRBWSD……Rosedale Rio Bravo Water Storage District
RWQCB……Regional Water Quality Control Board
SAGBI…… Soil Agricultural Groundwater Banking Index
SCV……Survey of California Vegetation
SDWIS…… State Drinking Water Information System
SGMA…… Sustainable Groundwater Management Act
SJVAPCD……San Joaquin Air Pollution Control District
SSJMUD…… Southern San Joaquin Municipal Utility District
SSURGO…… Soil Survey Geograohic Database
SWID……Shafter-Wasco Irrigation District
SWP……State Water Project
SWRCB……State Water Resource Control Board
SWSD, Semitropic, District……Semitropic Water Storage District
TCP……1,2,3-trichloropropane
TDS……Total Dissolved Solids
TNC……Transient Non-Community

UAVSR……..……Unmanned Aerial Vehicle Synthetic Apeture Radar
UC Davis…….…..……..……..University of California, Davis
USDA…….…..……..United States Department of Agriculture
USDW…….…..…….. Underground Source of Drinking Water
USEPA…….. United States Environmental Protection Agency
USGS…….……..United States Geological Survey
UWMP…….……Urban Water Management Plan
VegCAMP……..Vegetation Classification and Mapping Program

Executive Summary

This Groundwater Sustainability Plan (GSP) was written to represent the efforts of Semitropic Water Storage District and the Semitropic Water Storage District GSA as applicable (SWSD, District, or Semitropic) to comply with the California state regulated Sustainable Groundwater Management Act (SGMA) of 2014. According to SGMA, groundwater basins in California that have been classified as high or medium priority must correct current overdraft conditions in order to reset the balance of groundwater input/output as an effort to reach sustainability by the year 2040. This plan was written in conjunction with and in support of a basin-wide GSP drafted on behalf of the Kern Groundwater Authority (KGA). The KGA represents 15 member agencies within the boundary of the Kern County Subbasin (Subbasin) which are joined together by the adoption of a Joint Powers Agreement (JPA). While Semitropic will be coordinating with the KGA to comply with SGMA, it has elected to become its own Groundwater Sustainability Agency (GSA), and if necessary, this GSP can serve as a stand-alone GSP. This GSP follows the California Code of Regulations and discusses background information of the District and its corresponding management areas; current practices and existing plans; management structure and actions; and current groundwater conditions and future sustainability management practices required to comply with SGMA.

The District is located within the Tulare Lake Region of the Central Valley. Beneficial users serviced within the District boundaries consist of agricultural, municipal and domestic, industrial, and environmental. Groundwater is used in this region to support agricultural, production, and industrial practices that support the economic viability of local communities. This GSP includes a detailed overview of the District's historical, current and projected groundwater conditions, including groundwater storage, water quality, and land subsidence.

This plan provides the required elements of a GSP and identifies an initial path for sustainable management of the District's portion of the Subbasin. Once fully implemented, the projects and management actions described in this plan are expected to reduce the groundwater pumping as necessary for the District to avoid an "undesirable result," as defined by SGMA, including but not limited to significant and unreasonable (i) water quality degradation, (ii) land subsidence, and (iii) chronic lowering of groundwater levels.

This Page Left Blank Intentionally

1. Introduction

1.1 General Information

The purpose of this GSP is to comply with SGMA, which requires that a GSP be developed for designated medium and high priority groundwater basins in the State of California. The District has elected to form its own GSA, under the provisions of SGMA, for the management of groundwater resources within the boundaries of the District. This GSP will serve as the foundation for groundwater management within the District and is being developed in coordination with KGA to support the implementation of the KGA's Kern County Subbasin Umbrella GSP. As a component of the KGA's Umbrella GSP, this GSP accomplishes the following objectives:

- Defines and describes the geographic and geologic conditions of the lands within the boundaries of the District ("Semitropic Area") and the relationship of such lands to the Kern Subbasin of the Tulare Lake Basin.
- Identifies and describes the sustainability goal for the Subbasin and the Semitropic Area.
- Identifies and describes the six undesirable results set forth in SGMA, as they pertain to the Subbasin and the Semitropic Area.
- Identifies and describes specific minimum thresholds and measurable objectives required for SWSD to achieve SGMA's sustainability goal.
- Defines and identifies projects and management actions proposed by SWSD to achieve the sustainability goal.

1.2 Semitropic Information

1.2.1 District Information

Agency's Name:	Semitropic Water Storage District
Agency's Address:	1101 Central Avenue, Wasco, CA 93280
Agency's Phone Number:	(661) 758-5113
Agency's Website:	http://www.semitropic.com/
Contact Person:	Jason Gianquinto
Contact Person's Title:	General Manager, SWSD

Established in 1958, SWSD covers an area of more than 224,000 acres. SWSD is one of eight water storage districts in California and is the largest in Kern County. The SWSD was formed to acquire a supplemental surface water supply through the State Water Project (SWP) to address groundwater overdraft within the region. Today, the SWSD delivers water to nearly 300 customers for approximately 146,000 acres of irrigated agriculture.

In response to the enactment of SGMA, SWSD filed with the California Department of Water Resources (DWR) as a GSA and elected to participate in the preparation of a GSP in coordination with the KGA. Pursuant to the terms of the KGA's joint exercise of powers agreement, the District maintains authority over its own internal matters, including but not limited to, its surface water supplies, groundwater supplies, facilities, operations, water management, and water supply matters.

SWSD's Board of Directors is comprised of seven Board members each representing one of the seven divisions of the District. Board members must be landowners or a representative of a landowner within the District and are elected by the landowners within the division which they represent to serve four-year terms. Information regarding current SWSD Board representatives can be found at the Agency's website, http://www.semitropic.com/BoardOfDirectors.htm.

1.2.2 SGMA Authority

SWSD elected to form its own GSA on April 12, 2017 and therefore has secured the authorities and provisions afforded to a GSA under SGMA. It is the intent of the Semitropic GSA to work collaboratively with the KGA to develop a single GSP which will include those entities that have elected to have the KGA be their GSA along with the Semitropic GSA, while reserving Semitropic's legal authority as a GSA.

1.2.2.1 Participation in the Kern Groundwater Authority

On May 27, 2014, the KGA was formed through a joint exercise of powers agreement ("JPA"). Under the JPA, the KGA was granted the authority to serve as the GSA for some or all the members within the Kern Subbasin in a manner that allows the members (individually or collectively) to directly implement SGMA and a GSP within their respective management areas. The JPA was amended and restated on March 22, 2017. The amended and restated JPA includes the entities listed in Table 1-1 (this list is also provided in the KGA Umbrella GSP).

Table 1- 1: Kern Groundwater Authority Member Agencies

Arvin Community Services District	Rosedale-Rio Bravo Water Storage District
Arvin-Edison Water Storage District	Semitropic Water Storage District
Cawelo Water District	Shafter-Wasco Irrigation District
City of Shafter	Southern San Joaquin Municipal Utility District
Kern County Water Agency – Pioneer Project	Tejon-Castaic Water District
Kern-Tulare Water District	West Kern Water District
Kern Water Bank Authority	Westside District Water Authority
North Kern Water Storage District	Wheeler Ridge-Maricopa Water Storage District

1.2.2.2 Coordination Agreement

Discussion of coordination agreement(s) adopted as part of Subbasin coordination activities will be drafted with the development of coordination agreements.

1.3 GSP Implementation Costs

On behalf of its customers, SWSD will incur significant costs to implement its GSP including but not limited to five-year updates as required by SGMA. These costs will be incurred by SWSD both on its own and as a member of the KGA. These costs and sources of funding are described below.

1.3.1 Costs Generated by GSP Implementation

Table 1- 2 presents a description and an estimate of the costs associated with the implementation of the SWSD GSP and measures associated with SGMA compliance.

Table 1- 2: Estimated Costs for GSP Implementation

Item	Description	Estimated Cost
Annual Monitoring	Annual monitoring for water elevations, water quality and subsidence	$300,000
Projects and Management Actions	See Section 1 for a list of Projects and Management Actions	TBD
Annual Report	Coordination with the KGA for annual reporting to DWR	$100,000
Sustainability Management and Coordination	Participation and coordination with KGA on implementation of sustainability management practices	$100,000
5-Year GSP Update and Report	Coordination with the KGA for plan updates	$200,000

1.3.2 GSP Implementation Funding

The SWSD has existing authority, as well as its authority as a GSA, to impose fees, charges, assessments, and other levies to implement its GSP. The District collects fees for the general management of water resources under its existing General Project Services Charges to landowners. The District will utilize these fees, as appropriate, to continue to fund authorized water management activities. The District will also develop additional fee structures to collect additional funds to support the projects and management actions identified in Section 5 of this GSP and the administrative costs estimated in Table 1-2.

The costs associated with some of the projects and management actions identified in this GSP will be funded by the District for the benefit of all landowners participating in the General Project Service Charge or by a subset of landowner who elect to participate in certain projects (pay-to-play projects). New or increased District funding efforts requiring landowner participation may be subject to the Proposition 218 process. The District will also seek funding through State and federal grant programs to fund projects and management actions, as appropriate.

1.4 Description of Plan Area

The Semitropic Area is bounded by the Southern San Joaquin Municipal Utility District (SSJMUD), Shafter-Wasco Irrigation District (SWID), and North Kern Water Storage District (NKWSD) to the east; Rosedale Rio Bravo Water Storage District (RRBWSD) to the south; and Buena Vista Water Storage District (BVWSD) and Lost Hills Water District (LHWD) to the west, as shown in Figure 1-1. The northern boundary of the Semitropic Area is coincidental with the Kern County Subbasin's northern boundary and with undistricted lands in the unincorporated portion of Kern County. The Semitropic Area represents approximately 11% of the area within the Subbasin.

There are no adjudicated areas or incorporated cities within the Semitropic Area. There are a number of *de minimis* domestic water users and multi-parcel water systems located within the Semitropic Area, which are covered by this GSP.

1.4.1 Plan Area Setting

The total service area of SWSD is approximately 222,600 acres with approximately 144,100 acres of irrigated lands (including 6,400 acres of managed wetlands), 8,960 acres associated with the Kern National Wildlife Refuge, and the remainder being comprised of 69,500 acres of primarily undeveloped native vegetation. While the total irrigated acreage remains fairly consistent, the parcels actually receiving water from the district varies from year to year, based on decisions made by the landowners as to which properties will be irrigated and which crops will be grown. Land use within SWSD consists mainly of agricultural production and environmental land uses, as shown in Figure 1-2. Figure 1-3 shows the areas within the District that currently receive surface water and the areas that are dependent on groundwater. While some areas of the District receive surface water through the District, all areas of the District are dependent on groundwater to varying degrees.

Well densities for production, domestic, and public supply wells within the District are presented on Figures 1-4 through 1-6, respectively. This dataset is based on well statistics provided by DWR (2018d) from the Online System for Well Completion Reports (OSWCR) and is intended to be for qualitative informational purposes. Production wells include those described in completion reports as irrigation, municipal, public, or industrial wells. Well densities in the District ranging from 0 wells per sq. mi. to 13 wells per sq. mi. The well density for all well types is shown in Figures 1-4 through 1-6. These figures show well types for domestic, production, and public wells, respectively. Figure 1-4 shows the density of domestic water supply wells with the District, ranging from 0 to 6 wells per sq. mi. throughout SWSD. Figure 1-5, provides the density of production wells, generally ranging from 0 to 13 wells per sq. mi., with a majority of the area showing well densities of 2 to 4 wells per sq. mi. There are only a few public wells located within SWSD, as shown in Figure 1-6.

SWSD JURISDICTIONAL AREA

- Semitropic WSD Jurisdictional Area
- SWSD Service Area Boundary (v20190808)

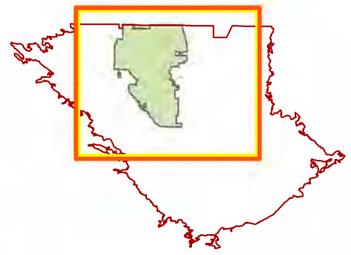
Adjacent Districts

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

- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4 8
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 1-1

SOURCE: SWSD (2019), DWR (2019)

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM0230_Jurisdictional_Area.mxd SI

LAND USE WITHIN SWSD

- Semitropic WSD GSA
- Kern County Subbasin Boundary

Land Use

- Agriculture
- Riparian Vegetation
- Native Vegetation
- Commercial
- Industrial
- Residential
- Urban Landscape
- Urban
- Surface Water
- Vacant

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 1-2

SOURCE: Land IQ, 2014; Kern County, 2016; DWR, 2006.

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM016_LandUse.mxd SI

SWSD AREAS RECEIVING SURFACE WATER

- Surface Water Deliveries
- Groundwater Dependent Area
- Semitropic Water Storage District
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 1-3

SOURCE: Safe Drinking Water Information System (2019)

05-Dec-2019 Z:\Projects\1704941_Semitropic_ET\SEM035_AreasReceivingSurfaceWater.mxd SI

WELL DENSITY BY SECTION (DOMESTIC WELLS)

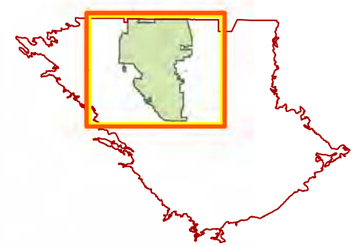
Domestic Well Count by Section

- 1 - 2
- 3 - 5
- 6 - 10
- 11 - 18
- 19 - 32

- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 1-4

SOURCE: DWR (May 2018)

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM31_WellDensity_Domestic.mxd SI

WELL DENSITY BY SECTION (PRODUCTION WELLS)

Production Well Count by Section

- 1 - 2
- 3 - 5
- 6 - 10
- 11 - 18
- 19 - 32

- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 1-5

SOURCE: DWR (May 2018)

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM32_WellDensity_Production.mxd SI

WELL DENSITY BY SECTION (PUBLIC WELLS)

Public Well Count by Section

- 1 - 2
- 3 - 5
- 6 - 10
- 11 - 18
- 19 - 32

- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 1-6

SOURCE: DWR (May 2018)

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM033_WellDensity_Public.mxd SI

All the state small and multi-parcel water systems in the SWSD jurisdictional areas are groundwater dependent. There are no incorporated cities within SWSD. The *de minimis* domestic water users located within SWSD jurisdictional areas are groundwater dependent.

1.4.2 Existing Plans in Plan Area

There are existing water management plans within the SWSD plan area: the 2007 Poso Creek Integrated Water Management Plan (IRWMP), the SWSD 2012 Groundwater Management Plan (GMP) and the 2013 Agricultural Water Management Plan.

Adopted in July 2007, the Poso Creek IRWMP was created to address short and long-term water supply challenges at a regional scale. The IRWMP was developed by the Poso Creek Regional Management Group comprised of seven agricultural districts, of which the SWSD was the lead agency. Groundwater goals within the IRWMP included:

- Maintaining groundwater levels at economically viable pumping lifts;
- Protecting the quality of groundwater and enhance where practical; and
- Enhancing monitoring activities to meet groundwater levels and water quality goals.

Of the highest priority in the IRWMP was facilitating enhanced groundwater management through increased recharge capacities, improved conveyance and coordinated operation of water management programs. Within the Subbasin's boundaries, federal, state, local, and regional programs monitor groundwater levels, groundwater and surface water quality, surface water inflow, weather and precipitation, and land subsidence. A description of these existing monitoring programs is provided in the basin setting and monitoring network sections of this GSP. In addition to these regional and district plans, the Kern County General Plan has land use elements which address water usage.

1.4.2.1 Kern County General Plan

The Kern County General Plan (2009) contains provisions within the land use, open space and conservation element that relate specifically to groundwater resource management. These provisions are:

Policy #10: To encourage effective groundwater resource management for the long-term economic benefit of the County, the following shall be considered:

a. Promote groundwater recharge activities in various zone districts.
b. Support for the development of Urban Water Management Plans (UWMP) and promote DWR grant funding for all water providers.
c. Support the development of groundwater management plans.

d. Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water and groundwater, and desalination.

Under the general provisions of the General Plan, there is a section which deals specifically with surface and groundwater. This section includes a policy statement which states that the County will "encourage the development of the County's groundwater supply to sustain and ensure water quality and quantity for existing users, planned growth, and maintenance of the natural environment" and that "new high consumptive water uses, such as lakes and golf courses, should require evidence of additional verified sources of water other than local groundwater. Other sources may include recycled stormwater or wastewater."

The implementation measures listed in the general provisions which are directly related to groundwater are:

Measure U: The Kern County Environmental Health Services Department will develop guidelines for the protection of groundwater quality which will include comprehensive well construction standards and the promotion of groundwater protection for identified degraded watersheds.

Measure X: Encourage effective groundwater resource management for the long-term benefit of the County through the following:

i. Promote groundwater recharge activities in various zone districts.

ii. Support for the development of UWMP and promote DWR grant funding for all water providers.

iii. Support the development of groundwater management plans.

iv. Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water and groundwater and desalination.

Measure Z: General Plan amendments subject to environmental review and not otherwise subject to California Water Code Section 10910 shall demonstrate through a water supply assessment that a long-term water supply for a 20-year timeframe is available. The water assessment shall include, but not limited to, the following:

i. Source and quantity of historical water use on the site.

ii. Estimated water consumption of the proposed development.

iii. Estimated storage, if any, in meeting the projected need.

iv. Recommendations for additional sources of water to address demand shortage. Such measures may include, but not limited to, development of future sources of additional surface water and groundwater, including water transfers, conjunctive

use, recycled water, conservation, and additional storage of surface water, groundwater, and desalination.

Written acknowledgement that water will be provided by a community or public water system with an adopted UWMP shall constitute compliance with this requirement.

1.4.3 Plan Elements from CWC Section 10727.4

Per Section 354.8(g) of the GSP emergency regulations, additional plan elements pertaining to Water Code Section 10727.4 shall be included in order to comply with SGMA. This section provides a general overview of plan elements with reference to sections included throughout this chapter for further details.

A. Control of Saline Water Intrusion

Seawater intrusion is not considered an issue in the Subbasin. The coastal range provides a barrier, preventing seawater from coming into contact with groundwater flow in the Subbasin.

B. Wellhead Protection Areas and Recharge Areas

Permits are issued by the Kern County Public Health Services Department (KCPHSD) Water Well Program to construct, reconstruct, and destroy water wells. The District assists its landowners through this process to comply with the wellhead protection area program. This program was implemented through the Safe Drinking Water Act and aims to prevent contamination in public water systems. The District also manages recharge areas such as the Pond-Poso Spreading Grounds. SWSD participates in adjacent water district recharge programs such as for the Kern Water Bank and the Pioneer Project.

C. Migration of Contaminated Groundwater

There are no known groundwater contamination plumes within SWSD's boundaries.

D. Well Abandonment and Well Destruction Program

The KCPHSD issues permits to destroy water wells. The process consists of completing a water well permit through the county. All state and county regulations must be followed during the destruction process. According to the Kern County Ordinance Code 14.08, any wells that are abandoned or wells with inadequate water supply must be destroyed. Furthermore, any abandoned wells on the site of an active new well construction permit must be destroyed prior to construction.

E. Replenishment of Groundwater Extractions

To manage the groundwater basin within its boundaries, the district actively participates in conjunctive use or underground storage programs (see Section 2.7.2). In addition to these efforts,

the district will work to implement additional projects to bring more water into the basin to maintain sustainable groundwater conditions.

F. Conjunctive Use or Underground Storage

The District actively participates in conjunctive use and underground storage programs to manage the groundwater basin within its boundaries. These projects aim to reduce demand on local groundwater resources. Projects include land fallowing, expansion of recharge facilities and water banking on behalf of the District (see Section 2.7.2).

G. Well Construction Policies

The KCPHSD, Environmental Health Division, issues permit to construct, deepen, or replace water wells. The permitting process consists of a county water well permit and the SGMA implemented Overdraft Supplemental Well Application accompanied by detailed site maps.

H. Groundwater contamination cleanup, groundwater recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects

Regarding groundwater contamination cleanup, there are no known groundwater contamination plumes within District's boundaries. For further details see Section 2.3 of this GSP.

Through its water management practices, the District is constantly pursuing water conservation. Efficient water management practices are described in District's GMP, which was updated in 2012. In addition to its conservation efforts, the District manages multiple groundwater recharge facilities and a large conveyance system that is used to deliver surface water for beneficial use in the District thereby reducing reliance upon the groundwater basin. For information regarding in-lieu use, water recycling, and extraction projects, see Section 2.7.2.

I. Efficient Water Management Practices

The District currently follows two existing groundwater management plans: Poso Creek IRWMP and the SWSD GMP. These plans were implemented to approach short and long-term water supply challenges throughout the region. These challenges were combatted with increased recharge capacities, improved conveyance, and coordinated operation of the water management programs.

J. Relationships with State and Federal Regulatory Agencies

The SWSD works closely with the Kern County Water Agency and the DWR for the coordination and delivery of its State Water Project supply. The District also coordinates with other state and federal agencies as needed to manage its water supplies, construct and implement water management projects, monitor and report local water conditions and coordinate and provide input to local, regional and state water policy matters.

K. Land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity.

Documents pertaining to land use plans and coordination between planning agencies are included in Section 1.4.2 of this GSP. The District will continue to coordinate with the KGA and other GSAs in the Subbasin as the SGMA implementation process proceeds.

L. Impacts on Groundwater Dependent Ecosystems

There is the potential for Groundwater Dependent Ecosystems (GDE) in the western portion of the District and along Poso Creek. However, the presence of GDE's has not been verified. Section 2.3 of this GSP provides an overview of the available information regarding GDEs in the District.

1.5 Notice and Communication

Per Section 354.10 of the DWR's GSP emergency regulations, the following sections discuss the notice and communication processes conducted by the GSA with other agencies and interested parties. A list of public outreach meetings and workshops for the District's beneficial water uses and users and other interested parties are provided along with a brief overview of their respective purposes.

1.5.1 Participating Agencies

The following agencies are engaged in public outreach activities related to the development of this GSP:

- Semitropic Groundwater Sustainability Agency
- Semitropic Water Storage District
- Kern Groundwater Authority

1.5.2 Beneficial Uses and Users

As required by Section 354.10(a) of the GSP emergency regulations, beneficial use and users in the District's portion of the Subbasin have been identified. The beneficial uses of groundwater in the Plan Area, consistent with the uses identified in DWR Bulletin 118, are:

- Agricultural
- Municipal and Industrial
- Domestic
- Environmental

Users of groundwater have been identified as landowners, agricultural operations (including farms, dairies, and food processors), rural residents, managed wetlands, commercial and industrial, the Wasco State Prison, and unincorporated communities. These beneficial users of groundwater have been identified as stakeholders for public outreach activities in the Semitropic Area.

1.5.3 Public Meetings

Throughout the development of this GSP, Semitropic has conducted a series of public meetings to educate and engage the beneficial users within the District boundaries regarding the planning and implementation of SGMA. Semitropic has also participated in and encouraged its beneficial users to participate in public meetings held by the KGA. A list of all meetings conducted by the District is provided in Table 1-3 below.

Following the enactment of SGMA in 2014, the District formed its own GSA and began conducting public outreach meeting and workshops to educate its beneficial users on SGMA implementation and to open the lines of communication for the development of this GSP. Active participation was encouraged for all beneficial users in order to accurately reflect the diverse social, cultural, and economic elements of the beneficial users in this GSP.

GSA-related items have been included in Semitropic's board agendas regularly since 2017. The principal purpose of these items is to coordinate with stakeholder and provide updates on meetings with members of the KGA as well as work to develop Semitropic's GSP. In addition to public board meetings, Semitropic conducted a series of public workshops and stakeholder meetings with the intent to garner feedback from the District's beneficial users. Large stakeholder outreach meetings occurred following by small group meetings, which gave stakeholders an opportunity to discuss workshop materials to provide feedback and recommendations on various elements of the GSP including, but not limited to, management areas, water budgets, and sustainable management criteria.

Feedback received was taken under consideration and used in the development of this GSP. The GSA Board, along with the General Manager and Consultant, considered feedback to formulate a plan that accurately captures all beneficial use/users and their interests with a goal to achieve groundwater sustainability by 2040.

All applicable meeting materials can be found on the groundwater communication portal on the District's website, which is provided in Section 1.2.1. The GCP is used to communicate all information regarding the GSA as well as the development and implementation of this GSP. This portal allows interested parties to register as an interested party in order to receive updates on upcoming events to stay informed of the GSA's activities.

Table 1-3. Public Meetings and Workshops

Date	Meeting	Purpose
October 29, 2015	SWSD Special Board Meeting	Introduction to SGMA and overview of initial steps for SGMA compliance.
April 12, 2017	SWSD Board Meeting	Discussion of SGMA.
July 11, 2017	GSA Board Meeting	Discussion of KGA participation and introduction of coordination agreement.
July 17, 2018	Semitropic Landowner Meeting	Presentation on SGMA, GSP participants, and overview of GSP Development.
August 8, 2018	GSA Board Meeting	Update on meetings with members of KGA and development of minimum thresholds.
September 12, 2018	GSA Board Meeting	Update on meetings with members of KGA and development of minimum thresholds as well as GSA areas of coverage.
October 9, 2018	GSA Board Meeting	Presentation on SGMA related topics discussed with member of KGA as well as discussion of undesirable results, sustainable management criteria, and management areas.
November 14, 2018	GSA Board Meeting	Update on GSP development as well as discussions of sustainable management criteria.
December 12, 2018	GSA Board Meeting	Update on GSP Development.
January 9, 2019	GSA Board Meeting	Update on SGMA and GSP development.
January 15, 2019	SGMA: Stakeholder Workshop	Review presentation of SGMA; GSP participants; and overview of GSP Development and sustainable management criteria. Meeting ended with a questions and answers session.
January 28, 2019	Hydrologic Zone Landowner/Stakeholder Meetings	Group meetings with landowners by hydrologic zones within SWSD to discuss January 15 meeting materials.
January 29, 2019	Hydrologic Zone Landowner/Stakeholder Meetings	Group meetings with landowners by hydrologic zones within SWSD to discuss January 15 meeting materials.
February 13, 2019	GSA Board Meeting	Review of stakeholder and landowner meetings that occurred in January as well as presentation on projected water levels through 2030. Discussion of setting initial MTs and MOs.
March 13, 2019	GSA Board Meeting	Update on GSP Development.
April 10, 2019	GSA Board Meeting	Update on GSP Development.
May 14, 2019	KGA SGMA Open House	Participate in Open House with poster board exhibits providing information on District's GSP, address

Date	Meeting	Purpose
		questions from stakeholders.
May 15, 2019	GSA Board Meeting	Review of May 22 workshop materials as well as discussions regarding water budgets and projects and management actions to achieve sustainability.
May 22, 2019	SGMA Stakeholder Workshop	Presentation of Semitropic GSA's SGMA compliance strategy and review of draft district water budget followed by a questions and answers session.
June 12, 2019	GSA Board Meeting	Review of ET analysis and coordination with landowners as well as report on GSP development. Review of KGA action requests.
July 10, 2019	GSA Board Meeting	Update on GSP Development
August 14, 2019	GSA Board Meeting	Review and approval of Draft GSP for Public Review and inclusion to KGA GSP
August 28, 2019	KGA Board Meeting	Present summary review of District GSP for approval of inclusion into KGA GSP
September 11, 2019	GSA Board Meeting	Update on GSP activities and public review process
September 26, 2019	KGA SGMA Open House	Participate in Open House with poster board exhibits providing information on District's GSP, address questions from stakeholders.
October 9, 2019	GSA Board Meeting	Update on GSP activities and public review process
October 24, 2019	SGMA Stakeholder Workshop	Review content of District's Draft GSP and provide directions for providing comments, followed by a question and answer session.
November 13, 2019	GSA Board Meeting	Update on GSP activities and public review process
December 11, 2019	GSA Board Meeting / Public Hearing	Public Hearing for the adoption of the District's GSP and approval for submittal to DWR.

All applicable meeting materials can be found on the groundwater communication portal on the District's website, which is provided in Section 1.2.1. The GCP is used to communicate all information regarding the GSA as well as the development and implementation of this GSP. This portal allows interested parties to register as an interested party in order to receive updates on upcoming events to stay informed of the GSA's activities.

1.5.4 Comments Received

In addition to the comments received during the outreach process identified in Table 1-3, the District provided for a formal comment period, between August 14, 2019 to November 28, 2019. This comment period also generally corresponded to the formal comment period established by

the KGA. The District received comments both directly, through mail and email, and through the KGA comment process.

The District received a total of 20 comments addressing some aspect of this GSP. Those comments are included in Appendix A.

1.6 GSP Organization

The District has developed this GSP using the GSP emergency regulations in conjunction with the SGMA Best Management Practices (BMPs). This GSP is organized as stated in Table 1-4 below.

Table 1-4. GSP Organization

Section	Title
1.0	Introduction
2.0	Basin Setting
3.0	Sustainable Management Criteria
4.0	GSP Monitoring Network
5.0	Projects and Management Actions
6.0	References and Technical Studies

This Page Left Blank Intentionally

2. Basin Setting

The Basin Setting is made up of the hydrogeologic conceptual model, the current and historical groundwater conditions, the water budget components of the Subbasin, and the description of Subbasin management areas. This section provides the local and regional details as context for defining and assessing reasonable sustainable management criteria and projects and management actions for SWSD.

2.1 Reference to Umbrella GSP and Local Sources of Data

Regional details for the entire Subbasin basin setting are included in the umbrella level section for the KGA GSP; whereas, most of the discussion provided in this section focuses on the extent of SWSD boundaries and the immediate vicinity. Pertinent details related to the entire Subbasin that apply to SWSD such as the definition of the vertical and lateral extents of the groundwater subbasin and the regional geology, regional structural setting, and aquifer hydrostratigraphy, are presented in this section.

In addition to pertinent regional data referenced from the umbrella level basin setting, much of the data presented in this section are based on subject matter presented in the *Semitropic Water Storage District 2012 Groundwater Management Plan* (SWSD, 2012), and the *Biennial Groundwater Monitoring Report for the Semitropic Water Storage District Water Banking Project (2015-2016)* (Schmidt and Associates, 2018).

2.1.1 Local Refinements to the Umbrella Setting

As mentioned above, this basin setting is a more detailed discussion as it relates to the SWSD GSA, both in text and in the maps presented herein. These local refinements are consistent with the interpretation and presentation of the umbrella basin setting. Many details and figures presented in the umbrella are also included and/or referenced in this basin setting.

2.2 Hydrogeologic Conceptual Model (HCM)

The HCM characterizes the physical components and interaction of the surface water and groundwater systems in the Semitropic Area. A brief description of the regional geology and structural setting of the area, including the vertical and lateral extents of the groundwater subbasin, groundwater flow, aquifer characteristics, and other physical characteristics are presented in this section.

2.2.1 Basin Regional Setting

As described in the umbrella basin setting, the Subbasin (5-22.14) is located in the southern San Joaquin Valley (Figure 2-1), known as the Tulare Lake Region of the Central Valley.



Figure 2-1. Central Valley Hydrologic Regions-Tulare Lake Region

The Tulare Lake Region encompasses the Central Valley subbasins from just north of Fresno to the Tehachapi Mountains and San Emigdio Mountains at the southern end of the valley; with the Sierra Nevada Mountains (Sierra Nevada) to the east, and the Coast Ranges to the west. SWSD is situated in the northern central portion of the Subbasin.

2.2.1.1 Sediment Deposition

The southern San Joaquin Valley (and most of the Central Valley), was a large basin with marine deposition occurring from Late Jurassic and Cretaceous Periods into the Tertiary Period. Thereafter, continental deposition of alluvial, fluvial, and lacustrine sediments occurred along the margins and into the center of the valley. These younger sediments were derived from the surrounding mountain ranges (Planert and Williams, 1995). A conceptual block diagram below (Figure 2-2) is provided as a general example of the sequence of deposition in the valley and shows the source of most fresh water into the basin originates from the Sierra Nevada mountains.

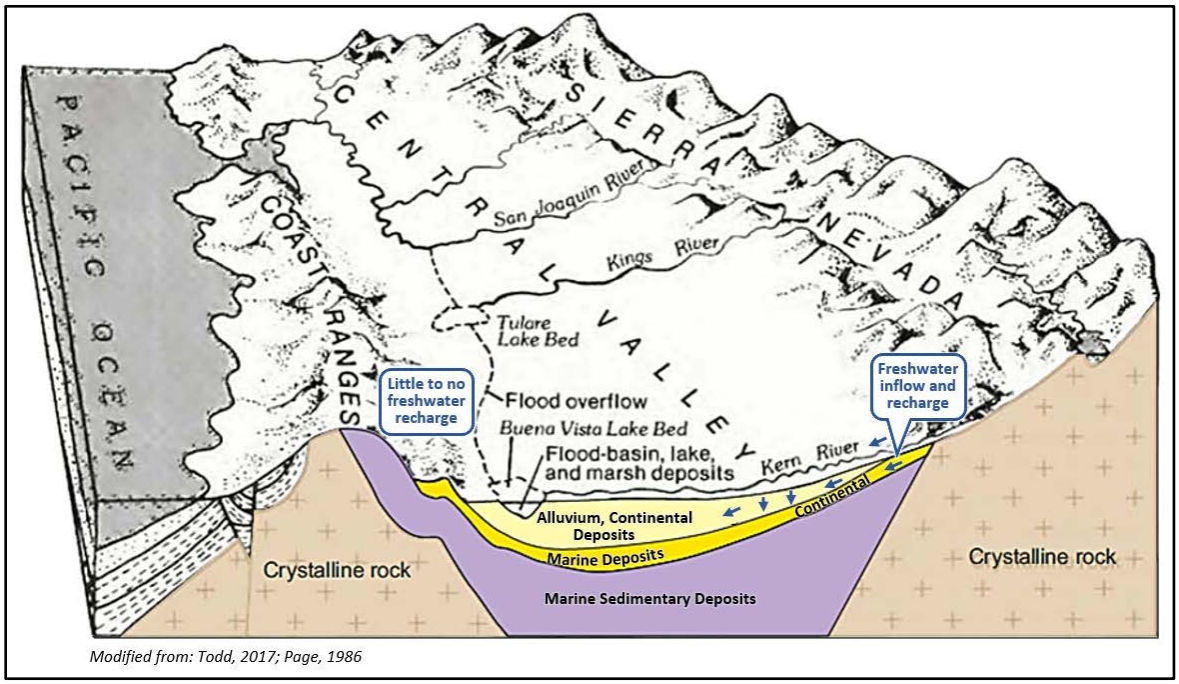


Figure 2-2. Conceptual Block Diagram Looking North from Kern River

During the late Tertiary and Quaternary Periods, crustal uplift raised the Sierra Nevada and Coast Range, causing the sea to regress out of the valley to its current position. While the sea regressed, continental deposits from alluvial, fluvial, and lacustrine systems were deposited over Tertiary-age marine sediment (Page, 1986). The continental deposits were produced by episodic Pleistocene glaciation in the Sierra Nevada mountains and continental erosion from the mountainous margins around the valley (Sierra Scientific, 2013). On the east side, these deposits were derived from the igneous and metamorphic rocks of the Sierra Nevada. On the west side, the continental erosion produced sediments from the marine rocks in the Coast Range and deposited these sediments on the west side of the valley during the regression. Some of these deposits, such as the Reef Ridge, Etchegoin, and San Joaquin Formations (derived from the

Coast Range), contain saline water, which may have migrated into adjacent and overlying fresh-water deposits (Page, 1986). Consequently, the alluvial aquifer system in the southern San Joaquin Valley is mostly comprised of continental deposits with fresh water on the central and eastern side, while eroded marine deposits produce water that is more saline on the western side (Page, 1986).

During the Quaternary Period, brackish and freshwater lakes were present within the southern San Joaquin Valley and produced thick deposits of clay, as found throughout the upper Tulare Formation and the Corcoran Clay. This clay has been mapped over much of the San Joaquin Valley and other equivalent clays have been correlated to clays beneath the Kern and Buena Vista dry lake beds in the southern part of the Subbasin, as well as the Tulare Lake sediments on the northern boundary of Kern County (Wood and Dale 1964; Croft 1972). Croft (1972) correlated six clays within the Corcoran Clay member and designated them as the A- (youngest) B-, C-, D-, through the E- (oldest) clay. Page (1986) presented the modified "E" Clay as a differing correlation of the E-Clay near the Buena Vista and Kern Lake Beds areas. These clay layers and especially the modified "E" clay is generally impermeable to semipermeable and divides shallower poor-quality water from higher quality water within the alluvial aquifer system and will be further described in the Section 2.2.3 Principal Aquifers and Aquitards.

2.2.2 Lateral and Vertical Boundaries of Groundwater for SWSD

The SWSD GSA manages an area that encompasses a large portion of the Subbasin, north of the Kern River. The SWSD GSA portion of the Subbasin is generally bounded to the north by Kings and Tulare County lines; to the east by the SSJMUD along CA Highway 43, NKWSD, and SWID; to the west by BVWSD boundary and LHWD, which overlaps the canal and aqueduct areas; and to the south by RRBWSD.

Within the jurisdiction of SWSD GSA, natural boundaries define the lateral and vertical extent of groundwater and the beneficial use of the groundwater in SWSD.

The KGA "Umbrella GSP" provides context for the discussion of lateral and vertical extents of groundwater in the Subbasin. By applying California Water Code §10723.2, the bottom of the groundwater subbasin includes groundwater that can be applied to beneficial use. In general, the groundwater subbasin extent, where no exemptions or commercially producible hydrocarbons or minerals exist, likely ranges between 3,000 milligrams per liter (mg/L) and 10,000 mg/L of total dissolved solids (TDS) depending on the feasibility of treatment and recovery of the groundwater for beneficial use.

2.2.2.1 Datasets with Lateral and Vertical Distribution of Groundwater in the Subbasin

The KGA Umbrella GSP basin setting discusses the use of Page's 1973 interpretation of the depth to the base of freshwater to consider the vertical and lateral distribution of groundwater at 2,000 mg/L of TDS. The base of fresh water as reported by Page (1973), is not however, the defined bottom of the groundwater subbasin. Nonetheless, based on Page's data (Figure 2-3), the

base of 2,000 mg/L TDS "freshwater" ranges from approximately -120 ft mean sea level (msl) (370 feet below ground surface), east of Lost Hills, to -550 ft msl north of Buttonwillow, to -1,150 ft msl west of SWID and Wasco, and -1,600 ft msl in the northeast just west of SSJMUD.

The depth to groundwater with a TDS of 10,000 mg/L (Figure 2-4), (one of the criteria for the USDW), is also presented herein as a dataset that presents the vertical and lateral distribution of based on recent research in the Subbasin (Gillespie et. al., 2017). As described by Gillespie et. al. (2017), the depth to 10,000 mg/L TDS was based on geochemical analysis of water samples and geophysical log analysis. The 10,000 mg/L TDS ranges from approximately -1000 ft msl (~1200 ft below ground surface (bgs)) northwest of Semitropic Ridge to -1,800 ft msl (~2,100 ft bgs) in the southeast and central-east portion of the District, and -1,900 ft msl (~2,190 ft bgs) in the northeast portion of the District.

Both the lateral and bottom boundaries of the groundwater in the Subbasin are constrained by the primacy productive limits with depths to hydrocarbons, and aquifer exemptions with corresponding depths. However, within SWSD there are no aquifer exemptions, and the oil field depth to hydrocarbons are below the base of the underground source of drinking water (USDW); therefore, there are no documented primacy limits or exemptions that are within close proximity to the boundaries of SWSD.

2.2.2.2 Vertical and Lateral Extent of Groundwater in SWSD

As depicted below, in a conceptual profile (Figure 2-5) of the groundwater basin in SWSD, the groundwater basin is laterally continuous until reaching the west side of the District, where groundwater in the lower zone is poorer quality and is not of the main production zone of the aquifer. Although the conceptual profile does not illustrate the oil fields within SWSD, as stated above, there are no primacy limits or aquifer exemptions within the boundaries of SWSD. Within the study area, Page's (1973) base of freshwater is shallowest on the west side and increases in depth toward the east and northeast. The vertical and lateral extents of the individual aquifer zones are provided in the aquifer section of this report.

2.2.3 Principal Aquifers and Aquitards

Several thousand feet of sediments have been deposited in an asymmetrical northwest-to-southeast-trending Kern County Subbasin, as described above and in the KGA Umbrella GSP. However, only the upper few thousand feet are considered aquifer material (SWSD, 2012), and as described in the above section, the west boundary of the district contains poor quality water with a base of fresh water (Page, 1973) that is much shallower than the east side. SWSD is located at or just east of the axis of the main valley trough where up to a few hundred feet of alluvium from the Sierra Nevada may underlie the study area (Croft, 1972). Interfingering with the alluvium and below it, are two thick sequences of valley aquifer sediments; the Tulare and Kern River Formations (Croft, 1972 and LADWP, 1974).

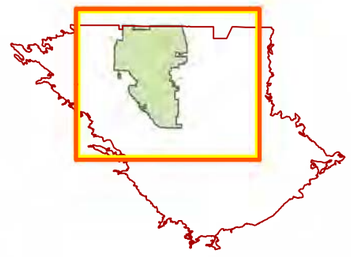
This Page Left Blank Intentionally

BASE OF FRESHWATER BY PAGE (1973) AND NON-USDWS

- Elevation Contour of Specific Conductance 3,000 micromhos per centimeter (Page-1973)
- Elev — Primacy Productive Limits (Hydrocarbon max Elevation)
- Elev — Aquifer Exemption (max Elevation)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4 8 Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-3

NOTES:

(Approximate) Elevation of base of fresh water (Specific conductance generally less than 3,000 micomhos per centimeter) or ~2,000 mg/L TDS.

Hydrocarbon elevations from primacy productive limits represent difference between average surface elevation and minimum depth of productive limit.

Elevation to hydrocarbons and the top of exempted aquifers are generalized. Refer to the report table for details. Exemptions are subject to change as applications are approved.

Per 40 CFR §144.3, exempted aquifers are not USDWs. Based on criteria of 40 CFR §146.4, primacy productive limits are not suitable USDWs.

USDW: Underground Source of Drinking Water (Source: Code of Federal Regulations).

Datum is Mean Sea Level

SOURCE: Base of Fresh Groundwater (Approximately 3,000 micromhos) in the San Joaquin Valley, California (R.W. Page 1973)

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM001_FreshwaterBase_Page1973_andDOGGR_PPL_Elevs.mxd SI

BASE OF 10,000 PPM TDS BY GILLESPIE ET. AL (2017) AND NON-USDWS

Elevation Contour of 10,000 mg/L TDS (Gillespie et.al. 2017)

Elev — Primacy Productive Limits (Hydrocarbon max Elevation)

Elev — Aquifer Exemption (max Elevation)

Semitropic WSD GSA

Kern County Subbasin Boundary

All Other Features

Highway

Waterway

Major Conveyance

NOTES:

(Approximate) Elevation of ~10,000 mg/L TDS.

Hydrocarbon elevations from primacy productive limits represent difference between average surface elevation and minimum depth of productive limit.

Elevation to hydrocarbons and the top of exempted aquifers are generalized. Refer to the report table for details. Exemptions are subject to change as applications are approved.

Per 40 CFR §144.3, exempted aquifers are not USDWs. Based on criteria of 40 CFR §146.4, primacy productive limits are not suitable USDWs.

USDW: Underground Source of Drinking Water (Source: Code of Federal Regulations).

Datum is Mean Sea Level

SOURCE: Approximately 10,000 mg/L TDS in the San Joaquin Valley, California (Gillespie et.al. 2017)

0 2 4 8 Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-4

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM002_FreshwaterBase_Gillespie2017_and_DOGGR_PPL_Elevs_20190508.mxd SI

The bottom of these formations effectively defines the lower extent of the aquifer system. As the base of fresh water is approached, the water progressively becomes more brackish, until is no longer considered suitable for beneficial use (SWSD, 2012), without blending or additional treatment.

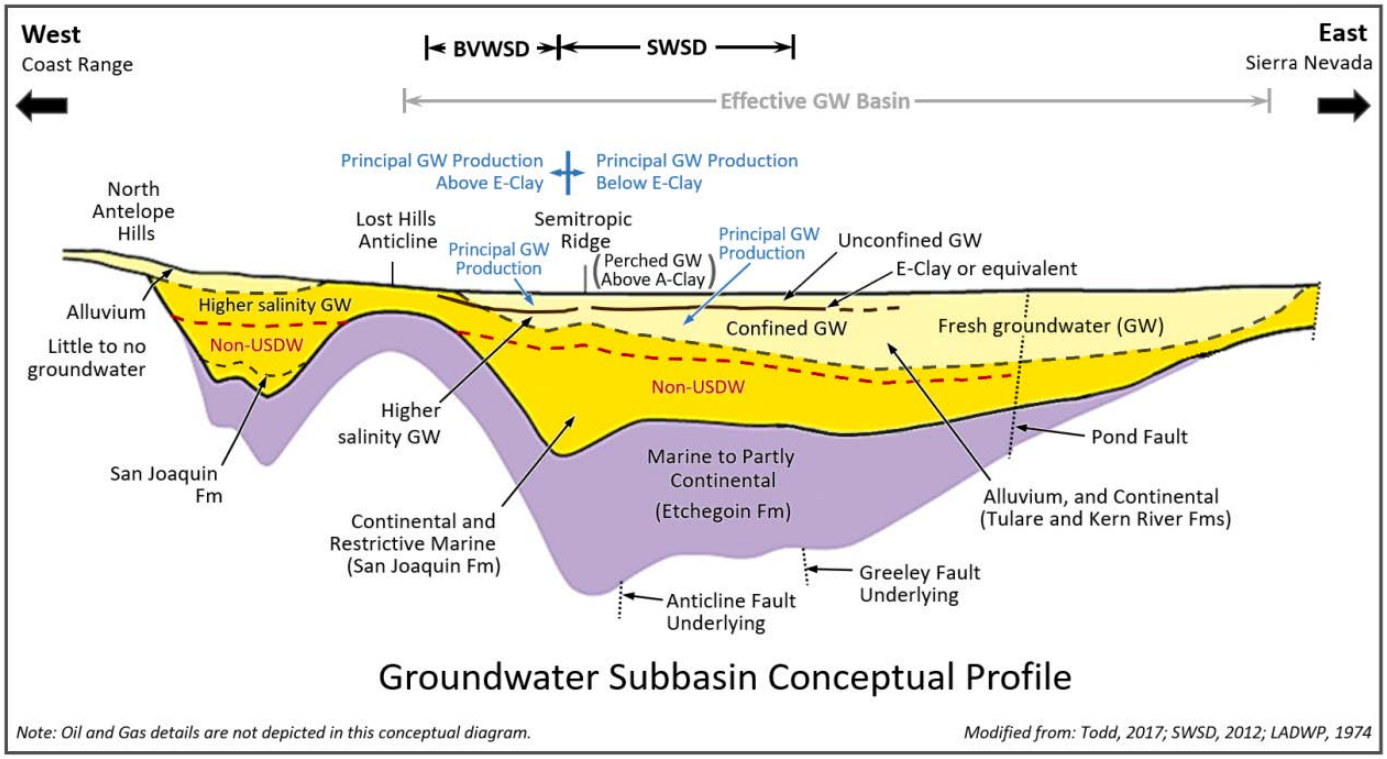


Figure 2-5. Groundwater Subbasin Conceptual Profile

As depicted below in the conceptual diagram (Figure 2-6) of general aquifer zones, the groundwater beneath SWSD is made up of:

1) a shallow aquifer zone (above the A-Clay or other equivalent);
2) an upper zone (unconfined to semiconfined) above the E-Clay or other equivalent); and
3) a lower zone (semiconfined to confined) below the E-Clay and extends to the base of fresh water (Page, 1973).

Below the base of fresh water is the USDW. Due to the lenticular nature of the subsurface, other localized zones of groundwater may be present, such as the "transition zone" reported in other investigations where water quality increases in dissolved solids until reaching the base of fresh water, and the "saline zone" where salinity below the base of fresh water increases to 5,000 mg/L salinity (SWSD, 2012); however, the transition zone is considered within the lower zone because it is below the E-Clay, and it transitions into the base of fresh water (Page, 1973), and the "saline zone" falls within the base of fresh water and the USDW.

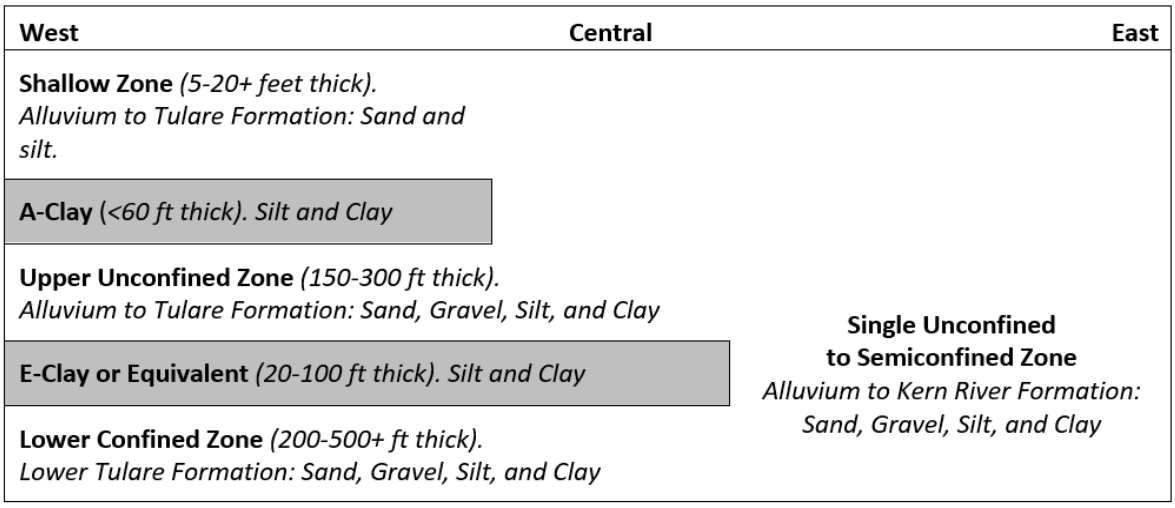


Figure 2-6. General Aquifer Zones of SWSD

2.2.3.1 Aquitards or Equivalent E-Clay

The description of confining beds or aquitards in this report relies heavily on Croft's (1972) designation of Corcoran A- through E- Clays, Page's (1986) modified E-Clay, and DWR's C2VSim interpretation (DWR, 2018). However, many different studies report significant differences in the Corcoran Clay (including E-Clay) correlation (Croft, 1972; LADWP, 1974; PGA, 1991; DWR, 2018a; and USGS, 2018a). Nonetheless, the presence of confining beds at various approximate depths between 300 and 400 feet below ground surface in the central part of the study area are considered the approximate boundary between the upper aquifer zone and the lower aquifer zone. For ease of discussion with previous studies, this approximate boundary may be synonymous with the Corcoran Clay, E-Clay, modified E-Clay, or other equivalent confining beds in this report. The term "confining beds" will generally be used in this report. For discussion of the shallow aquifer zone and shallow clays, Croft's (1972) designations of the A- and C-Clay are used.

2.2.3.2 Summary of Aquifer Zones

A summary of vertical and lateral extents of these aquifer zones is provided below. Additional details are provided in the subsequent description.

- A shallow aquifer zone, with water levels monitored from 5 to 20 feet below ground surface (KCWA, 2011; 2019), is typically situated in alluvium, and above the A-Clay in the western part of the study area (roughly 10 to 60 feet below ground surface) (Croft, 1972). The subsurface is generally saturated from the shallow aquifer zone to the base of the upper zone above the Corcoran Clay. Based on hydrographs presented in this report, shallow zone water levels trend with the upper aquifer zone in the north and west portions of the district. It is possible that the shallow zone is perched in the southeast portion of the study area, where upper zone water levels are lower. In general, monitoring

of the shallow zone is limited to the northwest and west sides of the district and adjacent BVWSD (Croft, 1972; KCWA, 2011; and Sierra Scientific, 2013), where shallow clays are present. The A-Clay is generally less than 60 feet thick (Croft, 1972). A depth to groundwater map for the shallow zone is included with the umbrella basin setting. This map has been included with Kern County Water Agency's (KCWA) Water Supply Reports for the last decade. This shallow zone is likely the result of percolation from applied surface water for irrigation, as well as recharge from unlined conveyance, and managed application of surface water to the Kern National Wildlife Refuge. The upper zone (unconfined to semiconfined) is present below the shallow zone. It may occur throughout the entire District although additional data is needed to confirm the extends to the west into BVWSD where it is the principal groundwater production zone for BVWSD. The upper zone extends from SWSD east into SSJMUD and likely into SWID and NKWSD, where it merges with the lower zone into a single aquifer at the eastern limit of the E-clay. There are reports of potential upper zones of groundwater in NKWSD separated by a "300-foot" clay, but at this time, data are insufficient for contouring from SWSD into SWID and NKWSD, or for further characterization. The upper aquifer zone groundwater elevations in 2015 ranged from approximately 220 to 140 feet msl or 50 to 140 feet below ground surface (Schmidt and Associates, 2018).

- The C-Clay is present in the upper aquifer zone below the A-Clay at depths between approximately 50 to 200 feet below ground surface. It is present at Semitropic Ridge and extends to the northwest portion of the district (Croft, 1972). The C-Clay may act as a localized aquitard for groundwater, and it likely affects conditions in the upper unconfined aquifer zone. Croft reported that the C-Clay is typically 10 feet thick but can reach 50 feet in thickness north of the district in the Tulare Lake Bed. Overall, the depocenter of the Corcoran Clay lies northwest of SWSD in the Tulare Lake beds, where it is likely a barrier to groundwater flow (Croft, 1972).

- The E-Clay separates the upper aquifer zone from the lower aquifer zone. It ranges from 20 to 100 feet in thickness, and acts as a confining unit for the lower zone. It ranges in depth from 300 feet 450 below ground surface according to the United States Geological Survey (USGS) (Faunt et al, 2009).

- The lower (semiconfined to confined) aquifer zone occurs below the E-Clay and is the principal groundwater production zone of SWSD. It extends west into BVWSD; however, the TDS increases toward the west where Page (1973) reports the base of freshwater is as shallow as 370 feet below ground surface. On the other hand, the base of freshwater (Page, 1973) on the eastside of the district, is as deep as 1900 feet below ground surface.

