B. Fremont Valley Basin Groundwater Management Plan

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FREMONT VALLEY BASIN

GROUNDWATER MANAGEMENT PLAN

DECEMBER 2018

Prepared by the Regional Water Management Group of the
Fremont Basin Integrated Regional Water Management Region

FREMONT VALLEY BASIN

GROUNDWATER MANAGEMENT PLAN

December 2018

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City of California City

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APPENDIX

Appendix A: Fremont Valley Groundwater Basin – Mass Balance Analysis

ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
µg/L	micrograms per liter
AB	Assembly Bill
ACS	American Census Survey
AF	acre-feet
AFY	acre-feet per year
AGR	Agricultural Supply
AVEK	Antelope Valley East Kern Water Agency
Basin Plans	Regional Water Quality Control Board Basin Plans
bgs	below ground surface
BLM	Bureau of Land Management
BMP	Best Management Practices
CA-NL	California State Notification Level
Cal Water	California Water Service Company
CASGEM	California Statewide Groundwater Elevation Monitoring
CDPH	California Department of Public Health
chromium-6	hexavalent chromium
CIMIS	California Irrigation Management Information System
City	City of California City
DAC	Disadvantaged Community
DDW	Division of Drinking Water
DOF	Department of Finance
DWR	Department of Water Resources
EPA	Environmental Protection Agency
ETc	monthly gross water requirements
ETo	evapotranspiration
FRSH	Freshwater Replenishment
FVGB	Fremont Valley Groundwater Basin
GAMA	Groundwater Ambient Monitoring and Assessment Program
GIS	Geographic Information System
GPCD	gallons per capita per day
GPS	Global Positioning System
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWMP	Groundwater Management Plan
IND	Industrial Service Supply
IRWM	Integrated Regional Water Management
Kc	unique crop factor
LADWP	Los Angeles Department of Water and Power

LLC	Limited Liability Company
LRWQCB	Lahontan Region Water Quality Control Board
MAF	million acre-feet
MCL	maximum contaminant level
MG	million gallons
mg/L	milligram per liter
MGD	million gallons per day
MHI	mean household income
MPUD	Mojave Public Utilities District
msl	mean sea level
MUN	Municipal and Domestic Supply
MW	megawatts
MWA	Mojave Water Agency
N	nitrogen
N.D.	no date
NO_3	Nitrate
PHG	Public Health Goal
Plan	Groundwater Management Plan
PV	photovoltaic
RCWD	Rand Communities Water District
RMS	Resource Management Strategy
RWMG	Regional Water Management Group
RWQCB	Regional Water Quality Control Board
SB	Senate Bill
SCADA	Supervisory Control and Data Acquisition
SDWIS	Safe Drinking Water Information System
SGMA	Sustainable Groundwater Management Act
SMCL	secondary maximum contaminant level
SNMP	Salt and Nutrient Management Plan
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
USDA	United States Department of Agriculture
USGS	U.S. Geological Survey
UV	Ultraviolet Disinfection
UWMP	Urban Water Management Plan
WWTP	wastewater treatment plant

1. INTRODUCTION

This Groundwater Management Plan (GWMP or Plan) was prepared for the Fremont Valley Groundwater Basin (FVGB). The GWMP development was led by the City of California City (City), the Antelope Valley East Kern Water Agency (AVEK), and the Mojave Public Utilities District (MPUD), in collaboration with local and regional stakeholders.

The FVGB supports a wide range of beneficial uses in the Plan area (described in Sections 2 and 3). Beneficial uses of individual water bodies in the Plan area are designated and maintained by the Regional Water Quality Control Board (RWQCB) for the Lahontan Region (LRWQCB) and the Lahontan Region Water Quality Control Plan (Basin Plan). The communities overlying the FVGB include urban areas as well as rural and agricultural lands. The FVGB is used as the primary supply source in the Plan area, in addition to imported surface water and recycled water generated by the City's Wastewater Treatment Plant (WWTP). Stormwater is not currently being captured for beneficial use in the Plan area. Recycled water is currently used in the City's existing recreational ponds and is served to irrigate park and golf course areas. Recycled water supply is projected to increase in the future as the population grows and the City expands its WWTP. The City is exploring the feasibility of using recycled water to irrigate a second golf course, in addition to expanding use for green belts and other end uses.

This GWMP was developed in coordination with two other key planning efforts within the FVGB, including the Fremont Basin Integrated Regional Water Management (IRWM) Plan and the Fremont Valley Basin Salt and Nutrient Management Plan (SNMP). These three planning efforts were undertaken in parallel and inform and support each other to ensure reliable water supplies are available to meet future regional demand, to promote the sustainable use of water supplies, and to facilitate groundwater resources management in the Plan area. The City, as the lead agency, coordinated with AVEK and MPUD and other local and regional stakeholders during the development of these three plans.

1.1 Regulatory Framework

GWMPs were required to be developed and submitted to the California Department of Water Resources (DWR) under past groundwater legislation (Assembly Bill (AB) 359 that became effective in 2013 or the earlier AB 3030 and SB 1938 legislation) until the Sustainable Groundwater Management Act (SGMA) passed into law in 2014. GWMP requirements were largely replaced by SGMA and adoption of GWMPs is no longer required under California law. Beginning January 1, 2015, no new GWMPs can be adopted in medium and high-priority basins. Rather, in accordance with SGMA, Groundwater Sustainability Plans (GSPs) are required in their place. Existing GWMPs will be in effect until GSPs are adopted in medium and high-priority basins. GWMPs may still be developed in very low or low-priority basins as they are not subject to SGMA Groundwater Sustainability Agency (GSA) or GSP requirements at this time.

This GWMP is intended to act as a "pre-GSP" document that will support and inform the future development of a GSP for the FVGB that the Plan area intends to develop at a later time when low priority basins are being addressed by DWR as defined by the California Statewide Groundwater Elevation Monitoring (CASGEM) program. The following is a description of AB 3030 and SGMA which provide the framework for the components of this GWMP.

1.1.1 Assembly Bill 3030

AB 3030, the Groundwater Management Act, was signed into law in 1992, and provided a systematic procedure for local water agencies to develop, adopt, and implement a Groundwater Management Plan in groundwater basins defined in DWR Bulletin 118. Development of an AB 3030 Plan under Water Code Sections 10750, et seq., allowed local entities to efficiently manage groundwater supplies, assure long-term water supplies, and distribute costs, benefits, and water sharing in a locally determined equitable manner. The plan can be developed only after a public hearing and adoption of a resolution of intention to adopt a groundwater management plan. Once the plan is adopted, rules and regulations must be adopted to implement the program called for in the plan. AB 3030 plans cannot be adopted in adjudicated basins or in basins where groundwater is managed under other sections of the Water Code without the permission of the court or the other agency.

AB 3030 also introduced twelve technical components that may be included in the groundwater management plan. It is highly encouraged by DWR to include as many of the twelve components as necessary for the successful management of the basin groundwater resources. The potential components of groundwater management plans are listed in Clean Water Code Section 10753 and consist of the following twelve voluntary components:

- Control of saline water intrusion.
- Identification and management of wellhead protection areas and recharge areas.
- Regulation of the migration of contaminated groundwater.
- 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.
- Facilitation of conjunctive use operations.
- Identification of well construction policies.
- Construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.
- Development of relationships with state and federal regulatory agencies.
- Review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

The California Water Code was subsequently amended as a result of Senate Bill (SB) 1938, effective January 2003. While the provisions of SB 1938 did not alter the potential components of a local groundwater management plan, it added several provisions. SB 1938 provided that adoption of a groundwater management plan will be a prerequisite to obtaining funding assistance for groundwater projects from funds administered by DWR. To comply with SB 1938, a groundwater management plan must include components that address monitoring and management of water levels, groundwater quality degradation, inelastic land subsidence, and changes in surface flows and quality that either affect groundwater or are affected by groundwater pumping. SB 1938 specifies that groundwater management plans contain provisions to cooperatively work with other public (and presumably private) entities whose service area or boundary overlies the groundwater basin. Provisions must also be made to allow participation by interested parties in development of the plan.

1.1.2 Sustainable Groundwater Management Act

SGMA was passed into California law in 2014 and took effect in January 2015. SGMA requires that state-designated high and medium priority groundwater basins form one or more GSAs by June 30, 2017, and that GSAs must develop and implement one or more GSPs by January 31, 2020, for critically overdrafted groundwater basins, or by January 31, 2022 for non-critically overdrafted groundwater basins. GSPs are considered a roadmap for how groundwater basins will reach and maintain long-term sustainability.

Prior to the passage of SGMA, DWR developed the CASGEM program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. CASGEM basin priority definitions were used to rank the priority of each groundwater basin in California as “very low”, “low”, “medium”, or “high”. The FVGB has been designated as a “low priority” groundwater basin. In addition, DWR identified the basins and subbasins that are in conditions of critical overdraft. Twenty-one basins and subbasins were identified; the FVGB was not identified as a critically overdrafted basin.

1.2 Plan Objectives

The primary goal of this GWMP is to document the groundwater conditions for the FVGB that will help inform future decisions regarding the long-term sustainable management of groundwater resources in the Plan area. The GWMP was developed in parallel with the FVGB SNMP and supports the technical analysis for the IRWM Plan, also developed in parallel.

While low and very low priority groundwater basins are not the focus of SGMA at this time, it is anticipated that they will need to develop GSAs and GSPs at a later date as determined by DWR and the State Water Resources Control Board (SWRCB). The FVGB is designated under CASGEM as a "low priority" groundwater basin at this time; thus, the agencies within the Plan area are not subject to SGMA GSA and GSP requirements. However, the City, AVEK, and MPUD have elected to initiate efforts to prepare the Plan area for SGMA compliance through the development of this GWMP. The City, AVEK, and MPUD, as well as other key stakeholders in the Plan area, may elect to form a GSA in the future and develop a GSP. This GWMP is intended to act as a "pre-GSP" document that will support and inform the future development of a GSP for the FVGB. As groundwater is the primary source of water supply in the FVGB, the City, in coordination with AVEK and MPUD, seeks to maintain sustainable groundwater management in the FVGB through the development of the GWMP and SNMP. Groundwater quantity and quality conditions documented for the FVGB in this GWMP will facilitate groundwater resources management in the Plan area and inform future groundwater studies, including those for SGMA purposes.

1.3 Document Organization

This GWMP is organized with the following sections that generally follow DWR's GSP guidelines and suggested elements, as applicable.

- Section 1, Introduction: Provides information on the purpose of the GWMP development and regulatory background.
- Section 2, Stakeholder Involvement: Presents information on the stakeholder involvement and outreach during the GWMP development.
- Section 3, Plan Area: Presents background information of the Plan area with respect to climate, land use, basin beneficial uses and water quality objectives, and other planning efforts undertaken in the Plan area.
- Section 4, Basin Characterization: Presents a summary description of the basin hydrogeology, groundwater conditions, and groundwater quality.
- Section 5, Water Supply and Demand: Presents the historical, current and future projections of water demand and supply conditions in the Plan area.
- Section 6, Basin Management Goals and Objectives: Summarizes the basin management objectives regarding groundwater levels and quality.
- Section 7, Basin Management Strategies and Projects: Describes the potential projects and water management strategies to achieve the goals and objectives of the Plan.
- Section 8, Monitoring Program: Describes prior and ongoing groundwater monitoring activities in the basin.
- Section 9, References: Provides a list of documents referenced in the GWMP.

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2. STAKEHOLDER INVOLVEMENT

The Fremont Valley Basin GWMP was developed in a collaborative setting with input from a wide range of stakeholders through a series of meetings and workshops. As described in this section, most of the stakeholder participation and outreach occurred during stakeholder group and working group meetings in the context of the Fremont Basin IRWM planning effort. The stakeholder outreach framework developed for the Fremont Basin IRWM Plan was utilized to coordinate meetings, communicate with stakeholders, obtain input on technical analyses and direction of the Plan, and guide the development of the Plan. This section contains descriptions of the process used to identify stakeholders, stakeholder group composition, meetings, and regulatory coordination processes.

2.1 Stakeholder Composition

The development of the GWMP was led by the City in close collaboration with AVEK, MPUD, and other regional stakeholders. GWMP outreach efforts were directed at stakeholders from local water agencies, state and federal agencies, municipalities, regulatory agencies, and local community groups, including tribal communities, disadvantaged communities (DACs), and other community associations. Cities, districts, water purveyors, and other organizations that participated in the development of the GWMP are listed in Table 1. The City coordinated with the stakeholders to reach consensus regarding the level of stakeholder participation appropriate for the larger IRWM planning effort and to identify ways to effectively involve as many stakeholders as practical.

Figure 1 shows the boundary of the FVGB and the IRWM Plan area. The IRWM boundaries coincide with the GWMP plan area along the southern portion of the FVGB and encompass a greater region than the GWMP Plan area in the northern part of the FVGB. Figure 2 shows the boundaries of the water agencies in the Plan area that participated in development of the GWMP. The boundaries for this GWMP area coincide with the FVGB boundaries defined by DWR Bulletin 118. Note that the entirety of the FVGB falls within the Fremont Basin IRWM Region.

The stakeholder process undertaken through the Fremont Basin IRWM Plan encouraged stakeholder involvement in the concurrent development of the GWMP and the Fremont Valley Basin SNMP. The Fremont Basin IRWM Region (Region) was formed in 2011 to be the most inclusive, contiguous area to represent the common water management issues and needs of the Region. The primary hydrologic feature of the Fremont Basin IRWM Region is its position overlying the FVGB (Figure 1). The Regional Water Management Group (RWMG) for the IRWM Region (consisting of the City, MPUD, and AVEK) was created in 2014 to facilitate collaboration and coordination throughout the Region. The RWMG developed an initial stakeholder list to aid in publicizing the IRWM Plan and soliciting groups that may want to participate in the IRWM Plan, GWMP, and SNMP development. Because groundwater from the FVGB is the primary water source in the Region, issues related to groundwater supply and quality are a priority concern for the Region. For this reason and because the populations served are nearly the same in the IRWM Region and FVGB, the IRWM stakeholder list was considered appropriate for the GWMP effort. The RWMG is discussed further in Section 2.1.1.

The City led outreach efforts to IRWM stakeholders for the GWMP using the Fremont Basin IRWM email list and website. The email list was developed based on groups that had shown interest in the program and those that attended IRWM stakeholder meetings. Individual stakeholders were also identified and contacted directly by email and phone to introduce them to the IRWM Plan, as well as the GWMP and SNMP efforts. The IRWM Plan website was developed for the Region to inform the public about upcoming stakeholder meetings and other related efforts, including updates for the GWMP and SNMP development. This website can be accessed at https://www.facebook.com/profile.php?id=100010202116257. Additionally, the City maintains a portion of their website dedicated to IRWM planning efforts, including the GWMP and SNMP development (http://www.californiacity-ca.gov/CC/index.php/fremont-basin-irwm). Through the email list and website, the RWMG solicits participation from interested stakeholders and keeps the public informed about the progress regarding the three parallel planning efforts (i.e., Fremont Basin IRWM Plan, Fremont Valley Basin GWMP, and Fremont Valley Basin SNMP). Additional information about stakeholder outreach can be found in Section 2.2.

Table 1: Fremont Valley Basin GWMP Stakeholders (based on Fremont Basin IRWM Program)

Entity Type	Agencies and Organizations	
Wholesale, Retail Water Agencies, and Local Water Purveyors	Antelope Valley-East Kern Water Agency California City California Water Service Company	Mojave Public Utilities District Rancho Seco, Inc. Rand Communities Water District Rosamond Community Services District
Wastewater Agencies	City of California City Kern County	Mojave Public Utilities District
Flood Control Agencies	City of California City	Kern County
Municipal and County Governments and Special Districts	City of California City Cantil	Kern County Mojave Chamber of Commerce
Environmental Organizations	Desert Tortoise Preserve Committee Friends of Jawbone Canyon	Eastern Kern County Resource Conservation District Red Rock Canyon State Park
Industry Organizations	Kern County Ag Commissioner Kern County Farm Bureau	Golden Queen Mining Mojave Air and Space Port
State Agencies	Department of Water Resources	Lahontan Regional Water Quality Control Board
Federal Agencies	Bureau of Land Management	
Media	Mojave Desert News	
DAC Representatives	Rancho Seco, Inc	Rand Communities Water District
Native American Tribes	Tubatulabal Indian Tribe	Tejon Indian Tribe
Other Stakeholders	Private Land Owners	

Figure 1: Fremont Basin IRWM Region Boundary and Fremont Valley Groundwater Basin Boundary

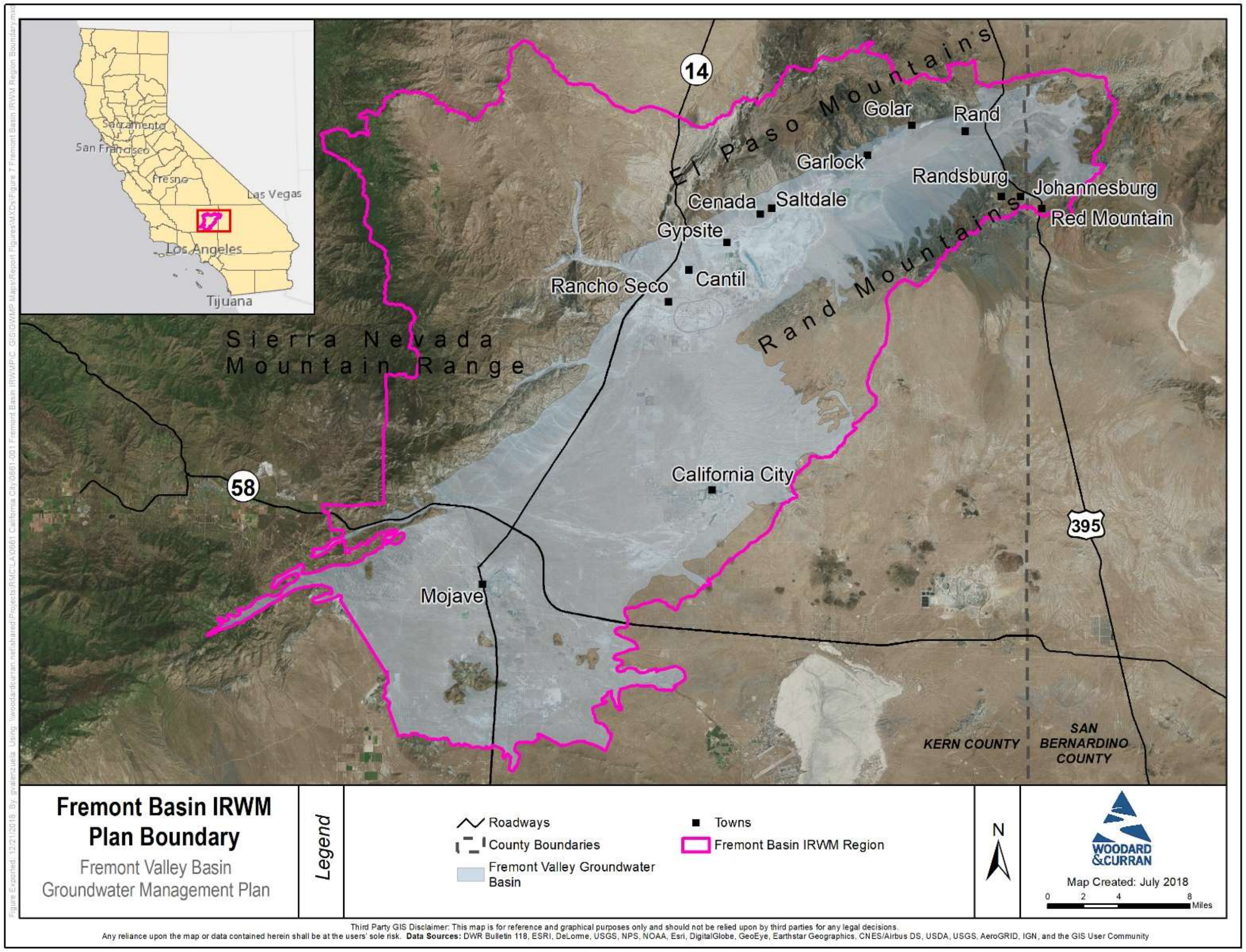
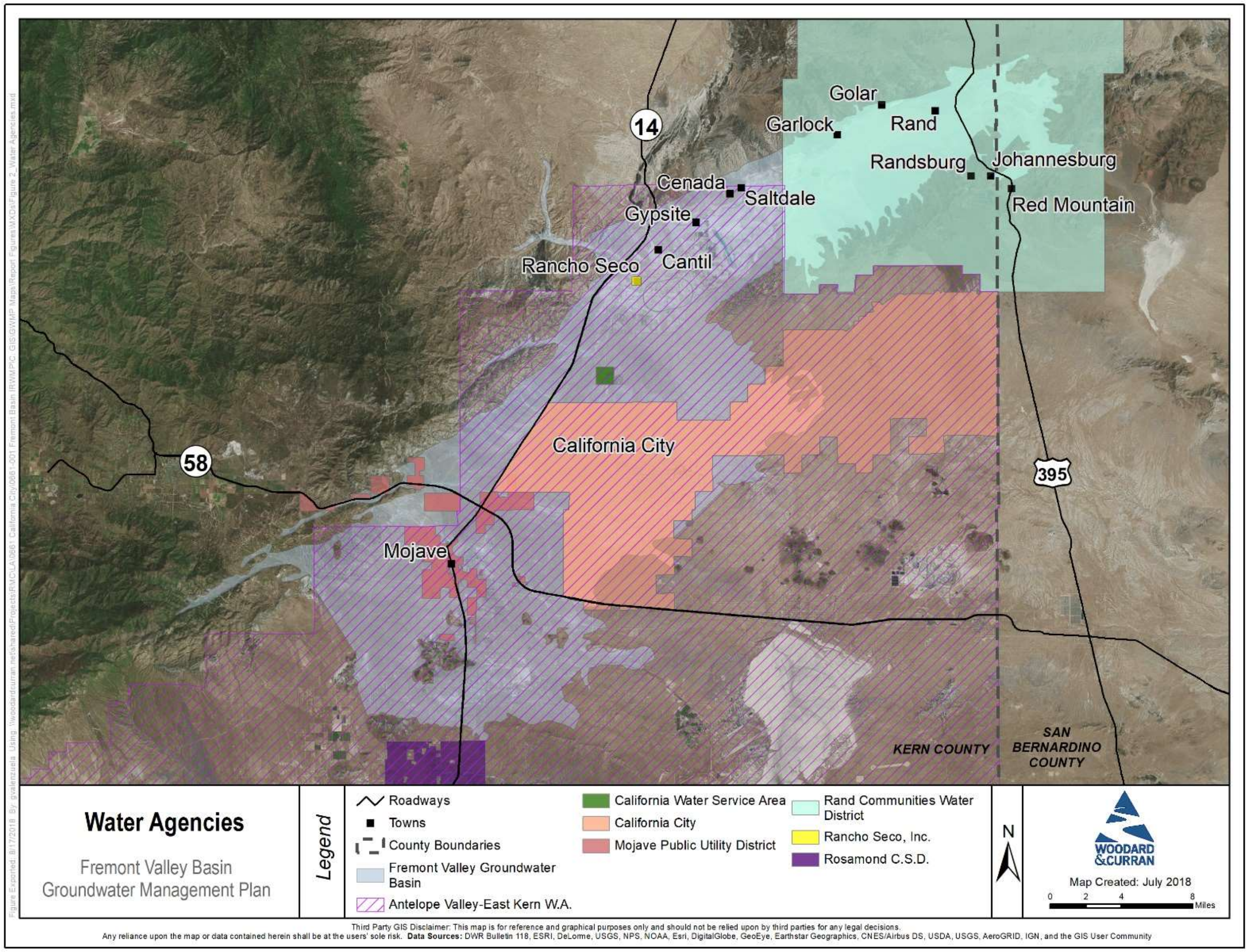


Figure 2: Water Agencies Participating in Fremont Valley Basin GWMP Development



The Fremont Basin IRWM stakeholders that have been identified and contacted through outreach efforts represent a range of interests specific to the Plan area. The stakeholders regularly coordinated with during GWMP development are listed in Table 1.

As part of the larger stakeholder effort for the Fremont Basin IRWM Plan development, the RWMG also identified DACs and tribal communities to identify, invite, and involve groups that could represent the interests and needs of these communities. The goals of the DAC outreach efforts are to encourage participation by DACs, solicit input for updates, and educate target audiences about the purpose and benefits of the three planning efforts for the IRWM, GWMP, and SNMP. Because the majority of the Fremont Basin IRWM Region is considered disadvantaged (having a median household income [MHI] below 80 percent of the Statewide MHI) or severely disadvantaged (MHI less than 60 percent of the Statewide MHI), nearly all of the stakeholder outreach efforts involved DACs. To facilitate participation of DACs in the Plan development process, the RMWG made multiple efforts to reduce potential barriers to DAC involvement. For example, the RWMG held stakeholder meetings in different locations throughout the Plan area, including some of the more isolated areas where representatives of DACs and severely DACs could more easily attend meetings. Additionally, because not all stakeholders have the same access to online resources and email, stakeholder meeting announcements are communicated through multiple media sources, including newspaper announcements, the City website, the Fremont Basin IRWM Facebook page, email notifications, and phone calls to specific groups, when appropriate.

There were no tribal interests or water issues specific to Native American Tribal Communities that were identified through this outreach process.

2.1.1 Regional Water Management Group

The RWMG was formed to facilitate water resources-related coordination, collaboration, and communication between all stakeholders in the IRWM Region. On October 21, 2014, the City, MPUD, and AVEK signed a memorandum of understanding forming the Fremont Basin RWMG, defining the organization, responsibilities, and governance structure for the Fremont Basin RWMG. The City is the lead agency tasked with providing meeting organization and startup funding for the IRWM Plan. The RWMG agreed to fund the development of the first Fremont Basin IRWM Plan, including the development of the GWMP and the Fremont Valley Basin SNMP, and to provide and share information for the IRWM Plan development , review drafts, adopt the final IRWM Plan, and assist with future grant applications (California City, MPUD, AVEK, 2014).

The RWMG acts as the oversight body for the Fremont Basin IRWM Region and is leading the effort to maintain sustainable groundwater management in the FVGB through the development of the GWMP and SNMP. The RWMG makes decisions about GWMP development and implementation based on the recommendations and information received from the stakeholder group and specialized working groups that provide input on key topics. The role of the RWMG is to provide leadership and guidance for planning and project implementation in the Region. The RWMG oversees the development of the GWMP to support the IRWM Plan, including coordination and data collection. The group also directs program activities, reviews projects submitted to the IRWM Plan, and submits grant applications to the State on behalf of the IRWM Region. The RWMG performs strategic and financial decision-making, and conducts program advocacy to optimize water resources protection in the FVGB.

To perform its role, the RWMG meets publicly at least quarterly to discuss policy and IRWM project selection with stakeholders, including DACs. The RWMG seeks to achieve consensus from the stakeholder group on key topics related to the IRWM Plan, the GWMP, and Fremont Valley Basin SNMP development at stakeholder meetings. Decisions within the RWMG are based on input and recommendations from the working groups, stakeholder group, DACs, and tribes; and decisions are made using broad facilitated agreement, led by the RWMG.

2.2 Stakeholder Outreach and Meetings

Stakeholders are an important part of the GWMP development process. Stakeholder involvement ensures the GWMP is developed to incorporate the interests of a variety of stakeholders, including non-profit groups, public agencies, organizations, and individuals. Stakeholders are not required to provide financial contributions to be engaged in the regional planning effort. Instead, they are encouraged to participate in the GWMP development by providing information and participating at stakeholder meetings and in working groups.

Stakeholder meetings were a key component in the Plan development as they provided an opportunity for stakeholders to contribute information, express concerns, provide recommendations, and relay information to and from their organizations. Through the Fremont Basin IRWM Plan development process, three initial stakeholder group meetings were held between September 2015 and March 2016 to establish the program and prepare for a planning grant; and 12 stakeholder group meetings were held on a semi-monthly basis from July 2017 to June 2018 in conjunction with the Fremont Basin GWMP development (funded by an IRWM Plan planning grant). Stakeholder meetings to date (including dates and locations) are summarized in Table 2. Meeting dates were announced on the Fremont Basin IRWM Facebook page and City website, as well as via email announcements sent to the stakeholder group.

Stakeholder meetings in 2015 and 2016 were primarily focused on introducing the Region to the IRWM Program and applying for IRWM Planning grant funding for IRWM Plan development. During the development of the GWMP in 2017 and 2018, meetings with stakeholders were held to discuss various topics, including the framework for GWMP, status of the GWMP development, data collection and needs for the basin characterization with respect to groundwater levels and water quality, roles and responsibilities of the agencies participating in the GWMP development, and future GWMP implementation. Though all stakeholder meetings covered material used for the GWMP development, five stakeholder meetings held in July 2017, September 2017, November 2017, February 2018, and March 2018 focused specifically on the GWMP development. Table 2 summarizes the stakeholder meetings held during the GWMP development including the GWMP topics covered, meeting dates, and locations. The Draft GWMP was presented at a public stakeholder meeting on August 23, 2018. Figure 3 presents the timeline of the overall stakeholder and collaborative process for the GWMP development.

In addition to the stakeholder meetings, several working group meetings were held during the GWMP development process to discuss data collection efforts, and basin characterization for groundwater levels and quality. Meeting dates, locations, and topics are summarized in Table 3. Similar to the stakeholder meetings, dates for the working group meetings were announced on the Fremont Basin IRWM websites, via email announcements sent to the stakeholder group, and via flyers posted at public facilities.

Figure 3: GWMP Collaborative Process

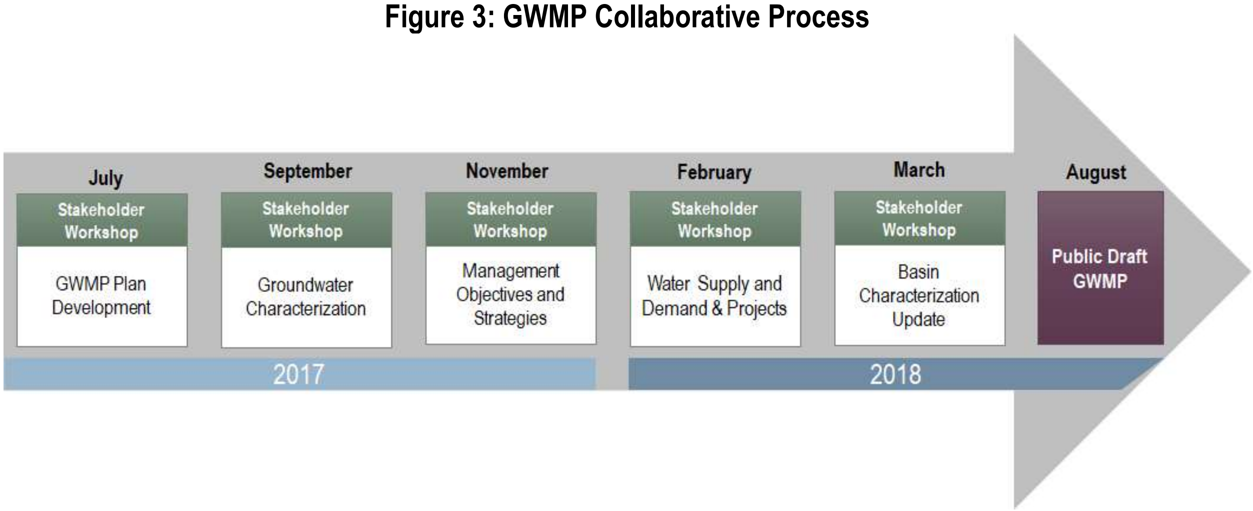


Table 2: Stakeholder Meetings

GWMP-Related Meeting Topics	Meeting Date	Meeting Location
Fremont Basin IRWM/GWMP/SNMP Plan Development and Stakeholder Process	July 27, 2017	California City Arts and Community Center
Region Description	August 15, 2017	California City Hall
Groundwater Characterization – Fremont Basin IRWM Integration with GWMP, Groundwater Well Locations and Elevations, Groundwater Quality Data	September 21, 2017	Jawbone Station Visitors Center
Supply and Demand; Water Management Objectives	October 19, 2017	Mojave Veterans Memorial Building
Water Management Objectives, Planning Targets, and Management Strategies	November 16, 2017	Johannesburg Community Center
Climate Change Impacts and Project Solicitation	December 14, 2017	California City Arts and Community Center
Fremont Basin IRWM Plan Project Review and Prioritization	January 18, 2018	California City Hall
Supply and Demand and Projects	February 15, 2018	Mojave Veterans Memorial Building
Basin Characterization Update – Groundwater Elevations; Project Implementation	March 15, 2018	Jawbone Station Visitors Center
Public Draft GWMP	August 23, 2018	California City Hall

Table 3: GWMP Working Group Meetings

Meeting Topic/Date	Meeting Date	Meeting Location
Groundwater Data Collection and Outreach	July 27, 2017	California City Arts and Community Center
Groundwater Data Collection and Outreach	August 15, 2017	California City Hall
Groundwater Data Collection and Outreach	September 21, 2017	Jawbone Station Visitors Center
Regional Water Supply and Demand	October 19, 2017	Mojave Veterans Memorial Building
Regional Planning Targets and Strategies; Groundwater Data Collection and Outreach	November 16, 2017	Johannesburg Community Center
Regional Objectives and Projects	December 14, 2017	California City Arts and Community Center
Regional Water Supply and Demand	January 18, 2018	California City Hall
Regional Water Supply and Demand; Projects	February 15, 2018	Mojave Veterans Memorial Building
Regional Projects	March 15, 2018	Jawbone Station Visitors Center

2.2.1 Technology and Information Access

In addition to stakeholder meetings and working group meetings, two websites provide an avenue for stakeholders to find information about the planning efforts: the Fremont Basin IRWM Region Facebook page and the City's website. The Fremont Basin IRWM Region Facebook page helps facilitate the overall stakeholder coordination and promote two-way communication between the RWMG and the stakeholders by allowing group members to post comments and information to the site. The webpage, managed by the City, also provides an avenue for the public to send messages to the RWMG through the Facebook messaging function. The RWMG uses the Facebook page and the Fremont Basin IRWM page on the City's website to alert the public about future stakeholder meetings and events and post documents related to the IRWM Plan development and its components, including GWMP development efforts. Resources provided include meeting agendas, presentations, and minutes, public review drafts of the three documents, and the final IRWM Plan itself (in which the GWMP is an appendix).

2.2.2 Process Used to Identify Stakeholders

The RWMG played a crucial role in identifying stakeholders in the Plan area by developing an initial stakeholder list to publicize the development of the GWMP. To initiate stakeholder involvement, stakeholders interested in participating in the Plan development process were emailed periodically to provide meeting information and electronic newsletters through the IRWM Plan development. The process the RWMG currently uses to identify and involve new stakeholders includes posting public announcements about the stakeholder meetings on the Fremont Basin IRWM webpages; soliciting recommendations for new groups to contact during stakeholder meetings; and targeting specific groups via email, phone calls, and letters. Stakeholders are welcome to join the stakeholder group and attend stakeholder meetings at any time. The California Native American Heritage Commission was directly contacted to identify stakeholders in the IRWM Region as well.

Extensive outreach efforts were conducted to bolster stakeholder participation during development of the IRWM Plan and GWMP. Outreach efforts included the development of working groups that focus on various subject areas, conducting monthly stakeholder meetings, and conducting targeted outreach to DACs and tribal groups through emails, phone calls, and media advertisements.

2.3 Plan Development

The development of the GWMP has been supported by grant funding through the IRWM Program. In 2017, the Fremont Basin IRWM Region was awarded a Proposition 1 IRWM Planning Grant to develop its first IRWMP in accordance with DWR's 2016 IRWM Grant Program Guidelines. This funding allowed the Region to establish regional objectives and targets, assess potential water management strategies, and evaluate and prioritize projects to address the needs of the Region. Funding also supported stakeholder and DAC outreach and involvement as well as the development of a GWMP and a SNMP to support the technical analyses for the IRWMP.

2.3.1 Public Comments Regarding the Plan

The draft GWMP was released for a 30-day public comment period from August 20, 2018 through September 19, 2018. The public comment period was announced via the Fremont Basin IRWM Plan stakeholder email list, the Fremont Basin IRWM Region Facebook page and the City of California City's website. The Public Draft GWMP was posted on the City of California City's website for public review and a hard copy of the document was kept at the main office of the City of California, MPUD, and AVEK during the public comment period. The RWMG and stakeholders reviewed the documents and summited comments on elements of the proposed GWMP. The RWMG compiled comments received regarding the GWMP and developed a summary of all responses. All comments were addressed before finalizing GWMP.

3. PLAN AREA

This section provides a description of the Plan area covered by this GWMP, including the physical setting, land use, and beneficial uses in the FVGB. Applicable general plans to the Plan area and other planning efforts undertaken in the Plan area are also described briefly. Historical, current, and future water demand and supply conditions are described in Section 5.

3.1 Plan Area Description

The Plan area is located in eastern Kern County, bounded by the Antelope Valley to the south, the Rand Mountains to the north, the southern ranges of the Sierra Nevada Mountains to the west, and San Bernardino County to the east (Figure 1). The City, located on the western edge of the Mojave Desert, is the only municipality within the Plan area (Figure 2). Small unincorporated communities in or near the Plan area include Mojave, Cantil, Rancho Seco, Gypsite, Cenada, Saltdale, Garlock, Rand, Goler, Johannesburg, Randsburg, and Red Mountain. Major highways giving access to the Plan area include State Route 14, a north-south aligned highway that traverses the Plan area, and State Route 58, a south-east aligned highway that crosses the Plan area's southwest boundary.

3.2 Fremont Valley Groundwater Basin

The FVGB underlies the Fremont Valley and is predominantly contained in eastern Kern County with a small, northeastern region within San Bernardino County. The FVGB is identified in DWR's Bulletin 118 (*California's Groundwater*) as Groundwater Basin Number 6-46 and underlies approximately 335,000 acres (DWR 2004a). Figure 4 shows the boundary of the FVGB and adjacent basins and subbasins as defined by DWR Bulletin 118. The FVGB is bounded on the northwest by the El Paso Mountains and the Sierra Nevada mountains; on the east by crystalline rocks of the Summit Range, Red Mountains, Castle Butte, Bissell Hills, and Rosamond Hills; and on the southwest by the Antelope Valley Groundwater Basin. The FVGB is categorized as low priority in DWR's CASGEM program (DWR 2014b).

The Fremont Valley is a relatively flat area with a depression near the center, the Koehn Lake. The Koehn Lake is a dry lake with the bed elevation at approximately 1,880 feet above mean sea level (msl). Ground surface elevation increases toward the surrounding mountains and reaches elevations up to 3,300 feet above msl.

Recharge to the basin is derived primarily from direct percolation of precipitation on the valley floor and runoff from the surrounding tributary watersheds. Most of the runoff is caused by infrequent thunderstorms in the El Paso Mountains. Surface water in the Fremont Valley drains toward Koehn Lake, except in Oak Creek where it drains in an easterly direction (Figure 5). The FVGB also receives subsurface flow from the Antelope Valley Groundwater Basin. Groundwater flow generally moves in an easterly direction along the surrounding mountains and then flows in the northerly direction towards Koehn Lake.

Long-term groundwater level data obtained from the CASGEM program and the U.S. Geological Survey (USGS) indicate that the groundwater levels in the FVGB have declined significantly since 1955, attributed to the prolonged drought period from 1945 to 1964 and excessive groundwater extraction in the FVGB in the late 1950s through the 1970s. Based on the same data, groundwater levels appeared to stabilize after the 1980s and have started recovering since that time as a result of decreased groundwater pumping for agriculture and imported surface water deliveries to urban users being introduced to the Plan area.

While data are limited, based on the information from DWR and previous investigations, groundwater in the alluvium is generally unconfined, although locally confined conditions occur near Koehn Lake (DWR 2004a).

Figure 4: Groundwater Basin Boundaries

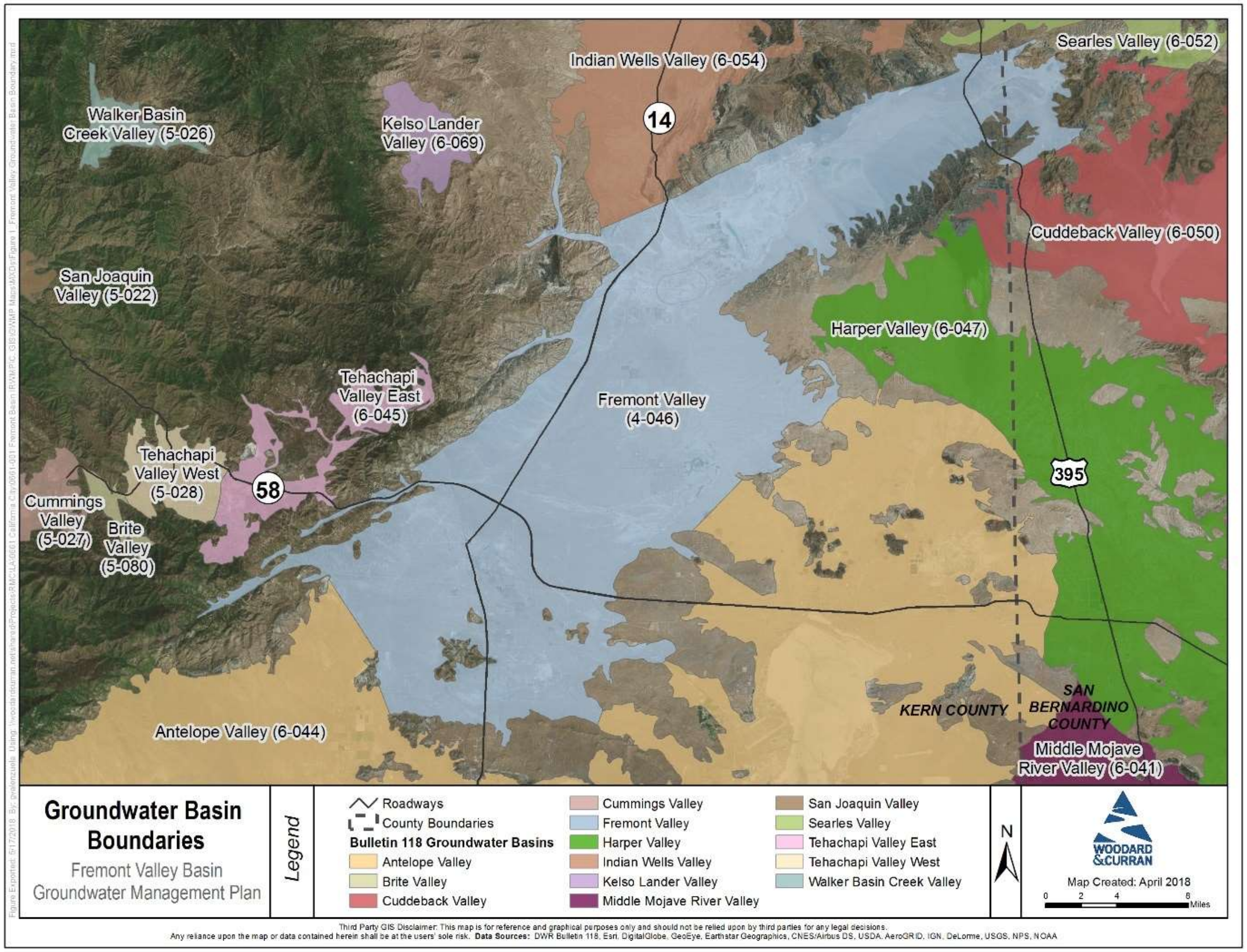
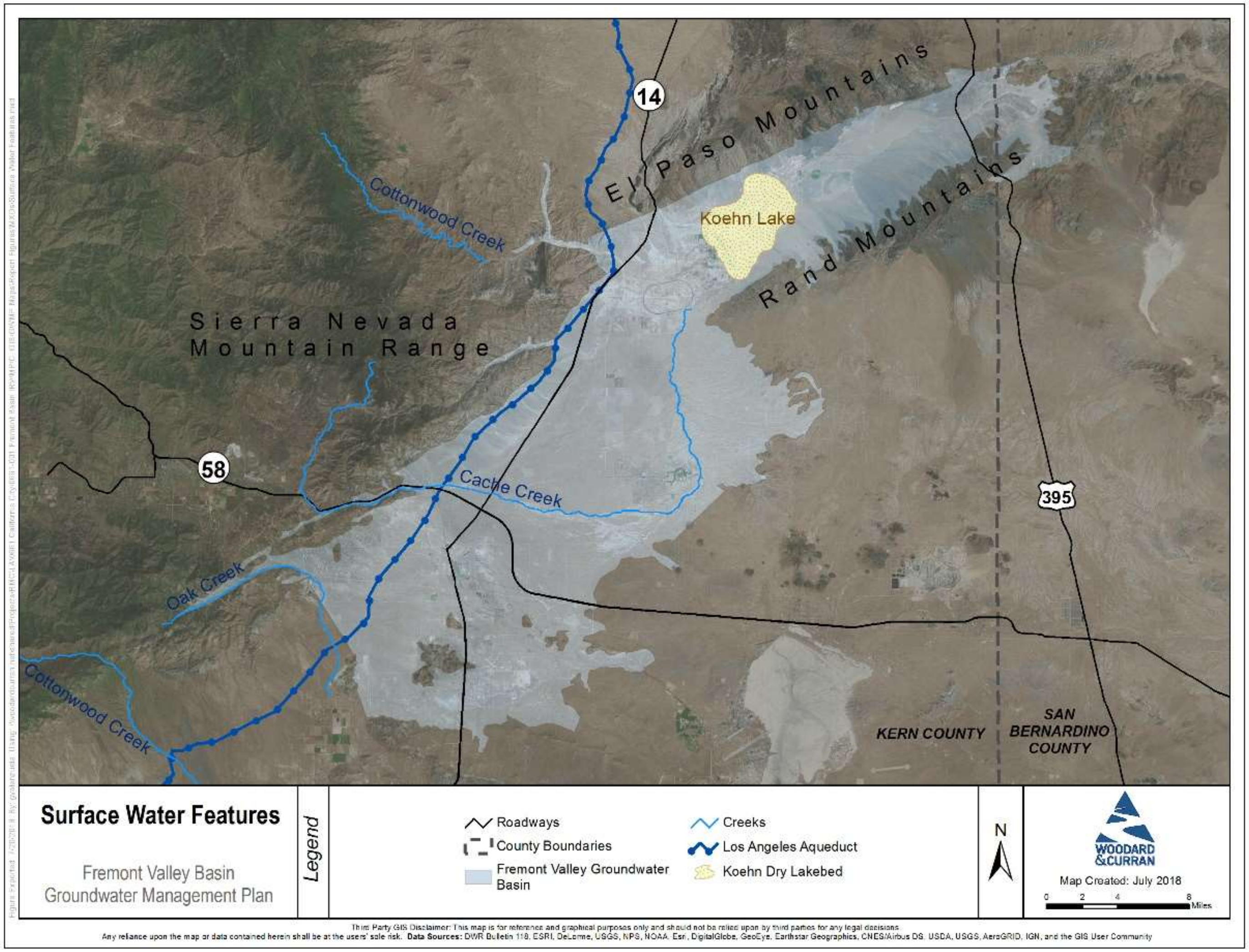


Figure 5: Surface Water Features



3.3 Physical Setting

3.3.1 Climate

The Fremont Valley Basin GWMP area is located in the high desert at an elevation of 2,300 to 4,000 feet above msl with the lowest elevation of about 1,880 feet msl at the Koehn Lakebed. The climate is semi-arid and characterized by warm, dry summers and mild, cool winters. The mean daily temperatures range from 33° Fahrenheit (F) in the winter to 98°F in the summer (Western Regional Climate Center N.D.). Native flora in the Plan area are dominated by sparse, drought-resistant vegetation that can tolerate both extreme heat and cold weather. Examples include Joshua trees, mesquite, sagebrush, desert cymopterus, and Mojave Creosote bush scrub. Carpets of wildflowers bloom during wet years, depending on rainfall intensity in the spring (City of California City N.D.a).

3.3.1.1 Precipitation

There are three precipitation stations with long-term records located within the Fremont Valley watershed: Mojave, Tehachapi, and Randsburg (Figure 6). The Mojave Station is located in the southern portion of the FVGB. Historical data available at the Mojave Station are presented in Table 4 for average monthly values based on data collected between 1904 and 2016. Figures 7, 8, and 9 show the annual precipitation and cumulative departure from annual mean precipitation between 1945 and 2017 at the Mojave, Tehachapi, and Randsburg stations, respectively. Cumulative departure curves are plotted relative to the long-term average precipitation and are used to delineate temporal trends in the precipitation data. A departure curve ascending to the right is considered a positive slope and indicates an accumulation of years of above average precipitation. Conversely, a departure curve descending to the right is a negative slope and indicates an accumulation of years of below average precipitation.

Table 4: Climate in the Fremont Valley Basin Area

Month	Average Monthly ETo (inches)[1]	Average Rainfall (inches)[2]	Average Max Temperature (F) [2]	Average Min Temperature (F) [2]
January	2.31	1.20	57.8	34.2
February	3.16	1.27	61.2	37.1
March	5.01	0.93	64.7	41.0
April	6.47	0.30	71.3	46.3
May	8.28	0.09	79.9	55.1
June	9.19	0.03	89.9	63.8
July	9.61	0.11	97.6	69.7
August	8.74	0.15	96.4	68.0
September	6.35	0.21	89.0	60.3
October	4.48	0.24	78.5	50.3
November	2.85	0.53	65.7	40.2
December	2.07	0.87	57.2	32.9
Annual	**68.52**	**5.93**	**75.8**	**49.9**

Sources: (1) California Irrigation Management Information System (CIMIS) Data for Palmdale No. 197 Station since April 2005. Accessed 9 August 2017 from: www.cimis.water.ca.gov/Stations.aspx; (2) Western Regional Climate Center, Mojave Station (045756) for the Years 1904 to 2016.