- Below the base of freshwater (Page, 1973) is the remainder of the aquifer system or USDW as mapped by Gillespie et al (2017). At this time, few wells within the district are

deep enough to extract groundwater for beneficial use from below the mapped base of fresh water by Page (1973).

2.2.3.3 Formation Names

Alluvium

Alluvium includes younger and older alluvium, which are often indistinguishable from each other. Holocene-age younger alluvium and flood basin deposits vary in character and thickness in the study area. These deposits consist of up to approximately 150 feet of interstratified and discontinuous beds of clay, silt, sand, and gravel. The sand and gravel sized alluvium were primarily deposited from Poso Creek and Kern River and are commonly referred to as the Poso Creek Fan and the Kern River Fan. The flood basin deposits are fine-grained and were deposited in low lying areas of the basin during periodic flooding. The deposits are difficult to distinguish from underlying older alluvium (Page, 1986; DWR, 2006).

Croft (1972), documented differences in sources of alluvium from west-east in the Subbasin, and in depositional conditions and exposure. Alluvium in the central portion of the Subbasin (study area) and East are dominated by Sierra Nevada sediment derived from granitic sources. West of the study area and the historical Kern River Channel, alluvium is derived from the Coast Range and is typically finer grained and derived from sedimentary formations. Oxidized alluvium, derived from the Sierra Nevada, has been delineated in shallow and eastern alluvium as described by Croft (1972). In general, oxidized alluvium was deposited in shallower, higher energy environments associated with the Kern River, Poso Creek, and Sierra Nevada drainage. Further west from the distal edges of the Kern River and Poso Creek Fans, are fine grained deposits that accumulated in the depocenter of the valley, typically under reduced conditions. During periods when lacustrine advances dominated the valley fine grained lenses of clay interfinger with alluvium (A, C, and E-Clays interfinger with alluvium). Many of these sediments were deposited in reduced environments and have been characterized in historical cross sections as reduced alluvial deposits (Croft, 1972).

Older alluvium and terrace deposits overly the Tulare and Kern River formations. Depositional processes are very similar to the younger alluvium. The older alluvium also makes up a portion of the regional aquifer system. These deposits are composed of up to 250 feet or more of Pleistocene-age lenticular deposits of clay, silt, sand, and gravel that are loosely consolidated to cemented (Croft, 1972). They are moderately to highly permeable and yield sufficient water to wells. They are often indistinguishable from the underlying Tulare and Kern River formations (DWR, 2006).

Tulare Formation, Corcoran Clay, and Equivalent Confining Beds

The Tulare Formation and overlying alluvium contain the shallow, upper, and lower zones of the aquifer system of the District. The Tulare Formation is Plio-Pleistocene in age, and in conjunction with the Kern River Formation (Mio-Pliocene to possibly early Pleistocene),

represents a west to east facies change across the Subbasin (SWSD, 2012). The Tulare and Kern River Formations contain moderately to highly permeable layers and are major freshwater sources within the Subbasin (Page, 1986; SWSD, 2012). The water-bearing layers are unconsolidated and lenticular in nature (B-E, 1968; B-E, 1972).

The Tulare Formation contains up to 2,200 feet of interbedded, oxidized to reduced sands, gypsiferous clays, and gravels derived primarily from Coast Range sources. The permeable deposits of the Tulare Formation are divided into upper and lower units, separated by the Corcoran Clay member of the formation.

As described above, there are differences in the interpretation of the Corcoran Clay beds that separate the upper aquifer zone and the lower aquifer zone, and whether they are a specific E-Clay or other equivalent (Figure 2-7). As described in the regional setting, Croft (1972) mapped the Corcoran Clay with A-, C-, and E-Clays in SWSD. The A-Clay is the aquitard for the shallow aquifer zone and the E-Clay is the confining bed above the lower aquifer zone. Page (1986) later modified maps of the E-Clay and designated it as the modified E-Clay. Groundwater beneath the E-Clay is typically confined to semiconfined (Page, 1986; SWSD, 2012). In addition to its confining properties, laboratory tests indicate that the Corcoran Clay is highly susceptible to compaction (Faunt, et al., 2009).

According to reports, the E-clay dips northwest and becomes over 100 feet thick and about 450 feet deep in the northwestern part of the District (SWSD, 2012). In the southeast and east part of the District, the E-Clay or other confining beds thin and split as they near the surface and become hydraulically ineffective as they merge into the “forebay” (or area of recharge to the aquifer system in SWSD). The “forebay” area is where the upper zone aquifer merges with the lower zone (Schmidt and Associates, 2018 and SWSD, 2012), the boundary is likely approximate and may coincide with the modelled extent of the E-Clay by DWR (2018) and USGS (2018). Regionally, the upper zone thins to the east and south, and the lower zone thickens to the east with the eastward dipping base of fresh water (SWSD, 2012).

Kern River Formation

The Kern River Formation underlies the very eastern and southeastern portion of the district, where the aquifer zones merge (B-E, 1972). The Kern River Formation generally occurs on the eastern side of the Subbasin and is not commonly associated with confining beds of the Corcoran Clay; however, there is likely some interfingering. The Kern River Formation is a significant aquifer zone within the Subbasin that becomes semiconfined to confined with depth. The Kern River Formation includes from 500 to 2,000 feet of poorly sorted, lenticular deposits of clay, silt, sand, and gravel derived from the Sierra Nevada (Bartow and Pittman, 1983). The formation consists mostly of poorly sorted fluvial sandstone and conglomerate with interbeds of siltstone or mudstone that becomes finer grained northward and westward. Some of the thicker siltstone or mudstone interbeds may represent deposits of small ephemeral lakes or ponds (Bartow and Pittman, 1983).

2.2.3.4 Physical Properties of Aquifers

As described in the KGA Umbrella GSP basin setting section, aquifer parameters within the Subbasin are available from both well pumping tests and calibrated groundwater models. These are summarized in tables and figures of the umbrella section of the KGA GSP. Aquifer properties include hydraulic conductivity which is a function of an aquifer's ability to transmit water (transmissivity) through an aquifer of a given saturated thickness, and the specific yield (unconfined systems) and storage coefficient (confined systems), which are functions of an aquifer's ability to store and release water from storage (storativity).

A select list of local aquifer data available from published sources are presented in Tables 2-1a and 2-1b. Data are derived from: 1) relatively short (1.5- to 5-hour) pumping tests by the USGS at irrigation wells during the late 1950s and 1960 (McClelland, 1962), and 2) from constant rate pumping tests from engineering consultants in the 2000s (Todd, 2012 and Fugro, Inc. 1978). The depth of these test wells varied from 250 to 800 feet below ground surface (bgs), and pumping rates varied from 72 to 2,600 gpm. The depth and pumping rate ranges are within the general range of agriculture supply wells in the lower aquifer zone within the district. The Fugro test well was in the range of the upper zone of the district. From these tests, the hydraulic conductivity was estimated to range from 40 to 200 feet/day. These values are typical for the upper range of silty sand and for clean medium- to coarse-grained sand (Heath, 1983). In addition, these values fall within the upper range of recent local groundwater models for the Kern Fan and Kern Delta Water District that were calibrated with these data (C2VSim; CVHM; Todd, 2018; Todd, 2017).

APPROXIMATE THICKNESS AND EXTENT OF E-MODIFIED CORCORAN CLAY

- Corcoran Clay Thickness Contour *(from model)*
- Approximate Extent of Corcoran Clay *(USGS)*
- Semitropic WSD GSA
- Kern County Subbasin Boundary
- Highway
- Waterway
- Major Conveyance



0 2 4 Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-7

SOURCE: C2VSIM Corcoran Clay layer top and bottom elevations, DWR (2018); Corcoran Clay extent, Faunt, USGS (2009); - http://pubs.usgs.gov/pp/1766/PP_1766.pdf

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM003_Corcoran.mxd SI

This Page Left Blank Intentionally

Table 2-1a. Local Aquifer Parameters

Well	Estimated Specific Capacity (gpd/ft.)	Estimated Transmissivity (gpd/ft^2)	Estimated Horizontal Hydraulic Conductivity (gpd/ft)	Estimated Horizontal Hydraulic Conductivity (ft./day)	Coefficient of Storage	Discharge Rate (gpm)	Drawdown (feet)	Perforated Intervals (feet)	Source
26S/24E-4H1	691,000	350,000	1,000	130	2E-03	1,960	4.1	148-502	McCelland, 1962
26S/25E-26N1	75,000	125,000 to 350,000	300 to 800	40 to 100	4E-04 to 1E-03	2,345	45.3	340-800	McCelland, 1962
27S/24E-35K1	274,000	230,000 to 460,000	800 to 1,600	100 to 200	1E-03	1,900	10	270-558	McCelland, 1962
27S/26E-32G1	--	260,000 to 450,000	500 to 800	70 to 100	1E-03	1,640	--	220-765	McCelland, 1962
28S/22E-15N3	44,000	100,000 to 350,000	300 to 900	40 to 120	--	2,140	70	204-600	McCelland, 1962
28S/22E-11H	15,000	28,000	100	10 to 20	--	1,950	--	480-740	Todd, 2012 (Schmidt and Associates)
28S/22E-12M	37,000	27,000	100	10 to 20	--	2,590	--	410-700	Todd, 2012 (Schmidt and Associates)
28S/23E-07N	65,000	40,000	100	10 to 20	--	1,990	--	200-500	Todd, 2012 (Schmidt and Associates)
26S/23E-16	23,000	10,000 to 22,000	70 to 150	10 to 20	1E-03 to 3E-04	72	4.5	70-130 to 160-250	Fugro, Inc. (1978)

Table 2-1b. Local Aquifer Parameters

Well	Estimated Specific Capacity (gpd/ft)	Source
T25S-R22E	53,000	Davis et. al. 1964
T25S-R23E	60,000	Davis et. al. 1964
T25S-R24E	81,000	Davis et. al. 1964
T26S-R22E	56,000	Davis et. al. 1964
T26S-R23E	94,000	Davis et. al. 1964
T26S-R24E	84,000	Davis et. al. 1964
T27S-R22E	88,000	Davis et. al. 1964
T27S-R23E	132,000	Davis et. al. 1964
T27S-R24E	94,000	Davis et. al. 1964
T28S-R22E	127,000	Davis et. al. 1964
T28S-R23E	158,000	Davis et. al. 1964
T28S-R24E	132,000	Davis et. al. 1964
T29S-R23E	161,000	Davis et. al. 1964
T29S-R24E	124,000	Davis et. al. 1964

Aquitards

The KGA Umbrella GSP basin setting section summarized representative data for aquitards, including the Corcoran Clay, within the aquifer system. Faunt et al., (2009) estimated horizontal hydraulic conductivities with the range of 0.0024 to 33 ft/d, which is within the range of silt to fine/medium sand (Heath, 1983). Vertical hydraulic conductivity was estimated from permeameters and field tests and ranged between 6.6×10^{-6} ft/d to 1.5×10^{-3} ft/d (Faunt et al., 2009), representing a potential vertical anisotropy range of 3.6×10^{2} to 2.2×10^{4}. As noted by Faunt et al., (2009) laboratory permeameter tests may have underestimated the hydraulic conductivity while field testing may have overestimated hydraulic conductivity due to potential for intra-borehole flow across the clay. Additionally, recent inelastic compaction of the Corcoran Clay in areas of subsidence may have further reduced vertical hydraulic conductivity (Faunt et al., 2009).

Aquifer Storativity

Aquifer storativity is the volume of water released from storage per unit surface area of the aquifer per unit decline in hydraulic head and storativity values are reported in the umbrella basin setting of the GSP. Note that while storativity applies to both confined and unconfined systems, it can be further simplified for these two systems. Storativity accounts for aquifer compression and water expansion (specific storage components), which are the primary factors for estimating storage in confined systems; thus, for confined systems, the specific storage or storage coefficient is most often reported. In contrast, for unconfined systems, the specific yield or effective porosity (gravity-driven dewatering of an aquifer) better represents storativity because aquifer compressibility and water expansion are somewhat negligible in unconfined

systems. For unconfined systems, specific yield is most often reported, and is a function of porosity and specific retention.

For confined systems, the aquifer compressibility of the storage coefficient can be further defined as elastic and inelastic skeletal specific storage, where inelastic storage will be lost once compression and dewatering occur. For the Central Valley, the inelastic specific storage is typically 30 to several hundred times larger than the elastic skeletal specific storage (Faunt et al., 2009; Ireland et al., 1984). Where fine-grained deposits with inelastic storage are thick in the aquifer system, released water could be a major source of water for a limited period of time, but typically result in a permanent loss in storage capacity of fine-grained sediments which leads to subsidence and lower ground surface elevations.

Specific yield of unconfined zones and the storage coefficient of confined zones within the subbasin have been estimated by laboratory testing of sample cores, calculation based on lithology type, and groundwater model calibration (Davis et al., 1964; Faunt et al., 2009; Todd, 2017 and 2018). A range of 0.0004 to 0.001 is presented in Tables 2-1a and 2-1b for storage coefficients in the lower aquifer zone of the district.

2.2.3.5 Structures Affecting Groundwater Flow

Numerous geologic structures are present in the Subbasin, including faults and folds, and these features are shown for the SWSD area in the Figure 2-8 below (Bartow, 1991). A basin-scale version of this map with descriptions of geologic formations is included in the umbrella section of the GSP. The southern portion of the district (roughly the Buttonwillow Improvement District) is within the westside structural zone of the Subbasin (dark gray boundary on Figure 2-8), which is defined by northwest-oriented faults and folds, subparallel to the Coast Range and the San Andreas Fault (Bartow, 1991; and Page, 1986).

Folds

Page (1986) and DWR (2006) identified some anticlinal folds of the westside of the Subbasin, specifically Lost Hills (outside the SWSD boundaries), as restrictions to groundwater flow within the lowlands. Other fold structures within the westside structural zone include the Buttonwillow and Semitropic Ridges (anticlines), the Bowerbank anticline, and the San Joaquin Valley (or Buttonwillow) syncline (Page, 1986; Bartow, 1991). The extent of groundwater flow restriction associated with these folds is still unknown.

Faults

Faunt et al., (2009) included four northwest-trending “potential horizontal flow barriers” in the groundwater Central Valley Hydrologic Model (CVHM) near Semitropic Ridge and Buttonwillow Ridge and east toward Pond-Poso Fault. Based on Bartow (1991), Lamar et. al. (1983), and CGS (2010a), there are four major faults, from southwest to northeast, known as the Semitropic anticline fault system (two faults at Buttonwillow and Semitropic ridges), the Greeley

fault system, and the Pond Fault (a part of the Pond-Poso Fault System), respectively. However, Los Angeles Department of Water and Power (LADWP) (1974), indicates that the Semitropic anticline fault system and Greeley fault system do not show displacement in sediments shallower than 10,000 feet (well below the base of USDW). In addition, based on seismic profiling, the "Semitropic anticline is expressed only in shallow, unfaulted horizons above 10,000 feet, which indicates that the anticline fault is not genetically related with the formation of the overlying fold" (LADWP, 1974).

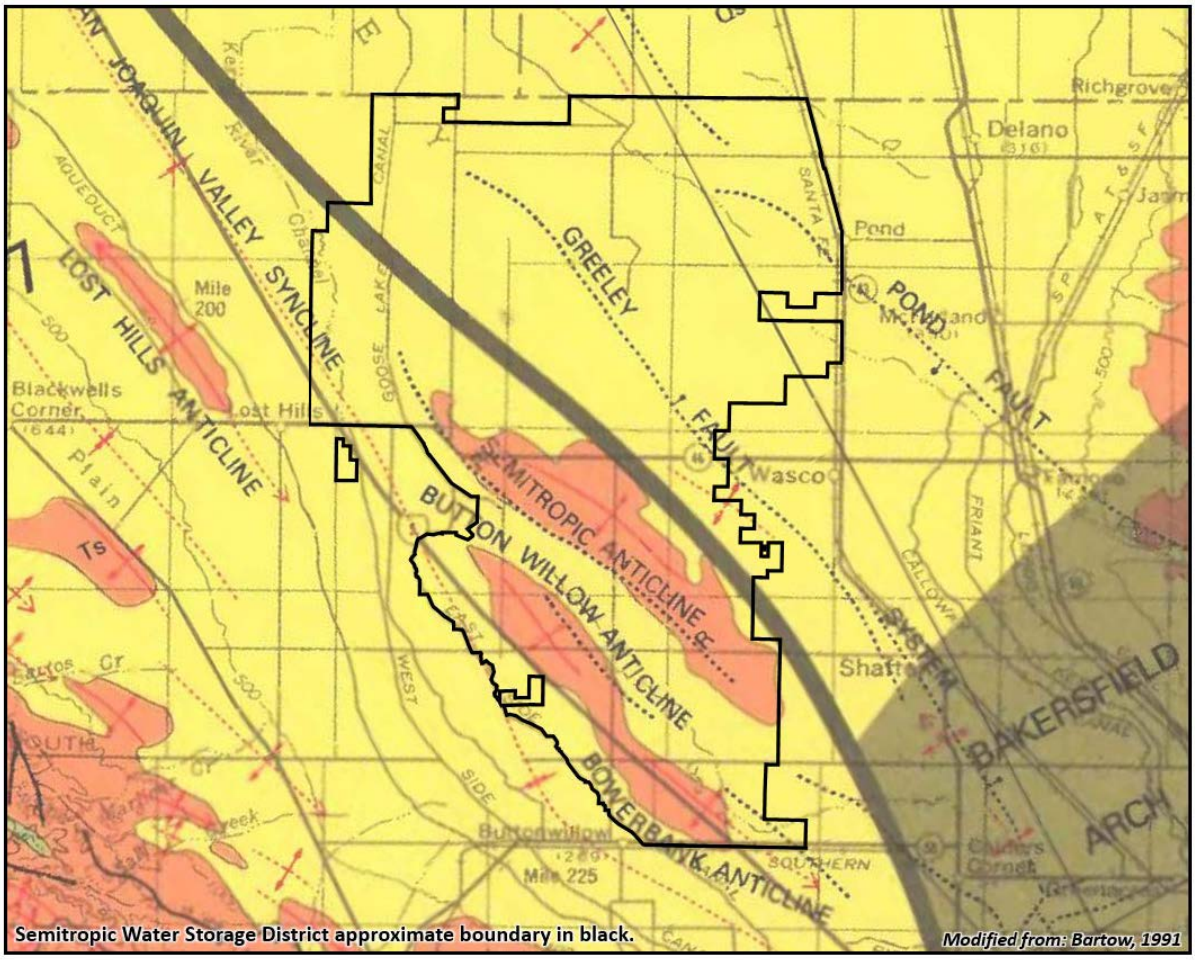


Figure 2-8. Geologic Map (Bartow, 1991)

Cross Sections with Structures that Affect Groundwater Flow in SWSD

The purpose of developing cross sections for this GSP was to identify prevailing conditions that affect groundwater flow and groundwater quality in SWSD, and not to focus on correlating detailed stratigraphy. Furthermore, sediments underlying SWSD are highly lenticular and, although some locally continuous clays are present, the continuity of the E-clay or other equivalent confining beds is still uncertain around Buttonwillow and Semitropic Anticlines (DWR, 2018 and USGS, 2018a); thereby making accurate correlations difficult. Although recent DWR and USGS model do not correlate the Corcoran E-Clay across the Buttonwillow and

Semitropic Ridges, previous regional investigations do (LADWP, 1974; and PGA, 1991). LADWP (1974) utilized downhole geophysics for their correlation while PGA (1991) used a combination of downhole geophysics and seismic correlation. Even with uncertainty in the literature regarding the correlation of the E-Clay, as described below in the current cross section development, the C2VSim Corcoran model layer (DWR, 2018), is displayed as the primary confining layer, on the cross sections, that divide the Upper and Lower aquifer zones.

To provide context for groundwater flow within SWSD, a brief discussion of correlated stratigraphy in the literature is provided below, with the understanding that developed cross sections for this GSP do not fully attempt to correlate stratigraphy where there are gaps in understanding from the literature.

Historical Cross Sections

Selected historical cross sections were reviewed for discussion on folded beds and structures across the area of interest (B-E [1968], PGA [1991], Croft [1972], and LADWP [1974]). SWSD is located on the east side, adjacent to the depositional axis/trough of the valley (San Joaquin Valley Syncline), based on the east to west regional cross section by LADWP (1974) and geologic map by Bartow (1991). Sedimentary deposits dip westward, toward the axis of the syncline throughout much of the district (B-E, 1968; Croft, 1972; LADWP, 1974; and PGA, 1991), as shown by the correlations of the E-Clay on the east side of the syncline (sediments on the west side dip eastward). Cross sections by B-E (1968), PGA (1991), Croft (1972), and LADWP (1974) further illustrate that shallow deposits of the fresh groundwater basin (Tulare Formation and alluvium), are folded due to the anticlinal uplifting and synclinal down-warping. These broad, gentle uplifts and down-warps within southern SWSD are more apparent in regional-scale correlations of the lower Tulare Formation and underlying deposits, as demonstrated by the first Mya in geophysical logs (LADWP, 1974) and bedding attitudes within seismic correlations (PGA, 1991). The first Mya (LADWP, 1974) or equivalent to the upper Mya as described by Page (1983), refers to the uppermost strata in which the burrowing pelycypod or clam Mya occurs in the San Joaquin Formation (Page, 1983). Page (1983) mapped the base of the Tulare Formation just above the Mya zone.

Other local cross sections (SWSD, 2012) provide some detail on the lenticular nature of sediments underlying SWSD. Broad discontinuous clay layers in B-B’ and C-C’ of the GMP (SWSD, 2012) further illustrate the lenses of gently folded deposits in the aquifer system.

Current Cross Sections

Cross sections for SWSD are provided as Figures 2-9 through 2-14 of this GSP, including the KGA cross sections A-A’ and B-B’. A geologic index map displaying the location of these sections is included as Figure 2-15. Cross sections A-A’, C-C’, D-D’, and F-F’, are northeast trending to be perpendicular to faults, folds, and the axis of the valley. Cross sections B-B’ and E-E’ are northwest trending to be parallel to the folds and axis of the valley. The cross sections include perforations from well drilling logs (DWR, 2017a), and pertinent faults by the California

This Page Left Blank Intentionally

A SW — NE **A'**

APPROXIMATE ELEVATION (FT MSL)

1,500 / 1,000 / 500 / 0 / -500 / -1,000 / -1,500 / -2,000 / -2,500

KCS Boundary

Belridge WSD

7th Standard Rd

SR-33

28/22-30_

California Aqueduct

Buena Vista WSD

28/22-27_

Semitropic WSD

Interstate 5

Ridge

28-23-8_

Spring 2015 GW Elevation (Upper Zone)

Ridge

27-23-25_

27-24-20_

SWID

27-24-14_

City of Wasco

SR-43

B-B'

SR-46

NKWSD

Poso Creek

26-25-25_

SR-99

SSJMUD

Friant-Kern Canal

Cawelo WD

26-26-12

Kern-Tulare WD

25-27-32

25-27-33

SR-65

26-27-4

25-27-24

25-28-17 (Projected)

KCS Boundary

25-28-14 (Projected)

Equivalent of Corcoran Clay Rector, 1983

Tulare Formation

Anticline

Base of Tulare Angular Unconformity

South Belridge Oil Field

Anticline (to the North)

Cymric Oil Field (North Extent)

Plio-Miocene Marine Deposits

Alluvium

Corcoran C2VSim Layer

Alluvium

Spring 2015 GW Elevation

Alluvium

Kern River Formation

Kern River Formation

Kern River Formation

Tulare Formation

Kern River Formation

Seismic Form Lines

Buttonwillow Syncline

Buttonwillow Anticline

Semitropic Anticline

Seismic Form Lines

Base of ~2,000 ppm TDS Page, 1973

Base of 10,000 mg/L TDS Gillespie et. al. 2017

Rector, 1983 DOGGR, 1998

Base of Tulare

Plio-Miocene Marine Deposits

Buttonwillow Gas Field

Semitropic Oil Field

Pond-Poso Fault (50 ° to 70° dip to SW)

Plio-Miocene Marine Deposits

Fault Unknown Depth (no subsurface data available)

Bartow, 1989

Santa Margarita

Olcese Sand

Basement Complex (Granitic)

Greater than 2,000 ppm TDS

Greater than 2,000 ppm TDS

Pyramid Hills / Vedder Sand / Walker

Estimated Extent of 2,000 mg/L TDS (Hilton et. al. 1961)

Approximate Scale
0 1.8 3.7 Miles
Vertical Exaggeration = 39x

Well Perforated Intervals
Resistivity (ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model
Alluvium / Kern River Formation / Tulare Formation
Plio-Miocene Marine Deposits (Etchegoin/San Joaquin)
Oil Field Primacy Extents (Approximate) (DOGGR, 1998)

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, CA

GEI Consultants

CROSS SECTION A-A'

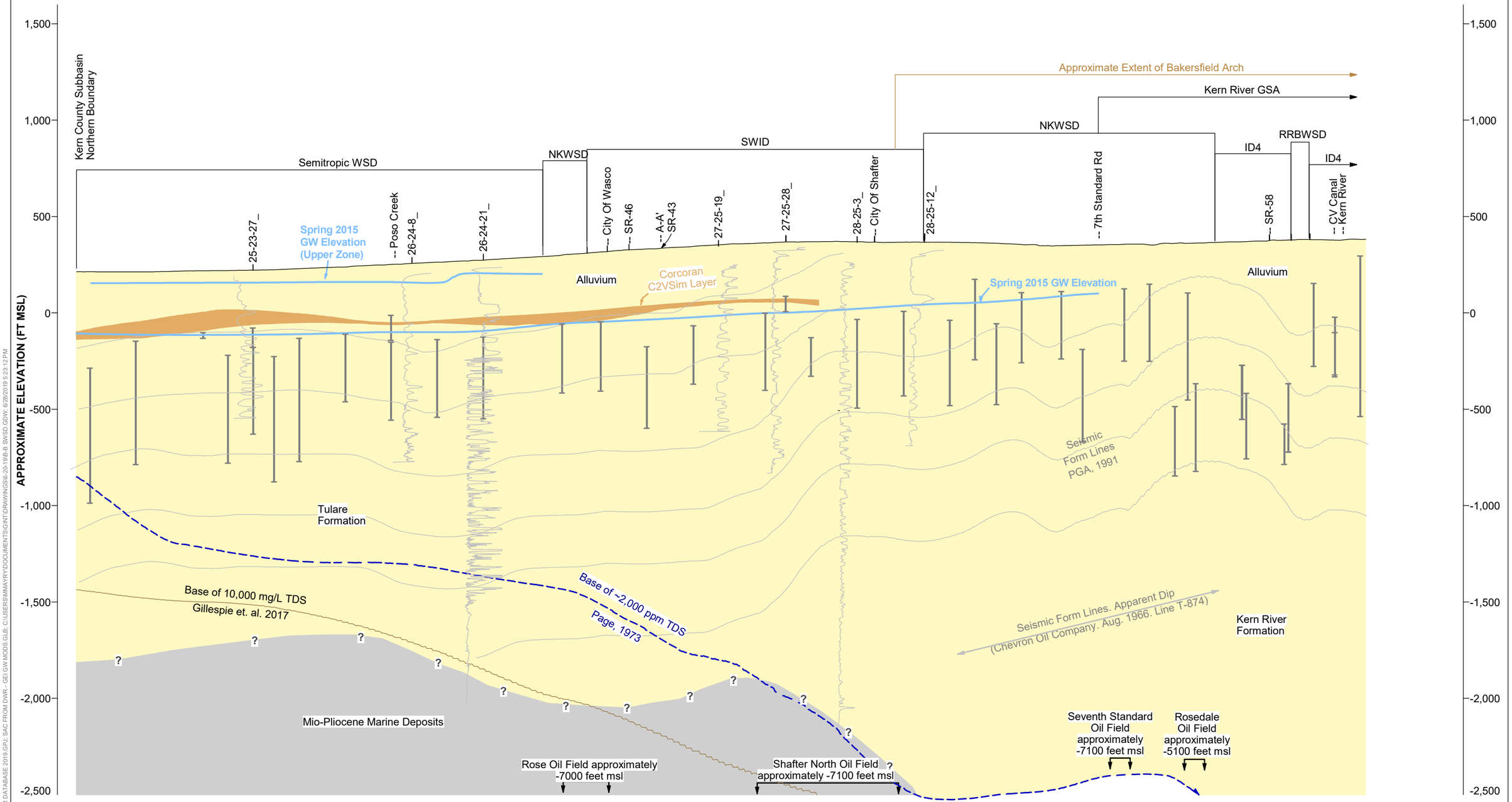
July 2019

FIGURE 2-9

FENCE GEI 11X17: KERN NORTH OF RIVER DATABASE 2019.GPJ; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\16-20-19\A-A SWSD.GDW; 4/17/2019 8:46:21 PM

Output Scale: Distance 1 inch = 19485 ft. H: to ft. V: 1 inch = 494 ft, 1500 to -2500 ft

B NW — SE B'



NOTE: Although contacts with the Top of San Joaquin Formation (Mio-Pliocene Marine Deposits) are reported in Oil and Gas records for some of this cross section, facies changes are likely occurring and can cause difficulty in correlation along the cross section.

Miles
0 1.4 2.9
Vertical Exaggeration = 31x

- Well Perforated Intervals
- Resistivity (0-100 ohm-m)
- Seismic Form Lines (PGA, 1991)
- Groundwater Elevation (Spring 2015)
- Corcoran Layer C2VSIM Model
- Alluvium / Kern River Formation / Tulare Formation
- Mio-Pliocene Marine Deposits

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, CA

GEI Consultants

CROSS SECTION B-B'

July 2019

FIGURE 2-10

FENCE GEI 11X17: KERN NORTH OF RIVER DATABASE 2019.GPJ; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\6-20-19\B-B SWSD.GDW; 6/28/2019 5:23:12 PM
Output Scale: Distance 1 inch = 15310 ft. H: to ft. V: 1 inch = 494 ft, 1500 to -2500 ft

C SW

NE C'

Buena Vista WSD

Semitropic WSD

Spreading Grounds

APPROXIMATE ELEVATION (FT MSL)

400
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400

-- CA Aqueduct
SR-58
-- East Side Canal
H-H'
28-23-33_x
28-23-28
--H85
28-23-16
28-23-15
28-23-11_x
28-23-3
A-A'
27-23-26
E-E'
27-23-25_x
27-23-23
27-23-13_x
27-23-12
SR-46
27-23-01
27-24-06
-- 27-24-5_x
26-24-31
-- G-G'
26-24-30
-- B-B'
26-24-8
-- Poso Creek
26-24-04-
25-24-33_x
25-24-27R
25-24-22
-- F-F'
25-24-15
25-24-11
25-24-01

Alluvium

Upper Zone Spring 2015 Groundwater Elevation

UPPER ZONE

Spring 2015 Groundwater Levels

C2VSIM Corcoran "E" Clay

LOWER ZONE

Buttonwillow Syncline

Tulare Formation

Buttonwillow Anticline

Semitropic Anticline

Alluvium

UPPER ZONE

LOWER ZONE

Tulare Formation

Seismic Form Lines

Pond-Poso Fault (50 ° to 70° dip to SW)

Base of Fresh Water (Page, 1973)

NOTE: The Upper and Lower Zone contact is considered approximate and preliminary based on the C2VSIM layer of the Corcoran Clay. The contact becomes better defined as the Corcoran Clay layer is revised.
Contacts between Alluvium and Tulare Formation are not presented on this section. Annotations represent general distribution of geology in the section.

Miles
0 1.2 2.4
Vertical Exaggeration = 56x

Well Perforated Intervals
Resistivity (ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model

Sand
Gravel with Sand
Sand with Clay
Clay and Sand
Clay
Gravel
Upper Zone of Aquifer (Approximate based on E-Clay)
Lower Zone of Aquifer (Approximate based on E Clay)

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, CA

GEI Consultants

CROSS SECTION C-C'

Jul 2019

FIGURE 2-11

Output Scale: Distance 1 inch = 12526 ft. H: to ft. V: 1 inch = 222 ft, 400 to -1400 ft

FENCE GEI 11X17- KERN NORTH OF RIVER DATABASE 2019.GPJ; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\7-11-19\C1.GDW; 7/22/2019 3:26:12 PM

D SW

Semitropic WSD

SWID

Semitropic WSD

North Kern WSD

NE D'

APPROXIMATE ELEVATION (FT MSL)

400
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400

27-22-23_x -- GOOSE LAKE CANAL
27-22-14
27-22-11
27-22-12
MAIN CANAL NORTH REACH -- E-E
27-23-7G1
-- POND-POSO CANAL
27-23-5R1 -- SR-46
27-23-4N2
27-23-10
27-23-03
27-23-3_x
27-23-2
26-23-35
27-23-01R
26-23-36
26-23-36_x -- POND-POSO CANAL
26-24-31_
-- C-C'
27-24-5_x
26-24-32
26-24-33
26-24-28_x
26-24-28
-- B-B'
26-24-27
26-24-26
26-24-25F1
26-24-25_x2
26-24-24R1

Alluvium

Upper Zone Spring 2015 Groundwater Elevation

UPPER ZONE

Spring 2015 Groundwater Levels

Tulare Formation

Corcoran "C" Clay (Croft, 1972)

C2VSIM Corcoran "E" Clay

LOWER ZONE

Semitropic Anticline

Seismic Form Lines

Base of Fresh Water (Page, 1973)

Base of 10,000 ppm TDS (Gillespie et al 2017)

NOTE: Individual well lithologies are not correlated with regional data (Corcoran Clay, Base of Fresh Water, and Seismic Form Lines).
The Upper and Lower Zone contact is considered approximate and preliminary based on the C2VSIM layer of the Corcoran Clay. The contact becomes better defined as the Corcoran Clay layer is revised.
Contacts between Alluvium and Tulare Formation are not presented on this section. Annotations represent general distribution of geology in the section.

Miles
0 0.5 1.1
Vertical Exaggeration = 25x

Well Perforated Intervals
Resistivity (ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model

Sand with Clay
Gravel with Sand
Clay
Gravel
Sand
Gravel, Sand, and Clay
Upper Zone of Aquifer (Approximate based on E-Clay)
Lower Zone of Aquifer (Approximate based on E Clay)

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, CA

GEI Consultants

CROSS SECTION D-D'

Jul 2019

FIGURE 2-12

FENCE GEI 11X17; KERN NORTH OF RIVER DATABASE 2019.GPJ; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\7-11-19\G1 REV.GDW; 7/12/2019 3:30:21 PM

Output Scale: Distance 1 inch = 5567 ft. H: to ft. V: 1 inch = 222 ft, 400 to -1400 ft

E NW

E' SE

Lost Hills WD

Semitropic WSD

Semitropic WSD

SWID

26-21-8 (projected from south)

Interstate 5

26-21-2_x

26-22-30

GOOSE LAKE CANAL

26-22-34

27-22-3

27-22-2

27-22-1

SR-46

27-22-12

MAIN CANAL NORTH REACH

G-G'

27-23-17F1

27-23-16N1

27-23-21

27-23-22

27-23-27C1

27-23-23_

27-23-26a

27-23-25_x

A-A'

27-24-31_x

27-24-32

28-24-5

28-24-4

28-24-9

28-24-3_x

28-24-10

28-24-15_2

28-24-15

28-24-13_x

Alluvium

Upper Zone Spring 2015 Groundwater Elevation

Corcoran "A" Clay (Croft, 1972)

UPPER ZONE

Corcoran "C" Clay (Croft, 1972)

Flood Basin, Lacustrine, and Marsh Deposits. (Center of Tulare Lake Bed to the North)

Spring 2015 Groundwater Levels

Tulare Formation

Approximate Extent of C2VSIM Corcoran "E" Clay

Well Logs in T26S-R21E are for Shallow Piezometers, Industrial Wells, or Cathodic Protection Wells

Tulare Formation

LOWER ZONE

Seismic Form Lines

Buttonwillow Syncline

Semitropic Anticline

Tulare Formation

Base of Fresh Water (Page, 1973)

Base of 10,000 ppm TDS (Gillespie et al 2017)

Base of Tulare (Rector)

APPROXIMATE ELEVATION (FT MSL)

400
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400

NOTE: Individual well lithologies are not correlated with regional data (Corcoran Clay, Base of Fresh Water, and Seismic Form Lines).
The Upper and Lower Zone contact is considered approximate and preliminary based on the C2VSIM layer of the Corcoran Clay. The contact becomes better defined as the Corcoran Clay layer is revised.
Contacts between Alluvium and Tulare Formation are not presented on this section. Annotations represent general distribution of geology in the section.

Miles
0 1.1 2.1
Vertical Exaggeration = 50x

Well Perforated Intervals
Resistivity (ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model

Clayey Sand
Sandy Lean Clay (CL)
Upper Zone of Aquifer (Approximate based on E-Clay)
Lower Zone of Aquifer (Approximate based on E Clay)
Clay
Sand with Clay
Gravel with Sand
Sand
Clayey Gravel

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, CA

GEI Consultants

CROSS SECTION E-E'

Jul 2019

FIGURE 2-13

FENCE GEI 11X17: KERN NORTH OF RIVER DATABASE 2019.GPJ; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\7-11-19E1 REV.GDW; 7/11/2019 2:04:21 PM

Output Scale: Distance 1 inch = 11134 ft. H: to ft. V: 1 inch = 222 ft, 400 to -1400 ft

F West — East F'

Semitropic WSD

SSJMUD

APPROXIMATE ELEVATION (FT MSL)

400
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400

-- Goose Lake Canal
25-22-29B1
25-22-28P1
25-22-27R1
26-22-3A
25-22-26M1
Extensometer
25-22-35B
25-22-25
26-23-7_x
25-23-30
25-23-29
25-23-28
25-23-27_2
25-23-27_x
25-23-26D1
25-23-25
25-24-30
25-24-29
25-24-8_x
25-24-28
25-24-21_x
25-24-27
-- C-C'
25-24-26
25-24-11a
25-24-25J3
25-24-24_x
SR-43
25-24-13
-- City Of Delano
City Limits
25-25-18
25-25-18_2
25-25-17_
25-25-20_x2

Corcoran "A" Clay (Croft, 1972)

Upper Zone Spring 2015 Groundwater Elevation

Alluvium

UPPER ZONE

Corcoran "C" Clay (Croft, 1972)

Tulare Formation

Spring 2015 Groundwater Levels

C2VSIM Corcoran "E" Clay

LOWER ZONE

Tulare Formation

?

Seismic Form Lines

Base of Fresh Water (Page, 1973)

Base of 10,000 ppm TDS (Gillespie et al 2017)

Pond-Poso Fault (50° to 70° dip to SW)

NOTE: Individual well lithologies are not correlated with regional data (Corcoran Clay, Base of Fresh Water, and Seismic Form Lines).
The Upper and Lower Zone contact is considered approximate and preliminary based on the C2VSIM layer of the Corcoran Clay. The contact becomes better defined as the Corcoran Clay layer is revised.
Contacts between Alluvium and Tulare Formation are not presented on this section. Annotations represent general distribution of geology in the section.

Miles
0 0.8 1.6
Vertical Exaggeration = 38x

Well Perforated Intervals
Resistivity (ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model

Sand with Clay
Gravel with Sand
Clay
Gravel
Sand
Gravel, Sand, and Clay
Upper Zone of Aquifer (Approximate based on E-Clay)
Lower Zone of Aquifer (Approximate based on E Clay)
Extensometer (Subsidence Monitoring Point)

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, CA

GEI Consultants

CROSS SECTION F-F'

JULY 2019

FIGURE 2-14

FENCE GEI 11X17- KERN NORTH OF RIVER DATABASE 2019.GPJ; SAC FROM DWR - GEI GW MODS.GLB; C:\USERS\MMAYRY\DOCUMENTS\GINT\DRAWINGS\7-11-19\F1 REV.GDW; 7/15/2019 4:58:12 PM

Output Scale: Distance 1 inch = 8351 ft. H: to ft. V: 1 inch = 222 ft, 400 to -1400 ft. H: 1.26" = 2 miles

GEOLOGIC INDEX MAP *(CGS, 2010)*

Regional Cross Section

Geologic Features

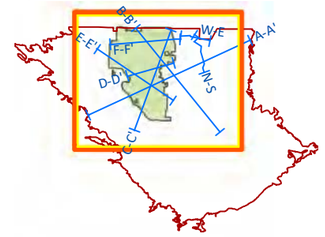
- fault, concealed
- thrust fault, certain
- Anticline, certain
- Anticline, concealed
- Syncline, concealed
- Fault, certain
- Fault, approx. located
- Fault, concealed

Geologic Units

- **Q** - Pleisto-Holocene: alluvium, lake, playa and terrace deposits; unconsolidated and semi-consolidated
- **Qoa** - Quaternary: older alluvium, lake, playa and terrace deposits
- **QPc** - Plio-Pleistocene: sandstone, shale and gravel deposits; mostly loosely consolidated
- **P** - Pliocene: sandstone, siltstone, shale and conglomerate; mostly moderately consolidated
- **Mc/M** - Miocene: sandstone, shale, conglomerate and fanglomerate; moderately to well consolidated
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4 8
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 2-15

SOURCE: California Geological Survey, 2010.

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM004_Geolgoic_XSecs.mxd SI

This Page Left Blank Intentionally

Geological Survey (CGS, 2010a, b), the base of fresh groundwater (Page, 1973), the E-Clay confining layer (DWR, 2018), groundwater elevations for the upper and lower aquifer zones, and general interpretations of faults and folds underlying SWSD. The E-Clay data on the cross sections represent the C2VSim Corcoran model layer. The C2VSim Corcoran model layer was compared with the CVHM model layer (USGS, 2018a) and mapped Page (1986) modified "E" clay extent and was found to be in general agreement. The C2VSim Corcoran layer was chosen because C2VSim fine-grid model is the basis for the Subbasin groundwater model. Croft's (1972) data on the A- and C-Clays are also plotted where present on local sections D-D', E-E', and F-F'. The cross sections also include a representation of general well construction across the study area. Logged fine-grained deposits in well logs are depicted to provide an interpretation of dipped bedding in the subsurface, as observed from seismic data correlations from Pacific Geotechnical Associated (PGA) (1991), and cross sections by B-E (1968).

Discussion

Comparing both historical and current cross sections underlying SWSD provides a better understanding of sedimentary, fold-belt, and fault structures that may affect groundwater flow. The following observations are provided for this comparison:

1. An upper unconfined aquifer zone and a lower confined aquifer zone are divided by clay layers at an average depth of 300 to 400 feet below ground surface. These layers may be part of an E-Clay as documented by C2VSim (DWR, 2018), and CVHM and USGS (2018); however, other correlations of the E-Clay, even if less accepted (PGA, 1991), may not match the CVHM and USGS interpretation. Nonetheless, the clay layers at 300 to 400 feet are the important confining layers of the aquifer system.

2. The C-Clay is present in the upper zone of sections D-D', E-E', and F-F'; however, data were not sufficient to determine the C-Clay thickness in these sections.

3. Most production in SWSD is from the lower zone, based on plotted well construction details on the cross sections, while the upper unconfined zone is the major groundwater production zone in BVWSD (west of SWSD). Groundwater production also occurs in the upper zone in SWSD, but to a lesser extent.

4. The base of the lower zone in SWSD becomes increasingly higher in TDS moving toward the west, owing to a shallower base of freshwater in the western portion of SWSD as documented by Page (1973).

5. The Greeley Fault and the faults associated with the anticlines (Semitropic Fault system) do not significantly alter displacement of sediment above the base of freshwater (Page, 1973), based on LADWP (1974) and PGA (1991). As reported by LADWP (1974), these faults do not displace strata shallower than approximately 10,000 to 13,800 feet below ground surface; and therefore, are not likely major influences on groundwater flow in the groundwater subbasin.

6. Fine-grained layers that dip inward on both sides of the Buttonwillow Syncline, as observed in C2VSim Corcoran model layer and PGA (1991) data, may alter or affect horizontal flow eastward into SWSD.

7. To the northwest of SWSD, thick Tulare Lake beds likely create a barrier to groundwater flow (G-G' of Croft, 1972), preventing significant inflow or outflow to the northwest of the study area. As reported on groundwater contour maps, flow directions have not trended to the northwest of the study area.

Various studies have briefly discussed whether faults and folds along the western SWSD boundary are a partial barrier to flow of poor-quality groundwater into the district from the west (B-E, 1968; Sierra Scientific, 2013; and GEI, 2014). Although eastward dipping clay strata within the syncline could affect groundwater flow, historical discussion has identified the potential for pumping-induced migration of poor quality, saline water from west of the district eastward (B-E, 1968), especially during seasons with high rates or longer durations of groundwater pumping, which may induce higher flow gradients toward pumping centers in SWSD. As discussed above, it is uncertain if the Semitropic anticline fault affects flow in the groundwater basin because the documented offset is much deeper than the base of USDW.

In addition to subsurface geological studies, groundwater contours span BVWSD eastward into SWSD and may provide insight into migration potential of groundwater eastward into SWSD. Published groundwater contour maps (Schmidt and Associates) of the upper and lower zone are discussed in the groundwater conditions section of this report; however, these data may also be inconclusive to evaluate flow across the boundary of SWSD and BVWSD because of the limited extent of available data.

2.2.3.6 General Water Quality of the Aquifer Zones

A high-level summary of groundwater quality is provided in this section for the aquifer zones, while a more detailed evaluation of groundwater quality is provided in Section 2.3.5. As described in the HCM, recharge generally occurs to the south and southeast of SWSD via the Kern River channel, which emanates from the Sierra Nevada and flows across the basin to varying degrees depending on the water-year type, while very little, if any, recharge to the basin comes from the Coast Range to the west. Likewise, more permeable sediments associated with the Poso Creek Fan and Kern River Fan lie to the east and southeast of SWSD, while less permeable, folded beds and clays lie to the west and northwest of SWSD. Additionally, the base of fresh groundwater (Page, 1973) is shallowest in the west and deepens toward the east. These geographic differences in geology and hydrology affect the quality of the groundwater in the Subbasin and in the SWSD.

Groundwater is generally lower in TDS concentrations toward the east and southeast where more permeable deposits in the forebay allow runoff from a granitic terrain to recharge via the Kern River and Poso Creek. Groundwater is generally higher in TDS in the west and northwest of SWSD where recharge is less and is impacted by marine sedimentary rocks in the Coast Range.

Groundwater in the shallow and upper zones are more susceptible to surface contaminants, such as nitrates and 1,2,3-trichloropropane (TCP), that migrate downward while the lower zone is isolated by the clay layers that limit downward migration of surface contaminants. As described in the umbrella basin setting, arsenic is often associated with bedrock deposits and the dewatering of clays. Both the upper and lower zones are susceptible to arsenic as numerous clay beds are present. An increase in arsenic concentrations may also occur in the lower zone in some portions of SWSD as groundwater pumping depth increases.

2.2.3.7 Primary Use of Aquifer Zones

As described in the umbrella basin setting, within SWSD, the unconfined zone to the east of the E-Clay and the lower confined zone beneath and outside the extent of the E-Clay provide the bulk of water production for beneficial use, but is likely to a lesser extent because there are very few well logs reported for the Upper Zone in comparison to the Lower Zone, according to DWR well records. Within SWSD, the upper unconfined zone above the E-Clay is also pumped for beneficial use. In general, the upper unconfined zone benefits shallow domestic wells, while the lower unconfined and confined zones benefit larger production and supply wells.

A DWR well records search for completions in the shallow zone returns only shallow monitoring piezometers, not producing or previously abandoned wells. It is likely that if any groundwater pumping occurs in the shallow zone, it is *de minimis* in nature.

According to DWR well logs and the California Statewide Groundwater Elevation Monitoring (CASGEM) program, groundwater wells in the district have been constructed for a variety of uses, in the Upper and Lower Zones, including:

- Water Supply Domestic
- Water Supply Public
- Water Supply Industrial
- Water Supply Irrigation – Agricultural
- Water Supply Stock or Animal Watering
- Monitoring
- Other Unknown

2.2.4 Mapped Topography

Topographic lines are plotted on Figure 2-16. They are generated from a 1-meter digital elevation model. The principal physiographic features associated with the District include Buttonwillow Ridge, Semitropic Ridge, Kern River Flood Canal, Jerry Slough, Goose Lake and the lower portions of alluvial fans from the Kern River and Poso Creek (B-E, 1968) (Figure 2-17).

Kern River Flood Canal, which is west 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. In the past, 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 ultimately to Tulare Lake (B-E, 1968). The Kern National Wildlife Refuge is down slope from the Goose Lake Canal and is situated in the northwestern part of the District.

Buttonwillow Ridge is located along the southwest portion of the District, trends northwesterly, and is an elongated topographic high with a maximum relief of about 65 feet (B-E, 1968). The ridge is about two miles wide and 15 miles long and separates the Kern River Flood Canal from Jerry Slough. 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 (B-E, 1968).

The alluvial fans along the eastern boundary of the District are relatively flat and featureless and were derived principally from materials deposited by the Kern River and Poso Creek. In the northern portion of the District, the area is characterized by low plains and overflow lands (B-E, 1968).

2.2.5 Surficial Geology

As described in the KGA Umbrella GSP basin setting section, the surficial geology of the Subbasin has been documented in a variety of previous investigations by Bartow (1991), Page (1986), and CGS (2010b). According to the CGS (2010b) (Figure 2-15), the District is underlain by Pleistocene to recent unconsolidated and semi-consolidated alluvial (Q), lake, playa, and terrace deposits. The surficial geology of the Buttonwillow and Semitropic Ridges are Plio-Pleistocene Tulare Formation deposits (QPc). Bartow (1991) provides a similar map (Figure 2-8) as the CGS map but refers to Quaternary alluvial and lacustrine sediments (Qs) on the valley floor and Tertiary sedimentary rocks (Ts) along the flanks and for the islands of older rocks in the valley center. As discussed further below, Bartow showed the location of the Bakersfield Arch as well as three structural regions within the Subbasin.

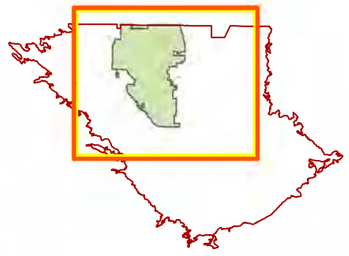
Page (1986) provides a somewhat different interpretation of the surficial geology, as shown by Figure 2-17. Recent river deposits (Qr) associated with the present-day Kern River, are shown as a long, narrow strip from the mouth of the Kern Canyon, and are comprised of gravel, sand, silt, and minor amounts of clay. The center of the valley floor is underlain by Recent flood basin (Qb) – clay, silt, and some sand; and by Pliocene to Recent lacustrine and marsh deposits (QTl) – clay, silt, and some sand with extensive subsurface clay layers (A-, C-, E- Clays). The former unit is associated with the original Kern River drainage and flood basin while the latter unit is associated with the historical Kern Lake Bed, Buena Vista Lake Bed, Goose Lake Beds, and the southern edge of the Tulare Lake Bed. The remainder of the valley is underlain by Miocene to Recent continental deposits (QTc) – a heterogenous mixture of gravel, sand, silt, and clay with

TOPOGRAPHIC MAP

- State Prison
- Airport
- Elevation Contour (NAVD88)
- Wildlife Refuge
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4 8
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-16

SOURCE: USGS, FWS

07-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM005_Topographic.mxd SI

DWR Bulletin 118 - San Joaquin Valley Groundwater Basin - Kern County Subbasin

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 Etchegbin Formation (Miocene and Pliocene) on western side of valley, and Chanac Formation (Miocene) on southern part

Tcmo **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

CORRELATION OF MAP UNITS

Qs Qb Qr	Holocene	QUATERNARY
QTl	Pliocene to Holocene	TERTIARY AND QUATERNARY
QTc	Miocene to Holocene	
Tvd Tcpm	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

SOURCE: Page, 1986, PP 1401-C Plate 2 - Geologic Map of the San Joaquin Valley, California

10 5 0 10
Miles

N W E S

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

Geologic Map Page (1986)

AUGUST 2019

FIGURE 2-17

some layers of conglomerate, sandstone, siltstone, and claystone. Like the other maps, remnants of older continental deposits are shown along the rim of the Subbasin, primarily the southeastern side, including Oligocene to Miocene deposits (Tcmo) of gravel, conglomerate, sand, and clay; and Eocene to Miocene deposits (Tcme) of conglomerate, sandstone, fanglomerate, claystone, and breccia plus limited occurrences of undifferentiated marine deposits (Tm) of sand, clay, silt, sandstone, shale, mudstone, and siltstone of Eocene to Pliocene ages.

Overlying the Tulare Formation is older alluvium, in some instances unconformably (B-E, 1968). Older alluvium is exposed on the surface along Buttonwillow and Semitropic Ridges (anticlines) and appears to reach a maximum of 250 feet in depth (B-E, 1968). Following cessation of folding of the ridges, 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 (B-E, 1968).

The lowland between the ridges, Jerry Slough, is a historical channel of the Kern River which has some sandy Kern River alluvial deposits reported in boreholes below the subsurface, however, at the surface are fine-grained flood basin deposits, silts and clays making up a relatively thin, impermeable layer (B-E, 1968). These flood basin deposits can reach depths up to 50 feet (B-E, 1968).

2.2.6 Soils

Soils within the study area can be categorized into three types according to texture, a measure which is indicative of other characteristics such as electroconductivity (EC) and acidity (pH). Fine-textured soils are found in the northwest and southwest corners of the area with soils in the southwest corner comprised of the Buena Vista and Kern lakebeds and swamp and overflow lands which continue north along the historical drainage paralleling Goose Slough, Goose Lake, and the southern edge of the Tulare Lake depositional environment. These soils are typically saline and high in pH. The remainder of the area includes medium- to coarse-textured soils which are relatively low in salinity and within the optimal pH range for crop production.