Figure 6: Precipitation Stations in the Fremont Valley Basin Area

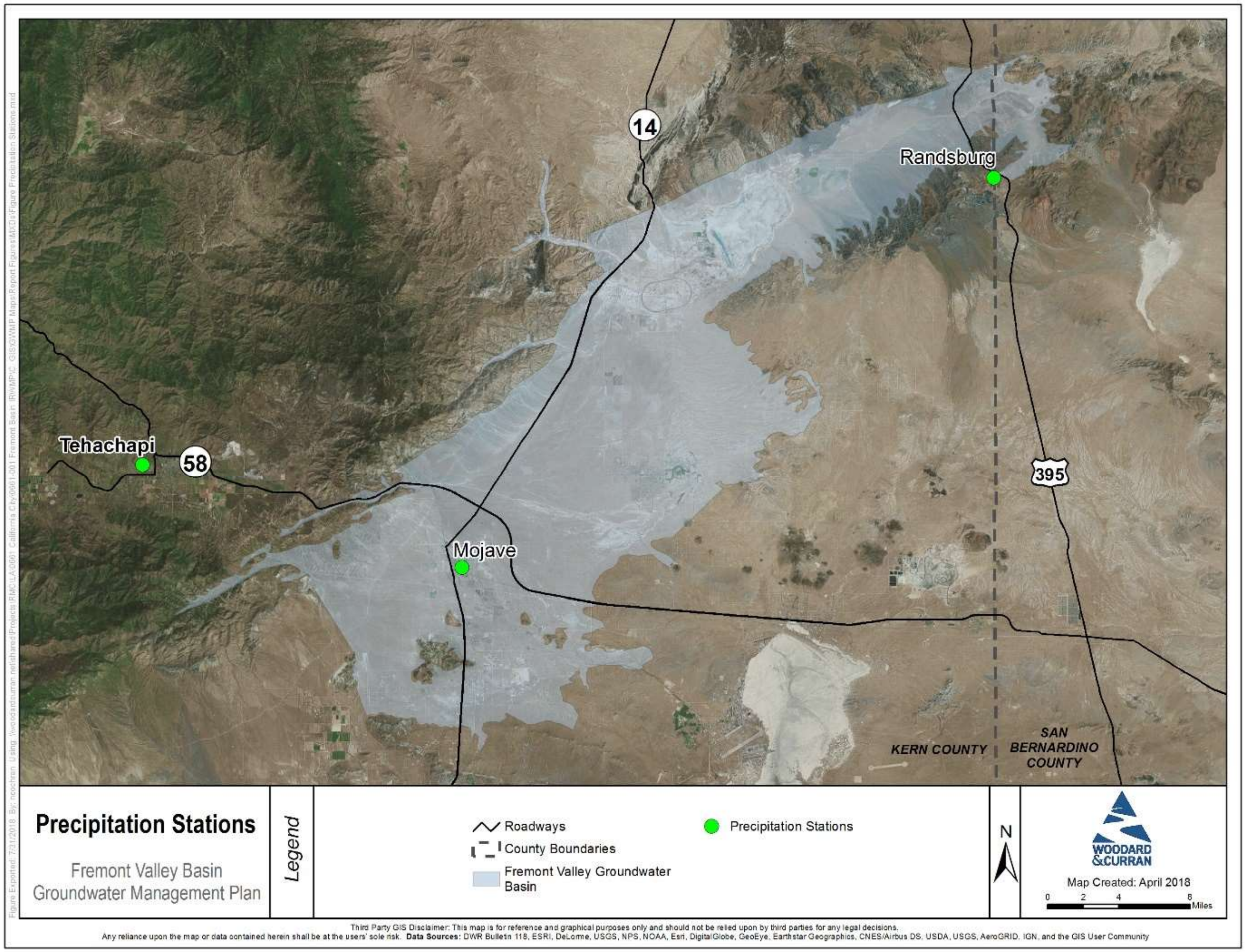
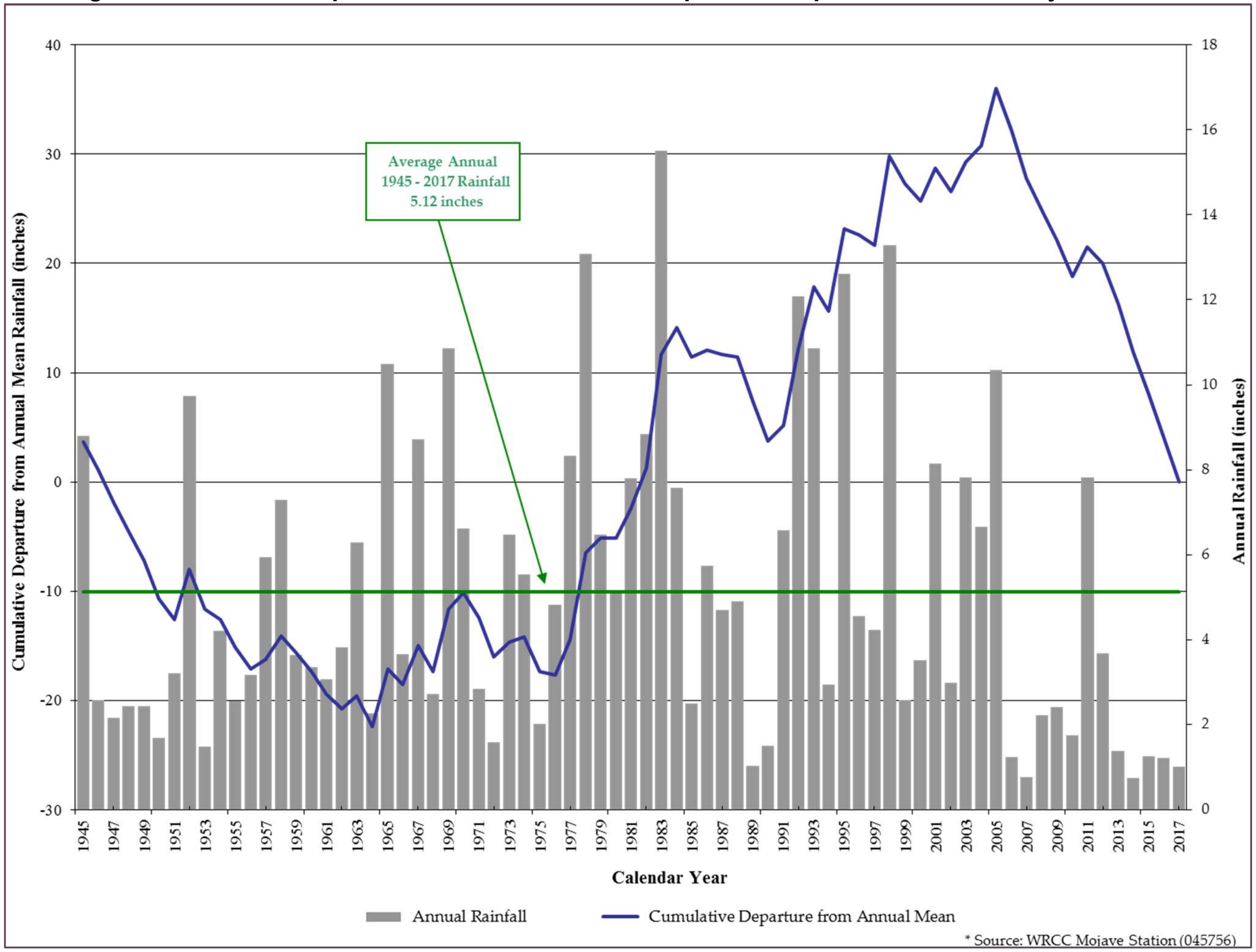
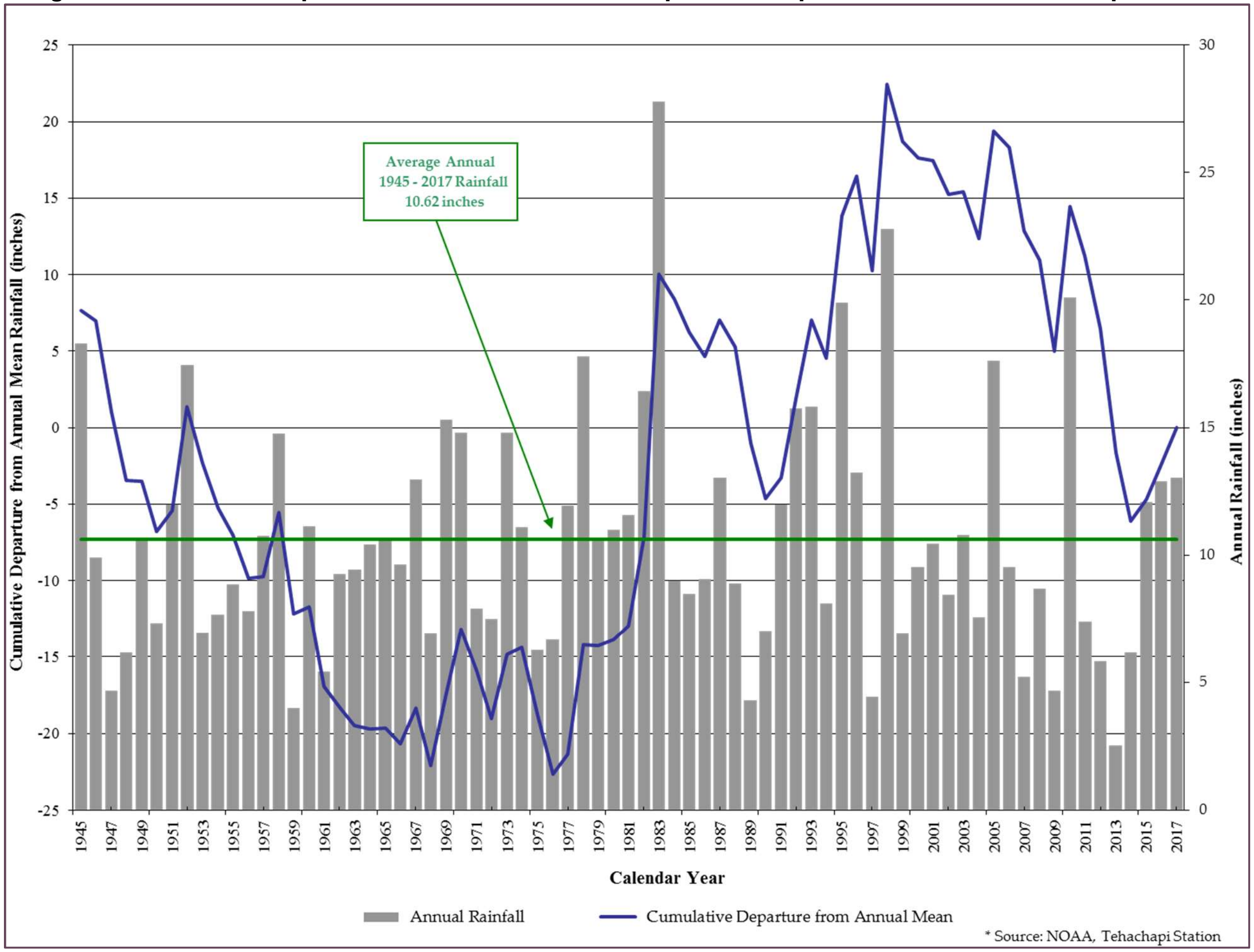


Figure 7: Annual Precipitation and Cumulative Precipitation Departure Curve at Mojave Station



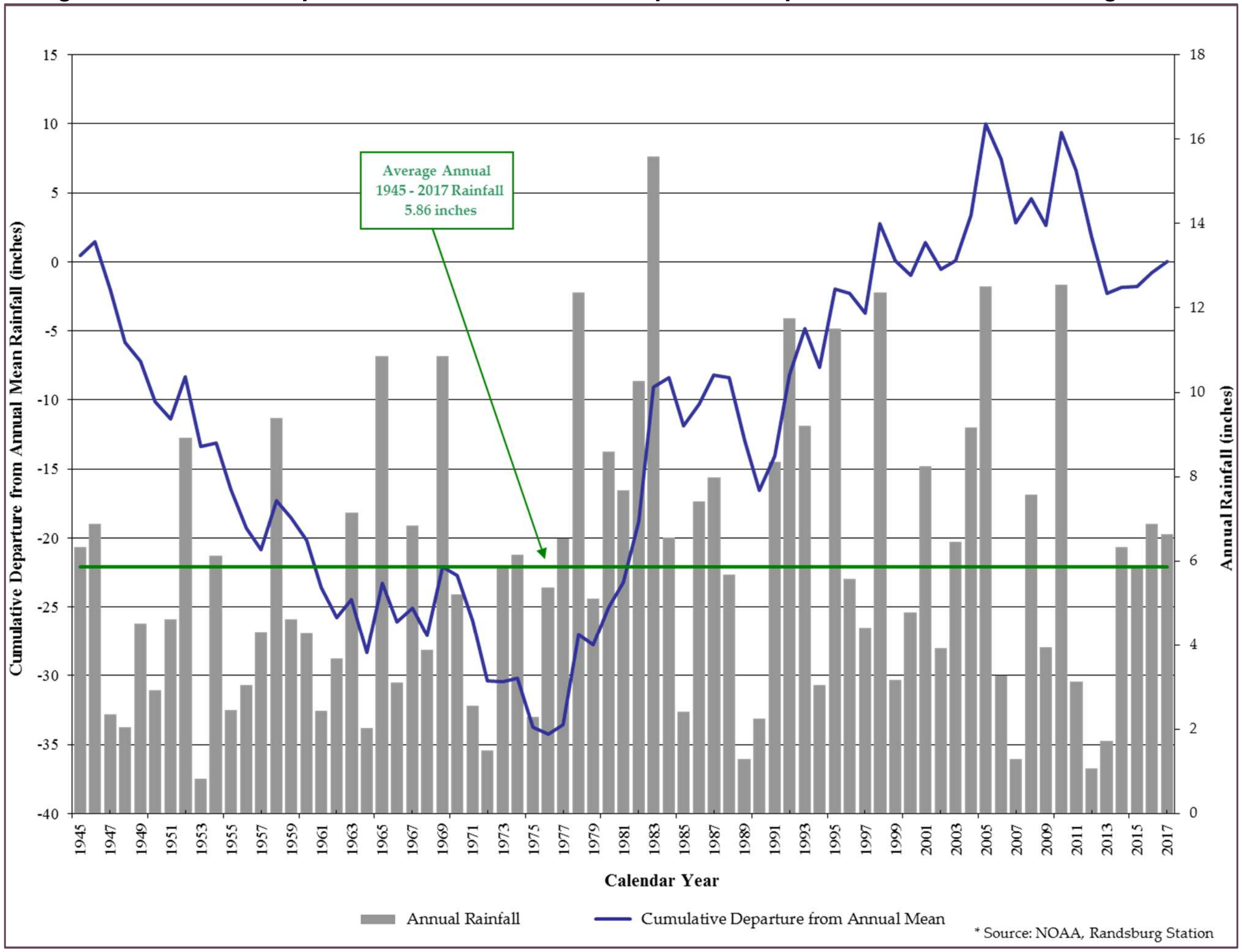
Notes: (1) Precipitation data for 2011 and the majority of the year 2012 were missing; data presented in the figure were estimated for these missing time periods based on the long-term average of a similar hydrologic year type. (2) Cumulative departure curves are plotted relative to the long-term average precipitation at the station.

Figure 8: Annual Precipitation and Cumulative Precipitation Departure Curve at Tehachapi Station



Notes: (1) Precipitation data for 2008 were missing; data presented in the figure were estimated for these missing time periods based on the long-term average of a similar hydrologic year type. (2) Cumulative departure curves are plotted relative to the long-term average precipitation at the station.

Figure 9: Annual Precipitation and Cumulative Precipitation Departure Curve at Randsburg Station



Note: Cumulative departure curves are plotted relative to the long-term average precipitation at the station.

Data indicate precipitation is highest at the Tehachapi Station and lowest at the Mojave Station. Annual precipitation at the Mojave Station ranged from 0.75 inches to 15.51 inches at an average of 5.1 inches (Figure 7). Annual precipitation at the Tehachapi Station ranged from 2.52 inches to 27.77 inches at an average of approximately 10.1 inches (Figure 8). Annual precipitation at the Randsburg Station ranged from 0.83 inches to 15.58 inches at an average of 5.9 inches (Figure 9). The cumulative departure curves at the Mojave Station indicate that the Fremont Valley has experienced wet-dry cycles with a prolonged drought period from 1945 to 1964, a prolonged wet period from 1976 to 1984, and a drought period since 2006. Precipitation on the valley floor may have significant losses from evaporation and transpiration; however, during an exceptionally wet season, flashfloods may occur and runoff may originate on or cross the valley floor to reach the Koehn Lake (Stetson 2009).

3.4 Land Use

Land use in the FVGB is predominantly comprised of undeveloped lands, urban lands, and a small percentage of developed agricultural lands. Current land uses within the Plan area are depicted in Figure 10 and are based on Kern County assessor data and aerial review. The largest urban area is within the City's boundary. A breakdown of each major land use category in the Plan area is defined as follows:

- Residential category uses include a mix of housing developed at varying densities. Residential densities in the Plan area range from "estate" (i.e., large lot parcels) to low, medium low, medium, and high densities. Single-family, multiple-family, condominium, mobile home, and senior housing are included within these categories.
- Commercial category includes commercial uses that offer goods for sale to the public (retail) and service and professional businesses housed in offices (doctors, accountants, architects, etc.). Neighborhood commercial includes retail businesses that serve local needs in a neighborhood area, such as restaurants, neighborhood markets, and dry cleaners. Community commercial businesses are those that serve community or regional needs, such as entertainment complexes, auto dealers, and furniture stores.
- Industrial category includes heavy industrial areas which are lands designated for intensive manufacturing, processing, and storing of materials. Light industrial and research is also included within this category. These non-intensive manufacturing processes are found in research and office park developments and areas adjacent to residential lands. Light industrial activities include some types of assembly work, utility infrastructure and work yards, solar energy production, wholesaling, and warehousing.
- Resources category encompasses land used for private and public recreational open spaces, and local and regional parks. Recreational use areas also include golf courses, cemeteries, water bodies and water storage. Also included in this category are conservation and restoration areas as well as mineral exploration.
- Agriculture category includes areas devoted to the production of irrigated crops, including alfalfa and pistachio production in recent years, and in some cases goats and cattle.
- Public Facilities category includes facilities used for public or semi-public services including airports, treatment plants, and water spreading areas.
- Vacant lands are undeveloped lands that are not preserved in perpetuity as open space or for other public purposes.

3.4.1 Applicable General Plans

California law requires that each city and county in the state develop and adopt a general plan. General plans are comprehensive long-term plans for the physical development of the plan area and contain a list of development goals and policies for the county or city. The seven mandated elements of a general plan are: Land Use, Open Space, Conservation, Housing, Circulation, Noise, and Safety. The City and the Kern County general plans are applicable to the Plan area.

In 2009, the City Council of the City of California City adopted an updated General Plan. The General Plan outlines the vision for the City's future and includes implementation measures to meet the vision. Planning and development decisions are made consistent with the goals and policies delineated in the General Plan. The planning area is comprised of the City's corporate limits and its coterminous sphere of influence, totaling 130,200 acres of land located on the western edge of the Mojave Desert in eastern Kern County (City of California City 2009). The City's General Plan designates 22,000 acres of land intended for future development in the central core of the City (Figure 11). While development in the northeastern portion of the City can still occur, as evidenced by the construction of the California City Correctional Facility, future development plans are expected to promote housing and open spaces, jobs, accommodate transportation needs, and reduce air and noise pollution (City of California City 2009). The major future development planned currently is the expansion of the CoreCivic Correctional Facility.

One notable impact to future land use in the Plan area is cannabis production. In 2016, California voters legalized cannabis in the State of California for recreational use. The City was one of the first municipalities in Kern County to permit cannabis cultivation, and land designation for agricultural land uses is underway. A municipal ordinance in 2017 increased the maximum number of each type of marijuana business that may operate at the same time within the City. The City expects a land use designation increase for indoor cultivation facilities, hemp outdoor cultivation facilities, processing and packaging facilities, distribution and transport facilities, and retail cannabis stores (City of California City N.D.b).

In 2004, Kern County adopted its General Plan and has completed several updates since then. The County General Plan's Land Use, Open Space, and Conservation element designates the proposed general distribution, location, and extent of land uses in unincorporated areas. The focus of the General Plan discussion is on ensuring future economic growth while conserving the County's agricultural, natural, and resource attributes (Kern County 2009).

Both the City and County General Plans were used to help describe the current and future land use conditions in the Plan area. The City of California City and the Kern County Planning and Natural Resources Department were consulted during Plan development to ensure current land use planning initiatives and processes were incorporated.

Figure 10: Existing Land Use in the Fremont Valley Basin Area

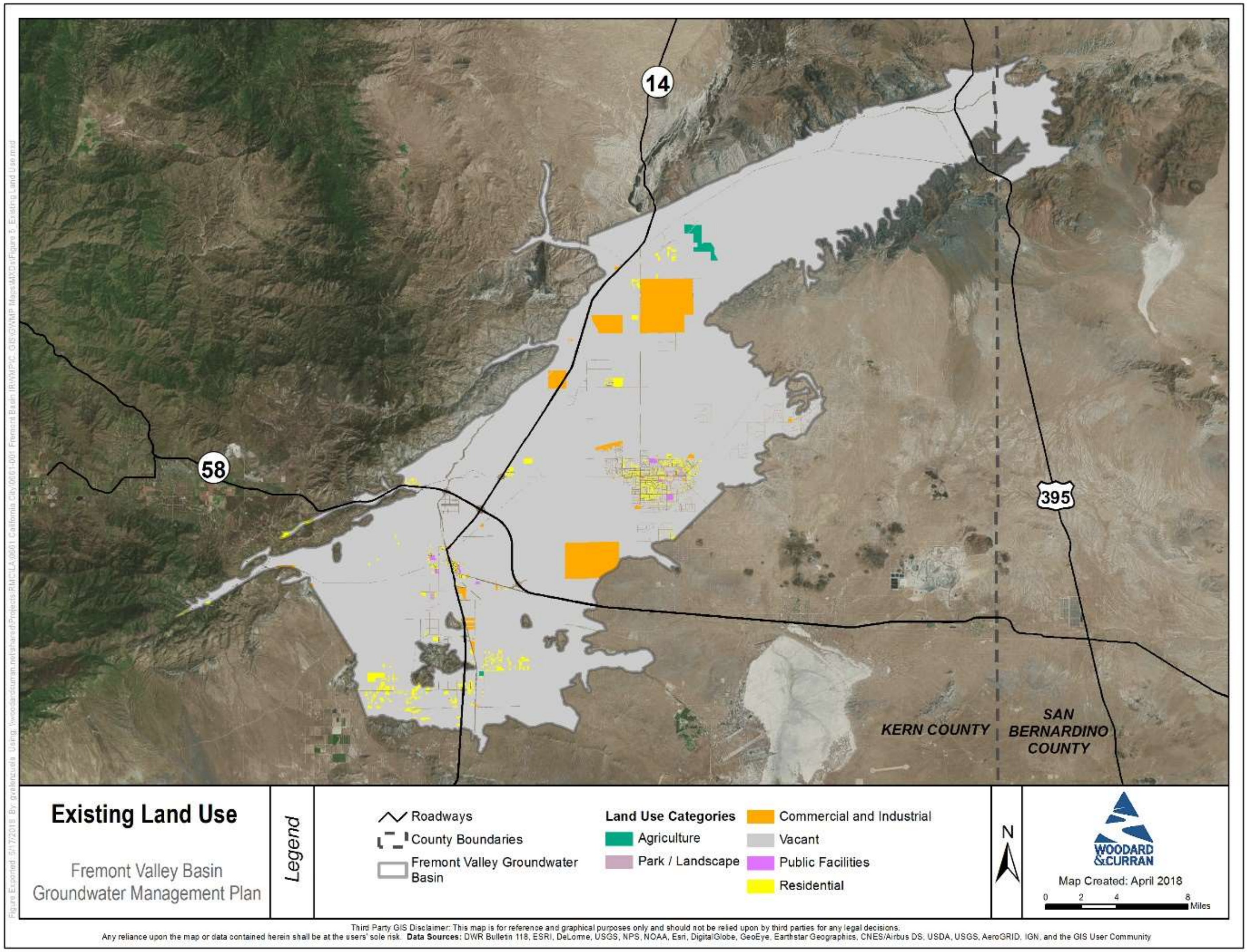
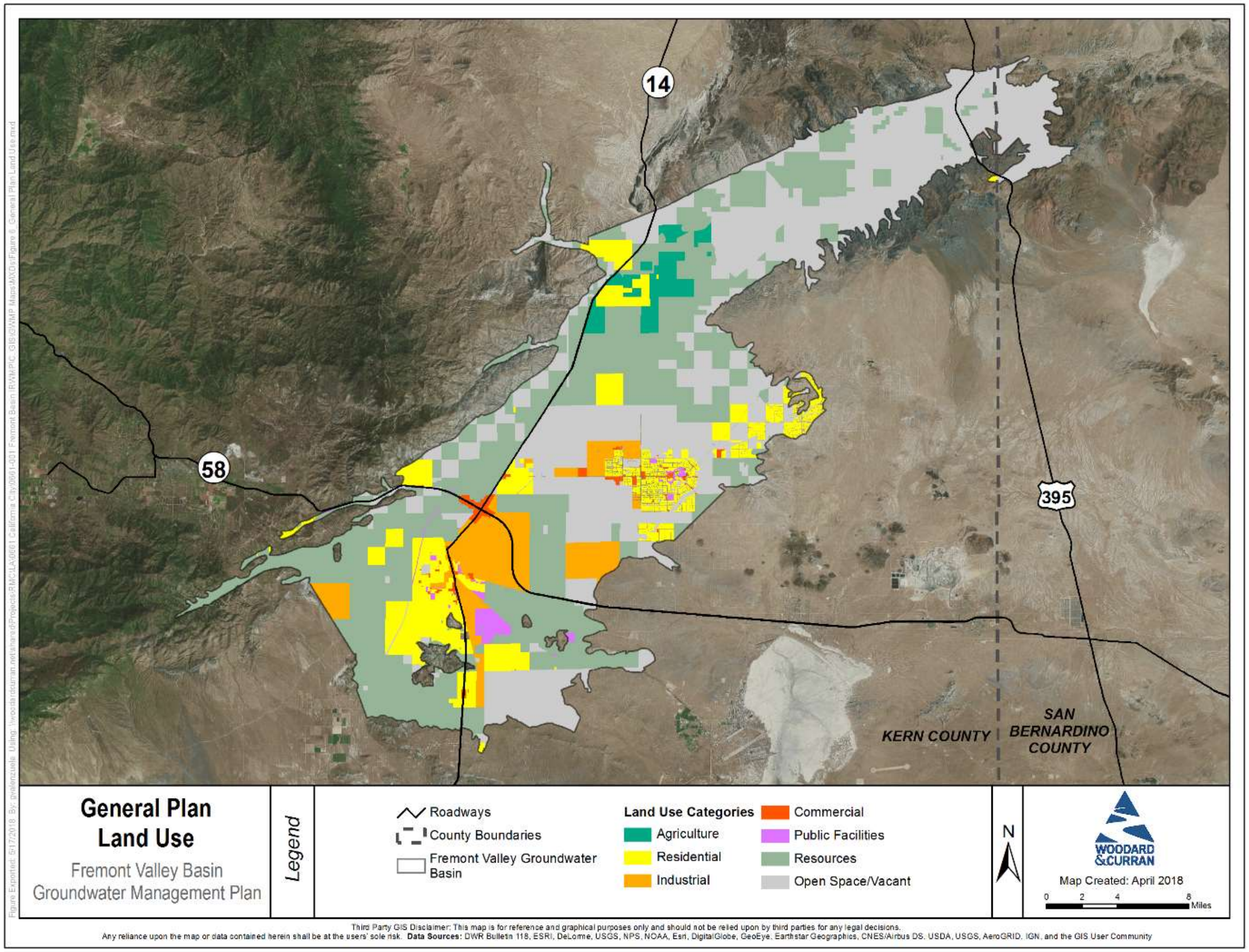


Figure 11: General Plan Land Use in the Fremont Valley Basin Area by 2028



3.4.2 Impacts of Land Use Plans Outside of Plan Area

Urban land development is expected to grow in response to increased employment opportunities and natural population growth in and around the Plan area. The Kern County General Plan assumes that the population in Kern County will continue to grow at its current rate of less than two percent annually over the next 20 years. Though the County has seen an increase of scattered urban density residential development throughout the County, the General Plan promotes higher-density residential development within areas with adequate public services and infrastructure. Commercial and public facilities will likely need to expand to support the increasing residential population (Kern County 2009). Entities in Kern County that have increased employment opportunities include the Air Force Base four miles southeast of California City outside the Plan area, the Mojave Air and Space Port inside the Plan area at the intersection of Highways 14 and 58, the Hyundai/Kia Automotive Test Facility, and the Honda Proving Center. Extraction of borates by the Rio Tinto Mine (formerly U.S. Borax Boron Mine) fifteen miles east of the City, outside the Plan area, also provides lucrative employment opportunities for residents (California City Water Department 2017).

Agriculture is also expected to continue to be a vital part of Kern County's future economy. Multiple plans aim to conserve prime agricultural lands and to support the long-term retention of agricultural production in the County through programs and policies that provide tax and economic incentives to agriculture. In the past two decades, the development of major water projects has greatly increased the amount of land in agricultural production in Kern County. Agricultural projections approved by stakeholders in the Plan area during the development of the Fremont Basin IRWM Plan assume that a larger proportion of land currently designated for agricultural uses near the FVGB will be used for crop production in the future. Increased agricultural water demands, coupled with increased urban, commercial, and industrial water demands as a result of population and economic growth inside and outside the FVGB, could affect the region's ability to achieve sustainable management of the FVGB. To meet increases in groundwater demand, the Kern County General Plan encourages effective management of groundwater resources, including promoting groundwater recharge activities, supporting Urban Water Management Plans (UWMPs), developing GWMPs, and diversifying the water supply portfolio.

3.5 Beneficial Uses and Users in Plan Area

The FVGB supports a wide range of beneficial uses in the Plan area. State policy for water quality control in California is directed toward achieving the highest water quality consistent with maximum benefit to the people of the State. Beneficial uses of individual water bodies in the Plan area are designated and maintained by the LRWQCB. The LRWQCB makes these designations to aid in the implementation of effective water quality criteria and control plans. The Water Quality Control Plan for the Lahontan Region (Lahontan Basin Plan) contains the beneficial uses and water quality objectives for the Lahontan Region. Based on the Basin Plan, the designated beneficial uses for the FVGB include municipal and domestic supply (MUN), agricultural supply (AGR), industrial service supply (IND), and freshwater replenishment (FRSH).

3.5.1.1 Municipal and Domestic Uses

There are five water agencies that supply residential water uses in the Plan area from the FVGB. These include the City, MPUD, California Water Service Company (Cal Water), Rand Communities Water District (RCWD), and Rancho Seco Inc (Figure 2). The City serves the City of California City through approximately 4,410 connections in the southeastern portion of Kern County within the Plan area. The City uses six groundwater wells and intends to add two more wells in 2018 and 2019. MPUD serves roughly 19 square miles of unincorporated residential, commercial, industrial, and undeveloped land overlaying the southern part of the FVGB. Cal Water has a small district north of the City. RCWD covers the north east portion of the Plan area and serves approximately 450 residents with two wells. Rancho Seco Inc. serves a small portion of the Plan area in the Cantil area with a single well in the FVGB. Users not served by these water purveyors rely on private wells to meet domestic water demands.

In addition to these purveyors, the American Honda Motor Company has a small water system that distributes pumped groundwater from the FVGB to the Honda Proving Center, an automotive testing center. The Honda Proving Center system is a non-community water system that does not provide water to residential users.

3.5.1.2 Agricultural Uses

The FVGB supports the production of irrigated crops, including alfalfa, other forage species, and pistachio nut production, in unincorporated areas of the Plan area. Agriculture is an important past and present component of the regional economy and can be a source of significant water demands. Given the regional and climatic conditions of the area, it is assumed that alfalfa is grown from February to October and pistachios from April to August.

3.5.1.3 Industrial Service Uses

In addition to agriculture, large industrial processes like solar energy production and cannabis cultivation[1] are also important components of the regional economy. While there is no cannabis cultivation in the Plan area currently, cannabis production is expected to become a key component of the area's economy. In 2016, California voters legalized cannabis in the State of California. The City was one of the first municipalities in Kern County to permit cannabis cultivation, and land designation for agricultural land uses is underway. A municipal ordinance in 2017 increased the maximum number of each type of medical marijuana business that may operate at the same time within the City. The City expects a land use designation increase for indoor cultivation facilities (City of California City N.D.b). Cannabis cultivation in the Plan area will be partially supported by water supplied from the FVGB. No legal cannabis cultivation is anticipated in the planning horizon for the unincorporated areas of the Plan area.

Within the Plan area, solar energy production is a major industry that also requires water for cleaning solar panels. Beacon Solar, LLC currently operates a roughly 2,500-acre photovoltaic solar facility one mile southwest of Cantil and Rancho Seco (Kern County Planning and Community Development Department 2012). This facility consists of five solar power station projects and is anticipated to generate approximately 250 megawatts (MW) for the Los Angeles Department of Water and Power (LADWP). There are also other solar photovoltaic (PV) projects in the Plan area, including Springbok and Barren Ridge 1 (Kern County 2013). Springbok solar farm, comprised of three projects, is located on the eastern side of Highway 14 near Rancho Seco and Cantil. Barren Ridge 1 is a 78 MW facility located along the western side of Highway 14 north of California City that began operating in 2016. As with the Beacon Solar project, LADWP purchases power from Springbok and Barren Ridge 1.

3.5.1.4 Freshwater Replenishment

The FVGB provides critical habitat for several species of special concern, including the desert tortoise, Mohave ground squirrel, and the burrowing owl. Limited wetted areas in the Plan area also provide critical habitats for migratory birds, making the area an important component of the Pacific Flyway. The Pacific Flyway is a major north-south migration route for birds, extending from Alaska to Patagonia. Each year, at least one billion birds migrate along the Pacific Flyway, following food sources, heading to breeding grounds, or traveling to wintering sites. This birds that rely on the Pacific Flyway depend on a diverse chain of habitats along the way as rest stops before continuing their migration. While there are limited surface water bodies in the Plan area, Central Park Lake in California City and other smaller ponds provide habitat for the birds on golf courses or on private property.

[1] Cannabis cultivation is being included as an industrial use in this GWMP because it is being regulated under the LRWQCB as an industrial water use.

3.6 Description of Other Plans

The GWMP was developed in coordination with two other key planning efforts within the FVGB, including the Fremont Basin IRWM Plan and the Fremont Valley Basin SNMP. In addition, the City and AVEK prepared their 2015 UWMPs as the major urban water suppliers serving over 3,000 acre-feet per year (AFY). These planning efforts inform and support each other to ensure reliable water supplies are available to meet future regional demand, to promote the sustainable use of water supplies, and to facilitate groundwater resources management in the Plan area. This section provides an overview of these planning efforts led by the City in close coordination with MPUD and AVEK in the Plan area.

3.6.1 Fremont Basin Integrated Regional Water Management

IRWM planning is a collaborative effort to manage all aspects of water resources in a region. IRWM crosses jurisdictional, water, and political boundaries; involves multiple agencies, stakeholders, individuals, and groups; and it attempts to address the issues and differing perspectives of all entities involved through mutually beneficial solutions. The IRWM process involves identifying and implementing water management solutions on a regional scale to increase regional self-reliance, reduce conflict, and manage water in a way that concurrently achieves social, environmental, and economic objectives.

An integral part of the IRWM program is developing an IRWM Plan, which is a comprehensive document of the outcome of IRWM planning efforts. The IRWM Plan reflects efforts and objectives of all stakeholders within a defined region and documents the development and implementation of effective strategies that promote sustainable water use, guarantees a reliable water supply, improves water quality, and endorses environmental stewardship within the Region. IRWM Plans also describe the water supply portfolio and demands in the region, as well as describe the existing and projected water management challenges with respect to climate change impacts and population changes.

The IRWM Region encompasses 992 square miles in eastern Kern County and in western San Bernardino County in the western edge of the Mojave Desert (Figure 1). The only incorporated city in the IRWM Region is the City of California City. The primary defining feature of the Fremont Basin IRWM Region is its position overlying the entirety of the FVGB. The first IRWM Plan for the Region was developed concurrently with this GWMP and is anticipated to be completed in early 2019.

3.6.2 Fremont Valley Basin Salt and Nutrient Management Plan

An SNMP was prepared for the FVGB to fulfill the requirements of the State's *Policy for Water Quality Control for Recycled Water* (Recycled Water Policy). The Fremont Valley SNMP development was led by the City, AVEK, and MPUD, in collaboration with local and regional stakeholders and in accordance with the Recycled Water Policy. The primary purpose of the SNMP is to assist the City, AVEK, MPUD, and stakeholders in complying with the Recycled Water Policy regarding the use of recycled water from municipal wastewater treatment facilities. The Recycled Water Policy supports use of recycled water as a source of water supply while requiring the management of salts and nutrients from all sources on a sustainable basis and maintaining water quality objectives and protection of beneficial uses covered by each of the RWQCB Basin Plans.

Recycled water is currently used in the City's existing ponds and served to irrigate park and golf course areas. Recycled water supply is projected to increase in the future as the City's population grows and the City expands its WWTP. The City is exploring the feasibility of using recycled water on a second golf course, in addition to expanding use for green belts and other end uses. The Fremont Valley Basin SNMP is intended to inform future decisions for use of recycled water and help streamline permitting of future recycled water projects while protecting the basin water quality objectives and beneficial uses. The Final SNMP was submitted to the LRWQCB for review and approval in December 2018.

3.6.3 Urban Water Management Plans

UWMPs are prepared by urban water suppliers to support long-term resource planning and ensure adequate water supplies are available to meet current and future water demands in their service areas. Preparation of an UWMP is a requirement of the Urban Water Management Planning Act for urban water suppliers with more than 3,000 connections or supplying more than 3,000 AF of water annually. These plans must be updated and submitted to DWR every five years to comply with the Urban Water Management Planning Act and be eligible for State funding.

In the Plan area, the City submitted its 2015 UWMP to DWR in 2017 (California City Water Department 2017). AVEK also published its 2015 UWMP in 2016 (AVEK 2016). The most recent UWMP prepared by MPUD was submitted to DWR in 2004 (MPUD 2004). Since that time, they have not been required to complete an UWMP because they have less than 3,000 connections and supply less than 3,000 acre-feet (AF) of water annually. The UWMPs for the urban water suppliers in the Plan area were used to help describe and calculate the water supplies and demands in the Plan area, as further described in Section 5.

3.6.4 Habitat and Conservation Plans

The Plan area provides critical habitat for diverse flora and fauna that have adapted to high desert conditions. To protect the area's biodiversity and ecosystem, various restoration efforts are underway. The California Department of Fish and Wildlife, the California Department of Transportation, local jurisdictions, and other regional stakeholders collaborated with the Bureau of Land Management (BLM) to develop the West Mojave Plan in 2005. The plan is a habitat conservation and federal land use plan that provides management strategies for the desert tortoise, Mohave ground squirrel, and over 100 other plants and animals that are vital for the preservation of these two species. The planning area is located to the north of the Los Angeles metropolitan area and includes the Plan area within its boundaries.

The West Mojave Plan designated 18 Habitat Conservation Areas to be managed by the BLM, four of which were established as Desert Wildlife Management Areas for the protection of desert tortoises. These added a total of 1.5 million acres reserved for desert tortoise conservation (BLM 2005). The adopted plan also established a Mohave Ground Squirrel Conservation Area comprised of 1.73 million acres of public lands (Leitner 2015). The conservation regions add to the existing 1.15 million acres of land set aside to preserve desert tortoises and are necessary for tortoises to recover from diseases, raven predation, and other pressures. The plan ensures the longevity of tortoise populations, allows for genetic connectivity among tortoise populations, and reduces tortoise mortality resulting from anthropogenic influences (BLM 2005).

The Desert Renewable Energy Conservation Plan (DRECP) is another collaborative plan in the Plan area. The DRECP was developed by the Renewable Energy Action Team, whose members include the California Energy Commission, California Department of Fish and Wildlife, the BLM, and the U.S. Fish and Wildlife Service. The plan covers 22.5 million acres of desert land in seven counties, including the Mojave Desert in Kern County. The DRECP promotes solar, wind, and geothermal energy development in desert regions by streamlining the permitting process for renewable energy projects. Simultaneously, the plan ensures that planning efforts meet state and federal policies, incorporate conservation objectives, and enhance natural ecosystems (BLM 2016).

4. BASIN CHARACTERIZATION

The purpose of this section is to present a description of the hydrogeology of the FVGB, geologic setting and groundwater conditions for levels, flow, storage, and water quality. This section relies on available data collected from public sources, data provided by the stakeholders, and review of information from previous investigations.

4.1 Regional and Geologic Setting

The geologic setting in the FVGB is described below and is based principally from previous work (U.S. Geological Survey (USGS) 1977; Richard C. Slade & Associates 1995; Layne Geosciences/Colog Group 2005; Stetson 2009). The geologic formations of the FVGB are divided into two main units: consolidated rocks of Tertiary and pre-Tertiary age, and unconsolidated deposits of Quaternary age. The consolidated rocks form the mountains and hills surrounding the valley area, and the basement complex underlying the unconsolidated deposits make up the sides and bottom of the FVGB.

Unconsolidated deposits form the FVGB and consist primarily of Recent Quaternary alluvium in the valley floor and Pleistocene Quaternary non-marine deposits in the alluvial fans along the low hills of the eastern boundary, FVGB northern tip, and the alluvial fans between the Oak Creek and the Cache Creek along the western boundary. Quaternary lake deposits are also present in low-lying areas (lower than the elevation of 2,000 feet msl). The thickness of the unconsolidated deposits southwest of Koehn Lake varies from 400 feet to 900 feet (USGS 1977). In the area northwest of Koehn Lake, the thickness of the unconsolidated deposits is unknown, but wells drilled to depths of 800 feet below land surface did not encounter consolidated rocks.

Older alluvium of Pleistocene age underlies most of the valley floor. It consists of poorly to moderately consolidated alluvial fan and stream channel deposits characterized by moderately to poorly sorted gravel, sand, and silt of Pleistocene (Quaternary) geologic age. The older alluvium is oxidized and generally unconsolidated, but in some places it is slightly cemented. This formation is permeable, extends below the water table, yields water freely to wells, and is the most important water-bearing unit in the area. According to available drillers' logs, these unconsolidated materials are interbedded with layers of shale at various thickness in many places, especially in the central portion of the FVGB. The older alluvium appears to have a maximum thickness of about 550 feet to 650 feet in the southern portion of the FVGB, and does not appear to extend to a depth greater than about 800 feet. Water wells in this area produce from older alluvium and Pliocene sediments (Richard C. Slade & Associates 1995).

The thickness of the unconsolidated deposits was estimated in several previous reports. DWR reports the alluvium is about 1,190 feet thick (Bader 1969; DWR 1964) along the margin of the basin and thins toward the middle of the basin, where it is interbedded with thick layers of lacustrine silt and clay near Koehn Lake. The most recent report, based on well data from USGS (1977), showed an alluvial thickness that ranges from 400 feet to 800 feet near Koehn Lake. Information from completed water supply wells suggests that the alluvial thickness reported by USGS (1977) of 800 feet may be low, as the total depths of the wells on the site vary from about 800 feet to 1,700 feet below the ground surface (bgs). If the wells were completed in alluvial materials, these depths suggest that unconsolidated materials may be thicker than previously reported. MPUD wells, located in the southern portion of the FVGB, have depths ranging from approximately 350 feet to 800 feet. The City's wells, located further north, have depths ranging from approximately 550 feet to 810 feet.

4.2 Structural Features

Several named and unnamed faults in the FVGB are identified on California geologic maps, as shown on Figure 12. Four major faults transverse the FVGB in a northeast-trending direction. The longest ones are the Garlock fault and El Paso fault system that run along the north and west sides of the basin, along the foothills of the Sierra Nevada and El Paso Mountains, and separates the consolidated rocks of the Tehachapi, Piute, and El Paso Mountains from the FVGB.

The Garlock fault zone is traceable for some 150 miles and has a left-lateral displacement of unknown magnitude However, earlier studies suggest a displacement of about 6 miles near Randsburg to a displacement of 40 miles based on offset of a dike swarm west of Searles Lake north of the fault from a similar dike swarm south of the fault about 40 miles east (Dibblee 1967). These faults from restrictive groundwater barriers on the west and northwest sides of the FVGB (Layne Geosciences/Colog Group 2005, Stetson 2009). The Garlock fault appears to act as a barrier to downslope movement of groundwater where groundwater on the upslope side apparently backs up against the fault, which acts as an "underground dam" and the overflow reaches the surface to seep out as one of more springs, as reported by Dibblee (1977).

The Cantil Valley fault, which appears to be a branch of the Garlock fault, runs from the Garlock fault near the town of Cantil, bisects the FVGB through Koehn Lake, and rejoins the Garlock fault approximately nine miles east of US 395. According to DWR, the effects of the Cantil Valley fault on groundwater flow are not known; but the USGS and recent studies indicate that it is a partial barrier to groundwater flow (USGS 1977). The USGS 1977 study notes different hydraulic characteristics on the two sides of the Cantil fault.

The Randsburg-Mojave fault runs along the northeastern side of the basin and separates the consolidated rocks of the Rand Mountains from the FVGB. The southern boundary of the FVGB is bounded on the south by the east-west trending Rosamond fault. These faults form restrictive groundwater barriers on the west and northwest sides of the FVGB (Dibblee 1967). The Randsburg-Mojave fault and the Muroc fault extension have been inferred by the USGS based on apparent barriers to groundwater flow, as reported by Richard C. Slade & Associates 1995.

The Muroc fault traverses the southern portion of the FVGB and forms a partial barrier to groundwater flow (DWR 1964). Previous studies by Stetson (2009) considered the Muroc fault as an intrabasin boundary dividing the basin into two subbasins: the California City subbasin on the north and the Mojave City subbasin on the south. The subsurface flow across the Muroc fault is reported to occur only when groundwater levels south of the Muroc fault is high enough to allow groundwater to overflow the groundwater barrier created by the fault. The subsurface flow appears to stop when groundwater levels south of the Muroc fault is lower than the barrier crest, which is estimated at an elevation of approximately 2,420 feet msl based on historical water levels near the Muroc fault. As further described in Section 4.8.2, review of historical and recent water levels at the wells within the FVGB do not appear to confirm the hydrogeologic effects of the faults in the area, except for the Muroc fault. The significant difference in the water levels in 1958 for two wells that are located approximately 1.3 miles across the Muroc fault confirm the hydrogeologic effects of this fault, as also reported by Stetson 2009.

The unnamed faults include a fault running parallel to the Muroc fault across the narrows between the Castle Butte and the Twin Buttes, and a southeast-northwest fault running from the Castle Butte to the vicinity of the Pine Tree Canyon mouth. The effects of these unnamed faults on groundwater in the FVGB are not known.

Because the Muroc fault is the only fault that has been documented as creating a barrier to groundwater flow and that has well data that support the fault as creating a partial barrier to flow, this fault was included in the groundwater modeling analysis described in Section 4.3 and 4.8.4. Groundwater conditions within the FVGB and across the Muroc fault are described using groundwater contour elevation maps generated based on the information available. See Section 4.8.1 and 4.8.2 for additional details on groundwater flows and elevations in the FVGB as well as the estimated groundwater contours.

4.3 Groundwater Subbasins and Subunits

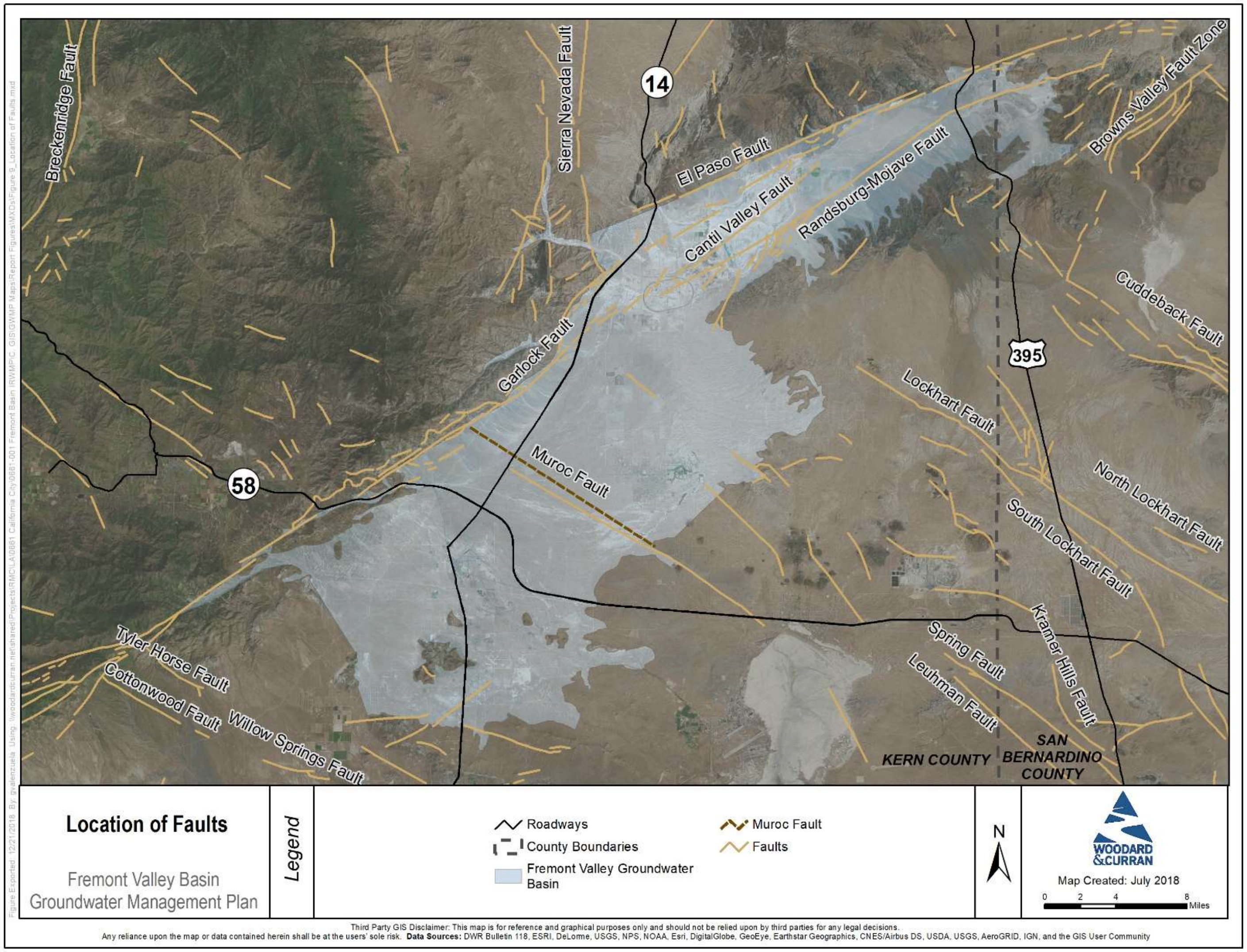
This GWMP uses the DWR Bulletin 118 groundwater basin boundary, as shown in Figure 1, for the basin characterization. Different nomenclature has been used to define subdivisions of the FVGB by DWR, USGS, and previous investigators. DWR and USGS definitions differ substantially on the division of the groundwater basin into subunits[1]. The subunit and subbasin boundaries and names identified by the USGS and previous investigators are summarized here. The findings from previous studies conducted for the FVGB were referenced for describing the basin geology and hydrogeology (Krieger and Stewart 1971; USGS 1977; Stetson 2009).

The USGS defined six subunits in the FVGB: Koehn, California City, Chafee, Oak Creek, Gloster, and Willow Springs Subunits. shows the general areas of these subunits as defined by the USGS. The Koehn and Oak Creek subunits are narrow elongated units bounded by the Garlock fault on the west and the Randsburg-Mojave fault on the east. The boundary between the two subunits appears to be located just south of a surface water divide. East of the Randsburg-Mojave inferred fault, the USGS defines the California City Subunit as north of the Muroc fault and the inferred extension of the fault, and defines the Chaffee Subunit as south of the Muroc fault. The Gloster Subunit is defined as south of the Chafee Subunit and the Willow Springs Subunit (not shown on Figure 13) south of the Gloster Subunit. The Chafee and Gloster Subunits are located east of the Randsburg-Mojave fault and south of the Muroc fault, but their boundaries are not well defined. Previous investigation by Stetson (2009) also described the Muroc fault acting as a groundwater barrier and dividing the basin into two subbasins, defined as the "California City Subbasin" north of the Muroc fault and the "Mojave City Subbasin" south of the Muroc fault. Figure 13 shows the boundaries used by Stetson; these boundaries do not conform with the DWR Bulletin 118 boundary for the FVGB.

In contrast to the USGS, DWR Bulletin 118 does not define any subunits in the FVGB. While this GWMP uses the Bulletin 118 boundary for the FVGB, the basin is represented as two subareas with the Muroc fault as a divider. In this way, it is similar to the USGS and other previous studies. The subareas defined for the purpose of this GWMP allows for the assessment of spatial variability and different trends that may potentially exist in groundwater conditions. Specifically, in this GWMP, the portion of the FVGB north of the Muroc fault is referred to as the "Northern FVGB" and the portion south of the Muroc fault is referred to as the "Southern FVGB". This terminology is utilized to differentiate the two subareas defined in the FVGB boundaries for the GWMP from the areas and naming conventions used by the USGS and previous Stetson study (2009). It is important to note that the geographic areas covered by these GWMP terms (Northern and Southern FVGB) are unique to this document. Figure 13 shows the subdivisions used by the USGS and previous Stetson investigation (2009) and those used in this GWMP (the Northern FVGB and Southern FVGB).

[1] Subdivisions of groundwater basins are generally referred to as "subbasins"; whereas in hydrologic studies, the term "subunits" is typically used to define subdivisions.

Figure 12: Location of Faults



4.4 Aquifer Systems

Data and information on the characteristics of the FVGB aquifer system, such as confining conditions (confined or unconfined), transmissivities, hydraulic conductivities, and coefficients of storage, are very limited. According to DWR, groundwater in the alluvium is generally unconfined, although locally confined conditions occur near Koehn Lake (DWR 2004a). This is consistent with interpretations in a previous investigation stating confined layers of sand and gravel, which thin or lens out downslope to impervious clay near playas such as Koehn Lake, produce the largest yields. Historical water level data also indicate a portion of the aquifer system in the FVGB, particularly in the vicinity of Koehn Lake, is under confined conditions. Results of a pump test, which was conducted in the Cinco area, suggest that the aquifer in that area is limited to semi-confined conditions.

4.5 Water Bearing Formations

Older alluvium constitutes the principal aquifer and underlies most of the valley floor. Older alluvium consists of poorly to moderately consolidated alluvial fan and stream channel deposits characterized by moderately to poorly sorted gravel, sand, and silt of Pleistocene (Quaternary) geologic age. DWR reports the alluvium is about 1,190 feet along the margins of the basin and thins toward the middle of the basin (Bader 1969, DWR 1964).

Water-bearing formations in the Southern FVGB at the surface of the Chafee Subunit consist primarily of older and younger alluvium (Richard C. Slade & Associates 1995). Most of the younger alluvium is above the water table and has a reported maximum thickness of 150 feet - 200 feet. Younger alluvium consists of alluvium, playa clay, and windblown sand of Holocene (Quaternary) geologic age. It is commonly described as yellow to brown clay, sandy clay, or silt with gravel lenses. The older alluvium appears to have a maximum thickness of about 550 feet - 650 feet in the Chaffee subunit and does not appear to extend to a depth greater than about 800 feet in the Chafee Subunit. Water wells in this area produce from the older alluvium and Pliocene sediments. Based on the cross-sections along the longitudinal axis of the FVGB, the thickness of the unconsolidated deposits in the Southern FVGB varies from approximately 280 feet south of the Muroc fault to 800 feet at the Muroc fault (Stetson 2009). MPUD wells in this area have depths ranging from approximately 350 feet to 800 feet.

North of the Muroc fault in the California City Subunit, a tertiary geologic unit also appears to yield groundwater. The thickness of the alluvium in the Northern FVGB was reported to range from 400 feet to 800 feet near Koehn Lake (USGS 1977). Based on the cross-sections along the longitudinal axis of the FVGB, the thickness of the unconsolidated deposits in the Northern FVGB varies from approximately 700 feet at the Muroc fault to 800 feet in the vicinity of Koehn Lake and then pinches out at the northern tip near US 395 (Stetson 2009). The City's wells, located north of the Muroc fault, have depths ranging from approximately 550 feet to 810 feet. In the area northwest of Koehn Lake, wells drilled to depths of 800 feet bgs did not encounter consolidated rocks. Previous investigations indicated the depth to water in the Southern FVGB varied from over 300 feet bgs in the alluvial fan areas along the Tehachapi Mountains to less than 150 feet bgs along the low hills between the Soledad Mountains and the Radio Tower Hills. The depth to water in the Northern FVGB varied more drastically from near or above the ground surface in the vicinity of Koehn Lake to over 600 feet bgs near the Muroc fault (Stetson 2009).

4.6 Soils

Soil data for the Plan area were obtained from the U.S. Department of Agricultural (USDA) SSURGO and STATSGO2 databases. Data are discussed based on hydrologic soil groups and saturated hydraulic conductivity as shown Figure 14 and Figure 15. Hydrologic soil groups are assigned based on measured rainfall, runoff potential, and infiltration. According to the data, most soils in the Plan area are either group A or group D with small areas of group B and group C, as described below:

Group A soils have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The saturated hydraulic conductivity of all soil layers exceeds 40 micrometers per second (5.67 inches per hour).

Group B soils have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have 10 percent to 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The saturated conductivity in the least transmissive layer between the surface and 50 centimeters (20 inches) ranges from 10 micrometers per second (1.42 inches per hour) to 40 micrometers per second (5.67 inches per hour).

Group C soils have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters (20 inches) is between 1.0 micrometers per second (0.14 inches per hour) and 10 micrometers per second (1.42 inches per hour).

Group D soils have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters (20 inches) and all soils with a water table within 60 centimeters (24 inches) of the surface are in this group. For soils with a water impermeable layer at a depth between 50 centimeters and 100 centimeters (20 and 40 inches), the saturated hydraulic conductivity in the least transmissive soil layer is less than or equal to 1.0 micrometers per second (0.14 inches per hour). For soils that are deeper than 100 centimeters (40 inches) to a restriction or water table, the saturated hydraulic conductivity of all soil layers within 100 centimeters (40 inches) of the surface is less than or equal to 0.40 micrometers per second (0.06 inches per hour).

As shown in Figure 14 and Figure 15, overall, areas that are assigned group A correlate well with areas of highest saturated hydraulic conductivity. In contrary, areas that are assigned group D correlate well with areas with lower saturated hydraulic conductivity. Areas with soils in group A and higher saturated hydraulic conductivities are more likely to be the potential recharge areas for the underlying groundwater basin.

Figure 13: Subunits and Subbasins

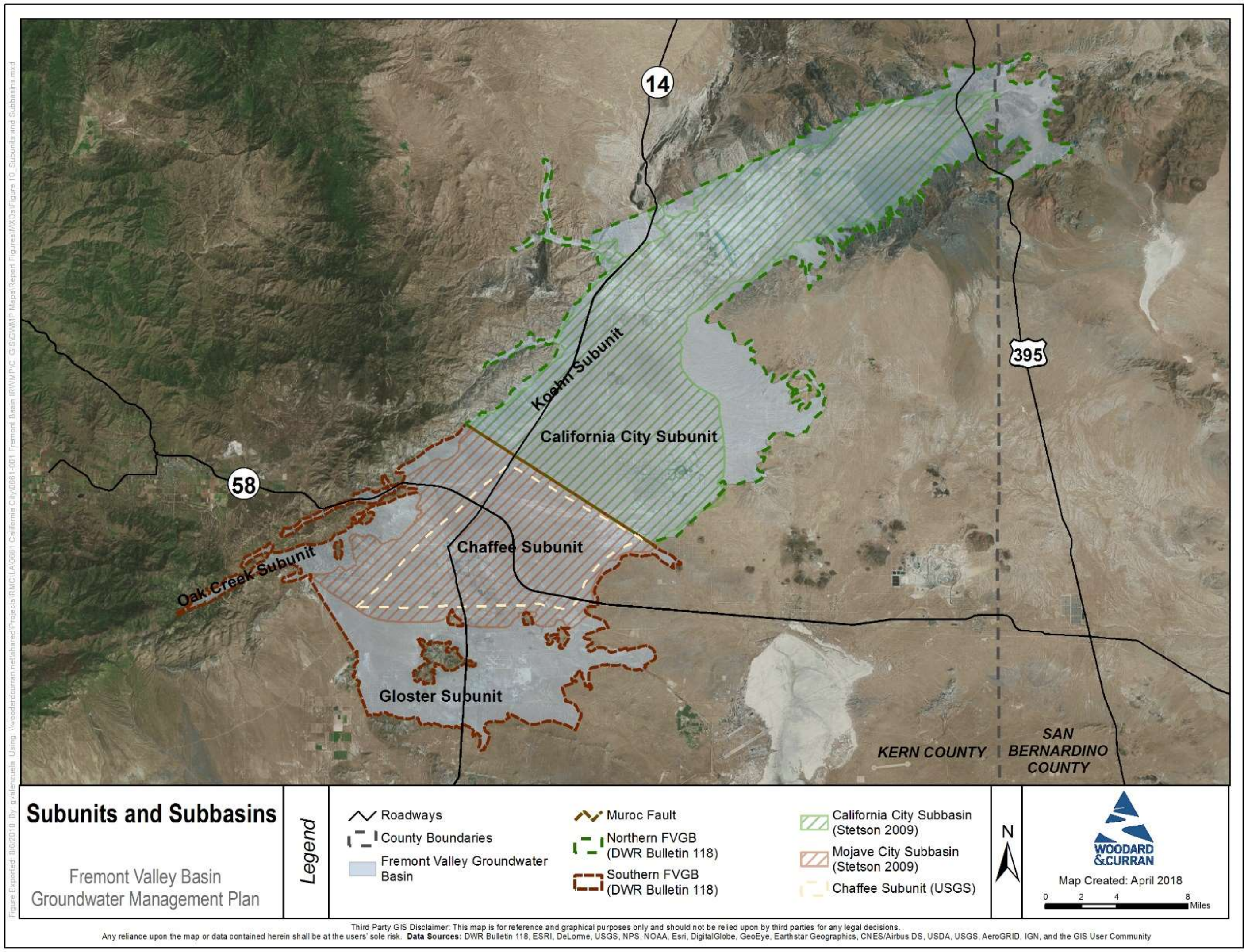


Figure 14: Hydrologic Soil Groups

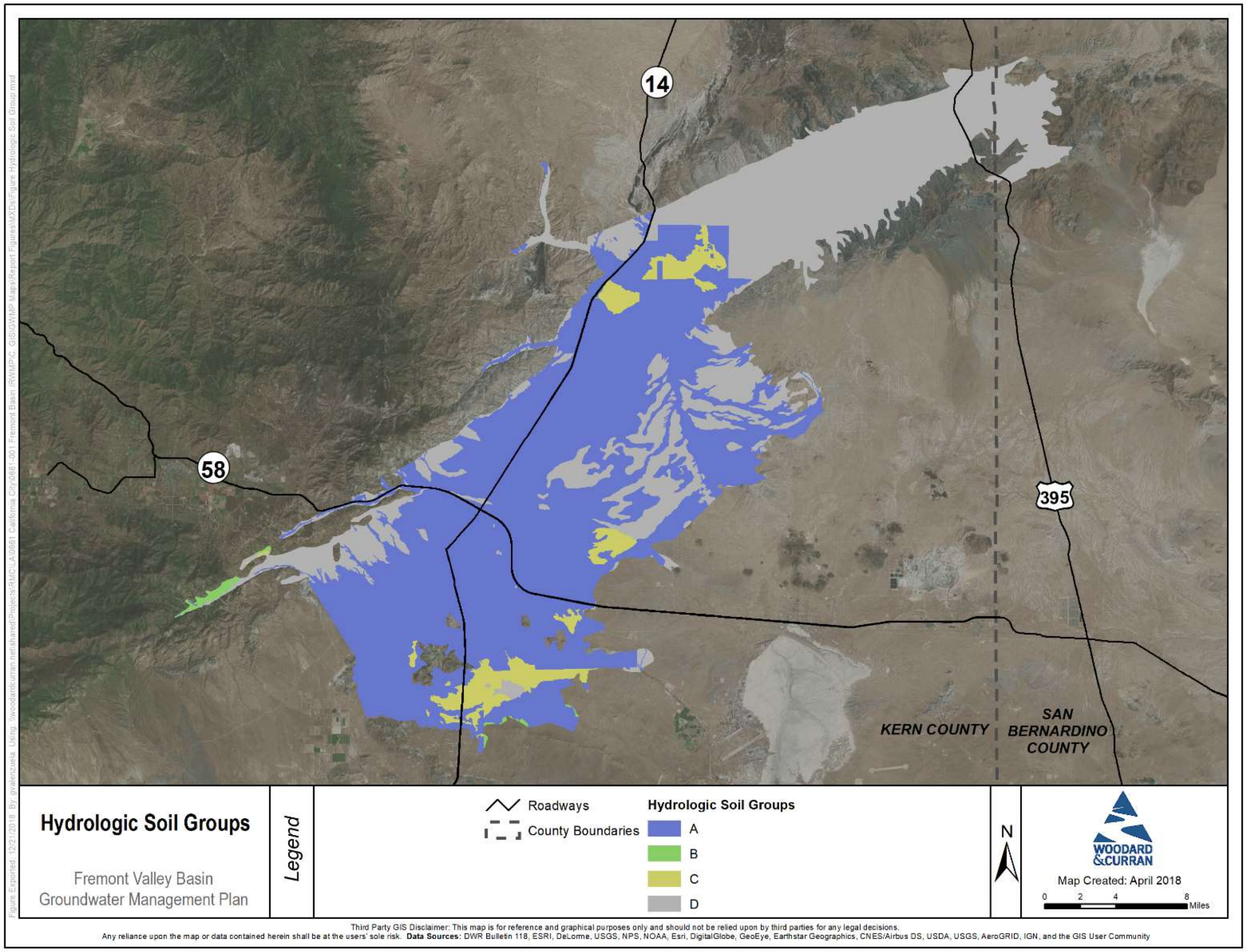
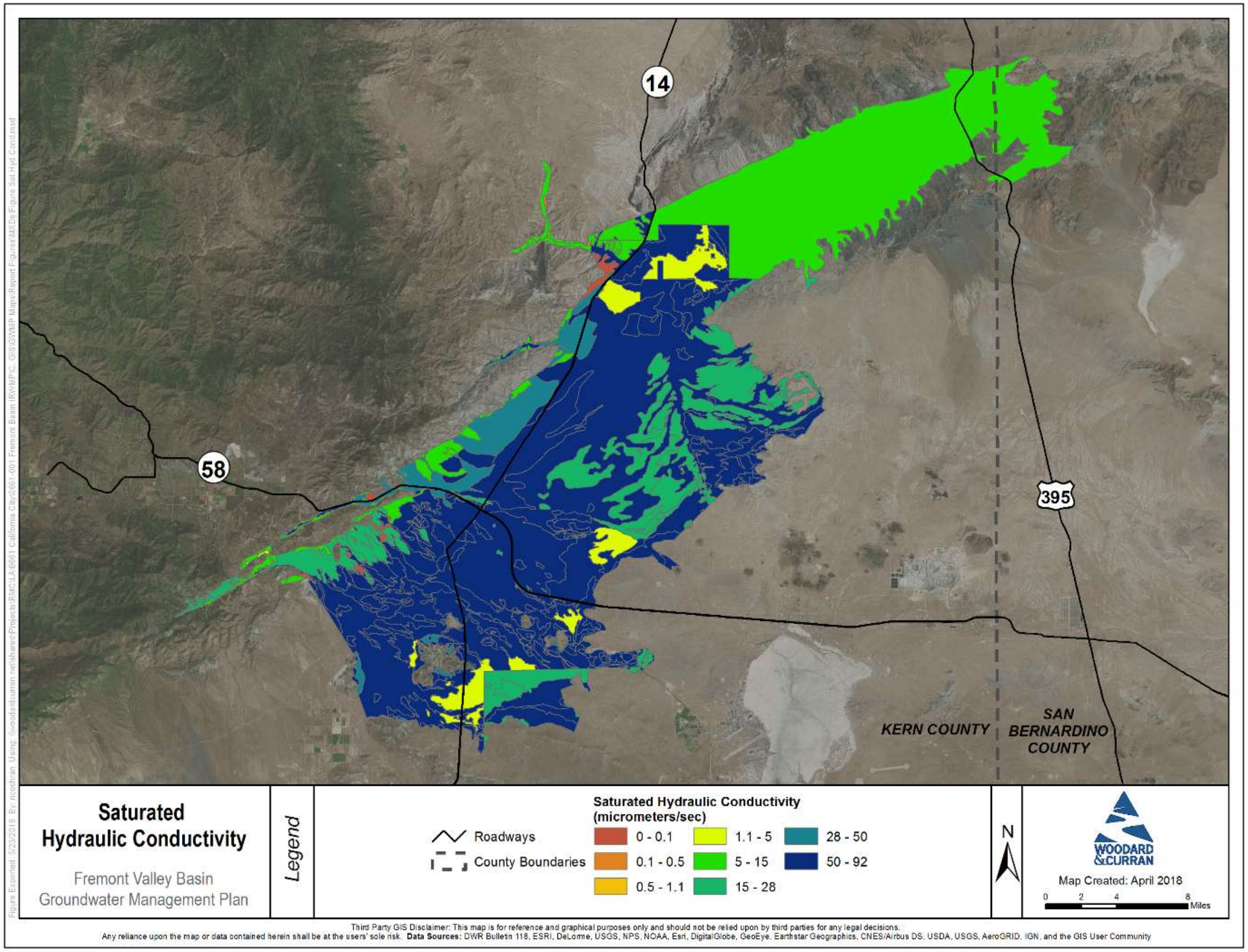


Figure 15: Saturated Hydraulic Conductivity



4.7 Surface Water Hydrology

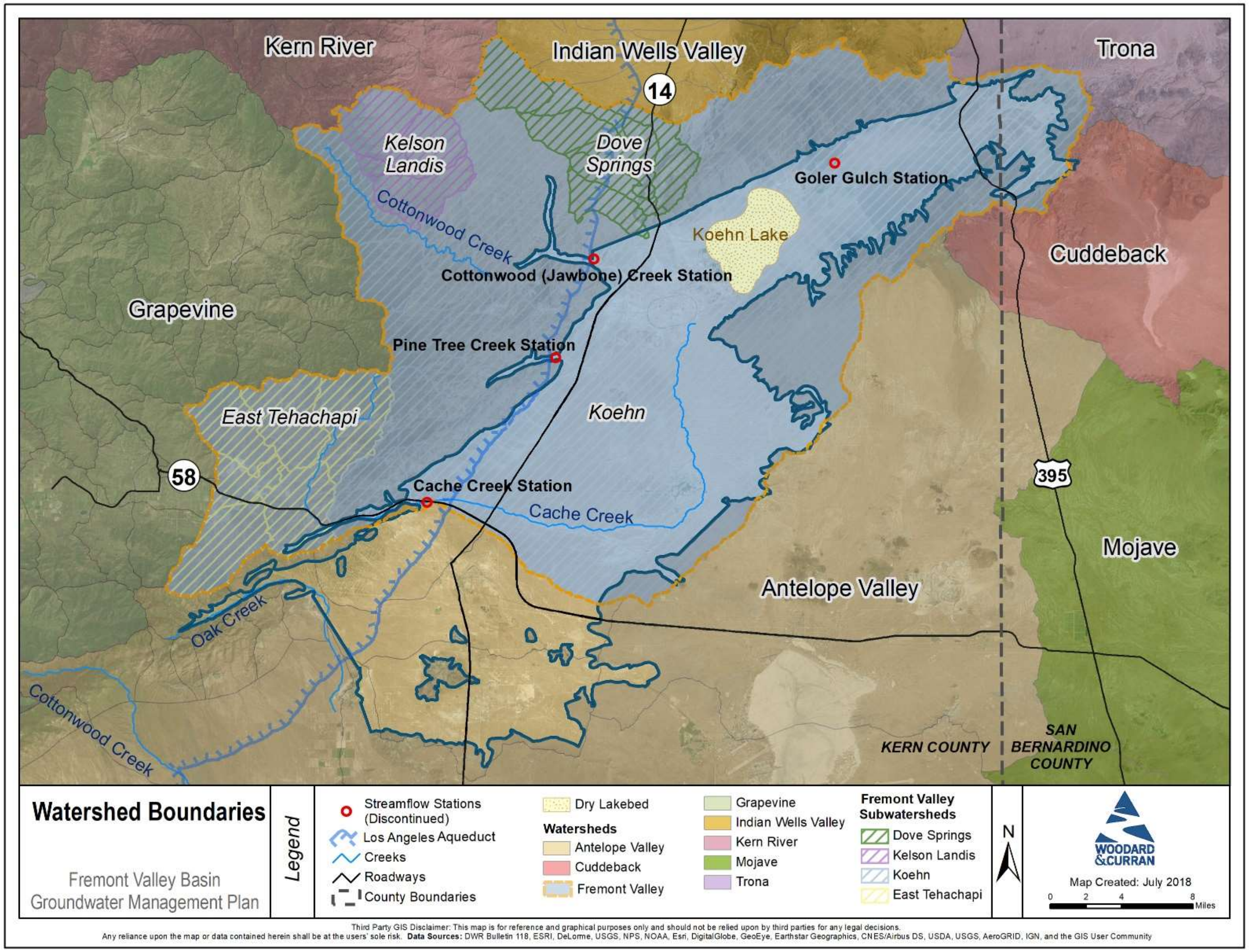
The Fremont Valley watershed overlays majority of the Plan area as shown in Figure 16. The Plan area is surrounded by the Antelope Valley watershed to the south and the Grapevine, Kern River, Indian Wells, and Trona watersheds to the north. The Fremont Valley watershed is part of the larger Antelope-Fremont Valleys watershed (Hydrologic Unit Code 18090206). The subwatersheds of the Fremont Valley watershed include the Koehn, East Tehachapi, Kelson Landis, and Dove Springs subwatersheds.

The Fremont Valley watershed is a dry, closed basin area surrounded by mountain ranges that receives surface water runoff from Pine Tree Canyon, Cache Creek, and other ridges adjacent to the area, including a significant drainage from the El Paso Mountains area. Surface runoff drains from the surrounding mountains and valley to Koehn Lake, a dry lake bed where the water either evaporates or percolates into the ground. The dry lake bed is located north of the City of California City and is the lowest topographical location in the basin, with a bed elevation of approximately 1,880 feet above msl. In addition to natural surface water features, the Los Angeles Aqueduct passes through the Plan area as a subterranean pipe. These surface water features are also shown in Figure 16.

The USGS established several streamflow stations in the Fremont Valley watershed on the Oak Creek, Cache Creek, Pine Tree Creek, Cottonwood Creek, and Goler Gulch (Figure 16). However, operation of these stations was discontinued. Available data indicate that the Fremont Valley may receive significant runoff from its watershed during wet years (Stetson 2009). Annual runoff at these streamflow stations based on historical data are as follows:

- Annual runoff at the Oak Creek Station from 1957 to 1986 varied from zero to 7,071 AFY at an average of 889 AFY. At the Cache Creek Station, annual runoff from 1962 to 1972 varied from zero to 270 AFY at an average of 80 AFY.
- Annual runoff at the Pine Tree Creek Station from 1958 to 1979 varied from zero to 1,557 AFY at an average of 179 AFY.
- Annual runoff from 1966 to 1972 at the Cottonwood Creek Station varied from zero to 97 AFY at an average of 40 AFY.
- Annual runoff at the Goler Gulch Station from 1966 to 1972 varied from zero to 46 AFY at an average of 12 AFY.

Figure 16: Watershed Boundaries



4.8 Groundwater Conditions

Historical and current groundwater conditions for general groundwater flow directions, groundwater levels, and groundwater storage are described in the following sections.

4.8.1 Groundwater Flow

There are two distinct directions of groundwater flow within the FVGB that have been reported by DWR Bulletin 118. In the southwestern part of the basin, groundwater flows from near Oak Creek northward toward the town of Mojave and continues under the surface drainage divide toward Koehn Lake (located in the northwestern part of the basin). The FVGB internally drains to the area below Koehn Lake. Figure 17, Figure 18, and Figure 19 show groundwater elevation contour maps representing spring 1990, spring 2010, and spring 2017 conditions, respectively. Overall, the general direction of groundwater flow in each of the contour maps is toward Koehn Lake, consistent with the DWR description. The most recent groundwater levels in the 2017 groundwater elevation contour map tend to be lower than the 1990 and 2010 levels in the basin.

As reported in the 1977 USGS study on the Koehn Lake area, groundwater moved from all directions toward Koehn Lake in 1958. A small pumping depression was reported five miles southeast of Koehn Lake because of increased agricultural pumping. Near Koehn Lake, irrigated acres increased from 4,100 acres in 1965 to 9,900 acres in 1976 for growing alfalfa. As pumping for irrigation increased in this area in 1976, the groundwater gradient from Koehn Lake toward a pumping depression increased. This condition caused concern about the possibility of saline water from under Koehn Lake migrating to the less saline areas. This condition has not occurred as there was a sharp decline in groundwater pumping as a result of reduction in agriculture after 1976. The groundwater elevation contour maps in Figure 17, Figure 18, and Figure 19 show that the lowest groundwater levels are observed near Koehn Lake, topographically the lowest point in the FVGB.

The Muroc fault acts as a partial groundwater barrier, which impedes but does not prevent the northerly movement of groundwater toward Koehn Lake. As mentioned above, the subsurface flow across the Muroc fault is reported to occur only when groundwater levels in the south of Muroc fault is higher than an elevation of approximately 2,420 feet msl, based on historical water levels near the Muroc fault, to allow groundwater to overflow the groundwater barrier created by the fault.

Figure 17: Spring 1990 Groundwater Elevation Contours

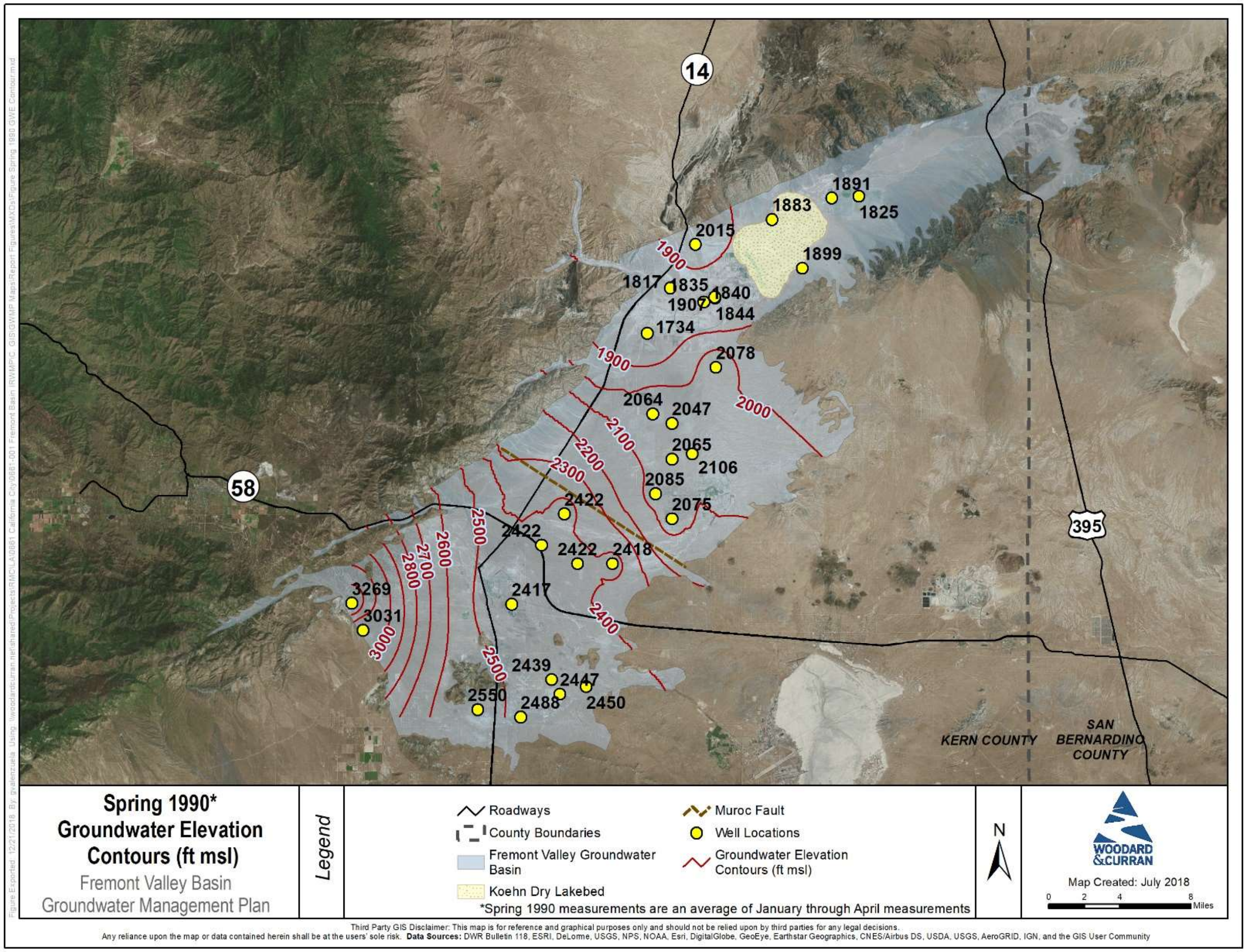


Figure 18: Spring 2010 Groundwater Elevation Contours

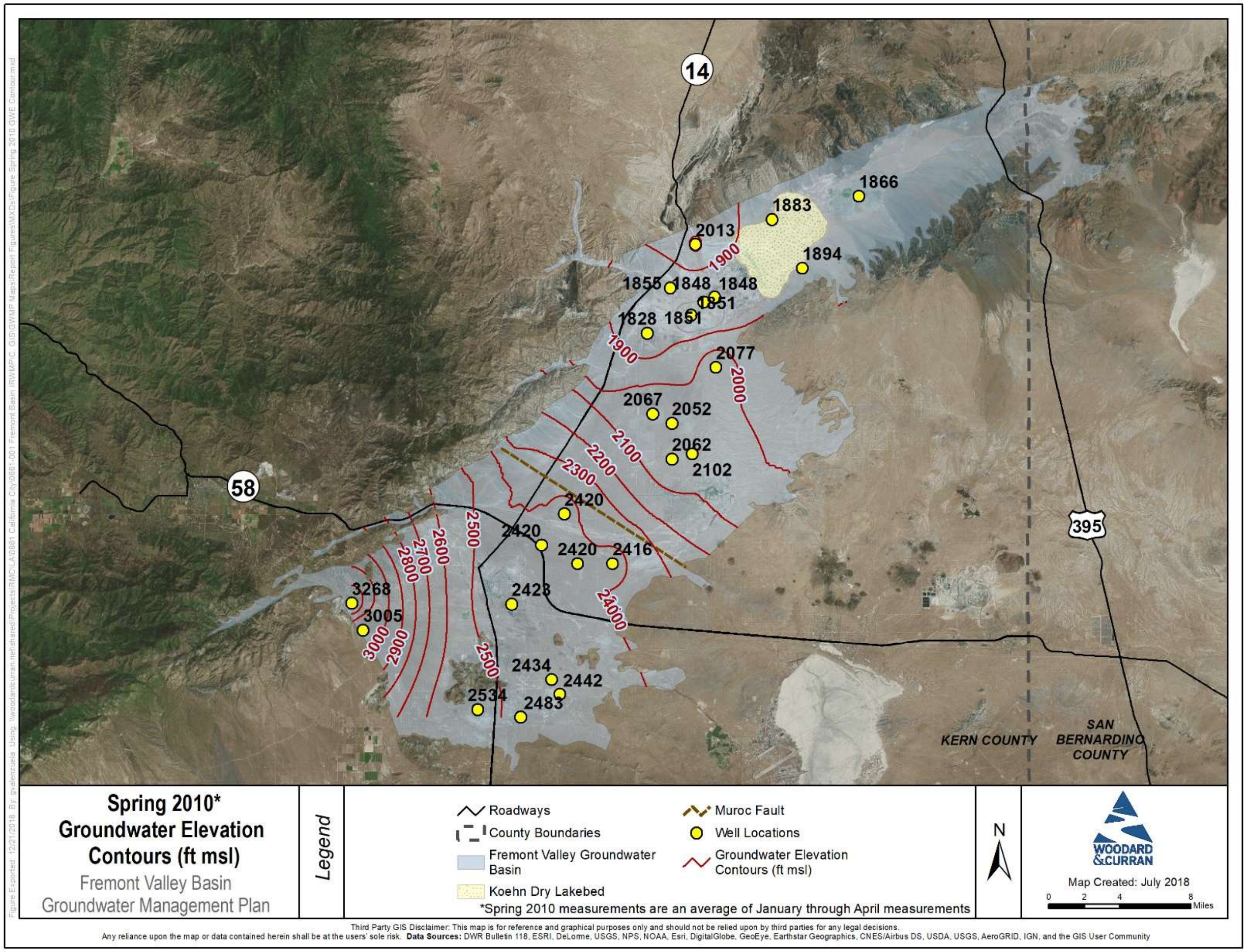
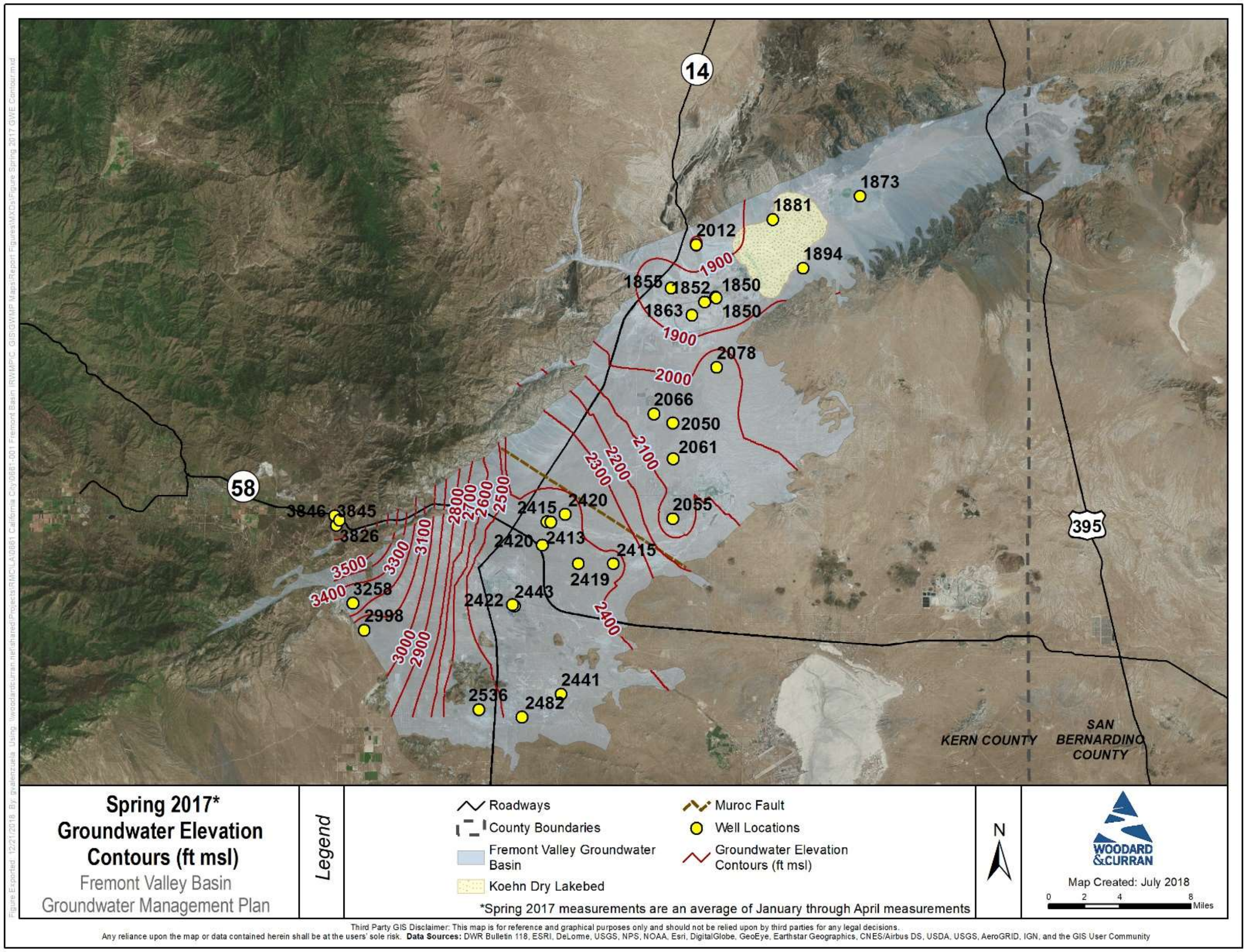


Figure 19: Spring 2017 Groundwater Elevation Contours



4.8.2 Groundwater Levels

Long-term trends in groundwater levels are described based on available data compiled from public databases and public agencies. Groundwater monitoring for groundwater levels in the FVGB occurs on a voluntary basis by the USGS, public and private entities. A summary of collected groundwater level data is presented in Table 5. Locations of wells with data in the Plan area are shown in Figure 20. Figure 21 shows well locations with data based on various data sources.

Table 5: Groundwater Level Data Summary

Reporting Agency	Number of Wells with Data[1]
California City[2]	7
MPUD	10
CASGEM	248
USGS	38
Kern County	55

Notes: (1) Reported number of wells is greater than unique number of wells because in some cases duplicate information was reported from different agencies. (2) Six California City wells are reported by USGS (Well 3 [USGS 351264N1179857W001]; Well 4 [USGS 350829117590201]; Well 5 [USGS 250919117590301]; Well 11 [USGS 350627117583201]; Well 14 [USGS 351411N1180043W001]; Well 15 {USGS 351169N1179863W001]). Well 10 had data unique to the Stetson report.

Long-term groundwater level data indicate that the groundwater levels in the FVGB have declined significantly since 1955, probably due to the prolonged drought period from 1945 to 1964 and increased groundwater extractions in the late 1950s through the 1970s. Twelve groundwater hydrographs are presented in Figure 22 as representative examples of trends seen in the basin based on available historical water level data. Data collected for groundwater elevation analysis included the publicly-available CASGEM Program and USGS databases. Additional data were acquired from MPUD and Kern County agencies and from a 2009 Evaluation of Groundwater Resources report conducted by Stetson for the City.

In the Southern FVGB, south of the Muroc fault, hydrographs generally show the highest levels in the late 1950s, prior to the start of pumping by MPUD in 1960. Representative groundwater hydrographs showing similar trends include wells 12N12W35R001S, 11N11W09A001S, and 32S36E35D001M. Groundwater levels declined gradually until approximately 1968, when water levels began to decline at a greater rate. This appears to coincide with MPUD production increasing from about 200 AFY - 300 AFY prior to 1968 to between 500 AFY and 900 AFY through 1980. Around 1980, water levels continued to decline but at a much lower rate. This decrease in rate of decline appears to coincide with decreased pumping by MPUD when AVEK imported water deliveries became available in 1980. Groundwater levels increased in this area after 1974, possibly due to a reduction in irrigation pumping in the area (10N12W13H001S). Hydrographs for the wells in the northern portion of the Southern FVGB show no obvious responses to significant precipitation events, such as the above-average rainfall from 1977 to 1984. Historical water level trends are quite different further south in the Southern FVGB where water levels showed increasing trends after 1975, as shown in the hydrographs for wells 11N12W26J001S and 11N12W22F002S. Well 11NR12W26J001S is located on or adjacent to the former Jameson Ranch and its hydrograph indicates sharp declines from 1960 through 1970. Following the apparent cessation of Jameson Ranch pumping at the end of 1970, water levels rose sharply between 1971 and 1974 and then gradually after 1974. While the USGS discontinued monitoring this well after 1987, hydrographs for well 11N12W22F002S (near unused MPUD well No. 31) shows that water levels are still rising slowly in the vicinity of the former ranch. This rising trend is inconsistent with the declining trends in the majority of the Southern

FVGB and could be due to a slow recovery from the cessation of agricultural pumping and/or due to the local effects of recharging wastewater treatment plant effluent.

Groundwater levels in the Northern FVGB, north of the Muroc fault, have been declining since approximately 1965 or 1970, and trends have varied more drastically compared to the Southern FVGB. Similar to the Southern FVGB, there is an apparent trend of rising groundwater levels after AVEK deliveries began in 1980. Groundwater levels at the City's Well No.2 (32S37E22N001M, destroyed in 1994) declined over 100 feet by the mid-1950s, reportedly due to irrigation pumping (Richard C. Slade & Associates 1995). By the mid-1960s, water levels had risen over 100 feet to near their pre-pumping levels. Water level increases observed from 1980 to1984 appear to correlate to AVEK deliveries beginning in 1980 and could also be attributed to the recharge effects of the 1977 - 1984 period of above-average precipitation. After 1984, water levels continued to decline, which was coincident with a reduction in AVEK deliveries (approximately 890 AFY - 1900 AFY for 1980 - 1984 reduced to approximately 50 AFY - 250 AFY for 1985 - 1990) and with a six-year period of below average precipitation in Mojave between 1985 and 1991.

The hydrograph for well 29S39E33K001M, which is located north of Koehn Lake, indicates a decline in groundwater levels of about 110 feet between 1976 and 1984. The water level in this well stabilized between 1985 and 1996 and has recovered about 70 feet since 1996, as shown on Figure 22. The hydrograph for well 30S38E24F001M, located near Koehn Lake, has historically shown a gradual decrease in groundwater levels but water levels appear to stabilize since early 2000. The hydrograph for well 30S37E36G001M, which is located in the central portion of the FVGB just south of Koehn Lake, indicates a decline of approximately 105 feet between 1953 and 1985. The groundwater level in this well appeared to stabilize between 1985 and 1995 and recovered approximately 17 feet since 1996. The hydrograph for well 31S37E35N001M, which is located in the south-central portion of the FVGB, just north of the California City, indicates a decline of approximately 28 feet between 1953 and 1980. The water level in this well appeared to stabilize between 1980 and 1991; then it recovered slightly and has been relatively stable in recent years. The hydrograph for well 32S37E26N001M (California City's Well No.1) indicates a decline of approximately 20 feet between 1961 and 1978. The water level in this well recovered approximately 14 feet between 1978 and 1984 and then declined approximately 35 feet after 1984.

Review of historical and recent water levels at the wells within the FVGB do not appear to confirm the hydrogeologic effects of the faults in the area, except for the Muroc fault. The significant difference in the water levels in wells 32S36E22C001M (reported as 2,110 feet msl in January 1958) and 32S36E21Q001M (reported as 2,429 feet msl in January 1958), which are located approximately 1.3 miles across the Muroc fault, confirm the hydrogeologic effects of this fault.