Soils in the valley floor have two general origins. The eastern alluvial fans were deposited primarily by runoff from the Sierra Nevada, Tehachapi, and Transverse mountain ranges. These soils originate from mixed igneous and metamorphic material and are typically well drained, and very low in salinity. The western alluvial fans originated from Coastal Range sedimentary marine rocks. This region tends to have more areas with fine-textured, poorly drained soils of relatively marginal quality. For example, the northern portion of the BVWSD includes heavy, poorly-drained soils underlain by a shallow water table containing groundwater with salinity exceeding 2,000 mg/L. These conditions result in poor infiltration, water encroaching into the root zone, and moderately saline soils (*Soil Survey of Kern County, California, Northwestern Part,* 1988). Detailed soil survey data for the entire study area can be found in two United States Department of Agriculture (USDA) reports: *Soil Survey of Kern County, California* (USDA, 1988 and 2007), including recent online updates.

Hydrologic Soils Groups

For the purposes of SGMA, a useful index of a soil's capacity to infiltrate precipitation and applied irrigation water is the National Resource Conservation Service (NRCS) Hydrologic Soils Group classification. Hydrologic Soils Groups typical of the Study area are defined below and are displayed on Figure 2-18 – Hydrologic Soils Groups - which was developed using data from the NRCS' Soil Survey Geographic Database (SSURGO).

- Hydrologic Group A – "Soils in this group have low runoff potential when thoroughly wet. Water transmitted freely" (NRCS, 2009). Group A soils have a high infiltration rate due to well drained sands or gravelly sands giving the group the highest potential for contributing to groundwater recharge.

- Hydrologic Group B – "Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission is unimpeded" (NRCS, 2009). Group B soils are moderately well drained due to moderately fine to coarse textures and have the second highest potential permeability and potential for contributing to groundwater recharge. These soils are present on the east, west, and south sides of the valley floor.
- Hydrologic Group C – "Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission is somewhat restricted" (NRCS, 2009). This group has limited potential to contribute to groundwater recharge. Group C soils have a low infiltration rate due to their fine texture or because of a layer that impedes downward movement of water. These soils are present along the valley floor, along the eastern highlands, and at various locations along the northwestern side of the Study area.

- Hydrologic Group D – "Soils in this group have high runoff potential when thoroughly wet. Water transmission is very restricted" (NRCS 2009). This group has a very limited capacity to contribute to groundwater recharge. These soils have a very slow infiltration rate due to the presence of clay and are located primarily along the northern boundary of the Study area.

Taxonomic Soil Orders

Figure 2-19 – Soils (USDA SSURGO)– displays taxonomic soil orders for the study area as defined by the Soil Survey Geographic Database (SSURGO) mapping obtained from the DWR SGMA Data Viewer website (DWR, 2018). This figure shows six soil orders with the most prominent being Aridisols and Entisols and Inceptisols along the eastern highland mixed with Alfisoils, Mollisols, and Vertisols.

Based on the NRCS publication *Keys to Soil Taxonomy* (NRCS, 12th edition, 2014), the following characteristics are associated with each of these soil types:

- Ardisols are dry soils characterized by a low humus, light colored surface horizon with a subsurface accumulation of soluble salts, silicate clays, and possibly a cemented layer of calcium carbonate, calcium sulfate (gypsum) or silica.

HYDROLOGIC SOIL GROUPS

- Semitropic WSD GSA
- Kern County Subbasin Boundary

Hydrologic Group - Dominant Condition

- A - HIgh Infiltration *(Sands or Gravels)*
- B - Moderate Infiltration *(Fine to coarse Soils)*
- B/D - Slow to Very Slow Infiltration
- C - Slow Infiltration *(Moderately Fine to Fine Soils)*
- C/D - Very Slow Infiltration *(Clay Soils)*
- D - Very Slow Infiltration
- No Data

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 2-18

SOURCE: NRCS SSURGO Soils (2018)

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM006_HydrologicSoils.mxd RS

SOILS (USDA SSURGO)

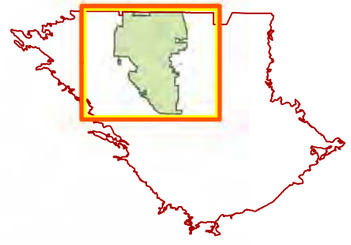
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Taxonomic Soil Orders

- Alfisols
- Aridisols
- Bodies of Water
- Entisols
- Mollisols
- Vertisols
- No Data

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-19

SOURCE: NRCS SSURGO Soils (2018)

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM007_Soils.mxd RS CG Acrobat. Changed heading for SSURGO Soils to Taxonomic Soil Orders

- Entisols are characterized by the absence of soil horizons due to recent deposition or active erosion under extreme wet or dry conditions.
- Inceptisols exhibit a weak appearance of soil horizons overlying a weathering-resistant parent material.
- Alfisols are characterized by well-developed soil horizons enriched with aluminum- and iron-bearing (Al/Fe) minerals but depleted of calcium carbonate. Translocated clays typically form a layer with relatively high amounts of mineral nutrients (calcium, magnesium, sodium, and potassium).
- Mollisols are characterized by a thick, dark surface horizon of humus, which typically originates from native grass vegetation with mineral nutrients present in most horizons.
- Vertisols are clay-rich soils (>30%) with significant cracking during the dry season due to the shrink-swell response of the clay minerals during the dry and wet seasons. The shrink-swell action produces significant vertical mixing of the soil.

2.2.7 Natural Recharge, Direct Recharge Areas, and Potential Recharge Areas

Direct recharge, potential recharge, and in-lieu recharge are differentiated in this section from natural recharge.

- Natural recharge occurs by groundwater underflow from adjacent sources, precipitation exceeding evapotranspiration to allow deep percolation in a subbasin, or from deep percolation of natural surface waters flowing into the subbasin.
- Direct recharge is either planned or unplanned deep percolation of surface water from unlined conveyance, field application, managed recharge, and spreading operations.
- In-lieu recharge refers to instances where surface water is applied to lands that otherwise would have been irrigated using groundwater. Imported surface water for in-lieu recharge to the study area is conveyed through the same pipelines and canals as contracted imported water. These conveyances are described in the surface water bodies section of this GSP. In-lieu recharge will be further discussed in the water budget section of this GSP because it is an accounting aspect of water input to the basin. It represents the application of surface water for use to meet water demands and does not represent direct recharge to the subsurface for the purposes of replenishing aquifers, although it benefits the aquifer system by alleviating groundwater pumping demand.

2.2.7.1 Natural Recharge

As discussed in the KGA Umbrella basin setting, natural recharge to the Subbasin occurs mainly by underflow or surface recharge from the eastern and southern highlands (Sierra Nevada and Tehachapi Mountains). The surface water bodies as a source of recharge are discussed in the next section.

Fresh water primarily recharges the lower aquifer zone of the District, from the south and east where the E-Clay or other equivalent beds "300-foot clay" are either not present or are not effective confining units (Schmidt and Associates, 2018). This area is commonly known as the "forebay" (Schmidt and Associates, 2018). Recharge into the forebay mainly originates from the south along the Kern River fan, but also along Poso Creek and Poso Creek Flood Channel (manmade), and through extensive seepage from unlined canals in the forebay area (SWSD, 2012). The lower zone contour map in the groundwater conditions section of the report provide a rough estimate of the forebay area to lower aquifer zone underlying SWSD.

In general, natural recharge by precipitation is minimal in the study area, and may only occur in extreme wet years, because typically evapotranspiration (ET) exceeds the amount of natural precipitation to the Subbasin (Provost and Pritchard et. al., 2015).

For the study area it has been assumed that precipitation which occurs in the undeveloped or native properties is offset by the consumptive use of the natural vegetation. Precipitation which occurs in the developed or agricultural properties is assumed to offset the irrigation demand necessary during the precipitation event.

In general, natural recharge by precipitation is minimal in the study area, and may only occur in extreme wet years, because typically ET of crops exceeds the amount of natural precipitation to the Subbasin. In contrast, the understanding of precipitation in relation to the ET of natural vegetation (both non water-stressed and rainfed) is still in development (Howes et al, 2015; Fox and Sears, 2014).

As described in the Groundwater Quality Assessment Report (GAR) for the Kern River Watershed Coalition Authority, historically, the average annual precipitation from the Shafter California Irrigation Management Information System (CIMIS) Station (No. 5) is 6.3 inches, which is relatively low compared to an annual potential ET of 57 inches transpired from healthy grass in a normal year (Jones, 1999). As a consequence, deep percolation of precipitation past the root zone occurs infrequently or not at all, but rainfall does offset a portion of the irrigation demand for irrigated lands. A daily soil moisture balance was completed for the Kern Fan (Todd, 2012) using the Thornthwaite and Mather method (1955 and 1957). This soil moisture balance showed that precipitation is generally consumed by ET within a few days of a rainfall event, and there is no excess available water for recharge to groundwater (Provost and Pritchard et. al., 2015).

The GAR describes effective precipitation as the portion of precipitation that can be beneficially used by crops. Historically, the estimate for effective precipitation has varied from approximately 1.2 inches in a dry year to approximately 4.9 inches in a wet year, with an average of approximately 3.4 inches in a normal year (Kern County Water Agency Water Supply Reports [2011 and others]).

2.2.7.2 Direct Recharge

Significant direct recharge to groundwater in SWSD occurs through managed recharge such as the Pond-Poso Spreading Grounds; as well as managed and unmanaged recharge through natural waterways such as the dry channel of Poso Creek, manmade waterways such as along the Poso Creek Flood Channel, percolation of applied surface water that passes below crop root zones, and unlined canals (Figure 2-20). Recharge may also occur from water applied to managed wetlands with the Semitropic Area.

Although not in SWSD boundaries, the District also participates in large-scale groundwater direct recharge/banking operations for the Kern Water Bank (KWB) and the Pioneer Project. These projects have been constructed along the Kern River where permeable sediments are prominent and well suited for spreading. During particularly "wet" years, direct recharge through the use of these spreading ponds is significant in the basin.

Potential Recharge Areas

The California Soil Resource Lab at University of California Davis (UC Davis) has developed an online application (https://casoilresource.lawr.ucdavis.edu/sagbi/) to present the Soil Agricultural Groundwater Baking Index (SAGBI), which estimates groundwater recharge suitability based on five major factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. As described in the umbrella basin setting, the SAGBI, may further estimate groundwater recharge suitability; however, the dataset may be limited to the shallow subsurface at or just below the root zone (O'Geen et al, 2015).

The UC Davis mapping coverage of the SAGBI indicates a moderately good to excellent rating for the Poso Creek alluvial fan in eastern SWSD and the Kern River alluvial fan in southern SWSD (Figure 2-21). SAGBI ratings are moderately poor to very poor along the eastern margin, central western margin, as well as the center of the valley from the former Kern and Buena Vista lake beds, north along the Goose Neck Slough to the Tulare Lake Bed. However, based upon the experience of the District, the SAGBI indicators are not definitive as to the suitability of a specific property relative to recharge potential as this is better defined by soil cores which are typical of the target site

2.2.7.3 Groundwater Discharge Areas

Groundwater discharge points, such as springs or seeps, in SWSD are not documented in the study area. The depth to usable groundwater is typically greater than 60 feet, although the shallow zone ranges in depth from 5 to 20 feet below ground surface (SWSD, 2012; KCWA water supply reports). This water is typically higher in electrical conductance than the production aquifer and is considered poorer quality. More details of this mapped shallow groundwater surface are described in the groundwater conditions section.

The combination of imported surface water to sustain marshes and recreational ponds and the effects of a shallow water table, capillary rise, and evapotranspiration, may result in the discharge of shallow groundwater in some areas; however, further monitoring would be necessary to confirm this possibility. Since the regulation of the Kern River, there are no significant sources of recharge to the shallow zone, except imported surface water and applied irrigation water.

2.2.8 Surface Water Bodies

Figure 2-22 presents the location of surface water bodies in SWSD according to the National Hydrography Dataset (NHD). Poso Creek is the main natural surface water body flowing into SWSD, which originates in the Sierra Nevada and only provides surface water in very wet years. West of Central Avenue, Poso Creek Flood Channel was built to control flood events. The NHD also includes manmade conveyance such as the California Aqueduct (SWP) and federal Central Valley Project (CVP) Friant-Kern Canal, and other local canals that help convey imported surface water into the Subbasin. In addition, the NHD also includes drainages in low lying areas along the western boundary of the District, such as Jerry Slough, and wetlands delineations for the Kern Wildlife Refuge. The refuge is now sustained by imported surface water typically wheeled from the California Aqueduct and conveyed by the Goose Lake Canal to the refuge (USFWS, 2005). Without this imported surface water, the refuge would lose the steady supply necessary to sustain many of the wildlife and vegetative populations without reverting to dependence upon groundwater.

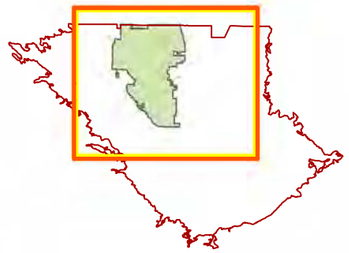
2.2.9 Source and Point of Delivery for Imported Water Supplies

SWSD uses both groundwater and surface water for beneficial use. Surface water comes from both local and imported sources. The primary source of imported water to the District is supplied by the State Water Project, which is conveyed through the California Aqueduct, transporting water from the Sacramento-San Joaquin Delta along the west side of the San Joaquin Valley to Kern County. Figure 2-23 presents the SWSD turnouts directly from California Aqueduct into the District service area. SWSD holds a contract with KCWA for a share of the imported water conveyed by SWP. The KCWA was formed in the 1960s to contract with DWR for the importation of SWP water to Kern County. Due to recent regulatory and judicial decisions, hydrologic conditions, and reservoir storage, the SWP is not able to deliver full amounts of contracted water in most years. In addition to SWP water, the District is also within the Federal place of use and is eligible to receive waters from the Federal Projects. Furthermore, the District may also receive Kern River water via interconnections with adjoining districts and by way of its participation in the Pioneer and Kern Water Bank projects located within the Kern Fan.

AREAS OF DIRECT RECHARGE

Major Canal
- *Lined*
- *Unlined*
- Minor Canal
- Area of Direct Recharge
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features
- Highway
- Waterway
- Major Conveyance



0 2 4 8
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-20

SOURCE: USGS NHD, Kern County

07-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM008_RechargeAreas.mxd SI

SOIL AGRICULTURAL GROUNDWATER BANKING INDEX

Kings County
Kern County
Tulare County
Kern County
Kern River Channel
Kern NWR
Garces Hwy
Delano
Friant-Kern Canal
Goose Lake Canal
Poso Creek Flood Channel
McFarland
Sherwood Ave
Famoso-Porterville Hwy
Poso Creek
Lost Hills
Pond Poso Canal
SWRU East-West Pipeline
Wasco
Semitropic Intake Canal
Semitropic Canal
California Aqueduct
Kern River Flood Canal
Buttonwillow Ridge Canal
Lerdo Hwy
W Lerdo Hwy
Shafter
E Lerdo Hwy
7th Standard Rd
East Side Canal
Buttonwillow

SOURCE: Soil Agricultural Groundwater Banking Index (SAGBI). UC Davis. SAGBI Unmodified Layer (2015)

R20E R21E R22E R23E R24E R25E R26E
T24S T25S T26S T27S T28S T29S

Z:\Projects\1704941_Semitropic_ETI\SEM009_SAGBI.mxd RS
08-Aug-2019

Semitropic WSD GSA
Kern County Subbasin Boundary
Kern National Wildlife Refuge (FWS 2018)

SAGBI Rating Group
- Excellent
- Good
- Moderately Good
- Moderately Poor
- Poor
- Very Poor

Other Features
- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-21

SURFACE WATER FEATURES FROM NATIONAL HYDROGRAPHY DATASET

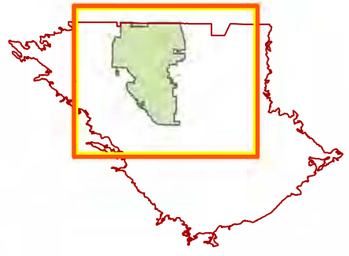
NHD Hydrology

- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Major Canal
- Minor Canal
- Lake/Pond
- Swamp/Marsh

- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway



0 2 4 8
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

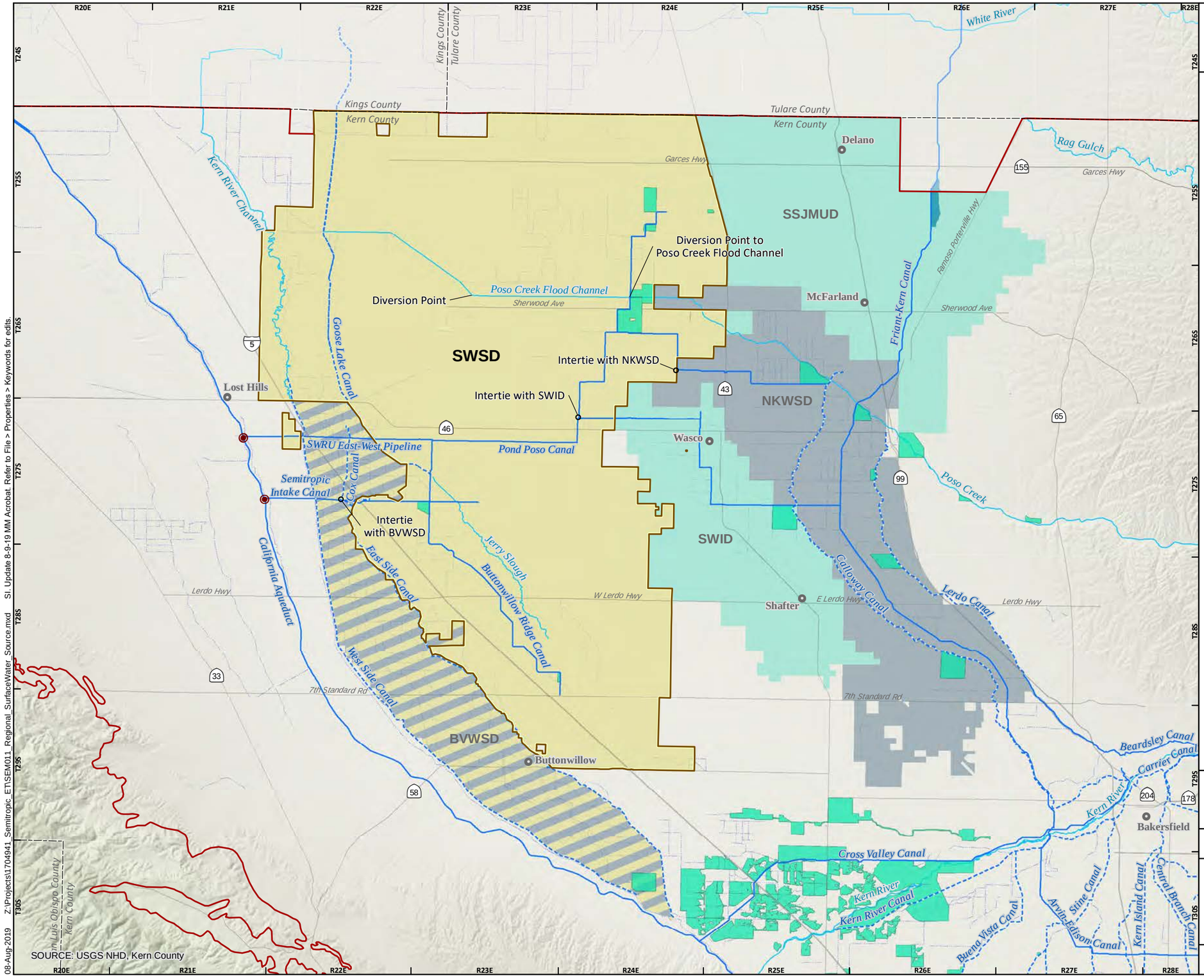
AUGUST 2019

FIGURE 2-22

SOURCE: USGS NHD, Kern County

07-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM010_SurfaceWaterNHD.mxd SI

SOURCE AND POINTS OF DELIVERY FOR IMPORTED WATER SEMITROPIC WSD



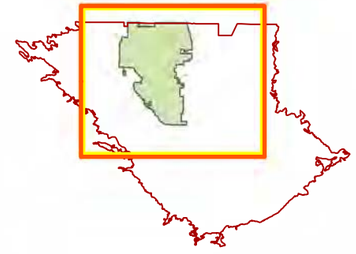
- Intertie with Adjacent Agency
- California Aqueduct Turnout
- Conveyance
- Unlined Canals of Interest
- Semitropic WSD GSA

Source of Imported Water

- Central Valley Project *(CVP)*
- State Water Project *(SWP)*
- SWP & Kern River
- Kern River

- Area of Direct Recharge
- Kern County Subbasin Boundary
- Highway
- Waterway

Note: This figure does not display all canals or conveyance, nor are all unlined canals noted as such.



0 2 4 8 Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019 FIGURE 2-23

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM011_Regional_SurfaceWater_Source.mxd SI. Update 8-9-19 MM Acrobat. Refer to File > Properties > Keywords for edits.

2.2.10 Data Gaps in the Hydrogeologic Conceptual Model

The primary data gaps in the hydrogeologic conceptual model include additional details on physical properties and groundwater quality of the aquifer zones underlying the study area, as well as characterization of physical structures and confining clays that may affect subsurface flow. The following details will provide more certainty for future HCM revisions:

- Groundwater quality in each of the principal aquifers within the SWSD area, from wells screened solely in a single aquifer zone
- Sufficient physical properties of the upper aquifer zone within SWSD.
- Physical properties of the confining clay layer within SWSD, and the extent of the confining layer across the Buttonwillow and Semitropic Ridges.
- Extent and thickness of the C-Clay.
- Data across the western boundary of SWSD and fold belts to evaluate the effects of stratigraphy and structure on groundwater flow.

2.3 Current and Historical Groundwater Conditions

Annual groundwater elevation contour maps covering much of SWSD have been prepared by Schmidt and Associates on behalf of the Semitropic Monitoring Committee since the 1990s, and KCWA in Water Supply Reports since before the 1990s. These maps were reviewed to illustrate seasonal high groundwater level conditions from winter and spring water level data prior to most of the active groundwater pumping during peak ET and growing season conditions.

Figure 2-24 is a generalized diagram of groundwater flow in the Subbasin. In the absence of pumping or significant barriers, groundwater naturally flows from high elevation points of recharge to lower elevation points with less recharge. Based on a review of the 1995 to 2017 Schmidt and Associates maps and historical groundwater data from USGS and KCWA (Page, 1986; and KCWA, 2018), groundwater generally flows westward from the Sierra Nevada and Kern River. Groundwater flows from natural and managed recharge points along the Kern River, which is situated on the Bakersfield Arch and has a broad topographical rise that gradually dips to the north and south of the river; thus, the rough alignment of the river effectively splits the Subbasin into northern and southern groundwater areas. To the north of the river, groundwater flows from the uplands along the east margins of the Subbasin toward the west and northwest until it leaves the Subbasin as subsurface underflow or is captured by pumping wells for irrigation or potable consumption. Figure 2-24 below presents the approximate location of the San Joaquin Valley (Buttonwillow) Syncline. The syncline likely negates the potential flow of saline connate water of the westside from significantly impacting groundwater in the main production zone of the Subbasin.

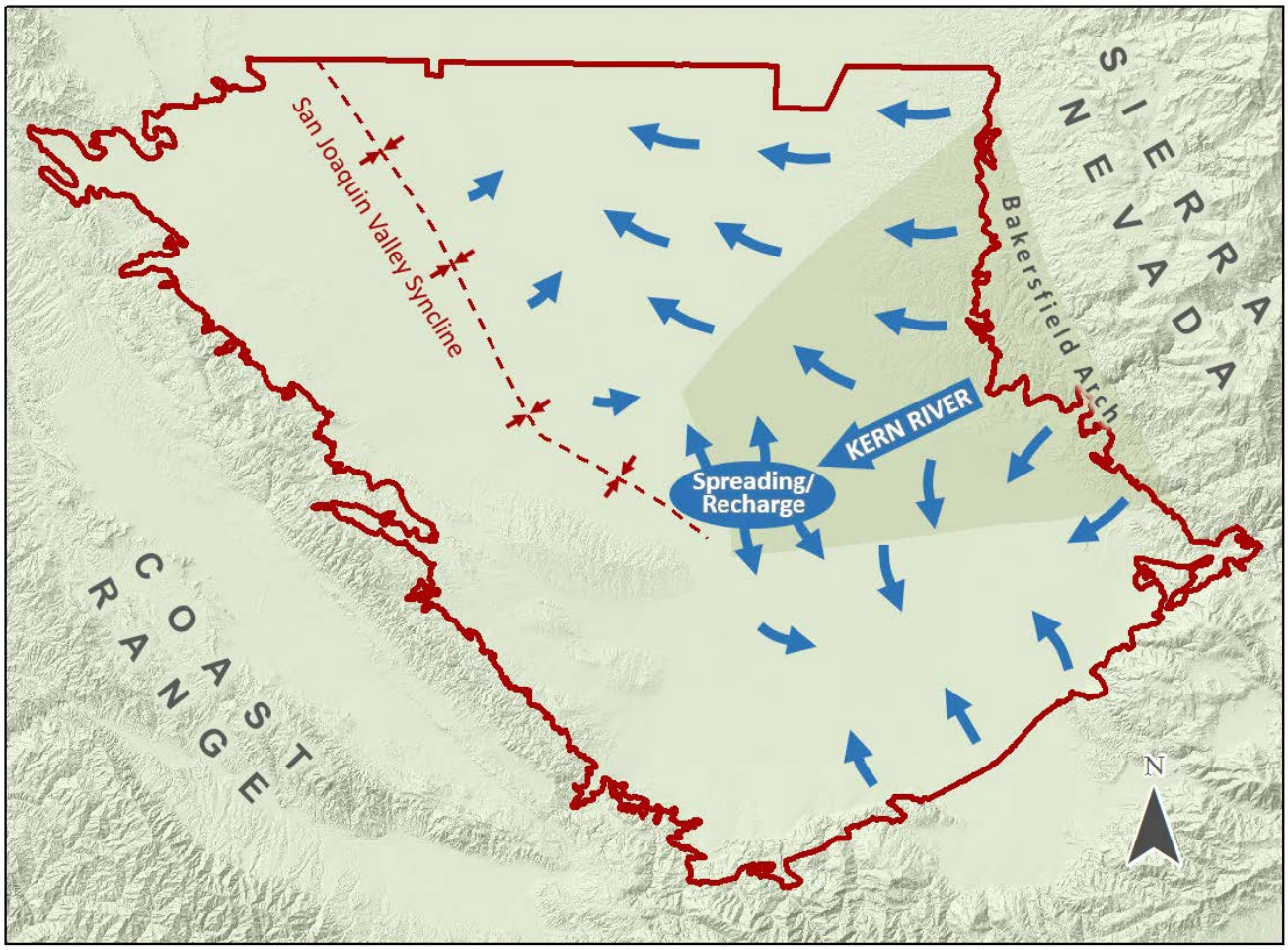


Figure 2-24. Generalized Groundwater Flow in Kern County Subbasin

As observed in cross sections, the seismic form correlations confirm the general flow direction of groundwater and the general topographic high of the Bakersfield Arch with bedding gradually dipping northerly on the northside of the Arch, and southerly on the south side of the Arch. Cross sections also depict some of the highs of the anticlines and the low of the Buttonwillow Syncline. In general, groundwater elevations near the river tend to respond to flow in the river channel and the management of groundwater banking projects located near the river, whereas, groundwater elevations further away from the river show more pronounced seasonal responses from pumping and recharge.

The following sections include the discussion of groundwater elevation contours, hydrographs, and other details to present the historical and current groundwater conditions within SWSD.

2.3.1 Groundwater Elevation Contour Maps

As mentioned above, Schmidt and Associates have prepared groundwater elevation contour maps since the mid-1990s for the Semitropic Water Banking Project. These maps are excellent sources of information for local groundwater conditions in SWSD. Two winter/spring-time maps

have been prepared for each year by Schmidt and Associates to contour the upper unconfined zone and the lower confined aquifer zone. Schmidt and Associates maps likely provide a more accurate picture of groundwater conditions in SWSD because they report contours for the two separate zones while other regional-scale contour maps in the Subbasin may have contoured the upper and lower zone water level data together on one map. Schmidt and Associates maps are based on static groundwater level data from District-owned dedicated monitoring wells, supply wells out of production, and other supply wells that were not pumping in order to collect static water levels (Schmidt and Associates, 2018).

In addition to the Schmidt and Associates maps, the KCWA has published high quality contour maps of the shallow aquifer zone which is typically considered groundwater above the A-clay or equivalent. These maps were published from 1979 to 2011. KCWA collects data during the summer months (usually July or August) from as many of the 300+ wells. The perforations typically range from 5 to 10 feet in length and are typically completed in shallow wells less than 100 feet deep, many of which are 20 feet deep (KCWA, 2019).

Two contour maps for the baseline evaluation period of spring 2015 were developed by Schmidt and Associates (2018) and are presented in Figures 2-25 and 2-26 to illustrate the upper unconfined zone and the lower confined aquifer zone conditions, respectively. The shallow contours for summer 2011 are included as Figure 2-27 because they are the most recent contours published by KCWA.

The following observations pertain to spring 2015 lower zone contours:

- Groundwater elevations in the lower zone range from 50 ft msl to (negative) -90 ft msl inside the District and vary from the southeast to the north-northeast.
- Groundwater flows northwesterly from the forebay area into SWSD at a gradient of 0.002 ft/ft, and on the west side of SWSD flows northeasterly at a gradient of 0.002 ft/ft.
- Very little lower zone pumping occurs to the west of SWSD, so data are limited in this area.
- The -50 ft msl contour appears to parallel the Semitropic Ridge in T27S-R23E Sections 20, 28, and 34; however, the effects of the ridge on groundwater flow are still uncertain and may require additional investigation.

The following observations pertain to spring 2015 upper zone contours:

- Groundwater elevations in the upper zone range from 140 ft msl to 220 ft msl in SWSD.
- Upper zone groundwater flow is variable across SWSD. At the western edge of SWSD, upper zone groundwater flows east-northeastward into SWSD at a gradient of about 0.003 ft/ft. Within the central and northeastern portion of SWSD, upper zone groundwater flows to the west and northwest at a gradient of 0.001 to 0.004 ft/ft toward a likely pumping center near Pond-Poso Spreading Grounds. In the southern portion, upper

zone groundwater flows south from T28S-R23E to T29S-R23E at a gradient of 0.005 to 0.006 ft/ft toward a possible pumping center in T29S-R24E.

- Little data are available for upper groundwater zone across Buttonwillow (NE T28S-R23E) and Semitropic Ridges (central T27S-R23E), where the USGS and CVHM datasets suggest gaps in the E-Clay or "300-ft" clay. Limited data are available between the Buttonwillow and Bowerbank anticlines (NE of T29SR23E and NW of T29SR24E) in the southwestern portion of SWSD where gradients are greater, and flow is to the south and east toward pumping centers.

The following observations pertain to the summer 2011 shallow zone contours and water level data provided by KCWA:

- Groundwater depths ranged from approximately 2 to 20 feet below ground surface. Groundwater elevations ranged from 167 feet to 286 feet msl.
- The extent or "footprint" of the shallow contours are similar to the upper zone contours extent. A comparison of water elevations between shallow and upper zones are provided in hydrographs for Section 2.3.2. In general, the elevations may be similar in the central and western portions of the District, while it is likely that the eastern and southeastern portions of the District
- The shallow contours extend eastward from the mapped extent of the A-Clay of Croft (1972), which is located predominantly within the Buttonwillow Syncline and further north into the Kern Wildlife Refuge. The shallow contour also extends beyond the extent of the deeper C-Clay, so it is likely that other A-Clay equivalent perching layers may contribute to the perching zone.

2.3.1.1 Historical Groundwater Contours and Change in Elevation

Historical water level contour maps were reviewed to consider groundwater elevations changes over time. Contour maps for the upper zone and the lower zone have been prepared for the Semitropic Groundwater Banking Program Monitoring Committee by Schmidt and Associates. In addition, a historical map for 1995 to 2015 calculated change in groundwater elevation are also included (Schmidt and Associates, 2017). Shallow zone contour maps have been prepared by KCWA for the periods of 1995 to 2011.

During the 20-year period (1995-2014) preceding SGMA, groundwater levels have generally declined during dry years, and have increased during wet years. During the drought of 2012-2016, groundwater levels reached historical lows. Contour maps of historical water levels in Semitropic are generally consistent with the overall trend from 1995-2014.

GROUNDWATER ELEVATIONS UPPER ZONE SPRING 2015

- Spring 2015 Upper Zone Groundwater Surface Elevation *(MSL)*
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-25

Notes:
Due to limited data, Contours are incomplete and the extent of the Upper Zone is not fully defined.

SOURCE: Kenneth D Schmidt and Assoc (Feb, 2018)

07-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM012_KernSB_GW_Spr2015_Schmidt_UpperZone.mxd SI

GROUNDWATER ELEVATIONS
LOWER ZONE SPRING 2015

Contour Type

- Lower
- Forebay
- Lower *Uncertain*

- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-26

SOURCE: Kenneth D Schmidt and Assoc (Feb, 2018)

07-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM013_KernSB_GW_Spr2015_Schmidt_LowerZone.mxd SI

REPRESENTATIVE SHALLOW GROUNDWATER CONTOURS

- Depth to Shallow Groundwater (Summer 2011 - KCWA)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-27

SOURCE: Kern County Water Agency, Water Supply Report 2011.

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETISEM026_NCCAG_Vegetation.mxd SI

This Page Left Blank Intentionally

Based on contour maps, groundwater elevations in the lower zone generally increased and supported pumping centers in the central portion of SWSD near T26S-R23E during wet years from 1995 to 2000. Dry years occurred from 2001-2004 and groundwater elevations decreased, and the pumping center shifted toward T27S-R23E. A slight increase in groundwater elevations occurred after the two wet years of 2005 and 2006. Overall, the critically dry years during the last drought from 2007 to 2016, resulted in substantial declines in groundwater elevations.

Changes in lower zone groundwater levels from 1995 through 2015, as reported by Schmidt and Associates (2017), ranged from 10 to 70 feet of decline in the Buttonwillow Improvement District to between 70 and 100 feet of decline in Pond-Poso Improvement District.

Historical upper zone contours fluctuate more frequently likely due to fewer control points for generating contours. In general, groundwater elevations in the upper zone have ranged from 140 to 220 ft msl from 1995 through 2015. Flow directions generally are to the northeast just north of Buttonwillow Ridge, and flow is to the south just south of Buttonwillow and Semitropic Ridges. Flow directions reportedly shift from year to year near the east central portions of SWSD near Pond-Poso Spreading Grounds, which may be due to insufficient control points in the data set. Flow in the northeast area can be toward the north as well as toward the south. Overall, groundwater elevations have decreased in the upper zone due to the latest drought, but the decrease is less than the decline in the lower zone. In some areas, the decrease varies from 20 to 40 feet in elevation.

Historical shallow zone contours as reported by KCWA were stable over time from 1995 through 2011— only slight changes between the 5- and 15-foot contours over time are noted. The general extent of the 20-foot contour is relatively unchanged from 1995 to 2011.

2.3.2 Hydrographs

Hydrographs provided in Appendix B present groundwater elevations versus time with corresponding water years are included for discussion in this section.

In general, groundwater levels decline during dry years and increase during wet years based on the availability of imported surface water supplies. As a reference for recent surface supply water years, Figure 2-28 below presents the water year indexes from 1995 to 2017 for both the Sacramento Valley Index (typically representative of the State Water Project allocations), and the San Joaquin Valley Index (typically representative of the Friant-Kern Canal allocations). The 23-year period (1995-2017) started with six years of wet to above-normal water years followed by 12 of the final 17 years as below normal to critically dry years. The implementation of SGMA (2015) began with critically-dry and dry years midway through a historic 5-year drought period.

Figure 2-29 is an example hydrograph from the study area showing that groundwater elevations decline during dry years when surface water supplies are generally less available, and groundwater elevations recover or increase during wet years when more surface water supplies are available.

Water Year	Sacramento Valley	San Joaquin Valley
1995	Wet	Wet
1996	Wet	Wet
1997	Wet	Wet
1998	Wet	Wet
1999	Wet	Above Normal
2000	Above Normal	Above Normal
2001	Dry	Dry
2002	Dry	Dry
2003	Above Normal	Below Normal
2004	Below Normal	Dry
2005	Above Normal	Wet
2006	Wet	Wet
2007	Dry	Critical
2008	Critical	Critical
2009	Dry	Below Normal
2010	Below Normal	Above Normal
2011	Wet	Wet
2012	Below Normal	Dry
2013	Dry	Critical
2014	Critical	Critical
2015	Critical	Critical
2016	Below Normal	Dry
2017	Wet	Wet

Source: http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST

Figure 2-28. Water Year Index (1995 to 2017)

A select group of representative hydrographs are included in the discussion below (Appendix B-1). A complete set of hydrographs for data in the data management system (DMS) is contained in Appendix B-2. The representative hydrographs were selected based on completeness of water level record from 1995 through 2015, available well construction data, trends that generally followed the mean trend of all hydrographs, data from dedicated monitoring wells, and pairs with upper zone water levels and lower zone water levels. In general, there is limited available data that match all the above criteria. Many wells with a long record of data were not dedicated monitoring wells, or well construction data were not available. Nonetheless, the hydrographs selected for discussion in this section represent some of the general trends observed in groundwater levels within SWSD. A summary table of the hydrograph wells is included in Appendix B-1.

Where possible, hydrographs were plotted in well groups that were located within a few square miles. The locations of the hydrographs and corresponding groups are included Appendix B-1.

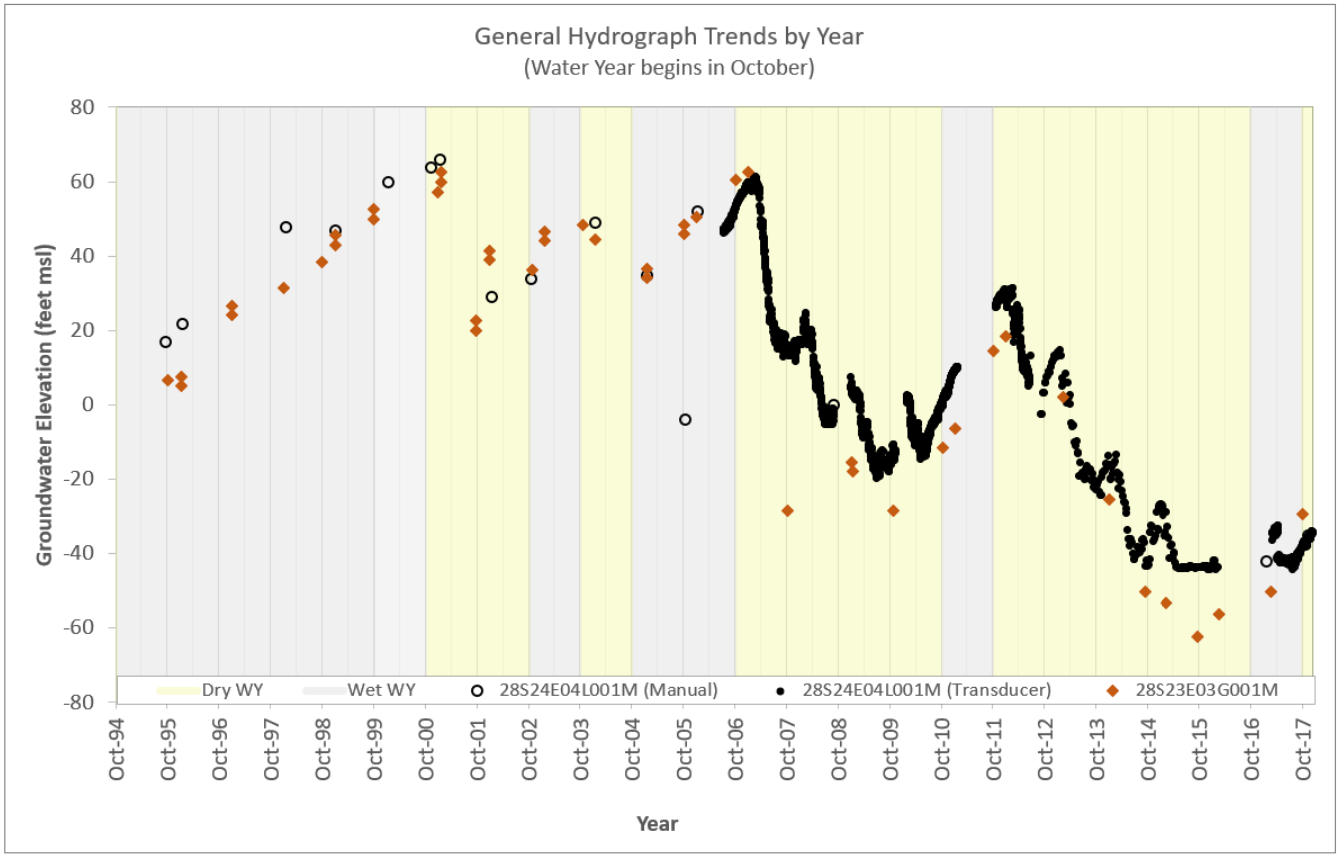


Figure 2-29. General Hydrograph Trends by Year

Group 1 hydrographs represent wells in the northwest portion of the study area and depict upper zone groundwater levels that do not change significantly during wet or dry years. On the other hand, the lower zone water levels increase during wet years and decrease during dry years. The transducer data of the S-12 monitoring well confirms the seasonal swing and drawdown observed during peak pumping. A-, C-, and E-Clays are present in Group 1.

Group 2 hydrographs represent wells in the northeast portion of the study area and depict groundwater that is more impacted by pumping than groundwater in the northwest. The upper zone groundwater levels in Group 2 increase during wet years and decrease with subsequent groundwater pumping during dry years, although these changes are a fraction of the changes that occur in the lower confined aquifer zone. The change in the upper zone is consistent with the interpretation that wells are pumping from the upper zone in this area of SWSD and to the east in SSJMUD just west of Delano. The change in lower zone water levels in 2007 to the end of 2009 are quite extreme. Some of the decline in water levels may be attributed to drawdown effects of pumping; however, the dedicated monitoring well also reports fairly large declines in water levels from the beginning of the dry periods (2007-2009 and 2012-2016) until the start of a wet year. E-Clay is present in Group 2.

Group 3 hydrograph trends are similar to trends for Group 1 except with the upper zone increasing slightly during wet years. The sharp drop in upper zone water level in the beginning of 2014 may be an anomaly. No further data is available for this 2014 data point. E-Clay is present in Group 3.

Group 4 hydrographs follow similar trends as Group 2, except that the upper zone well, between 1995 to 2003, has recorded water levels that more closely follow a lower zone well trend. E-Clay is present in Group 4.

Group 5 monitoring wells on the west side of SWSD along the boundary with BVWSD depict a lower zone that is less impacted by pumping when compared with the central portions of SWSD. Less pumping in the lower zone is consistent with the interpretation that higher salinity groundwater occurs in the lower zone at shallower depths along the boundary with BVWSD. The Group 5 hydrograph also indicates that water levels are impacted in the upper zone during dry years. This condition is consistent with the fact that wells (likely private) in BVWSD, and likely some western areas of SWSD, pump from the upper zone, even if minimal. C- and E-Clays are present in Group 5.

Group 6 water level trends are similar to Group 3 and Group 8. In general, the water level declines are less in Buttonwillow area than in Pond-Poso.

Group 7 depicts lower zone groundwater levels in two monitoring wells that may be screened at the base of the confining clay or E-Clay. The trends are similar to trends for Group 5 lower zone except with slightly greater increases in drawdown during dry years. This condition is consistent with the knowledge that pumping increases along the western boundary as you move south. C- and E-Clays are present in Group 7.

Group 8 lower zone trends are very similar to Group 6 trends. The upper zone well appears to be more influenced by pumping during dry years, which may be due to well perforation across the confining clay into the deeper zone. E-Clay is present in Group 8.

Group 9 lower zone trends are consistent with Group 8. The trends show that water level declines occurred during dry years, although on a smaller scale than what has been observed in the north central and northeastern portion of SWSD. E-Clay is present in Group 9.

Group 10 hydrographs depict an upper zone that is minimally influence by pumping during dry periods with some water level increase during wet years. The lower zone trends are similar to Group 9; the water levels are higher in elevation and exhibit fewer extreme swings associated with dry seasons likely because the southern portion of SWSD is closer to recharge/banking centers and the Kern Fan. The spike in the lower zone reading during the middle of 2001 is likely an anomaly. E-Clay is present in Group 10.

2.3.3 Change in Groundwater Storage

Change in groundwater storage is estimated in the KGA Umbrella GSP. Included with the description are graphs of the change in groundwater storage over the study time period of 1995 through 2015.

Historical changes in groundwater elevation maps for SWSD are documented in Schmidt and Associates maps prepared for the SWSD Water Banking Project Monitoring Committee. As observed with the change in elevation maps and hydrographs, groundwater storage is reduced during "dry" water years when imported surface water deliveries are limited, resulting in greater reliance on pumping groundwater to meet water demands in SWSD.

2.3.4 Seawater Intrusion

Seawater intrusion is not a risk factor in the Kern County Subbasin. The Coast Range is a barrier to groundwater flow and separates seawater from the Subbasin.

2.3.5 Groundwater Quality Issues

This section discusses groundwater quality issues that may affect the supply and beneficial uses of groundwater in the Semitropic Area. This section includes a discussion of water quality standards used and information relevant to describing the groundwater quality in SWSD boundaries.

2.3.5.1 Public Water Systems

While land use within SWSD is predominately agricultural, there are located within the District's service area as identified through GAMA. Two of these water systems are classified as community water systems, meaning that there are at least 15 service connections, or 25 year-round residents served. The remaining public water systems are either nontransient non-community (NTNC) or transient non-community water systems (TNC). This classification is generally designated for businesses who supply water to their employees, or a transient (pass through) population. Table 2-2 lists the public water systems with a brief description, classification and estimated population served. Figure 2-30 shows where they are located within the District boundaries.

Water quality data from regulated drinking water systems is available through the State Drinking Water Information System (SDWIS). Community NTNC water systems are required to test for most regulated constituents at least once every 3 years. TNC have less stringent monitoring requirements and typically only test for nitrate and bacteria on a regular basis.

This Page Left Blank Intentionally

PUBLIC WATER SYSTEMS IDENTIFIED WITHIN SWSD

- Public Water Service Area (generalized location)
- Spreading Facilities within SWSD
- Approximate Extent of Corcoran Clay (USGS)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-30

SOURCE: SWRCB GeoTracker GAMA - 2019

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETI\SEM015_PublicWaterSystems.mxd SI

This Page Left Blank Intentionally

Table 2-2. Public Water Systems within SWSD

Water System #	Water System Name	Type	Population Served	Service Area	Number of Wells
1502029	Buttonwillow Rest Stop Water System	TNC	1,500	Highway Rest Area	1
1503249	Buttonwillow Road Circuit, LP	TNC	R = 1 T = 650	Other Transient	1
1500491	Interstate 5 Utility Company	NTNC	NT = 196 R = 2 T = 2,750	Highway Rest Area	2
1503380	JG Boswell Tomato Company LLC	NTNC	225	Industrial/Ag	2
1510046	Lost Hills Utility District	C	2,412	Wholesaler	2
1502620	Pond Mutual Water Company	C	48	Residential	1
1503521	Primex Farms Water System	NTNC	125	Industrial/Ag	2
1503578	Sunnygem Hulling & Shelling	TNC	NT = 9 T = 60	Highway Rest Area	1
1510801	Wasco St. Prison Reception Ctr. (w/in SWSD service area, but not w/in SWSD GSA boundary)	C	6,514	Community	2

C = Community water system
NTNC = Nontransient non-community water system
TNC = Transient non-community water system
NT = Nontransient
T = Transient
R = Residential

2.3.5.2 Existing Water Quality Monitoring Programs

SWSD currently samples a combination of District-owned and landowner-owned production wells for their water quality monitoring program. They also have approximately 48 dedicated monitoring wells. These wells are sampled on a rotational schedule: on average, 50 to 75 production wells are sampled annually depending on the type of hydrological year. During wet water years, most wells are not in operation because surface water is available; therefore, offline wells are not sampled. During dry years, almost all their wells are operational and will be sampled.

Further, the District also participates in the California Aqueduct Pump-In Program; therefore, DWR requires wells used for this Program to be routinely sampled for Title 22 regulated parameters and DWR's Constituents of Concern (COC), as listed in their policy. Water quality data is available for 51 representative wells, from 2010 through 2018.

2.3.5.3 Domestic Wells

Domestic wells are used exclusively to supply general household needs of the property owner and are typically constructed to a shallower depth than municipal or agricultural wells.

Therefore, domestic wells are more commonly impacted by surface contaminants leaching into the groundwater.

Currently, information about domestic wells is limited. There is an effort being led by the State Water Resource Control Board (SWRCB), as well as multiple other agencies, to explore the best sources of information and to conduct a Needs Assessment of domestic wells in contaminated groundwater basins. An effort specific to SWSD is being conducted by the Tulare Kern Funding Area Disadvantaged Community Involvement Program that anticipates its study will be completed by the end of 2019. This study is seeking to quantify the number of domestic wells in the funding area. These studies will also gather information on the disadvantaged communities and domestic well owners and explore potential remedies for contaminated wells.

2.3.5.4 Water Quality Standards

Federal and State Drinking Water Standards are predominantly referenced when discussing water quality standards. However, the predominant land use in SWSD is for agricultural purposes. For this reason, the agricultural *Water Quality Goals* (Ag goals) will also be referenced for evaluation of groundwater quality in this area. The most applicable standard, Drinking Water Standard or Ag goals will be used as a reference point when discussing each constituent. Water quality constituents that have the potential to impact the groundwater quality to SWSD are: arsenic, hexavalent chromium, nitrate, chloride, sodium, boron, TCP, and dibromochloropropane (DBCP). The list of these constituents along with their corresponding standards are listed in Table 2-3. In the Subbasin, arsenic, hexavalent chromium, and boron are predominately naturally occurring. Constituents related to salinity - chloride and sodium - are also naturally occurring but concentrated by surface activities. Nitrate is predominately anthropogenic. DBCP and TCP are manmade chemicals and are completely anthropogenic.

Table 2-3. List of Constituents and Standards

Constituent	Units*	Drinking Water Standard	Agricultural Water Quality Goal
Arsenic	ppb	10	100
Boron	ppb	1,000	700
Chloride	ppm	250	106
Dibromochloropropane (DBCP)	ppt	2	n/a
Hexavalent Chromium	ppb	n/a	n/a
Nitrate	ppm	10	n/a
Sodium	ppm	n/a	69
1,2,3-Trichloropropane (TCP)	ppt	5	n/a

*ppt = parts per trillion / ppb = parts per billion / ppm = parts per million

2.3.5.5 Land Use

Multiple sources were used to determine the land and crop land uses within the District. Ideally one single source would be used, however none of the single sources cover the entire extent of Kern County. Using the combination of sources, land use for the entire county is accounted for. Sources that were used in priority order are: 2014 data from Land IQ, 2016 Kern County Data from Department of Agriculture and Measurement Standards, and 2006 data from DWR.

Land IQ was contracted by DWR to assist in obtaining land use data. In addition, Land IQ works in partnership with many other water districts within Kern County and uses satellite data to obtain the land and crop records. Given that SWSD has worked closely with Land IQ to develop the data, this dataset was given the highest priority of the three sources to develop the land and crop land uses within SWSD.

Data from Land IQ also covers much of the crop land in the county and it was determined that crop patterns have been consistent within the last ten years. 2016 Kern County data was then used to fill in any spatial gaps of missing data from Land IQ. The last source, 2006 DWR data, was used to fill in any missing gaps from the two other sources. Despite DWR data being older than Land IQ and Kern County data, much of the missing land data filled by DWR are generally riparian and native vegetation land. Geographic Information System software (GIS) was used to merge shapefiles from all three data sources together.

When evaluating water quality, it is important to know what the land uses are in the area. Often, the land use activities may impact the groundwater quality. SWSD has a total land acreage of 223,885 acres. Of the total land within SWSD, about 65 percent is dedicated to agricultural land. The next largest percentage of land use within SWSD is native vegetation at about 24 percent. Native vegetation is predominately located in the northwest portion of the District. Figure 2-31 shows the land use distribution.

2.3.5.6 Data Used

District Wells

District wells include both production and monitoring wells. Production wells are used exclusively for agricultural purposes but are routinely sampled. Data used to conduct this evaluation were obtained from SWSD's existing monitoring network and municipal wells that submit water quality test results to State Drinking Water Information System.

Due to the large quantity of wells within SWSD's monitoring network, the following method was used to select the representative wells to characterize the groundwater. Both monitoring and production wells with known well construction details were identified. Wells were then mapped using GIS to identify which areas displayed high-density and no wells.

SWSD's well network contains wells that pump from both the upper and lower zones of the aquifer. Well Completion Reports were used to determine which wells had perforations in the

upper and lower zones, screened across both zones, and where the Corcoran Clay is absent. The terminology used to distinguish the upper, lower zones, and unconfined, confined aquifer will be used interchangeably within this section. They were then grouped by the depth of their well perforation to identify wells that are representative of the groundwater aquifer.

To identify wells that will meet requirements for future monitoring, spatial distribution of wells was viewed by Township and Range grids. When multiple wells were identified within a Township-Range-Section, the most representative well was chosen with preference given to existing monitoring or production wells equipped such that samples can be readily obtained When precise well coordinates were not available, the location of the representative well was to be placed in the center of its respective Township-Range-Section grid.

Through this effort, 51 representative wells were identified to characterize the groundwater basin that underlies the District. These representative wells provide both geographic and vertical representation of the portion of the groundwater basin underlying SWSD. Figure 2-32 shows the distribution of wells used for this evaluation.

Water quality data is available for all 51 representative wells; however, not all wells have an adequate amount of data to conduct trending analysis. Therefore, only wells with more than three sets of results were trended and compared with other wells within their group to interpret the overall trend. Table 2-4 shows the total number of wells, what portion of the aquifer they represent, and the number of wells with sufficient data for trending analysis.