Figure 20: Locations of Wells with Groundwater Elevation Data

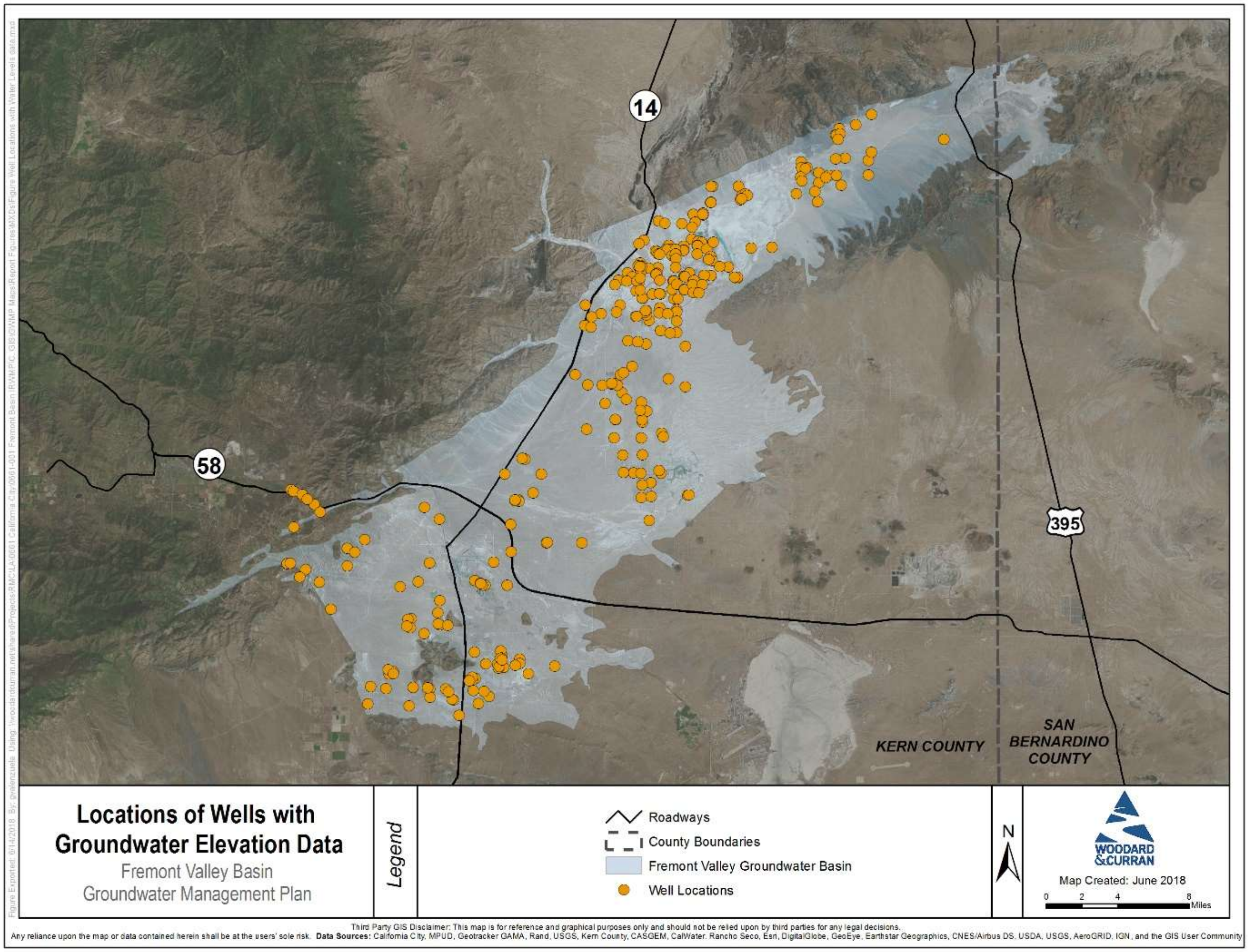


Figure 21: Data Source for Wells with Groundwater Elevation Data

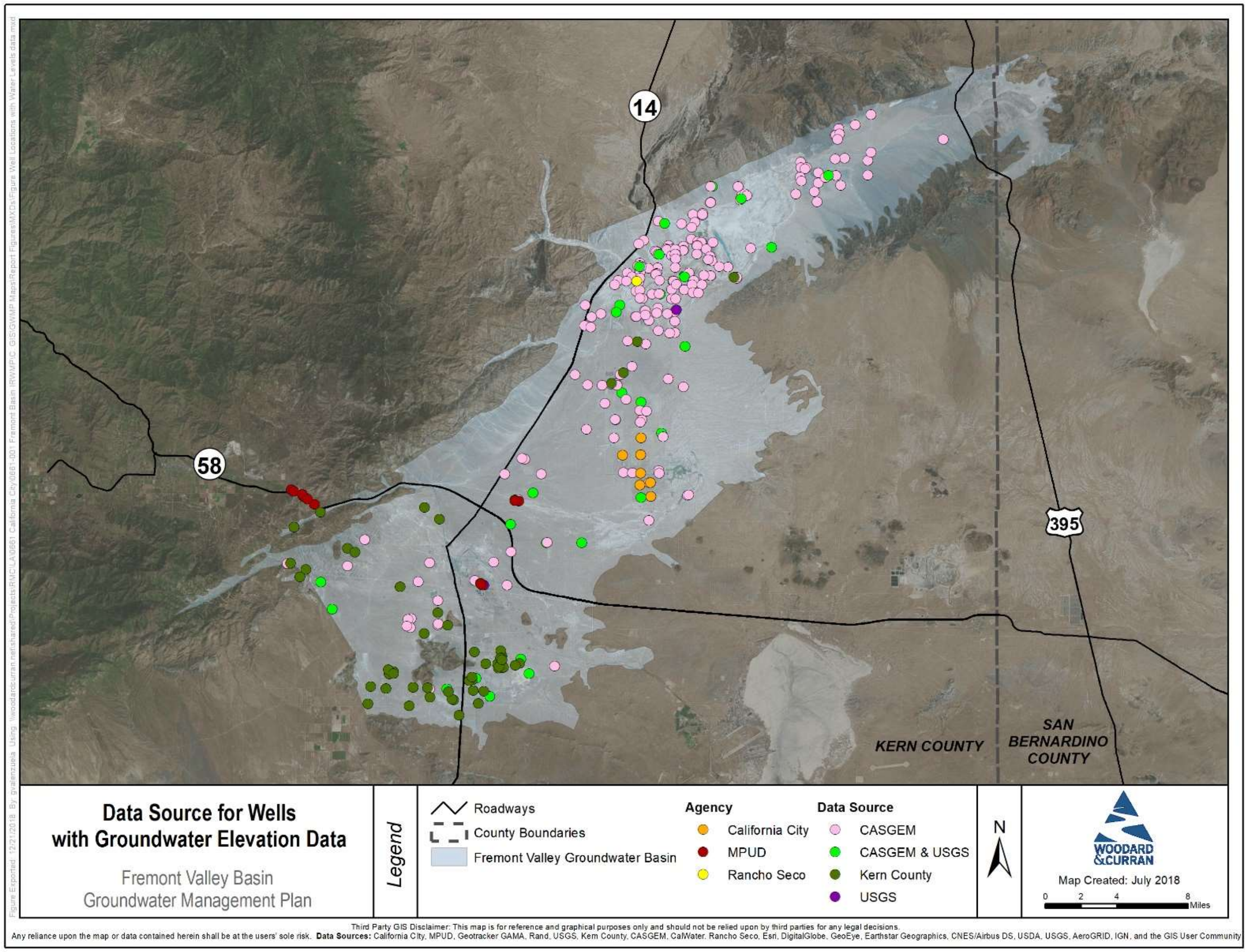


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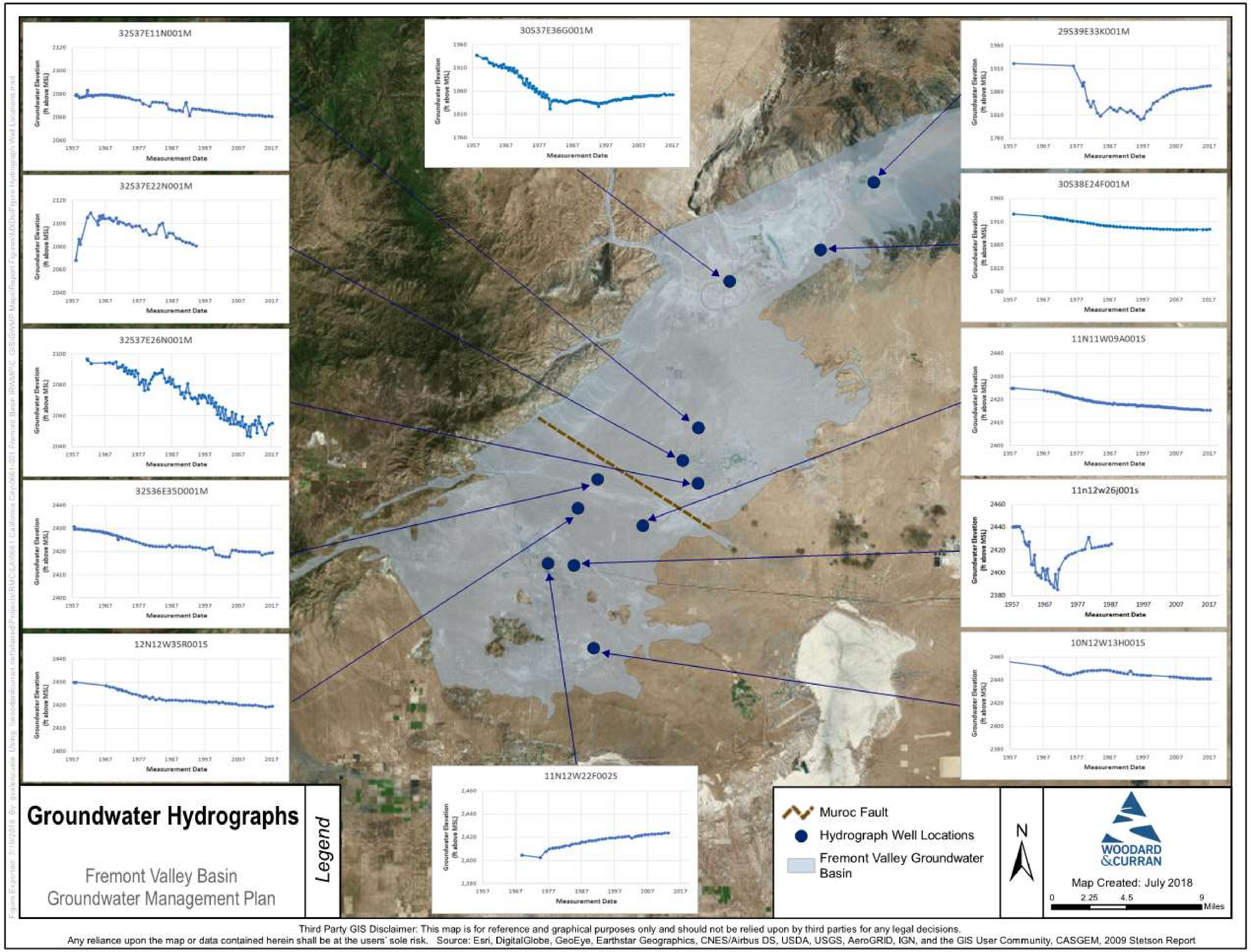
Figure 22: Groundwater Hydrographs



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4.8.3 Groundwater Storage

Different estimates of groundwater storage are reported for the FVGB or portions of the basin. DWR reports a storage capacity of 4.8 million acre-feet (MAF), though the amount of groundwater in storage is currently unknown. Groundwater storage was reported to be 4.1 MAF in 1976 based on a USGS study (USGS 1977). A recent investigation by Stetson (2009) estimated the groundwater storage for the Mojave City and California City Subbasins at approximately 5.66 MAF and 2.62 MAF, respectively. Groundwater storage under Koehn Lake, above the 500 feet depth, was estimated to be approximately 2 MAF by USGS (1977).

4.8.3.1 Change in Groundwater Storage

Change in groundwater storage for the FVGB was estimated as part of this GWMP based on the difference in subsequent groundwater elevation contours. Groundwater elevations were contoured for selected years between 1958 and 2017 and contour maps were compared to calculate the change in groundwater elevations and resulting change in groundwater storage. Total storage change was estimated as -738,100 AF for the FVGB, including -608,300 AF for the Northern FVGB and -129,800 AF for the Southern FVGB. The negative change indicates a decline in groundwater storage, and this trend is consistent with the generally declining trends seen in groundwater levels as described above. Figure 23 shows the locations of the wells with groundwater elevation data used for groundwater contouring. Appendix A presents a detailed description of the data sources, methodology used, and results of the change in groundwater storage calculations.

4.8.4 Groundwater Recharge

Natural recharge to the FVGB has two sources: recharge from precipitation to the valley floor and percolation of runoff from mountains and neighboring watersheds. As the runoff migrates over the valley floor, losses occur by evaporation and transpiration. When runoff is intense, some of the water reaches Koehn Lake. Infrequent runoff reaches as far as Koehn Lake, in the northeastern part of the FVGB or the other small playas throughout the basin. Because the lake bed is nearly impermeable, most of the water is ponded and lost to evaporation (USGS 1977). Recharge also occurs from underflow in the creek channels that emanate from the mountains. There is no appreciable quantity of groundwater flowing out of the basin and surface drainage of the basin is of the closed type. As discussed in Section 4.6, areas with soils in group A (Figure 14) and higher saturated hydraulic conductivities (Figure 15) are more likely to be the potential recharge areas for the underlying groundwater basin.

4.8.4.1 Groundwater Balance Model

A simplified, spreadsheet-based groundwater balance model was developed for this GWMP to estimate an annual average recharge to the FVGB. The model estimates inflows, outflows, and resulting changes in groundwater storage in the FVGB. Due to distinct trends in groundwater levels north and south of the Muroc fault, a separate groundwater balance analysis was performed for the each of the two subareas: the Northern FVGB and the Southern FVGB. Change in storage estimated from the water balance was calibrated against the change in storage estimated from the groundwater elevation contour maps, as discussed above. The calibration was performed to minimize the difference between the change in storage estimated from the water balance analysis and the change in storage estimated from the groundwater elevation contour maps. The water balance analysis was conducted for the years 1945 to 2017, but the groundwater contouring analysis begins in 1958 as groundwater elevation data prior to 1958 were sparse or lacking.

Based on the calibrated groundwater balance analysis, the average groundwater recharge was estimated as 13,800 AFY[1] for the FVGB, with approximately 11,300 AFY in the Northern FVGB (approximately 80 percent of total) and approximately 2,500 AFY in the Southern FVGB (approximately 20 percent of total). The last 20 years of data (1998-2017) were selected to calculate the average annual recharge as this period reflects a reduction in urban groundwater pumping. The reduction is likely a reflection of AVEK deliveries starting in 1980 and the significant reduction in agricultural pumping after 1976. This period also includes more complete groundwater elevation records and encompasses both hydrologically wet and dry periods, including the most recent years with below average precipitation. Appendix A presents a detailed description of the data sources and the methodology used and the results of the groundwater balance analysis.

4.8.5 Groundwater Quality

California's Groundwater Bulletin 118 characterizes the FVGB as sodium bicarbonate in the southeast, sodium bicarbonate or calcium-sodium sulfate in the southwest, sodium sulfate-bicarbonate to sodium chloride in the north, and complex with variable mixtures of sodium, calcium, chloride, sulfate, and bicarbonate in the central region. These chemical compositions not only affect localized water quality (and therefore, groundwater pumping) but can also influence concentrations throughout the FVGB through groundwater flow resulting from high-volume pumping.

Available groundwater quality data were collected from various sources, including the following publicly-available databases: Geotracker Groundwater Ambient Monitoring and Assessment Program (Geotracker-GAMA), USGS, records collected by the City, Kern County Public Health Department (Kern County), MPUD, and RCWD. Data for chemicals of concerns for the FVGB, including total dissolved solids (TDS), nitrate, arsenic, boron, chloride and hexavalent chromium (chromium-6), were compiled and analyzed to present spatial and temporal trends of the data. A summary of the collected data for these constituents is presented in Table 6. Datasets from different sources were compared and wells were matched by their USGS identification numbers; duplicate reports were identified and omitted to the extent possible. The reported number of wells is greater than the unique number of wells because, in some cases, duplicate information was reported from different agencies.

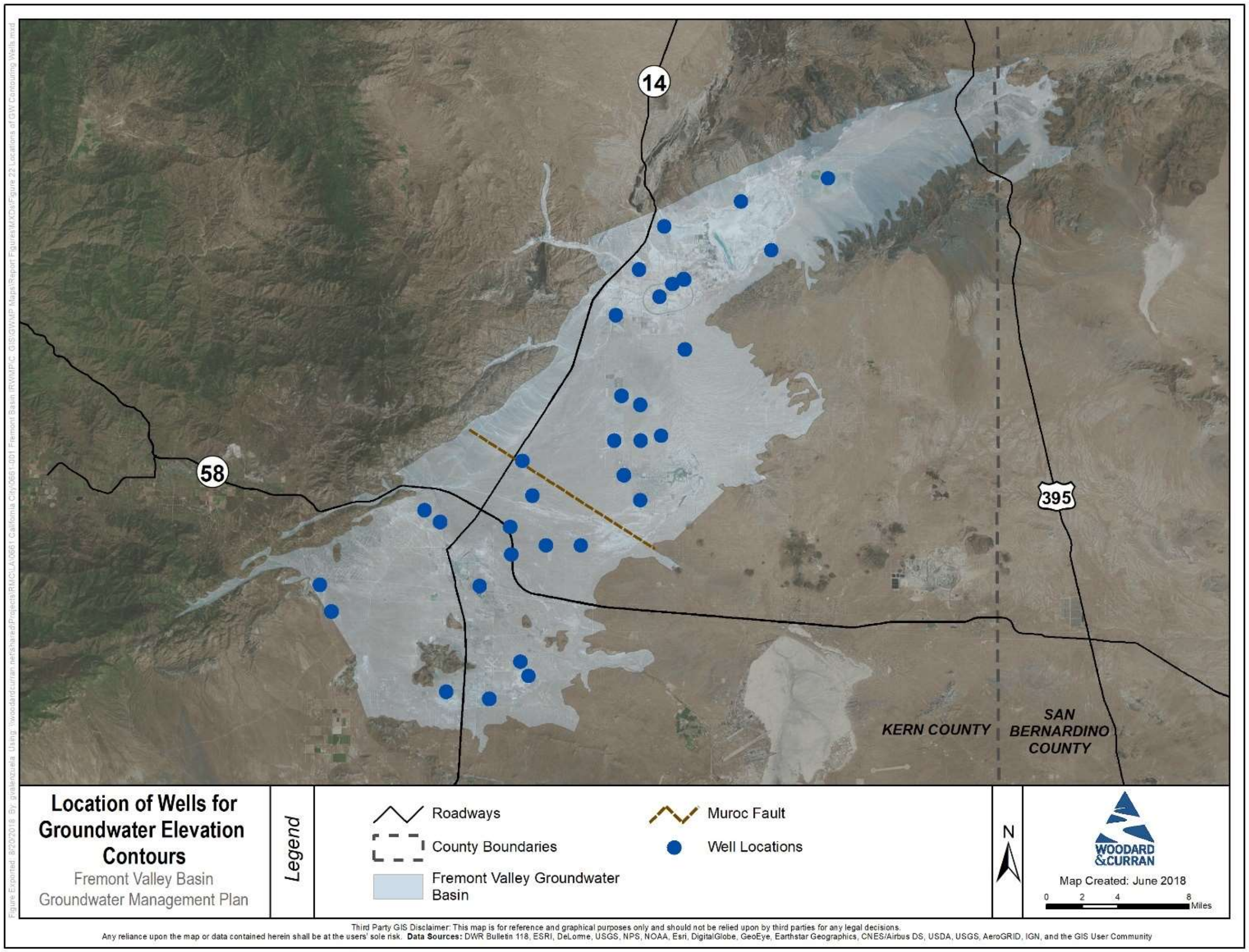
Table 6: Groundwater Quality Data Summary

Reporting Agency	Total Dissolved Solids (TDS)	Nitrate (as N)	Arsenic	Boron	Chloride	Hexavalent Chromium (Chromium-6)
California City	4	7	6	4	6	3
MPUD	6	6	6	2	6	6
Geotracker-GAMA	162	151	86	149	181	28
USGS	8	7	4	9	6	4
Kern County	N/A	76	76	N/A	76	N/A
RCWD	1	3	3	1	1	N/A

Note: Reported number of wells is greater than unique number of wells because, in some cases, duplicate information was reported from different agencies. The unique number of wells with data is estimated to be 166 for TDS, 236 for nitrate-N, 166 for arsenic, 154 for boron, 254 for chloride, and 32 for chromium-6.

[1] This recharge estimate is higher than the 1977 USGS recharge estimate which noted a local groundwater recharge of 10,200 AFY. The difference in the recharge estimates is primarily due to the different basin footprint used in the USGS analysis.

Figure 23: Location of Wells for Groundwater Elevation Contours



4.8.5.1 Basin Plan Water Quality Objectives

The FVGB is under the jurisdiction of the LRWQCB. The Basin Plan (SWRCB 2015) establishes water quality standards for surface water and groundwater of the region based upon designated uses of water and numerical objectives that must be maintained to protect beneficial uses. The designated beneficial uses for the FVGB include MUN, AGR, IND, and FRSH, as described in Section 3. Basin-specific water quality objectives for the FVGB are not identified in the Basin Plan. Water quality objectives which apply to all groundwaters in the Basin Plan apply to the FVGB. Per the Basin Plan, groundwater designated as MUN shall not contain concentrations of chemical constituents in excess of the maximum contaminant level (MCL) or secondary MCL (SMCL) based upon drinking water standards specified in the Title 22 of the California Code of Regulations. Water designated as AGR shall not contain concentrations of chemical constituents in amounts that adversely affect the water for beneficial uses for agricultural purposes. The numerical water quality objectives for groundwater in the FVGB are summarized in Table 7 for chemicals of concern in the basin.

Table 7: Water Quality Objectives for Groundwater in Fremont Valley Groundwater Basin

Constituent	Contaminant Limit
TDS	500 – 1000 – 1,500 mg/L[1]
Nitrate	10 mg/L[2]
Arsenic	10 µg/L[2]
Chloride	200 – 500 – 600 mg/L[1]
Boron	1,000 µg/L[3]
Hexavalent Chromium	Not applicable [4]

Notes: 1) Recommended MCL – Upper Limit – Short Term; 2) MCL; 3) Notification Level; 4) Chromium-6 is currently regulated with the MCL of 50 micrograms per liter (µg/L) for total chromium. A previously established California MCL of 10 µg/L was invalidated by the Superior Court of Sacramento County on May 31, 2017.

4.8.5.2 Total Dissolved Solids (TDS)

TDS is a measure of all dissolved constituents in water, including organic and suspended solids smaller than 2 micrometers, primarily from rocks and sediments with which the water comes in contact. TDS concentrations in groundwater may also increase due to human activities such as agriculture or other land uses and waste disposal practices. Because of this, TDS is seen as a good initial indicator of overall water quality and, as TDS is conservative (that is, it does not naturally decay or breakdown), concentration trends are often used as a long-term indicator of basin health. As detailed above, groundwater within the basin is characterized by varying mixtures and concentrations of sodium, calcium, chloride, sulfate, bicarbonate, sodium bicarbonate, calcium-sodium sulfate, and sodium chloride that can affect groundwater quality. While no Primary MCL exists for TDS, the SWRCB established an SMCL of 500 milligrams per liter (mg/L) for taste and odor thresholds (Table 7). Of the 169 wells analyzed for this report, 86 wells reported average TDS concentrations above the 500 mg/L SMCL.

Generally, relatively low TDS concentrations (less than 500 mg/L) are observed throughout most of the basin. Figure 24 present the average TDS concentrations of groundwater in wells based on the historical data available. Overall, the average TDS concentration appears to decrease over time with the last five years of the data showing lower average TDS levels than averages over the prior 10, 15, and 20 years. Of the 166 wells analyzed, 86 wells (52 percent) reported average TDS concentrations above the recommended SMCL of 500 mg/L and 24 wells (14 percent) above the upper limit SMCL of 1,000 mg/L. Elevated concentrations above 1,000 mg/L were generally observed around and north of Koehn Lake (Figure 25). Elevated levels of TDS near Koehn Lake were also noted by WR as an impairment to groundwater quality. If the basin experiences overdraft conditions, there is potential for saline water from under Koehn

Lake to migrate into the less saline areas. Overall, the percentage of wells exceeding the upper limit SMCL of 1,000 mg/L is low (14 percent of total number of wells). High concentrations of TDS from the 1950s and 1960s were reported near Koehn Lake, but there are no recent data available for the area.

Figure 26 shows time-concentration plots for TDS within the FVGB from selected wells. Eight wells with available data were selected to represent trends across the basin. Two wells show concentrations that are stable and consistently lower than the 500 mg/L SMCL. Two wells observed concentrations that are near or just below the 500 mg/L SMCL. Four wells show concentrations that exceed the 500 mg/L but generally fall between 500 and 600 mg/L.

TDS concentrations greater than 10,000 mg/L were reported in the dataset based on readings that occurred between 1953 and 1976 from four wells. Concentrations ranged from 13,100 mg/L (reported in 1953) to 100,100 mg/L (reported in 1962). For the purpose of the average TDS concentrations presented in Figure 25, these readings were considered as outliers and were excluded from the dataset. The highest TDS concentration after removal of outliers was 5,700 mg/L (reported in 1953).

Figure 24: Average TDS Concentrations

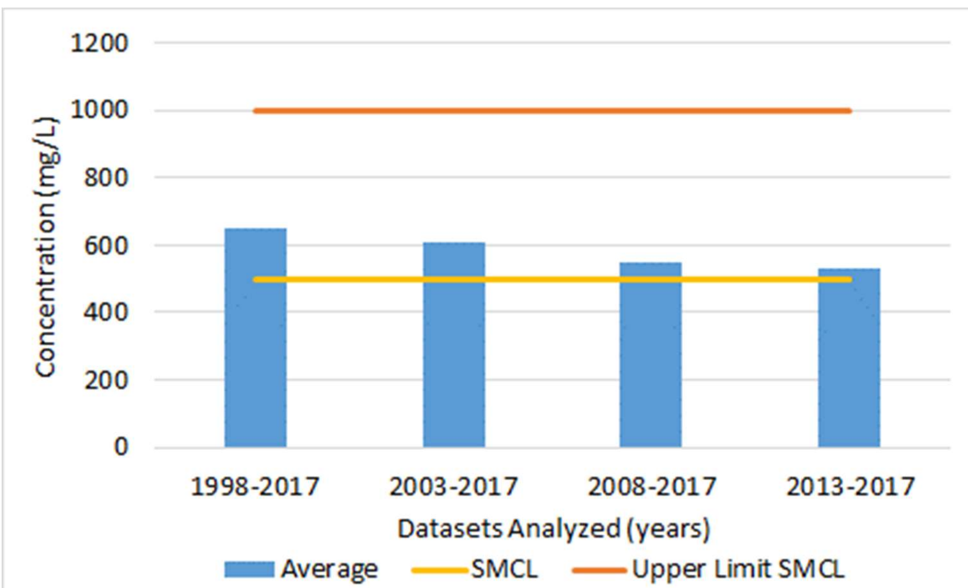


Figure 25: TDS Concentrations

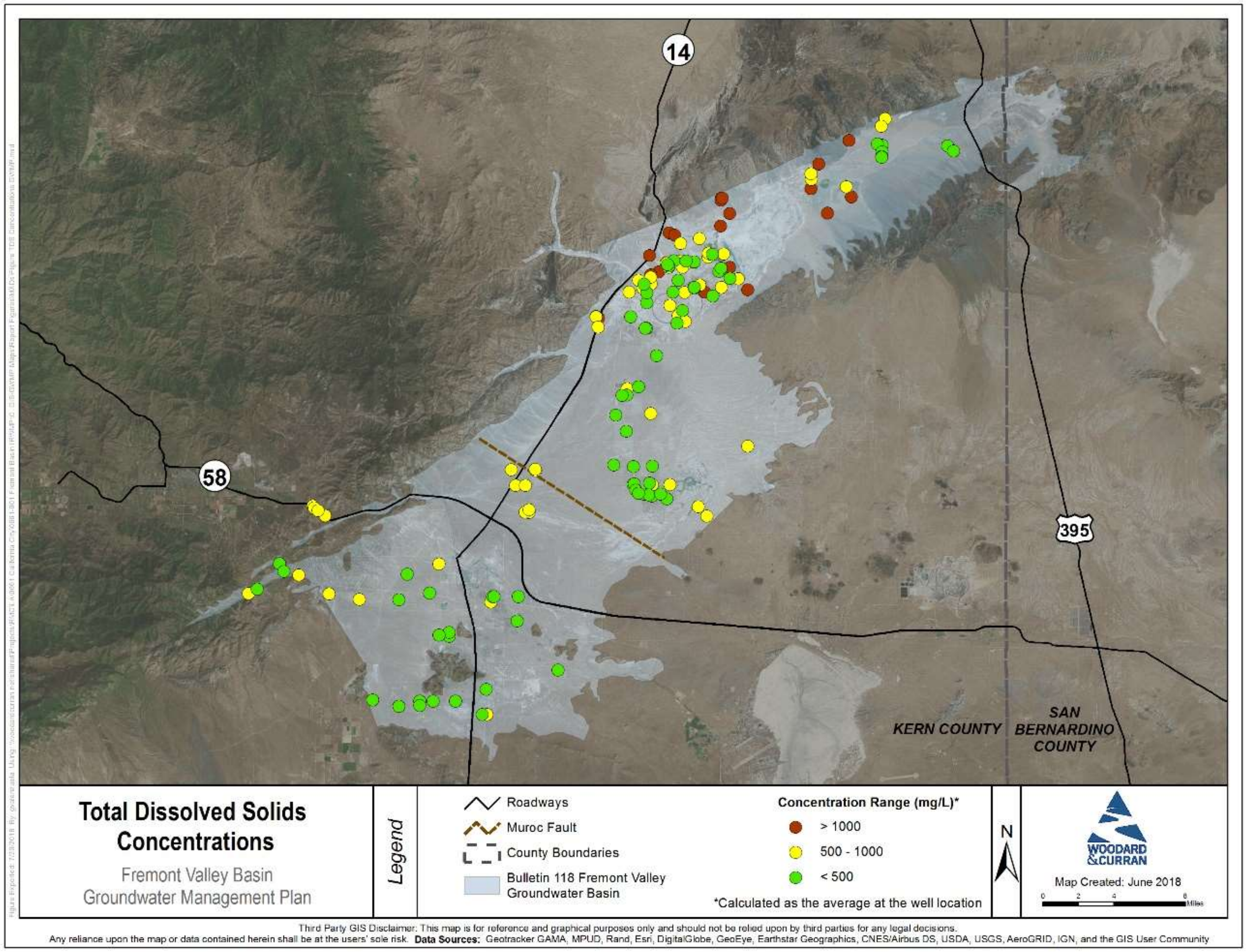
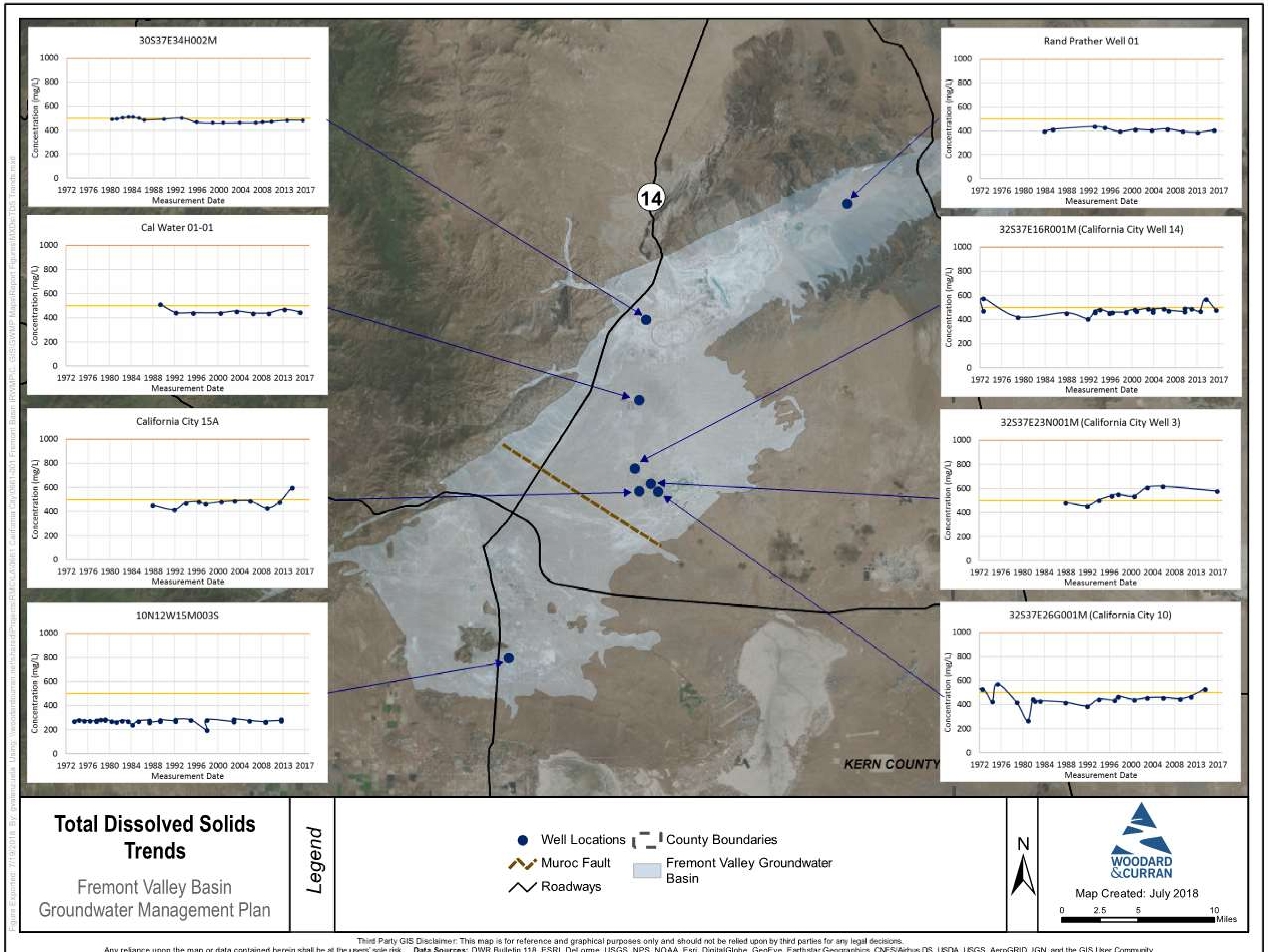


Figure 26: TDS Concentration Trends



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4.8.5.3 Nitrate

Nitrate is a naturally occurring constituent formed when nitrogen-containing organic compounds are broken down in the presence of oxygen. However, elevated concentrations in groundwater are often associated with human activities such as wastewater discharge, fertilizer application and land application of animal wastes. A regulated drinking water contaminant, nitrate has an established California MCL of 10 mg/L as "nitrate as nitrogen" (as N) or 45 mg/L as "nitrate" (NO_3) (Table 7). For the purposes of this GWMP, nitrate has been analyzed as "nitrate as nitrogen".

Nitrate-N concentrations are generally low across the basin with most of the wells at concentrations of nitrate-N below the 10 mg/L MCL. Figure 27 and Figure 28 show average nitrate-N concentrations for wells with available historical data. Overall, the average nitrate-N appears to increase slightly over time with the last five years of the data showing higher average nitrate-N than the data for the last 10, 15, and 20 years. Of the 236 wells analyzed, five wells (2 percent) reported average nitrate-N concentrations above the 10 mg/L MCL. The highest nitrate-N concentration in the dataset was 32.8 mg/L (reported in 1969).

Figure 29 shows time-concentration plots for nitrate-N trends within the FVGB. Eight wells with the most consistent data and spatial distribution were chosen to assess nitrate-N trends. One well shows fluctuations and concentrations exceeding the 10 mg/L MCL. The rest of the wells appear to show concentrations that are generally stable and less than 2 mg/L. Overall, the percentage of wells exceeding the water quality objective of 10 mg/L MCL is very low (2 percent). This small number of exceedances is likely reflective of localized conditions and not a regional, widespread nitrate issue.

Figure 27: Average Nitrate (as N) Concentrations

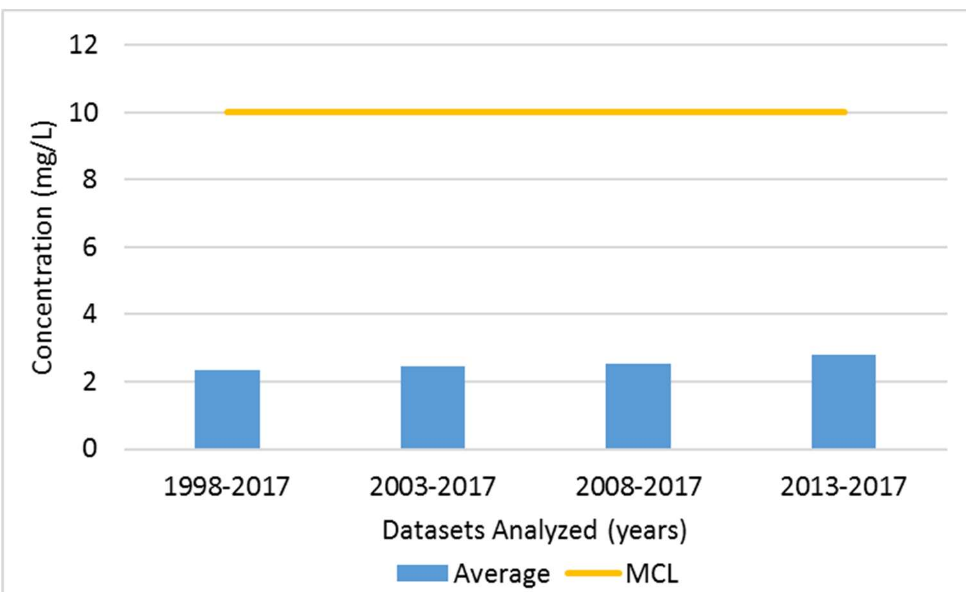


Figure 28: Nitrate (as N) Concentrations

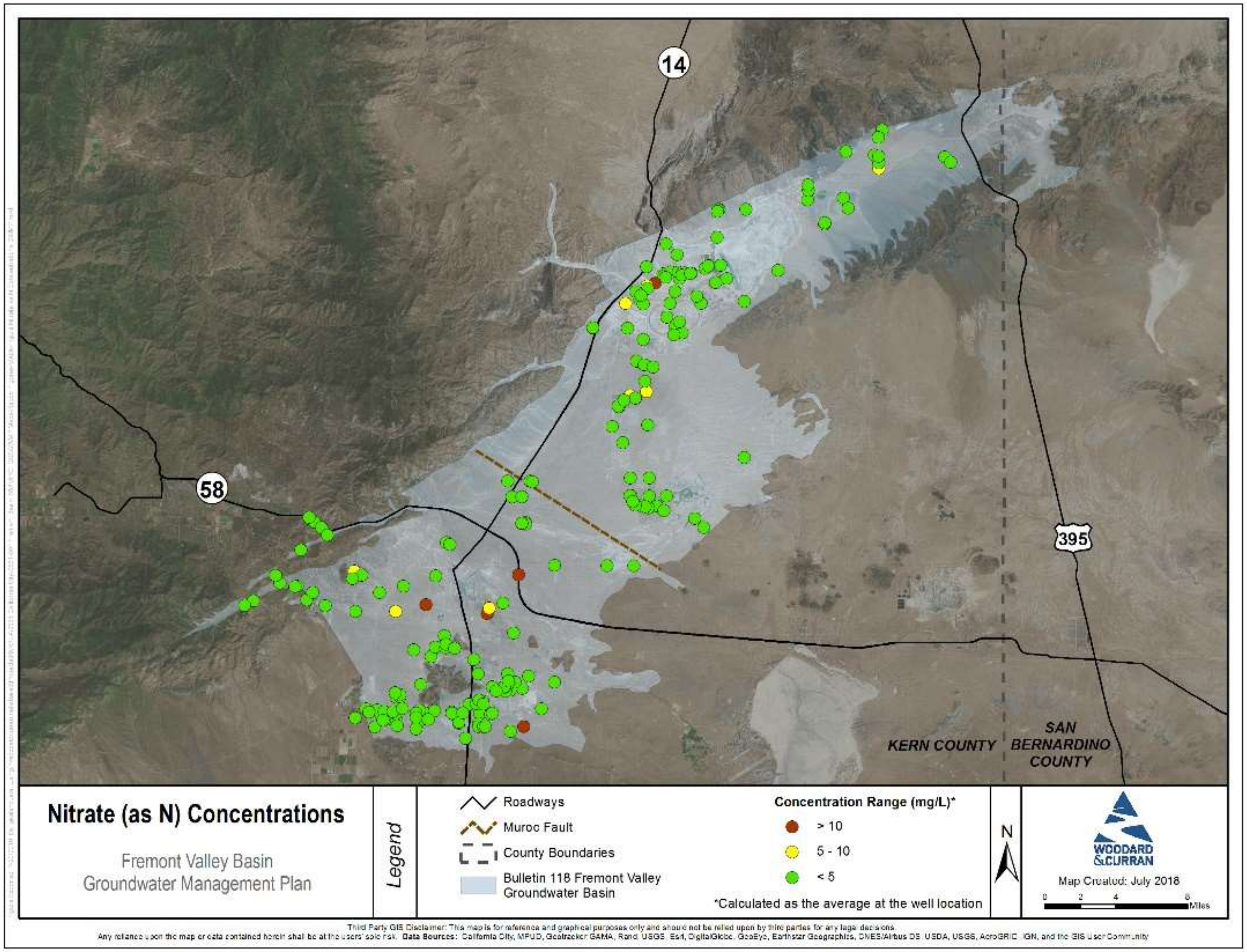
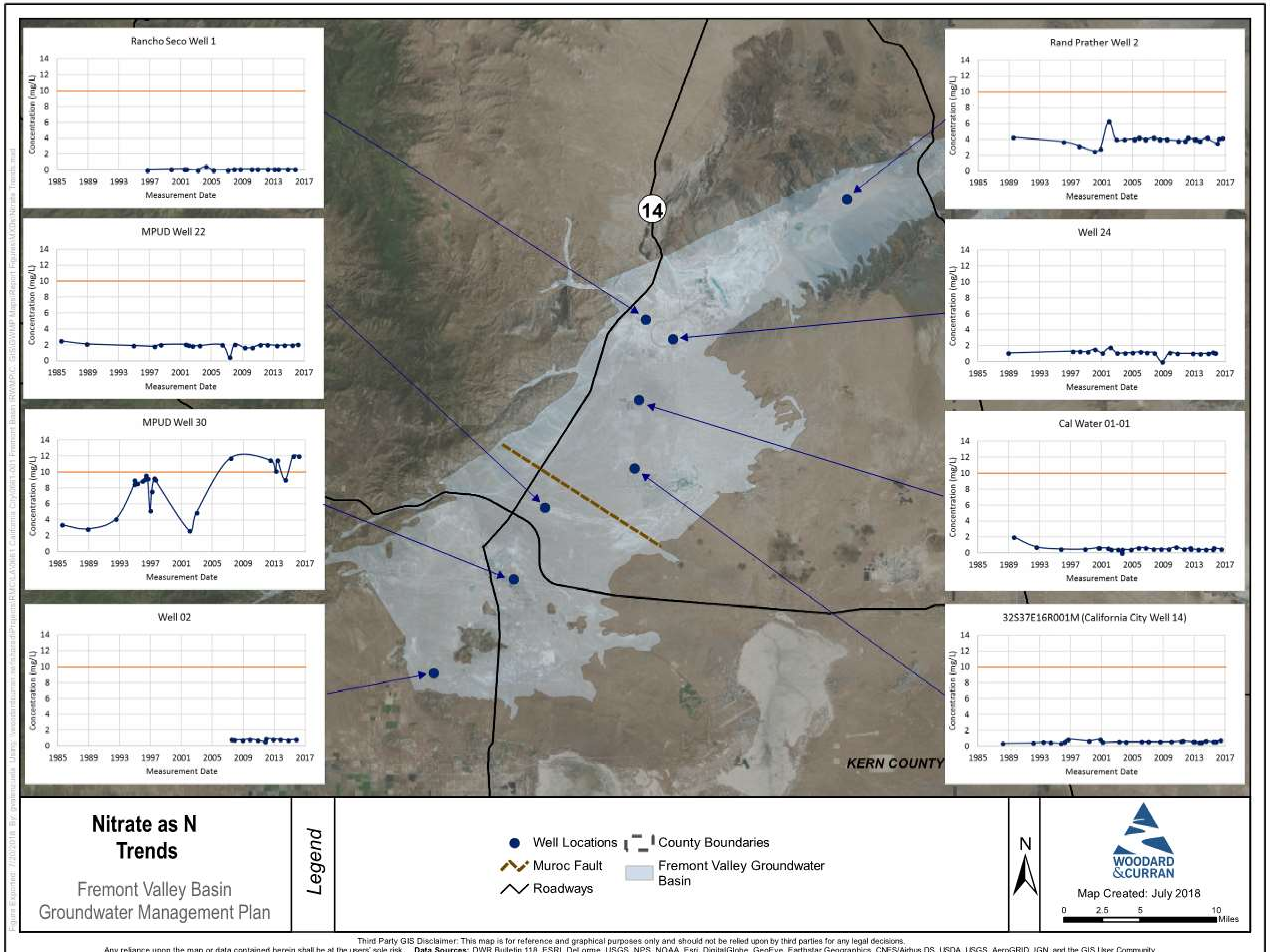


Figure 29: Nitrate (as N) Concentration Trends



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4.8.5.4 Arsenic

Arsenic is an odorless and tasteless semi-metal element that occurs naturally in rocks and soil, water, air, plants, and animals. It enters drinking water supplies from natural deposits in the earth or from agricultural, industrial, and mining practices. Higher levels of arsenic tend to be found more in groundwater sources than in surface water sources. Arsenic can be toxic in high concentrations and is linked to increased risk of cancer when consumed for a lifetime at or above the regulated Primary MCL of 10 micrograms per liter (µg/L) (Table 7). Historical averages of arsenic concentrations in the FVGB generally exceed the 10 µg/L Primary MCL (Figure 30). Of the 166 wells analyzed in the FVGB, 59 wells (36 percent) reported average arsenic concentrations above 10 µg/L (Figure 31).

Though wells with elevated arsenic concentrations are found throughout the FVGB, two hot spots exist in the northeastern and southwestern regions of the FVGB. Figure 32 shows time-concentration plots for arsenic trends within the FVGB. Five wells with the most consistent data and spatial distribution were chosen to assess arsenic trends. Three wells show fluctuations and concentrations exceeding the 10 µg/L MCL. Two wells appear to show concentrations that are generally near or less than 10 µg/L.

Arsenic concentrations greater than 100 µg/L were reported in the dataset based on readings from two wells: one with a single reporting in 1976 and the other well with a single reporting in 1998. Concentrations were 200 µg/L (reported in 1976) and 121 µg/L (reported in 1998). For the purpose of presenting average arsenic concentrations in Figure 32, these readings were considered as outliers and were excluded from the dataset. The highest arsenic concentration after removal of outliers was 99 µg/L (reported in 2017).

Figure 30: Average Arsenic Concentrations

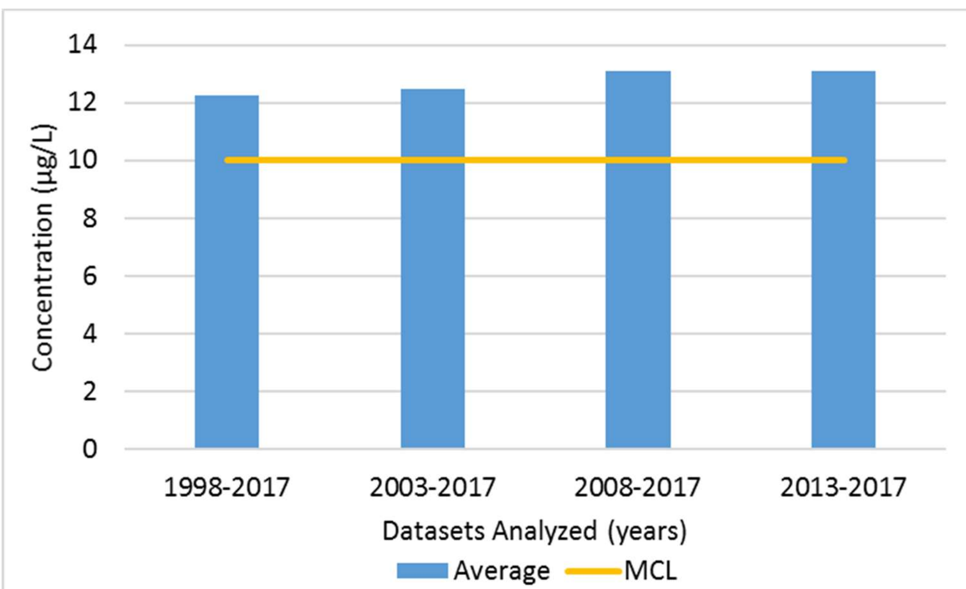


Figure 31: Arsenic Concentrations

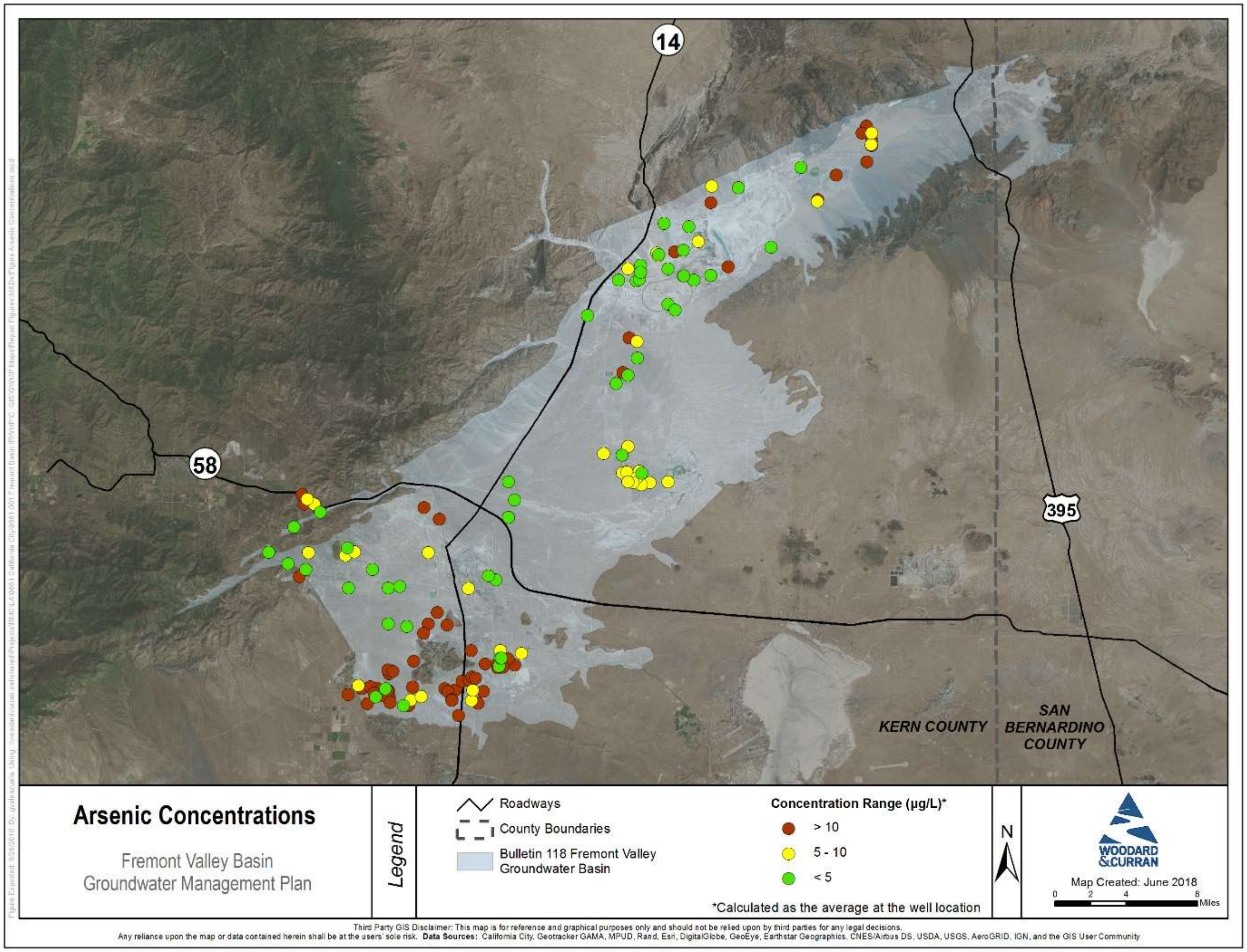
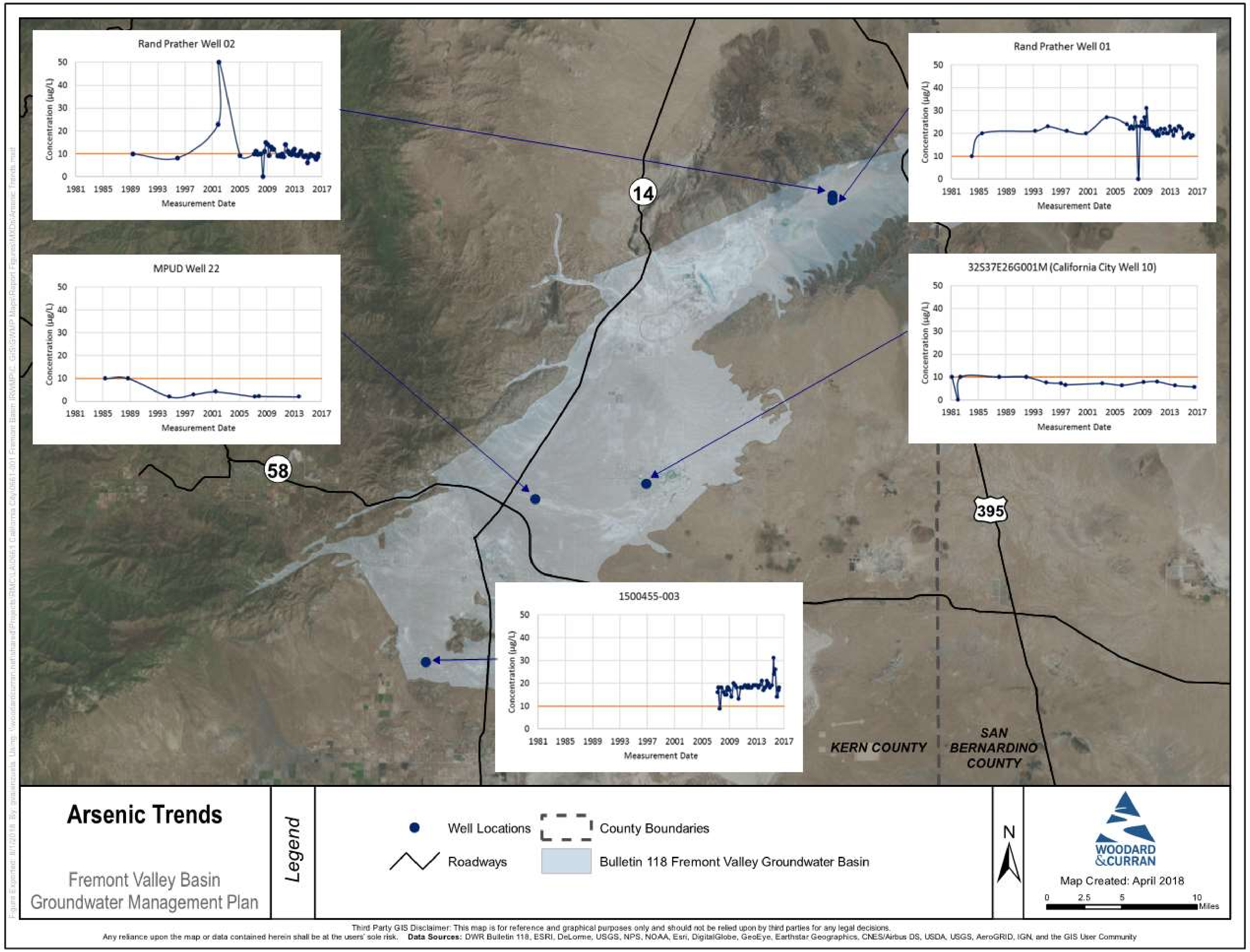


Figure 32: Arsenic Concentration Trends



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4.8.5.5 Boron

Naturally-occurring boron is usually found in sediments and sedimentary rock formations and rarely exists in elemental form. Other forms of boron include boric acid, borax, borax pentahydrate, anhydrous borax, and boron oxide. The principal uses for boron compounds in the United States include glass and ceramics, soaps and detergents, algicides in water treatment, fertilizers, pesticides, flame retardants, and reagents for production of other boron compounds. The major sources of free boron in the environment are exposed minerals containing boron and volcanic material. Anthropogenic inputs of boron to the environment are considered smaller than inputs from natural processes and may include: agriculture, waste and wood burning, power generation using coal and oil, glass product manufacturing, use of borates/perborates in the home and industry, borate mining/processing, leaching of treated wood, and sewage/sludge disposal. Contamination of water can come directly from industrial wastewater and municipal sewage, as well as indirectly from air deposition and soil runoff. Borates in detergents, soaps, and personal care products can also contribute to the presence of boron in water.

Boron does not have an established MCL but does have a California State Notification Level (CA-NL) of 1 mg/L, or 1,000 µg/L (Table 7). Historically, average boron concentrations within the FVG have exceeded the CA-NL. The average boron concentration for the last five years is significantly lower than the average of previous years, mainly because one of the wells with data (30S38E04D002M) had concentrations ranging from 19.8 – 23 mg/L, or 19,800 – 23,000 µg/L between 1980 and 2010. Boron data at this well are unavailable after 2010. As a result, the average boron concentration for the last five years was calculated to be lower, at approximately 526 µg/L, as shown in Figure 33.

Historically, average boron concentrations within the FVGB have exceeded the CA-NL (Figure 33 and Figure 34). Wells with elevated boron levels, including the well 30S38E04D002M, occur primarily in the northern half of the FVGB, particularly surrounding the Koehn dry lakebed. Of the 154 wells analyzed, 38 wells (25 percent) reported average boron concentrations above the 1,000 µg/L CA-NL (Figure 35). Figure 35 shows time-concentration plots for boron trends within the FVGB. Four wells with the most consistent data and spatial distribution were chosen to assess boron trends. Three of the four wells show a decreasing trend near the CA-NL, and the fourth well shows an increasing trend significantly higher than the CA-NL.

Figure 33: Average Boron Concentrations

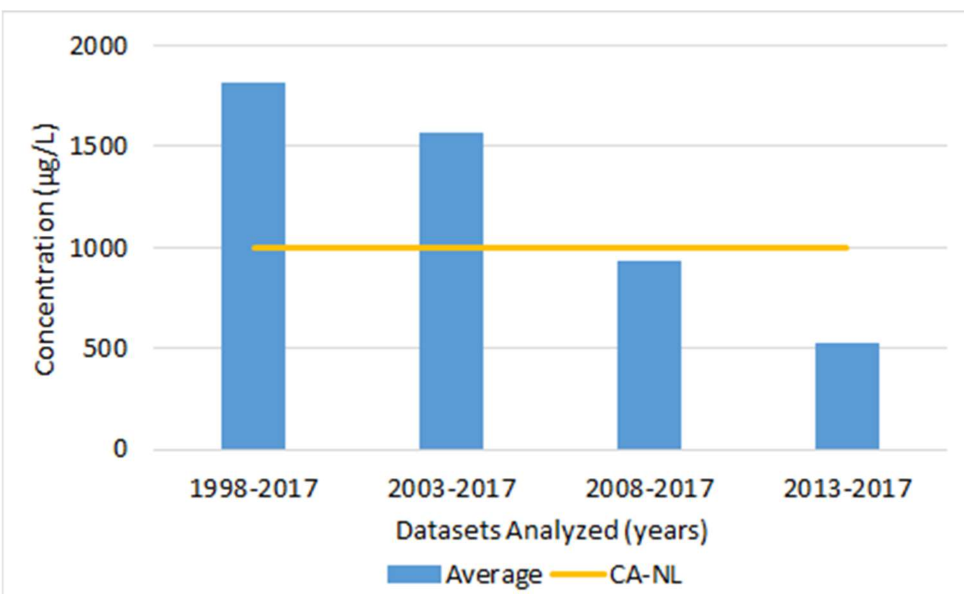


Figure 34: Boron Concentrations

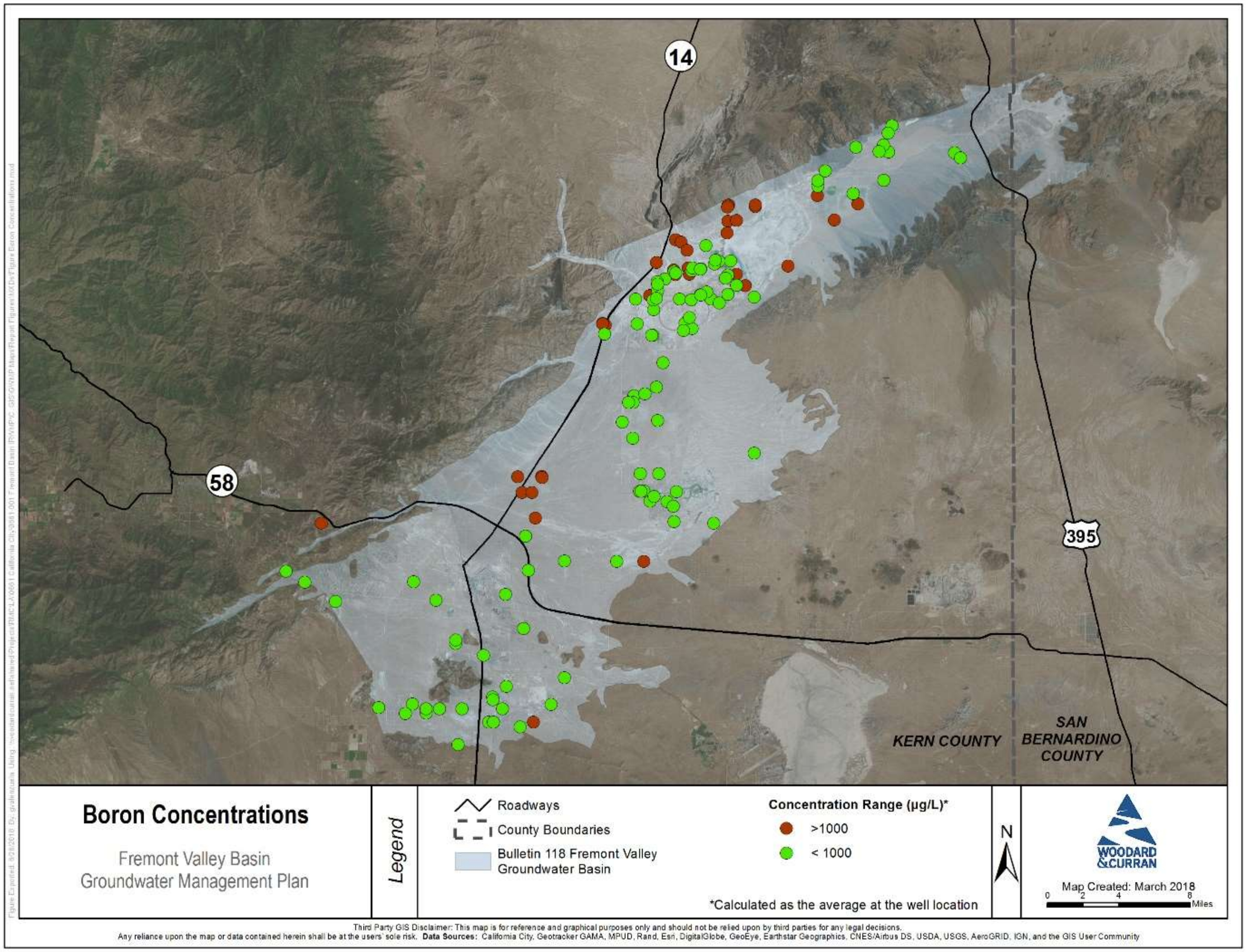
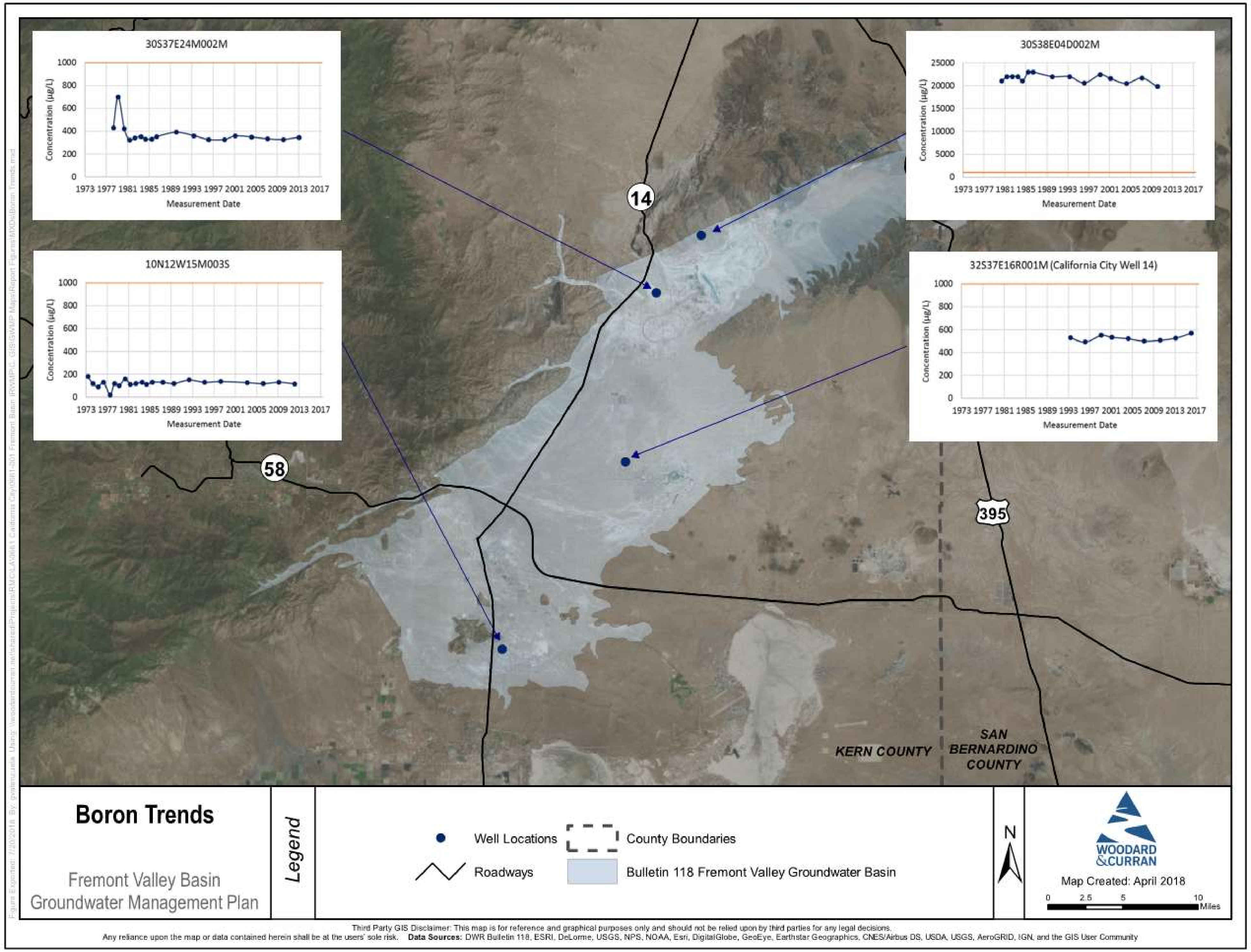


Figure 35: Boron Concentration Trends



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4.8.5.6 Chloride

Chloride is widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$). Chloride in groundwater is naturally occurring from weathering of rocks, negligible atmospheric deposition, and as result of human use and wastes. Sources of chloride from human use include food condiments and preservatives, potash fertilizers, animal feed additives, production of industrial chemicals, dissolution of de-icing salts, and treatment of drinking water and wastewater. Release of brines from industry processes, leaching from landfills and fertilized soils, discharge of wastewater from treatment facilities or septic systems affect chloride in groundwater.

As previously noted, groundwater in the northern part of the FVGB is sodium sulfate-bicarbonate to sodium chloride character, while the central portion is complex with variable mixtures of sodium, calcium, chloride, sulfate, and bicarbonate. While no MCL exists for chloride, the SWRCB established a recommended SMCL of 250 mg/L for taste and odor thresholds, with the upper limit set at 500 mg/L and a short-term limit set at 600 mg/L (Table 7).

DWR's Bulletin 118 designated groundwater near the Koehn dry lakebed as impaired due to elevated chloride levels. Despite these elevated concentrations, historical average chloride concentrations have remained below the SMCL (Figure 36). Of the 254 wells analyzed in the FVGB, 16 wells (6 percent) reported average chloride concentrations above the recommended SMCL of 250 mg/L. In general, chloride concentrations throughout the rest of the basin are low and have been steadily decreasing as shown in the time-concentration plots for chloride within the FVGB in Figure 38. Three of the four analyzed wells show decreasing and stable trends, and the fourth well shows an increasing trend.

Chloride concentrations greater than 1,000 mg/L were reported in the dataset based on readings from nine wells that occurred between 1953 and 1983. Concentrations ranged from 55,800 mg/L (reported in 1962) to 1,200 mg/L (reported in 1983). For the purpose of the average chloride concentrations represented in Figure 38, these readings were considered as outliers and were excluded from the dataset. The highest chloride concentration after removal of outliers was 980 mg/L (reported in 1983).

Figure 36: Average Chloride Concentrations

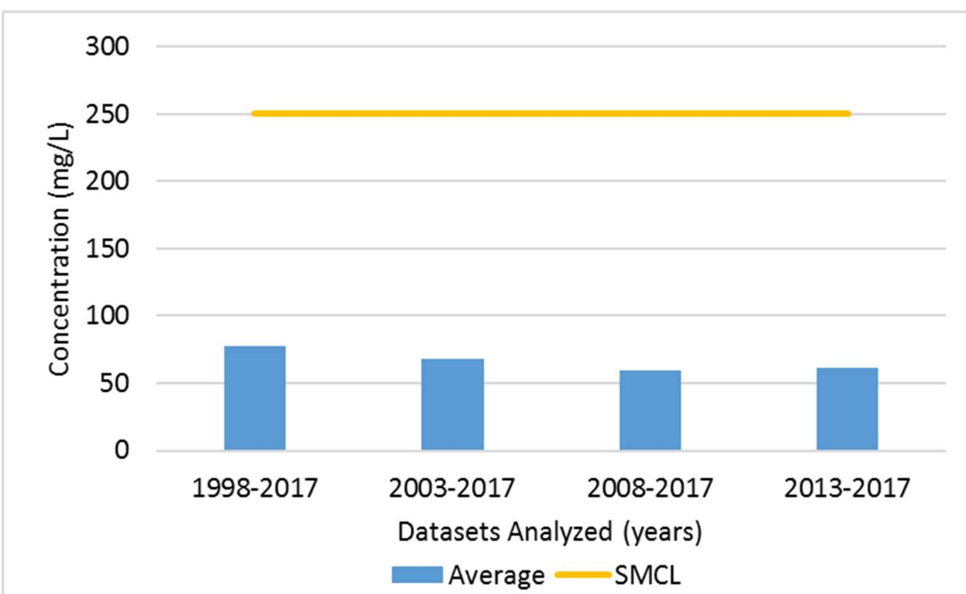


Figure 37: Chloride Concentrations

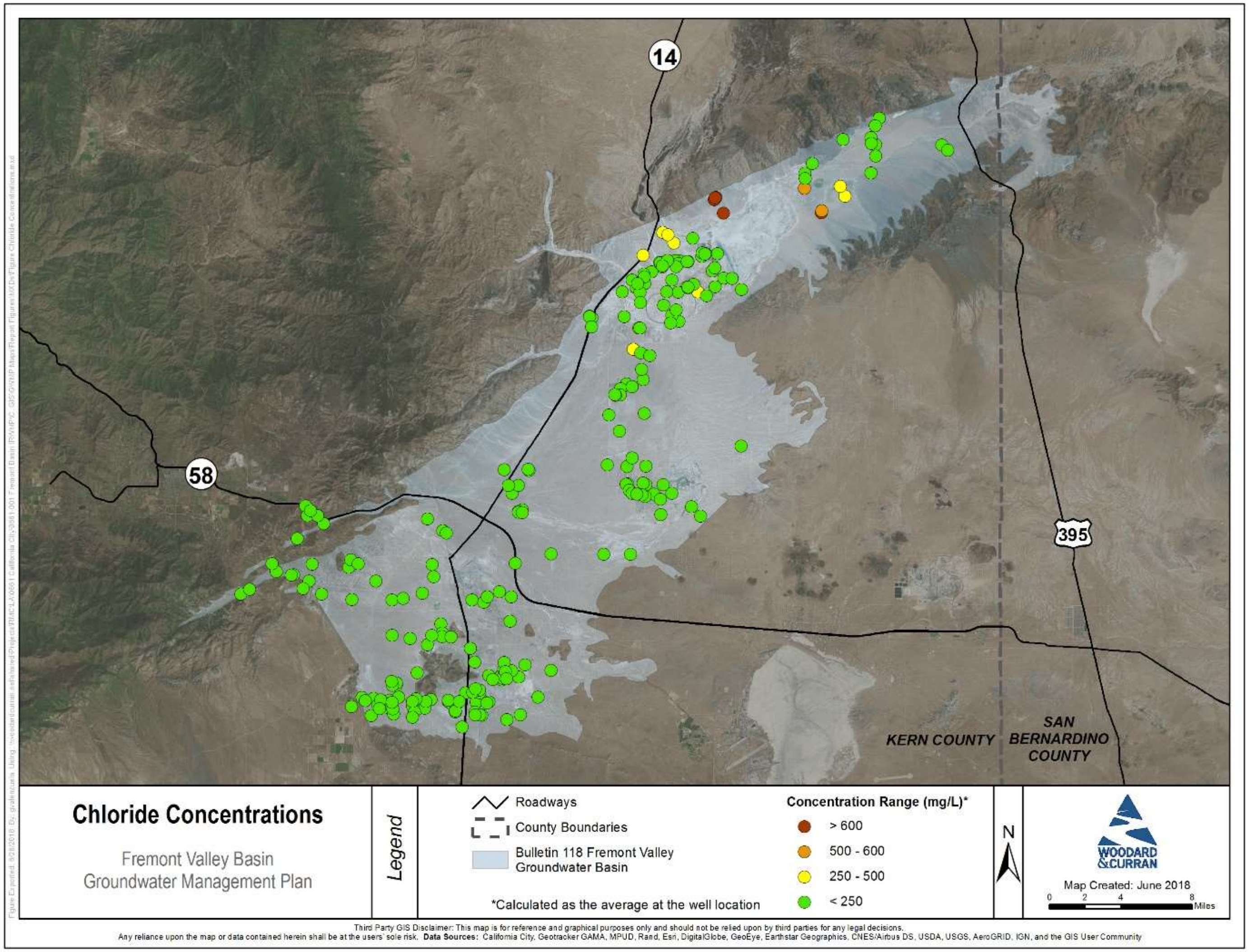
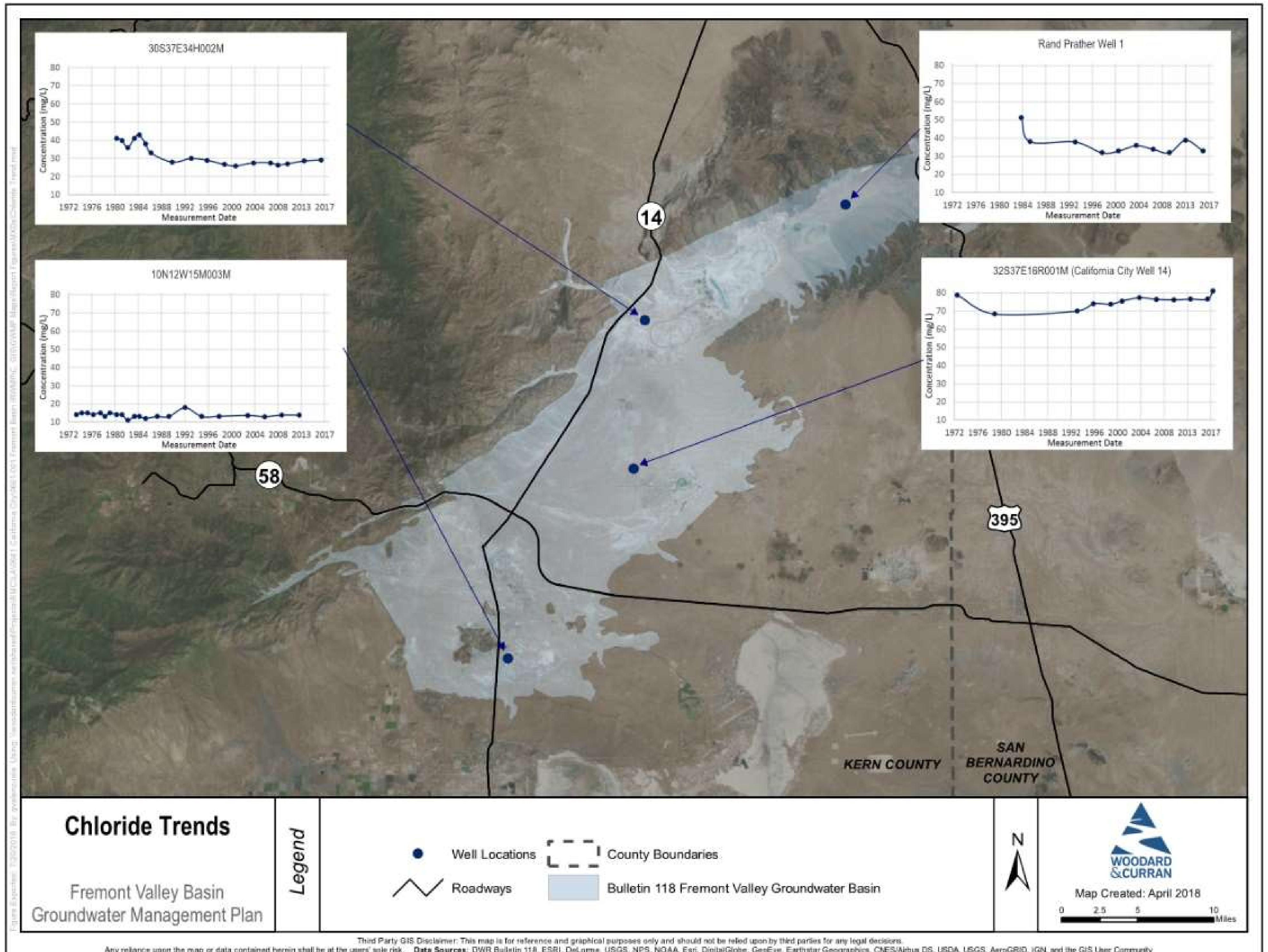


Figure 38: Chloride Concentration Trends



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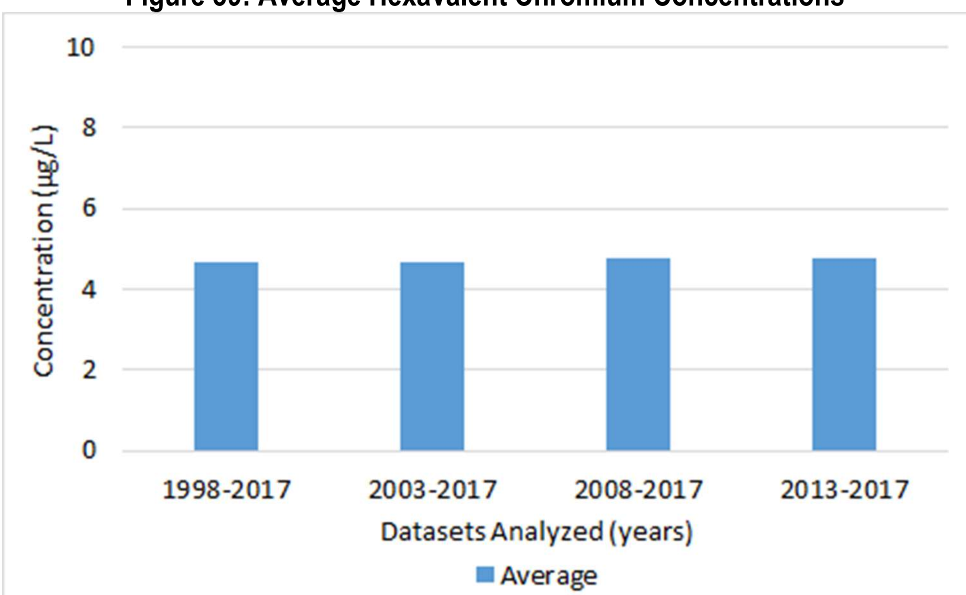
4.8.5.7 Hexavalent Chromium

Hexavalent Chromium, chromium-6, is an oxidized form of the metal that is commonly found in low concentrations in drinking water. Chromium-6 occurs naturally in the environment from the erosion of natural chromium deposits, and it can also be produced by industrial processes. There are demonstrated instances of chromium being released to the environment by leakage, poor storage or inadequate industrial waste disposal practices. A previously established California MCL of 10 µg/L was invalidated by the Superior Court of Sacramento County on May 31, 2017. California set a public health goal (PHG) of 0.02 µg/L, for chromium-6, and adopted an MCL of 10 µg/L in 2014. However, the chromium-6 MCL for drinking water was revoked in 2017 because the California Department of Public Health failed to consider the economic feasibility of compliance when adopting the MCL. Chromium-6 is currently regulated under the 50 µg/L MCL for total chromium.

Historically, average chromium-6 concentrations throughout the FVGB have remained below the previously enforced MCL of 10 µg/L (Figure 39). The average of the last five years was about 4.8 µg/L, which is below the previously enforced MCL of 10 µg/L and well below the current regulation of 50 µg/L. Of the 32 analyzed wells, one exceedance (3 percent) has been recorded from an area within the central part of California City (Figure 40). Figure 41 shows time-concentration plots for chromium-6 trends within the FVGB. Three wells with the most consistent data and spatial distribution were chosen to assess chromium-6 trends. Out of the three wells, one well located in the central part of California City shows an increasing chromium-6 trend.

Figure 39: Average Hexavalent Chromium Concentrations



Note: Chromium-6 is currently regulated with the MCL of 50 µg/L for total chromium. A previously established California MCL of 10 µg/L was invalidated by the Superior Court of Sacramento County on May 31, 2017.

Figure 40: Hexavalent Chromium Concentrations

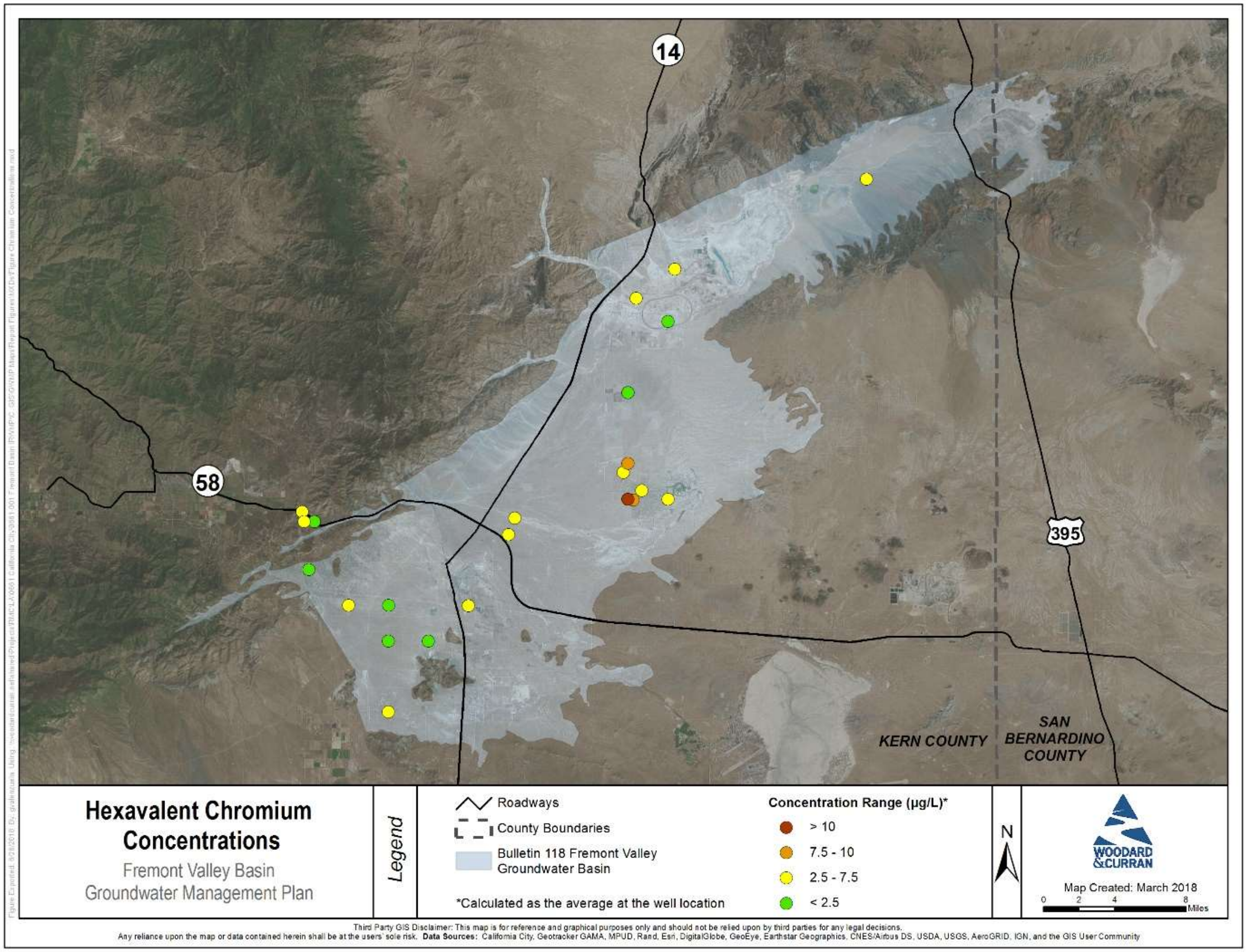
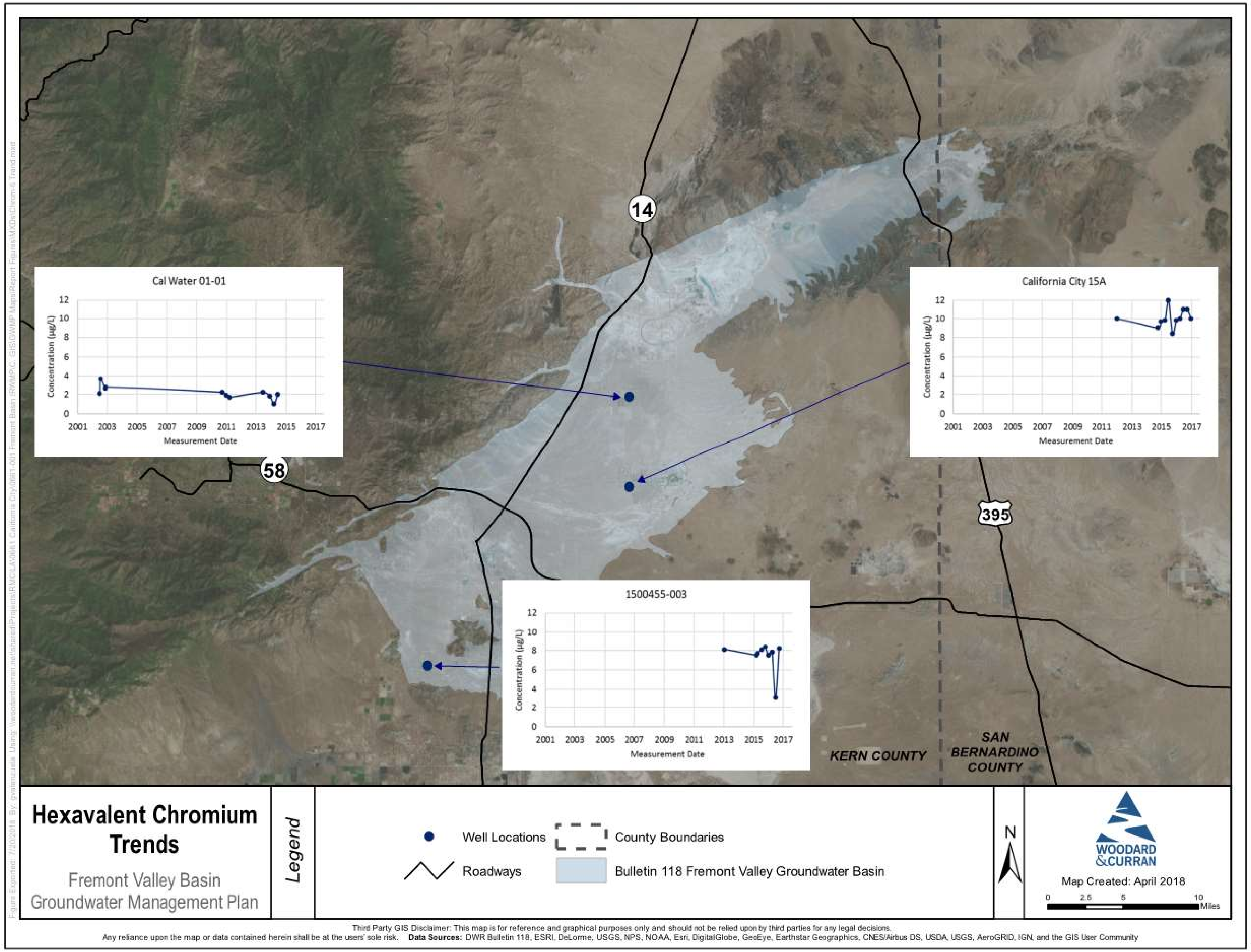


Figure 41: Hexavalent Chromium Concentration Trends



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4.8.6 Seawater Intrusion

Due to the geographic location of the FVGB, seawater intrusion is not a concern regarding groundwater quality degradation. Desalination to augment the basin's water supply is not practically or economically feasible.

4.8.7 Land Subsidence

The FVGB has documented historical land subsidence and is at medium to high risk of future occurrence. After decades of abundant production, by 1977, water levels in the central part of the basin had declined as much as 243 ft primarily in response to increased irrigation pumping (Borchers et al. 2014). Historical data were too sparse to map, but subsidence of 2 feet (0.48 meter) was measured between 1962 and 1978 on two leveling lines distance from the pumping locations, meaning subsidence near the valley center was likely considerably greater. A 2014 DWR study identified 30-50 percent of wells with groundwater levels within the basin to be at or below historical lows over long-term trends (>10 year) and continuous Global Positioning System (GPS) station data confirmed trending subsidence (DWR 2014b). As a result, differential subsidence has tilted the topographic gradient surrounding Koehn Lake so when surface water ponds, it also floods the area southwest where subsidence is centralized, leading to inland flooding. Differential compaction in areas where aquifer thickness varies substantially has also resulted in large earth fissures that can restrict groundwater flow throughout the basin. Because both observed subsidence and earth fissures were coincident with time of increased pumping and declining groundwater levels, both effects are believed to be related to groundwater development activities.

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5. WATER DEMAND AND SUPPLIES

The Plan area utilizes a combination of water sources to meet water demand, including groundwater, imported water, and some recycled water. Supplies are used to meet urban, agricultural, and domestic water demands and are delivered by water agencies as well as private wells. The following sections provide an overview of historical, current, and future projected water demand and supply sources within the Plan area.

5.1 Historical Water Demand

In the Plan area, water demands have historically been for urban and agricultural uses. Urban demand, comprised of residential users served by the City, MPUD, Cal Water, Rancho Seco Inc., RCWD, and private pumping, has increased over time as presented in Table 8. For the purpose of this plan, these demands include any commercial users served by the water purveyors and any associated distribution system water losses. Agricultural activities increased through the 1960s and 1970s and peaked in 1976, with groundwater extractions reaching a maximum of approximately 60,000 AFY according to previous USGS investigations (USGS 1977). Increased groundwater production led to significant groundwater declines in the FVGB that persisted through the mid-1980's. Agricultural activities significantly decreased thereafter; when comparing cultivated acreage from USGS 1977 to 2010 aerial imagery, as of 2010, only one percent of lands cultivated in 1976 were still in production. Aerial maps were used to estimate the areas cultivated historically and were used to verify that most agricultural activities were performed in the Northern FVGB. It was not possible to confirm the types of crops produced in the Plan area based on visual inspections of aerial maps. Since alfalfa has been historically grown throughout the Plan area, agricultural demand estimates assume that alfalfa is the only crop cultivated in the Plan area. Historical agricultural demands were estimated by applying a specific crop coefficient to the acres of land cultivated.

Historical urban water demands in the Plan area are based on estimated groundwater pumping data and imported water data provided by the City, MPUD, and AVEK. For years with missing water records, demands were interpolated/extrapolated using:

- The population overlaying the FVGB (provided by U.S. Census data)
- Historical growth rates in Kern County (provided by the Department of Finance (DOF))
- Average assumed gallons per capita per day (GPCD) for the City and MPUD (obtained from UWMPs).

For urban demand estimates in the Southern FVGB (south of Muroc fault), it was assumed that the population consists of the MPUD service area and approximately 30 percent of the population in unincorporated Kern County that overlies the basin. The 30 percent value is assumed because 30 percent of the current unincorporated Kern County population overlaying the basin resides south of the Muroc fault. All remaining population overlying the basin was assumed to be located in the Northern FVGB (north of Muroc fault).

Table 8: Estimated Historical Urban and Agricultural Demand in the Plan Area (AFY)

	1960	1970	1976[1]	1980	1990	2000	2010
Agricultural Demand[2]	17,500	34,000	60,000	39,600	10,200	2,700	700
Urban Demand[3]	2,800	3,200	3,600	3,900	5,100	5,200	5,700
Total Demand	**20,300**	**37,200**	**63,600**	**43,500**	**15,300**	**7,900**	**6,400**

Note: Data rounded to nearest hundred.
Source: (1) Values for 1976 are included because it was the peak year for agricultural demands; urban demands for 1976 were interpolated from 1970 and 1980 values; (2) Estimated from Cooperative Extension University of California Division of Agriculture and Natural Resources N.D.a. and N.D.b. and aerial maps; (3) Estimated from Department of Finance growth rates for Kern County for the years 1960 through 2010 and U.S. Census data for 1990, 2000, and 2010.

Future projected water demand in the Plan area is presented in Section 5.3, based on population growth and potential agricultural expansion scenarios.

5.2 Water Supplies

Water demand in the Plan area is met with local groundwater supplies, imported water from the State Water Project (SWP), and recycled water generated by the City's WWTP. Stormwater is not currently being captured for beneficial use in the Plan area. The Plan area utilizes these supplies to meet urban, agricultural, and domestic water demands. The following sections provide an overview of each supply source used within the Plan area. A more detailed description of the current and future projected water supply conditions in the Plan area is presented in Section 5.4.

5.2.1.1 Groundwater

The FVGB has been historically used as the primary water supply source in the Plan area. There are five water agencies that supply residential water from the FVGB in the Plan area: the City, MPUD, Cal Water, RCWD, and Rancho Seco Inc. The City supplies water to the southeastern portion of Kern County within the Plan area. MPUD serves unincorporated residential, commercial, industrial, and undeveloped land overlaying the southern part of the FVGB. Cal Water has a small district north of the City. RCWD covers the north east portion of the Plan area. Rancho Seco Inc. serves a small portion of the Plan area in the Cantil area. Users not served by these water purveyors rely on private wells to meet domestic water demands.

Historically, the City and MPUD depended entirely on groundwater until AVEK started delivering surface water in 1980. Based on available pumping data provided by the City for the years 2010 through 2016, the City's annual average groundwater pumping was approximately 3,000 AFY. Based on available data provided by MPUD for the years 2012 through 2016, MPUD's pumping ranged from 980 AF in 2016 to 1,340 AF in 2013. Combined pumping by small water suppliers (Cal Water, RCWD, and Rancho Seco) is estimated to be approximately 75 AFY, based on limited pumping data provided by the water suppliers. Pumping by private well owners is difficult to estimate as it is unmetered and unreported.

The FVGB also supports the production of irrigated crops, including alfalfa and pistachio production, in unincorporated areas of the Plan area. As discussed above, historically, agricultural activities have occurred in the northern portion of the FVGB and peaked in the 1970s with estimated groundwater extractions reaching up to approximately 60,000 AFY in 1976 (USGS 1977). Agricultural activities significantly decreased thereafter; and as of 2010, only 1 percent of lands cultivated in 1976 were still in production according to aerial imagery (USGS 1977; USDA 2017). In 2015, approximately 207 acres of land in the Plan area were cultivated for pistachios (approximately 50 percent of the total cultivated lands) and alfalfa (approximately 50 percent of the total cultivated lands) with an estimated demand of approximately 650 AF. In 2017, approximately 159 acres of alfalfa (approximately 40 percent of the total cultivated lands) and pistachios (approximately 60 percent of the total cultivated lands) were grown with estimated demand of approximately 410 AF. Groundwater is anticipated to be a significant supply for future agriculture demand.

5.2.1.2 Imported Water Supplies

AVEK, the SWP contractor in the Plan area, delivers imported SWP water to both the City and MPUD. According to AVEK's imported water record, historical imported water deliveries to the City averaged 669 AFY since 1980 and to MPUD averaged 208 AFY since 1979. Based on the 2015 UWMP for AVEK, approximately 653 AF was delivered to the Plan area in 2015, including 651 AF to the City and 2 AF to MPUD.

5.2.1.3 Surface Water

Imported water purchased from the SWP is the only surface water used to meet regional demands. Local surface waters are not reliable sources because most are ephemeral streams that are extremely limited by drought conditions. Much of the surface water in the Plan area percolates into the FVGB. Additionally, high desert conditions cause water that does not percolate into the groundwater basin to evaporate (AVEK 2016; California City Water Department 2017).

5.2.1.4 Recycled Water

There are two WWTPs in the Plan area, owned and operated by MPUD and California City. MPUD provides wastewater services to communities west of California City. Between 2012 and 2016, the average annual wastewater inflow to the plant was 435 AF (121.9 million gallons (MG)) and average annual effluent discharge to the percolation ponds was approximately 121 AF (33.8 MG). Most of the treated effluent remains on-site to evaporate from several evaporation ponds. Any solids remaining is sent to a specialized treatment facility off-site.

The WWTP owned and operated by the City is the only source of recycled water that is reused in the Plan area. MPUD does not have plans to generate and use recycled water from its WWTP in the near future. The collection system in these communities is gravity fed and only conveys domestic wastewater, not stormwater runoff. California City's WWTP is capable of producing secondary and tertiary treated recycled water. Currently, the only permitted sites for use of the secondary and tertiary treated effluent are the City's eight existing percolation ponds, the Central Park Lake (used as recreational non-contact water) and the Tierra Del Sol Golf course (used for landscape and course irrigation). The Central Park Lake is primarily a holding transfer point of tertiary treated effluent for the irrigation systems at Tierra Del Sol Golf Course (California City Water Department 2017).

Recycled water use in the Plan area ranged from 405 AFY in 2010 to 518 AFY in 2015, based on the City's 2015 UWMP. Recycled water use is anticipated to increase in the future, as discussed in Section 5.4.3.

In 2002, the capacity of the City's WWTP was expanded from 3 AF per day (1 million gallons per day (MGD)) to 4.6 AF per day (1.5 MGD) to accommodate population growth. When storage basins are full during the winter season, approximately 1 percent of the recycled water produced is diverted to percolation ponds to offset groundwater extractions.

5.3 Current and Projected Water Demand

Water demand in the Plan area is comprised of urban and agricultural water demands. Urban demands can be further classified into residential water uses and industrial activities, assuming residential includes water delivered by water purveyor systems (including commercial and water loss for the purpose of this analysis) as well as private pumping for residences. An estimated 19,400 people reside within the Plan area boundaries, and the population is expected to grow more than 35 percent by 2040 (Table 9), based on Kern County and the City's annual growth projections. Most population growth is expected to occur within the City and Mojave. The FVGB also supports an existing solar industry and emerging cannabis industry, both of which are expected to grow significantly in the next two decades. The basin-wide water demand described in the following sections is based on demands from individual sectors, including residential, agricultural, and industrial.

Total water demand in the Plan area is projected to increase more than 60 percent by 2040. Residential water use accounts for the biggest portion of current demand, making up approximately 70 percent. The current per capita water use in the Plan area is summarized in Table 10. Residential demand will continue to be the largest component of total water demand through 2040. Industrial activities account for the second largest component of current water demand, making up approximately 20 percent. In comparison, agricultural activities account for less than 10 percent of all demand. Water loss associated with water purveyor distribution systems are not separated from the residential category for the purpose of this analysis but, it is important to note, are significant issues for many distribution systems in the Plan area. Water demand projections in this section do not consider climate change, natural disasters, or other events that may affect water demand. Potential impacts of climate change on demands are discussed qualitatively in Section 5.5.