In general, there are very few wells with perforations in the unconfined aquifer. The one well selected to represent the unconfined aquifer is the only well with more than one set of sample results available. Most wells are constructed with perforations only in the confined aquifer, which is located about 300 feet below ground surface.

Table 2-4. Representative Wells in Relation to Aquifer

Land Use	Acres	Percentage (%)
Agriculture	146,000	65.21
Industrial	685	0.31
Commercial	461	0.21
Riparian	20,109	8.98
Native Vegetation	53,624	23.95
Urban Landscape	48	0.02
Residential	129	0.06
Vacant	817	0.36
Surface Water	2,009	0.90
Total	223,885	100

LAND USE WITHIN SWSD

- Semitropic WSD GSA
- Kern County Subbasin Boundary

Land Use

- Agriculture
- Riparian Vegetation
- Native Vegetation
- Commercial
- Industrial
- Residential
- Urban Landscape
- Urban
- Surface Water
- Vacant

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-31

SOURCE: Land IQ, 2014; Kern County, 2016; DWR, 2006.

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM016_LandUse.mxd SI

REPRESENTATIVE WELLS FOR WATER QUALITY EVALUATION

- Spreading Facilities within SWSD
- Approximate Extent of Corcoran Clay (USGS)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Representative Well

- No Perforation Data
- Outside of Corcoran Clay Extents
- Well Above Corcoran Clay
- Well Above and Below Corcoran Clay
- Well Below Corcoran Clay

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-32

SOURCE: Semitropic WSD

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETI\SEM017_RepresentativeWells.mxd SI

Public Water System Wells

Public water systems were identified through the State Water Resource Control Board's Groundwater Ambient Monitoring and Assessment Program (GAMA) and water quality data was extracted from the United States Environmental Protection Agency's (USEPA) Safe Drinking Water Information System (SDWIS). Since most of the water systems identified within SWSD are businesses, monitoring requirements are sometimes less extensive than municipalities serving residential communities. Consequently, there are some water systems with no data or only one result available for the identified constituents of concern in this region. Of the eight water systems identified, 12 wells were evaluated, and water quality data was trended from 2008 to current.

Well construction details were not available for public supply wells, which was challenging in determining where wells are perforated within the aquifer. This information is helpful for understanding what the water quality trends mean in relation to the aquifer. Water level data is also of value to determine if water quality trends are related to fluctuation in wet and dry water years. When examining the data, depths where constituents are more prevalent in the aquifer should be considered. Knowing this can help determine if water levels and well construction have an impact on water quality conditions.

2.3.5.7 Water Quality Evaluation

An evaluation of groundwater conditions in SWSD was conducted using a combination of 51 representative District wells and public water system data. Water quality data extracted from GAMA, Envirostor and Drinking Water Watch was evaluated to identify constituents of concern. Not all constituents commonly found in the Subbasin, as identified in Table 2-3, are found at above one-half of the respective MCLs in SWSD. Therefore, only arsenic, chloride, and sodium are addressed as constituents of concern. Nitrate and TCP are addressed as likely contaminants of concern; however, the representative wells evaluated for SWSD indicate that nitrate and TCP are not widespread contaminants in this region. Wells were selected based on geographical representation as well as aquifer characteristics. The discussion of each contaminant in the following sections summarizes the number of wells evaluated and which portion of the aquifer the well represents.

Sodium and Chloride

Since land use within SWSD is predominately agricultural, the State Water Board's Ag goals are referenced as the appropriate value, rather than drinking water standards. Sodium and chloride have an Ag goal of 69 and 106 ppm, respectively. Drinking water does not apply a limit for sodium. The recommended limit for chloride is 250 ppm and the upper limit is 500 ppm.

Ag goals were published by the Food and Agriculture Organization of the United Nations in 1985. The criteria are protective of various agricultural uses of water, including irrigation of

various types of crops and stock watering. At or below the thresholds presented in the Water Quality Goals database, agricultural uses of water should not be limited.

Both sodium and chloride show similar trends in the wells evaluated; therefore, for this discussion, they will be collectively referred to as salinity. Since sodium concentration is an important measurement to crop yield, the focus of salinity level discussion will be on sodium. Table 2-5 summarizes sodium concentrations and their relationship to well perforations.

Table 2-5. Summary of Sodium Prevalence Within SWSD

Well Perforation in Relation to Aquifer	# of Wells	# Wells Trended
Upper Zone/Unconfined Aquifer	1	1
Lower Zone/Confined Aquifer	19	6
Screened Across Both Zones	6	3
Corcoran Clay is Absent	8	5
No Perforation Data	17	5
Total	51	20

When compared against Ag goals, data indicates there are elevated sodium levels. More than half of the representative wells have sodium above the goal. Figure 2-33 shows where the highest sodium concentrations occur in wells screened across both aquifers. Wells located in the Upper Zone showed an inverse relationship between sodium and water levels. Figure 2-34 shows that as the water level increased, the sodium level decreased. The decreased sodium level is most likely due to dilution from the increased water level.

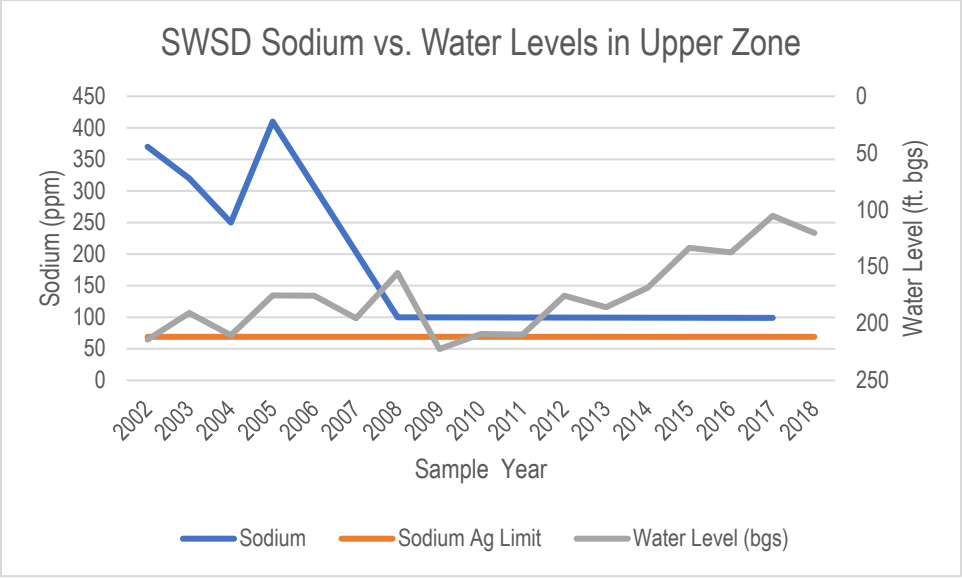


Figure 2-34. SWSD Sodium Versus Water Level in Upper Zone

Wells screened exclusively in the lower zone have overall lower sodium concentrations. Figure 2-35 represents sodium concentrations below the Corcoran Clay, in the confined aquifer. With the groundwater gradient flowing in the westerly and northwesterly direction, it was noted that

sodium levels in wells located west and northwest of the spreading ground have decreasing levels.

Figures 2-36 and 2-37 show this comparison between wells, with similar well construction, located near one of the District's spreading grounds. Figure 2-36, which is located west of the spreading grounds (downgradient), shows a decreasing trend and a direct relationship between the sodium and water level. In contrast, the well to the south (upgradient) in Figure 2-37 shows an increasing sodium trend and an inverse relationship to water level. Both graphs depict the sodium levels as decreasing due to dilution from the introduction of water to the basin for recharge.

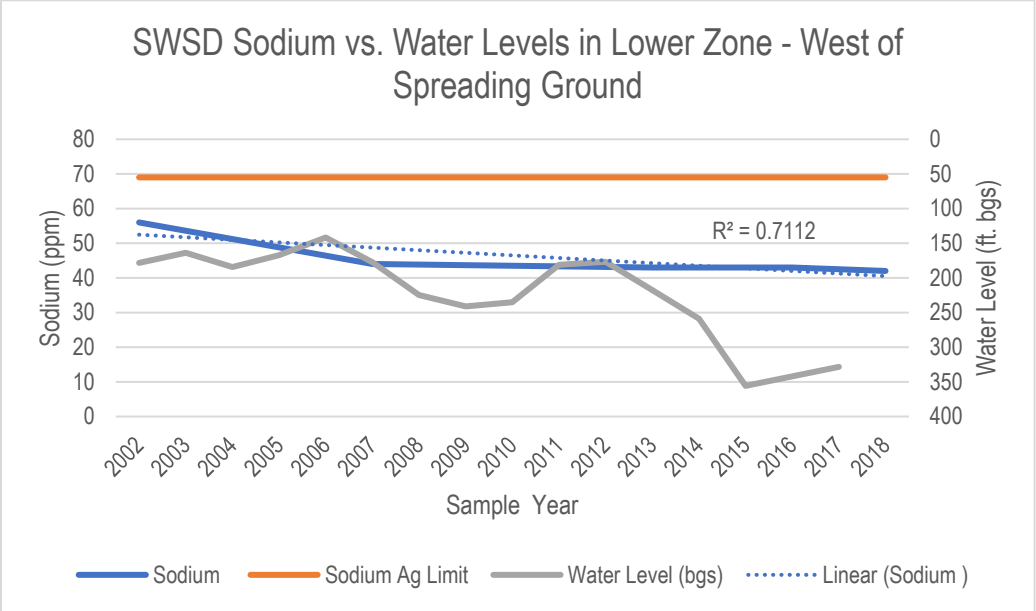


Figure 2-36. SWSD Sodium Versus Water Level in Lower Zone West of Spreading Ground

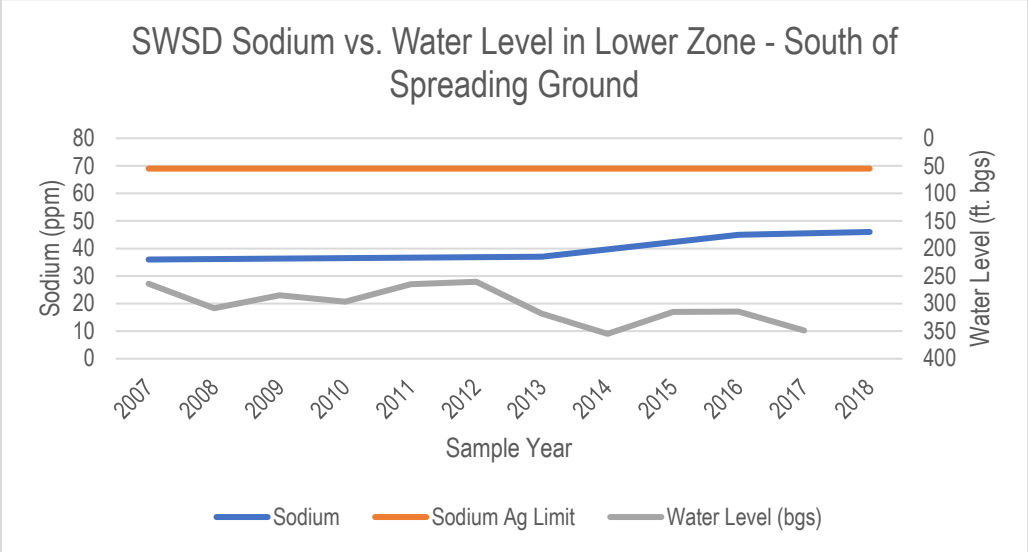
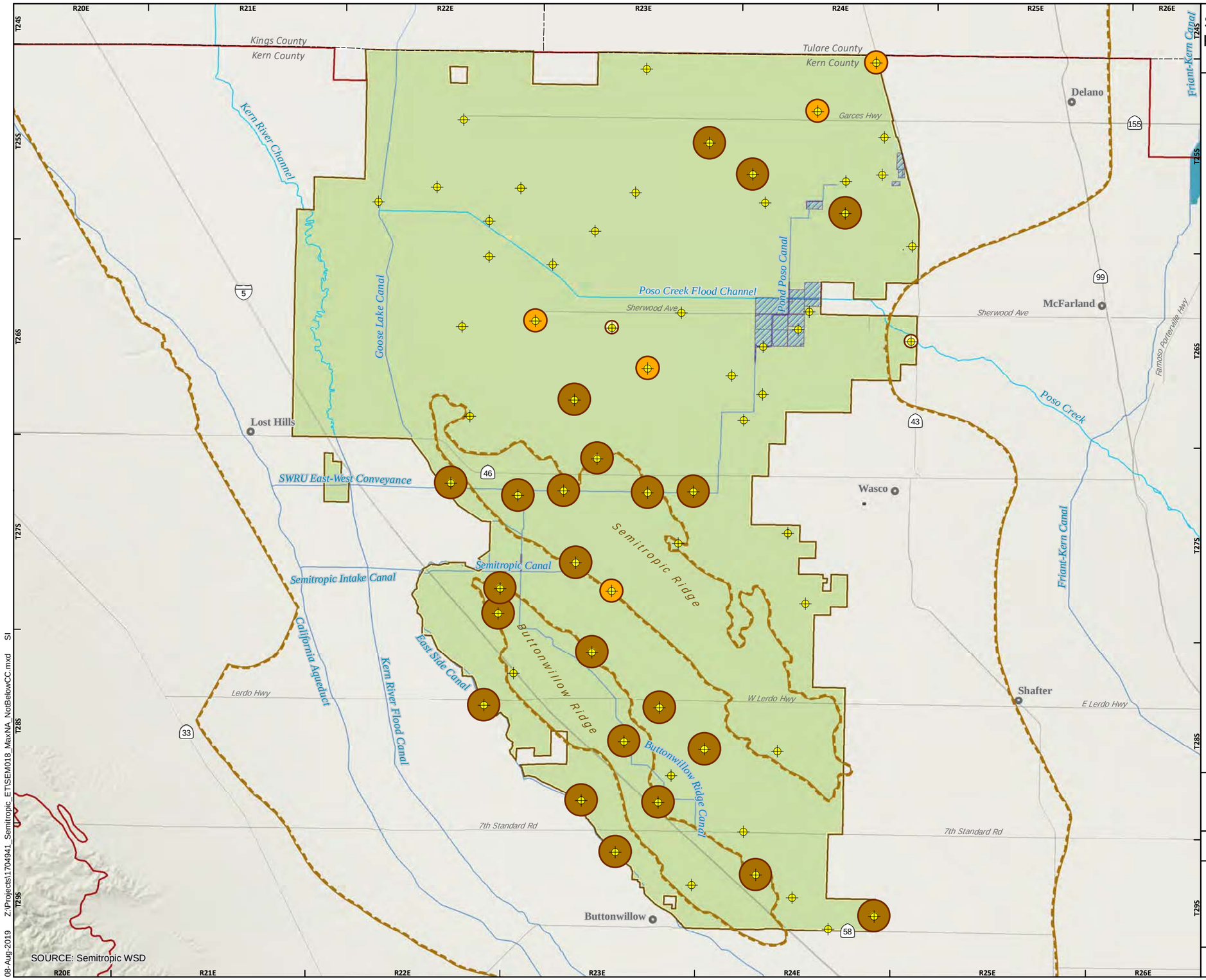


Figure 2-37. SWSD Sodium Versus Water Level in Lower Zone South of Spreading Ground

This Page Left Blank Intentionally

SWSD MAX SODIUM CONCENTRATIONS IN REPRESENTATIVE WELLS NOT SCREENED ENTIRELY BELOW CORCORAN CLAY



Representative Well

Spreading Facilities within SWSD

Approximate Extent of Corcoran Clay (USGS)

Semitropic WSD GSA

Kern County Subbasin Boundary

Representative Wells not Screened entirely below Corcoran Clay

Max. Sodium (ppm)

- 0 - 35
- 36 - 70
- >70

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4

Miles

N

SOURCE: Semitropic WSD

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-33

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM018_MaxNA_NotBelowCC.mxd SI

SWSD MAX SODIUM CONCENTRATIONS IN REPRESENTATIVE WELLS IN LOWER ZONE

- Representative Well
- Spreading Facilities within SWSD
- Approximate Extent of Corcoran Clay (USGS)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Representative Wells Screened Entirely below Corcoran Clay

Max. Sodium (ppm)

- 2 - 35
- 36 - 70
- >70

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-35

SOURCE: Semitropic WSD

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETI\SEM019_MaxNA_BelowCC.mxd SI

In general, it is observed that the sodium levels located throughout the District, particularly in the eastern and southern portions of the District, are elevated based on Ag goals and have increasing trends. Wells in the lower zone located downstream of the spreading grounds show lower sodium levels and decreasing trends. The SWSD recharge operations appear to dilute sodium levels coming from the east and south. The groundwater gradient flowing westerly and northwesterly indicates that wells downgradient of the spreading ground have lower sodium levels due to dilution. Since managing sodium concentrations to meet Ag goals is important to the land uses within SWSD, management actions that will slow or reverse the increasing sodium trends may be considered. Studies conducted through the Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS), and the projects that are planned, will aid in salinity management.

Arsenic

In terms of drinking water quality, arsenic is the primary contaminant of concern in SWSD. There is a primary drinking water standard of 10 ppb for arsenic. The Ag goal is 100 ppb. All water quality data in SWSD indicates that arsenic is below the Ag goal.

The most common source of arsenic is from natural geochemical processes that leach metals from the sediments, particularly in the lakebed areas and where dark clay deposits occur. Studies conducted by USGS found that arsenic is in an easily exchangeable state where oxidizing geochemical conditions, caused by groundwater containing higher oxygen content, dissolve the pyrite (a mineral which can contain arsenic) and release arsenic into the groundwater. Smith et. al. (2018) found that over-pumping in the San Joaquin Valley has led to land subsidence due to compaction of the lakebed deposits (clay layers) that then releases the high arsenic pore water from the clay layers into the groundwater.

About 64 percent of the wells evaluated exceed the drinking water limit for arsenic. For the District, 36 percent of the wells with elevated arsenic are in the confined aquifer. Figure 2-38 shows the SWSD representative well locations and their respective concentration levels. These wells are prevalent throughout the District. Tables 2-6 and 2-7 shows the number of wells within the District and public water system and their respective arsenic concentration levels.

Table 2-6. Summary of Arsenic Prevalence within SWSD

	Sodium Concentrations		
Well Location	**<34 ppm**	**35-69 ppm**	**>70 ppm**
Upper Zone/Unconfined Aquifer	0	0	1
Lower Zone/Confined Aquifer	1	10	7
Screened Across Both Zones	0	3	3
Corcoran Clay is Absent	1	0	7
No Perforation Data	4	7	19
Total Wells	6	20	37

Table 2-7. Summary of Arsenic Prevalence Among Public Water Systems

	Arsenic Concentrations			
Water System	**<5 ppb**	**6-10 ppb**	**>11 ppb**	**No Data**
Buttonwillow Rest Stop Water System				1
Buttonwillow Road Circuit, LP			1	
Interstate 5 Utility Company		2		
JG Boswell Tomato Company LLC			2	
Lost Hills Utility District			2	
Pond Mutual Water Company			1	
Primex Farms Water System	1		1	
Sunnygem Hulling & Shelling		1		
Total Wells	1	3	7	1

Because arsenic is believed to be naturally occurring in the Subbasin and leaching from dark clay deposits is the principal local source of contamination, arsenic concentrations greater than 10 ppb are most commonly found in wells that are screened across pyrite sediments. These sediments are generally found between 200 and 700 feet bgs.

Overall, the representative wells screened in the lower aquifer or across both zones have decreasing arsenic trends. Wells that represent the upper zone have increasing trends. Figure 2-39 shows two representative wells: one is screened in the lower zone and the other is screened across both zones. As shown in this graph, arsenic levels tend to decrease when water levels drop. This trend indicates that the water being pumped is not in contact with the clay layers that release arsenic.

While there is only one representative well screened in the upper zone, the trend for this well shows a positive relationship between arsenic and water levels. Figure 2-40 shows that as the water levels increase, arsenic levels also increase. Since there is only one representative well with this trend, it is difficult to explain the correlation. One potential explanation is that wells with longer screened intervals (perforations that extend between both aquifers) have more dilution from the confined aquifer, so arsenic released into the unconfined aquifer is less concentrated.

SWSD MAX ARSENIC CONCENTRATIONS

- Representative Well
- Spreading Facilities within SWSD
- Approximate Extent of Corcoran Clay (USGS)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Max. Arsenic (µgl)

- 0 - 5
- 6 - 10
- > 11

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-38

SOURCE: Semitropic WSD

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETI\SEM020_MaxArsenic.mxd SI

This Page Left Blank Intentionally

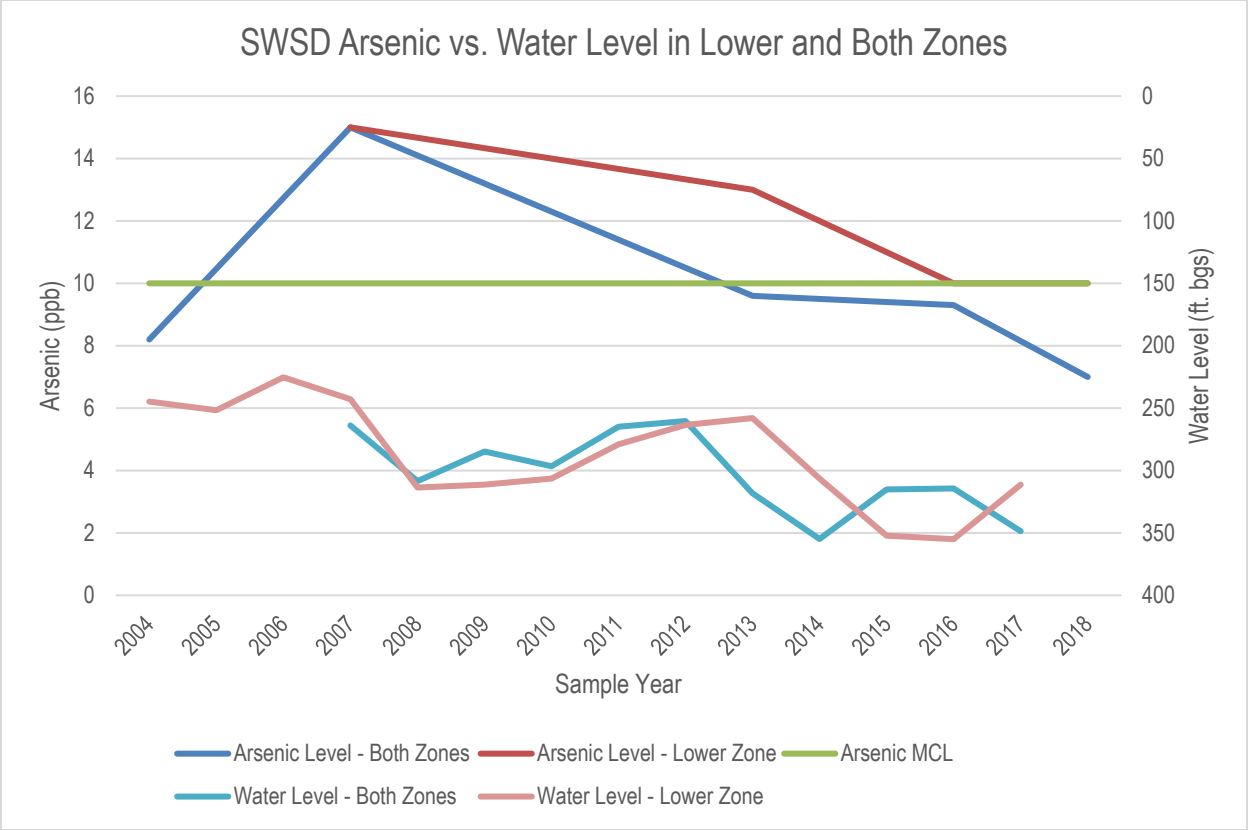


Figure 2-39. SWSD Arsenic and Water Level Relationship in Lower and Both Zones

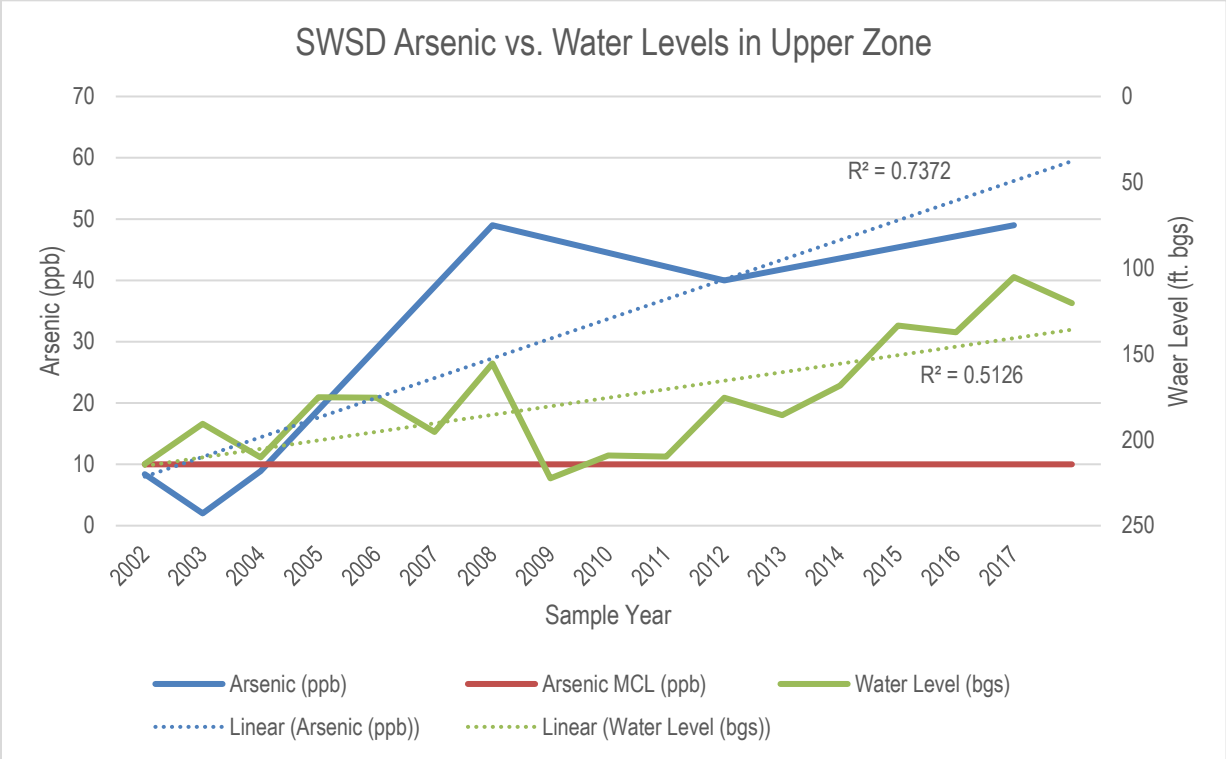


Figure 2-40. SWSD Arsenic and Water Level Relationship in Upper Zone

Another common trend in SWSD, and throughout the Subbasin, is the relationship between the completed well depth and arsenic concentration. Wells that extract groundwater exclusively from the confined aquifer and have a well bore which terminates closer to the base of fresh water, generally have elevated arsenic levels. Figure 2-41 shows six wells perforated in the confined aquifer and their average arsenic levels. This coincides with studies conducted by USGS in the Subbasin, explaining that arsenic concentrations tend to be elevated in the deeper part of the aquifer.

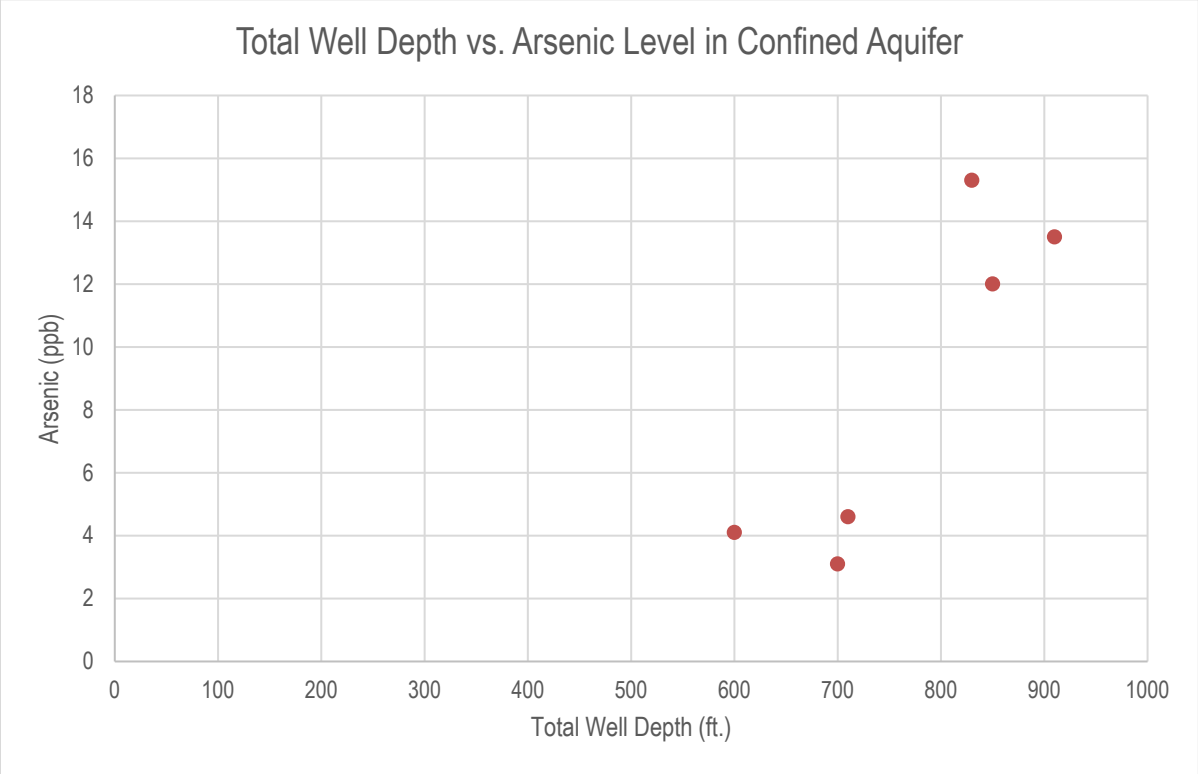


Figure 2-41. SWSD Well Depth vs. Arsenic Level in Confined Aquifer

1, 2, 3 – Trichloropropane (TCP)

TCP is a newly regulated synthetic organic chemical. The State Water Board reports that TCP contamination in the Central Valley is predominately from legacy pesticide applications of certain soil fumigants. The drinking water MCL for TCP is 5 ppt; there is no Ag goal.

While TCP contamination is widespread throughout the Subbasin, there appears to be less occurrence where the Corcoran Clay is present. Detections in SWSD are relatively intermittent and appear to only occur above the 5 ppt detection limit when wells are perforated in the upper aquifer, or when a nearby well is serving as a conduit between the upper and lower aquifers.

Of the public supply wells tested, 17 percent have TCP detections above the MCL of 5 ppt. Table 2-8 shows the water systems and the number of wells that are impacted by TCP. The District also collected samples throughout their service area between November 2017 to August

2018. Among the 195 samples collected, 40 samples (21 percent) exceeded the MCL for TCP. The percentage of wells within SWSD impacted by TCP is low compared to other areas in the Subbasin. Therefore, TCP is not a constituent of concern in the District due to the low percentage of exceedance compared to other constituents.

Table 2-8. Summary of TCP Prevalence Among Public Water Systems

	Arsenic Concentrations			
Water System	**<5 ppb**	**6-10 ppb**	**>11 ppb**	**No Data**
Buttonwillow Rest Stop Water System				1
Buttonwillow Road Circuit, LP			1	
Interstate 5 Utility Company		2		
JG Boswell Tomato Company LLC			2	
Lost Hills Utility District			2	
Pond Mutual Water Company			1	
Primex Farms Water System	1		1	
Sunnygem Hulling & Shelling		1		
Total Wells	1	3	7	1

Nitrate

Nitrate contamination is a significant concern in rural communities, particularly where agriculture is the predominant land use; accordingly, the MCL for Nitrate is 10 ppm as N. However, a significant source of nitrate also comes from septic systems that are used in these rural communities. Since municipal services (drinking water or wastewater collection systems) are not available in SWSD, all domestic and public wastewater disposal is through onsite septic systems.

Based on the data used in this evaluation, nitrate does not appear to be a widespread problem in SWSD. Of the 51 District wells used to characterize groundwater, only 2 exceed the MCL for nitrate. Sample results for the other 49 well ranged from non-detect to 6.5 ppm of nitrate as nitrogen (N). The 2 wells that exceed the MCL, had detections of 19 and 22 ppm as N: well construction details are not available for these two wells.

Table 2-9 summarizes nitrate concentrations of the public supply wells. As shown, no wells exceed the nitrate MCL and only 2 wells contain concentrations greater than one-half of the MCL. Nitrate trends throughout SWSD were consistent throughout the 8-year data period (2010 – 2018).

Contamination Plumes

A search of contamination plumes within SWSD was conducted using both GeoTracker and EnviroStor databases. The criteria outlined in the umbrella basin setting was applied during this review. Both databases yield no known contaminant plumes identified in the District.

Table 2-9. Summary of Nitrate Concentrations Public Water Systems

	TCP Concentrations		
Water System	**<5 ppt**	**>5 ppt**	**No Data**
Buttonwillow Rest Stop Water System			1
Buttonwillow Road Circuit, LP			1
Interstate 5 Utility Company	2		
JG Boswell Tomato Company LLC	2		
Lost Hills Utility District	2		
Pond Mutual Water Company			1
Primex Farms Water System		2	
Sunnygem Hulling & Shelling	1		
Total Wells	7	2	3

2.3.6 Land Subsidence

As described in the KGA Umbrella GSP basin setting section, inelastic (irrecoverable) land subsidence (subsidence) is a potential concern in areas of active groundwater extraction with underlying fine-grained sediment. Undesirable results of land subsidence may include, but are not limited to, flood risk in low lying areas; well casing damage or collapse, canal and infrastructure damage or collapse; and reduced groundwater storage (LSCE, 2014).

According to DWR (2014), the Subbasin was rated with a high potential for future subsidence, due to: 1) a majority of wells monitored with water levels at or below historical lows; 2) documented historical subsidence; and 3) documented current subsidence. Moreover, greater amounts of subsidence are occurring to the north of SWSD boundaries in the Tulare Subbasin. The amount of future subsidence will depend on whether future water levels decline below previous low levels and remain low for a considerable amount of time. Maintaining water levels above the previous low water levels could limit the risk of future subsidence.

Several processes contribute to land subsidence in the Subbasin including, in order of decreasing magnitude: aquifer compaction by overdraft, hydro compaction (shallow or near-surface subsidence) of moisture deficient deposits above the water table that are wetted for the first time since deposition, petroleum reservoir compaction due to oil and gas withdrawal, and subsidence caused by tectonic forces (Ireland et al., 1984).

Inelastic compaction (subsidence) typically occurs in the fine-grained beds of aquifers and in the aquitards. The fine-grained beds contain water in the pore spaces between the clay particles at the time of deposition and this water supports the clay particles which contributes to the thickness of the fine-grained bed. The dewatering of these deposits causing a one-time release of water from the clay (dewatering). This one-time release is also referred to as the inelastic skeletal specific storage of clay. Once the clays dewater, the volume released from inelastic storage results in permanent realignment of the clay particles and the collapse of the clay layer structure, or permanent land subsidence. Although space within the overall aquifer is reduced by an amount equivalent to subsidence of the land surface (due to reduced thickness of underlying clay

layers), this storage reduction does not substantially decrease usable storage for groundwater in the aquifer because the clay layers do not typically store significant amounts of recoverable, usable groundwater (LSCE, 2014). However, this one-time release of water and the associated compaction of the clay layers has been substantial in some areas of the Central Valley; and it is estimated that by the mid-1970s, about one-third of the volume of water pumped from storage in areas such as Los Banos-Kettleman City, came from compaction of fine-grained beds (Poland et al, 1975; Faunt et al, 2009); therefore, water budget projections may need to consider the one-time release of water from compaction as an irrecoverable water source for future projections. Although the largest body of fine-grained beds is the Corcoran Clay, a relatively insignificant volume of water has been released from storage in the Corcoran Clay (Faunt et al, 2009). However, aquifer water quality could be impacted by poor quality water released from the dewatering of clays, as postulated for an increase in arsenic (Smith et. al, 2018). The surface displacement of subsidence represents the reduced thickness of the impacted clay layers and this vertical displacement, if significant enough, may cause damage to wells and other surface structures.

Groundwater overdraft is considered to be the primary driver of historical land subsidence in the Central Valley (Faunt et. al., 2009). USGS estimates that about 75 percent of the subsidence occurred in the 1950s and 1960s, corresponding to extensive groundwater development (Galloway, et al., 1999), prior to implementation of the SWP, CVP, and other development of surface water resources. Below is a conceptual diagram (Figure 2-42) of where land subsidence can occur due to over pumping in aquifers with fine grained deposits. In general, lower zone pumping is where dewatering of clays occurs, which leads to subsidence. Less is known about any risk of land subsidence due to pumping in the upper zone where the C-Clay is present.

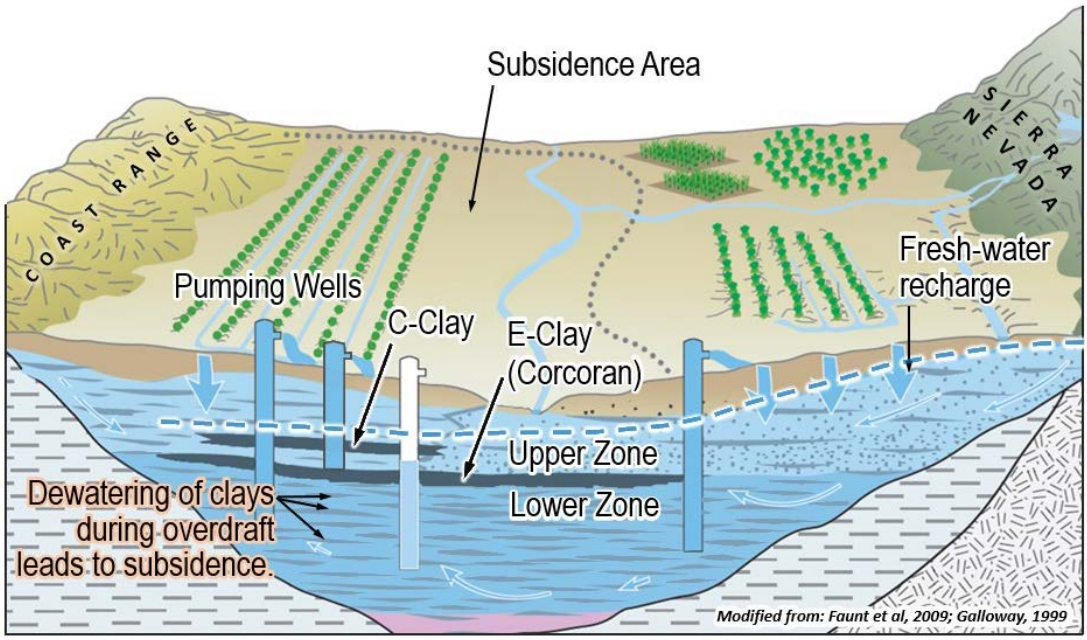


Figure 2-42. Conceptual Diagram of Subsidence

2.3.6.1 Subsidence Results and Methodology in the Study Area.

Results of subsidence estimates for the areas within and immediately adjacent to SWSD are summarized in the Table 2-10 below. Figures 2-43 through 2-47show subsidence estimates for the Semitropic Area and areas to the north, where subsidence is more extensive and likely a contributor to subsidence in the Semitropic area. In addition, time-series charts of subsidence are provided in Appendix C. Results were compiled from historical leveling surveys, recent Global Positioning Data (GPS) data, extensometer data, and satellite- and aircraft-based remote sensing.

Historical Results

Within the study area, historical subsidence has been documented from leveling surveys by the National Geodetic Survey at up to 6.5 feet from 1926 to 1970 (Ireland et al., 1984). Compaction data by the extensometers were plotted against the DWR water year indices. Greater rates of compaction generally correlated with low water year indices (critical, dry, or below normal) while compaction rates were lower during high water year indices (wet, and above normal).

In general, Figures 2-43 through 2-47 show that the center of historical subsidence occurs northeast of SWSD and propagated outward to the west and southwest into SWSD.

Continuous Global Positioning System (CGPS)

Recent subsidence studies of the Central Valley, and the Kern Subbasin have utilized continuous GPS (CGPS) station data as obtained by UNAVCO which installs, operates, maintains and collects data from geodetic instruments that comprise the Plate Boundary Observatory (PBO). CGPS stations are valuable because continuous data can be collected and transmitted remotely for land surface monitoring. The downside to using CGPS for subsidence monitoring is that CGPS stations measure change in ground surface relative to a datum such as sea level, rather than measuring a specific depth interval of interest such as an aquifer where groundwater pumping is occurring. Although CGPS is not directly measuring depth intervals of interest, other indirect relationships can be established. Datasets that are presented, herein, to better understand the cause of subsidence include hydrographs of nearby wells and the water year type to consider relative magnitude of regional groundwater extraction. In addition, other causes of subsidence were considered. These include seismic activity and underlying oil field operations. Based on data evaluation, seismic activity did not impact long-term trends of land subsidence from groundwater extraction. Within the SWSD study area, no long-term signatures were identified that could be related to nearby oil and gas operations. In general, CGPS data showed that land subsidence was more prevalent during dry years when water levels drop, and subsidence was not as active during wet years when water levels were recovering.

SWSD HISTORICAL SUBSIDENCE

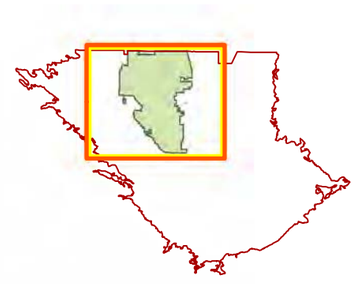
- Line of Equal Subsidence (ft)
- Approximate Extent of Corcoran Clay (USGS)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Subsidence 1926 to 1970

- More than 12 ft
- 10 to 12 ft
- 8 to 10 ft
- 6 to 8 ft
- 4 to 6 ft
- 2 to 4 ft
- 1 to 2 ft
- 0 to 1 ft

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

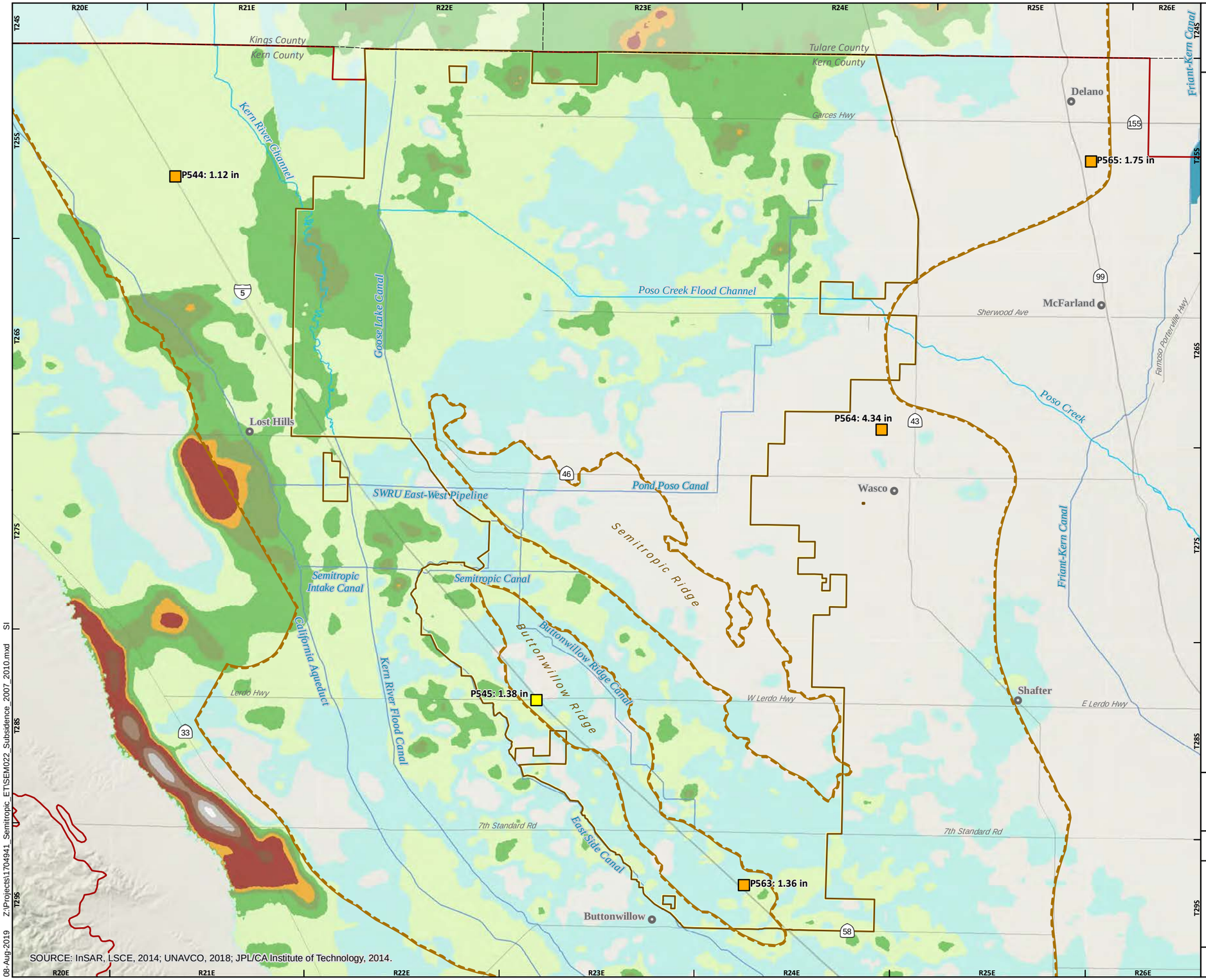
GEI Consultants

AUGUST 2019

FIGURE 2-43

SOURCE: Subsidence Contours by Geodetic Leveling (1926 - 1970), Ireland, 1984.

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM021_Subsidence_Historical.mxd SI



SOURCE: InSAR, LSCE, 2014; UNAVCO, 2018; JPL/CA Institute of Technology, 2014.

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM022_Subsidence_2007_2010.mxd SI

SWSD SUBSIDENCE 2007 - 2010

- NOAA CORS Station
- SOPAC Continuous GPS Monitoring Location
- Approximate Extent of Corcoran Clay (USGS)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Subsidence 2007 through 2010 (LSCE InSAR, 2014)

- More than 25 in
- 20 to 25 in
- 15 to 20 in
- 10 to 15 in
- 5 to 10 in
- 4 to 5 in
- 3 to 4 in
- 2 to 3 in
- 1 to 2 in
- 0 to 1 in

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-44

SWSD SUBSIDENCE 2015 - 2016

- SWSD Extensometer
- NOAA CORS Station
- SOPAC Continuous GPS Monitoring Location
- Approximate Extent of Corcoran Clay (USGS)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Subsidence 2015 through 2016 (LSCE InSAR, 2017)

- More than 25 in
- 20 to 25 in
- 15 to 20 in
- 10 to 15 in
- 5 to 10 in
- 4 to 5 in
- 3 to 4 in
- 2 to 3 in
- 1 to 2 in
- 0 to 1 in

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-45

P544: -0.06 in
25S/22E-35B001
1.4 in
P565: 3.71 in
P564: 2.99 in
P545: 0.57 in
P563: 0.33 in
Kings County
Kern County
Tulare County
Kern County
Delano
McFarland
Wasco
Shafter
Buttonwillow
Lost Hills
Kern River Channel
Goose Lake Canal
Poso Creek Flood Channel
Sherwood Ave
Famoso Porterville Hwy
Poso Creek
Pond Poso Canal
SWRU East-West Pipeline
Semitropic Ridge
Semitropic Canal
Semitropic Intake Canal
California Aqueduct
Kern River Flood Canal
Buttonwillow Ridge
Buttonwillow Ridge Canal
East Side Canal
Friant-Kern Canal
Lerdo Hwy
W Lerdo Hwy
E Lerdo Hwy
7th Standard Rd
R20E R21E R22E R23E R24E R25E R26E
T24S T25S T26S T27S T28S T29S
5 33 46 43 58 99 155

SOURCE: InSAR, LSCE, 2017; UNAVCO, 2018; JPL/CA Institute of Technology, 2017.

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM023_Subsidence_2015_2016.mxd SI

SWSD SUBSIDENCE RATE 2007 - 2010

- NOAA CORS Station
- SOPAC Continuous GPS Monitoring Location
- Approximate Extent of Corcoran Clay (USGS)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Subsidence Rate 2007 to 2010

- More than 8 in/yr
- 7 to 8 in/yr
- 6 to 7 in/yr
- 5 to 6 in/yr
- 4 to 5 in/yr
- 3 to 4 in/yr
- 2 to 3 in/yr
- 1 to 2 in/yr
- 0 to 1 in/yr

Other Features

- Highway
- Waterway
- Major Conveyance

P544 0.3 in/yr
P565 0.4 in/yr
P564 1.0 in/yr
P545 0.4 in/yr
P563 0.3 in/yr

Kings County
Kern County
Tulare County
Kern County
Kern River Channel
Goose Lake Canal
Poso Creek Flood Channel
Garces Hwy
Sherwood Ave
Famoso-Porterville Hwy
Poso Creek
Pond-Poso Canal
SWRU East-West Pipeline
Semitropic Ridge
Semitropic Intake Canal
Semitropic Canal
Buttonwillow Ridge Canal
California Aqueduct
Kern River Flood Canal
Lerdo Hwy
W Lerdo Hwy
E Lerdo Hwy
7th Standard Rd
East Side Canal
Friant-Kern Canal

Delano
McFarland
Wasco
Shafter
Lost Hills
Buttonwillow

R20E R21E R22E R23E R24E R25E R26E
T24S T25S T26S T27S T28S T29S

0 2 4
Miles

N

SOURCE: InSAR, LSCE, 2014; UNAVCO, 2018

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-46

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM024_SubsidenceRate_2007_2010.mxd SI

SWSD SUBSIDENCE RATE 2015 - 2016

P544 -0.04 in/yr

25S/22E-35B001
1.1 in/yr

P565 2.8 in/yr

P564 2.2 in/yr

P545 0.4 in/yr

P563 0.2 in/yr

Kings County
Kern County
Tulare County
Kern County

Kern River Channel
Goose Lake Canal
Poso Creek Flood Channel
Pond Poso Canal
SWRU East-West Pipeline
Semitropic Ridge
Semitropic Intake Canal
Semitropic Canal
California Aqueduct
Kern River Flood Canal
Buttonwillow Ridge
Buttonwillow Ridge Canal
East Side Canal
Friant-Kern Canal
Poso Creek
Ramsog Porterville Hwy

Delano
McFarland
Wasco
Shafter
Lost Hills
Buttonwillow

Sherwood Ave
Lerdo Hwy
W Lerdo Hwy
E Lerdo Hwy
7th Standard Rd

5
33
46
43
58
99
155

R20E R21E R22E R23E R24E R25E R26E

T24S T25S T26S T27S T28S T29S

SOURCE: InSAR, LSCE, 2017; UNAVCO, 2018.

- SWSD Extensometer
- NOAA CORS Station
- SOPAC Continuous GPS Monitoring Location
- Approximate Extent of Corcoran Clay (USGS)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Subsidence Rate 2015 to 2016

- More than 10 in/yr
- 9 to 10 in/yr
- 8 to 9 in/yr
- 7 to 8 in/yr
- 6 to 7 in/yr
- 5 to 6 in/yr
- 4 to 5 in/yr
- 3 to 4 in/yr
- 2 to 3 in/yr
- 1 to 2 in/yr
- 0 to 1 in/yr

Other Features

- Highway
- Waterway
- Major Conveyance

0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-47

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM025_SubsidenceRate_2015_2016.mxd SI

This Page Left Blank Intentionally

Table 2-10. Subsidence Results

District Area	Date Range	Approximate Cumulative Subsidence (inches)	Approximate Annual Rate of Subsidence (inches/year)	Source
North of SWSD boundary (Historical)	1926 to 1970	0 to 150	0 to 3.4	Ireland, 1984. Topographic Maps and Leveling Data
West, South, SW SWSD (Historical)	1926 to 1970	0 to 48	0 to 1.1	Ireland, 1984. Topographic Maps and Leveling Data.
North-Central SWSD	1979 - 1982	-0.2 to 0.2	-0.0 to 0.0	USGS Extensometer 26S/23E-16H2 and H3
NE SWSD	1926 to 1970	24 to 78	0.5 to 1.8	Ireland, 1984.
	1962 to 1970	12 to 24	1.5 to 3	Poland et al, 1975.
West SWSD	1926 to 1970	12 to 48	0.3 to 1.1	Ireland, 1984.
	1962 to 1970	12 to 24	1.5 to 3	Poland et al, 1975.
Central SWSD	1926 to 1970	12	0.3	Ireland, 1984.
	1962 to 1970	6	0.8	Poland et al, 1975.
NW SWSD	Dec-13 to Oct-16	3.0	1.0	25S22E35B001 Extensometer
I-5 West of SWSD	Oct-06 to Oct-09 Jan-07 to Mar-11 Oct-11 to Oct-16 May-15 to Sep-16 Dec-13 to Oct-16	0.6 1.1 0.5 -1.0 0.3	0.2 0.3 0.1 -0.8 0.1	CGPS PBO (P544). Negative values are potential uplift.
I-5 southwest within SWSD	Oct-06 to Oct-09 Jan-07 to Mar-11 Oct-11 to Oct-16 May-15 to Sep-16 Dec-13 to Oct-16	0.8 1.4 1.9 0.60 1.4	0.3 0.3 0.4 0.5 0.5	CGPS PBO (P545).
I-5 south within SWSD	Oct-06 to Oct-09 Jan-07 to Mar-11 Oct-11 to Oct-16 May-15 to Sep-16 Dec-13 to Oct-16	1.1 1.4 1.5 0.3 1.2	0.4 0.3 0.3 0.2 0.4	CGPS PBO (P563).
Wasco Proximity	Oct-06 to Oct-09 Jan-07 to Mar-11 Oct-11 to Oct-16 May-15 to Sep-16 Dec-13 to Oct-16	5.5 4.3 10.3 3.0 6.8	1.8 1.0 2.1 2.3 2.4	CGPS PBO (P564).
Delano proximity	Oct-06 to Oct-09 Jan-07 to Mar-11 Oct-11 to Oct-16 May-15 to Sep-16 Dec-13 to Oct-16	2.0 1.7 10.7 3.7 8.0	0.7 0.4 2.1 2.9 2.9	CGPS PBO (P565).
SWSD extent	Jan. 2007 to Mar. 2011	-2.7 to 4.1	-0.6 to 1	LSCE, 2014. Compiled from InSAR (negative values are potential uplift in land surface).
North of SWSD boundary		-3.3 to 5.6	-0.8 to 1.3	
SWSD extent	May 2015 to Sept. 2016	0.4 to 10.4	0.3 to 8.0	InSAR ESA Sentinel-1A (Farr et al., 2016)
North of SWSD boundary		1.1 to 14.5	0.9 to 11.2	

The following CGPS stations are located in or near the study area: P544 (Twisselman Road – west of Semitropic along I-5 and Twisselman Road), P545 (Lerdo Highway – southwest of Semitropic along I-5 just north of Lerdo Highway), P563 (Buttonwillow Rest Area – south of Semitropic along I-5 at the Buttonwillow Rest Area), P564 (Wasco – east of Semitropic at the Wasco Airport), and P565 (Delano – east of Semitropic at the Delano Municipal Airport). Day-to-day CGPS height solutions vary by as much as about 35 mm, likely due to variable atmospheric conditions, random walk noise, and other effects not directly related to land-surface-elevation change (Zerbini and others, 2001; Williams and others, 2004; Langbein, 2008) and, for this reason, short-term day-to-day comparisons of CGPS data to characterize land subsidence in the Central Valley is not ideal. Based on the time-series charts in Appendix C, CGPS data are more meaningful in characterizing land subsidence when looking at quarterly and annual trends. Therefore, cumulative subsidence and rates of subsidence were calculated by taking averages of the dataset for each water year. For CGPS data plotted with interferometric synthetic aperture radar (InSAR) data (Figures 2-43 through 2-47), cumulative subsidence and rates were estimated by daily averages.