Table 9: Estimated Population in the Fremont Valley Groundwater Basin

	2015	2020	2025	2030	2035	2040
Northern FVGB[1]	15,139	16,287	17,539	18,890	20,340	23,492
Southern FVGB[2]	4,313	4,540	4,860	5,213	5,572	5,926

Notes: (1) Based on California City's annual growth rate for population with California City, and Kern County annual growth rate for population outside of California City; (2) Based on Kern County's annual growth rate.
Sources: (1) California City Water Department 2017; California Department of Finance (DOF) 2017. County Population Projections (2010-2060). Available at: http://www.dof.ca.gov/Forecasting/Demographics/projections/; (2) California Department of Finance (DOF) 2017. County Population Projections (2010-2060). Available at: http://www.dof.ca.gov/Forecasting/Demographics/projections/

Table 10: Water Purveyor Population, Urban Demand and Per Capita Water Use

	2015 Population Served	2015 Total Potable Water Demand (AF)	Average per Capita Water Use (GPCD)
California City[1]	14,233	3,606	226
Cal Water[2]	189	14	66
MPUD[3]	4,200	986	210
Rancho Seco[4]	30	9	268
Rand CWD[5]	400	47	105
Water Purveyor Total	**19,052**	**4,662**	
Regional Average			**218**

Note: Total population and water demand shown only includes potable water served by water purveyors. Total population in the Plan area is estimated at 19,400 people. Additional water demands are included in the residential demand total that include recycled water and private pumping.
Sources: (1) California City Water Department 2017; (2) California Water Service 2016; (3) Estimated from U.S. Census 2010; (4) Data provided by Rancho Seco on January 18, 2018; (5) SDWIS. N.D.b.

A summary of water demand by land use is provided in Table 11 and described in detail in Sections 5.3.1 through 5.3.3. Residential demands include water purveyor potable system demands (including commercial and water loss), recycled water demands, and the estimated unincorporated Kern County private pumping demands. For the purposes of the demand analysis, 2015 was assumed to represent current conditions. Table 11 reflects a "Baseline Condition" that assumes residential and industrial demands steadily increase according to planned development documented in UWMPs or cited by City planning officials, whereas agricultural demands remain static at 2015 levels.

Three future agricultural growth scenarios ("light", "medium", and "heavy") were developed and compared to the Baseline Condition. Though there are no formal plans to increase agriculture beyond the current levels, the Baseline Condition plus the three agricultural "growth scenarios" were developed and analyzed to estimate water demands for potential growth and future agricultural activity. The agricultural growth scenarios are intended to illustrate how much additional groundwater demand would be required in the Plan area to support future agricultural growth and to inform the Plan area in future decisions for managing the basin sustainably. Table 11 reflects the Baseline Condition, in which agricultural demands remain static, as there currently are no specific plans to increase or decrease agriculture in the planning area. Yet, because an increase in agricultural land use is possible, three growth scenarios were included in the demand analysis for comparison, as described in Section 5.3.2.

Table 11: Current and Projected Water Demand in the Plan Area (AF) – Baseline Condition

	2015	2020	2025	2030	2035	2040
Residential[1]	5,278	7,339	7,686	8,045	8,408	9,328
Agricultural	647	647	647	647	647	647
Industrial	1,442	1,501	1,707	1,914	2,120	2,326
Plan Area Total	**7,367**	**9,487**	**10,040**	**10,606**	**11,175**	**12,301**

Note: 1) Residential water demands include recycled water and unincorporated Kern County private pumping

5.3.1 Current and Projected Residential Water Demand

The total current residential demand for 2015 in the Plan area is estimated to be 5,278 AFY for a total population of approximately 19,000. The water demand projections for the City are based on the 2015 UWMP (California City Water Department 2017) and include demands for recycled water. Demands in the City service area are projected to increase by approximately 90 percent by 2040, primarily due to the planned expansion of a correctional center (California City Water Department 2017).

Current and future demands for MPUD, Cal Water, RCWD, and private pumping in unincorporated Kern County were calculated by applying estimated DOF Kern County population growth rates to each agency's 2015 water deliveries in the Plan area (DOF 2017; California Water Service 2016). Private pumping demand in unincorporated Kern County was estimated to be 98 AF[1], based on population in the areas outside of established service areas (U.S. Census 2010) and an average per capita water use value for the Plan area. Approximately 70 percent of these residential water demands are expected to occur in the Northern FVGB based on the current population distribution estimated north of the Muroc fault. A summary of the projected residential water demands is shown in Table 12.

[1] The population estimate in unincorporated Kern County is based on discussions with the Fremont Basin RWMG and their knowledge of communities outside of established service areas.

Table 12: Current and Projected Residential Water Demand (AF)

	2015	2020	2025	2030	2035	2040
California City[1]	4,124	6,125	6,386	6,650	6,917	7,743
Cal Water[2]	14	15	16	17	18	19
MPUD[2]	986	1,038	1,111	1,192	1,274	1,355
Rancho Seco[2]	9	9	10	11	12	12
RCWD[2]	47	49	53	57	61	65
Unincorporated Kern County Private Pumping[2]	98	103	110	118	126	134
Plan Area Total	**5,278**	**7,339**	**7,686**	**8,045**	**8,408**	**9,328**

Note: Water demands shown in the table above include current and projected recycled water demands.
Sources: (1) Projections based on DOF growth rates for the City; (2) Projections based on DOF growth rates for the unincorporated Kern County.

5.3.2 Current and Projected Agricultural Water Demand

Agriculture is an important component of the water demand for the Plan area and it is anticipated to be a source of significant demand in the Northern FVGB in the future. Though it is assumed that only alfalfa has been historically cultivated in the Plan area, both the Sustainable Groundwater Management tool provided by DWR and aerial maps confirmed that pistachios are currently cultivated in the Plan area in addition to alfalfa. To estimate current agriculture demands, approximately 207 acres of land in the Plan area were assumed to be cultivated; and for the purposes of estimating current and projected future agricultural water use, it is assumed that approximately half of the area was cultivated with alfalfa and the other half of the area was cultivated with pistachios in 2015. Agricultural water demands for these two crops were estimated based on the calculated monthly gross water requirements (ETc) as the product of the reference evapotranspiration (ETo) from the Palmdale CIMIS Station and a unique crop factor (Kc). Kc values account for specific daily evapotranspiration variations due to growth and development in different crops. Alfalfa has an annual gross water requirement more than eight times greater than that of pistachios, which results in a significant difference in agricultural water demand for a given acreage (Table 13) (Cooperative Extension University of California Division of Agriculture and Natural Resources N.D.a. and ND.b.). Assuming an irrigation system efficiency of 75 percent under normal conditions (USDA 2013), crop ETc is estimated at approximately 60.1 inches for alfalfa and 7.3 inches for pistachios, resulting in water demand estimates of 630 AF for alfalfa and 17 AF for pistachios in 2015. Alfalfa is a very water-intensive crop; and though it was assumed to be cultivated only on an estimated 50 percent of all farm lands in the Northern FVGB in 2015, it accounts for more than 97 percent of the total agricultural water demand after average rainfall is taken into account.

To estimate future agricultural demands, a different approach was used. The viability of agricultural operations depends on several factors, including but not limited to available zoned land, the price of water, market prices for various crop types, and local community support. The Kern County General Plan zoning and descriptions were reviewed for land use designations noted as a potential use of irrigated cropland. Though there are no formal plans to increase agriculture beyond 2015 levels, available documents indicate that agricultural demands in the FVGB have been as high as 60,000 AFY in the 1970s, with cultivated acreage covering a much larger area than today. To plan for potential future agricultural activity and estimate the water demands, the Baseline Condition plus three agricultural “growth scenarios” were developed and analyzed using the historical maximum of 60,000 AFY water demand as a basis. The three growth scenarios represented in the demand analysis for the GWMP represent potential future growth conditions based on realistic percentages of the maximum historical agricultural demand experienced in the Planning area.

Table 13: Crop Water Requirements in the Plan Area

	Alfalfa	Pistachios
Monthly Gross Water Requirements (in.)	60.7	7.4
Average Rainfall (in.)	5.9	5.9
Total Net Average Monthly Water Requirements (in.)	54.8	1.4
Irrigation Efficiency (%)	75%	75%
Total Water Net Usage (in.)	73.1	2.0
Total Net Water Demand (AF/acre)	6.1	0.2
Acreage (Acres)	103.5	103.5
Total Water Demand (AFY)	630	17
Total Agricultural Demand (AFY)	**647**	

The Baseline Condition assumes that 2015 demands for agriculture remain unchanged at 647 AFY in future years (about one percent of the historical maximum of 60,000 AFY). Building on the Baseline Condition, each of the three growth scenarios assumes agricultural demand in the Plan area would increase to approximately 5, 10, and 15 percent of the historical maximum by 2040. These are referenced as the “light growth”, “medium growth”, and “heavy growth” agricultural scenarios, respectively. While pistachio farming may increase in the Plan area due to their low water use requirements, the FVGB demand analysis was designed to assess potential future demand scenarios and is not intended to represent precise future crop profiles. Because alfalfa requires significantly more water than pistachios, the projections assume that pistachio cultivation will remain constant through 2040 and all future agricultural demand growth would be from increased alfalfa cultivation. Alfalfa cultivation is also assumed to increase linearly from 2015 to 2040. The total acres cultivated in the Plan area under the Baseline Condition and each of the three growth scenarios are shown in Table 14. It should be noted that other crop combinations could be cultivated and that actual agricultural demands could remain constant or decrease. It is also possible that agricultural expansion could occur more rapidly, given historical cultivation levels; but the following future scenarios are considered to be reasonable projections for the purposes of this GWMP by the RWMG and IRWM stakeholders.

Table 14: Agricultural Growth Scenarios - Total Area Cultivated (acres)

	Scenario	2015	2020	2025	2030	2035	2040
Northern FVGB	Baseline Condition	207	207	207	207	207	207
	Scenario 1: Light Growth	207	265	322	380	437	495
	Scenario 2: Medium Growth	207	343	480	616	753	889
	Scenario 3: Heavy Growth	207	422	638	853	1,068	1,283
Southern FVGB	Baseline Condition	0	0	0	0	0	0
	Scenario 1: Light Growth	0	20	39	59	79	99
	Scenario 2: Medium Growth	0	39	79	118	158	197
	Scenario 3: Heavy Growth	0	59	118	177	237	296

Assumptions: 80 percent of agricultural activities will occur in the Northern FVGB and 20 percent in the Southern FVGB to reflect proportion of the total recharge assumed to occur in the Northern and Southern FVGB. Each of the three growth scenarios assumes linear agricultural demand increase to approximately 5, 10, and 15 percent of the historical maximum by 2040. Pistachio cultivation is assumed to remain constant through 2040, and all future agricultural demand growth is assumed to be from increased alfalfa cultivation. Projections assume an irrigation system efficiency of 75 percent under normal conditions.

Given these parameters and assumptions, alfalfa production in the FVGB has the potential to increase by approximately five times by 2040 in Scenario 1 (light growth), approximately 10 times by 2040 in Scenario 2 (medium growth), and approximately 14 times by 2040 in Scenario 3 (heavy growth) (Table 15).

Table 15: Agricultural Growth Scenarios - Current and Projected Water Demand by Crop Type (AFY)

	2015	2020	2025	2030	2035	2040
Baseline						
Alfalfa	630	630	630	630	630	630
Pistachios	17	17	17	17	17	17
Total	**647**	**647**	**647**	**647**	**647**	**647**
Scenario 1 (Light Growth): 5% of Historical Agricultural Maximum						
Alfalfa	630	1,101	1,571	2,042	2,512	2,983
Pistachios	17	17	17	17	17	17
Total	**647**	**1,118**	**1,588**	**2,059**	**2,529**	**3,000**
Scenario 2 (Medium Growth): 10% of Historical Agricultural Maximum						
Alfalfa	630	1,701	2,771	3,842	4,912	5,983
Pistachios	17	17	17	17	17	17
Total	**647**	**1,718**	**2,788**	**3,859**	**4,929**	**6,000**
Scenario 3 (Heavy Growth): 15% of Historical Agricultural Maximum						
Alfalfa	630	2,301	3,971	5,642	7,312	8,983
Pistachios	17	17	17	17	17	17
Total	**647**	**2,318**	**3,988**	**5,659**	**7,329**	**9,000**

Assumptions: Each of the three growth scenarios assumes linear agricultural demand increase to approximately 5, 10, and 15 percent of the historical maximum by 2040. Pistachio cultivation is assumed to remain constant through 2040, and all future agricultural demand growth is assumed to be from increased alfalfa cultivation. Projections assume an irrigation system efficiency of 75 percent under normal conditions.

To estimate the breakdown of agricultural demand projections between the Northern and Southern FVGB, findings from the groundwater balance analysis were used. As described earlier in Section 4, the groundwater balance analysis estimated an average annual recharge rate of approximately 13,800 AFY, with about 80 percent of the recharge assumed to occur in the Northern FVGB and approximately 20 percent assumed to occur in the Southern FVGB. The breakdown of 80 and 20 percent for the Northern and Southern FVGB, respectively, was used for estimating agricultural demand based on the proportion of estimated annual natural recharge for the Northern and Southern FVGB.

Table 16 summarizes the current and projected agricultural water demands, separated into values for the Northern and Southern FVGB. Agricultural demand by 2040 is projected to be 3,000 AF for Scenario 1 (light growth), 6,000 AF for Scenario 2 (medium growth), and 9,000 AF for Scenario 3 (heavy growth).

Table 16: Agricultural Growth Scenarios - Current and Projected Water Demand for Northern and Southern FVGB (AFY)

	Scenario	2015	2020	2025	2030	2035	2040
Northern FVGB	Baseline Condition	647	647	647	647	647	647
	Scenario 1: Light Growth	647	998	1,348	1,699	2,049	2,400
	Scenario 2: Medium Growth	647	1,478	2,308	3,139	3,969	4,800
	Scenario 3: Heavy Growth	647	1,958	3,268	4,579	5,889	7,200
Southern FVGB	Baseline Condition	0	0	0	0	0	0
	Scenario 1: Light Growth	0	120	240	360	480	600
	Scenario 2: Medium Growth	0	240	480	720	960	1,200
	Scenario 3: Heavy Growth	0	360	720	1,080	1,440	1,800

Assumptions: 80 percent of agricultural activities will occur in the Northern FVGB and 20 percent in the Southern FVGB to reflect proportion of the total recharge assumed to occur in the Northern and Southern FVGB. Each of the three growth scenarios assumes linear agricultural demand increase to approximately 5, 10, and 15% of the historical maximum by 2040. Pistachio cultivation is assumed to remain constant through 2040, and all future agricultural demand growth is assumed to be from increased alfalfa cultivation. Projections assume an irrigation system efficiency of 75 percent under normal conditions.

5.3.3 Current and Projected Industrial Water Demand

In addition to agriculture, industrial processes are also an important component of the water demand in the Region. The four largest industrial water user categories are the solar, cannabis, mining and manufacturing industries. The cannabis industry, while traditionally thought of as an agricultural water use, is currently being regulated under the LRWQCB as an industrial water use for waste discharge requirements. Because of this, cannabis cultivation, specifically indoor cannabis cultivation, is being described in this Plan under the industrial water uses. Other types of industrial demands in the Plan area are assumed to be negligible, though small manufacturers may be included in future updates to the GWMP.

5.3.3.1 Solar Energy Production

The Beacon Photovoltaic solar plant is the largest solar facility in the Plan area. Water use by all other solar power plants is assumed to be negligible due to their relative sizes. Previous studies have estimated that the Beacon Photovoltaic solar plant uses an average of 6 AFY for panel cleaning (Frisvold & Marquez 2013). Demand projections assume that solar demand will remain relatively constant through 2040, as shown in Table 17.

5.3.3.2 Cannabis Cultivation

Cannabis is a new industry being developed in the Plan area. The City expects continued development of the cannabis industry over the next few years. The City expects to approve roughly 20 permits for 20,000 square-foot indoor cannabis grow houses by 2020 and as many as approximately 300 permits by 2040. According to the California City Public Works Director, the facilities are anticipated to operate within municipal boundaries using approximately 2.2 AFY to 2.9 AFY of potable water per facility. This water use assumes that each facility will also reuse 70 to 80 percent of its irrigation wastewater internally. Demand projections for cannabis cultivation through 2040 conservatively assume a demand of 2.9 AFY per facility (Table 17).

5.3.3.3 Mining and Manufacturing

Golden Queen Mining Company uses open pit mining methods to extract gold and silver at the Soledad Mountain Mine near Mojave. The mining operations utilize water pumped from 5 production wells and 9 domestic wells to support operations. CalPortland operates a plant in Mojave for cement production. The plant uses water pumped from a private well. Like the solar industry, water demands for mining and manufacturing are assumed to remain constant through 2040, and water use by all other manufacturing operations are assumed to be negligible. Future updates to the GWMP may include additional demand estimates for small manufacturers pumping from the FVGB. General water demand estimates determined from communication with CalPortland Company management and Golden Queen Mining Company management are shown in Table 17.

Table 17: Total Current and Projected Industrial Water Demand (AF)

	2015	2020	2025	2030	2035	2040
Solar[1]	6	6	6	6	6	6
Cannabis[2]	0	59	265	472	678	884
Mining[3]	1,105	1,105	1,105	1,105	1,105	1,105
Manufacturing[4]	331	331	331	331	331	331
Total	**1,442**	**1,501**	**1,707**	**1,914**	**2,120**	**2,326**

Sources: (1) Frisvold, G., & Marquez, T. 2013; (2) Communication with California City Staff 2018; (3) Communication with Golden Queen Mining Company Management 2018; (4) Communication with CalPortland Company management 2018.
Assumptions: Energy production will remain constant through 2040. Cannabis cultivation will grow to 20 facilities by 2020 and approximately 300 facilities by 2040; each facility is projected to use approximately 2.9 AFY of potable water with 70 to 80 percent wastewater reuse.

5.4 Current and Projected Water Supplies

Water demand in the Plan area is met with local groundwater supplies, imported water from the SWP, and recycled water generated by the City's WWTP. Stormwater is not currently being captured for beneficial use in the Plan area. There are no planned stormwater capture projects at this time; therefore, stormwater was not included in the future supply analysis. The following is an analysis of the projected groundwater, imported water, and recycled water supplies in the Plan area through 2040 under normal conditions. The projected supplies are for an average year and do not account for climate change impacts, catastrophes, changes in legislation, and other events that can disrupt supply deliveries. Potential impacts of climate change on supplies are discussed qualitatively in Section 5.5.

Total water supplied within the Plan area is expected to increase by more than 60 percent by 2040 to match demand under the heavy agricultural growth scenario, as shown in Table 18. These projections assume agricultural demands will increase to 9,000 AFY by 2040 which represents 15 percent of the historical maximum of 60,000 AFY (heavy agricultural growth scenario).

It should be noted that, assuming the average groundwater recharge value of 13,800 AFY described in Section 4.8.4.1, the light and medium agricultural growth scenarios are likely to be sustainable (i.e., not produce a condition of basin overdraft). The heavy agricultural growth scenario, however, may not be sustainable (i.e., could produce a condition of overdraft).

Table 18: Total Current and Projected Water Supplies (AF)

	2015	2020	2025	2030	2035	2040
Baseline						
Groundwater	6,197	7,516	7,985	8,456	8,931	9,893
Imported Water	653	1,190	1,240	1,300	1,360	1,420
Recycled Water	518	783	816	850	884	988
Total	**7,368**	**9,489**	**10,041**	**10,606**	**11,175**	**12,301**
Scenario 1 (Light Growth): 5% of Historical Agricultural Maximum						
Groundwater	6,197	7,986	8,926	9,867	10,813	12,246
Imported Water	653	1,190	1,240	1,300	1,360	1,420
Recycled Water	518	783	816	850	884	988
Total	**7,368**	**9,959**	**10,982**	**12,017**	**13,057**	**14,654**
Scenario 2 (Medium Growth): 10% of Historical Agricultural Maximum						
Groundwater	6,197	8,586	10,126	11,667	13,213	15,246
Imported Water	653	1,190	1,240	1,300	1,360	1,420
Recycled Water	518	783	816	850	884	988
Total	**7,368**	**10,559**	**12,182**	**13,817**	**15,457**	**17,654**
Scenario 3 (Heavy Growth): 15% of Historical Agricultural Maximum						
Groundwater	6,197	9,186	11,326	13,467	15,613	18,246
Imported Water	653	1,190	1,240	1,300	1,360	1,420
Recycled Water	518	783	816	850	884	988
Total	**7,368**	**11,159**	**13,382**	**15,617**	**17,857**	**20,654**

Assumptions: For these supply/demand calculations, it is assumed that future engineered stormwater capture/recharge is negligible. The projected supplies are for an average year and do not account for climate change impacts, catastrophes, changes in legislation, and other events that can disrupt local and imported supply deliveries.

5.4.1 Groundwater

Groundwater volumes pumped and distributed within the City for the year 2015 were documented in the City's 2015 UWMP. Because almost the entire population of the City is within the Plan area, all groundwater extractions occur from the FVGB and almost all are consumed within the FVGB boundary. Cal Water pumping data for the year 2015 reflects the groundwater supplies that were distributed solely to the Fremont Valley System. MPUD and RCWD provided groundwater pumping data for 2015. Demands estimated for the portions of unincorporated Kern County not served by the City, MPUD, Cal Water, Rancho Seco Inc., or RCWD are assumed to be met by groundwater pumping.

Groundwater pumping is projected to increase over the next two decades due to population growth, cannabis cultivation, and agricultural growth scenarios, as shown in Table 19 through Table 22. The projected groundwater pumping is assumed to be the variable for supplies and is set to be equal to the total projected demand minus projected recycled and imported water supplies. Projected imported water supply deliveries were calculated based on historical delivery records. The calculations are based on the following key assumptions:

- Agricultural demands assume the Baseline Condition (Table 19); light agricultural growth (Table 20); medium agricultural growth (Table 21), and heavy agricultural growth (Table 22) by 2040.
- Groundwater is the only available water supply outside of the City and MPUD service areas.
- Groundwater pumping is used to make up supply shortfalls that are not met with other sources.

Since groundwater pumping is assumed to make up supply shortfalls in this GWMP, the agricultural growth scenarios would increase dependence on groundwater pumping in the Plan area significantly. Future plans for agricultural growth in the Plan area should be evaluated such that the FVGB is managed sustainably in the long-term without causing overdraft conditions similar to those that the basin has experienced historically.

Table 19: Current and Projected Groundwater Extractions in the Plan Area (AF) – Baseline Condition

Source	2015	2020	2025	2030	2035	2040
California City[1]	2,955	4,273	4,450	4,620	4,793	5,455
Cal Water[2]	14	15	16	17	18	19
MPUD[3]	985	918	991	1,072	1,154	1,235
Rancho Seco[4]	9	9	10	11	12	12
RCWD[5]	47	49	53	57	61	65
Unincorporated Kern County Private Pumping[6]	2,187	2,251	2,465	2,679	2,893	3,108
Total	**6,197**	**7,515**	**7,985**	**8,456**	**8,931**	**9,894**

Note: Unincorporated Kern County Private Pumping captures private groundwater pumping for agricultural, industrial, and residential demands outside any given service area within the FVGB.
Sources: (1) California City Water Department 2017; (2) Cal Water pumping data for the Fremont Valley System; (3) MPUD pumping data; (4) Rancho Seco pumping data; (5) RCWD pumping data; (6) Estimated from supply shortfall
Assumptions: 2015 demands for agriculture remain unchanged at 647 AFY in future years (about 1 percent of the historical maximum of 60,000 AFY).

Table 20: Current and Projected Groundwater Extractions in the Plan Area (AF) – Light Agricultural Growth

Source	2015	2020	2025	2030	2035	2040
California City[1]	2,955	4,273	4,450	4,620	4,793	5,455
Cal Water[2]	14	15	16	17	18	19
MPUD[3]	985	918	991	1,072	1,154	1,235
Rancho Seco[4]	9	9	10	11	12	12
RCWD[5]	47	49	53	57	61	65
Unincorporated Kern County Private Pumping[6]	2,187	2,722	3,406	4,091	4,776	5,461
Total	**6,197**	**7,986**	**8,926**	**9,868**	**10,814**	**12,247**

Note: Unincorporated Kern County Private Pumping captures private groundwater pumping for agricultural, industrial, and residential demands outside any given service area within the FVGB.
Sources: (1) California City Water Department 2017; (2) Cal Water pumping data for the Fremont Valley System; (3) MPUD pumping data; (4) Rancho Seco pumping data; (5) RCWD pumping data; (6) Estimated from supply shortfall.
Assumptions: Agricultural demand will increase to approximately 5 percent of the historical maximum by 2040; projections assume that pistachio cultivation will remain constant through 2040 and all future agricultural demand growth would be from increased alfalfa cultivation.

Table 21: Current and Projected Groundwater Extractions in the Plan Area (AF) – Medium Agricultural Growth

Source	2015	2020	2025	2030	2035	2040
California City[1]	2,955	4,273	4,450	4,620	4,793	5,455
Cal Water[2]	14	15	16	17	18	19
MPUD[3]	985	918	991	1,072	1,154	1,235
Rancho Seco[4]	9	9	10	11	12	12
RCWD[5]	47	49	53	57	61	65
Unincorporated Kern County Private Pumping[6]	2,187	3,322	4,606	5,891	7,176	8,461
Total	**6,197**	**8,586**	**10,126**	**11,668**	**13,214**	**15,247**

Note: Unincorporated Kern County Private Pumping captures private groundwater pumping for agricultural, industrial, and residential demands outside any given service area within the FVGB.
Sources: (1) California City Water Department 2017; (2) Cal Water pumping data for the Fremont Valley System; (3) MPUD pumping data; (4) Rancho Seco pumping data; (5) RCWD pumping data; (6) Estimated from supply shortfall
Assumptions: Agricultural demand will increase to approximately 10 percent of the historical maximum by 2040; projections assume that pistachio cultivation will remain constant through 2040 and all future agricultural demand growth would be from increased alfalfa cultivation.

Table 22: Current and Projected Groundwater Extractions in the Plan Area (AF) – Heavy Agricultural Growth

Source	2015	2020	2025	2030	2035	2040
California City[1]	2,955	4,273	4,450	4,620	4,793	5,455
Cal Water[2]	14	15	16	17	18	19
MPUD[3]	985	918	991	1,072	1,154	1,235
Rancho Seco[4]	9	9	10	11	12	12
RCWD[5]	47	49	53	57	61	65
Unincorporated Kern County Private Pumping[6]	2,187	3,922	5,806	7,691	9,576	11,461
Total	**6,197**	**9,186**	**11,326**	**13,468**	**15,614**	**18,247**

Note: Unincorporated Kern County Private Pumping captures private groundwater pumping for agricultural, industrial, and residential demands outside any given service area within the FVGB.
Sources: (1) California City Water Department 2017; (2) Cal Water pumping data for the Fremont Valley System; (3) MPUD pumping data; (4) Rancho Seco pumping data; (5) RCWD pumping data; (6) Estimated from supply shortfall
Assumptions: Agricultural demand will increase to approximately 15 percent of the historical maximum by 2040; projections assume that pistachio cultivation will remain constant through 2040 and all future agricultural demand growth would be from increased alfalfa cultivation

5.4.2 Imported Water

AVEK delivers imported SWP water to both the City and MPUD. The 2015 imported water supplies and future projections for the City and MPUD were obtained from the City's and AVEK's 2015 UWMPs. The City's 2015 UWMP projects that imported water supplies will nearly double within the next two decades, whereas MPUD's imported water supplies are expected to remain constant through 2040 as shown in Table 23.

Table 23: Current and Projected Imported Water Supplies (AF)

	2015	2020	2025	2030	2035	2040
California City[1]	651	1,070	1,120	1,180	1,240	1,300
MPUD[2]	2	120	120	120	120	120
Total	**653**	**1,190**	**1,240**	**1,300**	**1,360**	**1,420**

Sources: (1) 2015 data from California City Water Department 2017; 2020-2040 data from AVEK 2016; (2) 2015 data from AVEK 2016; 2020-2040 projections per communication with MPUD General Manager at the January 18, 2018 Working Group Meeting.
Assumptions: For an average water year; does not account for climate change impacts, catastrophes, changes in legislation, and other events that can disrupt imported supply deliveries.

5.4.3 Recycled Water

Recycled water generated by the City is utilized within the Plan area to irrigate the Tierra Del Sol Golf Course and as makeup water for Central Park Lake. Recycled water supply is projected to increase 90 percent by 2040 as shown in Table 24. As described in the City's 2015 UWMP, the increase is based on population growth that will increase potable water demand and produce higher wastewater flows to the WWTP. The City currently manages all available recycled water at eight percolation ponds, the Central Park Lake, and the Tierra Del Sol Golf Course. To increase recycled water supply and use, the City would need to expand the WWTP so that additional flows can be accepted and treated. While there are no specific plans to expand recycled water use at this time, the City is exploring the feasibility of using recycled water on green belts, parks, and other facilities, including the Par 3 Golf Course (California City Water Department 2017).

In 2002, the capacity of the WWTP was expanded from 3 AF per day (1 MGD) to 4.6 AF per day (1.5 MGD) to accommodate population growth. Currently, the plant can treat an average flow of 4.6 AF per day (1.5 MGD) and a peak flow of 9.2 AF per day (3.0 MGD), though the average influent currently averages 2.5 AF per day (0.8 MGD). Biosolids are dewatered, dried, and disposed of at a landfill (California City Water Department 2017). During a normal year, the City collects approximately 19 percent of total potable water production as wastewater (or 675 AF); 75 percent of this water, or approximately 500 AF, is recycled and used for irrigation at Tierra Del Sol Golf Course. When storage basins are full during the winter season, approximately 10 AF, or 1 percent of the recycled water produced, is diverted to percolation ponds to offset groundwater extractions.

Table 24: Current and Projected Recycled Water Supplies (AF)

	2015	2020	2025	2030	2035	2040
Recycled Water	518	783	816	850	884	988

Source: California City Water Department 2017.

5.5 Potential Climate Change Impacts

Climate change could impact the water supplies and demands in the Plan area. Climate change is expected to reduce SWP supply deliveries by up to 21 to 25 percent by 2100. However, the average annual precipitation is expected to remain relatively unchanged through 2100 (California Energy Commission 2017). Despite the minimal impact on total annual precipitation, climate change is expected to result in a larger proportion of precipitation coming in the form of intense single-day events, which could increase the difficulty of recharging stormwater and could contribute to declining groundwater levels (EPA 2017; California Emergency Management & Natural Resources Agency 2012). Longer drought periods could strain water supplies in the Plan area, as water demands are expected to increase while supplies decrease. Increased temperatures due to climate change, combined with decreased rainfall, could increase water demands in an already water-limited area.

6. BASIN MANAGEMENT GOALS AND OBJECTIVES

In this GWMP, basin management objectives were developed using the IRWM Region's broader list of goals and objectives. As described earlier, the management goals and objectives presented in this section are considered to be "pre-GSP" objectives and will serve as foundational information to support future groundwater management activities and decision-making processes if the agencies in the Plan area elect to form a GSA and develop a GSP. Future development of basin goals and objectives under SGMA will build off the initial work completed for the Fremont Valley Basin GWMP, the Fremont Valley Basin SNMP and the Fremont Basin IRWM Plan. The goals and objectives presented in this GWMP are based on the SGMA sustainability indicators and a subset of the Fremont Basin IRWM regional objectives that address those indicators.

6.1 SGMA Sustainable Management Criteria

One key component of SGMA implementation is the identification of undesirable results in a groundwater basin and the development of sustainable management criteria to facilitate the long-term sustainable management of the basin. While the FVGB is not currently subject to SGMA, this GWMP is considered a pre-curser to a GSP; so, an overview of the SGMA sustainable management criteria and sustainable indicators is included herein.

SGMA requires the evaluation of a groundwater basin's vulnerability to the following six sustainable indicators and requires establishing minimum thresholds for each indicator to avoid undesirable results:

- **Groundwater Levels** - Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods
- **Groundwater Storage** - Significant and unreasonable reduction of groundwater storage
- **Seawater Intrusion** - Significant and unreasonable seawater intrusion
- **Degraded Water Quality** - Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies
- **Land Subsidence** - Significant and unreasonable land subsidence that substantially interferes with surface land uses
- **Surface Water Depletion** - Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

If the agencies in the Plan area elect to form a GSA, criteria and minimum thresholds would be developed and adopted for each indicator that is applicable to the FVGB in accordance with GSP requirements (DWR 2017). Anticipated potential undesirable results could be mitigated through the implementation of projects and management strategies (Section 7) and through monitoring of basin conditions (Section 8).

6.2 Groundwater Levels

While the FVGB has historically been able to provide sufficient supply to meet overlying demand, there is a limited understanding of storage and withdrawal capacity in the basin. Also, because the basin is not adjudicated, pumping is not currently managed by a Watermaster or other oversight entity, and the FVGB is located near other groundwater basins that are experiencing overdraft conditions (like the Indian Wells Valley Groundwater Basin, DWR 2014b; DWR 2004b). Demands in the Plan area are projected to increase from new development and new land uses such as cannabis cultivation and solar energy, and the FVGB is the main source of water for the Plan area. Therefore, to address the SGMA indicator for "groundwater levels", this GWMP uses the following objective and planning targets already developed for the Fremont Basin IRWM Plan:

1. **Objective**: Ensure sustainable use of the Fremont Valley Groundwater Basin
    a. **Target**: Begin developing a GSA and GSP for the Fremont Valley Groundwater Basin by 2019
    b. **Target**: Define the safe yield of the Fremont Valley Groundwater Basin by 2027
    c. **Target**: Manage the Fremont Valley Groundwater Basin such that the 10-year average change in groundwater levels is zero.

To establish minimum thresholds under future GSP efforts, the stated objective and the targets may need to be modified.

6.3 Water Quality

Groundwater quality is generally good within most parts of the FVGB and is influenced by historical and existing land use practices, water extractions, industrial discharges, urban and agricultural runoff, and natural conditions. Preventing degradation of the groundwater quality is critically important to the IRWM Region given that the FVGB is used to meet the majority of water demands. Effective management of water quality challenges related to the chemicals of concerns in the FVGB, as discussed in Section 4, is critical for the long-term sustainability of the Plan area. Therefore, to address the SGMA indicator for "water quality", this GWMP uses the following objectives and planning targets already developed for the Fremont Basin IRWM Plan:

1. **Objective**: Provide drinking water that meets regulatory requirements and customer needs
    a. **Target**: Meet Federal and State water quality standards as well as customer standards for taste and aesthetics on an ongoing basis
2. **Objective**: Protect water quality in groundwater basins in the Region
    a. **Target**: Prevent degradation of groundwater basins with respect to Basin Plan objectives

To establish minimum thresholds under future GSP efforts, the stated objectives and the targets may need to be modified.

6.4 Groundwater Storage

As described in Section 4 and Appendix A, the groundwater mass balance analysis conducted in this GWMP estimates changes in groundwater storage in the FVGB based on a simplified, spreadsheet model approach. This initial analysis is intended to provide a basic understanding of the groundwater system.

Groundwater flow models can evaluate fluctuations in groundwater storage volume as a result of changes to hydrological conditions, recharge rates, pumping rates, land use, demand, climate change or other factors. They can be used as a tool to achieve and maintain the sustainability goal with respect to groundwater storage and levels. As stated, the SGMA Modeling Best Management Practice (BMP), groundwater models can estimate future groundwater conditions, support decision-making about monitoring networks and management actions, and allow exploring alternative management approaches.

For the purposes of this GWMP, the SGMA indicator for "groundwater storage" is assumed to be addressed by the same Fremont Basin IRWM objective and planning targets described above for the "groundwater levels" indicator.

6.5 Seawater Intrusion

As described in Section 4, seawater intrusion is not a concern with respect to groundwater quality degradation in the FVGB due to its geographic location.

For the purposes of this GWMP, the SGMA indicator for "seawater intrusion" is assumed to be not applicable.

6.6 Land Subsidence

Land subsidence is a major problem caused in part by increased groundwater extraction. As described in Section 4, the FVGB has documented historical land subsidence and was ranked at "medium" to "high" risk of future occurrence in a 2014 study conducted by DWR. That study documented recent and historical subsidence and estimated the potential for future subsidence.

Current pumping levels in the FVGB are significantly lower than the historical peaks reported in 1977, and declines in groundwater levels have decreased significantly since that time. While the current pumping conditions are not considered to pose an immediate threat to the basin with respect to land subsidence, the potential for future subsidence should be monitored.

The FVGB does not currently have a subsidence monitoring network, though groundwater levels are monitored under CASGEM and other programs. It is important to understand the historical rate and extent of subsidence and identify areas that could be susceptible to future subsidence. If a GSP is developed in the future, the monitoring program should include site-specific studies and a land subsidence monitoring network with continuous GPS or extensometers in the areas susceptible to future subsidence.

For the purposes of this GWMP, the SGMA indicator for "land subsidence" is assumed to be addressed by the same Fremont Basin IRWM objective and planning targets described above for the "groundwater levels" indicator.

6.7 Interconnected Surface Water

Local surface waters in the FVGB are not reliable supply sources because most are ephemeral streams that percolate into the FVGB or evaporate on the impervious Valley floor. As described in Section 4, stream flow stations that were historically monitored were discontinued. For future work under a GSP, surface water monitoring in the basin could be important to understand stream flow conditions, stream-groundwater interactions, potential impacts on beneficial uses of surface water, groundwater dependent ecosystems in local streams and creeks, and minimum thresholds for groundwater-surface water interaction. While the FVGB does not rely on surface water as a water supply, available historical data based on stream flow monitoring suggest that the Fremont Valley may receive significant runoff from its watershed during wet years (Stetson 2009). Therefore, reestablishing stream flow monitoring stations in the Fremont Valley watershed may be critical to a more precise understanding of potential recharge to the basin from local runoff.

For the purposes of this GWMP, the SGMA indicator for "interconnected surface water" is assumed to be addressed by the same Fremont Basin IRWM objective and planning targets described above for the "groundwater levels" indicator.

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7. BASIN MANAGEMENT STRATEGIES AND PROJECTS

This section describes the management strategies and projects identified to support the long-term sustainable management of the FVGB. Several programs and identified projects that will help manage groundwater supplies and quality are already underway in the Plan area. The projects included in this Plan inform and support the regional goals and objectives described in the Fremont Basin IRWM Plan; they also support future development of projects related to sustainable management of groundwater resources.

As described earlier, even though it is not required at this time, the management strategies and projects identified in this GMWP may provide the foundation for a future GSP effort if the agencies in the Plan area elect to form a GSA under SGMA.

7.1 Resource Management Strategies

Various Resource Management Strategies (RMSs) were identified through the Fremont Basin IRWM Plan to help local agencies manage water and water-related resources. RMSs that are pertinent to the GWMP are as follows:

- Agricultural water use efficiency - Using and applying scientific processes to control agricultural water delivery and use to achieve a beneficial outcome.
- Urban water use efficiency - Implementing activities that reduce urban water use by increasing water use efficiency.
- Groundwater/aquifer remediation - Improving the quality of degraded groundwater for beneficial use by removing constituents that affect its beneficial use.
- Pollution prevention - Reducing or eliminating waste at the source by modifying production processes, promoting the use of non-toxic or less toxic substances, reducing the generation and/or discharge of the pollutants, and preventing pollutants from entering the environment prior to treatment.
- Urban runoff management - Managing stormwater and dry-weather runoff by reducing pollutant loading and the volumes and velocities or urban runoff discharged to surface waters.
- Land use planning and management - Planning for the housing and economic development needs of a growing population, while providing for the efficient use of water, water quality, energy, and other resources.
- Recharge areas protection - Implementing activities that ensure areas suitable for recharge continue to be capable of adequate recharge and prevent pollutants from entering the groundwater to avoid expensive treatment that may be necessary prior to beneficial use.
- Public outreach and education - Using tools and practices to facilitate contributions by public individuals and groups toward good water management outcomes.

7.2 Basin Water Management Projects

Water management projects related to the GWMP are presented in Table 25 and are described in the following sections. These projects will benefit the FVGB by supporting regional water supply reliability, promoting sustainable use of the FVGB, and providing drinking water that meets regulatory requirements. The projects in Table 25 reflect many stages of development, from conceptual to planning to implementation. Projects are classified as either “conceptual” or “developed” in Table 25 based on the project’s status, level of development, and readiness to proceed. Conceptual projects are those with minimal planning completed and that require further development to quantify project benefits, costs, and schedule. Conceptual projects are generally expected to evolve into developed projects as planning and design progress.

Table 25: Basin Water Management Projects

Project	Purpose	Implementing Agency	Stage	Impact to FVGB
Water Main Replacements	Replace 53 miles of existing underground water pipes to decrease water losses	City of California City	Developed	Improves urban water use efficiency and conveyance.
Wastewater Treatment Plant Upgrades	Upgrade the City's WWTP to be able to treat additional flows and produce more tertiary recycled water	City of California City	Developed	Protects groundwater quality and augments water supplies for non-potable use.
Conjunctive Use Programs	Coordinated and planned use and management of both surface water and groundwater resources	City of California City, MPUD	Conceptual	Maximizes the availability and reliability of water supplies.
Fremont Valley Basin GSP Development	Develop a GSP for the FVGB to guide sustainable management	City of California City	Conceptual	Could include measures for protecting groundwater quality and quantity and sustaining groundwater resources.
Recycled Water Projects	Increase use of recycled water	City of California City	Conceptual	Maximizes the availability and reliability of local water supplies.
Septic to Sewer Conversion	Convert septic systems to sewer to improve groundwater quality	City of California City	Conceptual	Decreases pollutant concentrations in groundwater basin.
Stormwater Capture and Reuse/Recharge	Capture and recharge stormwater that would have otherwise evaporated from Valley floor	City of California City	Conceptual	Increases available local water supplies and basin sustainability.
Well Blending and Distribution System Enhancements	Blend groundwater from MPUD's Well 30 with groundwater from MPUD's other six wells to reduce nitrate-N in Well 30 below the 10 mg/L MCL	MPUD	Developed	None directly, but decreases nitrate concentrations in potable water supply and potentially in return flows; and extends the volume of water available for potable use.

Project	Purpose	Implementing Agency	Stage	Impact to FVGB
New Water Meters	Replace water meters for 300 connections	RCWD	Conceptual	Accurately measure flow rates and promotes water conservation.
Water Distribution System Upgrades	Repair valves for fire hydrants in the district.	RCWD	Conceptual	Saves water in the event of a catastrophic event.

7.2.1 Fremont Valley Groundwater Basin GSP Development

As previously discussed, the FVGB is designated as a "low priority" groundwater basin and the agencies within the Plan area are not required to comply with SGMA's GSA and GSP requirements. However, the City, AVEK, and MPUD have initiated efforts to prepare the Plan area for SGMA compliance through the development of this GWMP. The City, AVEK, and MPUD, as well as other key stakeholders in the Plan area, may elect to form a GSA in the future and develop a GSP. As a pre-cursor to the GSP, this GWMP may support and inform the future development of a GSP. The GSA for the FVGB would identify and prioritize projects and management actions to maintain the health of the groundwater basin. The future GSP for the FVGB may include the following:

- Basin-wide groundwater level and quality monitoring
- Subsidence monitoring
- Groundwater studies, including development of a robust, 3D groundwater models of water levels, salinity, geological features, and stratigraphy
- Water recycling projects to offset groundwater pumping
- Stormwater capture and reuse/recharge studies that can be conducted in conjunction with the Fremont Basin IRWM Plan
- Public Outreach Plan
- Surface water monitoring program
- Updating land cover maps for future agricultural expansion
- Encouraging conservation and BMPs for agriculture

This project would impact the FVGB by including measures for protecting groundwater quality and quantity and sustaining groundwater resources.

7.2.2 Well Blending and Distribution System Enhancements

This project will be implemented by MPUD and is currently at the developed stage. The project includes blending groundwater from MPUD's Well 30 with groundwater from MPUD's other six wells to reduce nitrate-N in Well 30 below the 10 mg/L MCL. The goal of the project is to provide drinking water that meets regulatory requirements with respect to nitrate. The project will not change groundwater quality with respect to nitrate, but it will decrease nitrate concentrations in the potable water supply and increase overall potable supply quantities; thus, it will serve water that meets drinking water quality requirements and could decrease nitrate concentrations in return flows.

Currently, Well 30 is out of service due to high levels of nitrate exceeding the 10 mg/L MCL as nitrate-N. The blending system would be controlled by a Supervisory Control and Data Acquisition (SCADA) system that would allow preset amounts of water into the blending tank from both Well 30 and the distribution system. Continuous nitrate as N analyses would be performed on the effluent line from the tank. After the water is blended down to 80 percent of the nitrate-N MCL or lower, the blended water would be pumped back into the distribution system. The constructed project will include a new, higher head well pump, 500,000-gallon bolted steel blending tank, booster pump station, plant piping and valves, two continuous nitrate analyzers, connection to the MPUD SCADA system, and about 3/4th of a mile of 8-inch diameter transmission pipeline.

Though this project would not have direct impacts on the FVGB, it decreases nitrate-N concentrations in potable water supply and potentially in return flows and increase the quantity of overall potable supplies.

7.2.3 Conjunctive Use Programs

Conjunctive management refers to the coordinated and planned use and management of both surface water and groundwater resources to maximize the availability and reliability of water supplies. Though there are currently no conjunctive use programs identified in the Plan area, the IRWM Plan identified conjunctive management as an applicable RMS to help local agencies and governments manage their water and water-related resources in accordance with the objectives defined in the IRWM Plan. Within the Plan area, storing excess surface water in the groundwater basin, when available, can be an effective strategy for improving local supply reliability and ensuring sustainable use of the FVGB. This strategy can involve management of both imported water and stormwater to recharge the groundwater basin to prevent groundwater depletion and provide water quality improvement benefits.

These programs would impact the FVGB by maximizing the availability, quality and reliability of water supplies.

7.2.4 City of California WWTP Upgrades

The City is at the developed stage for a number of upgrades to its WWTP to accommodate increases in flow and to improve water quality. One major upgrade involves conversion from a chlorine to ultraviolet (UV) disinfection. The UV process will eliminate the need to generate, handle, transport, or store toxic, hazardous, or corrosive chemicals. This upgrade will improve the water quality to be recycled by removing some organic contaminants that might affect the FVGB.

Overall, the WWTP upgrades will impact the FVGB by protecting groundwater quality and increasing the quantity of recycled water for non-potable use.

7.2.5 Recycled Water Projects

Currently, the City's WWTP can treat an average flow of 4.6 AF per day (1.5 MGD) and a peak flow of 9.2 AF per day (3.0 MGD), though the average influent currently averages 2.5 AF per day (0.8 MGD) (California City Water Department 2017). During a normal year, approximately 500 AF is recycled and used for irrigation at the golf course. When storage basins are full during the winter season, approximately 10 AF is diverted to percolation ponds to offset groundwater extractions. Recycled water projects will augment the quantity of recycled water supplies from 518 AF in 2015 to 988 AF in 2040 for irrigation and percolation.

This project would impact the FVGB by maximizing the availability and reliability of local water supplies.

7.2.6 Septic to Sewer Conversion

Septic tanks are one of the major sources of nutrients in the FVGB. Septic to sewer conversions would decrease nitrate and TDS concentrations in the FVGB as septic tanks contribute nutrients and salts to the basin. Septic to sewer conversions are considered in the Plan as a potential option to maintain nitrate levels in groundwater.

The Fremont Valley Basin SNMP analyzed the amount of septic conversion that would be necessary to maintain current nitrogen levels under four future scenarios: the baseline condition and three future agricultural growth scenarios ("light", “medium”, and “heavy”). The analysis suggested that almost all of the existing septic systems (approximately 3,700) would need to be removed to maintain current nitrate levels. It should be noted that nitrate levels projected for all four scenarios are well below the Basin Plan Objective for nitrate. These calculations in the SNMP demonstrated that the FVGB has sufficient assimilative capacity for nitrate. For TDS, the SNMP evaluated the assimilative capacity of the basin both for the recommended SML of 500 mg/L and the upper limit of the 1,000 mg/L. Based on the upper limit of the 1,000 mg/L that was considered as the water quality objective for the basin, the SNMP demonstrated the FVGB has sufficient assimilative capacity for TDS.

This project would impact the FVGB by decreasing pollutant concentrations in the groundwater basin.

7.2.7 Stormwater Capture and Reuse/Recharge

Stormwater capture and reuse/recharge projects could be beneficial to the Plan area and groundwater by potentially improving water quality in the FVGB as stormwater is likely to contain very low concentrations of all constituents. Stormwater projects are being considered conceptually as part of the Fremont Basin IRWM Plan as they are considered viable options to potentially recharge the basin, augment water supplies, and improve water quality in the basin. The Fremont Valley Basin SNMP analyzed the amount of stormwater recharge that would be needed to maintain the 2015 TDS concentrations under four future scenarios: the baseline condition and three future agricultural growth scenarios (“light”, “medium”, and “heavy”). It should be noted that these projects would be intended to capture and recharge stormwater that would otherwise evaporate from the Valley floor. Stormwater recharge amounts ranging from approximately 3,200 AFY (for the baseline condition) to over 11,000 AFY (for the agricultural “high” growth scenario) were needed to maintain 2015 TDS levels.

This project would impact the FVGB by decreasing pollutant concentrations in the groundwater basin and increasing available local water supplies.

7.2.8 Central Park Lake Restoration

The City has found that some inside surface areas of the lake are failing. This project will fix these failing spots by installing lining on damaged areas and installing water recirculation pumps to improve water quality. The project is currently in the developed stage - water quality analyses were completed and a visual inspection of the lake was performed. The lake is used to store recycled water before delivery to the golf course for irrigation. The lack of proper lining in the lake could cause recycled water seepage to groundwater basin and could cause water quality issues with TDS and nitrate.

This project will protect water quality of the FVGB and could reduce TDS and/or nitrate concentrations in the groundwater basin.

7.2.9 Water Mains Replacement

The City’s water distribution system experiences significant water losses. On average, 24 percent of pumped water is lost to leaks and inefficiencies in the City. The City intends to replace approximately 53 miles of existing underground water pipe to address these leaks. Not only will these improvements reduce the amount of accidental water loss, but they will also improve the reliability of the water system and increase water storage capacity.

This project will increase regional water supply and increase water use efficiency and conveyance.

7.2.10 New Water Meters

RCWD has very costly and outdated mechanical meters that give inaccurate production and flow rate readings. RCWD will implement FlowIQ2100 meters to accurately record water deliveries to each connection from the FVGB. The new meters are highly accurate and have a lifespan of more than 20 years, thus helping improve groundwater sustainability by promoting water use conservation.

This project will promote conservation of supplies in the FVGB.

7.2.11 Water Distribution System Upgrades

RCWD is planning a number of needed system upgrades and equipment replacement to reduce water loss and improve management of the water distribution system. These projects include installing shut-off valves at fire hydrants in RCWD's service area and replacing failing distribution system isolation valves.

This project will prevent the loss of water in the event of a catastrophe.

7.3 Performance Measures

Performance measures are used to assess whether the goals and objectives of the GWMP are being met. The Fremont Basin IRWM Plan identifies performance measures that can be utilized to ensure the RWMG is effectively addressing key regional issues by meeting objectives and planning targets. Led by the City of California City, the RWMG will collectively monitor progress towards meeting the IRWM objectives by reviewing the performance measures outlined in the IRWM Plan and the GWMP. The objectives, targets and performance measures that apply to the GWMP are summarized in Table 26. Each performance measure identifies at least one data source that can be used to track the targets described in Section 6.

Table 26: Plan Performance Measures

Target	Indicators	Data Source	Monitoring Responsibility
Water Supply Objective: Ensure sustainable use of the Fremont Valley Groundwater Basin			
Begin developing a GSA and GSP for the Fremont Valley Groundwater Basin by 2019	GSP development status	Notes from preliminary GSA development meetings	City of California City
Define the safe yield of the Fremont Valley Groundwater Basin by 2027	Safe yield quantification	GSP	GSA
Manage the Fremont Valley Groundwater Basin such that the 10-year average change in groundwater levels is zero	Groundwater level data	CASGEM and USGS well level data; GSP	GSA
Water Quality Objective: Provide drinking water that meets regulatory requirements and customer needs			
Meet Federal and State water quality standards as well as customer standards for taste and aesthetics on an ongoing basis	Drinking water quality data	Consumer Confidence Reports	Local water purveyors
Water Quality Objective: Protect water quality in groundwater basins in the Region			
Prevent degradation of groundwater basins with respect to Basin Plan objectives	Groundwater quality data	SNMP Monitoring Plans; GeoTracker GAMA	RWMG

8. MONITORING PROGRAM

At this time, a specific monitoring program for the GWMP is not required. However, to set the stage for a possible future GSP, this section presents an inventory of prior and current groundwater monitoring activities and programs in the FVGB. It includes a preliminary monitoring plan proposed as part of the Fremont Valley Basin SNMP as it will monitor basin conditions with respect to beneficial uses and applicable water quality objectives for TDS and nitrate.

Monitoring activities documented here are for informational purposes to support future groundwater work. If the agencies in the Plan area elect to form a GSA in the future and develop a GSP, existing monitoring activities and programs will serve as the basis for development of a basin-wide monitoring network in compliance with SGMA.

The City and Plan area stakeholders recognize that cooperation across agencies involved in the basin management is essential to promote long-term sustainability, support the GWMP goals and objectives, and streamline data collection and reporting efforts. Therefore, the current monitoring activities and the monitoring plan proposed in the SNMP could be potentially modified to meet requirements under a larger GSP effort.

8.1 SGMA Monitoring Networks and Identification of Data Gaps BMP

Groundwater monitoring is a fundamental component of SGMA. An appropriately-designed monitoring network and program is required to demonstrate that the basin is being managed to achieve the sustainability goals for each of the SGMA indicators (see Section 7). To help provide technical assistance to GSAs, DWR has developed a BMP for identification of data gaps to aid in the development of a monitoring network.

If the agencies in the Plan area elect to form a GSA in the future and develop a GSP, monitoring networks may need to be expanded and updated beyond those used for existing, pre-SGMA monitoring programs.

8.2 Existing Monitoring and Management Programs

Monitoring for groundwater levels in the FVGB is currently performed by the USGS, DWR under CASGEM, local public entities, and local private entities. Groundwater quality is monitored by public agencies, including the SWRCB, to achieve compliance with existing drinking water regulations. The various existing programs are described below.

8.2.1 Groundwater Levels

Groundwater level data in the FVGB are monitored by local public agencies, local private entities, DWR under CASGEM, and the USGS; some of these data are made publicly available through CASGEM and USGS databases. Data and monitoring frequencies from the local public agencies, CASGEM, and USGS are described briefly in this section.

8.2.1.1 Local Public Agencies

Among the public agencies in the Plan area, the City, MPUD, and Rancho Seco Inc. have active water supply wells monitored for groundwater levels on a regular basis. Based on the data received from these agencies and the USGS, monitoring frequencies used by each agency vary; but the majority of the wells report annual to semi-annual groundwater level data. Production and motoring wells are summarized in Table 27.

Table 27: Production and Monitoring Wells in the FVGB

Agency	Production /Monitoring Wells	Monitoring Frequency	
		Groundwater Levels	Groundwater Quality
City of California City	Six water supply wells (Wells 3, 5, 10, 11, 14, 15) and one well (Well 4) that is not in production	Monitored annually to semi-annually	Monitored annually; USGS reports data every three years for the City's wells 10, 14, 16, and 4 (not in production)
MPUD	Seven public supply wells (Wells 6, 7, 8, 9, 21A, 22, 30) and three monitoring wells (Wells 1, 2, and 31); six of the wells (Wells 1, 2, 6, 7, 8, 9) are located outside of the FVGB	Monitored monthly	Monitoring ranges from annual monitoring (e.g., nitrate) to quarterly (e.g., arsenic, chromium-6)
Rancho Seco, Inc	One active public supply well	Monitored annually	Monitored annually
RCWD	Two public supply wells (Well 01 and Well 02)	No groundwater elevation data	Monitoring ranges from annually (e.g., TDS, chloride) to quarterly (e.g., nitrate, arsenic); data are also represented by the Geotracker-GAMA dataset, where readings are reported three to four times per year for all major constituents
Cal Water	Two public supply wells (01-01 and 01-02)	No groundwater elevation data	Monitored annually; Water Well 1 is also represented in the Geotracker-GAMA dataset where readings are reported every three years

8.2.1.2 California State Groundwater Elevation Monitoring (CASGEM) Program

The CASGEM program was developed by DWR in response to Senate Bill x7-6 that was passed by the legislature in 2009 to establish collaboration between local monitoring parties and DWR to collect statewide groundwater elevations. The CASGEM program builds upon the many previously established local long-term groundwater monitoring and management programs to track seasonal and long-term groundwater elevation trends statewide.

The CASGEM website provides data for over 250 wells through 2010, but groundwater elevation monitoring occurs on a voluntary basis. Currently, the FVGB is categorized as a low priority basin and the majority of the FVGB is not covered by a designated CASGEM monitoring entity. The majority of reported wells have USGS and DWR listed as the monitoring agency. Data are generally reported annually and semi-annually, with annual readings typically reported between February and April. Semi-annual readings are reported between February and April and then between October and December. Some wells had more frequent readings for a given year.

The Mojave Water Agency (MWA) was approved as the CASGEM monitoring agency for the portion of the FVGB in San Bernardino County. MWA's monitoring plan was submitted under the requirements outlined in AB1152 as an alternate plan and were approved under those criteria. According to the MWA's monitoring program, there are no wells actively monitored by the USGS in the portion of the FVGB that is in San Bernardino County.

8.2.1.3 USGS

Existing water levels are currently monitored by the USGS for 34 wells within the basin and data are reported on the USGS website (https://nwis.waterdata.usgs.gov/ca/nwis/gwlevels). Data are reported annually to semi-annually for spring and fall, depending on the well. Spring readings are taken in March while fall readings occur in either August or September of the same year.

8.2.1.4 Local Private Entities

Private entities that are not served by public water suppliers pump groundwater to meet their demand in the FVGB. Based on the well locations data provided by the Kern County, private well locations are known but their monitoring activities are unknown. The Kern County dataset provides one-time sampling of major chemicals of concerns from private wells.

8.2.2 Groundwater Quality

Groundwater quality data in the FVGB are monitored by public agencies and are made publicly available through resources such as the USGS and SWRCB's Geotracker-GAMA program. Data compiled from various data sources for groundwater quality, including the Geotracker-GAMA, are briefly descried in this section. The primary chemicals of concerns for the FVGB include TDS, nitrate, arsenic, boron, chloride, and hexavalent chromium (chromium-6).

8.2.2.1 Public Agencies

Groundwater quality is currently monitored by various public water purveyors in the FVGB (the City, MPUD, RCWD, Rancho Seco Inc, and Cal Water) to meet regulatory requirements, including drinking water regulations enforced by the California Department of Public Health (CDPH), the SWRCB Division of Drinking Water (DDW), and the Kern County Environmental Health Department. The Kern County's Water Well and Small Water System Programs ensure the public receives water that is safe to drink and the quantity supplied is adequate to meet the community's needs. The Water Well Program issues permits to construct, reconstruct and destroy water wells. The Small Water System Program is involved with the permitting, inspection, and monitoring of small public water systems and the evaluation of the construction and water quality of existing water wells. The monitoring frequencies used by the public agencies are summarized in Table 27.

8.2.2.2 Geotracker-GAMA

The Geotracker-GAMA groundwater information system is California's comprehensive groundwater quality monitoring program that was created by the SWRCB in response to the Groundwater Quality Monitoring Act of 2001 (AB 599). AB 599 required the SWRCB to incorporate and display existing water quality data though a publicly accessible interactive online map from various monitoring programs throughout the State. Geotracker-GAMA is based on interagency collaboration with the SWRCB, Regional Water Boards, DWR, the Department of Pesticide Regulations, USGS, and Lawrence Livermore National Laboratory. It also relies on cooperation from local water agencies and well owners. Groundwater information is constantly integrated into the system from various public and private sources using the SWRCB's secure Electronic Submission of Information module or by GAMA program staff.

Data reporting frequencies under Geotracker-GAMA range from every three years, to annual, to quarterly, depending on the well and constituent. In the FVGB, groundwater quality is monitored by public agencies at their wells in addition to the data reported by the Geotracker-GAMA online website. Since the Geotracker-GAMA includes data from public and private sources, it is possible for the Geotracker-GAMA data to include wells operated by public agencies.

8.2.2.3 USGS

In addition to the Geotracker-GAMA website, USGS maintains water quality data for groundwater basins in the National Water Quality Information System. USGS reports concentration values every three years. Most readings are taken in August.

8.2.3 Proposed SNMP Monitoring Plan

In addition to previous, ongoing monitoring activities for groundwater levels and quality in the FVGB, the Fremont Valley Basin SNMP developed and proposed a preliminary monitoring network to monitor and evaluate salt and nutrient constituents in the FVGB (Woodard & Curran 2018). The SNMP monitoring plan proposes to monitor several primary parameters on an annual basis, including electrical conductivity, pH, temperature, TDS and nitrate, in addition to general minerals and physical constituents (e.g., calcium, magnesium, potassium, sodium, copper, iron, manganese, zinc, chloride, sulfate, alkalinity and hardness). Using CASGEM and SGMA monitoring well density guidelines, seven wells from the pool of existing wells were selected for the SNMP monitoring plan. The SNMP also provided a framework for standard monitoring protocols to be used for data collection and reporting. The SNMP may support and inform the future development of a GSP for the FVGB with respect to basin management strategies, monitoring plans, and implementation strategies related to TDS and nitrate water quality.

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APPENDIX A: FREMONT VALLEY GROUNDWATER BASIN – MASS BALANCE ANALYSIS

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TECHNICAL MEMORANDUM

SUBJECT: Fremont Valley Groundwater Basin Spreadsheet-Based Mass Balance Analysis

TO: California City of California

PREPARED BY: Sevim Onsoy (PhD), Woodard & Curran

REVIEWED BY: Brian Dietrick (PE No. C54920), Chris Van Lienden (PE No. C75034), Woodard & Curran

DATE: August 6, 2018

A spreadsheet-based groundwater mass balance model was developed for the Fremont Valley Groundwater Basin (FVGB) as part of the Fremont Valley Basin Groundwater Management Plan (GWMP). The model uses hydrological data and estimated basin inflows and outflows as inputs. The model was set up on annual basis and was calibrated against historical changes in groundwater storage volume estimated using groundwater elevation contour maps between 1958 and 2017. The model was used as a tool to estimate annual groundwater recharge to the basin along with changes in storage volume due to changes in local hydrology and pumping activity. This technical memorandum (TM) describes the methodology and assumptions used for the modeling analysis.

1. INTRODUCTION

There is a limited understanding of groundwater storage capacity in the FVGB. Different estimates of groundwater storage capacity have been reported for the FVGB or portions of the basin, though the amount of groundwater in storage is currently unknown. A recent investigation by Stetson (2009) estimated the groundwater storage for two subunits, referred to as Mojave City and California City Subbasins, at approximately 2.62 million acre-feet (MAF) and 5.66 MAF, respectively. It is important to note that this previous estimate was based on assumed basin boundaries that were different than the Department of Water Resources (DWR) Bulletin 118 basin boundary used for the GWMP.

The spreadsheet-based mass balance model uses simplifying assumptions to quantitatively estimate the changes in storage as a result of changing hydrology and pumping activity in the FVGB. Calibration of the model was performed by comparing two parallel analyses, a mass balance analysis and groundwater contour analysis. For the groundwater contour analysis, groundwater elevations were mapped for selected representative years; and these contour maps were compared over time to calculate the changes in groundwater elevations and resulting changes in groundwater storage volume. For the mass balance analysis, inflows and outflows to the basin were estimated using certain assumptions and historical data. The mass balance values were then calibrated against the changes in groundwater storage volume estimated from the groundwater contour analysis. The mass balance analysis was conducted on an annual basis for years between 1945 and 2017. The groundwater contour analysis begins in 1958 as groundwater elevation data prior to 1958 were unavailable.

2. DATA SOURCES

Various data sources were used to quantify values for the mass balance model, to delineate watershed boundaries, and to estimate model inputs for the mass balance analysis. These data included crop acreages, precipitation values, urban and agricultural demands, groundwater pumping volumes, and groundwater subsurface inflows and outflows. In addition, groundwater elevation data were used to generate the groundwater contour maps that were used to calibrate the changes in groundwater storage for the mass balance analysis. Data types and sources are summarized in Table 1 and the key data sources are described in the following sections. References for specific data sources presented in Table 1 were included in the GWMP.

Table 1: Data Sources for FVGB Mass Balance and Groundwater Contouring Analyses

Data Type	Data Sources	Methodology/Assumptions
Model Area	DWR Bulletin 118	Use to define the FVGB, Northern FVGB, and Southern FVGB boundaries.
Watershed Boundaries	Stetson (2009)	Areas of surrounding watersheds contributing runoff to FVGB. Contributing areas were recalculated to include areas outside of the Bulletin 118 basin boundary.
Precipitation	Mojave Station (WRCC); Ransburg Station (NOAA); Tehachapi Station (NOAA)	Reported precipitation data at three precipitation stations located within the Fremont Valley watershed were used to estimate direct recharge and runoff recharge to the FVGB.
Recharge Coefficients	NA	Recharge coefficients estimated through calibration to calculate the amount of precipitation that is assumed to infiltrate into groundwater.
Crop Acreages	USGS (1977); USDA National 2017 Cropland Data Layer; Google Earth Aerial Maps	Estimated from previous investigations and aerial maps; missing years were interpolated
Crop Types	USGS (1977); Richard C Slade & Associates (1995); DWR (https://gis.water.ca.gov/app/NCDatasetViewer/#)	Historically assumed alfalfa; alfalfa and/or pistachios in years 2014 – 2017.
Urban Demand	Population by U.S. Census data; historical growth rates in Kern County by the Department of Finance (DOF); average assumed gallons per capita per day (GPCD) from UWMPs	Estimated based on historical groundwater pumping data and imported water data; missing water, demand records were interpolated/extrapolated.
Agricultural Demand	Cooperative Extension University of California Division of Agriculture and Natural Resources N.D.a. and N.D.b.; Google Earth Aerial Maps, CIMIS station Palmdale 197	Calculated by applying specific crop coefficients to crops; agricultural demand was assumed to be met by groundwater pumping.
Urban Pumping	Richard C Slade & Associates 1995; Stetson (2009); Public Agencies (City of California, MPUD, Cal Water, Rancho Seco Inc, RCWD)	Estimated based on groundwater pumping data to meet the estimated urban demand.
Agricultural Pumping	USGS (1977); Richard C Slade & Associates (1995)	Estimated based on historical data available for consumptive use. Years without pumping records were estimated based on crop acreages and calculated consumptive water use.
Other Pumping	NA	Unknown pumping estimated through calibration in the Southern FVGB.
Groundwater Inflow and Outflow	Stetson (2009)	Subsurface inflow from Antelope Valley Groundwater Basin to Northern FVGB
	Stetson (2009)	Subsurface inflow from Southern FVGB to Northern FVGB.
Groundwater Elevations	DWR CASGEM and USGS	Used to generate groundwater elevation contour maps.

Notes: WRCC: Western Resources Climate Center; NOAA: National Oceanic and Atmospheric Administration; NA: Not available; UWMP: Urban Water Management Plan

3. MODEL AREA

For the groundwater mass balance analysis, the FVGB (as defined by DWR Bulletin 118) is represented as two subareas with the Muroc fault as a hydrogeologic divider. This approach allows for a more precise assessment of spatial variability and localized trends in groundwater levels. In this analysis, the portion of the FVGB north of the Muroc fault is referred to as the "Northern FVGB" and the portion south of the Muroc fault is referred to as the "Southern FVGB". This terminology was introduced to differentiate the two subareas from the other naming conventions used by the USGS and the 2009 Stetson study, which also assumed different geographic coverage for subbasins. Figure 1 shows the geographic coverage for the two subdivisions used in this modeling analysis as compared to the geographic coverage for the two subbasins used in the previous Stetson investigation.

The area overlying the FVGB as defined by DWR Bulletin 118 is approximately 335,200 acres, including approximately 198,600 acres in the Northern FVGB and 136,600 acres in the Southern FVGB. In comparison, the California City Subbasin and Mojave City Subbasin defined by Stetson (2009) cover approximately 142,450 acres and 73,330 acres, respectively. This constitutes a difference of 119,400 acres.

3.1 Watershed Boundaries

The spreadsheet mass balance model accounts for both direct recharge (directly overlying the FVGB) and runoff recharge to the FVGB from tributary watersheds. To estimate runoff recharge, tributary watershed areas were used in combination with historical precipitation data. The tributary watershed boundaries defined by Stetson (2009) were used as the starting point to estimate contributing runoff, but the boundaries were adjusted to reflect the FVGB basin boundary per DWR Bulletin 118. Tributary watersheds that contribute runoff to the basin include the El Paso Mountains, Tehachapi, Oak Creek and Rand Mountains, as shown in Figure 2 . Since the FVGB basin boundaries are different than those assumed in the 2009 Stetson report, this also affects the tributary watershed boundaries. Note that portions of the tributary watersheds that fall within the Bulletin 118 FVGB boundary were excluded from runoff recharge calculations to avoid double counting; these areas inside the Bulletin 118 boundary are accounted for as part of direct recharge to the basin.

Figure 1: Fremont Valley Groundwater Basin Subdivisions

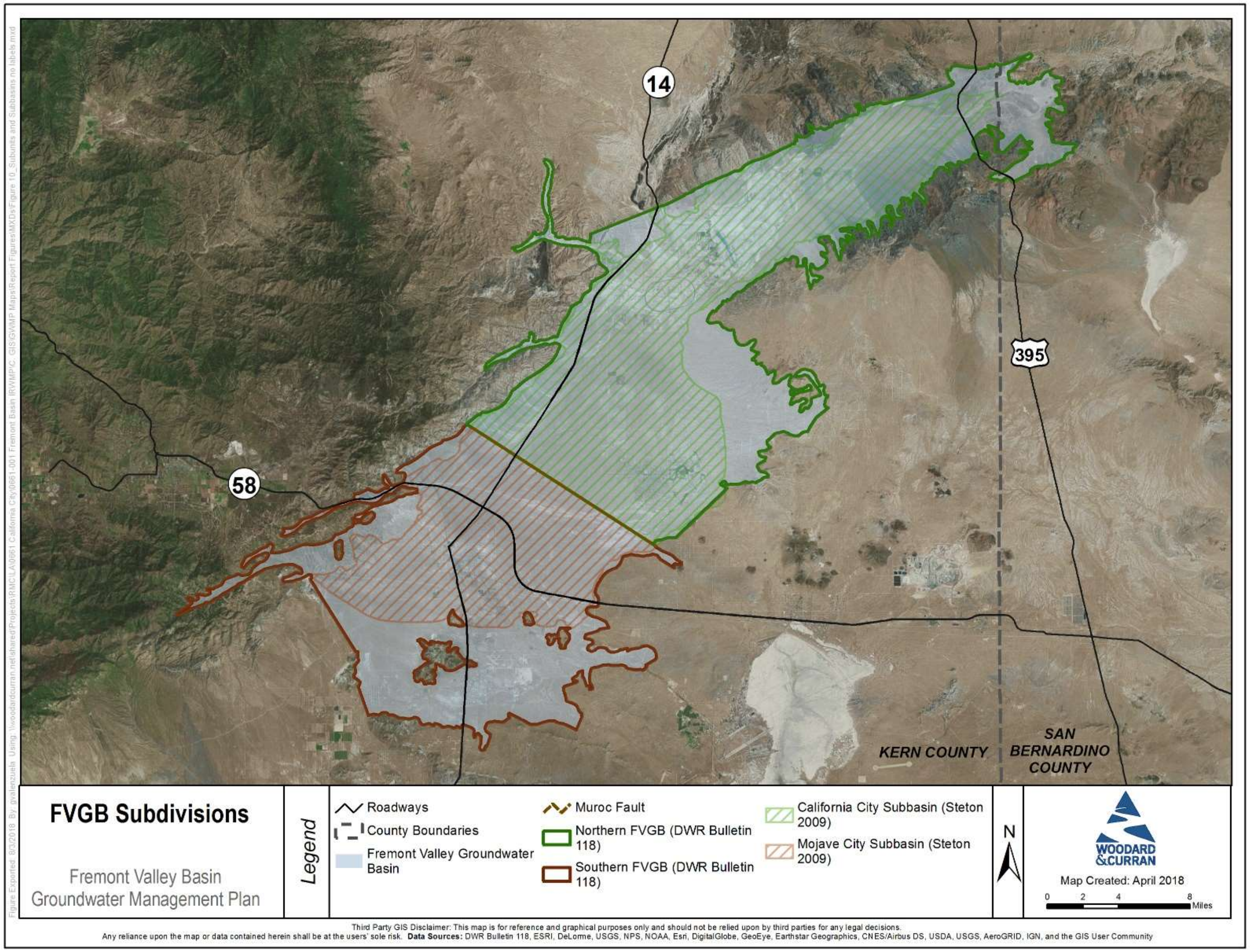
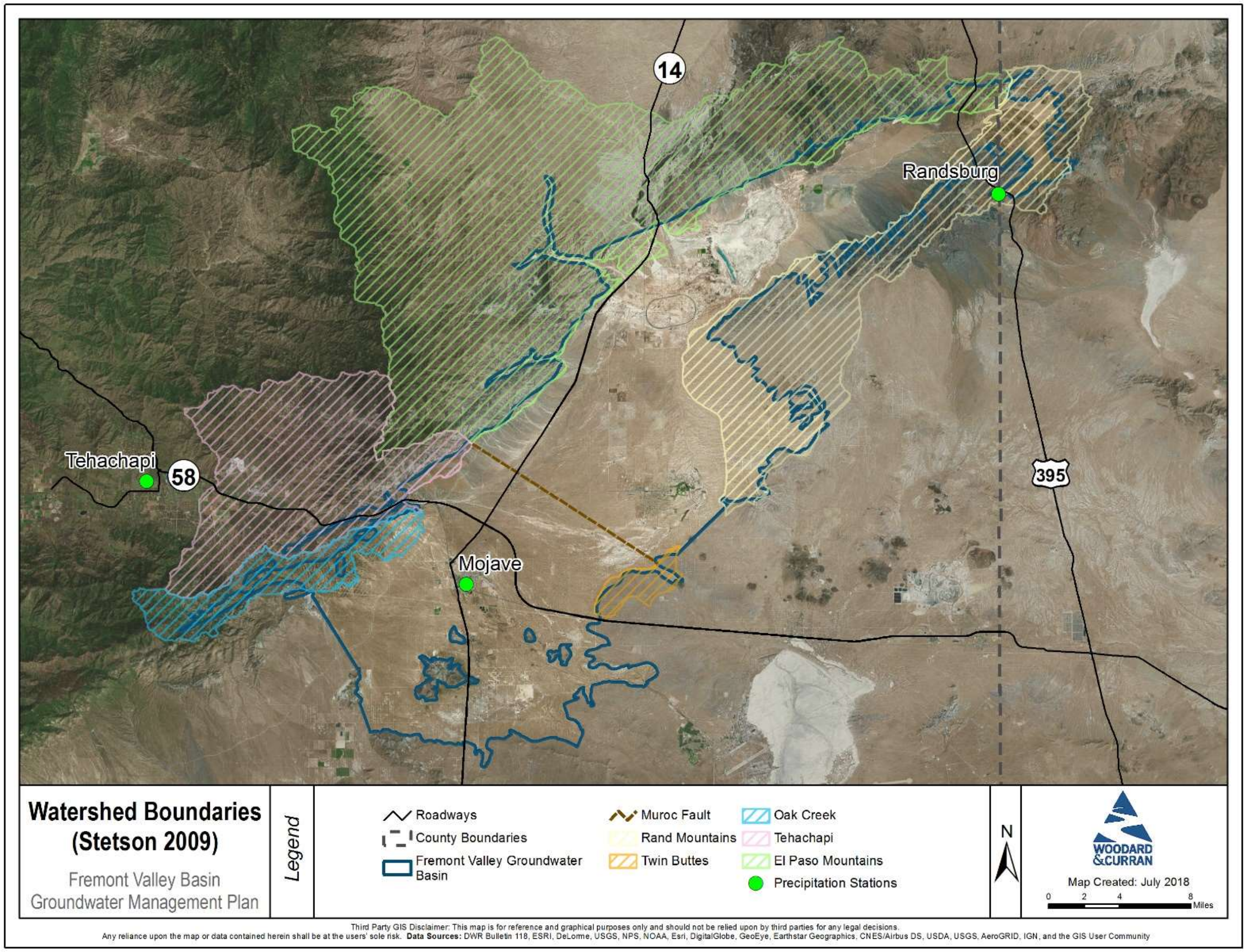


Figure 2: FVGB – Tributary Watershed Boundaries

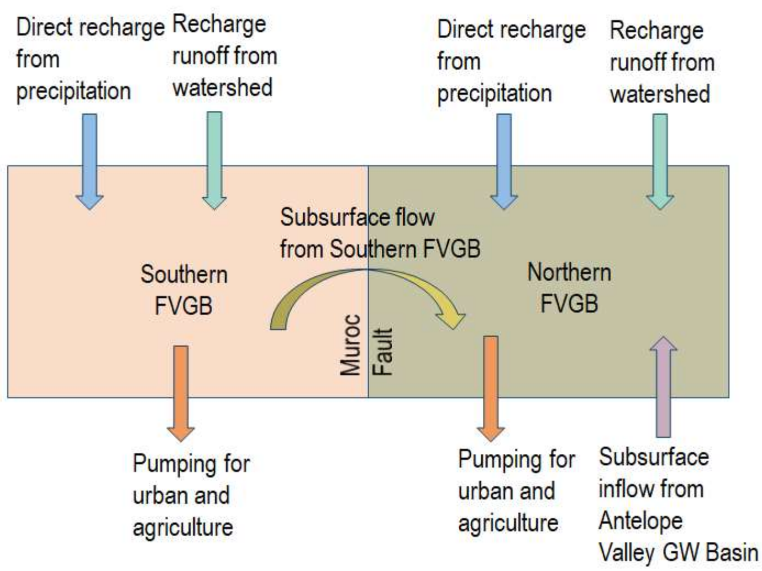


4. GROUNDWATER MASS BALANCE ANALYSIS

The mass balance analysis was set up to track annual inflows and outflows separately for the Northern and Southern FVGB to calculate annual changes in groundwater storage volume. Water balance calculations were performed as shown in the following equation and as depicted schematically in Figure 3 .

Change in Storage Volume = Inflows (Recharge from Direct Precipitation + Recharge Runoff from Watersheds + Subsurface Inflows) – Outflows (Pumping + Subsurface Outflows)

Figure 3: Schematic Groundwater Mass Balance Approach



4.1 Inflows

Major inflows both in the Northern and Southern FVGB include direct recharge from precipitation to the basin and runoff recharge from the neighboring tributary watersheds. The Northern FVGB receives recharge runoff contributions from the El Paso Mountains watershed to the west and from the Rand Mountains watershed to the east. The Southern FVGB receives recharge runoff contributions from the Oak Creek and Tehachapi Mountain watersheds to the west. The Northern FVGB is also assumed to receive a small amount of underflow from the Antelope Valley Groundwater Basin, estimated at approximately 2,570 acre-feet per year (AFY) based on the Stetson report (2009) and a small amount of underflow from the Southern FVGB across the Muroc fault. This subsurface flow across the fault was based on the Stetson report (2009) and was assumed to occur historically up until 1958 only, ranging from zero to 5,475 AFY.

4.1.1 Precipitation and Recharge

The overlying areas for the Northern and Southern FVGB, as shown in Figure 1 , were used to estimate direct recharge from precipitation to remain consistent with Bulletin 118 basin boundary for the FVGB. Annual precipitation data were used from three precipitation stations located in the Fremont Valley watershed: Mojave Station, Tehachapi, and Ransburg (see Figure 2). The Mojave Station is located in the southern portion of the FVGB. Historical data between 1945 and 2017 indicate precipitation is highest at the Tehachapi Station and lowest at the Mojave Station. Annual precipitation at the Mojave Station ranged from 0.75 inches to 15.51 inches, for an average of approximately 5.1 inches. Annual precipitation at the Tehachapi Station ranged from 2.52 inches to 27.77 inches, for an average of approximately

10.1 inches. Annual precipitation at the Randsburg Station ranged from 0.83 inches to 16.4 inches, for an average of approximately 5.9 inches. Annual precipitation data at each station are available in the Fremont Valley Basin GWMP.

Precipitation data from the Mojave station were used to estimate natural recharge to the Northern and Southern FVGB; precipitation data from the Ransburg station were used to estimate recharge runoff from the Rand Mountains watershed to the Northern FVGB; and precipitation data from the Tehachapi station were used to estimate recharge runoff from the El Paso Mountains watershed to the Northern FVGB and from the Oak Creek and Tehachapi Mountain watershed to the Southern FVGB.

Recharge coefficients were developed to estimate the amount of precipitation that is assumed to infiltrate into the basin as natural recharge, whether direct or from runoff. Direct recharge from precipitation and recharge runoff from precipitation from tributary watersheds were calculated as follows:

$$R = P \times R_c \times A$$

Where R represents the estimated annual recharge (AF); P represents annual precipitation (feet); R_c represents a dimensionless recharge coefficient that calculates the percentage of precipitation that results in recharge; and A is the surface area of the overlying basin or tributary watershed (acres). Recharge coefficients were generated for each of the three precipitation stations separately during calibration. The methodology used to generate the recharge coefficients are described in the Calibration section (Section 6) below.

4.2 Outflows

Major outflows both in the Southern and Northern FVGB include groundwater pumping. As described above, a small amount of underflow was assumed from the Southern FVGB to the Northern FVGB; but there is no significant known quantity of groundwater flowing out of the basin.

4.2.1 Pumping

Groundwater extraction in the FVGB includes pumping for urban and agricultural end uses.

4.2.1.1 Urban Demand and Pumping

Historically, the City and MPUD were entirely dependent on groundwater until AVEK began delivering imported surface water from the SWP in 1980. Pumping by smaller water suppliers (Cal Water, Rand Communities Water District, and Rancho Seco Inc.) has been fairly small based on the limited data available. Pumping by private well owners, which make up the remaining demands in the FVGB, is difficult to estimate as it is unmetered and unreported.

Urban pumping was estimated based on imported water sales data provided to the City and MPUD by AVEK and the assumption that remaining demands are met with pumped groundwater. For years with missing water records, demands were extrapolated using:

- Population overlying the FVGB (provided by U.S. Census data)
- Historical growth rates in Kern County (provided by the Department of Finance (DOF))
- Average assumed gallons per capita per day (GPCD) for the City and MPUD (obtained from UWMPs)

In the Northern FVGB (north of Muroc fault), surface water deliveries from AVEK to the City of California and MPUD were available from 1979 to 2017 and were used to estimate urban pumping for the City of California and MPUD. For years where the surface water deliveries were available and groundwater pumping records were unavailable or incomplete, surface water deliveries were subtracted from the total estimated demand to estimate urban groundwater pumping. Total urban pumping estimated in the Northern FVGB for the last 20 years averaged 3,400 AFY, including the City's average pumping of approximately 3,200 AFY plus the remaining pumping for small communities and private wells. The City of California annual pumping data were available for 1953-1969 and 2000-2007 based on the Stetson report (2009). Data for 2010-2016 were based on records provided by the City. For years without pumping records, urban demand was assumed to be met by groundwater pumping after surface water deliveries were taken into account, as described above.

In the Southern FVGB (south of Muroc fault), total urban pumping estimated by MPUD for the last 20 years averaged approximately 860 AFY. MPUD pumping was estimated for 1951 to 1993 based on total metered water sold, after surface water was taken into account, beginning in 1979 (Richard C Slade & Associates 1995). Pumping volumes for 2012 – 2016 were based on pumping records provided by MPUD. For years with missing pumping data, urban demand was assumed to be met by groundwater pumping after surface water deliveries were taken into account. For urban demand estimates in the Southern FVGB, it was assumed that the population consists of the MPUD service area and approximately 30 percent of the population in unincorporated Kern County that overlies the FVGB. The 30 percent value is assumed because approximately 30 percent of the current unincorporated Kern County population overlying the basin resides south of the Muroc fault. All remaining population overlying the basin was assumed to be located in the Northern FVGB.

4.2.1.2 Agricultural Demand and Pumping

Historically, agriculture has been an important component of the water demand and groundwater pumping for the FVGB. Agricultural pumping was estimated based on agricultural demands, assuming that all agricultural demands were met by groundwater pumping. Data used for crop acreages and the methodology used for calculating agricultural demand are summarized in Table 2 and explained in the following sections.

Table 2: Data Sources, Methodology, and Assumptions Used for Crop Acreages and Agricultural Demand in the Northern FVGB

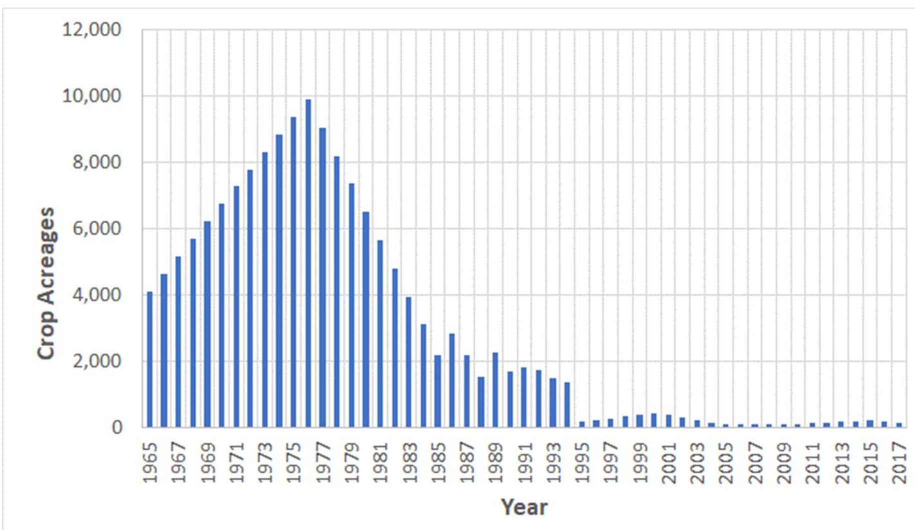
Years	Data Source	Methodology/Assumptions Used for Data Gaps
1945 – 1964	No data available for crop acreages	Agricultural demand assumed during calibration.
1960 – 1976	USGS (1977); Google Earth Aerial Maps	Agricultural demand based on the USGS estimates, except for 1967. Missing data for 1967 was interpolated.
1977 – 1983	No data for crop acreages were available	Crop acreages interpolated based on data between 1976 and 1984; agricultural demand calculated based on crop acreages.
1984 – 1995, 2000, 2005, 2010	Google Earth Aerial Maps	Agricultural demand calculated based on crop acreages from aerial maps; assumed 100% alfalfa.
2014	No data available for crop acreages	Crop acreages were interpolated; agricultural demand calculated based on crop acreages; assumed 100% pistachios.
2015	Google Earth Aerial Maps	Agricultural demand calculated based on crop acreages from aerial maps; assumed 50% alfalfa and 50% pistachios.
2016	No data available for crop acreages	Crop acreages were interpolated; agricultural demand calculated based on crop acreages; assumed 50% alfalfa and 50% pistachios as in 2015.
2017	USDA National 2017 Cropland Data Layer; Google Earth Aerial Maps	Agricultural demand calculated based on crop acreages; assumed 40% alfalfa and 60% pistachios.
Other Years	No data available for crop acreages	Crop acreages were interpolated between subsequent years; agricultural demand calculated based on crop acreages; assumed 100% alfalfa.

4.2.1.2.1 Crop Acreages

To estimate the areas cultivated historically, visual observations of aerial maps were used. Table 2 presents the years for which historical aerial maps were available. These observations suggested that most agricultural activities were performed in the Northern FVGB, but it was not possible to confirm the types of crops produced in the Northern FVGB based on the aerial maps. Since alfalfa has historically been grown throughout the Plan area, agricultural demand estimates assume that alfalfa is the only crop cultivated in the Plan area, except for 2014 and 2017 when more precise data were available. In 2014, pistachios were assumed to be cultivated based on the DWR data confirming that fruits and nuts were grown in the area. Overall, agricultural activities and crop acreages increased through the 1960s and 1970s and peaked in 1976, according to previous USGS investigations (USGS 1977). Agricultural activities significantly decreased thereafter; and as of 2017, only 159 acres of land was estimated to be cultivated for alfalfa (approximately 40 percent of the total cultivated lands) and pistachios (approximately 60 percent of the total cultivated lands). For years when aerial maps were not available or not compiled, crop acreages were interpolated using the values for known crop acreages. Data sources and assumptions used for data gaps are summarized in Table 2. Estimated crop acreages for the Northern FVGB are shown in Figure 4.

Three were no specific crop acreages identified for the Southern FVGB. Estimates of agricultural pumping were available only for 1964 – 1973 (Richard C Slade & Associates 1995) and these data were incorporated into the mass balance calculations (see calibration discussion in Section 6).

Figure 4: Estimated Crop Acreages for Northern FVGB



4.2.1.2.2 Agricultural Demand

Agricultural water demands for alfalfa and pistachios were estimated based on the calculated monthly gross water requirements (ETc) as the product of the reference evapotranspiration (ETo) and a unique crop factor (Kc). Kc values account for specific daily evapotranspiration variations due to growth and development in different crops. Alfalfa has an annual gross water requirement more than eight times greater than that of pistachios, which results in a significant difference in agricultural water demand for a given acreage (Cooperative Extension University of California Division of

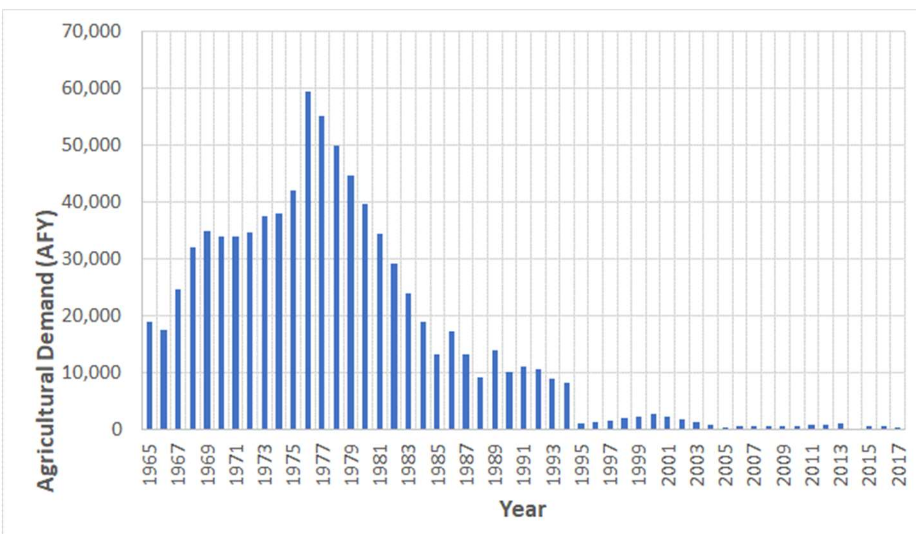
Agriculture and Natural Resources N.D.a. and ND.b.). Average annual rainfall data[1] were subtracted from average crop demand. Based on an assumed irrigation efficiency of 75 percent under normal conditions (USDA 2013) and annual average rainfall, crop ETc is estimated at approximately 60.7 inches for alfalfa and 7.4 inches for pistachios. For 2017, for instance, this results in water demand estimates of 390 AF for alfalfa and 16 AF for pistachios. Note that Alfalfa is a very water-intensive crop; and though it was assumed to be cultivated on about 40 percent of all farm lands (64 acres) in the Northern FVGB in 2015, it is estimated to account for more than 96 percent of the total agricultural water demand.

4.2.1.2.3 Agricultural Pumping

Agricultural pumping, assumed to meet all agricultural demands, was estimated based on crop coefficients and available crop acreages, using assumptions and interpolation to fill in data gaps. Table 2 presents the data sources, assumptions used for estimating agricultural demand from 1945 to 2017 for the Northern FVGB. Figure 5 presents the estimated agricultural demand for the Northern FVGB. Overall, agricultural activities increased through the 1960s and 1970s and peaked in 1976, with groundwater extractions reaching a maximum of approximately 59,500 AFY according to previous USGS investigations (USGS 1977).

For the Southern FVGB, estimates of agricultural pumping were available only for 1964 – 1973 (Richard C Slade & Associates 1995), as mentioned above. For other years, pumping rates were unknown and values were assumed during calibration (see calibration discussion in Section 6).

Figure 5: Estimated Agricultural Demand for Northern FVGB (AFY)



[1] CIMIS Palmdale No. 197 Station rainfall records since April 2005. Accessed 9 August 2017 from: www.cimis.water.ca.gov/Stations.aspx.

5. GROUNDWATER ELEVATION CONTOUR ANALYSIS

A network of wells was selected north of the Muroc fault and south of the Muroc fault to calculate the change in storage volumes for the Northern FVGB and the Southern FVGB separately over time. Figure 6 shows the locations of the wells that were selected for the contouring analysis. Twenty representative years were selected based on the availability of sufficient groundwater level data; the years were also selected such that both dry and wet hydrologic periods were included. Table 3 presents the years selected; it identifies the hydrologic condition of each year with respect to long-term average precipitation. Each year, an average of January, February, March, and April groundwater elevation measurements were averaged to represent spring groundwater elevations, when available (i.e., to capture conditions that occur, generally, after the "rainy season"). Representative wells were then selected from the available data for each of the twenty years; the same wells were selected for each year when possible. For wells with missing data, groundwater elevation values were interpolated based on adjacent years or nearby wells, as appropriate. Appendix A of this TM presents the groundwater hydrographs used for the groundwater contouring analysis based on measured and interpolated values. Groundwater hydrographs with data records shown in blue represent the measured groundwater elevations and data records shown in orange represent interpolated groundwater elevations.

The "Natural Neighbors" tool for raster[1] interpolation in Geographic Information System (GIS) software was used to develop groundwater contours for the Northern and Southern FVGB separately. Appendix B presents the groundwater contours generated for the Northern and Southern FVGB for the selected years and selected wells. The change in groundwater elevation between each of the selected years was then calculated using raster math in GIS. This approach estimates the volume of dewatered sediments and multiplies that value by the specific yield of the sediments for each consecutive year contoured. The change in storage was calculated by multiplying the change in groundwater elevation for each cell of a raster by the area covered by the raster, using a specific yield value of 0.098[2]. The value assumed for the specific yield was based on the previous investigation by Stetson (2009) for the unconsolidated deposits. The 1977 USGS study had an average specific yield of 1.1 percent (0.011) for the Koehn Lake area.

Some portions of the basin were not contoured because data were sparse or lacking. To calculate the change in storage outside of the raster areas for a given time period, the average change in groundwater elevation inside the raster areas was used.

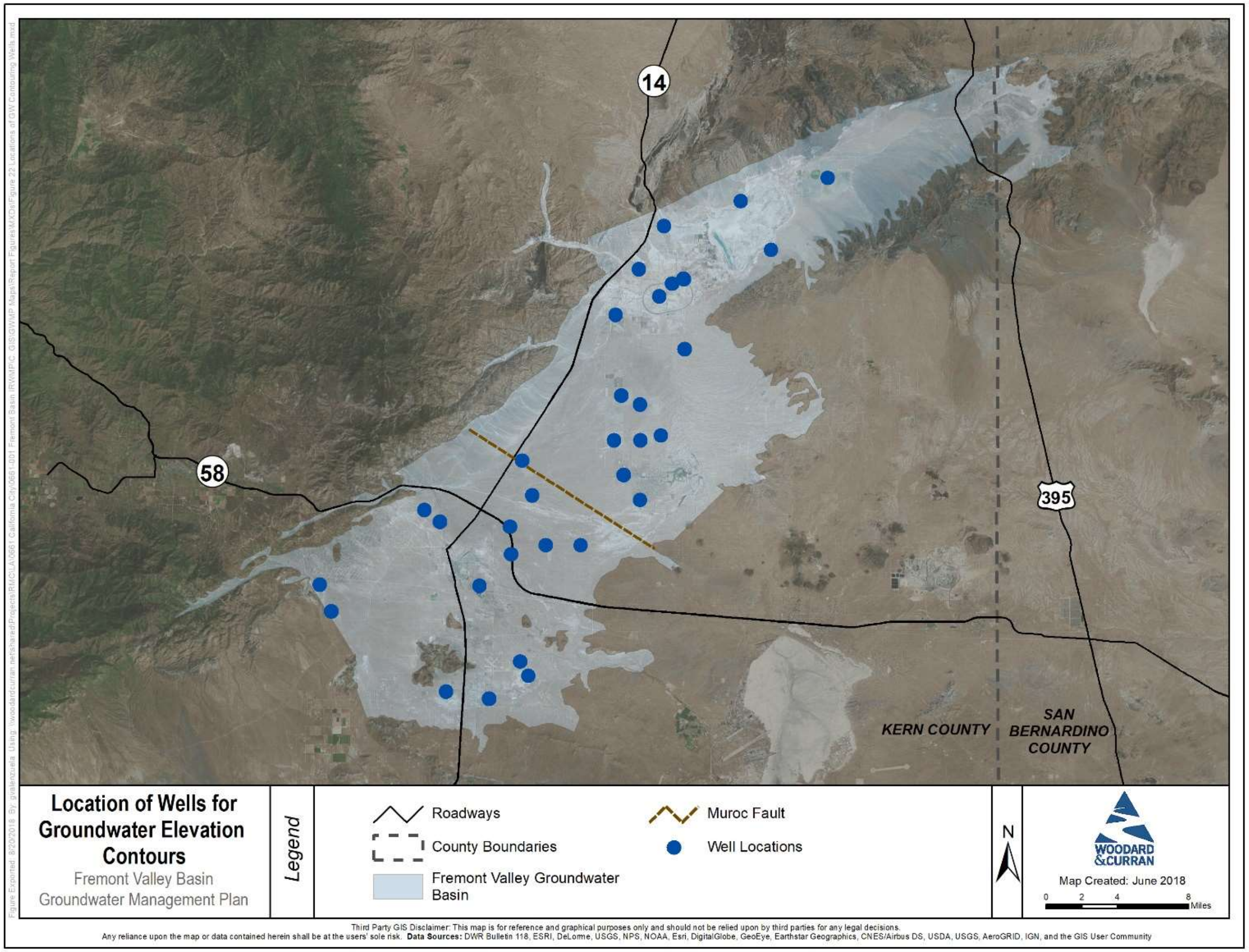
[1] A raster is a spatial data model that defines space as an array of equally sized cells arranged in rows and columns composed of single or multiple bands. Each cell contains an attribute value (such as groundwater level) and location coordinates.
[2] Specific yield is defined as the percentage by volume of drainable pore spaces.

Table 3: Years Selected for Groundwater Elevation Contours

Year	Year Type	Year	Year Type
1958	Wet Year	1990	Dry Year
1969	Wet Year	1993	Wet Year
1972	Dry Year	1995	Wet Year
1975	Dry Year	1998	Wet Year
1978	Wet Year	2005	Wet Year
1980	Dry Year	2007	Dry Year
1981	Dry Year	2010	Dry Year
1983	Wet Year	2013	Dry Year
1985	Dry Year	2015	Dry Year
1987	Dry Year	2017	Dry Year

Note: Wet years represent year with precipitation above the long-term average at the Mojave Station; dry years represent precipitation below the long-term average at the Mojave Station.