In general, CGPS data show relatively modest subsidence to the south and west of SWSD (P544, P545, P563) and much higher decline to the east and northeast of SWSD (P564 and P565). As will be discussed with InSAR data, northeast SWSD may be experiencing subsidence rates similar to the rates observed at CGPS stations P564 and P565. However, despite reported subsidence in the SWSD area per INSAR, particularly in the north east portion of the District, the District through evaluation of the “As-built” records for facilities in the area is unable to confirm the extent of the subsidence as indicated by the INSAR data.

Extensometer

Semitropic currently maintains an extensometer (25S/22E-35B001) for monitoring compaction in the subsurface. This extensometer was completed to a depth of 900 feet below ground surface in 2006. The benefit of an extensometer over other datasets such as CGPS or InSAR, is that an extensometer measures a discrete subsurface interval, or typically the interval of the ground surface to the total depth of the extensometer. CGPS and InSAR monitor overall change in ground surface relative to a datum such as sea level, regardless of the depth interval. Moreover, InSAR provides information over a wide area.

Ideally, an extensometer should be installed below the base of the compacting aquifer system (Galloway et. al, 1999), in order to monitor the entire compaction zone. Although Page’s base of freshwater and nearby supply wells to the southeast suggest the lower aquifer zone extends below the extensometer, the upper 900 feet that the extensometer monitors is a very active depth interval of groundwater production.

Extensometer data have been collected over time, and a consistent dataset from December 2013 to present is provided in the Table 2-10 above. Time-series (Appendix C) data show that between December 2013 and October 2016, the rate of subsidence recorded by 25S/22E-35B001

extensometer was nearly 1.0 inch per year. This rate is within the range of rates reported for CGPS points in the area (0.1 to 2.8 inches per year) and is consistent with the interpretation that higher rates of subsidence are northeast of SWSD and lower rates are observed in central SWSD, to the south and to the west.

Time-Series Data

Time-series data (Appendix C) present cumulative subsidence from approximately 2006 to 2017 with corresponding water level elevation hydrographs observed from nearby wells. Below normal to "critical dry" water years are shaded in yellow, while above normal to "wet" water years are shaded in gray. All wells are within the lower zone or main production groundwater zone unless noted with "upper zone".

Generally speaking, the variation in subsidence on the time-series is a function of:

- elastic subsidence, to inelastic subsidence, and the lag time of subsidence after dewatering,
- the distribution of fine-grained sediments in the subsurface,
- the amount of water pumped and the stress of dewatering fine-grained units, and
- potential near-surface factors such as shrinking and swelling of some soil types due to precipitation or other factors.

All of the factors mentioned above may introduce additional signals or noise to the CGPS data; however, general broad trends are discernible when plotting data with water year type and nearby water levels. In the future, more water level monitoring and pumping data in areas near these CGPS stations and the extensometer may provide finer resolution of data to interpret lag times, elastic changes, and other short-term signals and determination as to which specific geologic strata is responsible for the observed surface subsidence. Where there are any questions of the cause of subsidence in a certain area, additional seasonal water level monitoring and subsidence monitoring are advisable. Where necessary depth-specific extensometers can confirm depth intervals at which subsidence is occurring.

Based on the attached time-series, residual subsidence persists after each pumping season (especially in dry years) for relatively long periods of time (several months to over a year). Researchers note that delayed or residual subsidence response may occur in the Central Valley for years after pumping (USGS, 2018b).

The following observations were derived from the time-series data:

- P544 (Twisselman Road) shows increasing subsidence associated with dry years. Subsidence may lag up to 6 months after pumping season, while long-term residual subsidence and elastic rebound is observed from 6 to 18 months. No water level data in nearby pumping zones were available. Only water levels from shallow monitoring piezometers are plotted on this chart.

- P545 (Lerdo Highway) shows increasing subsidence associated with dry years and water level decline in the lower zone. Water levels and some elastic subsidence may recover/rebound within a month of the beginning of a wet water year; however, both elastic and inelastic subsidence lags for at least 6 to 18 months or longer after a dry year. Subsidence rates trend more with lower zone water levels than upper zone water levels. The included upper zone well is located in neighboring BVWSD and is screened above the "E" Clay or equivalent. Water levels in this upper zone well may vary over time with pumping because groundwater production occurs primarily in the upper zone in BVWSD.P563 (Buttonwillow Rest Area) data are similar to P545, with subsidence associated with dry years and a subsequent rebound from elastic subsidence due to wet year conditions and stabilization of water levels. The subsidence time lag is evident in the elastic recovery from April 2011 to summer 2012. Similar to P545, changes in subsidence rates do not correlate significantly with upper zone water levels. Subsidence rates are associated with decline in water level from the lower zone.
- Data for SWSD Extensometer 25S22E35B001M are collected monthly to quarterly rather than daily, so any small-scale noise, rebound, or recovery aren't seen in the data. Consequently, subsidence may be more apparent in the extensometer data while water levels are variable during each year. Continued monitoring may confirm the consequences of residual drawdown during sequential wet years. In general, subsidence or compaction occurs during dry years, and a decrease in the rate of subsidence is observed during wet years.
- P564 (Wasco) to the east of SWSD. In general, rates of subsidence increase during dry years and decrease during wet years. Between 2009 to 2011, elastic rebound (recovery) appears to outgain inelastic subsidence. On the other hand, between the wet year 2016 to 2017, subsidence continued but at a low rate even after some recovery of water levels. Note: P564 subsidence data are plotted on a smaller vertical scale (from -2 to 18 inches) than P545 and P563. As a result, smaller monthly changes in subsidence observed in the latter, aren't as apparent in P564
- P565 (Delano) to the east of SWSD, also plots subsidence on a smaller vertical scale. P565 shows a lesser rate of subsidence between 2006 and 2009 in comparison to P564 but shows a similar rate of decline between 2011 and 2016. Overall, subsidence at P565 increases during dry years and decreases in wet years. A slight elastic rebound is observed in wet years. This plot is consistent with overall regional trends of declining water levels during the drought.

Remote Sensing

Recent investigations of subsidence include Satellite-based InSAR, aircraft-based L-band SAR or Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR). The data from these remote sensing techniques have been processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL). Reported data have been published in a subsidence

study commissioned by the California Water Foundation (LSCE, 2014), and by JPL via the DWR SGMA Data Viewer (DWR, 2018a) and the DWR website (Farr et al, 2015, and Farr et al, 2016). The InSAR data were processed from a group of satellites including but not limited to: Japanese PALSAR, Canadian Radarsat-2, and European Space Agency's (ESA) satellite-borne Sentinel-1A. Data reported herein are from 2006 to 2017 with a gap from 2011 to 2014 when satellite outage occurred before the launch of the ESA's Sentinel satellites in 2014.

DWR is currently evaluating the remote sensing data with in-field measurements, such as from CGPS stations, as a means of "ground truthing" the remote sensing data (DWR, 2018b). This plan does not intend to validate the InSAR data, but only to present it as best available regional data. Data gaps are undoubtedly present, and therefore, the discussion below is a qualitative interpretation of the data. Nonetheless, cumulative subsidence and rates of subsidence, based on InSAR data, are also provided in the Table 2-10 above and in Figures 2-43 – 2-47.

Along with InSAR data, the CGPS and extensometer data are plotted as cumulative subsidence on Figures 2-44 and 2-45, and rates of subsidence on Figures 2-46 and 2-47. Data from 2007 to 2011 show subsidence ranging from 1.4 to 4.3 inches in CGPS points within SWSD and to the east, and 0 to ~4 inches for InSAR data within SWSD. Data from 2015 to 2016 show subsidence ranging from 0.3 to 3.7 inches in CGPS points within SWSD and to the east, and 0 to ~10 inches for InSAR data within SWSD.

Discussion of Results

Overall, the subsidence data indicate that centers of greatest decline, both historically and recently, occur northeast of SWSD in the adjacent subbasin and propagate outward to the south, west, and southwest into SWSD. As a qualitative observation, the CGPS, extensometer, and InSAR data agree with the trends as stated above. From a quantitative standpoint, the magnitude of subsidence reported from InSAR from 2015 to 2016 is much higher than surrounding CGPS and extensometer data points. In the future, additional monitoring points would be beneficial to corroborate the highest subsidence rates detected by InSAR in the northeast part of SWSD. The northeast area may be considered a data gap in quantifying the magnitude of recent subsidence. The district will evaluate potential monitoring points in the northeast for future monitoring.

Based on time-series data, subsidence appears generally to trend with water levels from lower zone wells – deeper wells with screens below confining clays ("E" clay or equivalent), which are more likely to dewater fine-grained beds below the confining units. Consequently, recent subsidence does not trend as closely with upper zone water levels.

Continued monitoring of water levels, pumping, and subsidence, as well as more detailed subsurface lithologic characterization may provide a better dataset for future projection of subsidence. At this time, the calculated rates of subsidence have been posted on the results table and the time-series charts. These historical rates present an estimate of possible future subsidence rates if groundwater extraction continues at the current rate.

Future Data Availability and Subsidence

According to USGS, the ESA's Sentinel satellites collect InSAR data at an approximate weekly rate, and data are available for download and interpretation (personal communication, USGS). These InSAR data are available but will require users support for the interpretation and distribution of the information. Likewise, CGPS data will likely to be available for future use. DWR is currently evaluating the remote sensing data with in-field measurements such as from CGPS stations, as a means of "ground truthing" the data (DWR, 2018b). Continued improvements in data interpretation and processing will benefit remote subsidence monitoring along with continued collection of CGPS and extensometer data. Further discussion of subsidence monitoring will be addressed in the Monitoring Networks section of this report.

2.3.7 Interconnected Surface Water Systems

Interconnected surface water systems are surface waters that are hydraulically connected by a continuous saturated zone to an underlying aquifer (DWR, 2016). There are no known natural interconnected surface water systems in the Semitropic Area. The Poso Creek channel is the only channel that experiences natural recharge from the surrounding highlands. However, Poso Creek is ephemeral and only flows during limited wet periods.

2.3.8 Potential Groundwater Dependent Ecosystems

SGMA defines a groundwater dependent ecosystem (GDE) as ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. SGMA states that a GSP shall include impacts on GDEs but does not explicitly state the requirements that warrant a GDE to be eligible for protection.

The first step in evaluating a potential GDE is to identify vegetation communities that are typically associated with groundwater, and secondly, to confirm the presence of shallow groundwater that could support potential GDEs. Lastly, is to evaluate any active groundwater pumping that could lead to shallow groundwater level change in the vicinity of potential GDEs.

In the Semitropic area, many of the vegetation communities that could be potential GDEs are likely to be associated with managed wetlands and riparian areas that are supported by a combination of pumped groundwater and imported surface water. In addition, other potential habitats include ephemeral wetlands covered by water seasonally but supported by irrigation deliveries and precipitation, and groundwater recharge basins that are artificially flooded with surface water. Therefore, additional investigation is needed to identify potential locations of vegetation that are dependent on groundwater and not indirectly linked to imported surface water from managed wetlands.

Currently, the best available dataset for evaluating the occurrence of vegetation communities that are typically associated with groundwater is the *Natural Communities Commonly Associated with Groundwater* (NCCAG) dataset (DWR, 2018c). DWR has stated that use of the NCCAG

dataset is not mandatory and does not represent DWR's determination of a GDE. Rather, NCCAG can provide a starting point for the identification of GDEs within a groundwater basin (DWR, 2018c).

Below is a discussion of what is known regarding shallow groundwater levels in the Semitropic area, the results of mapped vegetation as documented in the NCCAG dataset, and the current data gaps in evaluating potential GDEs.

2.3.8.1 Review of NCCAG Dataset Components

The NCCAG dataset was compiled based on 48 layers of publicly available data sets developed by state or federal agencies that map vegetation, wetlands, springs, and seeps in California (DWR, 2019). A technical working group with representatives from DWR, California Department of Fish and Wildlife (CDFW), and The Nature Conservancy (TNC) reviewed the datasets compiled to assemble the NCCAG. This dataset attempts to extract mapped vegetation and wetland features that have indicators suggesting dependence on groundwater. The data presented in NCCAG display vegetation polygons that have indicators of GDEs based on published and/or field observations of phreatophytic vegetation characteristics in California, flooding frequency, or areas classified as perennial hydrologic features. A phreatophyte is defined as a "deep-rooted plant that obtains water that it needs from the phreatic zone (zone of saturation) or the capillary fringe above the phreatic zone" (TNC 2018b). The dominance of phreatophytic plant species in a mapped vegetation type is a primary indicator of GDEs. A list of plant species considered to be phreatophytes based on review of peer-reviewed scientific literature on rooting depths, published lists of phreatophytes, expert field observations, and vegetation alliance descriptions is publicly available (Klausmeyer et al. 2018, TNC 2018a).

While developing the NCCAG dataset of areas with indicators of GDEs, the technical working group attempted to exclude vegetation and wetland types and polygons that are less likely to be associated with groundwater (Klausmeyer et al. 2018). For example, riparian vegetation along perennial mountain streams is generally not in the NCCAG dataset, because although these communities contain species that can act as phreatophytes, vegetation at those sites is generally sustained by surface waters that are not locally interconnected with shallow groundwater aquifers. The working group also attempted to remove any polygons that are not likely to be GDEs where they occurred in areas where they are more likely supported by alternate artificial water sources (e.g. local seepage from agricultural irrigation canals), or where appropriate available data indicated the shallow groundwater depth is located well below the rooting zone (Klausmeyer et al. 2018).

The Vegetation Classification and Mapping Program (VegCAMP) and National Wetland Inventory (NWI) are the vegetation mapping datasets that cover the water districts of interest and a discussion of each dataset follows below.

The VegCAMP dataset is the primary vegetation base layer used for the NCCAG dataset. Fish and Game code Section 1940 directed CDFW to develop and maintain a standardized vegetation

dataset for the state of California, which conforms to the U.S. National Vegetation Classification Standards, and to produce a hierarchical classification of vegetation types. VegCAMP is the product of the Survey of California Vegetation (SCV). Vegetation polygon attributes are assigned to the alliance taxon level in the hierarchical classification system, when possible. An "alliance" is a lower taxonomic rank that is based on plant species composition as compared to higher taxon levels that more broadly define the life form (tree, shrub, or herbaceous) and ecological drivers (e.g., climate, regionalism). The alliance-level taxon is a group of diagnostic plant species that repeat across a landscape reflecting regional to sub-regional climate, substrate, hydrology, moisture/nutrient factors, and disturbance regimes. The VegCAMP data also includes polygons of group-level, which are higher level and less specific than alliance level descriptions. Alliances are defined and described in detail by *A Manual of California Vegetation* (Sawyer et al. 2009).

The VegCAMP vegetation maps are geospatially registered polygons that are digitized on base imagery that meets or exceeds the National Agricultural Imagery Program (NAIP) resolution standards of 1-meter ground sample distance. VegCAMP is considered the highest resolution data source for California vegetation mapping and is therefore used as the basis of the NCCAG dataset. The minimum map unit (MMU) of VegCAMP data is typically 1–2 acres, with a maximum of 10 acres; wetlands identified in VegCAMP have an MMU of 0.25 acre with the minimum polygon width of at least 10 meters (DWR 2018c). Accuracy Assessments are conducted in-field as a form of quality control, to correct any specific and systematic errors prior to map finalization and release. SCV requires every map to be verified and to meet a standard of at least 80 percent overall accuracy between map units and spot checks, and the maps typically exceed this standard. Data gaps and overlaps are ideally eliminated through geodatabase quality checking of each map (CDFW, 2018).

The National Wetland Inventory (NWI) created by the U.S. Fish and Wildlife Service (USFWS) is a mapping tool that identifies wetlands by type (based on the Cowardin classification; Cowardin et al. 1979) and distribution throughout the United States. NWI relies on trained image analysts to digitize wetland habitats, which are identified based on vegetation, visible hydrology and geography. Mapping is completed at 1:24,000 scale (1-inch equals 2000 feet). A margin of error is inherent in the identification of wetlands on imagery; thus, detailed on-the-ground inspection of any site may result in revision of the wetland boundaries or classification established through image analysis (USFWS, 2018). In the continental United States, NWI uses a target MMU of 0.5 acre (USFWS, 2015). Certain types of "farmed wetlands" and submerged aquatic vegetation found in intertidal and subtidal zones of estuaries are specifically excluded from the NWI dataset.

2.3.8.2 NCCAG Results

As described above, field investigation may be needed to verify the NCCAG vegetation and wetlands data are presented in Figures 2-48 and 2-49, along with shallow water contours. According to the NCCAG dataset, distribution of mapped vegetation occurs in the natural lowlands associated with Jerry Slough and in the northwest along the Kern River Channel, just southwest of KNWR, along the Poso Creek Flood Channel (manmade), and in the north-central portion of SWSD. In addition, NCCAG wetlands are mapped along the Kern River Channel and near Jerry Slough.

All vegetation species in the NCCAG dataset, for the study area, are presented in Table 2-11. Approximately 16 of the 18 entries in NCCAG are recognized as phreatophytes in California by the TNC. Documented potential rooting depths range from 1 foot in depth to greater than 20 feet in depth. Eight of the data entries do not have an estimated root depth listed in the TNC database. As described above, field investigation may be needed to verify if there are phreatophytes in the study area as presented in the NCCAG dataset.

2.3.8.3 NCCAG Discussion

The vegetation data presented in the NCCAG dataset is a good starting point for the identification of potential GDEs because the dataset includes the best available public data and has been screened to include only areas that have indicators of groundwater dependent vegetation. The identification of vegetation communities that are typically associated with groundwater is the first step to identifying a GDE, but not all wetland or riparian vegetation communities qualify as a GDE for consideration under SGMA. For example, GDEs may also be associated with subterranean streams, which are groundwaters flowing through known and definitive channels. Subterranean streams are regulated through California's surface water rights system; SGMA is not applicable to subterranean streams (SWRCB, 2018).

Field verification of mapped vegetation polygons may also be a critical step to identifying GDEs. For example, there are polygons in the VegCAMP dataset that identify vegetation at a high taxon (e.g., Southwestern North American Salt Basin and High Marsh is a group-level designation). Field survey efforts to map vegetation provide the opportunity to re-classify broad group-level vegetation polygons to the alliance level that provide more specific information about the floristic composition of an area. Information about floristic composition, coupled with information about ground water levels and knowledge of rooting zone depths of dominant vegetation would help in the identification of GDEs.

Identifying the ecological value of a GDE may be helpful when considering sustainable management of GDE habitats. Ecological value is typically considered higher for GDEs that contain legally protected species, habitats, and ecologically diverse communities (TNC 2018b).

2.3.8.4 Shallow Groundwater and Land Use

Shallow piezometric contour maps, groundwater level hydrographs, and land use data are presented herein, to consider the presence of shallow groundwater and potential for groundwater pumping in the vicinity of mapped vegetation by NCCAG.

Shallow groundwater piezometric contour maps present lateral distribution of water levels to compare with the mapped NCCAG dataset. The 2011 contour data are plotted with NCCAG data on Figures 2-48 and 2-49.

Representative hydrographs from 1995-2015 present shallow, upper zone, and lower zone water level data (Appendix B-1) for 10 different groupings across the study area. Data were plotted to evaluate the trends in water levels of the shallow zone with the upper and lower zones where groundwater pumping occurs. Although there is insufficient data to confirm where most of the groundwater pumping occurs in the upper zone, Schmidt and Associates (2018) contours upper zone water levels (Figure 2-25) from groundwater supply wells in Townships, which are presented on the hydrographs (Groups 1 to 4, 8, and 10 of Appendix B-1). Group 5 upper zone well (S-1) is a district monitoring well and does not represent active pumping; however, other wells on Schmidt's map may indicate pumping in the upper zone near Group 5. KCWA shallow piezometers, as described in the Groundwater Conditions section of this report, are typically shallow monitoring wells that are less than 100 feet deep but in general are 20 feet deep. As presented in the summary table of Appendix B-1 the actual shallow piezometer construction details were not available.

District land use data showing active irrigated agricultural lands were reviewed with NCCAG data to verify if potential groundwater pumping could be occurring adjacent to NCCAG mapped data. The results are discussed below.

2.3.8.5 Shallow Groundwater and Land Use Results

Piezometric Contours

Based on KCWA contour data (Figures 2-48 and 2-49), shallow groundwater occurs within the vicinity of the NCCAG vegetation and wetlands at depths between 5 and 20 feet bgs. The NCCAG vegetation and wetlands are located primarily in the northwest and north-central areas of the District, along Poso Creek flood channel (manmade), and along Jerry Slough. In general, KCWA shallow water level data, from 1995 to 2011, varies slightly by water year. For example, from 1995 to 2000 (wet period) water levels are stable and decrease in depth. On the other hand, during mostly dry periods (2000 to 2005 and 2007 to 2010), water levels increase in depth. The magnitude of changes between these periods is small in most areas but is most noticeable in the KNWR where the depth to water level increases from 5 feet to predominately 10 feet from 2000 to 2005 (a dry period). Water level changes appear to be more heavily influenced by dry years than wet years. The lateral extent of mapped shallow groundwater varies from year to year with some areas persistently shallow and others fluctuating in depth to water as seen in KNWR.

Table 2-11. NCCAG Vegetation Dataset - Semitropic Water Storage District, Kern County, California

NCCAG Dataset			TNC database		
VEGETATION NAME	DOMINANT SCIENTIFIC NAME	DOMINANT COMMON NAME	Approximate Maximum Rooting Depth (feet)*	CA Phreatophytes	Reference
Allenrolfea occidentalis	Allenrolfea occidentalis	Iodine Bush	6	Yes	Lech Naumovich. 2017 TNC Crowdsourcing Campaign Survey Response.
Atriplex lentiformis	Atriplex lentiformis	Quailbush	Depth not listed in TNC dataset	Yes	
Atriplex spinifera	Atriplex spinifera	Spinescale	Depth not listed in TNC dataset	Yes	
Baccharis salicifolia	Baccharis salicifolia	Mule fat	2	Yes	Stromberg, J. 2013.
Isocoma acradenia	Isocoma acradenia	Alkali Goldenbush	Depth not listed in TNC dataset	Yes	
Juncus arcticus (var. balticus, mexicanis)	Juncus arcticus	Arctic Rush	1	Yes	Stromberg, J. 2013.
Lepidospartum squamatum	Lepidospartum squamatum	Scalebroom	Depth not listed in TNC dataset	Yes	
Pluchea sericea	Pluchea sericea	Arrow-weed	4	Yes	Gary, 1963
Populus fremontii	Populus fremontii	Fremont Cottonwood	7	Yes	Stromberg, J. 2013.
Rubus armeniacus	Rubus armeniacus	Himalayan blackberry	Depth not listed in TNC dataset	Yes	
Salix exigua	Salix exigua	Narrowleaf Willow	Depth not listed in TNC dataset	Yes	
Salix gooddingii	Salix gooddingii	Goodding's Willow	7	Yes	Stromberg, J. 2013.
Salix laevigata	Salix laevigata	Red Willow	Depth not listed in TNC dataset	--	
Sambucus nigra	Sambucus nigra	Common Elderberry	10	Yes	Kourik, R. 2015.

NCCAG Dataset			TNC database		
VEGETATION NAME	DOMINANT SCIENTIFIC NAME	DOMINANT COMMON NAME	Approximate Maximum Rooting Depth (feet)*	CA Phreatophytes	Reference
Schoenoplectus (acutus, californicus)	Schoenoplectus acutus	Hardstem Bulrush	2	Yes	Stromberg, J. 2013.
Suaeda moquinii	Suaeda moquinii	Shrubby Seepweed	Depth not listed in TNC dataset	Yes	
Tamarix spp.	Tamarix spp.	Tamarisk	72	Yes	
Typha (angustifolia, domingensis, latifolia)	Typha angustifolia	Narrowleaf Cattail	1	--	Stromberg, J. 2013.

Notes:

-- unavailable or unknown

* The maximum rooting depth may be in other states or regions. These are not exclusive to San Joaquin Valley.

Several reported root depths may be reported. Root depth is dependent on soil substrate, nutrients, water table and therefore reporting depths do vary.

NCCAG Notes:

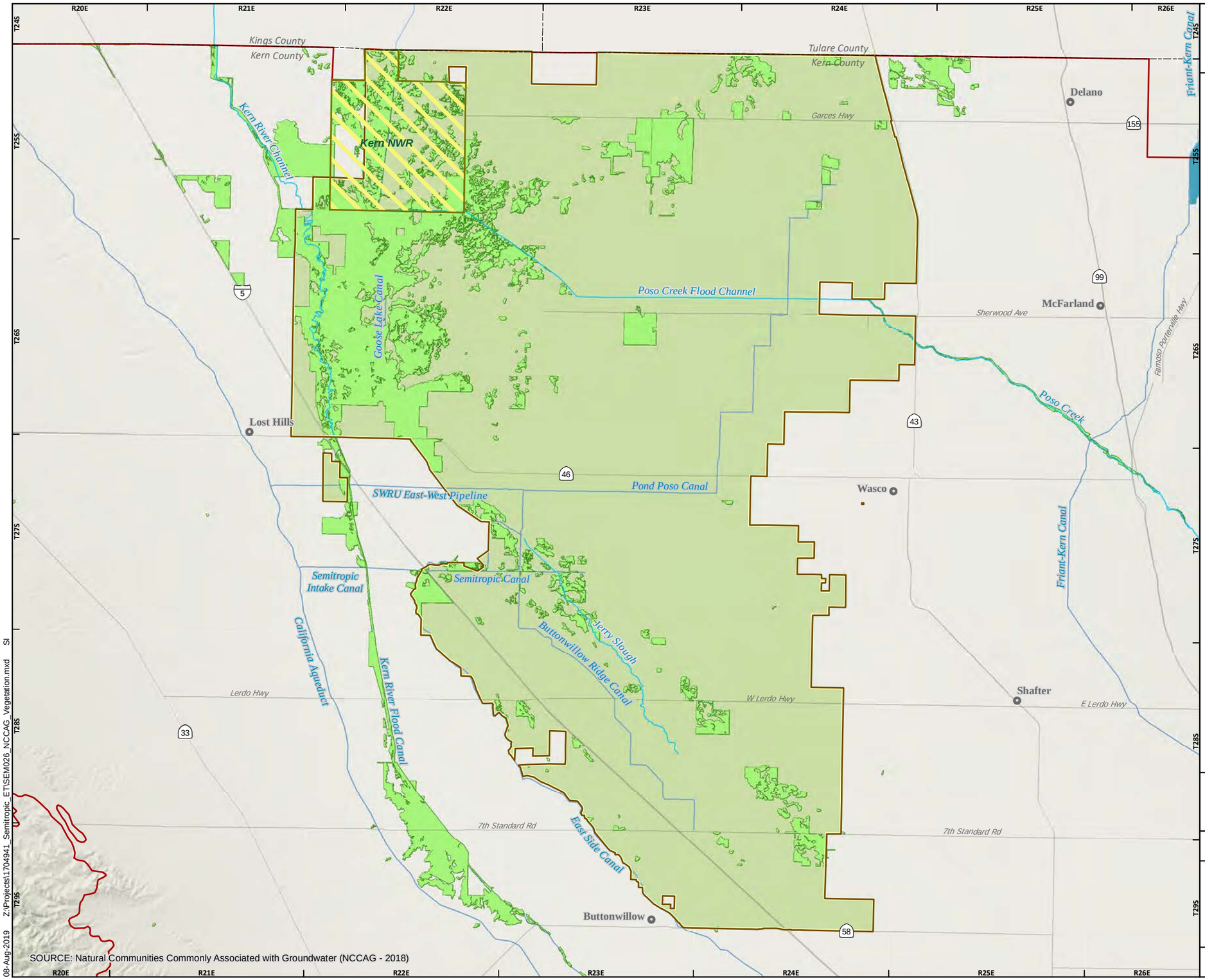
NCCAG Source Code: vc99

Modified by: kklausmeyer on March 9, 2018

TNC Notes

Rooting depth data obtained from Plant_Rooting_Depth_Database_20180419.excel file produced by TNC.

Available: https://groundwaterresourcehub.org/gde-tools/gde-rooting-depths-database-for-gdes/



NCCAG VEGETATION

- Vegetation (NCCAG)
- Kern National Wildlife Refuge (FWS 2018)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

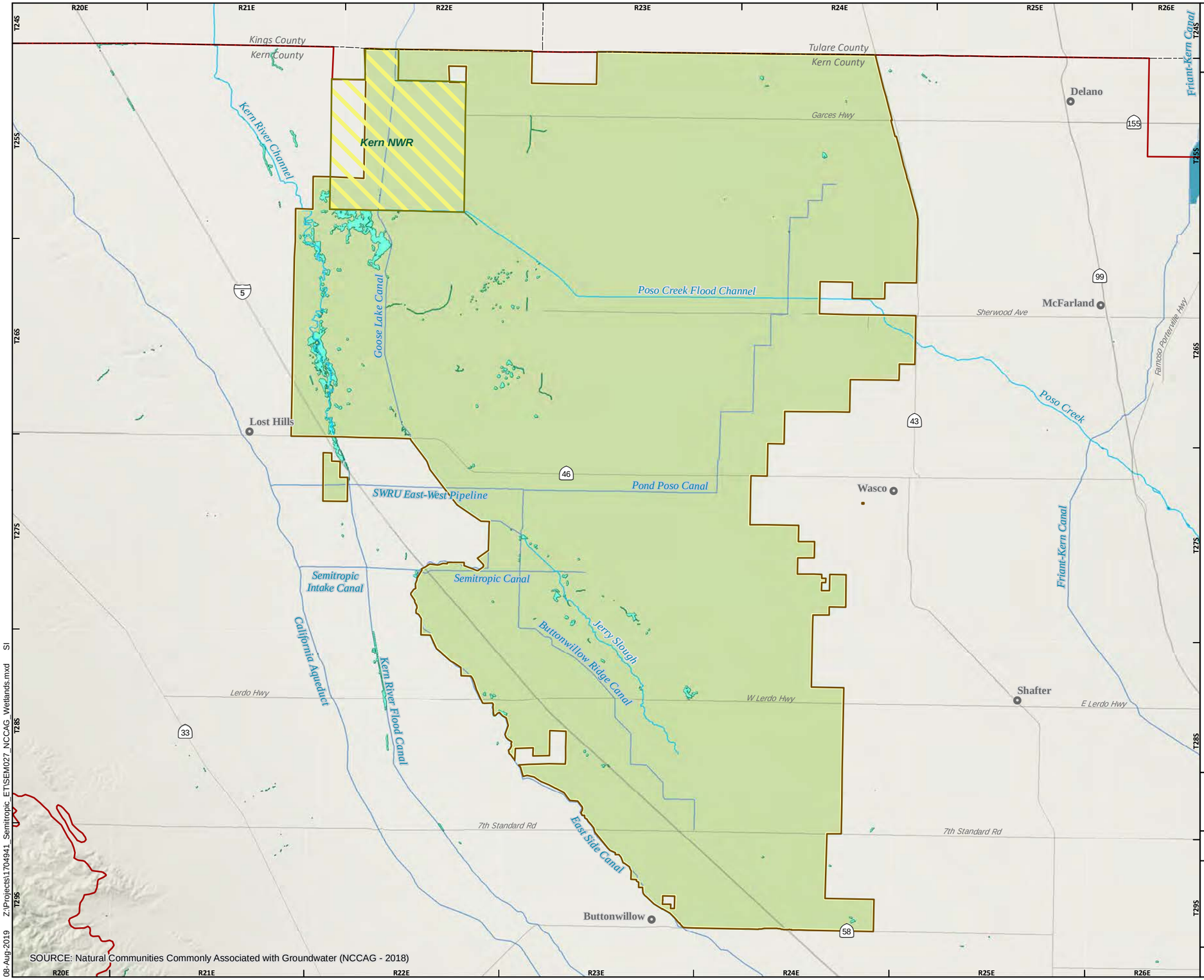
Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-48

08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM026_NCCAG_Vegetation.mxd SI



NCCAG WETLANDS

- Wetlands (NCCAG)
- Kern National Wildlife Refuge (FWS 2018)
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-49

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM027_NCCAG_Wetlands.mxd SI

Hydrographs

In general, hydrographs for Groups 1, 3, 6, and 10 present stable shallow water levels that do not significantly vary from water year type. This suggests that pumping may not affect shallow water levels in these areas. Hydrographs for Groups 5, 7, and 8 present shallow water levels that decline during dry years, although the decline is much less than observed in the upper and lower zones. It is uncertain if the shallow water level decline in Groups 5, 7, and 8 are related to increased groundwater pumping or if they are related to increased evapotranspiration, reduced effective precipitation and recharge, and reduced applied surface water which could affect recharge and water levels in the shallow zone.

Groups 3 (T26SR23E / T26SR24E) and 5 (T27SR22E) show upper zone and shallow water levels trending at similar water level elevations indicating the shallow zone is not perched in these areas and that the subsurface may be saturated from the shallow to the upper zone. Group 3 upper zone water levels ranged from 10 to greater than 20 feet below ground surface and were somewhat comparable to shallow zone levels. There is little, if any, decline in Group 3 shallow and upper water levels during dry years. In Group 5, the upper and lower zone water levels drop during dry years, and an apparent drop also occurs in the shallow zone. From 1995-2015, shallow water level depths ranged from 5 to 15 feet below ground surface. Although Group 5 shallow and upper water levels appear to decrease during dry periods, additional monitoring is needed to evaluate if pumping occurs in the upper zone near Group 5, and if any groundwater pumping may affect shallow water levels. As described above, the Group 5 upper zone water levels are from a monitoring well (S-1) with a short perforation interval.

Land Use Data

Land use data surrounding NCCAG vegetation and wetlands indicate actively managed wetlands as well as agricultural land. The agricultural lands may employ groundwater pumping in dry years; however, it is unknown if pumping occurs in the upper zone. In general, the actively managed wetlands are reliant on a combination of surface water and pumped groundwater. For example, the KNWR (Figures 2-48 and 2-49), is sustained by surface water imports.

2.3.8.6 Shallow Groundwater and Land Use Discussion

Based on KCWA contours, the mapped NCCAG vegetation and wetlands in the west, north west, and north-central portions of the study area may be underlain by shallow groundwater (from 5 to 20 feet below ground surface).

Hydrographs for Groups 3 and 5 (central and west portions of the study area) report data that suggest a saturated subsurface from the shallow zone to the upper zone. However, it is unclear where upper zone pumping may occur in the study area, and if shallow groundwater levels are affected by groundwater supply pumping.

Land use data and NCCAG vegetation dataset indicate that vegetation may be adjacent to actively managed wetland and agricultural land. It is unknown if or from which aquifer zone groundwater pumping occurs for adjacent agricultural land. It is also unknown how much imported surface water to actively managed wetlands may be sustaining shallow water levels in areas that are mapped in the NCCAG dataset.

2.3.8.7 Conclusions

Based on data gaps described in this section, the following are suggestions to better understand the potential for GDEs in the study area:

- Field verification of mapped NCCAG vegetation polygons, and potentially a reconsideration of broad group-level vegetation polygons to the alliance level. If significant NCCAG vegetation communities are identified that are not linked to areas with imported surface water, then further investigation into rooting zone depths at these areas may be beneficial.
- Field verification of the satellite-based land use data.
- Additional monitoring of shallow groundwater to identify critical areas that are not linked to imported surface water from managed wetlands.
- Additional water level monitoring and investigation on upper zone pumping to evaluate if pumping in the upper production zone is impacting shallow groundwater underlying NCCAG areas.

2.4 Water Budget

2.4.1 Subbasin Coordinated Water Budgets

All GSAs in the Subbasin coordinated and collaborated on the development of a groundwater model (Model) to evaluate historical, baseline and projected groundwater conditions. The GSAs entered into a Cost Share Agreement with the Kern River GSA who took the lead and contracted with Todd Groundwater to develop the Model on behalf of the Subbasin. The contract required that Todd Groundwater use the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) provided by DWR. Considerable effort and resources were expended to update C2VSim with local data to better represent Subbasin conditions. The process Todd Groundwater used to update C2VSim is more fully described in the Historical and Projected Future Water Budget Development (see Attachment H in Umbrella GSP). Basin-wide water budget results from the Model are provided in Attachment H and show the Subbasin, as a whole, has a total storage deficit of approximately 324,326 acre-feet per year (AFY) over the baseline period.

The Subbasin's dynamic conjunctive use programs, water banking operations, and water transfers/exchanges made it necessary to coordinate a GSA level water accounting system

(Checkbook) using Subbasin specific values for supply, demand and net results. The Model results reflect Subbasin-wide conditions and do not allocate water shortages/surpluses, nor do the results allocate the "ownership" of water. As a result, the GSAs, through a coordinated effort, developed the Checkbook that estimates current conditions for each GSA that are generally consistent with the Model results under baseline condition. The Checkbook and Model budgets are based upon best available information, recognizing however, each estimate includes data gaps and has varying degrees of accuracy and/or reliability in the interest of developing a Subbasin coordinated approach.

To ensure the individual water budgets reflected actual conditions, the KGA members developed the Checkbook budget and coordinated water accounting methodology. The result of that effort indicates a current baseline shortage/deficit for KGA members of approximately 256,281 AFY[1]. This reflects the difference between a total demand for KGA members of 1,939,409 AFY, and a total supply of 1,683,128 AFY. Of the shortage/deficit of the KGA the District's portion of the KGA shortage/deficit is 165,910 AFY, reflecting a total District demand of 392,426 AFY and a water supply of 226,516 AFY.

As is mentioned above, the Model and Checkbook approaches includes data gaps and have varying degrees of accuracy and/or reliability. The Checkbook is complimentary to the Model and reflects the allocation of water supply benefits and obligations independent of geographic constraints within the Subbasin. This was important to recognize and ensure the coordination of the various groundwater banking projects and water management programs amongst the various GSA's within the groundwater basin.

The Semitropic Area water budget described in the following section was developed based on historical and projected water supply conditions appropriate under Baseline Conditions. The District's water budget is represented as a range to reflect the current variability of imported water supplies from the SWP, uncertainty relative to the quantity of native groundwater yield and variations in demands, based on local climate and planting conditions. The water budget range, described below, includes the estimated deficit of 165,910 AFY developed through the Checkbook process.

2.4.2 Semitropic Area Water Budget

The water budget for the Semitropic Area has been developed based on historic data and existing projects for the baseline condition, which represents the current delivery capacity of the SWP, and other imported water supplies available to the SWSD and a range of Native Supply from groundwater and rainfall estimates as coordinated with the KGA and other GSAs in the Subbasin, as referenced above. The water budget presented here is a starting point on which the

[1] The water supplies available to each KGA member from the Pioneer and Kern Water Bank banking programs are incorporated into the listed total available supplies. Note that both programs only store surface supplies, and do not have consumptive demands that contribute to the listed shortages. For more detail on the banking projects, please see the respective management area plans.

SWSD will develop its projects and management actions to achieve sustainability by 2040, keeping in mind that SGMA defines "sustainable yield" in terms of avoidance of an "undesirable result." (Water Code section 10721(w), (x)).

SWSD has developed a baseline condition and 2030 water supply budget scenarios, where:

- Native Supply represents the combined range of native groundwater yield and local precipitation available to meet ET. The District assumes this range of native groundwater yield and precipitation to be 0.25 to 0.75 acre-feet per acre (af/ac) for all lands in the District. This range is inclusive of the native yield agreed to by the GSAs of the Subbasin of 0.15 af/ac applicable to all lands and 0.48 af/ac for average annual precipitation on irrigated lands.
- Current conditions represent current inflows and outflows for the District, based on the most recent hydrology, water supply, water demand and land use information. The major supply component for the District is the SWP and its supply reliability is based on DWR's 2017 Delivery Capacity Report (Table 2-12)
- 2030 climate conditions represent the 2030 climate conditions modeled in the California Water Commissions CALSIM runs for deliveries by the SWP. The District's supplemental supplies were adjusted to be consistent with the changes projected in the SWP deliveries or held constant with current conditions estimates. (Table 2-13).
- 2070 climate conditions are not developed for the District. The District's ability to manage towards sustainability is demonstrated in the basin-wide modeling analysis presented Section 2 of the KGA Umbrella GSP. If climate conditions are experienced at the 2070 projection level and the sustainability measures implemented by the District are insufficient, the District will adaptively manage demands in the District to achieve sustainability.

The details of these budgets are provided in the following sections.

The District's demand based on satellite evapotranspiration remote sensing methodology conducted by the District ranges from 320,000 to 405,000 acre-feet per year for developed agricultural lands based on annual cropping patterns. The demand for undeveloped or native properties is not included as it is assumed that the demand associated with the native vegetation is met by localized precipitation and not groundwater pumping. Due to the relatively small change in water supplies available to the District between the current conditions and 2030 climate conditions, the District proposes to use the current conditions water supply and demand estimates as the initial basis for the developing projects and management actions to reach sustainability within the District.

Table 2-12. SWSD Water Supplies for Current Conditions

Water Supply Source	Projected Availability acre-feet / year	Comment
State Water Project – Table A	95,200	*61% reliability*
District Supplemental Supplies		
SWP Article 21	*3,400*	*Projected availability*
Imports, transfers & exchanges	*21,600*	*Historic avg (1990-2018)*
Poso Creek supplies	*400*	*Historic avg (1990-2018)*
Banking Project leave behind	*7,800*	*Historic avg (1990-2018)*
TOTAL	**33,200**	
Native Supply	55,400 to 166,100	*0.25 to 0.75 af/acre*
Total Projected Supply	**183,800 to 294,500**	

Note: The Checkbook approach identifies a District water supply of 226,516 AFY, which is within the range presented in the above table.

Table 2-13. SWSD Water Supplies for 2030 Climate Conditions

Water Supply Source	Projected Availability acre-feet / year	Comment
State Water Project – Table A	93,000	*60% reliability*
District Supplemental Supplies		
SWP Article 21	*3,300*	*Projected availability*
Imports, transfers & exchanges	*21,400*	*Adjusted Historic avg (1990-2018)*
Poso Creek supplies	*400*	*Historic avg (1990-2018)*
Banking Project leave behind	*7,800*	*Historic avg (1990-2018)*
TOTAL	**32,900**	
Native Supply	55,400 to 166,100	*0.25 to 0.75 af/acre*
Total Projected Supply	**181,300 to 292,000**	

Based on the current conditions average annual water supply budget and demand, the District is in a deficit position from a water budget standpoint. Table 2-14 shows the worst-case scenario with the highest demand and lowest supply along with the best-case scenario of lowest demand and highest supply providing a deficit range of 222,200 to 25,500 acre-feet per year for the District. Currently, this deficit is met with local groundwater pumping. Note that the Checkbook approach developed in coordination with all GSAs in the Subbasin identifies a deficit of 165,900

AFY, which is within the range developed through the Semitropic Area approach. Again, under SGMA a deficit of this type is not the end of the inquiry; SGMA requires additional analysis to determine whether an "undesirable result" (as defined by SGMA) has been or will be caused by long-term conditions in the basin.

Table 2-14. SWSD Net Water Budget for Current Conditions

	Worst Case Acre-feet / year	Best Case Acre-feet / year
District Demand	405,000	320,000
District Supply	182,800	294,500
District Deficit	**222,200**	**25,500**
Average Deficit	**123,900**	

Note: The Checkbook approach identifies an average annual deficit of 165,910 AFY, which is within the range presented in the above table.

2.5 Existing Monitoring Programs

The purpose of this section is to identify and discuss existing water resource monitoring programs as required under §354.8(c). This section specifically focuses on water level and groundwater quality monitoring within the District's boundaries.

2.5.1 Existing Water Level Monitoring

The KGA Umbrella GSP describes existing water level monitoring networks at a generalized regional scale. These networks include the Kern Fan Monitoring Committee (KFMC), KCWA groundwater monitoring, and water level data reported to CASGEM. In addition, KCWA monitors shallow piezometers (in a group of several hundred monitoring points) with a depth ranging from 20 feet to less than 100 feet below ground surface. There are over 100 of these shallow monitoring points in the District, many of which can provide valuable information for first encountered groundwater in the western half of the District. These regional networks benefit data collection and inform SWSD on water level changes occurring in the subbasin. The KGA Umbrella GSP provides details on the KFMC, KCWA, and CASGEM networks, an approximate number of wells and locations of monitoring throughout the subbasin. This section focuses on groundwater monitoring at the local-level, and provides a brief description of the monitoring network, well types, well construction, participants in local monitoring, and a map with locations. The monitoring efforts described below will continue through their various regulatory programs. As described in Section 4.0, a subset of these wells may also be utilized as SGMA required representative monitoring sites to measure the District's progress towards sustainability and avoidance of undesirable results. The information collected from ongoing monitoring efforts will continuously be reviewed to understand groundwater responses to changing conditions and implementation of proposed SGMA projects and management actions.

2.5.1.1 Groundwater Level Monitoring

SWSD operates an existing water level monitoring network that includes dedicated monitoring wells and production wells.

Semitropic Water Storage District Water Banking Project Monitoring Committee

Groundwater elevations are monitored in coordination with the monitoring committee for the Semitropic Water Storage District Water Banking Project. The SWSD Water Banking Project Monitoring Committee, is comprised of the following entities: Semitropic Water Storage District, Southern San Joaquin Municipal Utility District, Cawelo Water District, Shafter-Wasco Irrigation District, North Kern Water Storage District, Rosedale-Rio Bravo Water Storage District, and Buena Vista Water Storage District, with KCWA and Department of Water Resources working alongside the monitoring committee. The committee submits biennial monitoring reports which first began in 1995 and have continued to the present. The reports include groundwater elevation maps, discussion of groundwater flow trends, groundwater quality, land subsidence, and time series data on hydrographs. The latest report: *Biennial Groundwater Monitoring Report for the Semitropic Water Storage District Water Banking Project* (Schmidt and Associates, 2018), provides well construction details for approximately 29 of 48 monitoring wells (some with continuously reading pressure transducers), and perforation intervals for approximately 65 wells in SWSD, 53 wells in North Kern Water Storage District, 8 wells in Buena Vista Water Storage District, and approximately 11 wells in Shafter-Wasco Irrigation District. Previous reports include a few wells from Rosedale-Rio Bravo Water Storage District and Southern San Joaquin Municipal Utility District. A summary is presented in Table 2-15 below.

Table 2-15. Summary of Monitoring Committee

Monitoring Network	Number of Wells Monitored	Date Range	Source
SWSD Water Banking Monitoring Committee	29 SWSD monitoring wells ~ 65 supply wells SWSD, ~53 wells NKWSD, ~8 wells in BVWSD, ~ 11 wells in SWID, a few wells RRBWSD, and SSJMUD	1995 to present	Biennial Groundwater Monitoring Report for the Semitropic Water Storage District Water Banking Project.

In addition to the monitoring committee activities, other monitoring tasks include monitoring recharge at District spreading grounds and monitoring water levels near the Kern National Wildlife Refuge. Although many of these wells have water level data recorded by transducers, they also have data collected by manual water level gauging as often as monthly to semiannually in frequency.

The benefit of the monitoring committee is in the coordination of water level data collection and reporting, which provides more understanding of water levels at the boundaries between SWSD

and neighboring districts. Data that are a result of this coordination, including groundwater contour maps, hydrographs, and subsidence data, are presented in the Groundwater Conditions section of this report. Many of the wells in the committee's monitoring network are included in the monitoring network for this Groundwater Sustainability Plan.

2.5.2 Existing Land Subsidence Monitoring

The KGA Umbrella GSP describes existing land subsidence monitoring networks at a generalized regional scale. These networks include borehole extensometers, continuous GPS (CGPS), leveling surveys, and remote sensing. These regional networks benefit data collection and inform SWSD on land subsidence changes occurring in the Subbasin. The KGA Umbrella GSP and the groundwater conditions section of this report provide details on these networks and status of data usability and collection. This section focuses on land subsidence monitoring at the local-level. Details on data availability and locations are provided below.

2.5.2.1 SWSD Land Subsidence Monitoring

As part of the SWSD monitoring committee, land subsidence has been monitored and data reported in the biennial reports prepared by Schmidt and Associates. The monitoring network includes SWSD's borehole extensometer, as well as nearby continuous GPS points P545, P563, and P564. These GPS stations are maintained, and data are processed and reported, by affiliates of UNAVCO https://www.unavco.org/instrumentation/networks/status/pbo and SOPAC http://sopac-csrc.ucsd.edu/index.php/sopac/. A location map of the existing land subsidence monitoring network is included in Appendix D.

Details including data for the CGPS points and extensometer, and benefits and frequency of the data, are further discussed in the groundwater conditions of this report. In general, CGPS points record daily to sub-daily frequency, while the extensometer is currently set up for manual measurements that require periodic visits to record data values. While CGPS points record near continuous data, their limitations are in that they measure land surface deformation referenced to a datum but cannot measure discrete intervals in the subsurface. On the other hand, the borehole extensometer can measure a discrete interval from the bottom of the extensometer to ground surface, thus providing a more accurate approximation of compaction in the intervals subject to groundwater pumping.

2.5.2.2 SWSD Borehole Extensometer

SWSD operates a borehole extensometer (25S22E35B001M) in the northwest part of the study area. A generalized diagram of the extensometer is provided below (Figure 2-50). It was completed to a depth of 910 feet below ground surface and has a perforated screen interval from 680 to 700 feet below ground surface. It measures the compaction in the subsurface from ground surface to 910 feet in depth.

Measurements can be collected as often as necessary. Typically, readings have been reported every few months. SWSD's extensometer will continue to be utilized for the monitoring network as part of this GSP.

2.5.2.3 Remote Sensing Land Subsidence Monitoring

In addition to CGPS and SWSD's borehole extensometer, NASA and DWR have collected remote sensing data (INSAR and UAVSAR) on a regional scale to better understand the lateral and temporal extent of subsidence within the San Joaquin Valley. The methodology and approach for collecting and processing the data has varied over the last decade as refinements have been made. NASA and DWR are working together to field calibrate these remote sensing data with CGPS points to better understand the quantitative estimates of land subsidence that have been reported.

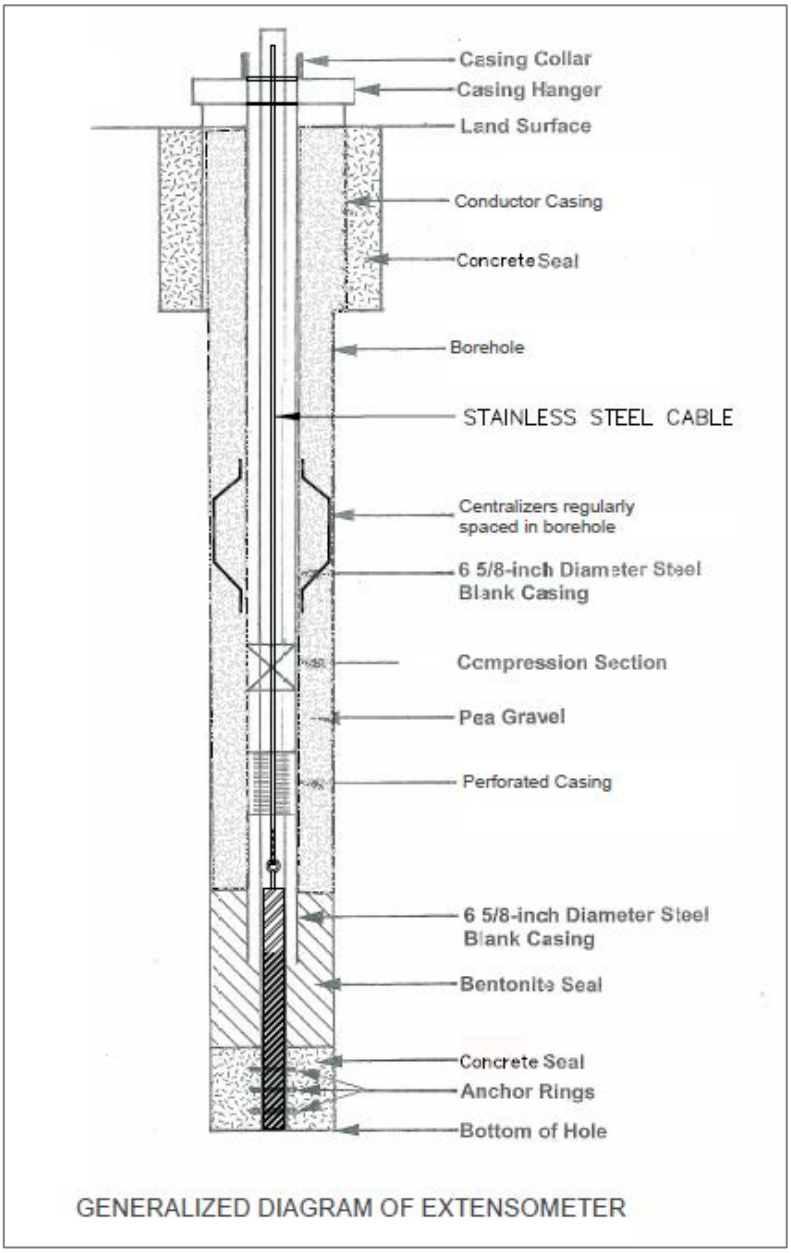


Figure 2-50. Generalized Diagram Extensometer

The existing monitoring data are available for some date ranges and therefore are discussed further in the Groundwater Conditions of this report. In addition, the KGA Umbrella GSP also provides details on INSAR and UAVSAR reporting and availability. As remote sensing data continue to be available, it will be used for the monitoring network of this GSP.

Summary of Land Subsidence Monitoring

Below is a table (Table 2-16) of currently available land subsidence monitoring for the study area.

Table 2-16. Summary of Land Subsidence Monitoring in Study Area

Type	Stations	Range of Available Data	Source
Borehole Extensometers	24S/22E-35B001	December 2013 to present	SWSD
Continuous GPS Stations	P544, P545, P563, P564, P565	Varies. 2000 to present 2005 to present	UNAVCO PBS www.unavco.org Access data from: Instrumentation > Network Monitoring > Plate Boundary Observatory (PBO).
InSAR / UAVSAR	Remote Satellite Imagery	Recent. Range of freely accessible data: 2007 to 2011 2014 to present	Areal extent varies depending on dataset. Not always extensive across the Subbasin. Post-processed data available from (Farr, et. al., 2016), JPL, and USGS.

2.5.3 Existing Groundwater Quality Monitoring

The District is actively engaged in groundwater quality monitoring through its existing monitoring network established under AB-3030 and SB-1938. Additionally, the District collaborates with other regional and state agencies to better characterize its groundwater quality. A summary of each of the Districts' local and regional efforts programs are discussed in this section.

Groundwater quality in the District is monitored by a network of dedicated monitoring wells, production wells, and domestic wells. Table 2-17 summarizes the types of monitoring program implemented within the District.

The monitoring programs previously described are implemented through sampling a combination of the District's network of wells. This network is described in detail below.

Table 2-17. Types of Monitoring Programs Implemented within the District

Well Type	Number of Wells	Monitoring Program		
		AB 3030	Title 22	DWR Pump-in Program
Production	442	X		X
Monitoring	48	X		
Public Water system Wells	12		X	

2.5.3.1 Semitropic's Water Quality Monitoring Program

District's water quality monitoring, including water sampling and analytical chemical testing, aims at identifying the suitability of groundwater for various uses. Under the District's monitoring programs, water samples are collected annually from a representative network of 48 dedicated monitoring wells located throughout the District's service area. These wells are screened at discreet intervals to monitor groundwater quality across both confined and unconfined aquifers.

Sampling recommended by AB-3030 monitors water quality for in-District groundwater uses. This program is focused on constituents relevant to irrigation water analysis, which is a limited group of general minerals (Agricultural Water Management Plan, 2013). The District's GMP identifies that this program was in place from 1994 to 2012.

In 2013, the monitoring program was expanded to comply with DWR's Pump-In Policy. The District augmented its existing groundwater quality testing both in terms of the frequency of sampling and the number of additional drinking water constituents tested. As a requirement of the District's participation in DWR's Pump-In Program, approximately 442 production wells are sampled for Title 22 regulated inorganics, at least once every three years. Additional sampling is conducted as specified in DWR's water quality policy for acceptance of Non-Project water into the SWP (DWR, 2005). During active recovery years, Semitropic uses a selection of these wells to pump-back water into the SWP.

Active recovery involves production wells belonging to both the District and some landowners. The sampling program that complies with DWRs policy further enhances the District's monitoring network. Depending on the type of hydrological year, approximately 50-75 production wells are sampled each year. During wet years, most of the production wells are not in operation due to the availability of surface water, therefore they are not sampled. For example, the District did not sample any production wells in the hydrologically wet year of 2017. Alternatively, extensive sampling was conducted during the hydrologically dry years of 2009, 2013, and 2016. Table 2-18 summarizes the constituents monitored as part of the District's existing monitoring network.

Table 2-18. Constituents Monitored as Part of the Current Monitoring Program

Constituents	Frequency
General Minerals	Triennially
Inorganic Chemicals	Triennially
Hexavalent Chromium	Triennially
Total Organic Carbon	Triennially
Boron	Triennially
1,2,3-TCP	Triennially

As discussed in the District's GMP, the collected data is used to provide basis for identification of long-term water quality trends. This data was used to characterize Groundwater Quality

Conditions (Section 2.3.5). Trends prepared for this evaluation indicate that minimal degradation has occurred since the monitoring program was implemented.

2.5.3.2 Kern Subbasin Water Quality Monitoring Efforts

Apart from maintaining its own monitoring network the District established a groundwater monitoring committee that includes Semitropic and five other neighboring water districts. KCWA and DWR are interested parties and periodically participate in the committee activities. One of the committee's key objectives is to *control degradation of groundwater quality and enhance quality where practicable* (GMP, 2003). Since its inception in 1994, this committee has been preparing a biennial monitoring report that provides a comprehensive study of the underlying groundwater with the objective of identifying and implementing specific programs as needed to reflect changing conditions in the basin. The biennial report characterizes the groundwater quality based on the collected data from Semitropic's monitoring network, and the five neighboring water districts.

Additionally, the District is an active member of multiple regional groundwater quality monitoring programs. These programs are described in the umbrella GSP. The following sections explain how those programs are implemented within SWSD boundaries. Groundwater quality data from these programs will be used by the District for SGMA monitoring purposes.

Irrigated Lands Regulatory Program

The Kern River Watershed Coalition Authority (KRWCA) implements the Irrigated Lands Regulatory Program (ILRP) in the Subbasin, which is currently governed by Revised General Order R5-2013-0120-07 adopted by the California Regional Water Quality Control Board, Central Valley Region, in February 2019. Data collected and reported as a part of ILRP are provided to the SWRCB and are available in the GeoTracker database for download and use. The KRWCA's primary group is made up of 10-member agencies representing approximately 1.5M acres of irrigated land, out of which 15% of the irrigated acreage is under Semitropic's jurisdiction.

California Drinking Water Information System Database (SDWIS)

Routine water monitoring data is also available from the eight Public Water Systems (PWS) within SWSD boundaries. These systems are required to routinely sample for Title 22 regulated constituents. These water systems were identified through the GAMA database. Water quality data is available through SDWIS. This program provides data for an additional 12 wells. Table 2-19 summarizes the PWSs identified within SWSD boundaries.

Table 2-19. PWS within the Semitropic Service Area

Water System Number	Water System Name	Type*	Number of Connections	Population Served	Service Area	Number of Wells
CA1502620	Pond Mutual Water Company	C	18	48	Residential	1 well
CA1503521	Primex Farms Water System	NTNC	3	125	Industrial/Ag	2 wells
CA1510046	Lost Hills Utility District	C	430	2412	Wholesaler	2 wells
CA1500491	Interstate 5 Utility Company	NTNC	21	NT=196; R=2; T=2750	Highway rest area	2 wells
CA1503249	Buttonwillow Road Circuit, LP	NC	2	R=1; T=650	Other Transient	1 well
CA1503578	Sunnygem Hulling & Shelling	NC	3	NT=9; T=60	Highway rest area	1 well
CA1503380	J.G Boswell Tomato Company	NTNC	6	225	Industrial/Ag	2 wells
CA1502029	Buttonwillow Rest Stop	NC	1	1500	Highway rest area	1 well
1510801	Wasco St. Prison Reception Ctr. (w/in SWSD service area, but not w/in SWSD GSA boundary)	C	1768	6,514	Community	2

*C = Community water system
NTNC = Nontransient non-community water system
TNC = Transient non-community water system
NT = Nontransient
T = Transient
R = Residential

2.6 Management Areas within SWSD

The SWSD has identified three management areas within the boundaries of its GSA. These boundaries roughly correspond to the Pond Poso Improvement District, the Buttonwillow Improvement District and the areas that are primarily undeveloped agricultural lands. The boundaries of the management areas have been modified from the improvement district boundaries to capture the extent of irrigated lands within management areas 1 and 2. Management area 3 includes managed wetlands (private Duck Clubs) and the Kern National Wildlife Refuge, and undeveloped native lands. Figure 2-51 shows the boundaries of the three management areas established for the Semitropic GSA.

2.7 Existing Water Resource Programs

This section identifies and discusses current water resources programs the District participates in. Expanding off Section 1.4.2, this section provides an in-depth overview of each program and District involvement

2.7.1 Management Plans

The State of California has pre-SGMA programs for the management of groundwater supply and quality. These programs are managed at various levels of government by existing public agencies, either individually or collaboratively with neighboring agencies within the same groundwater basin. The following section provides an overview of these programs and the elements addressed in each.

2.7.1.1 Groundwater Management Plans

In 1992, the State of California passed the Groundwater Management Act (AB 3030). This legislation provided guidelines for the agencies and districts to provide planned and coordinated monitoring, operation, and administration of groundwater basins with the goal of long-term sustainability. There are several types of Groundwater Management Plans.

Pre-SB 1938 Plans: These plans, typically adopted before 2002, could be prepared by a local agency in a Bulletin 118-desginated basin on a voluntary basis. The voluntary components of these plans include:

- The control of saline water intrusion.
- Identification and management of wellhead protection areas and recharge areas.
- Regulation of the migration of contaminated groundwater.
- The administration of a well abandonment and well destruction program.
- Mitigation of conditions of overdraft.
- Replenishment of groundwater extracted by water producers.
- Monitoring of groundwater levels and storage.
- Facilitating conjunctive use operations.
- Identification of well construction policies.
- The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.
- The development of relationships with state and federal regulatory agencies.
- The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

SWSD MANAGEMENT AREAS

- Semitropic WSD GSA
- Inprovment District Boundary

Management Area

- SWSD-1
- SWSD-2
- SWSD-3
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 2-51

Kings County
Kern County
Tulare County
Kern County
Kern River Channel
Groundwater Dependent Ag
(MA-3)
Pond Poso Improvement District (approx.)
(MA-1)
Goose Lake Canal
Poso Creek Flood Channel
Pond Poso
Improvement
District
Delano
Garces Hwy
Friant-Kern Canal
McFarland
Sherwood Ave
Famoso-Porterville Hwy
Poso Creek
Lost Hills
Pond Poso Canal
SWRU East-West Pipeline
Wasco
Semitropic
Intake Canal
Semitropic Canal
California Aqueduct
Kern River Flood Canal
Buttonwillow Ridge Canal
Buttonwillow
Improvement
District
Lerdo Hwy
W Lerdo Hwy
E Lerdo Hwy
Shafter
Buttonwillow Improvement District (approx.)
(MA-2)
7th Standard Rd
East Side Canal
Buttonwillow
SOURCE: SWSD
08-Aug-2019 Z:\Projects\1704941_Semitropic_ET\SEM029_ProposedManagementAreas.mxd SI

This Page Left Blank Intentionally

SB 1938 Plans: These plans were generally adopted during or after 2002, incorporating the elements of the Pre-SB 1938 Plans. With the passage of SB 1938, the following components were required as part of any GMP:

- Basin Management Objectives: The GMP shall include basin management objectives 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.
- Agency Cooperation: The local agency shall prepare a plan to involve other agencies that enables the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin.
- Mapping: The local agency shall prepare a map that details the area of the groundwater basin, as defined in DWR's Bulletin 118, and the area of the local agency, that will be subject to the GMP, as well as the boundaries of other local agencies that overlie the basin in which the agency is developing a GMP.
- Monitoring Protocols: The local agency shall adopt monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence (in basins for which subsidence has been identified as a potential problem), and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin.
- Located outside Bulletin 118 Groundwater Basins: Plans located outside DWR Bulletin 118 alluvial groundwater basins will incorporate the above components and shall use geologic and hydrologic principles appropriate to those areas.

AB 359 Plans: When AB 359 was enacted in 2013, it required additional technical components related to groundwater recharge areas and modification to several of the existing GMP adoption procedures in place as part of SB 1938. The additional technical components are as follows:

- The groundwater projects to which these requirements apply include projects that are part of an IRWMP or plan.
- Groundwater projects require a description of how recharge areas identified in the plan substantially contribute to the replenishment of the groundwater basin and a map identifying the recharge areas, as defined, for the groundwater basin to be included in a GMP for purposes of the state funding requirements.
- Require the local agency to provide the map of the recharge areas to local planning agencies and notify the department and other interested persons when a map is submitted to those local planning agencies.

Semitropic adopted a GMP in 2003, in compliance with SB 1938. This GMP has been updated regularly to comply with updated regulatory requirements. The most recent GMP was adopted by SWSD in 2012.

2.7.1.2 Integrated Regional Water Management Plans

In 2002, the Regional Water Management Planning Act (SB 1672) created the IRWM program. The IRWM program is used as a collaborative effort to identify and implement water management solutions on a regional scale that increase regional self-reliance, reduce conflict between agencies and users, and manage water to concurrently achieve social, environmental, and economic objectives. By collaborating on projects, participants in the IRWM program can provide these benefits and meet their water supply and quality goals. In the Subbasin, there are two IRWM plans: the Poso Creek IRWM Plan and the Kern County IRWM Plan. SWSD is a participant in the Poso Creek IRWM Plan, which was adopted in 2007 and has been periodically updated since.

2.7.1.3 Irrigated Lands Regulatory Program

The Tulare Lake Basin General Order (Order R5-2013-0120-07) for the ILRP was adopted by the California Regional Water Quality Control Board, Central Valley Region (RWQCB), in February 2019. This order requires that any irrigated land having the potential to discharge to surface water or groundwater must comply with the requirements set by the RWQCB. Compliance includes membership in a coalition or obtaining coverage through an individual order from the RWQCB. SWSD is a member of the Kern River Watershed Coalition Authority, which was formed in 2011.

2.7.1.4 Groundwater Export Ordinance

Kern County adopted a groundwater export ordinance in 1998, which requires a conditional use permit (CUP) for export of water to areas both outside the County and within watershed areas of underlying aquifers in the County. This ordinance applies to the transport or transfers of native groundwater from or taking place in the unincorporated areas of Kern County lying within the southeastern drainage of the Sierra Nevada and Tehachapi mountain ranges as defined by the jurisdiction of the Lahontan Regional Water Quality Control Board, where “native groundwater” includes connate water and percolating groundwater originating as precipitation within Kern County or its watershed areas. The term “native groundwater” does not include water which is both recharged by artificial means, including water recharged through groundwater banking programs, and which originates outside Kern County and its watershed areas.

2.7.1.5 Title 22 Drinking Water Program

The Division of Drinking Water regulates public drinking water systems, which include municipal and state small water systems. While SWSD does not have any incorporated communities with public water systems, there are several state small systems and multi-

parcel/multi-connection systems in SWSD's jurisdiction. These systems are required to comply with the standards set forth in Title 22 of the California Code of Regulations. For single parcel/single-connection systems, Kern County Environmental Health Services provides regulation and oversight to meet the requirements of Title 22.

2.7.2 Conjunctive Use Programs

Semitropic was established to obtain surface water supplies to supplement groundwater supplies within the District boundaries. Stable groundwater conditions prevailed in the Semitropic area until the mid-1940s. Subsequently, increased pumping caused water levels to decline at a rate of about 8 feet per year with fluctuations approaching 100 feet per year. These declines continued until initiation of surface water deliveries from the SWP in 1973. From 1973 to the early 2000s, pump lifts were not only stabilized, but reduced by approximately 30-feet throughout the District. However, with increasing curtailments of SWP water supplies and decreasing delivery reliability in more recent years, groundwater levels in the Subbasin have declined.

The essence of the District's conjunctive use strategy is to maximize the use of available surface water supplies in lieu of pumped groundwater. Semitropic has implemented a number of conjunctive-use measures, both structural and non-structural. 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. This accounts for approximately 20,000 acres within the District.
- 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 for third-party water banking obligations)
    - 12,000 acres ("discretionary absorptive capability", i.e., District has first priority access for recharge)
- 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 (In-Lieu Service Area)
- Pioneer Project
- Kern Water Bank

3. Sustainable Management Criteria

3.1 Sustainability Goals

SGMA requires that a sustainability goal be defined for the basin (CWC §10727(a)), and DWR's GSP emergency regulations further clarify that the sustainability goal be defined on a basin-wide basis. The District has defined its sustainability goal as follows:

> The sustainability goal for the District is to balance the average annual inflow and outflows of water in the District and implement measures as necessary to avoid undesirable results, including preventing the lowering of average groundwater levels, beyond 2040. This goal is expected to improve and maintain groundwater levels and avoid significant and unreasonable negative change in groundwater storage, water quality degradation, and land subsidence. To reach the sustainability goal by 2040, the District will implement projects and management actions as described herein over time that increase supply and/or reduce demand. Once fully implemented, such projects and management actions are expected to reduce the groundwater pumping in the District as necessary to ensure operation within the basin sustainable yield.

This sustainability goal statement is consistent with and supportive of the basin-wide sustainability goal developed by the KGA and other GSAs in the Subbasin. The Subbasin-wide sustainability goal statement is as follows:

- Achieve sustainable groundwater management in the Kern County Subbasin through the implementation of projects and management actions at the member agency level of each GSA.
- Maintain its groundwater use within the sustainable yield of the basin as demonstrated by monitoring and reporting groundwater conditions.
- Operate within the established sustainable management criteria, which are based on the collective technical information presented in the GSPs in the Subbasin.
- Collectively bring the Subbasin into sustainability and to maintain sustainability over the implementation and planning horizon.

3.2 Undesirable Results

Undesirable results for each sustainability indicator have been developed through a collaborative process with all GSAs in the Subbasin, in compliance with DWR's GSP emergency regulations, which state that undesirable results are to be defined consistently throughout the basin (23-CCR § 354.20). The definitions of "undesirable results" provide flexibility for each management area within the Subbasin to define minimum thresholds that constitute significant and unreasonable impacts to the beneficial uses and users of groundwater within the specific management areas.

The definition of "undesirable results" for the Subbasin are described in the KGA Umbrella GSP and repeated here with additional information regarding causes and effects of each sustainability indicator for the Semitropic GSA management areas.

3.2.1 Undesirable Results for Chronic Lowering of Groundwater Levels

The basin-wide definition of "undesirable results" for chronic lowering of groundwater levels is as follows:

> *The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth/elevation of water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.*
>
> *This is determined when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by each management area). Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans, minimum thresholds, measurable objectives, and interim milestones.*

Within the Subbasin, a management area will be considered an undesirable result watch area for lowering of groundwater levels when it exceeds its minimum threshold criteria, as determined by each management area. Within the Semitropic GSA, a management area will be considered an undesirable result watch area when 51% of the representative monitoring sites in a management area violate their minimum threshold for groundwater levels. If multiple undesirable results watch areas meet the criteria for a Subbasin undesirable result, as defined above, the Subbasin would be considered be experiencing an undesirable result.

3.2.1.1 Potential Causes of Undesirable Results

Potential causes of undesirable results due to chronic lowering of groundwater levels in all three of Semitropic's management areas include a continued or increased reliance on groundwater pumping due to the reduction of imported water supplies. As the primary use of groundwater in Semitropic is for agricultural purposes, increased groundwater pumping could also occur if new land is put into agricultural production or if water use per acre on existing irrigated land increases. To reduce the potential for new lands to be put into agricultural production, the District, in 2017, implemented a New Land Surcharge applicable to newly developed agricultural lands. This surcharge is intended to de-incentivize landowners from developing new irrigation demands. The volume of water pumped by municipal and industrial users is relatively minimal when compared to the volume of water used for agricultural production. No significant development is anticipated in the area based on the review of the current General Plan that covers all or a portion of Semitropic.

3.2.1.2 Potential Effects of Undesirable Results

The primary potential effect of undesirable results caused by chronic lowering of groundwater levels on beneficial uses and users of groundwater in Semitropic may include groundwater well dewatering and increased pumping lift. Well dewatering is detrimental to wells as it can lead to increased maintenance costs (e.g., well rehabilitation/redevelopment and pump lowering) and reduced well lifespan due to corrosion of well casings and screens. Increased pumping lift results in more energy use necessary per unit volume of groundwater pumped and corresponding higher pumping costs, as well as increased wear and tear on well pump motors and reduced well efficiency.

3.2.2 Undesirable Results for Reduction of Groundwater Storage

The Subbasin-wide definition of undesirable results for reduction of groundwater storage is as follows:

> *The point at which significant and unreasonable impacts, as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended 10-year drought period.*
>
> *This is determined when the volume of storage (above the groundwater level minimum thresholds) is depleted to an elevation lower than the groundwater level minimum threshold in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the Subbasin (as measured by the acreage of each management area).*
>
> *Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.*

Within the Subbasin, a management area will be considered an undesirable result watch area for reduction in storage when it exceeds its minimum threshold criteria, as determined by each management area. Within the Semitropic GSA, a management area will be considered an undesirable result watch area for reduction in groundwater storage when 51% of the representative monitoring sites in a management area violate their minimum threshold for groundwater levels, since water elevations serve as a proxy for reduction of groundwater storage. If multiple undesirable results watch areas meet the criteria for a Subbasin undesirable result, as defined above, the Subbasin would be considered be experiencing an undesirable result.

3.2.2.1 Potential Cause of Undesirable Results

Reduction of groundwater storage is generally correlated to chronic lowering of groundwater levels. Therefore, the potential causes of undesirable results due to reduction in groundwater storage are generally the same as the potential causes listed above for undesirable results due to chronic lowering of groundwater levels.

3.2.2.2 Potential Effects of Undesirable Results

Semitropic has defined the undesirable result of reduction of groundwater storage as the reduction of available groundwater volumes needed to support a 10-year drought period, similar to that experienced over the 2006 to 2016 period. The volume of groundwater storage needed to support a 10-year drought is above the minimum threshold for chronic lowering of groundwater levels, therefore groundwater elevations below this minimum threshold would have the same effects on beneficial uses and users in the Semitropic management area.

3.2.3 Undesirable Results for Degraded Water Quality

The Subbasin-wide definition of undesirable results for degraded water quality is as follows:

> *The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.*
>
> *This is determined when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent management areas that represent at least 15% of the Subbasin or greater than 30% of the designated monitoring points within the basin. Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.*

Within the Subbasin, a management area will be considered an undesirable result watch area for degraded water quality when it exceeds its minimum threshold criteria, as determined by each management area. Within the Semitropic GSA, a management area will be considered an undesirable result watch area for degraded water quality when 51% of the representative monitoring sites in a management area violate their minimum threshold for groundwater levels, since groundwater levels serve as a proxy for degraded water quality. If multiple undesirable results watch areas meet the criteria for a Subbasin undesirable result, as defined above, the Subbasin would be considered be experiencing an undesirable result.

3.2.3.1 Potential Cause of Undesirable Results

As described in Section 2.3.5, groundwater within SWSD management area plan's boundaries is high quality that meets nearly all existing standards, including the SWRCB's Water Quality Goals. Based on the available data and trend analysis, arsenic and salinity are the primary constituents of concern. Potential causes of undesirable results for these constituents are:

- **Arsenic:** potential causes of undesirable results from arsenic is believed to be naturally occurring in the Subbasin and leaching from dark clay deposits. Arsenic concentrations greater than 10 ppb are most commonly found in wells screened across pyrite sediments. Representative wells screened in the lower aquifer or across both zones showed

decreasing arsenic trends as water levels decreased, which indicates that the water being pumped is not in contact with the clay layers that release arsenic.

- **Salinity:** potential causes of undesirable results related to salts and lower water levels are unknown at this time. Data trending indicates that salinity levels decrease when water levels drop, and banking activities tends to freshen the groundwater which also helps mitigate salt loading. Studies and management plans conducted through CV-SALTS are expected to have a greater impact on salt loading/management than groundwater levels.

The extent and impact that groundwater levels have had historically, and may have in the future, should continue to be analyzed and addressed in future updates of this plan. It is proposed to monitor the interaction of water management actions with groundwater levels, and in turn the interaction of groundwater levels with water quality, over the next five years to determine if a correlation exists. With respect to point source contamination issues, GeoTracker and EnviroStor databases should be routinely monitored for any updates or new contamination sites.

3.2.3.2 Potential Effects of Undesirable Results

Potential effects of an undesirable result for salinity depend on the beneficial users. Salinity levels are unlikely to increase to levels that exceed the drinking water limits. Therefore, agricultural users are the most impacted. Effects of levels above the SWRCB Ag goals could potentially reduce crop yield.

While it is important for SWSD and KGA to closely monitor the correlation between groundwater levels and contaminant concentrations, other water quality regulatory programs are expected to have a greater impact. The (ILRP) and the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) program both focus on managing the increasing salinity and nitrate levels in the Central Valley. ILRP is contributing to reducing nitrate loading through its nitrogen management plans. By 2022, CV-SALTS will require waste discharge permittees to establish and participate in management zones that are focused on supporting the Human Right to Water and provide replacement drinking water where nitrate exceeds the MCL of 10 ppm.

Because degraded water quality could potentially reduce the amount of usable supply delivered to groundwater users or require the need for treatment systems, which could potentially have a negative economic effect, SWSD and KGA intend to cooperate with the regulatory programs focused on studying, mitigating and managing nitrate and salts in the groundwater.

3.2.4 Undesirable Results for Land Subsidence

The Subbasin-wide definition of undesirable results for land subsidence is as follows:

> *The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the Subbasin, that affects the surface land uses or critical infrastructure.*

This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a Subbasin wide coordinated GSP subsidence monitoring plan.

It is generally recognized that land subsidence is occurring within the Subbasin and also within Semitropic, especially within Management Area 2. However, within any of the three Semitropic management areas no impacts to critical infrastructure have been identified. The lowering of groundwater levels within the Semitropic area could potentially contribute to subsidence, as can the groundwater pumping from neighboring area. As no impacts to critical infrastructure have been identified and because it is not clearly understood how groundwater pumping in different areas of the basin effect subsidence, Semitropic has identified land subsidence as a data gap. As such no minimum thresholds are established for land subsidence at this time. Semitropic will work cooperatively with the KGA and other GSAs in the Subbasin to collect additional data and develop a better understanding of the causes (amount and locations of groundwater pumping) and impacts to critical infrastructure. Minimum thresholds will be adopted by Semitropic at such time that a clear understanding of the causes and effects can be developed.

3.2.4.1 Potential Cause of Undesirable Results

Land subsidence can be caused by several mechanisms, but the mechanism most relevant to sustainable groundwater management is the depressurization of aquifers and aquitards due to lowering of groundwater levels, which can lead to compaction of compressible strata and lowering of the ground surface. Therefore, the potential causes of undesirable results due to land subsidence are generally the same as the potential causes listed above for undesirable results due to chronic lowering of groundwater levels.

3.2.4.2 Potential Effects of Undesirable Results

Potential effects of land subsidence include damage to critical infrastructure including pipelines, roads, building, water conveyance systems, and flood control facilities. Damage to these systems could impact water delivery to surface water, resulting in increased groundwater use.

3.3 Minimum Threshold

This section sets the minimum threshold for each of the sustainability indicators applicable to the Semitropic Area. Thresholds are discussed as a proposed minimum groundwater elevation that would exhibit undesirable results if groundwater elevations fall below the proposed thresholds for any sustainability indicator. Of the six sustainability indicators, seawater intrusion and interconnected surface water are not issues within the District, as indicated in the Basin Setting.

In accordance to §354.28 (d), the District thresholds with respect to groundwater elevations are used as a proxy for identifying undesirable results in groundwater storage, groundwater water quality, and land subsidence. Although groundwater storage in the basin is plentiful, it becomes uneconomical to obtain groundwater at certain depths. Therefore, the SWSD has elected to

maintain approximately 10-years of groundwater storage (by volume) above the minimum threshold for groundwater elevation to manage a 10-year operational drought, similar to the 2006-2016 historical period. With respect to water quality, water levels cause changes in concentration of constituents at different depths of water level per location. Subsidence is known to be caused by the dewatering clay layers (from water level decline) and can be represented by groundwater levels.

The minimum threshold values are determined by separating the basin underlying the SWSD into different hydrogeologic zones (HZs), areas with similar hydrologic and geologic conditions. The creation of the HZs was closely coordinated with those districts adjacent to SWSD. Figures in Appendix E shows the distribution of HZs across the District. Spring water level data spatially representative of individual HZs were plotted together and a linear trend was projected from 2006 to 2016 (historic 10-year drought period). Within the District, all HZ groundwater elevation plots show a declining groundwater slope during the 2006-2016 period. This 10-year period was then projected to 2040 with a unique equal slope for each HZ to estimate the resulting groundwater level if the 2006-2016 conditions persisted for the 20-year implementation period from 2020 through 2040. This methodology was chosen as it would represent a worst-case condition and present a case which could be evaluated by the District's stakeholders to understand what level of impact would be considered significant and unreasonable to individual stakeholder within each HZ. As previously stated, this methodology represents a worst-case scenario in terms of imported water supply deliveries and local hydrology.

The 2040 conditions are set as the minimum threshold value and are shown in Figure 3-1. The projected 2040 water levels indicate the expected change to groundwater level with hydrology maintaining the 2006 to 2016 trend through 2040. This trend represents a worst-case scenario in which the District does not implement any management actions, or projects to mitigate pumping beyond what currently exists and is the case landowners/stakeholders were presented to determine which impacts would be significant and unreasonable. Through a series of workshops and individual meetings between the District staff and landowners, the results of this projected future condition were reviewed with District stakeholders. Based on the review and feedback from landowners and stakeholders, the District adopted the minimum thresholds and measurable objectives described in the following section.

Table 3-1 shows all representative monitoring sites and their respective minimum thresholds and measurable objectives for the sustainability indicators discussed in the following section.

This Page Left Blank Intentionally

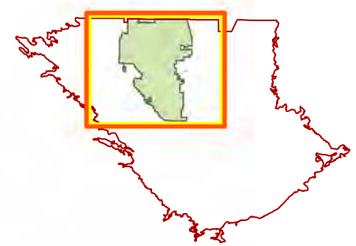
MINIMUM THRESHOLDS AND MEASURABLE OBJECTIVES

Monitoring Network (GSP Status)
Aquifer: U = Upper | L = Lower

- Primary
- Future Installation *(To fill data gap)*
- Interim Well *(to be replaced)*
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 3-1

Notes:
Monitoring network well locations subject to change pending updated geographic survey results.
.
Primary- Permanent monitoring wells that are primary sources of data for the monitoring network

Future Installation - New installation to fill gap in network.

Interim - Well is temporary, to be replaced with a permanent monitoring well.

SOURCE: SWSD

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM028_ProposdMonitoringNetwork.mxd SI

Kings County
Kern County
Tulare County
Kern County
Lower TBD (L)
MT: -292 | MO: -219
S-13A (L)
MT: -371 | MO: -269
Garces Hwy
Delano
Friant-Kern Canal
Kern River Channel
S-12 (L)
MT: -261 | MO: -194
25S/23E-30N01 (U)
MT: 118 | MO: 7
25S/24E-33F01 (U)
MT: 155 | MO: 132
S-6 (L)
MT: -306 | MO: -209
S-11 (L)
MT: -258 | MO: -195
Goose Lake Canal
Poso Creek Flood Channel
26S-23E-15A1 (L)
MT: -345 | MO: -244
Sherwood Ave
McFarland
S-14B (L)
MT: -335 | MO: -233
Lower TBD (L)
MT: -217 | MO: -148
Famoso-Porterville Hwy
Poso Creek
Lost Hills
S-8A (L)
MT: -331 | MO: -229
SWRU East-West Conveyance
S-1 (U)
MT: 165 | MO: 80
Pond Poso Canal
Lower TBD (L)
MT: -268 | MO: -185
Wasco
S-2 (L)
MT: -200 | MO: -127
Semitropic Intake Canal
Semitropic Canal
S-5 (L)
MT: -242 | MO: -161
Friant-Kern Canal
California Aqueduct
Buttonwillow Ridge Canal
S-9A (L)
MT: -227 | MO: -146
S-4 (L)
MT: -144 | MO: -76
Lerdo Hwy
W Lerdo Hwy
Shafter
E Lerdo Hwy
Kern River Flood Canal
7th Standard Rd
East Side Canal
29S/24E-04E01 (U)
MT: 134 | MO: 119
7th Standard Rd
Lower TBD (L)
MT: -180 | MO: -101
948L02 (L)
MT: -180 | MO: -101
Buttonwillow
R20E R21E R22E R23E R24E R25E R26E
T24S T25S T26S T27S T28S T29S
5 33 46 58 43 99 155

This Page Left Blank Intentionally

3.3.1 The Chronic Lowering of Groundwater Levels

The minimum threshold for the chronic lowering of groundwater levels was determined from the interpolated 2040 contours created from the groundwater level estimates using the 2006 to 2016 as a base scenario which represents a worst-case condition. The minimum threshold values for each of the monitoring point in the three management areas are shown in Table 3-1.

SWSD believes the proposed minimum groundwater elevations will not cause undesirable results in the Subbasin. The District will reevaluate the threshold based upon the District's ability to implement projects and management actions and, if necessary, will adjust the minimum threshold if they are able, to prevent causing an undesirable result in the basin.

The impact of drawing water levels to the proposed minimum threshold were analyzed by using well construction data for agriculture, municipal, and domestic wells. From the well impact analysis based on the minimum threshold values per each HZ (represented as depth to water values), it was observed that a portion of the wells are impacted to varying extents, but most wells are expected to be in operation (with a decrease in efficiency) and the bottom of the screens still remain in the water. Further details are provided in Appendix E.

Although the data presented is a subset of the total wells in the areas, it is reasonable to assume that many wells will maintain operation even at the proposed minimum threshold values. The minimum threshold conditions in terms of depth to water were presented to landowners along with the well impact analysis data to determine if it would be economical to mitigate the impacts of agricultural, domestic, and municipal wells. It was determined that at the average 2040 water levels, impacts to agricultural wells could and would be mitigated by landowner to the extent that declining groundwater levels was created by localized actions by those landowners. It was determined that none of the identified agricultural water wells within the SWSD would be dewatered, however in many instances water levels near the minimum threshold would require lowering of pump bowls. It was also identified that if water levels were to fall to levels near the minimum threshold then mitigation would be necessary to address the impacts to the few impacted domestic wells in the area. Any further decrease in water level below the established minimum threshold would create a significant and unreasonable impact to overlying groundwater users and would cause an undesirable result. In normal operating conditions, the extent of impact to wells is expected to be less as water levels are expected to be at higher elevations than the minimum threshold. However, the analysis determined it is possible for the District to drop water levels to the established minimum threshold values and not have undesirable results that cannot be mitigated.

Table 3-1. Summary of Minimum Thresholds and Measurable Objectives

Sustainability Indicator	Subbasin RMS ID	Management Area	Local ID	Measurable Objective		Minumim Threshold		Margin of Operational Flexibility (ft)
				Elevation (ft-msl)	Depth to Water (ft)	Elevation (ft-msl)	Depth to Water (ft)	
Chronic Lowering of Groundwater Levels	RMW-119	Buttonwillow Improvement District (MA-2)	S-02	-127	368	-200	440.6	72.6
	RMW-121	Buttonwillow Improvement District (MA-2)	S-04	-76	325	-144.1	393.1	68.1
	RMW-122	Buttonwillow Improvement District (MA-2)	S-05	-161	402	-241.6	482.9	80.9
	RMW-139	Buttonwillow Improvement District (MA-2)	948L02	-101	399	-179.6	477.2	78.2
	RMW-142	Buttonwillow Improvement District (MA-2)	Proposed-003	-101	399	-179.6	477.2	78.2
	RMW-143	Buttonwillow Improvement District (MA-2)	Proposed-004	-185	453	-267.6	535.6	82.6
	RMW-130	Groundwater Dependent Ag (MA-3)	S-11	-195	419	-257.9	481.8	62.8
	RMW-131	Groundwater Dependent Ag (MA-3)	S-12	-194	414	-260.5	481.2	67.2
	RMW-141	Groundwater Dependent Ag (MA-3)	Proposed-002	-219	433	-292.3	506.5	73.5
	RMW-207	Groundwater Dependent Ag (MA-3)	25S/23E-07B02	-270	484	-377.55	591.7	107.7
	RMW-123	Pond Poso Improvement District (MA-1)	S-06	-209	491	-306	588.5	97.5
	RMW-126	Pond Poso Improvement District (MA-1)	S-08A	-229	508	-331.3	609.6	101.6
	RMW-128	Pond Poso Improvement District (MA-1)	S-09A	-146	444	-226.7	524.7	80.7
	RMW-132	Pond Poso Improvement District (MA-1)	S-13A	-269	493	-371.2	594.9	101.9
	RMW-134	Pond Poso Improvement District (MA-1)	S-14A	-233	509	-334.5	611.4	102.4
	RMW-135	Pond Poso Improvement District (MA-1)	S-14B	-233	509	-334.5	611.4	102.4
	RMW-137	Pond Poso Improvement District (MA-1)	S-15A1	-244	479	-345.3	580.2	101.2
	RMW-140	Pond Poso Improvement District (MA-1)	Proposed-001	-148	382	-217.3	451.6	69.6
Reduction of Groundwater Storage	Groundwater Elevations as Proxy							
Degraded Water Quality	Groundwater Elevations as Proxy							
Land Subsidence	To Be Developed							
Seawater Intrusion	N/A							
Depletion of Interconected Surface Water	N/A							

3.3.1.1 Upper Zone Groundwater Levels

Sustainable management criteria were developed for upper zone wells. Data are included in Appendix B-3. Minimum thresholds were established by trending upper zone hydrographs from 1995 to 2015/2017 to consider long-term decline. In general, most of the upper zone wells were not significantly affected by the drought and therefore, trending did not show significant declines. In addition to trending, thresholds were also considered with respect to the elevation of the Corcoran C-Clay as was also considered for neighboring Buena Vista GSA.

Minimum thresholds were set at or above the C-Clay where present to be consistent with adjacent agencies, and to avoid potential for dewatering below the C-Clay. No significant impacts could be considered because little data are available for the extent and depth intervals of groundwater pumping from the upper zone underlying the District, and the characterization of water quality in upper zone wells. Thresholds have been adopted with respect to neighboring Buena Vista GSA, the depth to C-Clay, and historical lows observed in the hydrographs.

As more data are collected, the subsequent five-year updates to this GSP will further refine SMCs in the Upper Zone where necessary.

3.3.2 Groundwater Storage

The minimum threshold for groundwater storage was set in conjunction with the minimum threshold for the groundwater level. In this Subbasin, groundwater storage is not a significant issue regarding water supply since there is enough storage in the Subbasin to use beyond the set minimum threshold, but access is reduced based on what is economical to currently extract. The minimum thresholds impact to groundwater users for reduction of groundwater storage are the same as those for the chronic lowering of groundwater based on the ability to economically access the water and the proposed water levels are not expected to cause an undesirable result.

3.3.3 Subsidence

The minimum threshold for land subsidence is set equivalent to the chronic lowering of groundwater levels minimum threshold. Land subsidence currently occurs and is expected to continue with lowering of groundwater levels. The proposed water levels are unknown to cause an undesirable result regarding subsidence. In the future, when more consistent and better calibrated data is available, it may be necessary to adjust the minimum threshold dependent on what new information is available. Information needed is the magnitude of subsidence around facilities and infrastructure, which are areas that may cause a significant economic problem affecting water users and others. In the future, minimum thresholds will be derived from monitoring programs implemented to increase the available data in suspected critical areas and to calibrate spatial data available. The management area's contain different levels of subsidence and, based on the data, it is evident that the northern sections of the district are faced with higher subsidence rates and cumulative subsidence; however it is not clear if the subsidence occurring

in the northern extent of the SWSD is a result of pumping operations within the localized area or if it due to pumping operations in a larger geographical area which extends beyond SWSD.

3.3.4 Degraded Water Quality

Minimum thresholds are not set for degraded water quality because the data analysis conducted does not indicate that water quality is degraded by lowered water levels. Data trending was performed on several representative wells in the management area plans to evaluate contaminant concentration changes and identify correlations to groundwater levels. This trending indicated that in the upper zone, arsenic levels increased as water levels increased, however, one well showing this trend is not a conclusive correlation for all wells in the upper zone. In the lower zones or across both zones, decreasing water levels showed decreasing arsenic levels. Salinity levels were generally lower when water levels decreased.

Based on these findings, groundwater levels will be used as a proxy for degraded water quality as the GSA continues to analyze water level and water quality trends. Even though SGMA does not require GSAs to comply with federal and state drinking water standards, the various monitoring programs overseen by regulatory agencies (as discussed in Section 2.5.3) were incorporated into this plan by reference. Existing regulatory programs include Title 22 (Regulations Related to Drinking Water), ILRP, and CV-SALTS. While managing groundwater levels, the GSA will work cooperatively with entities implementing these regulatory programs to share facilities, data, and when applicable, management actions to protect all users and beneficial uses of groundwater.

As defined in Section 4, Monitoring Network, water quality sampling coincides with groundwater levels. This approach is expected to provide clear correlations between water quality and groundwater levels. Monitoring sites and parameters were strategically selected to inform on future degradation of water quality.

3.4 Measurable Objectives and Interim Milestones

The measurable objective is established in accordance to regulation §354.30 (d), groundwater elevations can serve as the value for multiple sustainability indicators where the representative value is a reasonable indicator for multiple measurable objective. As with the minimum threshold, measurable objective values were not established for depletion of interconnected surface water and sea water intrusion as these are not applicable to the basin.

The measurable objective values are determined in the same manner as explained in Section 3-3 for the minimum threshold with the exception that the measurable objective is set at 2030 water levels per the methodology described above. In the Semitropic Area, the measurable objective is the adopted goal to maintain groundwater levels at or above the interpolated 2030 water levels as shown in Appendix E. Setting the measurable objective at the 2030 water level was determined based on the margin of safety giving the District an approximate storage of 10-years (may vary

significantly) of water supply in the instance the District is faced with a similar water supply situation as experienced during the 2006 to 2016 drought.

The interim milestones are the points at which the District plans to set its water levels to reach the sustainability goal at the District level within 20 years of plan implementation. The milestones are set every five years and are based on a linear trend to reach the measurable objective values by 2040, as shown in Appendix E. The District will implement projects and management actions to maintain a path along the interim milestones and to meet the measurable objectives.

3.4.1 The Chronic Lowering of Groundwater Levels

The measurable objective for the chronic lowering of groundwater levels is set at projected 2030 water levels and are monitored at the specific representative monitoring sites. The measurable objective in each management area are monitored at various location. The established measurable objective values are determined from the 2030 water level contours and are shown for each representative monitoring point as shown in Table 3-1. The interim milestones were determined trending a linear trend to reach the measurable objective by 2040.

The proposed measurable objective will allow the District to operate in a worst-case scenario drought condition (2006 to 2016 conditions) and maintain operation before approaching the minimum threshold for an approximated 10 years. Prior to 10 years, the District would have the ability to implement projects or perform emergency actions to reduce pumping.

The measurable objective, like the minimum threshold values vary within the different management areas (and the basin) due to hydrology and the projected decrease in water level determined in each HZ subzone. One Management area contains multiple measurable objectives dependent on hydrologic gradients and spatial distribution.

The steps to reach the measurable objectives will be set by the interim milestones which are checked every five years during the plan's implementation. At these points, projects and management actions will be taken to reduce the reliance on groundwater supply. Section 1 contains details of the projects and management actions which will be used to achieve the interim milestones every five- years. A linear interpolation between the 2015 spring groundwater levels and the measurable objective (2030 water level projections) are used in setting the interim milestones.

3.4.1.1 Upper Zone Groundwater Levels

As described in the above section for minimum thresholds, sustainable management criteria were developed for upper zone wells. Data are included in Appendix B-3. Measurable objectives were established by trending upper zone hydrographs from 1995 to 2015/2017 to consider long-term decline. In general, most of the upper zone wells were not significantly affected by the drought and therefore, trending did not show significant declines. In addition to trending, objectives were

also considered with respect to the elevation of the Corcoran C-Clay, as was also considered for neighboring Buena Vista GSA.

Measurable objectives were set above the C-Clay where present to be consistent with adjacent agencies. Objectives were typically between the projected 2030 to 2040 water levels and the respective hydrograph low from 1995 to 2016.

No significant impacts could be considered because little data are available for the extent and depth intervals of groundwater pumping from the upper zone underlying the District, and the characterization of water quality in upper zone wells. However, objectives have been adopted with respect to neighboring Buena Vista GSA, the depth to C-Clay, and historical lows observed in the hydrographs.

As more data are collected, the subsequent five-year updates to this GSP will further refine SMCs in the upper zone where necessary.

3.4.2 Groundwater Storage

The measurable objective for the reduction in groundwater storage is based on the measurable objective for the chronic lowering of groundwater levels. In setting the measurable objective at the 2030 projection and the minimum threshold at the 2040 water level projection (based on the historical drought), approximately 10 years of storage is available to the District before reaching the minimum threshold, this was set as a factor of safety. A linear interpolation between the 2015 spring groundwater levels and the measurable objective (2030 water level projections) are used in setting the interim milestones.

3.4.3 Subsidence

The measurable objective for land subsidence at this time is based on the measurable objective of chronic lowering of groundwater levels. As mentioned in Section 2.3.6,3.3.3 the magnitude and severity of subsidence is unknown, and data is needed to be collected to ensure the set reasonable measurable objective and minimum threshold. The data will be reviewed at the five-year intervals. A linear interpolation between the 2015 spring groundwater levels and the measurable objective (2030 water level projections) are used in setting the interim milestones.

3.4.4 Degraded Water Quality

For similar reasons as defined in Section 3.3.4 – Minimum Threshold for degraded water quality, the measurable objective of lowering of groundwater levels will be used as a proxy for degraded water quality. A linear interpolation between the 2015 spring groundwater levels and the measurable objective (2030 water level projections) are used in setting the interim milestones. As defined in Section 4, Monitoring Network, water quality sampling coincides with groundwater levels. This approach is expected to provide clear correlations between water quality and groundwater levels.

3.5 Potential Effects Beyond GSP Area

The setting of the minimum threshold and measurable objective in the GSP area is coordinated with neighboring subbasins to maintain a similar water level gradient as 2015 conditions. It is not expected to severely effect areas outside of the Subbasin in terms of changing surrounding water levels to either lower, or higher than conditions of neighboring subbasin plans. Also, groundwater storage is correlated with the change in groundwater levels and is not expected to cause severe impact to neighboring GSAs.

Subsidence is a potential impact from neighboring Districts, GSAs and subbasins. This extent is currently unknown, and more data will need to be collected to determine where the impacts may occur, and which areas are contributing to these impacts.

Water quality data used to characterize groundwater conditions does not indicate that water quality degrades when water levels decline. Regardless, a sampling program has been established to monitoring changes in quality related to water levels. No minimum threshold or measurable objective is set because degradation has not been observed.

Degraded water quality within SWSD is defined as an increasing trend in salinity (sodium and chloride) that potentially threatens agriculture viability within the district; or concentrations of nitrate, arsenic or hexavalent chromium exceeding the respective drinking water standard, because of declining water levels. While these constituents are present throughout the district, the overall trends indicate lower concentrations with lower water levels. In contrast, higher concentrations are typically observed with higher water levels.

This Page Left Blank Intentionally

4. GSP Monitoring Network

This chapter describes the objectives, design, rationale, monitoring protocols, and data reporting requirements of the monitoring network to be implemented. This chapter discusses any data gaps, and a plan for assessment and future improvement to the monitoring network to fill data gaps.

The monitoring network and protocols are designed to collect data of sufficient quality, frequency, and distribution to characterize groundwater conditions and water budget components in the District, and to evaluate changing conditions due to water management actions and future water supply projects.

4.1 Monitoring Network Objectives

The monitoring network in the District is designed to meet the following objectives of this plan:

- Monitor impacts of groundwater pumping on beneficial uses and users of groundwater,
- Monitor progress toward measurable objectives of this plan relative to minimum thresholds,
- Collect data to quantify annual changes in water budget components of the study area, and
- Monitor changes in groundwater conditions relative to the sustainability indicators.

The monitoring network design relative to these four objectives are discussed in this chapter. These objectives will monitor the following pertinent sustainability indicators:

- Groundwater potentiometric surfaces, or groundwater levels,
- Groundwater storage,
- Groundwater quality, and
- Land subsidence

4.1.1 Water Level Monitoring as a Key Sustainability Indicator

As described in the sustainable management criteria section of this plan, groundwater elevation is the key sustainability indicator for undesirable results in the District because the lowering of groundwater levels leads to:

- Increased groundwater well pumping costs,
- A decrease in groundwater storage,

- Potential increased land surface subsidence most notably where fine-grained units and active groundwater overdraft are present, and
- Potential changes in groundwater quality.

The groundwater level monitoring network is key to informing the progress of the GSP's objectives for all sustainability indicators, and therefore is used as a proxy to monitor all primary sustainability indicators. While water levels are the key sustainability indicator for which minimum thresholds have been established, the monitoring network continues to include data collection stations for water quality, land subsidence, and other water budget components such as water demand and water supply inputs. The following sustainability indicators are not pertinent to this GSP: seawater intrusion and depletions of interconnected surface water. Seawater intrusion is anticipated to not be a problem since the District is several miles from the ocean. For details on depletions of interconnected surface water, please refer to Section 2.3.7.

4.2 Monitoring Progress Toward Measurable Objectives

The monitoring network will inform progress of sustainable management to reach interim milestones and measurable objectives. As described in Section 3.3 of this plan, groundwater levels are the primary indicator for which minimum thresholds have been set, and for which interim milestones and measurable objectives will be compared. However, all indicators are included in the monitoring network. As groundwater levels progress, effects on other indicators can be evaluated. Tracking the progress of water levels as well as other indicators will inform the effectiveness of water management actions, implemented projects, and quantification of water budget components. The details for how the measurable objectives and minimum thresholds were developed for groundwater levels are described in Section 3.3 of this plan.

Monitoring the progress toward reaching interim milestones and measurable objectives will provide information needed to evaluate whether adjustments to management actions and monitoring networks are required. Table 4-3 contains lists of the measurable objective and minimum threshold for each monitoring site included as part of this network. As stated in §354.34(g)(3), minimum thresholds, measurable objectives, and interim milestones will be established at each monitoring site or representative monitoring site. Where needed, interim milestones and minimum thresholds for groundwater levels or other sustainability indicators may be adjusted in the five-year updates to maintain the objectives of this GSP.

4.2.1 Potential Impacts to Beneficial Uses and Users of Groundwater

The monitoring network to be implemented will provide data to monitor the impacts of sustainable groundwater management on beneficial uses and users of groundwater, as well as secondary impacts such as land subsidence. A summary of potential impacts is included in Table 4-1.

Table 4-1. Potential Impacts of Overdraft with Corresponding Monitoring

User Group	Potential Impacts	Monitoring and Data Collection
Irrigated Agriculture	• Increased pumping costs and maintenance • Decrease in groundwater storage	• Water level monitoring • Incorporate data into the subbasin model to monitor storage outlooks with interim milestones
	Increased salinity in the upper zone and migration into the lower zone	Water quality monitoring
Industrial, Commercial, and Residential Wells	• Increased pumping costs and maintenance • Well Dewatering • Decrease in groundwater storage	• Water level monitoring • Incorporate data into the subbasin model to monitor storage outlooks with interim milestones
	Increased Arsenic	Water quality monitoring
	Increased TCP and Nitrates	Water quality monitoring in lower aquifer zone
Public Facilities	Damaged infrastructure	Land subsidence monitoring
Groundwater Dependent Ecosystems (Preliminary NCCAG mapped dataset).	• Decline in shallow groundwater levels • Reductions in shallow groundwater storage due to groundwater pumping	• Water level monitoring • Confirm NCCAG mapped areas by field survey and evaluation • If applicable, compare pumping in the upper and lower zone with water levels in the shallow zone

4.2.2 Monitoring Network for Water Budget Components

One of the objectives of the network is to monitor the water budget components to quantify the change in water budget over time. This aspect of the network will rely on local monitoring stations for water levels, but also regional weather stations and remote sensing methods for consumptive use. In addition, water supply and exports accounting are required to monitor the water budget components. These aspects of the network are briefly described below.

4.2.2.1 Water Inputs to the Subbasin

As described in the water budget section of the report. Water inputs to the Subbasin within the District includes:

- Diverted surface water (both imported and natural), that satisfies consumptive use, or becomes managed or unmanaged direct recharge to the Subbasin;
- Precipitation; and
- Subsurface inflow.

4.2.2.2 Surface Water Diversions

The District monitors imported surface water from the State Water Project, banking partners, and neighboring districts, at conveyance interties by metering or by other gauging methods. Other surface water diversions if any from ephemeral Poso Creek may also be gauged seasonally. A map of surface water interties is included in Figure 2-23 in the basin setting. All imported surface water into the District counts as water inflow to the Subbasin, whether it is contracted and will be used for direct consumptive use, other exchanges, in-lieu banking, or direct recharge. Surface water diversions and imports are monitored by the District and are available annually to be incorporated in data evaluation.

4.2.2.3 Precipitation

Depending on the water year, precipitation may account for recharge as well as satisfying a portion of consumptive use in the Subbasin. It is a component of water budget accounting that is monitored by weather stations. The following weather stations (Table 4-2) may be used for monitoring purposes in or near the Subbasin. Online weather station data are updated daily to monthly.

Table 4-2. Weather Stations within the Vicinity

Station Name	ID	Latitude	Longitude	Elevation (feet msl)	Other
Shafter	CIMIS 5	35.532556	-119.281790	360	
Delano	CIMIS 182	35.8330	-119.255960	300	Just north of Subbasin

Source: https://cimis.water.ca.gov/Stations.aspx

4.2.2.4 Subsurface Inflow

Historical quantities of groundwater inflow to the Subbasin underlying the study area have been estimated in various regional models, calculated in local studies by Darcian Law, and may be estimated by water budget accounting in the future.

As the groundwater model of the study area continues to be refined, groundwater inflow calculations may become more accurate. In addition, annual water budget accounting as well as semiannual water elevation monitoring, contouring and gradient estimating, will continue to provide data that can support estimates of groundwater inflow in the future.

4.2.2.5 Water Leaving the Subbasin

As described in the water budget section of the report, water leaving the Subbasin includes:

- Consumptive use from crop demand, other vegetation, evaporation, and other beneficial use such as water recreation, domestic use, municipal or industrial use, etc.;
- Exported water or “Pump Back”; and

- Subsurface outflow.

4.2.2.6 Consumptive Use

Sources of water for consumptive use include surface water, precipitation, and groundwater. As described in the water budget section of this plan, consumptive use from crop demand, other vegetation, and evaporation has been calculated at the basin level using remote sensing techniques (GEI, 2017; ITRC-METRIC). The District as implemented a more robust remote sensing protocol and continues to use remote sensing methodology to further quantify consumptive use within the study area for monitoring (Land IQ, 2019). The Subbasin will continue to coordinate techniques and methodology for monitoring consumptive use to update water budget components for the Subbasin.

4.2.2.7 Exported Water and "Pump back" Water

The District monitors water that leaves the study area for banking partners or exchanges by metering or other gauging methods. These data are included in annual accounting of the water budget and will continue to be available in the future.

4.2.2.8 Subsurface outflow

Historical quantities of groundwater outflow from the Subbasin underlying the study area have been estimated in various regional models, calculated in local studies by Darcian Law, and estimated by water budget accounting in the past.

As a model of the study area is refined, groundwater outflow calculations may become more accurate. In addition, annual water budget accounting as well as semiannual water elevation monitoring, contouring and gradient estimating, will continue to provide data to support estimates of groundwater outflow in the future.

4.3 Monitoring Network Design and Sustainability Indicators

The monitoring network design considers the use of existing monitoring networks, and the coverage required to monitor areas within the District with current and projected groundwater use to adequately demonstrate the short-term, seasonal, and long-term trends in groundwater and related surface conditions. The network to be implemented is designed to have new locations installed for data collection to fill pertinent data gaps in groundwater conditions.

As discussed previously, the monitoring network is designed to collect data with respect to the applicable sustainability indicators in the study area: groundwater levels and reduction of groundwater storage, degraded water quality, and land subsidence. Seawater intrusion and interconnected surface waters are not applicable sustainability indicators in the study area, as described in the basin setting of this report, and are, therefore, not included in the design of this

monitoring network. A brief summary of the network design is introduced below. Details are provided in the sections on the monitoring of sustainability indicators.

4.3.1 Monitoring Frequency Design

The monitoring frequency is outlined in the protocols for monitoring sustainability indicators. In general, monitoring will occur semiannually for groundwater and monthly for land subsidence with co-located groundwater gauging. This frequency provides sufficient short-term, seasonal, and long-term data to evaluate the effectiveness of management actions. Further details on monitoring frequency is outlined in the discussions pertinent to each sustainability indicator.

4.3.2 Spatial Density Design

The spatial density of the monitoring network design accounts for three management areas in the District which have been established to better implement and monitor sustainable groundwater management. These three management areas are described in more detail in Section 2.6 and Figure 2-51. They are the southern-central area encompassing much of Buttonwillow Improvement District; the northeast area covering much of Pond-Poso Improvement District; and the northwest area with some irrigated land, but which is made up of predominantly non-irrigated, undeveloped land, and the KNWR.

The monitoring wells identified as part of this monitoring network will be used to monitor both groundwater levels and groundwater quality. The spatial distribution of the monitoring sites is presented in Figure 4-1. Additionally, the monitoring network also includes a selection of sites that monitors land subsidence. The locations of the land subsidence monitoring sites are included as part of Appendix D. For additional details on the spatial density for each of the monitoring sites, refer to the sections below on the monitoring of sustainability indicators.

4.3.3 Rationale for Design

Rationale regarding the design of the monitoring network is provided in the sections below dedicated to each sustainability indicator. In general, monitoring stations were chosen based on the following scientific rationale:

- Aquifer representation – Per DWR guidelines §354.34, monitoring wells were chosen to represent each underlying aquifer under the jurisdiction of the District.
- Potential impacts to beneficial users of groundwater
- Availability of site-specific historical data and technical information
- Spatial and vertical representation
- Identification of dedicated monitoring wells
- Site accessibility

Additionally, this study led to the identification of data gaps within the monitoring network, which resulted in identifying locations to install supplemental (or future) monitoring wells. The locations of these future monitoring wells have been identified in Figure 4-1 and Table 4-3.

4.3.4 Chronic Lowering of Groundwater Levels and Reduction of Groundwater Storage

This monitoring network consists of 19 wells spread across the three management areas that are part of the District's GSP. As evidenced in Figure 4-1, these 19 wells have been spatially distributed to provide adequate coverage throughout the District. As explained in the basin setting section of this GSP, due to the presence of Corcoran clay, the subsurface is made up of three aquifers – shallow, upper, and lower. Therefore, this monitoring network also accounted for the distinct aquifers within each management area. Table 4-3 identifies the location, type, and construction details, for each management area per aquifer zone.

4.3.4.1 Rationale

The District's monitoring network design and site selection for monitoring the groundwater levels was based on the same rationale outlined in Section 4.3.3 of this chapter.

Since the District owns both agricultural production wells, and monitoring wells, an additional column has been added in the table to indicate the level of compliance with the DWR BMP guidelines for monitoring networks (DWR, 2016b). The level of compliance has been categorized into the following:

- Primary or SGMA compliant - Primary wells in the monitoring network are existing monitoring wells that were designed and constructed for monitoring purposes and selected to meet the necessary spatial distribution. These wells meet the requirements stated in the BMP (DWR, 2016b) to be SGMA compliant
- Interim wells (originally designed and constructed as agricultural production wells) were selected for the network to provide adequate spatial distribution until a permanent dedicated monitoring well can be installed. These interim wells generally have water level gauging data reported historically; however, not all of them have available well construction data. Interim wells selected were chosen based on spatial location to fill gaps in the existing monitoring network in both the upper and lower aquifer zones.
- Future installation – To identify sites for future installation of wells, one rationale was to select areas in which no current dedicated monitoring wells exist and where spatial coverage was desired. For example, minimal groundwater use characterizes the northwest portion of the district, whereas primary groundwater production occurs in the central part of the District; therefore, monitoring was designed to cover the eastern portion of the northwest management area, closest to production. This design provides adequate coverage with respect to the amount and location of pumping in the

northwest management area. A second rationale was to design a network where wells in respective aquifer zones (upper and lower) could be paired for vertical hydraulic gradient calculations. This design component will aid in the objective to monitor potential impacts of lower zone pumping to groundwater users in both the upper and lower aquifer zones. The future monitoring locations may be adjusted after site evaluation has occurred.

The monitoring network for each respective aquifer zone considers where active groundwater production occurs and where aquifer zones are present. For example, the shallow monitoring network is primarily located in the central and western areas of the District where shallow water occurs. As described in the basin setting of this chapter, no pumping for beneficial uses occurs in the shallow zone and is classified as *de minimis*, consequently, the monitoring network does not include any monitoring of this zone. Similarly, the use of the upper zone is minimal as the groundwater pumping for beneficial use predominantly occurs in the lower zone. Therefore, congruous to the pumping occurring in those zones, the lower zone has more representation in the monitoring network than the upper zone.

4.3.4.2 Monitoring Frequency for groundwater conditions

The monitoring network will be capable of collecting sufficient data to demonstrate seasonal, short-term (1 to 5 years) and long-term (5 to 10 years) trends in groundwater and related surface conditions and yield representative information about groundwater conditions as necessary to evaluate plan implementation. In general, water level monitoring will be seasonal to evaluate groundwater elevations during spring time (seasonal high prior to summer irrigation demands) and fall (seasonal low after the summer irrigation demands).

4.3.4.3 Spatial Density

In general, the monitoring network well density follows the recommendation of 4 to 10 wells per 100 square miles (DWR, 2016b), in active groundwater production zones. The below Table 4-4 lists the well density for the network with interim wells and with future installation of monitoring wells. The well density is listed in relation to the three management areas.

SWSD GSP Monitoring Well Network

Monitoring Network (GSP Status)
Aquifer: U = Upper | L = Lower

- Primary
- Future Installation *(To fill data gap)*
- Interim Well *(to be replaced)*
- Semitropic WSD GSA
- Kern County Subbasin Boundary

Other Features

- Highway
- Waterway
- Major Conveyance

RMW-141
Lower TBD (L)
MT: -292 | MO: -219

RMW-132
S-13A (L)
MT: -371 | MO: -269

RMW-131
S-12 (L)
MT: -261 | MO: -194
25S/23E-30N01 (U)
MT: 118 | MO: 7

25S/24E-33F01 (U)
MT: 155 | MO: 132

RMW-123
S-6 (L)
MT: -306 | MO: -209

RMW-130
S-11 (L)
MT: -258 | MO: -195

RMW-137
26S-23E-15A1 (L)
MT: -345 | MO: -244

RMW-135
S-14B (L)
MT: -335 | MO: -233

RMW-140
Lower TBD (L)
MT: -217 | MO: -148

RMW-126
S-8A (L)
MT: -331 | MO: -229

S-1 (U)
MT: 165 | MO: 80

RMW-143
Lower TBD (L)
MT: -268 | MO: -185

RMW-119
S-2 (L)
MT: -200 | MO: -127

RMW-122
S-5 (L)
MT: -242 | MO: -161

RMW-128
S-9A (L)
MT: -227 | MO: -146

RMW-121
S-4 (L)
MT: -144 | MO: -76

29S/24E-04E01 (U)
MT: 134 | MO: 119

Lower TBD (L)
MT: -180 | MO: -101

948L02 (L)
MT: -180 | MO: -101

RMW-139

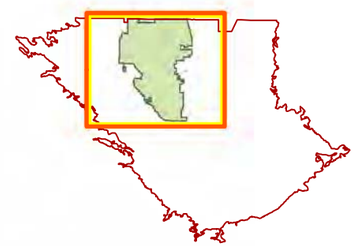
Notes:
Monitoring network well locations subject to change pending updated geographic survey results.

Primary- Permanent monitoring wells that are primary sources of data for the monitoring network

Future Installation - New installation to fill gap in network.

Interim - Well is temporary, to be replaced with a permanent monitoring well.

SOURCE: SWSD



0 2 4
Miles

N

Semitropic Water Storage District
Groundwater Sustainability Plan

Kern County, California

GEI Consultants

AUGUST 2019

FIGURE 4-1

08-Aug-2019 Z:\Projects\1704941_Semitropic_ETSEM028_ProposdMonitoringNetwork.mxd SI

Table 4-3
Monitoring Wells and Corresponding Sustainable Management Criteria
Groundwater Sustainability Plan
Semitropic Water Storage District

Regional ID	Map ID	DMS ID	CASGEM ID	T-R-S	MA	Latitude	Longitude	Well Type	GSP Well Monitoring Status	GSP Parameters Type	Borehole Depth (ft)	Well Depth (ft)	Perforated Interval (ft)	Annular Seal (ft)	Casing Diameter (in)	Material	Aquifer Zone
RMW-137	26S-23E-15A1	2567	356736N1194735W001	26S-23E-15A1	MA-1	35.673653	-119.473336	Monitor Well	Primary (SGMA compliant)	WL and WQ	--	350	310-350	0-80	6.625 (O.D.)	--	Lower
RMW-139	948L02	8055	354189N1194216W001	29S-24E-8L02	MA-2	35.41889	-119.421573	Monitor Well	Primary (SGMA compliant)	WL and WQ	--	625	525-625	--	6	--	Lower
--	S-1	8135	355944N1195814W001	27S-22E-10J	MA-2	35.594406	-119.581411	Monitor Well	Primary (SGMA compliant)	WL and WQ	422	340	285-315	--	5.761	Sch.80 PVC	Upper
RMW-130	S-11	8027	356956N1195623W001	26S-22E-2J	MA-3	35.695554	-119.562279	Monitor Well	Primary (SGMA compliant)	WL and WQ	900	700	550-700	--	6 & 8	1/4-in. Steel	Lower
RMW-131	S-12	8028	357228N1195538W001	25S-22E-25L	MA-3	35.722805	-119.553797	Monitor Well	Primary (SGMA compliant)	WL and WQ	940	740	510-740	--	6 & 8	1/4-in. Steel	Lower
RMW-132	S-13A	8029	357609N1194366W001	25S-24E-18D	MA-1	35.760891	-119.436645	Monitor Well	Primary (SGMA compliant)	WL and WQ	695	690	660-690	0 - 630	6	1/4-in. Steel	Lower
RMW-135	S-14B	3907	356668N1193841W002	26S-24E-16J	MA-1	35.666849	-119.384129	Monitor Well	Primary (SGMA compliant)	WL and WQ	485	480	430-480	0 - 410	6	3/16-in. Steel	Lower
RMW-119	S-2	8014	355687N1195623W001	27S-22E-24D	MA-2	35.568704	-119.562328	Monitor Well	Primary (SGMA compliant)	WL and WQ	500	448	370-410	--	5.761	Sch.80 PVC	Lower
RMW-121	S-4	8016	355205N1195821W001	28S-22E-3H	MA-2	35.520514	-119.582118	Monitor Well	Primary (SGMA compliant)	WL and WQ	501	445	390-420	--	5.761	Sch.80 PVC	Lower
RMW-122	S-5	8017	355506N1195271W001	27S-23E-29M	MA-2	35.550636	-119.527138	Monitor Well	Primary (SGMA compliant)	WL and WQ	500	430	380-410	--	5.761	Sch.80 PVC	Lower
RMW-123	S-6	8018	357036N1193392W001	25S-24E-36Q	MA-1	35.703571	-119.339174	Monitor Well	Primary (SGMA compliant)	WL and WQ	450	431	381-431	0 - 356	6	3/16-in. Steel	Lower
RMW-126	S-8A	9408	356305N1194021W001	26S-24E-33D	MA-1	35.630484	-119.402125	Monitor Well	Primary (SGMA compliant)	WL and WQ	700	687	637-687	0 - 600	6	1/4-in. Steel	Lower
RMW-128	S-9A	8022	355219N1193943W001	28S-24E-4L	MA-1	35.521942	-119.394311	Monitor Well	Primary (SGMA compliant)	WL and WQ	700	690	660-690	0 - 640	6	1/4-in. Steel	Lower
--	25S/23E-30N01	7889	357183N1195417W001	25S-23E-30N	MA-1	35.7183	-119.5417	Production Well	Interim (to be replaced)	WL and WQ	--	--	99-150	--	--	--	Upper
--	25S/24E-33F01	10876	357106N1193928W001	25S-24E-33F	MA-1	35.7106	-119.4	Production Well	Interim (to be replaced)	WL and WQ	--	--	182-320	--	--	--	Upper
--	29S/24E-04E01	10454	354350N1194070W001	29S-24E-04E	MA-2	35.435	-119.4	Production Well	Interim (to be replaced)	WL and WQ	--	--	150-250	--	--	--	Upper
RMW-141	Lower TBD	--	--	25S-23E-07B02	MA-3	35.7722	-119.5349	Monitor Well	Future Installation	WL and WQ	--	--	--	--	--	--	Lower
RMW-143	Lower TBD	--	--	27-23-10	MA-2	35.587579	-119.475195	Monitor Well	Future Installation	WL and WQ	--	--	--	--	--	--	Lower
RMW-140	Lower TBD	--	--	26S-23E-30M	MA-1	35.637236	-119.544155	Monitor Well	Future Installation	WL and WQ	--	--	--	--	--	--	Lower

-- data are not available
DMS - Data Management System
Interim - Well is temporarily used until a permanent replacement is installed.
Primary- Permanent monitoring wells that are SGMA compliant
Future Installation - New installation to fill data gap. TBD- To be determined
WL - Water Level

4.3.4.4 Data Gaps

While the monitoring network provides a good spatial coverage of the entire District, the interim wells identified lack well construction details and require confirmation of perforation intervals. As referenced in § 352.4 of the regulations, *"If an Agency relies on wells that lack casing perforations, borehole depth, or total well depth information to monitor groundwater conditions as part of a Plan, the Agency shall describe a schedule for acquiring monitoring wells with the necessary information, or demonstrate to the Department that such information is not necessary to understand and manage groundwater in the basin."*

The description of steps to fill this data gap has been identified in Section 4.5 below.

Table 4-4. Monitoring Network Well Density per 100 Square Miles (approximate)

Management Area	Area (Sq. miles)	Corresponding minimum number of wells recommended in DWR BMP	Monitoring wells included as part of the network
Pond Poso Improvement District (MA-1)	144.7	6	9
Buttonwillow Improvement District (MA-2)	129.1	5	7
Groundwater Dependent Agriculture area (MA-3) *	74.8	3	3

*Well Density adequately represents the limited production pumping in its management area

4.3.5 Seawater Intrusion

Seawater intrusion is not applicable to this chapter.

4.3.6 Degraded Water Quality

The District proposes to utilize the same network of wells that were identified as part of the groundwater level monitoring network.

4.3.6.1 Rationale

Since the District's monitoring network comprises wells for both water quality and level monitoring, the same rationale elaborated in Section 4.3.4.1 applies here.

4.3.6.2 Spatial Density

As described in Section 4.3.4.3 and evidenced in Table 4-4, the monitoring network well density follows DWR's BMP recommendation of 4 to 10 wells per 100 square miles, in active groundwater production zones.

4.3.6.3 Data Gaps

The data gaps identified in Section 4.3.4.4 are also applicable here.

4.3.7 Land Subsidence

As part of the SWSD monitoring committee, land subsidence has been monitored and data reported in the biennial reports prepared by Schmidt and Associates. The monitoring network includes SWSD's borehole extensometer, as well as nearby continuous GPS points P545, P563, and P564. These GPS stations are maintained, and data are processed and reported, by affiliates of UNAVCO https://www.unavco.org/instrumentation/networks/status/pbo and SOPAC http://sopac-csrc.ucsd.edu/index.php/sopac/. A location map of the existing land subsidence monitoring network is included in Appendix D.

Details including data for the CGPS points and extensometer, and benefits and frequency of the data, are further discussed in the groundwater conditions of this report. In general, CGPS points record daily to sub-daily frequency, while the extensometer is currently set up for manual measurements that require periodic visits to record data values. While CGPS points record near continuous data, their limitations are in that they measure land surface deformation referenced to a datum but cannot measure discrete intervals in the subsurface. On the other hand, the borehole extensometer can measure a discrete interval from the bottom of the extensometer to ground surface, thus providing a more accurate approximation of compaction in the intervals subject to groundwater pumping.

SWSD Borehole Extensometer

SWSD operates a borehole extensometer (25S22E35B001M) in the northwest part of the study area. A generalized diagram of the extensometer is provided in the basin setting (Figure 2-50).

It was completed to a depth of 910 feet below ground surface and has a perforated screen interval from 680 to 700 feet below ground surface. It measures the compaction in the subsurface from ground surface to 910 feet in depth. Measurements can be collected as often as necessary. Typically, readings have been reported every few months.

SWSD's extensometer will continue to be utilized for the monitoring network as part of this GSP.

Remote Sensing Land Subsidence Monitoring

In addition to CGPS and SWSD's borehole extensometer, NASA and DWR have collected remote sensing data (INSAR and UAVSAR) on a regional scale to better understand the lateral and temporal extent of subsidence within the study area. The methodology and approach for collecting and processing the data has varied over the last decade as refinements have been made. NASA and DWR are working together to field calibrate these remote sensing data with

CGPS points to better understand the quantitative estimates of land subsidence that have been reported.

The existing monitoring data are available for some date ranges and therefore are discussed further in the Groundwater Conditions of this report. In addition, the KGA Umbrella GSP also provides details on INSAR and UAVSAR reporting and availability. As remote sensing data continue to be available, it will be used for the monitoring network of this GSP.

Summary of Land Subsidence Monitoring

Below is a table (Table 4-5) of currently available land subsidence monitoring for the study area.

Table 4-5. Summary of Land Subsidence Monitoring in Study Area

Type	Stations	Range of Available Data	Source
Borehole Extensometers	24S/22E-35B001	December 2013 to present	SWSD
Continuous GPS Stations	P544, P545, P563, P564, P565	Varies. 2000 to present 2005 to present	UNAVCO PBS www.unavco.org Access data from: Instrumentation > Network Monitoring > Plate Boundary Observatory (PBO).
InSAR / UAVSAR	Remote Satellite Imagery	Recent. Range of freely accessible data: 2007 to 2011 2014 to present	Areal extent varies depending on dataset. Not always extensive across the Subbasin. Post-processed data available from (Farr, et. al., 2016), JPL, and USGS.

Additionally, the District will continue working in collaboration with the KGA to monitor land subsidence at the Subbasin level.

4.3.7.1 Rationale

Discrete monitoring stations are paired with water level monitoring points to record changes in land subsidence over time with respect to groundwater. The monitoring network is designed to take advantage of available data from CGPS and remote sensing sources. Most importantly, as the network consistently collects data for several years, an understanding of the long-term effects of groundwater extraction on local land subsidence will improve.

4.3.7.2 Monitoring Frequency

Monitoring frequencies will differ for each subsidence dataset. CGPS data points are collected daily while InSAR data are collected, processed, and reported typically over monthly and annual intervals. In general, seasonal and annual cumulative averages provided a good resolution in the Basin Setting for observing seasonal effects of subsidence.

At a minimum, data will be collected seasonally (Spring and Fall) and will be evaluated annually. Where possible, extensometer data will be collected monthly. See Table 4-6 below.

Table 4-6. Monitoring Schedule

Monitoring Type	Data Collection/Processing Frequency	Reporting and Monitoring Frequency
Continuous GPS	Daily to Monthly	Semiannually to Annually
Extensometer	Monthly to Semiannually	Semiannually to Annually
InSAR Surveys	Where Available	Annually where available

4.3.7.3 Land Subsidence Spatial Density

The District currently has an existing land subsidence monitoring network comprised of CGPS points, and a District extensometer that are roughly spaced 15 miles away from each other. InSAR data has been used to evaluate land subsidence in between these monitoring points.

Future coordination with other Subbasin stakeholders will be critical to provide input on regional basin-wide remote sensing surveys to continue to provide coverage between subsidence monitoring points.

4.3.7.4 Data Gaps

The northeast and central parts of the District do not currently have discrete point stations for monitoring subsidence, rather InSAR regional data has been used. Based on InSAR data, these areas appear to experience greater subsidence relative to adjacent portions of the District where subsidence point stations are located (Extensometer, P545, and P563). If deemed appropriate, in the future, installation of discrete point stations such as NGS-type concrete survey monuments or CGPS stations, may be useful control points to compare with InSAR data in the northeast and central parts of the District.

4.3.8 Depletion of Interconnected Surface Water

As explained previously, depletion of interconnected surface water is not applicable to the Subbasin.

4.4 Monitoring Protocols and Reporting Standards

The District monitoring protocols for collection of groundwater levels and water quality samples will follow the Groundwater Monitoring Protocols, Standards, and Sites BMP produced by DWR (DWR, 2016c). The protocols and standards for monitoring and reporting requirements are provided below.

4.4.1 Groundwater Level Monitoring Network Protocol and Standards

The monitoring network in the District includes production wells and dedicated monitoring wells. Until enough dedicated monitoring wells are installed to fill data gaps, production wells will be used to expand the spatial coverage of the existing network.

As referenced in § 352.4 of the GSP emergency regulations, monitoring sites/wells will conform to BMP for geographic locations, identification, and details on well construction. The following are requested standards.

	§ 352.4 Standards for Required Monitoring Well Information
Well Identification	Use the CASGEM well identification number. If a CASGEM well identification number has not been issued, appropriate well information shall be entered on forms made available by the Department.
Well/Site Location	Geographic locations shall be reported in GPS coordinates by latitude and longitude in decimal degree to five decimal places, to a minimum accuracy of 30 feet, relative to NAD83, or another national standard that is convertible to NAD83. Reference point elevations shall be measured and reported in feet to an accuracy of at least 0.5 feet, or the best available information, relative to NAVD88, or another national standard that is convertible to NAVD88, and the method of measurement described.
Well Type and Construction Details	A description of the well use/type, whether the well is active or inactive, and whether the well is a single, clustered, nested, or other type of well. Casing perforations, borehole depth, and total well depth shall be reported. Well completion reports will be provided, if available, from which the names of private owners have been redacted. Geophysical logs, well construction diagrams, or other relevant information will be provided, if available, including any other relevant well construction information, such as well capacity, casing diameter, or casing modifications.
Monitoring Zone	Identification of principal aquifer or aquifer zones monitored.

Monitoring Protocols

As referenced in § 352.4 of the regulations, "monitoring protocols shall be developed according to BMP. Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan and modified as necessary."

As per DWR's Monitoring Protocol BMP and KGA's White Paper for Groundwater Elevation Data:

- All groundwater levels in a basin will be collected within as short a time as possible, preferably within a 1 to 2-week period.

- Depth to groundwater will be measured relative to an established Reference Point (RP) on the well casing. The RP is usually identified with a permanent marker, paint spot, or a notch in the lip of the well casing. By convention in open casing monitoring wells, the RP reference point is located on the north side of the well casing. If no mark is apparent, the person performing the measurement will measure the depth to groundwater from the north side of the top of the well casing.

- The sampler will remove the appropriate cap, lid, or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement will follow a period of time to allow the water level to equilibrate.

- Field measurements of depth to groundwater and land surface will be measured and reported in feet to an accuracy of at least 0.1 feet relative to NAVD88, or another national standard that is convertible to NAVD88, and the method of measurement described (i.e. electric sounder, steel tape, plopper, transducer, acoustic sounder [questionable data accuracy], or airline).

- The water level meter will be decontaminated after measuring each well.

- To assure that the same well is being measured each time, the District will create a Well Identification Sheet for each well site. The Well Identification Sheet will be used to track each well being monitored. Each Well Identification Sheet will include: well number, date of the District's survey, latitude and longitude, depth to water from reference point (RP), RP elevation, location description and map, well type, well completion type, total depth if applicable, screened intervals if applicable, well completion report number if applicable, well use, description of RP, landowner information, and of RP location.

- The sampler will replace any well caps or plugs and lock any well buildings or covers.

- All data will be entered into the GSA DMS as soon as possible. Care will be taken to avoid data entry mistakes and the entries will be checked by a second person for compliance with the data quality objectives.

Pressure Transducers

As per DWR's Monitoring Protocols BMP, groundwater levels and/or calculated groundwater elevations may be recorded using pressure transducers equipped with data loggers installed in monitoring wells. When installing pressure transducers, care will be exercised to ensure that the data recorded by the transducers is confirmed with hand measurements.

The following general protocols will be followed when installing a pressure transducer in a monitoring well:

- The sampler will use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation.

- The sampler will note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.

- Transducers will be able to record groundwater levels with an accuracy of at least 0.1 foot. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers will be included in the evaluation.

- The sampler will note whether the pressure transducer uses a vented or non- vented cable for barometric compensation. Vented cables are preferred, but non- vented units provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.

- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that data quality objectives are being met for the GSP.

- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.

The transducer data will periodically be checked against hand measured groundwater levels to monitor electronic drift or cable movement. This will happen during routine site visits, at least annually or as necessary to maintain data integrity

- The data will be downloaded as necessary to ensure no data is lost and entered into the basin's DMS following the QA/QC program established for the GSP. Data collected with non-vented data logger cables will be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been

safely downloaded and stored, the data will be deleted from the data logger to ensure that adequate data logger memory remains.

As mentioned above, for specific details regarding the monitoring network for groundwater level and change in groundwater storage for each management area, please refer to the respective individual chapters. The data gaps and steps for improvement of the respective monitoring networks have also been identified in those chapters.

4.4.2 Water Quality Monitoring Network Protocol and Standards

The existing monitoring network in the District includes production wells and dedicated monitoring wells. Until enough dedicated monitoring wells are installed to fill data gaps, production wells will be used to expand the spatial coverage of the existing water quality network.

As referenced in § 352.4 of the regulations, monitoring sites/wells will conform to BMP for geographic locations, identification, and details on well construction. The following are requested standards.

Monitoring Protocols

The monitoring protocols will follow, at a minimum, the sampling guidelines as provided in DWR's *Groundwater Monitoring Protocols, Standards, and Sites BMP* (2016c).

Groundwater quality sampling protocols will ensure that:

- Groundwater quality data are taken from the correct location,
- Groundwater quality data are accurate and reproducible,
- Groundwater quality data represent conditions that inform appropriate basin management and are consistent with the data quality objectives,
- All important information is recorded to normalize, if necessary, and compare data, and
- Data are handled in a way that ensures data integrity.

The following points are general guidance in addition to the techniques presented in the previously mentioned USGS *National Field Manual for the Collection of Water Quality Data.*

Standardized protocols include the following:

- Prior to sampling, the sampler will contact the laboratory to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.
- Each well used for groundwater quality monitoring will have a unique identifier. This identifier will appear on the well housing or the well casing to avoid confusion.

- In the case of wells with dedicated pumps, samples will be collected at or near the wellhead. Samples will not be collected from storage tanks, at the end of long pipe runs, or after any water treatment.
- The sampler will clean the sampling port and/or sampling equipment and the sampling port and/or sampling equipment will be free of any contaminants. The sampler will decontaminate sampling equipment between sampling locations or wells to avoid cross-contamination between samples.
- The groundwater elevation in the well will be measured following appropriate protocols described above in the groundwater level measuring protocols.
- For any well not equipped with low-flow or passive sampling equipment, an adequate volume of water will be purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. Purging three well casing volumes is generally considered adequate. Professional judgment will be used to determine the proper configuration of the sampling equipment with respect to well construction such that a representative ambient groundwater sample is collected. If pumping causes a well to be evacuated (go dry), document the condition and allow well to recover to within 90% of original level prior to sampling. Professional judgment will be exercised as to whether the sample will meet the DQOs and adjusted as necessary.
- Field parameters of pH, electrical conductivity, and temperature will be collected for each sample. Field parameters will be evaluated during the purging of the well and will stabilize prior to sampling. Measurements of pH will only be measured in the field, lab pH analysis are typically unachievable due to short hold times. Other parameters, such as oxidation-reduction potential (ORP), dissolved oxygen (DO) (in situ measurements preferable), or turbidity, may also be useful for meeting DQOs of GSP and assessing purge conditions. All field instruments will be calibrated daily and evaluated for drift throughout the day.
- Sample containers will be labeled prior to sample collection. The sample label will include: sample ID (often well ID), sample date and time, sample personnel, sample location, preservative used, and analytes and analytical method.
- Samples will be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection.
- Samples will be collected according to appropriate standards such as those listed in the Standard Methods for the Examination of Water and Wastewater, USGS National Field Manual for the Collection of Water Quality Data, or other appropriate guidance. The specific sample collection procedure will reflect the type of analysis to be performed and DQOs.
- All samples requiring preservation will be preserved as soon as practically possible, ideally at the time of sample collection. Ensure that samples are appropriately filtered as recommended for the specific analyte. Entrained solids can be dissolved by preservative

leading to inconsistent results of dissolve analytes. Specifically, samples to be analyzed for metals will be field-filtered prior to preservation; do not collect an unfiltered sample in a preserved container.

- Samples will be chilled and maintained at 4 °C to prevent degradation of the sample. The laboratory's Quality Assurance Management Plan will detail appropriate chilling and shipping requirements.
- Samples will be shipped under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.
- The laboratory will be instructed to use reporting limits that are equal to or less than the applicable DQOs or regional water quality objectives/screening levels.

Specific standards and protocols for sampling are discussed in the chapter for each MA of the KGA.

As mentioned above, for specific details regarding the monitoring network for groundwater quality for each management area, please refer to the respective individual management area plans. The data gaps and steps for improvement of the respective monitoring networks have also been identified in those chapters.

4.4.3 Land Subsidence Monitoring Network

Monitoring Protocols

Per DWR's Monitoring Protocols BMP: "Various standards and guidance documents for collecting data include:

- Leveling surveys will follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- GPS surveys will follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- USGS has been performing subsidence surveys within several areas of California. These studies are sound examples for appropriate methods and will be utilized to the extent possible and where available: http://ca.water.usgs.gov/land_subsidence/california-subsidence- measuring.html
- Instruments installed in borehole extensometers will follow the manufacturer's instructions for installation, care, and calibration.
- Availability of InSAR data is improving and will increase as programs are developed. This method requires expertise in analysis of the raw data and will likely be made available as an interpretative report for specific regions.

4.5 Monitoring Network Improvement Plan

The District has included a management action for development of a monitoring network improvement plan with an assessment of improvements required every five years. This improvement plan contains areas of data gaps in the initial monitoring network, in which additional data or monitoring sites are needed. An assessment of the monitoring network is provided below to discuss future improvements.

4.5.1 Water Level, Groundwater Storage, and Water Quality Monitoring Network Assessment

As indicated previously in the data gaps section, construction details of the interim well need to be determined to improve on the monitoring network. This will be mitigated by conducting downhole well surveys and desktop surveys to fill in the well construction details gap.

Additionally, the plan also includes the following:

- Rank or prioritize future installation sites and reject any redundant monitoring sites if any.
- Finalize the monitoring network and develop a schedule for station installation.
- Continue evaluating the monitoring network for data gaps.
- Plans for network revisions to adjust the monitoring frequency and density of monitoring sites to better assess the effectiveness of management actions, if there are:
    - Minimum threshold exceedances,
    - Highly variable spatial or temporal conditions,
    - Adverse impacts to beneficial uses and users of groundwater, or the potential to adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of sustainability goals in an adjacent basin.

4.5.2 Land Subsidence Network Assessment

As described in the data gaps section of the land subsidence network, the northeast and central parts of the District do not currently have discrete point stations for monitoring subsidence. Rather, InSAR regional data has been used to provide coverage between discrete monitoring stations. A better understanding of subsidence in the northeast and central parts of the District are needed to evaluate land subsidence as a sustainability indicator.

Based on InSAR data, the northeast area of the district appears to have experienced greater subsidence relative to adjacent portions of the District where subsidence point stations are located (Extensometer, P545, and P563). If deemed appropriate, in the future, installation of discrete point stations such as NGS-type concrete survey monuments or CGPS stations, may be

useful control points to compare with InSAR data in the northeast and central parts of the District.

Alternatively, as described in the Basin Setting, various groups have or are comparing InSAR data with monitoring point stations (CGPS and extensometer) to evaluate the effectiveness of using InSAR in lieu of monitoring stations. A better understanding and continued monitoring of subsidence by remote sensing such as InSAR and point station data are needed to further this evaluation.

As described in the Basin Setting, reduction in storage as potentially an undesirable result, has been documented from land subsidence in the San Joaquin Valley. In order to evaluate potential changes in storage, water level data with subsidence data from stations such as CGPS or extensometers are needed. This evaluation requires reliable co-located groundwater monitoring stations within the vicinity of the subsidence stations.

Plan to fill data Gaps

Within the next five years, the District will implement a management action to fill data gaps in the subsidence monitoring network include:

- Evaluate future benchmark monitoring sites co-located with future well monitoring network, especially in the northeast and central portions of the District, where monitoring stations are not currently present.
- Assess the existence of, or ability to install, co-located water level monitoring stations with CGPS and extensometers, to better evaluate water levels with subsidence monitoring data.
- Continue to collect data to evaluate InSAR data in relation to discrete point stations such as CGPS and extensometers, to assess the feasibility of using InSAR or other remote sensing data as a supplement for data gaps in the monitoring station network.

5. Projects and Management Actions

This section describes projects and management actions to meet this sustainability goal for the SWSD GSA in a manner that can be maintained over the planning and implementation horizon. The projects and management actions presented here represent the best available engineering and analysis completed to-date. This list will be updated throughout the planning and implementation period to reflect additional analyses and new and emerging opportunities.

The SWSD has identified its water budget in Section 2.4 of this GSP. The SWSD's water budget indicates an annual deficit of between 222,200 to 25,500 acre-feet, with a median of 123,900 acre-feet. To eliminate the deficit, the District will need to reduce groundwater extractions by 123,900 acre-feet over the implementation period (the median value of the District's deficit). In order to reduce deficit by 2040 as necessary to achieve sustainability, i.e., avoidance undesirable results, the District will implement Projects and Management Actions described in this plan. As additional analysis is completed on the Subbasin water budget the District's water budget could change, and as those changes are accepted by the KGA and other Subbasin GSAs, the District will make the appropriate adjustments to the projects and management actions needed to meet sustainability.

Throughout this GSP projects and management actions are collectively referred to as management actions.

5.1 Management Actions Processes

The following sections describe the processes required for management actions to be implemented, the sustainability indicator addressed and overview of the expected benefits. A summary list of the all management actions being considered by the SWSD are provided in Table 5-1 below.

5.1.1 Goals and Objectives

Per Section 354.44 of DWR's GSP emergency regulations, GSPs are to include management actions to address any existing or potential undesirable results for the identified relevant sustainability indicators. SWSD plans to implement management actions that will meet the measurable objectives of the following sustainability indicators: (1) chronic lowering of groundwater levels, (2) reduction of groundwater storage, (3) degraded water quality, and (4) land subsidence. Implementation of each project and management action will address the chronic lowering of

groundwater levels. Table 5-1 provides an indication of the sustainability indicators that may be addressed by the proposed management actions.

5.1.2 Circumstances for Implementation

Given the circumstances of conditions described in the Basin Setting of this GSP, SWSD has already begun implementation of certain management actions to manage groundwater within the District. Management actions will be implemented as determined by the District and certain management actions will be implemented as soon as 2020 following the adoption of this GSP. Table 5-1 provides an estimated timeline for implementation of each management action and the circumstances for which each will be implemented.

5.1.3 Public Noticing

The public notice and outreach processes for the District include public board meetings and the CEQA process each management action is required to undergo before implementation. Semitropic provides public noticing by posting all board meeting notices, agendas, and minutes on their website (see Section 1.5) according to the Brown Act.

5.1.4 Permitting and Regulatory Process

Permitting and regulatory requirements vary for the different management actions SWSD plans to implement. Specific requirements will depend on the type of project, which could be recharge and infrastructure projects as well as administrative actions that incentivize reduced groundwater pumping. The following is a list of the types of permitting at the federal, state, and county level that could apply, but not necessarily, to all management actions.

- Federal
    - If federal grants are used, National Environmental Policy Act (NEPA) documentation is required;
    - National Pollution Discharge Elimination System (NPDES) stormwater program permit;
- State
    - California Environmental Quality Act (CEQA) documentation may be required prior to implementation of some of the management actions. These documents include one or more of the following: Notice of Exemption, Initial Study, , Negative Declaration, Mitigated Negative Declaration, and Environmental Impact Report;
- Regional
    - San Joaquin Valley Air Pollution Control District (SJVAPCD) permit and regulations;
- Local/County
    - Encroachment Permits;

- Kern County Grading Permit;
- Kern County Well Permit;
- Kern County Supplemental Well Permit.

5.1.5 Implementation Timetable and Status

The current status of each management action is included in Table 5-1 below. Since most management actions are in the conceptual phase of development, the timelines for permitting and regulatory process requirements and other particulars are estimated and subject to change depending on project need and supplemental water availability. SWSD will begin to implement management actions to reduce groundwater extractions as soon as 2020 and will continue to implement based on their estimated timeline.

The status of each management action is also provided in Table 5-1. Each management action is designated as follows:

Conceptual: The management action is identified but has not undergone significant planning, engineer or feasibility analyses.

Not yet started: This management action as undergone some initial evaluations but has advanced to an implementation phase. The management action will likely require additional feasibility analyses.

Initiated: The management action has undergone initial planning and feasibility assessments and being advanced to implementation.

Ongoing: The management action is part of an ongoing effort by the District and will continue to be implemented to meet the sustainability goals of the District.

5.1.6 Expected Benefits

Table 5-1 provides the estimated benefits for each management action the District plans to implement. As previously stated, most of the proposed actions are in their conceptual phase of development; therefore, a range has been provided for the estimated benefits each action is expected to yield but is subject to change.

5.1.7 Source and Reliability of Water Outside SWSD

SWSD will bring in supplemental water from outside the District to support its management actions. While not all management actions require water from outside the District, there are several that do. As discussed in Section 2.2.9 of this GSP, SWSD's primary source of imported water is supplied by the SWP from a contract the District has through KCWA, which will help support existing and future management actions. In addition, the District will be seeking other sources of water and will continue to participate in various surface water transfer and exchange

programs as well as explore purchasing markets in the Central Valley to support their effort to achieve groundwater sustainability by 2040.

5.1.8 Legal Authority Required

Semitropic is both a GSA and a Member Agency under the KGA GSA. Under the KGA Joint Powers Agreement, each District maintains its authority over in-district services and projects. Thus, SWSD has the legal authority to implement projects and management actions in order to achieve groundwater sustainability.

5.1.9 Estimated Costs and Funding

As previously stated, most of the projects are in their conceptual phase of development; therefore, costs may not available. Where costs have been estimated, they are subject to change as the management action undergoes more detailed analysis.

In regard to funding, the District has been successful in securing grants through various government agencies for past projects. Semitropic will continue these efforts and apply for various funding sources at all levels of government in order to implement project and management actions.

5.2 Management Actions Descriptions

Through the course of the implementation period, 2020 to 2040, the SWSD will implement a variety of management actions to achieve groundwater sustainability. These management actions will include a capital investment projects to develop additional water supplies to off-set groundwater pumping, voluntary incentive-based demand reduction programs to curtain groundwater pumping, and mandatory groundwater reduction programs, as needed, to curtain groundwater pumping, all combined to achieve the achieve the District's and Subbasin's sustainability goal.

The SWSD will implement projects and management actions over the course of the implementation period and according estimated timelines provided in Table 5-1. Many of the management actions will require additional planning, engineering and environmental/regulatory analysis before they can be implemented. And the possibility exists that some project will not be feasible to implement. If the identified management actions cannot be implemented to achieve sustainability, SWSD will implement a mandatory groundwater curtailment program to reduce groundwater extractions to the level required to achieve sustainability. SWSD will adjust the implementation of its proposed management actions accordingly to achieve sustainability, i.e., avoidance of undesirable results as required by SGMA.

Table 5-1. Proposed List of Projects and Management Actions for Semitropic GSA

MA Number	MA Name	Summary Description	Relevant Sustainability Indicators Affected			Cirumstance for Implementation	Public Noticing Process	Permitting and Regulatory Process Requirements	Status	Timetable / Circumstances for Initiation	Timetable for Completion	Timetable for Accural of Expected Benefits	Expected Benefits				Source(s) of Water, if Applicable	Legal Authority Required	Estimated Costs		
													Primary		Secondary						
			Goundwater Levels and Storage	Goundwater Quality	Land Subsidence								Water Supply Augmentation	Water Demand Reduction	Water Quality Improvement	Water Management Flexibility / Efficiency			One-time Costs	Ongoing Costs (per year)	Potential Funding Source(s)
1	Landowner Water Budgets	Establish individual water budget for landowners by landowner classes	●	●	●	Establish water budgets by landowner	Semitropic GSA Board Meetings & Website	CEQA	Under development	2020	2020	2020		Est. 60,000 af total (3,000 af/yr to 2040)				District / SGMA authorities		$100,000	Distirct
2	Tiered Pricing for Groundwater Pumping	Develop pricing structure to incentize groundwater users to manage groundwater extractions to MA1 water Budgets	●	●	●	Implementation of MA 1	Semitropic GSA Board Meetings & Website	218 Process	Not yet started	2020	2021	Through 2040		Consistent with MA1				District / SGMA authorities	$50,000	$25,000	District
3	District Fallowing Program	support land fallowing as a District action and by individual landowners or groups of landowners.	●	●	●	Implementation of MA 1	Semitropic GSA and District Board CEQA compliant process	CEQA	Not yet started	2020	2021	Through 2040		Consistent with MA1				District authorities	$300,000		District
4	Enhanced Groundwater Recharge	Development of surface and subsurface recharge projects underlying developed agricultural lands to increase groundwater recharge capacity	●			Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	Site specific (CEQA)	Ongoing	2020	2040	During above average water alloaction years	Up to 20,000 af average annual		●	●	SWP supplies and other local and imported sources	District authorities	TBD	$25,000	District
5	Monitoring Network Improvement Plan	Assess and identify monitoring network requirements for full compliance with SGMA and development of an implementation plan for achieving full compliance.	●	●	●	Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	Site specific (CEQA)	Initiated planning	2020	2030	Upon project completion						District authorities	TBD	TBD	District
6	Evaluation and Assessment of GDEs with the Semitropic Area	Conduct additonal analysis to verify the presence and extend fo GDE's in the Semitropic and, if present, develop appropriate monitoring protocols.	●			Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	TBD	Not yet started	2020	2025							District authorities	$50,000		District
7	Brackish Water Desalination	Development of a braackish water treatment facility to treat locally sourced brackish water for District use.	●			Upon completion of environmental and regulatory requirements	Semitropic GSA Board Meetings & Website	CEQA	Initiated planning	2022	2025	Upon project completion	1,800 af / year			●	Local brackish water	District authorities		up to $500 af	District
8	In-District Water Markets and Transfers	District will allow for the development of market for in-district transfers	●			Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	TBD	Not yet started	2022	2024	Upon project completion	TBD			●	SWP supplies and other local and imported sources	District / SGMA authorities	TBD	$25,000	District
9	Poso Creek MAR	Development of floodwater capture and recharge program ffrom Poso Creek flood flows	●		●	Upon completion of feasibility and permitting requirements	Semitropic GSA Board Meetings & Website	CEQA	Undergoing pre-feasibility analysis	2020	2028	Wet year following project completion	1,200 af average annual				Poso Creek	District authorities	TBD	TBD	District
10	Tulare Lake Project	Development of conveyance facilities to divert Kings River flood flows for direct use and recharge in the SWSD	●	●	●	Upon compeltion of water rights determination	Semitropic GSA Board Meetings & Website	CEQA / State Board / Regulatory	Under development	2018	2035	Wet year following project completion	70,000 af average annual		●	●	King River flood flows	District authorities	TBD	TBD	District
11	Water Market Acquitition s	Increased participation in state-wide water markets for spot market and long-term water transfers	●		●	Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	CEQA / DWR	Ongoing	2020	2020	Immediately	4,000 af average annual			●	Other imported water supplies	District authorities	TBD	TBD	District
12	Stored Water Recovery Unit	Development of water storage to expand in-lieu service areas	●		●	Upon approval by SWSD BOD and identification of funding	Semitropic GSA Board Meetings & Website	CEQA (Completed)	Initiated	2025	TBD	During years of higher than average water delvieries to District	Increases capacity & flexibility of conveyance for recharge			●		District authorities	$32,000,000	TBD	District
13	Pond-Poso Spreading Grounds, Phase II	Development of spreading facililiteis to increase groundwater recharge capacity	●		●	Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	CEQA	Initiated	2020	2024	During years with high Poso Creek flows	Increases groundwater recharge capacity			●		District authorities	TBD	TBD	District
14	Pond-Poso Entrance Ponds	Development of spreading facililiteis to increase groundwater recharge capacity	●		●	Upon approval by SWSD BOD and identification of funding	Semitropic GSA Board Meetings & Website	CEQA	Initiated	2024	2026	During years with high Poso Creek flows	Increases capacity & flexibility of conveyance for recharge			●		District authorities	TBD	TBD	District
15	Multi-District Conveyance (CA to Friant-Kern Canal)	Development of a conveyance system to deliver surface water for groundwater recharge and irrigation	●		●	Upon approval by SWSD BOD and identification of funding	Semitropic GSA Board Meetings & Website	None	Ongoing			During years of higher than average water delvieries to District	Increases capacity & flexibility of conveyance for recharge			●		District authorities	$70,000,000	TBD	District
16	Schuster Spreading Grounds	Development of spreading facililiteis to increase groundwater recharge capacity	●		●	Upon approval by SWSD BOD and identification of funding	Semitropic GSA Board Meetings & Website	CEQA	Not yet started	2030	2035	During years of higher than average water delvieries to District	Increases groundwater recharge capacity			●		District authorities	TBD	TBD	District
17	Leonard Avenue System	Development of an intertie system to provide east to west surface water conveyance to for supply in groundwater dependent areas	●		●	Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	CEQA	Initiated	2019	2022	Upon project completion	Increases capacity & flexibility of conveyance for recharge			●		District authorities	TBD	TBD	District
18	Diltz Intertie	Connection of an intertie to provide surface water converyance for agricultural irrigation	●		●	Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	None	Ongoing	2018	2021	All years	Increases capacity & flexibility of conveyance for recharge			●		District authorities	TBD	TBD	District
19	Cox Canal	Developed canal for the conveyance of surface water for groundwater recharge	●		●	Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	None	Ongoing	2018	2021	All years	Increases capacity & flexibility of conveyance for recharge			●		District authorities	TBD	TBD	District
20	Stored Water Recovery Unit- XYZ		●		●	Upon adoption of Semitropic GSP	Semitropic GSA Board Meetings & Website	None	Ongoing	2019	2022	All years	Increases capacity & flexibility of conveyance for recharge			●		District authorities	TBD	TBD	District

This Page Left Blank Intentionally

5.2.1 Existing Projects and Management Actions

The District has already implemented programs to limit/discourage continued development of additional irrigated lands dependent on groundwater. The intent of these programs, which are expected to be continued under this plan, are to limit additional dependence on groundwater resources. The programs include:

- New Lands Surcharge program: Any new land developed after July 1, 2017 would be charged $500/AF of consumptive use greater than the allocated native groundwater yield.
- SGMA Basin Sustainability Charges/Credits: A program whereby the District utilizes remote sensing data to determine the consumptive use (as Et) for each parcel and the aggregate by Landowner of Record in the District. The consumptive use for an irrigated parcel is compared to the average consumptive use of all irrigated fields. If the consumptive use for a single parcel is in excess of the average, then the parcel is levied a charge (the basin sustainability charge). If the consumptive use of a parcel is less than the average, then the parcel is due a credit (the basin sustainability credit). At this time the basin sustainability charges and credits are calculated as follows:
    - Basin Sustainability Charge = (General Project Service Charge) ÷ (Average consumptive use (Et) as af/ac) x 1.5
    - Basin Sustainability Credit = (General Project Service Charge) ÷ (Average consumptive use (Et) as af/ac) x 1.0
        - The General Project Service Charge (GPSC) is an assessment levied by the District on all lands developed with a reliance upon groundwater, the current GPSC as of 2019 is $137.90 per parcel acre.
    - Since the program's implementation in 2017, there has been a reduction of approximately 7,000 irrigated acres from calendar years 2018 to 2019 in the District, equal to roughly 22,300 acre-feet of groundwater pumping.

    The implementation of MA-1 (Landowner Water Budgets) and MA-2 (Tiered Pricing Structure), described below, will replace this existing program.

Additionally, the SWSD has implemented a number of projects and management actions aimed at increasing conjunctive use within the District and reducing the overall demand on local groundwater resources. These projects include:

- Land fallowing
- Banking water on behalf of the District
- Cap on third party banking obligations
- Expansion of District recharge facilities

- Expansion of District in-lieu distribution – not associated with third party banking obligations

5.2.2 Future Projects and Management Actions

The list of potential management actions is provided in Table 5-1. These management actions are proposed by the SWSD for development over the 20-year implementation period. The management actions as presented in Table 5-1 are in the general order of priority for implementation, but as additional analysis is completed on the individual actions these priorities could change.

The SWSD developed the following suite of projects and management actions based on the following principles for local sustainable management.

- The Semitropic GSA recognizes that landowners must be provided options for achieving sustainability while also being incentivized to make appropriate changes and encouraged to participate in the sustainability solution for our GSA.
- Not all lands within the Semitropic GSA are equal relative to surface water nor are they equal relative to the allocation of the deficit of groundwater overdraft calculated for the GSA, due to varying levels of surface water supplies and water demands.
- The outcomes of landowner's decisions will likely result in inconsistent outcomes among landowners.
- Management Actions within the Semitropic GSA will be structured in a manner to allow sustainability compliance options for each landowner.
- It is recognized that within the Semitropic GSA a "one size fits all" mentality is not appropriate for District landowners.
- Management actions will be developed in a manner which allows for the creation of a "market" for the transfer of water among District landowners.
- Management actions structured to allow sustainability options for landowners
- Equal access to participate proportionate to investment
- District to provide financial incentive to drive sustainability
    - Tiered use charges for demand in excess of annual water supply
    - Surface water, native groundwater, Incremental Pumping Allowance (IPA) and (banked water)
- Compliance achieved through market options
    - Market restrictions reduced as District gets closer to sustainability
    - All lands have options to bank within District

Ultimately, the District was created for the benefit of its landowners; therefore, the District will strive to structure projects and management actions for SGMA compliance leveraging the District's capabilities in the best interest of its landowners.

Management Actions 1, 2 and 3 are described in more detail below. All other management actions are listed in Table 5-1.

5.2.3 Management Action 1: Landowner Water Budgets

An important first step in managing local groundwater resources is understanding the availability of water resources to the individual landowner. SWSD has developed a management action that allocates the water supply of the District, including the Native Supply, to each landowner based on their landowner class. As defined in Section 2.4, the District considers the Native Supply to include the Native Groundwater Yield and precipitation available to meet consumptive use demands.

The water budgets derived for landowners within this management action will define the required reduction in consumptive water demand and associated groundwater extractions as necessary to meet consumptive water demand within the District. The District will also strive to develop multiple SGMA compliance options as either incentivized fallowing options, in-District water markets, and supply augmentation program to assist landowners achieve the required reduction in groundwater extractions. In the event that voluntary programs are not sufficient to achieve the required reduction in groundwater extractions the District will enforce mandatory groundwater extraction restrictions, within the extent of authorities existing in the District and provided through SGMA, to the amounts specified in each landowner's water budget to be developed in the process described below.

The Landowner water budgets are developed based on the following principles:

- All lands within the Semitropic GSA receive a proportionate water supply benefit from District activities (not including SWP Table A) relative to their GPSC assessment paid to the District.
- Each parcel of property within the Semitropic GSA will have an established budget relative to their share of the Native Supply and the District's water surface water supplies, based on their landowner class.
    - Each parcel will share in the Native Supply of the basin on an af/ac basis.
    - The Native Supply for the creation of the initial GSP is assumed to be within the range of 0.25 to 0.75 af/ac.

5.2.3.1 Landowner Classes

- **Contract Lands and GPSC**: Lands which have an existing contract with the District to receive SWP contract (Table A) supplies and paying GPSC assessments.

- **Groundwater Service Area GPSC:** Lands paying GPSC and not receiving SWP contract supplies (Table A)
- **Special GPSC (Duck Clubs):** Lands paying a reduced GPSC, typically Duck Clubs
- **District "White Lands":** Lands within the boundaries of the District which do not pay the GPSC or Special GPSC.

  Note: Per action taken on May 17, 2017, the District implemented the Basin Sustainability Charge, Basin Sustainability Credit, and New Land Surcharge. The New Land Surcharge was implemented to address concerns relative to the development of any new agricultural properties within the jurisdiction of the Semitropic Water Storage District which would exacerbate the extent of the Districts overdraft. Accordingly any property not paying the District's General Project Service Charge as of July 1, 2017 which is developed after July 1, 2017 would be subject to the New Land Surcharge which would be assessed to secure water supplies necessary to meet the additional water demands of newly developed property which exceeds the properties share of the native supply to avoid further stress upon the groundwater basin.

5.2.3.2 Water Supply Categories

- **Contract Water:** The contract water classification is only allocated to those properties which have entered into a contract with the District for SWP supplies. The supply allocated to the property will be determined by the specific contract the landowner has with the District and will be the then current long-term reliability of the SWP as determined by DWR. At this time (2019) the stated average long-term reliability of the SWP is 61% (DWR, Delivery Capacity Report and Studies, 2018). The District will provide this average water supply to the contract landowner each year regardless of whether the year is wet or dry. In a wet year the water will be available on the surface, in a dry year the contract landowner would be able to pump their contract allocation from the groundwater basin. The District will be responsible for managing the overall contract supply.

  The District will buffer the SWP supply to landowners in all years, such that a landowner will receive the then current average of the SWP availability. In other words, if the long-term average water reliability of the SWP, as provided by DWR, is 50% and a landowner has a contract with the District to provide 4 af/ac of SWP supply, then the landowner would receive 2 af/ac annually. This allocation to the landowner will be available despite the delivery of the SWP. Therefore, if the SWP allocation for a given year is 100% this landowner would only receive 2 af/ac for that year. Likewise, if the SWP allocation is 25% then the landowner would still receive an allocation of 2 af/ac. In years with above average SWP deliveries the District will bank the volume of water above the average landowner allocation in in-District or other local Kern County banking programs for use in below average SWP delivery years.

- **Supplemental District Supplies:** This category is comprised of all water supplies acquired by the District on behalf of all landowners paying the GPSC or the Special GPSC. These supplies will be allocated to each landowner proportional to what they pay in assessments as either the GPSC, Special GPSC or combination of GPSC and Special GPSC. This supply includes:
  - Leave behind from banking activity on behalf of third parties,
  - Article 21,
  - Section 215,
  - Dry year purchases, and
  - Other water purchases.
- **Native Supply:** This is the amount of water available to each landowner from the Native Groundwater Yield of the basin and precipitation available to meet consumptive use.
- **Temporary Consumptive-use Allowance (TCA):** This is each landowner's share of the estimated overdraft during the 2020 to 2040 SGMA implementation period. The TCA will be established by the District and set such that on average no individual landowner will be short of a water supply at the initiation of the SGMA implementation period. The TCA is available to the landowner for consumptive use upon the properties owned by the landowner for a given year. Any unused TCA is not transferable, may not be separated from the property holding of the landowner and may not be accrued or carried over as a groundwater supply for future use. Furthermore, it is not the intent of the District for the TCA to be an asset, the TCA will be the key tool of the Semitropic GSA to gradually reduce groundwater pumping over the 20-year SGMA implementation period. Accordingly, under the District's GSP, the TCA will be reduced to 0 by 2040 and will be 0 from 2040 on.

  The initial TCA will be allocated to each property such that the total water supply available to the landowner at the beginning of the implementation period is equivalent to either 4.2 af/acre for lands paying the GPSC and the Special GPSC.

  The TCA for all lands will be reduced to 0 by 2040. District white lands, or currently undeveloped / unirrigated lands will not receive an TCA.
- **Banked Supplies:** This is comprised of the District's banked water supplies as acquired prior to 2020 (pre-SGMA) and banked supplies as acquired by an individual landowner under the District's banking programs. These banked supplies can be drawn upon whenever the annual consumptive use is greater than the annual allocated water supply.

5.2.3.3 Example Water Budget

All landowners in the District will receive a water budget based on their individual contractual arrangements with the District for either SWP supplies or the GPSC to utilize for meeting the consumptive use (Et) of their properties. Presented below are example water budgets for the three land classes that will receive a water budget. District White lands will not receive a water budget.

Contract Lands and GPSC

Contract Lands receive an average of 2.25 af/ac of SWP supplies, as Table A, and 0.27 af/ac of District supplemental supplies, based on the water budget presented in Section 2.4. The current assumption for the District is that all lands within the District will receive 0.5 af/ac of "native supply", which for the current SGMA planning purposes includes native groundwater yield and precipitation. To support an initial total water budget of 4.20 af/ac, contract lands will receive an TCA of 1.18 af/ac in 2020. The water budget for contract lands is shown in Table 5-2, below. The TCA will be reduced to 0 by 2040, as shown in Figure 5-1.

Table 5-2. Example Water Budget for Contract Lands

Contract Lands Water Supply Sources	**Average Supply (acre-feet/acre)**		
Contract Surface Water (SWP)	**2.25**		
District Supplemental Supplies	**0.27**		
Banked Supplies	**TBD**		
Native Supply	0.25	**0.50**	0.75
Temporary Consumptive-use Allowance	1.43	**1.18**	0.93
Total Available Supply in 2020	**4.20**		

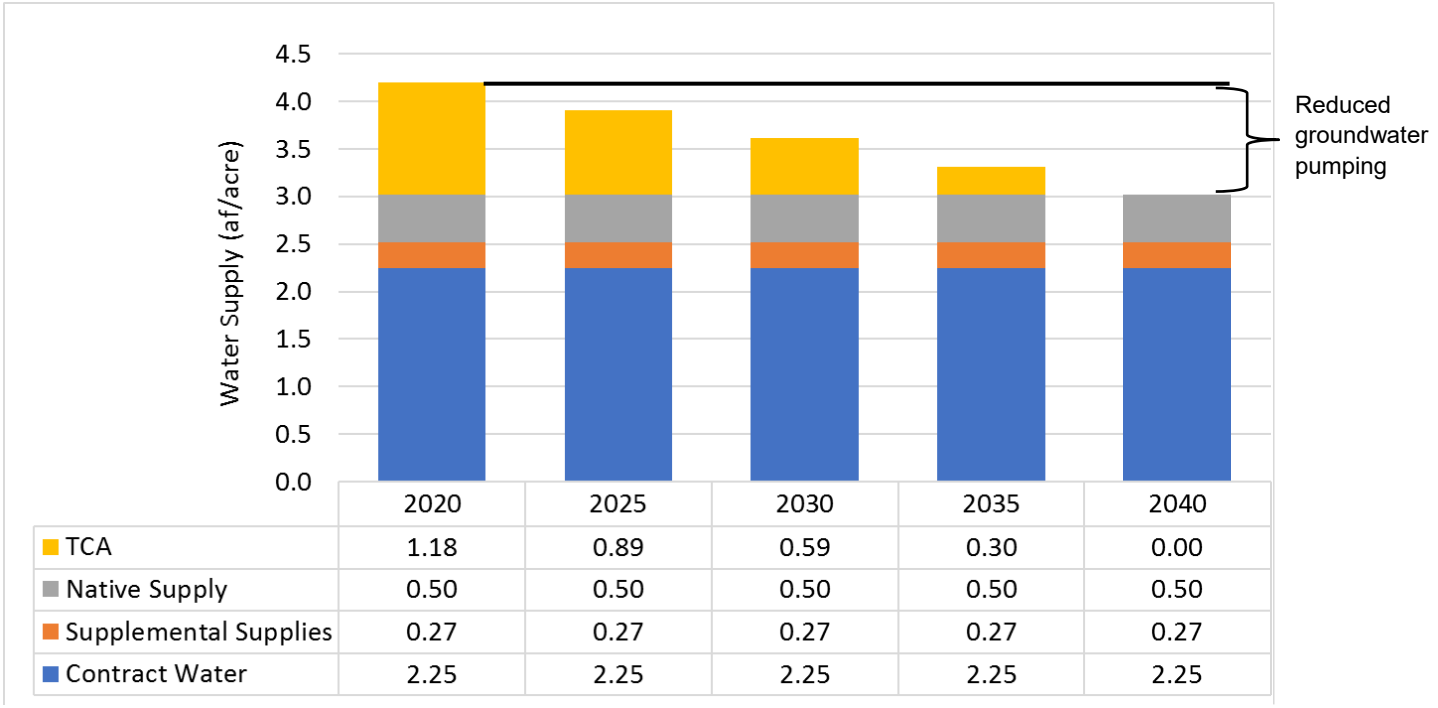


Figure 5-1. Example Water Budget for Contract Lands Through the Implementation Period

Groundwater Service Area GPSC

Groundwater Service Area GPSC lands receive no SWP supplies, as Table A, and an average of 0.27 af/ac of District supplemental supplies, based on the water budget presented in Section 2.4. Under the current SGMA planning assumption these lands will also receive 0.5 af/ac of "native supply". To support an initial total water budget of 4.20 af/ac, groundwater service area lands will receive an TCA of 3.43 af/ac in 2020. The water budget for Groundwater Service Area GPSC lands is shown in Table 5-3, below. The TCA will be reduced to 0 by 2040, as shown in Figure 5-2.

Table 5-3. Example Water Budget for Groundwater Service Area GPSC Lands

Groundwater Service Area GPSC Water Supply Source	**Average Supply (acre-feet/acre)**		
Contract Surface Water (SWP)	**0**		
District Supplemental Supplies	**0.27**		
Banked Supplies	**TBD**		
Native Supply	0.25	**0.50**	0.75
Temporary Consumptive-use Allowance	3.68	**3.43**	3.18
Total Available Supply in 2020	**4.20**		

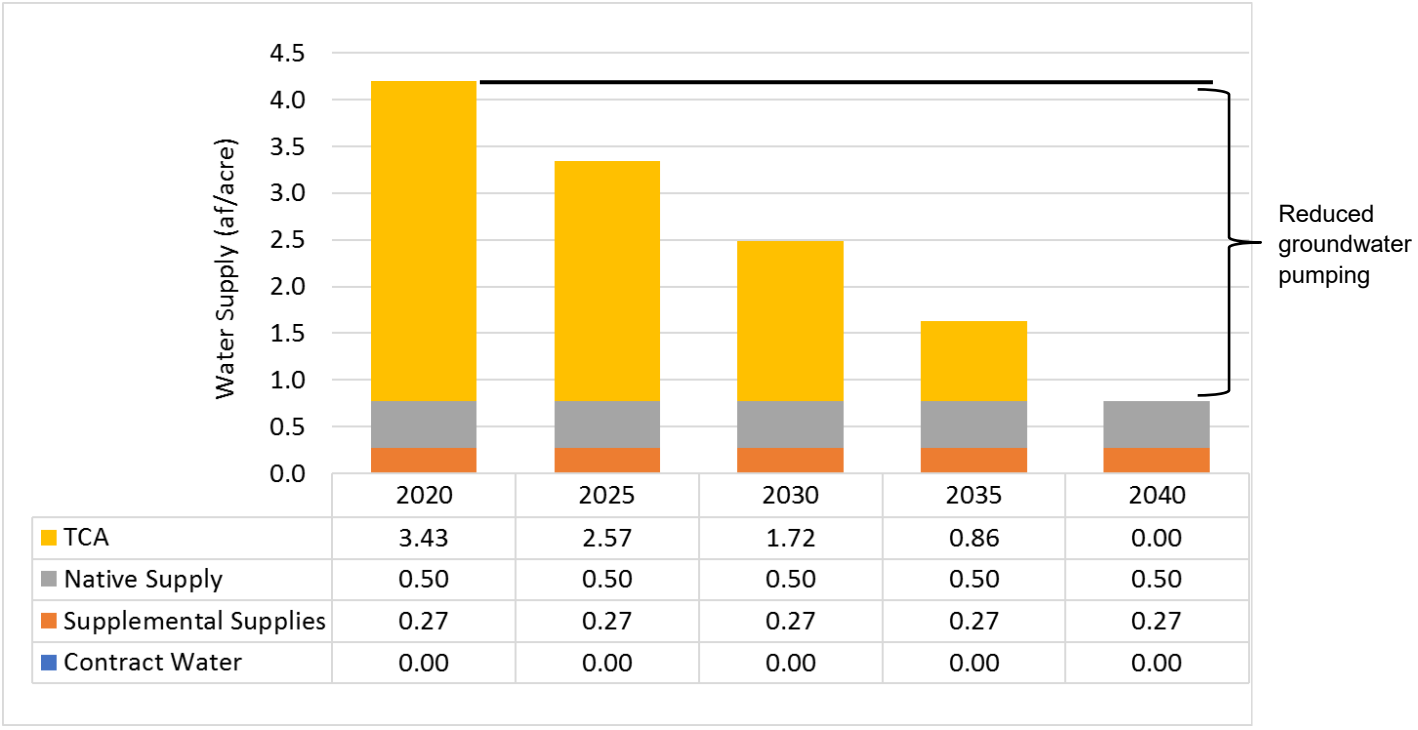


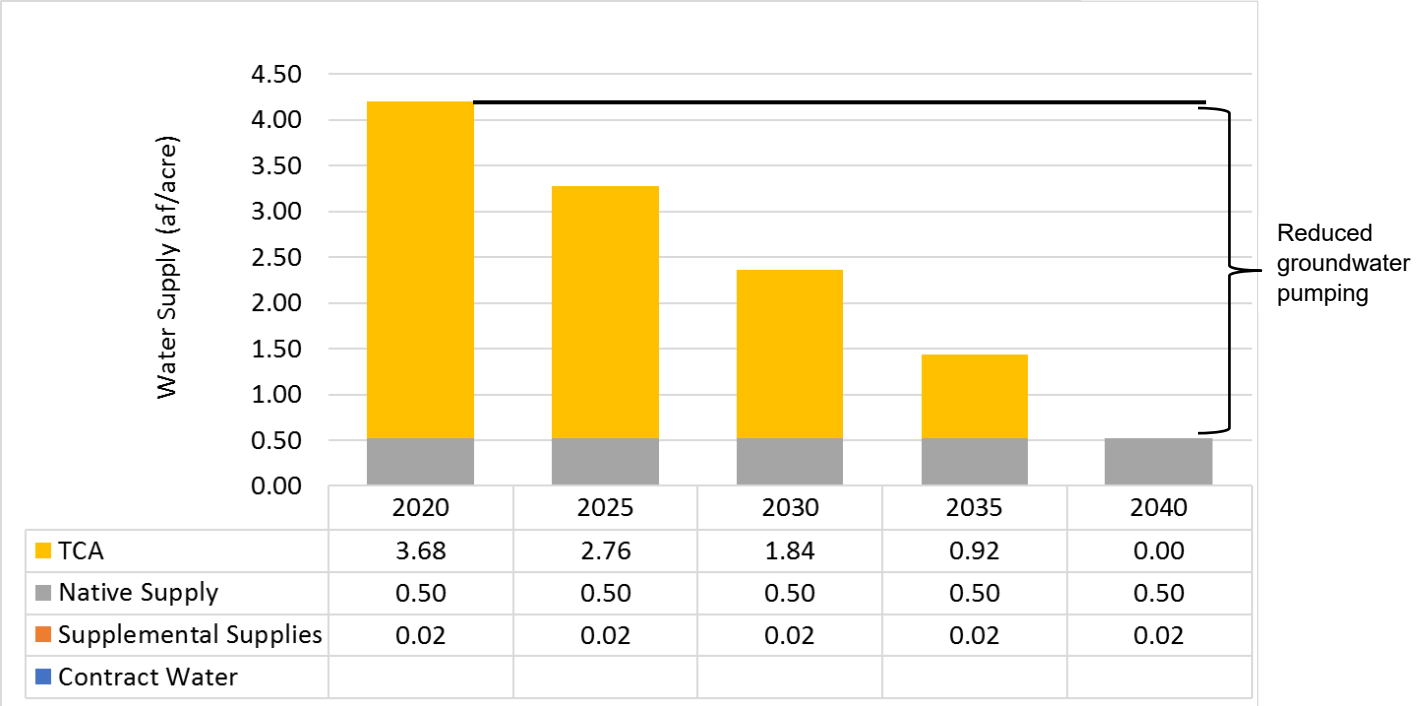
Figure 5-2. Example Water Budget for Groundwater Service Area GPSC Lands Through the Implementation Period.

Special GPSC (Duck Clubs)

Special GPSC (Duck Clubs) lands pay a reduced GPSC charge to the District and, therefore, receive a lower allocation of the District's Supplemental Water Supplies. Special GPSC lands receive no SWP supplies, as Table A, and an average of 0.02 af/ac of District supplemental supplies, based on the water budget presented in Section 2.4. Under the current SGMA planning assumption these lands will also receive 0.5 af/ac of "native supply". Because Special GPSC lands are typically duck clubs and not developed agricultural lands they do not have high consumptive use requirements. Currently there is some uncertainty regarding consumptive-use (Et) on Duck Clubs and other managed wetlands. Additional consumptive-use analysis for Duck Clubs and other managed wetlands will be conducted as an additional management action of the District. Until the consumptive-use for the Special GPSC lands can be developed the total consumptive-use for Special GPSC lands will be set at 4.20 af/ac. To support the initial total water budget of 4.20 af/ac, special GPSC lands will receive an TCA of 3.68 af/ac in 2020. The water budget for special GPSC lands is shown in Table 5-4, below. The TCA will be reduced to 0 by 2040, as shown in Figure 5-3.

Table 5-4. Example Water Budget for Special GPSC Lands

Special GPSC (Duck Club) Lands Water Supply Sources	**Average Supply (acre-feet/acre)**		
Contract Surface Water (SWP)	**0**		
District Supplemental Supplies	**0.02**		
Banked Supplies	**TBD**		
Native Supply	0.25	**0.50**	0.75
Temporary Consumptive-use Allowance	3.93	**3.68**	3.43
Total Available Supply in 2020	**4.20**		



	2020	2025	2030	2035	2040
TCA	3.68	2.76	1.84	0.92	0.00
Native Supply	0.50	0.50	0.50	0.50	0.50
Supplemental Supplies	0.02	0.02	0.02	0.02	0.02
Contract Water					

Figure 5-3. Example Water Budget Special GPSC (Duck Club) Lands Through the Implementation Period.

SWSD recognizes that to set an allocation for groundwater extractions, either as the Native Groundwater Yield component of the Native Supply or as the TCA will require compliance with CEQA, and possibly other applicable law, prior to implementation. Immediately following the establishment of the landowner water budgets, the process of CEQA compliance will be initiated and completed before utilization of water budgets for SGMA compliance.

The District Fallowing Program (Management Action 3) will assume an estimated reduction in groundwater pumping of 123,900 af annually or the fallowing of 39,000 acres of currently irrigated lands over the implementation period. This is the worse-case scenario under which the District does not implement any water supply augmentation programs or projects to offset some portion of the land fallowing estimated to be required to eliminate overdraft within the District.

However, it is the intent of the SWSD to work with its landowner to continue to develop new and enhanced supplemental water supply projects and to the extent possible maintain as many irrigated acres within the District as possible. As needed, the District will initiate environmental review and regulatory compliance efforts for other projects and management action that enhance the District's supplemental water supplies.

5.2.4 Management Action 2: Tiered Pricing Structure

Separately or as part of Management Action 1 to reinforce the adherence to the established water budgets described above, the District would create a volumetric rate structure such that if a landowners consumptive use (Et) exceeds its annual water budget as determined by evapotranspiration then the landowner would be charged fee in accordance with Water code Section 10730.2 and/or other applicable authorities. It is the expectation that the fee would be charged on a volumetric basis and would be tiered based on the quantity of groundwater consumed (Et) in excess of the established annual water budget.

5.2.5 Management Action 3: District Fallowing Program

The fallowing program to be developed by District to support land fallowing would be proposed as a District action and/or action by individual landowners or groups of landowners. An objective of the program would be the total reduction in groundwater extractions required to reduce or eliminate water budget deficit within the District. This represents up to an estimated reduction in groundwater pumping of 123,900 af annually or the fallowing of 39,000 acres of currently irrigated lands. This is the worse-case scenario under which the District does not implement any water supply augmentation programs or projects and the deficit is not reduced by other actions.

However, it is the intent of the SWSD to work with its landowners to continue to develop new and enhanced supplemental water supply projects and to the extent possible maintain as many irrigated acres within the District as possible. As needed the District will initiate environmental and regulatory compliance efforts for other projects and management actions that enhance the District's supplemental water supplies.

Nothing in this GSP or its implementation is intended to or will determine or alter surface water rights, or groundwater rights under common law, any provision of law that determines or grants surface water rights or otherwise. (Cal. Water Code section 10720.5(b)). This GSP shall be construed in a manner that is consistent with Article X, Section 2 of the California Constitution and nothing in this GSP modifies rights or priorities to use or store groundwater except as expressly stated in Cal. Water Code section 10720.5(a). The District reserves and retains all rights to the use of water to the extent provided by law.

5.3 Implementation

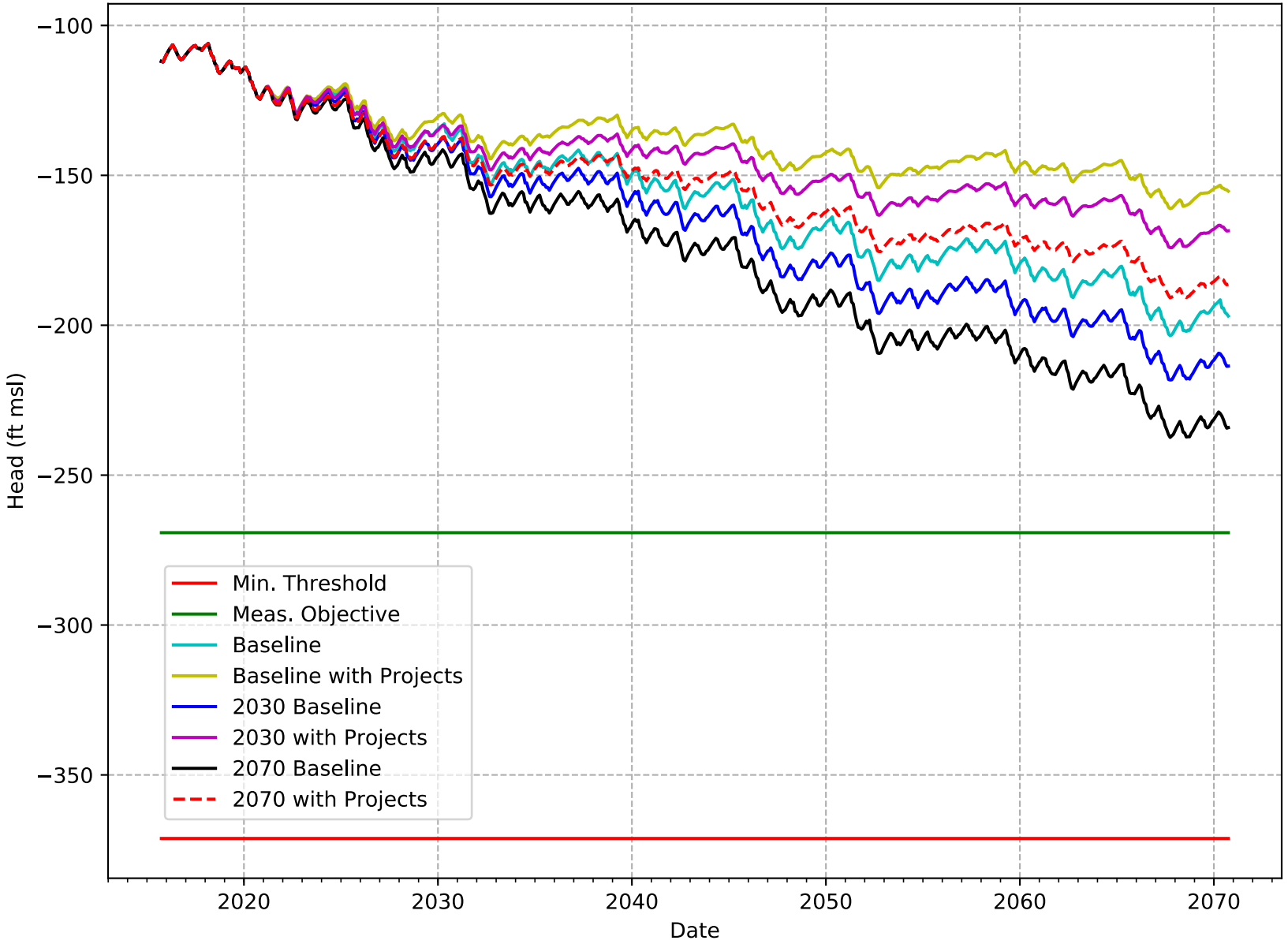
The implementation of the proposed projects and management actions identified in Table 5-1 will be done through an adaptive management process. Ultimately the District will work to reduce the demand on the groundwater basin to avoid undesirable results, as described in the previous sections. This District's primarily objective will be to reduce demand through the development of supplemental water supplies so that the economic vitality of agriculture in the District can be maintained. The District recognizes that developing supplemental water supplies

in the San Joaquin Valley will be a significant challenge under SGMA. To the extent that supplemental water supplies cannot meet the demand reduction needed to avoid undesirable results, the District will implement management actions to remove irrigation demands, primarily through fallowing programs.

Through the Subbasin modeling process, described in Section 2.4, Todd Groundwater prepared future conditions modeling scenarios that includes the implementation of the Districts projects and management actions and the targeted reduction in groundwater demand of 123,900 AFY. Todd Groundwater developed future modeling scenarios for the baseline condition (current water delivery expectations and demands), and 2030 and 2070 future climate conditions. The details of these modeling scenarios can be found in the KGA Umbrella GSP, Attachment H. Figures 5-4 through 5-7 show the results of those modeling scenarios as hydrographs at selected representative monitoring sites in the District. See Figure 4-1 for the location of the representative monitoring sites. As these figures show the groundwater response to the implementation of the District's projects and management actions maintains and, in some cases, increases groundwater level in the District at levels well above the initial measurable objectives and minimum thresholds. These figures also show the response of the groundwater basin without the implementation of proposed projects and management actions. In all cases, groundwater elevations continue to decline if projects and management actions are not implemented.

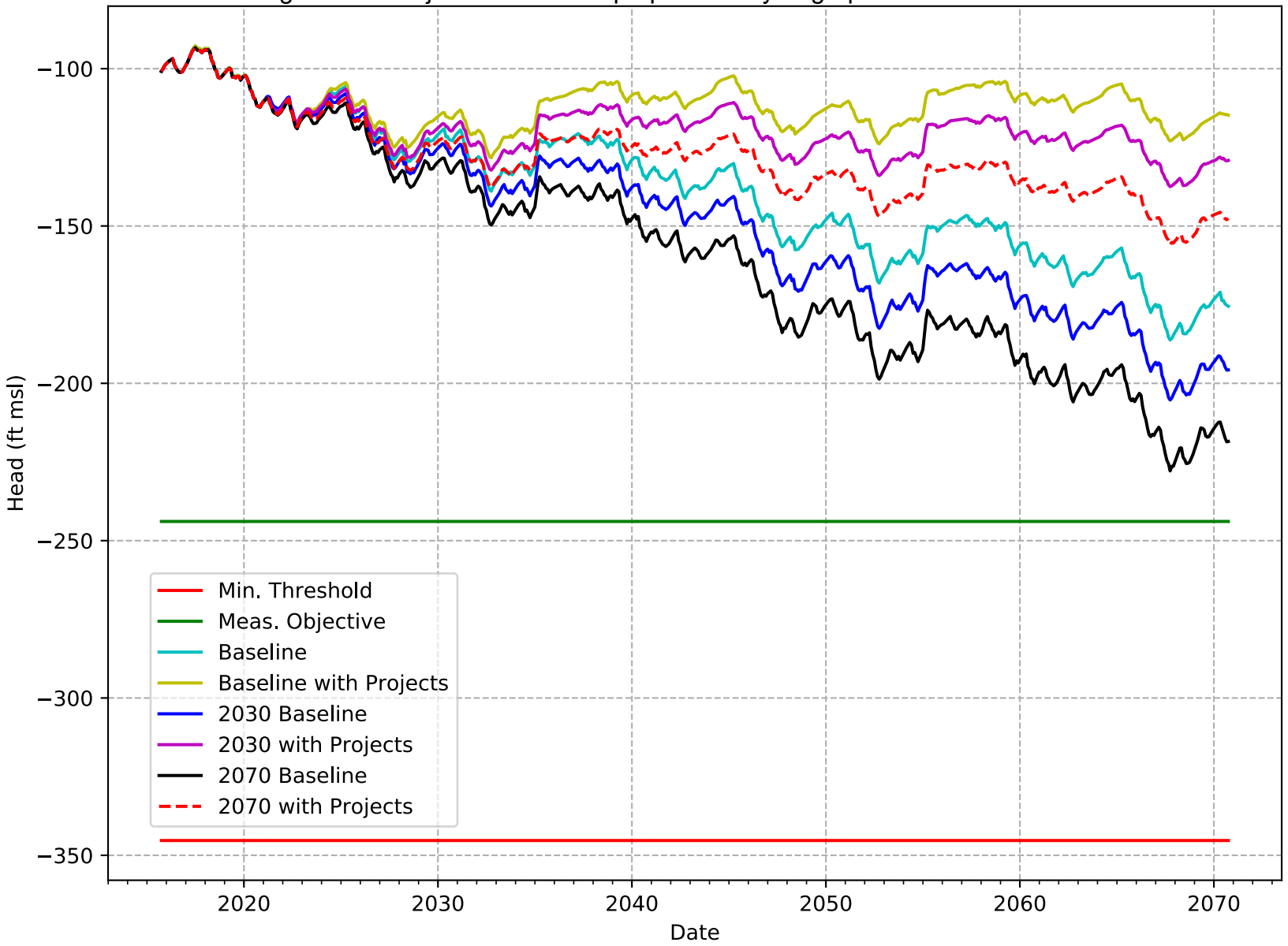
This Page Left Blank Intentionally

Figure 5-4. Future Superposition Hydrograph: RMW-132-SWSD



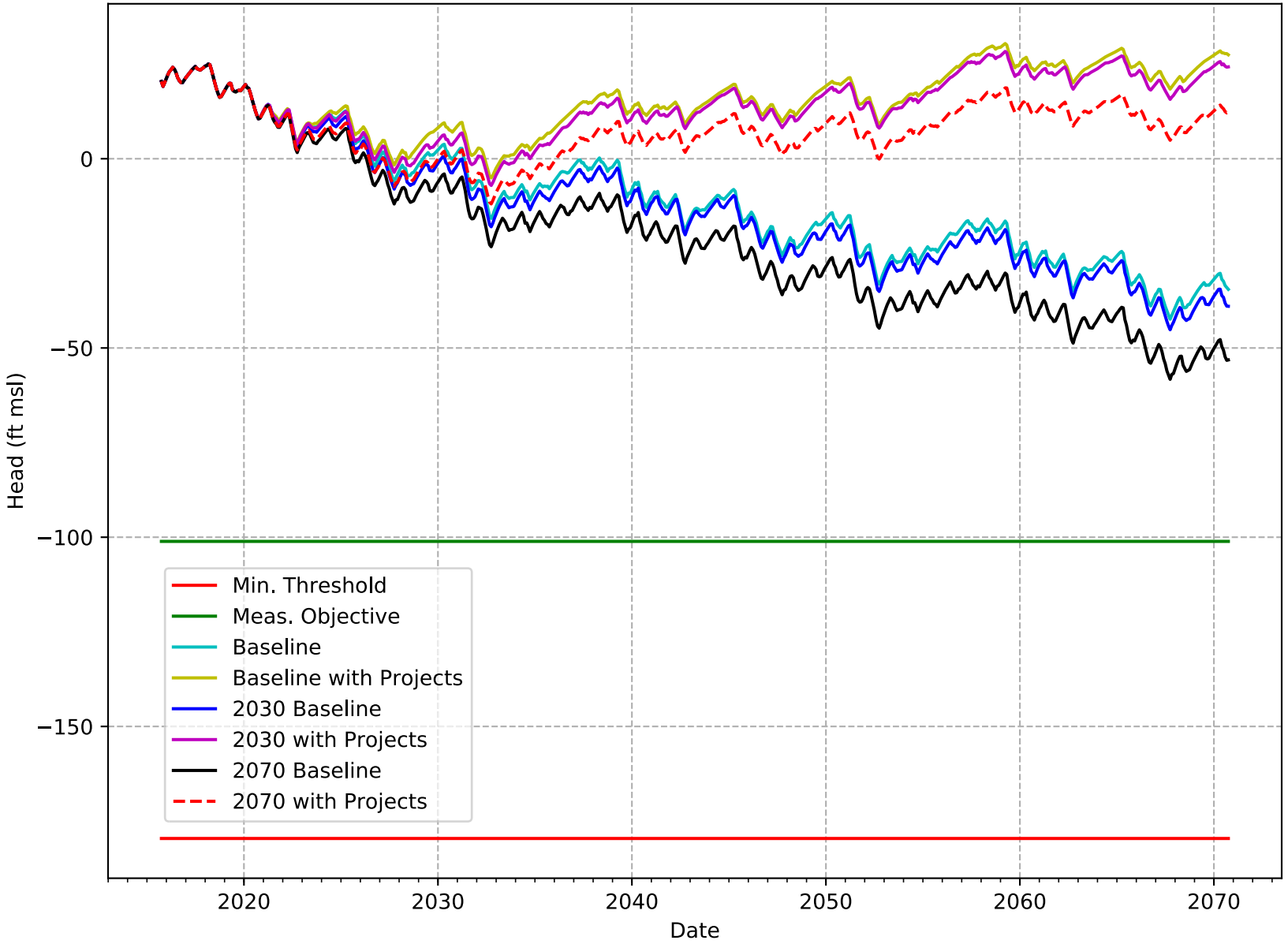
Source: Todd Groundwater, December 2019

Figure 5-5. Projected-Future Superposition Hydrograph: RMW-137-SWSD



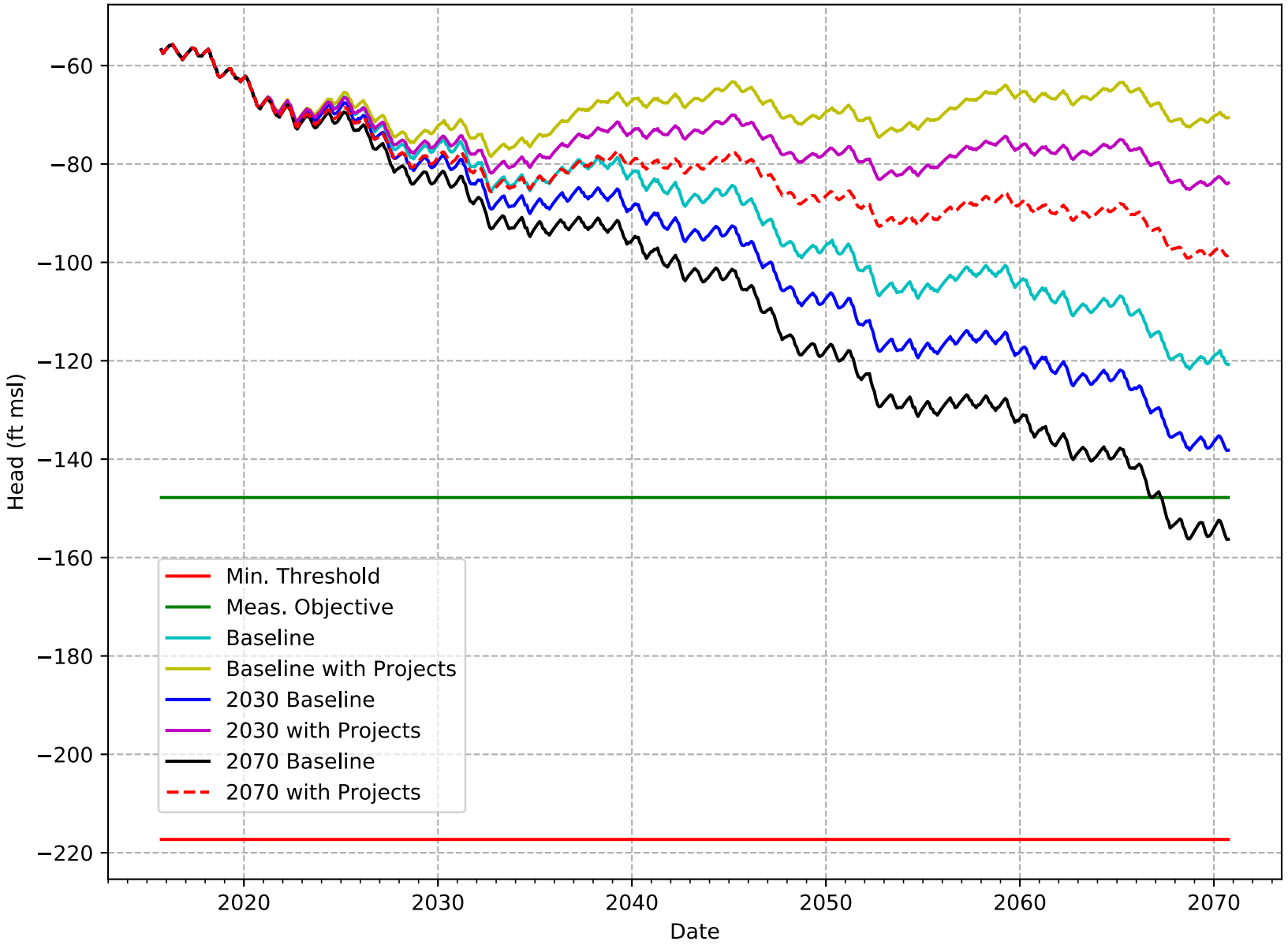
Source: Todd Groundwater, December 2019

Figure 5-6. Projected-Future Superposition Hydrograph: RMW-139-SWSD



Source: Todd Groundwater, December 2019

Figure 5-7. Projected-Future Superposition Hydrograph: RMW-140-SWSD



Source: Todd Groundwater, December 2019

6. References and Technical Studies

Bartow J. Alan and Gardner M. Pittman, 1983. The Kern River Formation. Southeastern San Joaquin Valley, California. USGS Bulletin 1529-D.

Bartow, 1991. The Cenozoic Evolution of the San Joaquin Valley. United States Geological Survey Professional Paper 1501.

B-E. 1972. Engineering Report in Support of Application for Federal Loan Under Public Law 984 For Construction of An Irrigation Distribution System. Prepared for Pond-Poso Improvement District of Semitropic Water Storage District, Kern County, CA. Amended April.

Bookman-Edmonston Engineering, Inc (B-E). 1968. Engineering Report in Support of Application for Federal Loan Under Public Law 984 For Construction of An Irrigation Distribution System. Prepared for Buttonwillow Improvement District of Semitropic Water Storage District, Kern County, CA. Amended April.

California Department of Fish and Wildlife (CDFW). 2018 (January). Survey of California Vegetation Classification and Mapping Standards.

California Department of Water Resources (DWR). 2006. San Joaquin Valley Groundwater Basin, Kern County Subbasin, Groundwater Basin Number 5-22.14, last update January 20, 2006.

Cowardin, L.M., Carter, V., Golet, F.C. & LaRoe, E.T. (1979). Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service. Washington D.C.

Croft, M.G. 1972. Subsurface Geology of the Later Tertiary and Quaternary Water-Bearing Deposits of the Southern Part of the San Joaquin Valley, California. U.S. Geological Survey Water-Supply Paper 1999-H.

Davis, G. H., Lofgren, B. E., and Mack, Seymour. 1964. Use of ground-water reservoirs for storage of surface water in the San Joaquin Valley, California. U.S. Geological Survey Water-Supply Paper 1618, 125 p.

Department of Water and Power, City of Los Angeles (LADWP). 1974. San Joaquin Nuclear Project. Early Site Review Report. Vol. 1. February 28.

DWR, 2016a. California's Groundwater. Bulletin 118. Interim Update 2016. December 22.

DWR. 2016b. Monitoring Networks and Identification of Data Gaps. December.

DWR. 2016c. Monitoring Protocols, Standards, and Sites. December.

DWR. 2017a. Well Completion Report Map Application. last update 2017. http://wdl.water.ca.gov/groundwater/wells/well_completion_reports.cfm. Accessed March 12, 2018.

DWR. 2018. GIS files for C2VSIM Fine Grid Beta model. https://data.cnra.ca.gov/dataset/c2vsimfg-beta-model/resource/899d59f6-2615-47ae-86ea-aad75afb6715. Accessed November 2018.

DWR. 2018a. Data download. Accessed from: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer. March.

DWR. 2018b. Personal Communication with SGMA and TSS Staff. July.

DWR. 2018c (April). Summary of the "Natural Communities Commonly Associated with Groundwater" Dataset and Online Web Viewer. Available: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Statewide-Reports/Natural-Communities-Dataset-Summary-Document.pdf

DWR. 2018d. Well Completion Reports. https://water.ca.gov/Programs/Groundwater-Management/Wells/Well-Completion-Reports

DWR. 2019 (January). Natural Communities Dataset Viewer. Available: https://gis.water.ca.gov/app/NCDatasetViewer/#.

Farr, T.G., C. Jones, Z. Liu, 2015, Progress report: Subsidence in the Central Valley, California. Submitted to California Department of Water Resources. Available at: http://www.nasa.gov/jpl/nasa californiadrought-causing-valley-land-to-sink.

Farr, T.G., C. Jones, Z. Liu, 2016, Progress report: Subsidence in the Central Valley, California, March 2015 - September 2016. Submitted to California Department of Water Resources. Digital raster data provided by JPL for mapping.

Faunt, C., R.T. Hanson, K. Belitz, W. Schmid, S. Predmore, D. L. Rewis, and K. McPherson, 2009, Groundwater availability of the Central Valley Aquifer, California. USGS Professional Paper 1766. Reston, Va.: United States Department of the Interior, Geological Survey. http://pubs.usgs.gov/pp/1766.

Fox, P., and Sears, L. (2014). Natural vegetation in the central valley of California, Technical Rep., State Water Contractors and San Luis and Delta-Mendota Water Authority, Los Baños, CA.

Fugro, Inc. 1978. 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. April.

Galloway, Devin; Jones, David R.; and Ingebritsen, S.E. 1999. Land Subsidence in the United States. U.S. Geological Survey Circular 1182

Gary, 1963. Root distribution of five-stamen tamarisk, seep-willow, and arrow-weed: Forest Science, v. 0, p. 311-314.

GEI Consultants, Inc. (GEI). 2014. Assessment of Potential Groundwater Impacts Northern Pipeline Project. Prepared for Buena Vista Water Storage District. September.

Gillespie, Janice, David Kong, and Stephen D. Anderson. 2017. Groundwater salinity in the southern San Joaquin Valley. AAPG Bulletin. v. 101, no. 8, p. 1239-1261.

Heath, R.C., 1983. Basic ground-water hydrology. U.S. Geological Survey Water-Supply Paper 2220, 86p.

Howes, DJ; Fox, P; and Hutton, HP. 2015. Evapotranspiration from natural vegetation in the Central Valley of California: Monthly grass reference-based vegetation coefficients and the dual crop coefficient approach. Journal of Hydrologic Engineering, 20 (2015).

Ireland R.L., J.F. Poland, and F.S. Riley. 1984. Land subsidence in the San Joaquin Valley, California, as of 1980. U.S. Geological Survey Professional Paper 437-I, 93 p. http://pubs.er.usgs.gov/usgspubs/pp/pp437I.

Jones, D.W., R.L. Snyder, S. Eching and H. Gomez-McPherson. 1999. California Irrigation Management Information System (CIMIS) Reference Evapotranspiration. Climate zone map, Sacramento, Cal.: Department of Water Resources.

KCWA, 2018. Digital Data Delivery to GEI for historical groundwater records used in water supply contour maps.

KCWA. 2019. Personal Communication. February.

Kern County Planning Department, 2009. Kern County General Plan https://kernplanning.com/planning/planning-documents/general-plans-elements/

Kenneth D. Schmidt and Associates (Schmidt and Associates). 2017. Biennial Groundwater Monitoring Report for the Semitropic Water Storage District Water Banking Project (2011-2014).

Kenneth D. Schmidt and Associates. 2018. Biennial Groundwater Monitoring Report for the Semitropic Water Storage District Water Banking Project (2015-2016).

Kern County Water Agency (KCWA). 2011. Water Supply Report.

Klausmeyer, K., Howard J., Keeler-Wolf T., Davis-Fadtke K., Hull R., and Lyons A. 2018. Mapping Indicators of Groundwater Dependent Ecosystems in California: Methods Report. San Francisco, CA.

Kourik, R. 2015. Understanding Roots…discover how to make your garden flourish. Metamorphic Press, Occidental, CA.

Lamar, D.L.; J.L. Smith; J.W. La Violette; K. Custis; and P.J. Scrivner. 1983. Application of Private Site-Specific Data to Regional Evaluation of Earthquake and Faulting Potential in Southern California. USGS Open File No. 83-834.

Langbein, John, 2008, Noise in GPS displacement measurements from Southern California and Southern Nevada: Journal of Geophysical Research, v. 113, B05405, 12 p.

Luhdorff & Scalmanini Consulting Engineers (LSCE), Borchers James W. and Carpenter, Michael. 2014. Land Subsidence from Groundwater Use in California. Full Report of Findings. April.

McClelland, E.J. 1962. Aquifer-test compilation for the San Joaquin Valley, California. USGS Open-File Report 62-80.

O'Geen, A.T.; Matthew B.B. Saal; Helen Dahlke; David Doll; Rachel Elkins; Allan Fulton; Graham Fogg; Thomas Harter; Jan W. Hopmans; Chuck Ingels; Franz Niederholzer; Samuel Sandoval Solis; Paul Verdegaal and Mike Walkinshaw. 2015. Soil suitability index identifies potential areas for groundwater banking on agricultural lands. California Agriculture, V. 69, No. 2

Pacific Geotechnical Associates, Inc. (PGA). 1991. Study of the Regional Geologic Structure Related to Groundwater Aquifers in the Southern San Joaquin Valley Groundwater Basin, Kern County, California. Prepared for Kern County Water Agency. September.

Page, R.W. 1973. Base of Fresh Ground Water (approximately 3,000 micromhos) in the San Joaquin Valley, California. Hydrologic Investigations Atlas HA-489. Washington D.C.: United States Department of the Interior, Geological Survey.

Page, R.W. 1983. Geology of the Tulare Formation and Other Continental Deposits, Kettleman City Area, San Joaquin Valley, California, with a Section on Groundwater Management Considerations and Use of Texture Maps. USGS Water Resources Investigations Report 83-4000.

Page,R.W. 1986. Geology of the Fresh Groundwater Basin of the Central Valley, California with Texture Maps and Cross Sections. Professional Paper 1401-C.

Planert, Michael and Williams, J.S., 1995, Ground water atlas of the United States, segment 1, California, Nevada: U.S. Geological Survey Hydrologic Investigations Atlas 730–B, 28 p. Available at http://pubs.usgs.gov/ha/ha730/ch_b/index.html.

Poland, J.F.; Lofgren, B.E.; Ireland, R.L.; and Pugh R.G. 1975. Land Subsidence in the San Joaquin Valley, California. USGS Professional Paper 437-H.

Poso Creek Integrated Regional Water Management Group, 2017. Poso Creek Integrated Regional Water Management Plan. http://www.semitropic.com/pdfs/Poso%20Creek%20IRWM/PosoCreek2007IRWMP.pdf

Provost and Pritchard, Land IQ, and Todd Groundwater. 2015. Kern River Watershed Coalition Authority. Groundwater Quality Assessment Report. February 2015.

Sawyer, J. O., T. Keeler-Wolf, and J. M. Evens. 2009. A Manual of California Vegetation, 2nd Edition, California Native Plant Society. Sacramento, CA.

Semitropic Water Storage District (SWSD). 2012 Groundwater Management Plan.

Semitropic Water Storage District (SWSD). 2013 Agricultural Water Management Plan.

Sierra Scientific Services (Sierra Scientific). 2013. The Geology and Groundwater Hydrology of the Buena Vista Water Storage District, Buttonwillow, Ca, including Descriptions of Relevant Facilities and Operations. Prepared for Buena Vista Water Storage District. May 20.

Smith, Ryan; Knight, Rosemary; and Fendorf, Scott. 2018. Overpumping leads to California groundwater arsenic threat. Nature Communications. V. 9. No. 2089.

Soil Survey Staff. USDA-Natural Resources Conservation Service (USDA or NRCS). 2014. Keys to Soil Taxonomy, 12th ed, Washington, DC.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture (USDA or NRCS). 2018. Web Soil Survey. Available online at https://websoilsurvey.nrcs.usda.gov/. Accessed [4/11/18].

State Water Resource Control Board (SWRCB). 2018 (June 11). FAQs Available: https://www.waterboards.ca.gov/water_issues/programs/gmp/faqs.html.

State Water Resources Control Board (SWRCB). 2019. Drinking Water Needs Assessment. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/needs.html

Stromberg, J. 2013. Root patterns and hydrogeomorphic niches of riparian plants in the American Southwest. Journal of Arid Environments 94 (2013) 1-9.

The Nature Conservancy (TNC). 2018a. (April 19). Plant Rooting Depth Database. Available: https://groundwaterresourcehub.org/gde-tools/gde-rooting-depths-database-for-gdes/.

Thornthwaite, C. W., and J.R., Mather. 1955. The Water Balance. Publ. in Climatology. 8(1): 1-104.

Thornthwaite, C.W. and J.R. Mather. 1957. Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance. Publ. in Climatology. 10(3): 185-311.

TNC. 2018b (January). Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans.

Todd Groundwater. 2012. Technical Memorandum No. 1 Site Conceptual Model "With and Without Banking" Evaluation, Kern Fan Area. September.

Todd Groundwater. 2017. Final Groundwater Impacts Assessment Report. Kern River Water Allocation Plan. Kern Delta Water District. July 7.

Todd Groundwater. 2018. Kern Fan Model Report for Kern Fan Monitoring Committee. February.

Tulare Kern Funding Area Disadvantaged Community Involvement Program. Grant Agreement Between the State of California (Department of Water Resources) and Tulare County – Agreement 4600012219. February 2018. https://tularelakebasin.com/alliance/index.cfm/tulare-kern-dac-involvement/funding-agreement/

United States Department of Agriculture (USDA). 1988. Soil Survey of Kern County, California, Northwestern Part.

USDA. 2007. Soil Survey of Kern County, Northeastern Part, and Southeastern Part of Tulare County, California.

United States Department of Agriculture Natural Resources Conservation Service (USDA or NRCS). 2009. National Engineering Handbook, Part 630 Hydrology, Chapter 7 Hydrologic Soil Group. January 2009.

United States Fish and Wildlife Service (USFWS). 2005. Kern and Pixley National Wildlife Refuges. Final Comprehensive Conservation Plan. February.

United States Geological Survey (USGS). 2018a. GIS files for MODFLOW2000_FMP1_1 model used to simulate the groundwater flow of the Central Valley Aquifer, California. In Groundwater Availability of the Central Valley Aquifer, California. Ed. Claudia C. Faunt.

United States Geological Survey Professional Paper 1766. https://water.usgs.gov/GIS/metadata/usgswrd/XML/pp2009-1766.xml. Accessed May 2018

United States Geological Survey (USGS). 2018b. Land Subsidence Monitoring, San Joaquin Valley. Proceedings from Water Education Foundation Event: Monitoring Land Subsidence in the San Joaquin Valley. Presented by Michelle Sneed. October 2.

USFWS. 2015. Data Collection Requirements and Procedures for Mapping Wetland, Deepwater, and Related Habitats of the United States (version 2). Falls Church, VA.

USFWS. 2018 (June 25). Data Limitations, Exclusions, and Precautions. Available: https://www.fws.gov/wetlands/data/Limitations.html.

Williams, S.D.P., Bock, Yehuda, Fang, Peng, Jamason, Paul, Nikolaidis, R.M., Prawirodirdjo, Linette, Miller, Meghan, and Johnson, D.J., 2004, Error analysis of continuous GPS position time series: Journal of Geophysical Research, v. 109, B03412, 19 p

Wood & Dale, 1964. Geology and Groundwater Features of the Edison-Maricopa Area, Kern County, CA USGS Water Supply Paper 1656.

Zerbini, Susanna, Richter, Bernd, Negusini, Monia, Romagnoli, Claudia, Simon, Dietrich, Domenichini, Francesco, and Schwahn, Wolfgang, 2001, Height and gravity variations by continuous GPS, gravity and environmental parameter observations in the southern Po Plain, near Bologna, Italy: Earth and Planetary Science Letters, v. 192, no. 3, p. 267–279.

This Page Left Blank Intentionally