Figure 6: Locations of Wells Used for Groundwater Elevation Contours



6. CALIBRATION

Calibration was performed to minimize the difference between the change in storage estimated from the mass balance analysis and the change in storage estimated from the groundwater elevation contour analysis. The model was calibrated using a trial-and-error approach. Initial iterations used the solver function available in the Microsoft Excel program, but the calibration included a manual process. The primary model parameters subject to calibration were the recharge coefficients, which were adjusted to achieve a good match between the two analyses. Note that recharge coefficients, as a percentage of precipitation, tend to be higher with increasing precipitation as the effects of evaporation become less significant relative to percolation.

The changes in storage between the two datasets were plotted and then recharge coefficients were adjusted within probable ranges, between 0.001 and 0.2. Visual comparison of the change in storage curves calculated between the two datasets also provided a qualitative evaluation of the calibration. The root-mean-square-error (RMSE)[1] was also used to quantitatively evaluate the difference (i.e. residuals) between the two datasets during calibration. Given the uncertainties of the groundwater pumping used in the mass balance analysis, the overall aim for calibration was to capture the general trends of the change in storage volumes estimated from the groundwater contour analysis. Table 4 presents the range of values for precipitation and recharge coefficients established during the calibration process.

Table 4: FVGB Recharge Coefficients

Precipitation Station	Type of Recharge	Basin/Watershed Contributing Runoff	Precipitation Range (inches)	Recharge Coefficient
Mojave Station	Direct, Valley Floor	Northern FVGB, Southern FVGB	0 - 2.4	0.001
			2.4 – 3.8	0.002
			3.8 – 7.3	0.005
			7.3 – 15.5	0.01
Tehachapi Station	Runoff, Tributary Watershed	El Paso Mountains Watershed	0 – 7.4	0.001
			7.4 – 9.6	0.002
			9.6 – 12.6	0.008
			12.6 – 27.8	0.07
Randsburg Station	Runoff, Tributary Watershed	Rand Mountains Watershed	0 - 3.1	0.001
			3.1 - 5.6	0.002
			5.6 - 7.7	0.01
			7.7 - 16.4	0.2

In the Northern FVGB, the initial years through the early 1960s indicate a relatively poor fit between the two change in storage curves. Since the contour maps started in 1958, and due to lack of data for water balance values, this period was not critical to the overall calibration process. For the period from 1960 to 1976, agricultural demand and pumping were based on values from the 1977 USGS study. No adjustments were made to those values to improve the calibration for this period. The decline in storage was greater during years where agricultural pumping was high, from the 1960s through the late 1970s. This is consistent with declining trends observed in groundwater elevations. The model also showed the largest decline in storage around the mid-1980s followed by a reversed, increasing trend for change in storage thereafter. This is also consistent with general trends observed in groundwater levels where declines in groundwater levels slowed down or became more stable after agricultural pumping declined significantly and surface

[1] RMSE is the square root of the average of squared residuals between two datasets.

water deliveries began. A better fit was obtained for later years, which was likely due to less uncertainty in the pumping data.

For the Southern FVGB, agricultural and private pumping was lumped into "other groundwater extraction" due to a lack of data to differentiate pumping end uses. Estimates of agricultural pumping were available only for 1964 – 1973 (Richard C Slade & Associates 1995). No adjustments were made to those values to improve the calibration for this period. For all other years, pumping rates were unknown and values were assumed for a close fit during calibration. The calibration process for the Southern FVGB revealed that some form of outflow would have to be assumed in order to provide a close match between the change in storage estimates. While there is no evidence of significant agricultural development after 1973 in this subarea, it is possible that this represents basin outflow (i.e., private well pumping) that cannot be explained by available data or reasonable assumptions; thus, it was lumped into "other groundwater pumping".

7. CHANGE IN GROUNDWATER STORAGE

Figure 7 and Figure 8 present the individual mass balance components along with the changes in storage calculations for the Northern and Southern FVGB, respectively. The figures are based on the mass balance analysis (black dashed line) and the groundwater contour analysis (black solid line). The cumulative change in storage after calibration was estimated to be -738,000 AF, with approximately -608,000 AF in the Northern FVGB and -130,000 AF in the Southern FVGB. The negative change indicates a decline in groundwater storage, and this trend is consistent with the generally-declining trends seen in groundwater levels in both the Northern and Southern FVGB. While the trends and the extent of the change in storage are significantly different in each part of the FVGB, each curve follows patterns similar to groundwater elevations observed. Based on results from the mass balance analysis, recharge from precipitation and pumping are the most important components. Historically, urban pumping was a small portion of the total pumping, as assumed in each part of the FVGB.

8. ESTIMATED GROUNDWATER RECHARGE

Based on the calibrated groundwater mass balance analysis, the average groundwater recharge was estimated as 13,800 AFY for the FVGB, with approximately 11,300 AFY in the Northern FVGB (approximately 80 percent of total) and approximately 2,500 AFY in the Southern FVGB (approximately 20 percent of total). The last 20 years of data (1998-2017) were selected to represent the average annual recharge as this period reflects a reduction in groundwater pumping that is assumed to represent future conditions. The reduction is probably a reflection of AVEK deliveries starting in 1980 and the significant reduction in agricultural pumping after 1976. This period also includes more complete groundwater elevation records and encompasses both hydrologically wet and dry periods, including the most recent years with below-average precipitation.

Figure 7: Groundwater Budget for the Northern FVGB

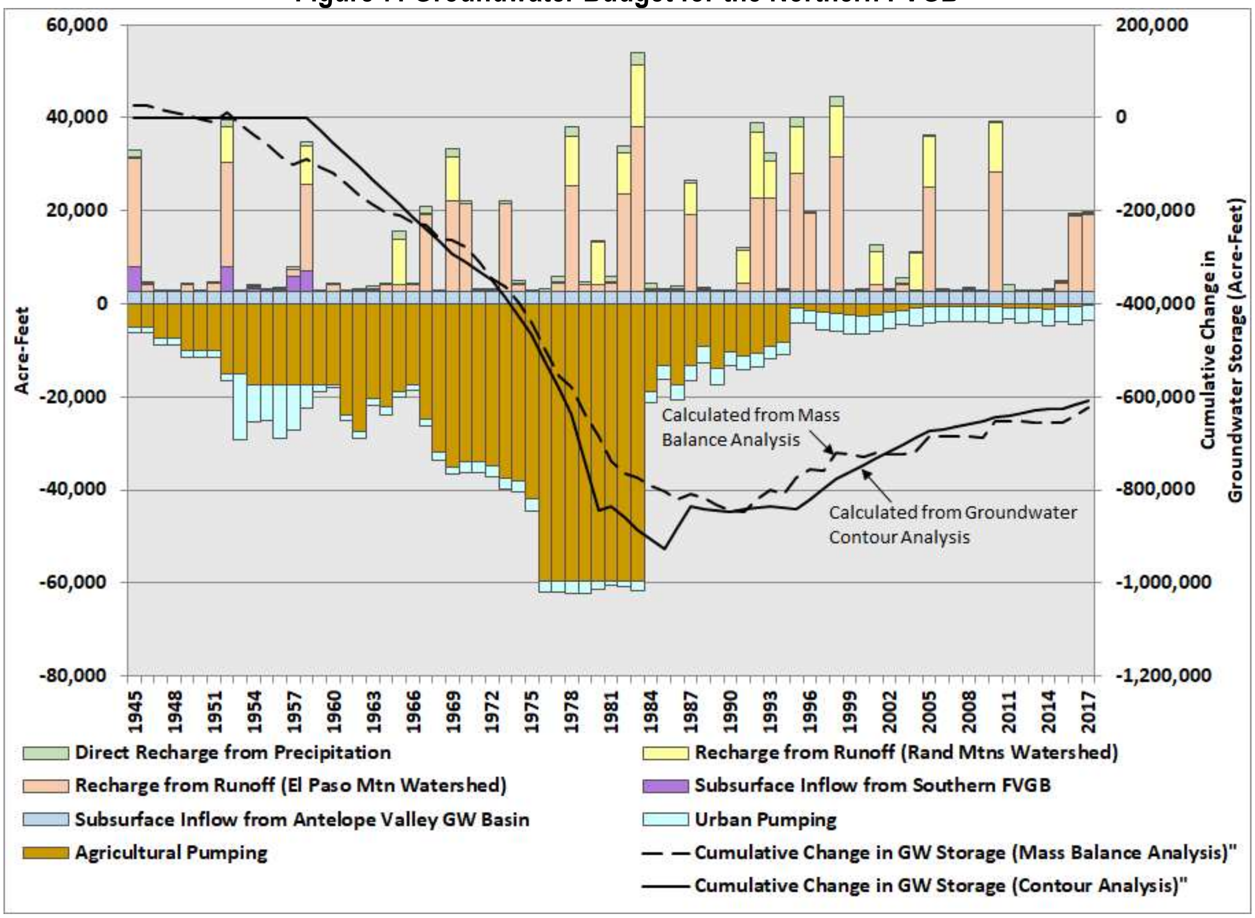
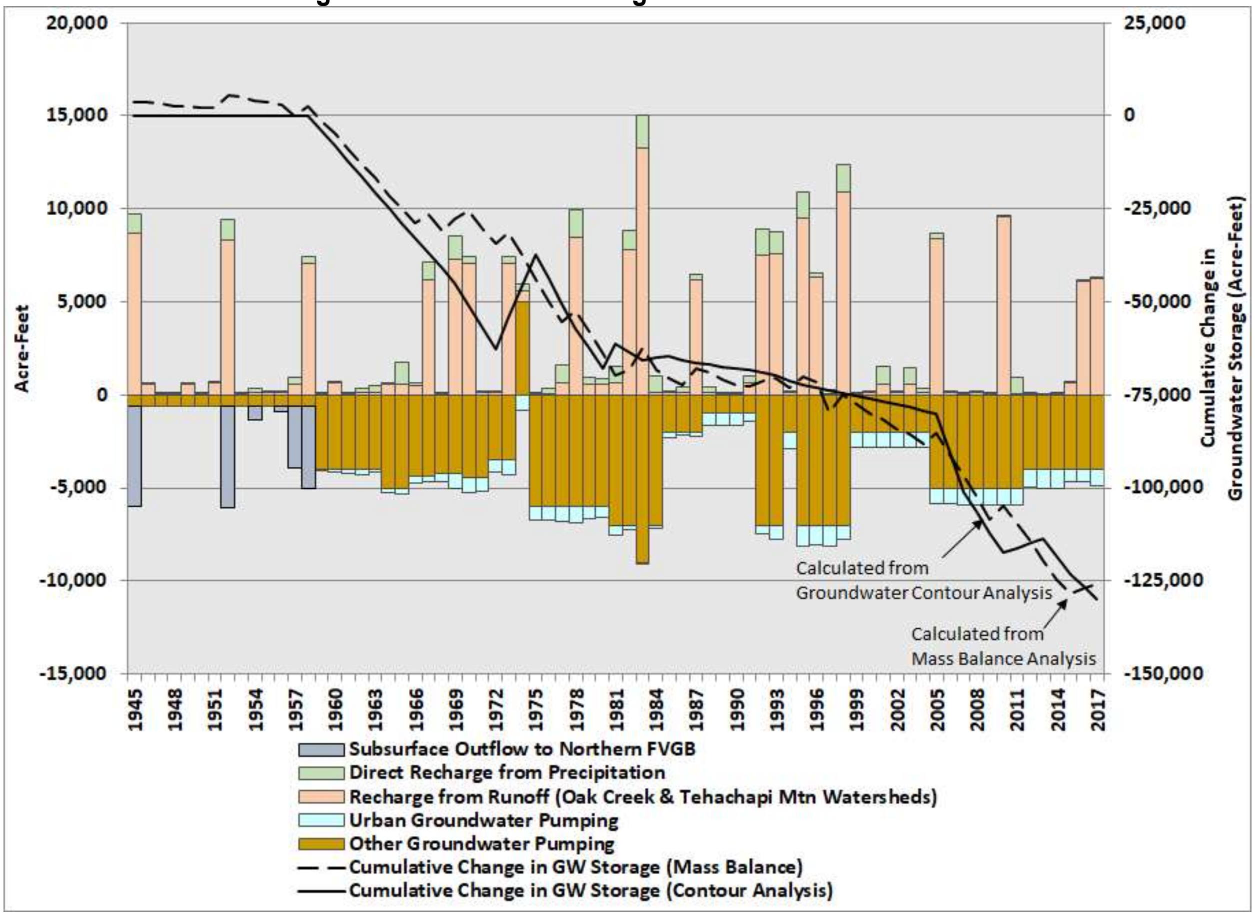


Figure 8: Groundwater Budget for the Southern FVGB



9. MODEL LIMITATIONS

The mass balance spreadsheet presented in this TM greatly simplifies a highly complex, dynamic groundwater system of the FVGB. The applicability of this model is most suited for initial groundwater work at a conceptual level. The following model limitations should be noted for future study and analysis of the FVGB:

- The model is set up on an annual basis and does not account for monthly or seasonal variations in the groundwater system.
- The model does not account for site-specific variables for hydrologic or subsurface properties.
- The model is a simplified representation of water balance components in the FVGB and treats each the Northern and Southern FVGB as a "bathtub" model with complete mixing. It does not account for complex and dynamic interactions within and across the Northern and Southern FVGB and with adjacent basins.
- The model cannot estimate localized variations in groundwater storage.
- Well pumping data have uncertainties due to data limitations. Urban pumping by individual public agencies were incomplete and missing data were estimated to meet the urban demand after surface water deliveries.

- Pumping data for agriculture were not available for all years for the Northern FVGB; it was estimated based on the total agricultural demand.
- Crop acreages or pumping data for agriculture were not available for all years for the Southern FVGB; many of these values were estimated during calibration.
- To estimate natural recharge, the calibration relied on precipitation coefficients that are not based on field measured parameters.

A more robust, numerical groundwater flow model would be required for future groundwater work to support a Groundwater Sustainability Plan. A numerical model can better quantify the basin conditions and water budget components.

10. REFERENCES

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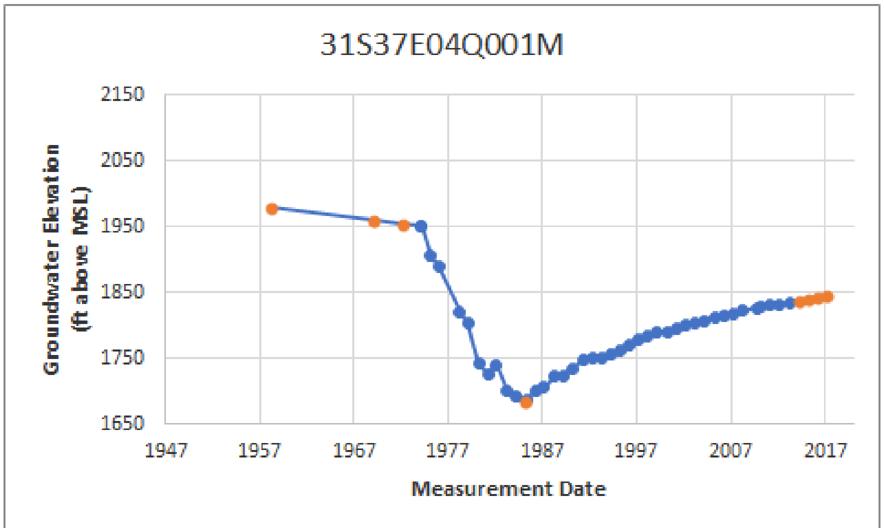
APPENDIX A: GROUNDWATER HYDROGRAPHS

NORTHERN FVGB GROUNDWATER HYDROGRAPHS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1957
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2007
2017
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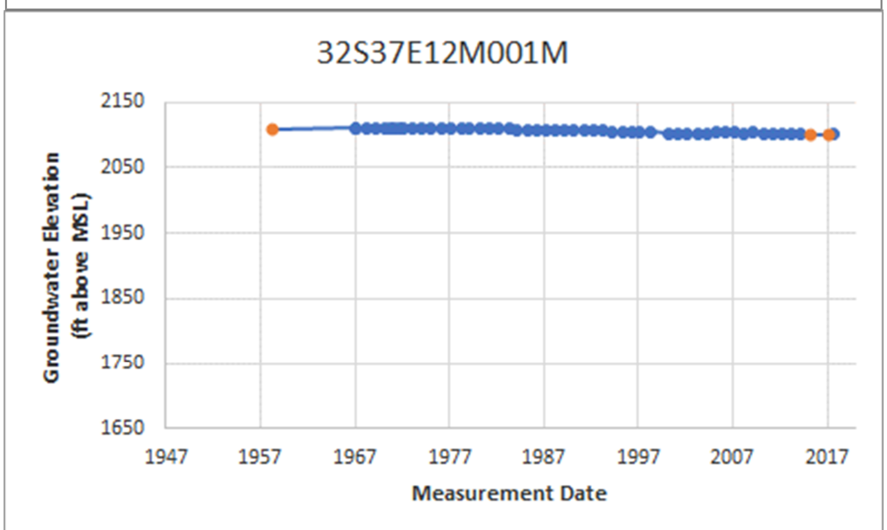
Measurement Date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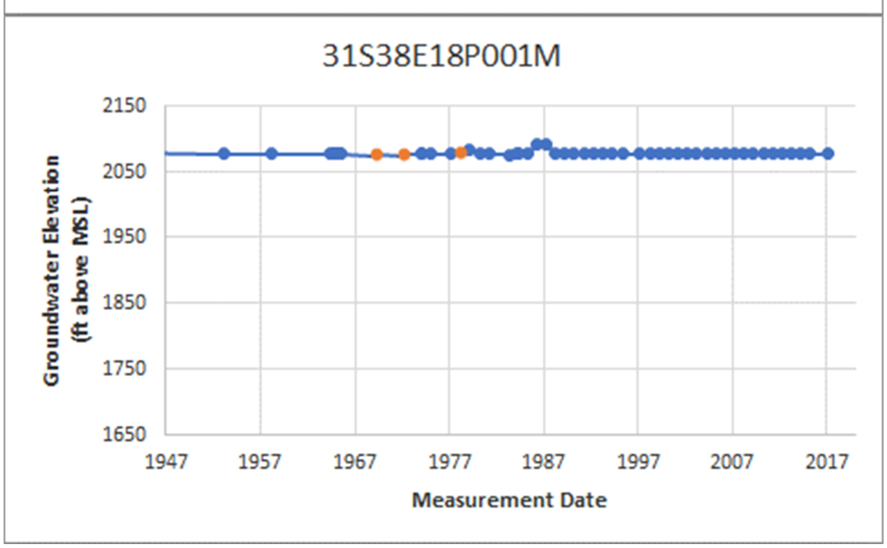
(ft above MSL)
Measurement Date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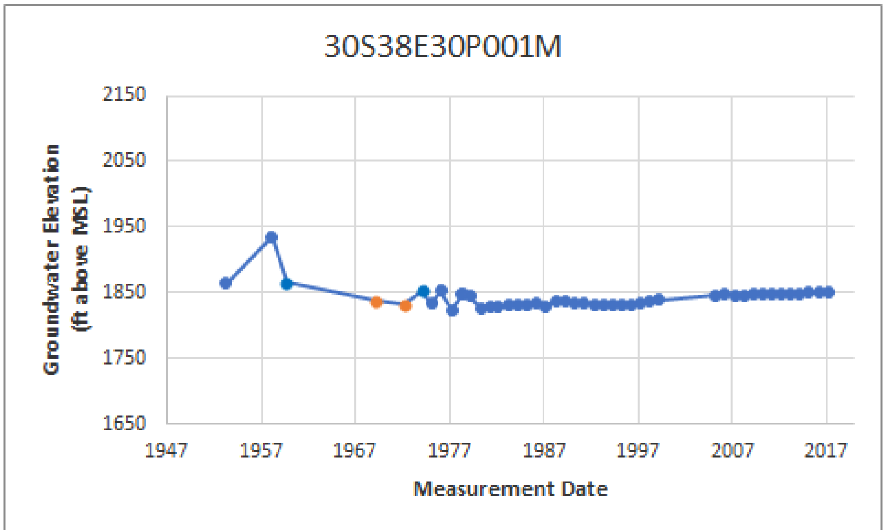
(ft above MSL)
Measurement Date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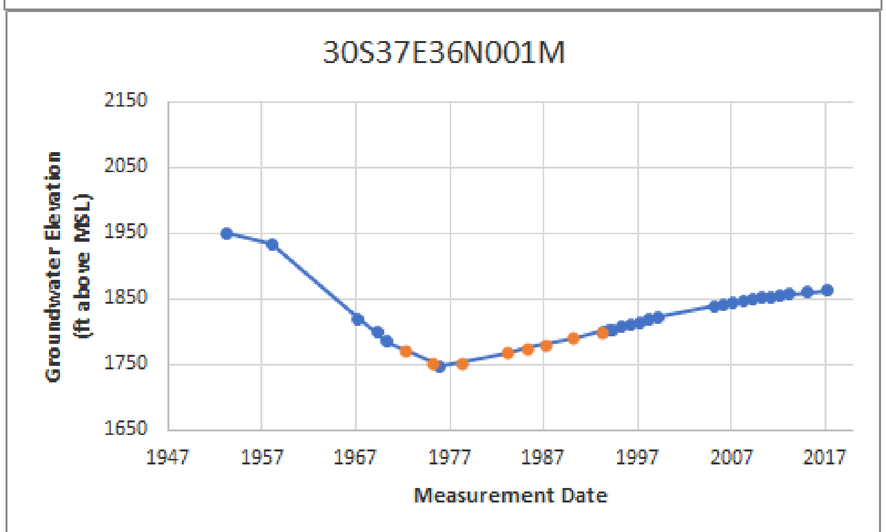
Measurement Date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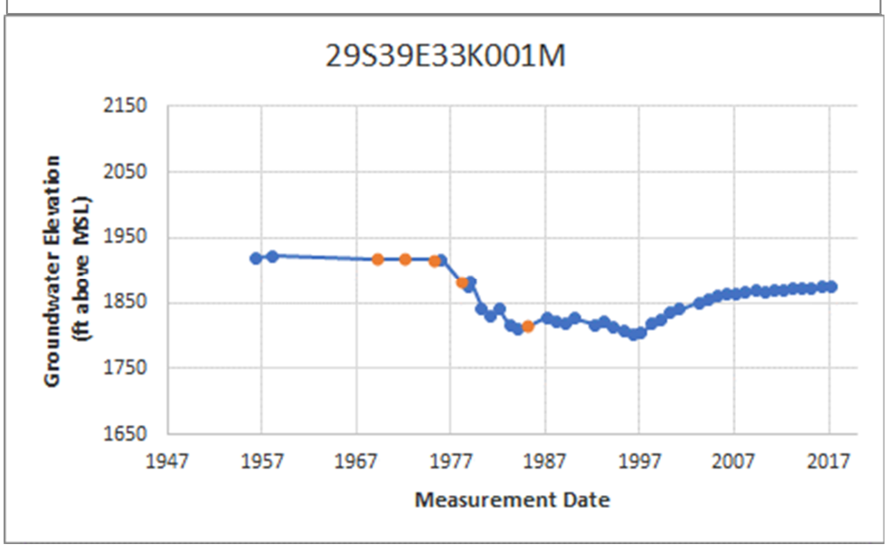
Measurement Date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2007
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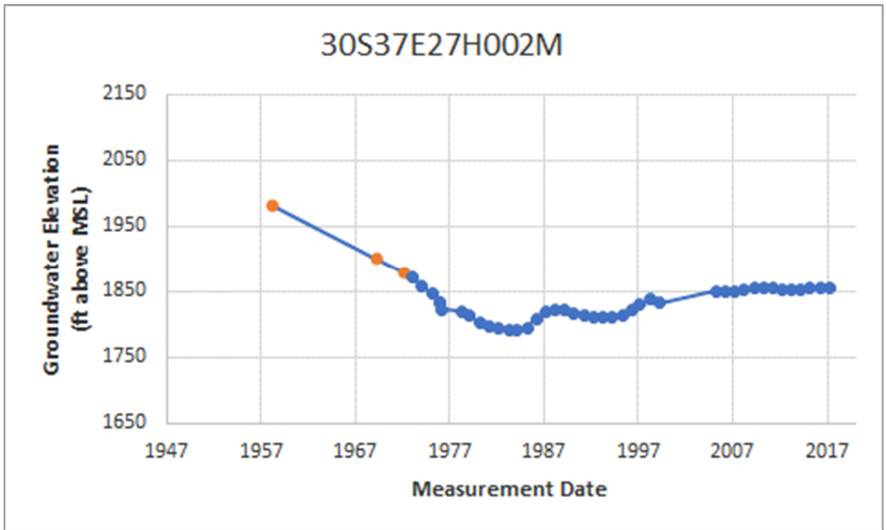
Measurement Date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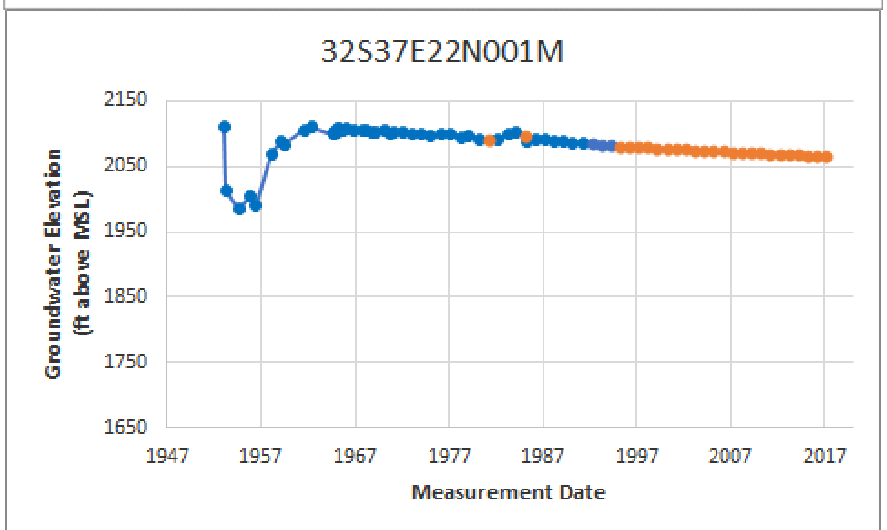
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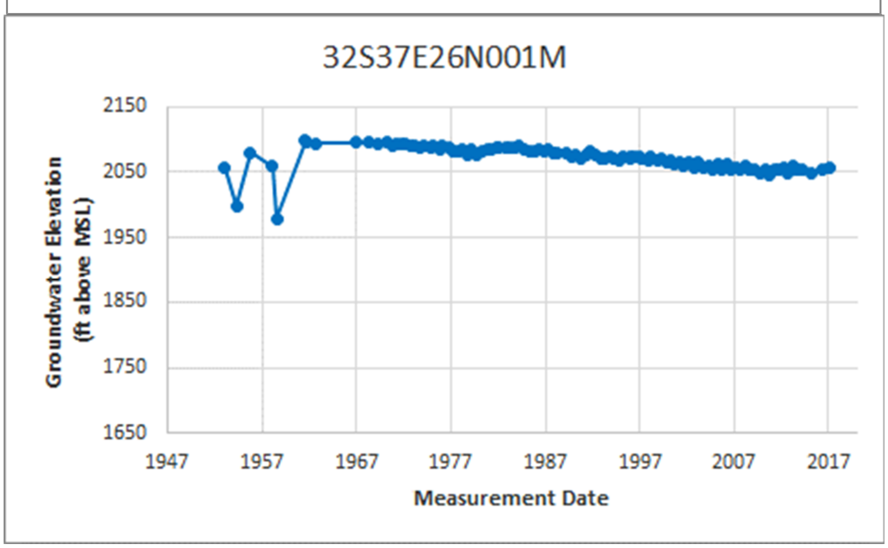
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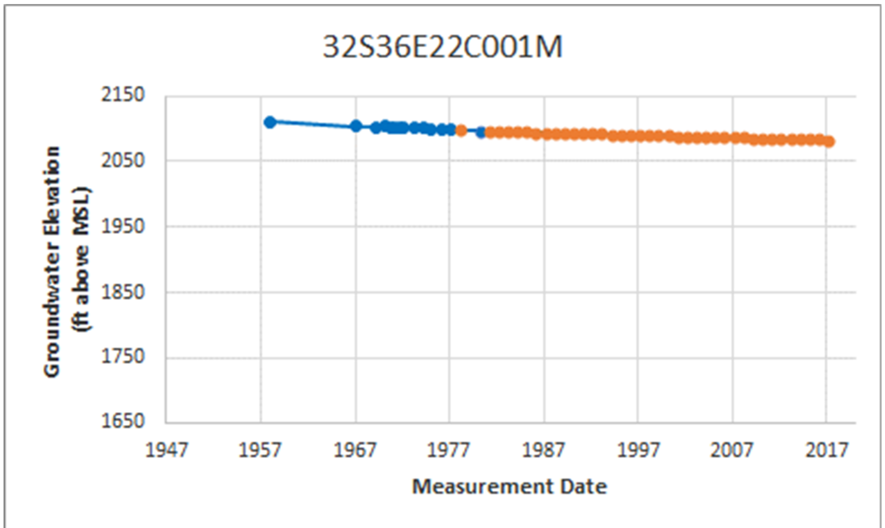
Measurement Date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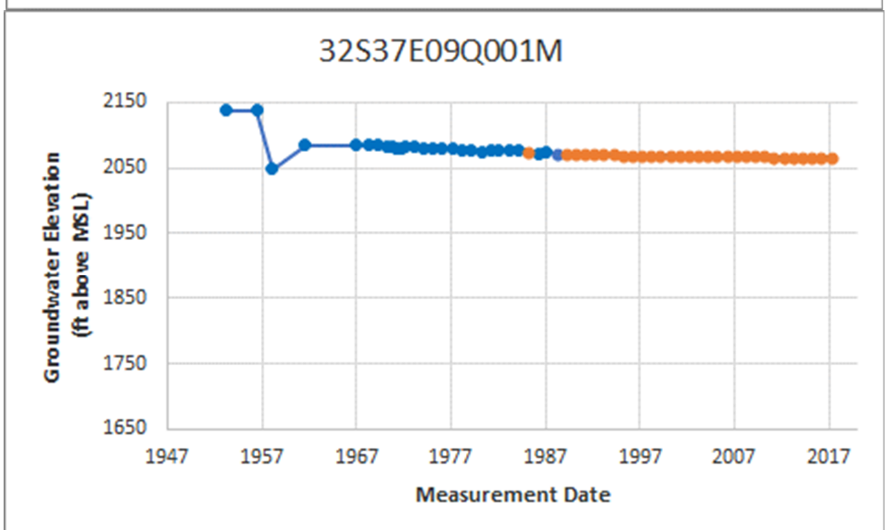
2007
2017
Measurement Date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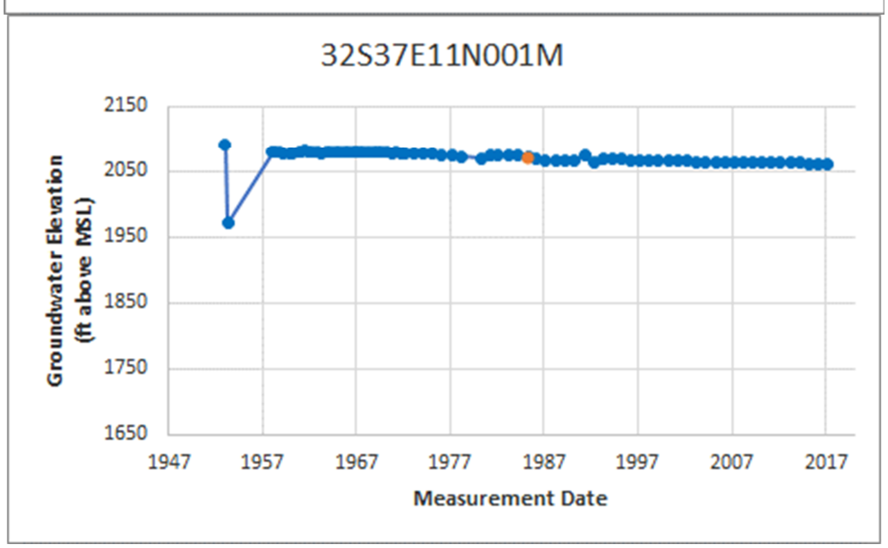
Measurement Date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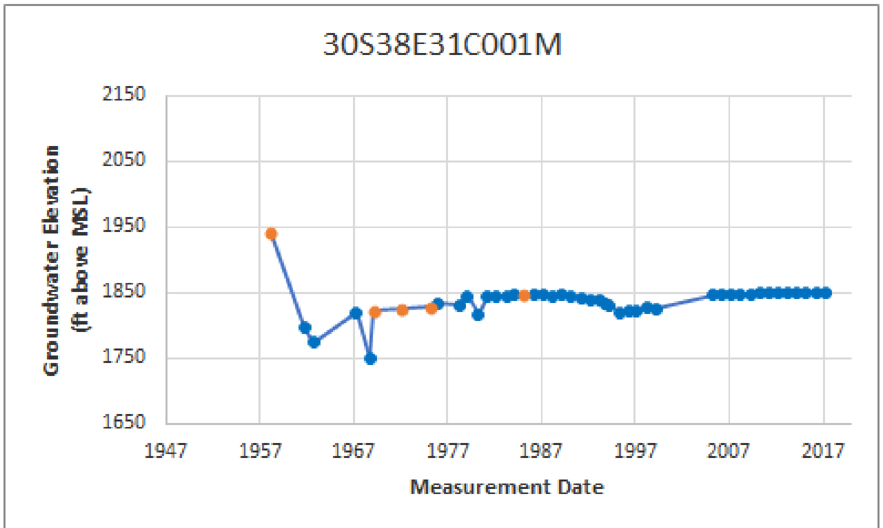
Measurement Date



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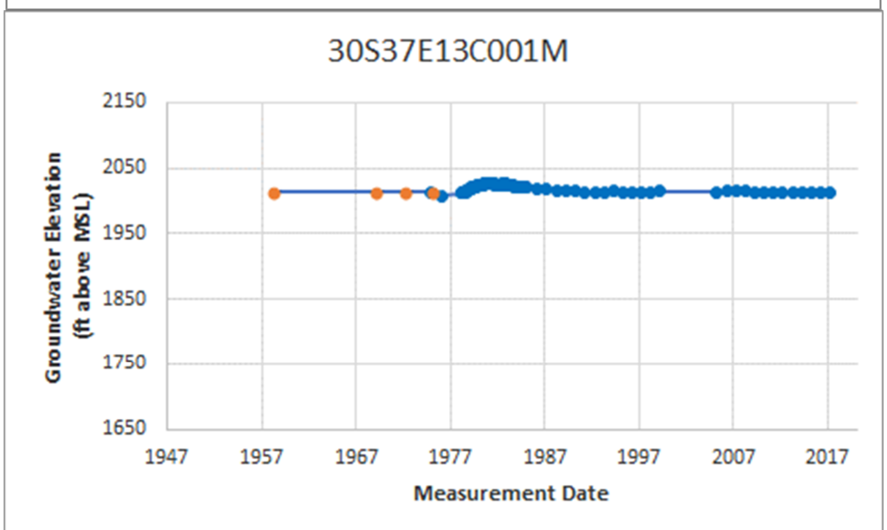
(ft above MSL)



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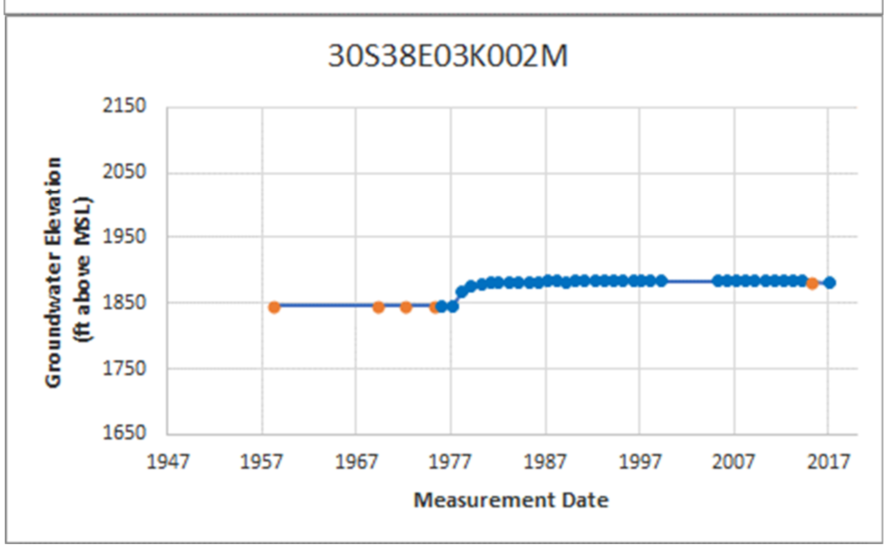
Groundwater Elevation
(ft above MSL)



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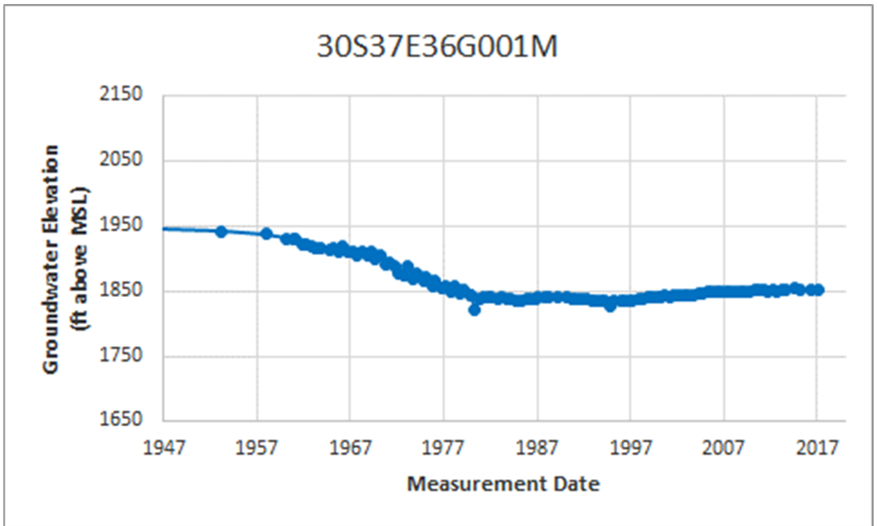
2007
2017
Measurement Date
Groundwater Elevation
(ft above MSL)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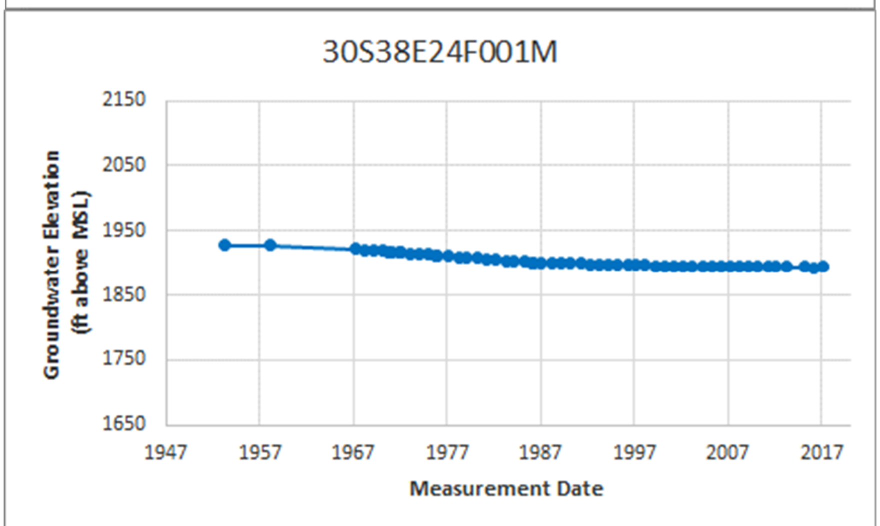
1997
2007
2017
Measurement Date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2007
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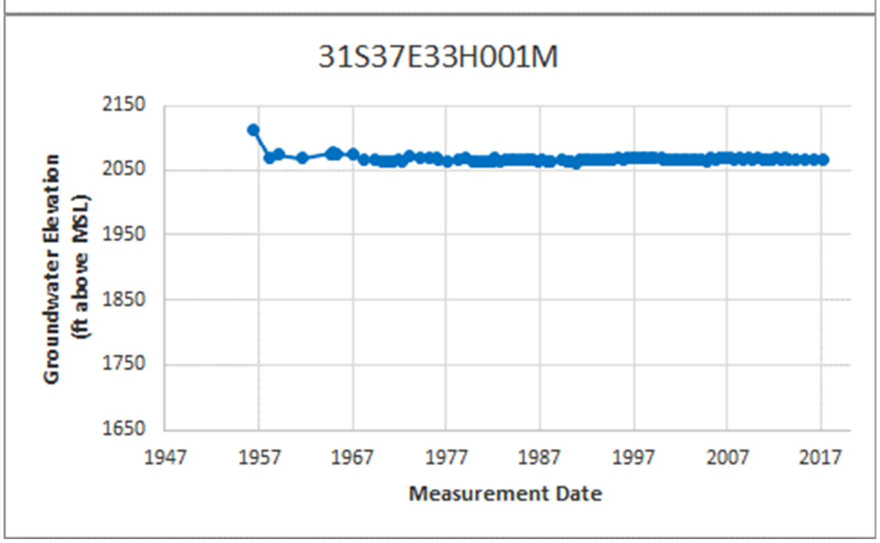
Measurement Date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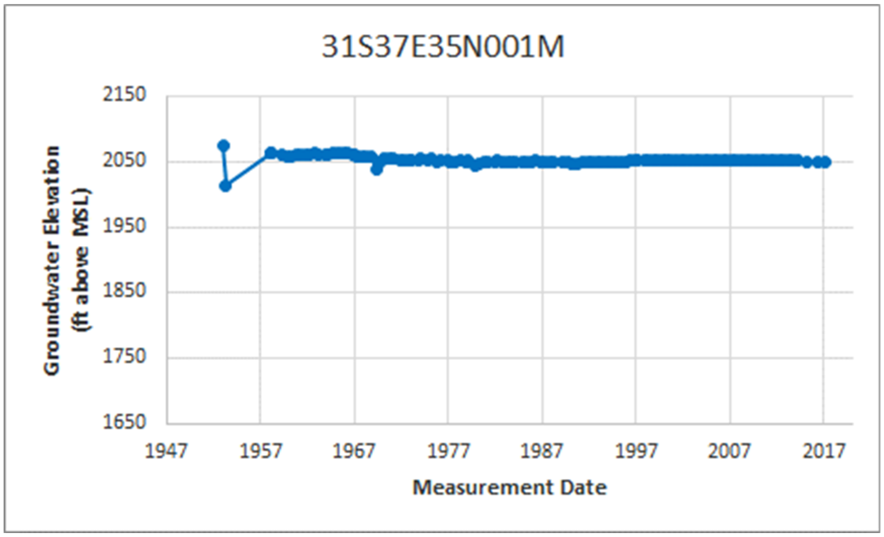
2007
2017
Measurement Date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2150
2050
1950
1850
1750
1650
Groundwater Elevation (ft above MSL)
1947
1957
1967
1977
1987
1997
2007
2017
Measurement Date

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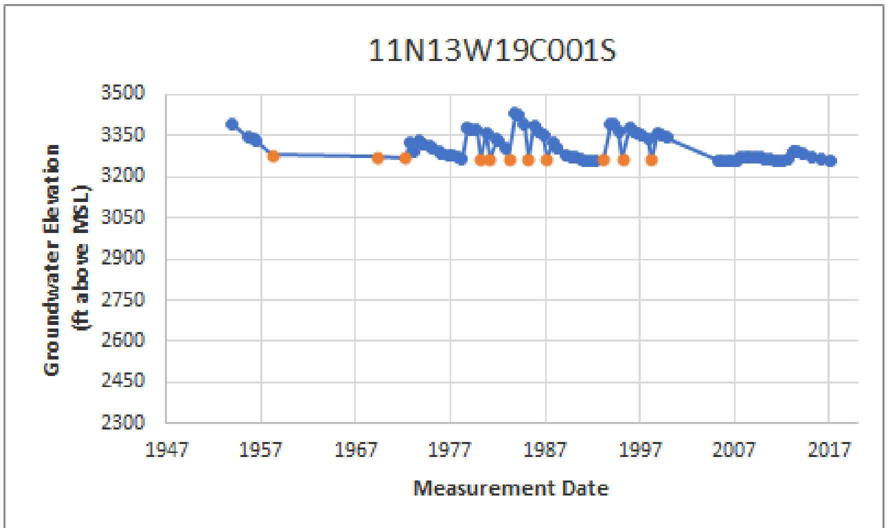
SOUTHERN FVGB GROUNDWATER HYDROGRAPHS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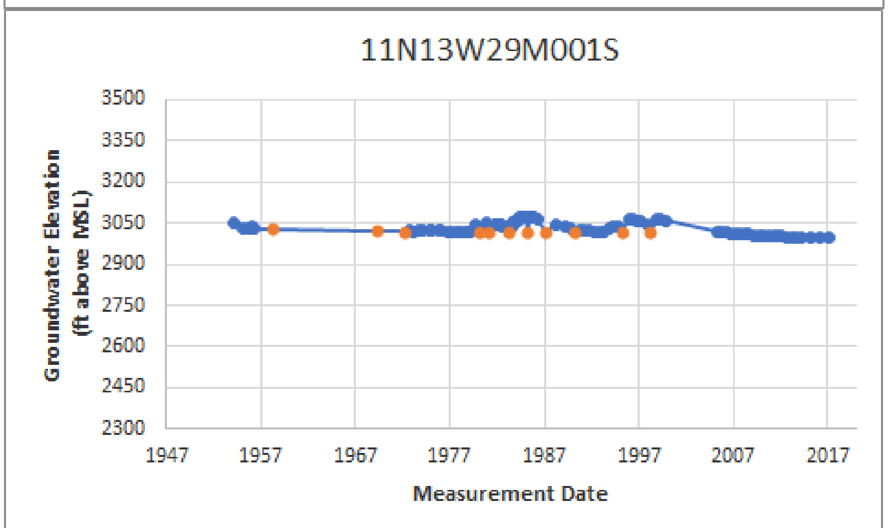
1997
2007
2017
Measurement Date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1967
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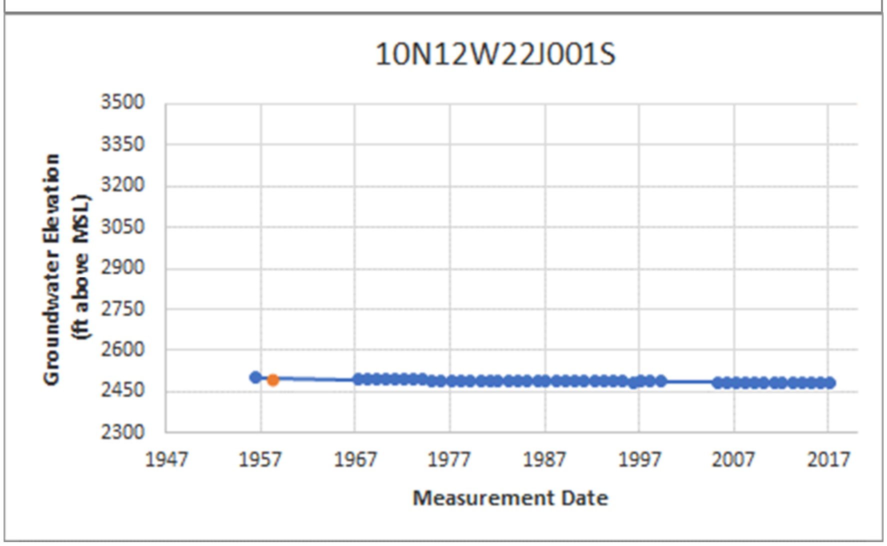
1987
1997
2007
2017
Measurement Date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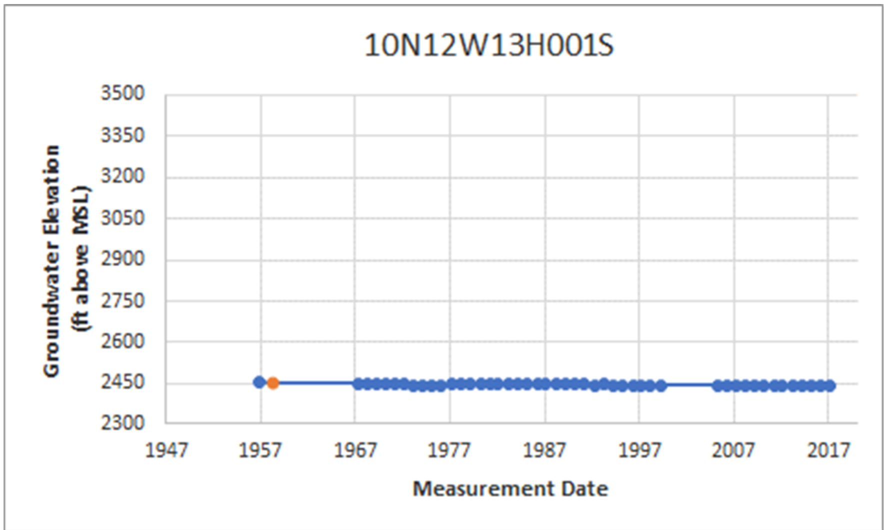
1997
2007
2017
Measurement Date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1957
1967
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2007
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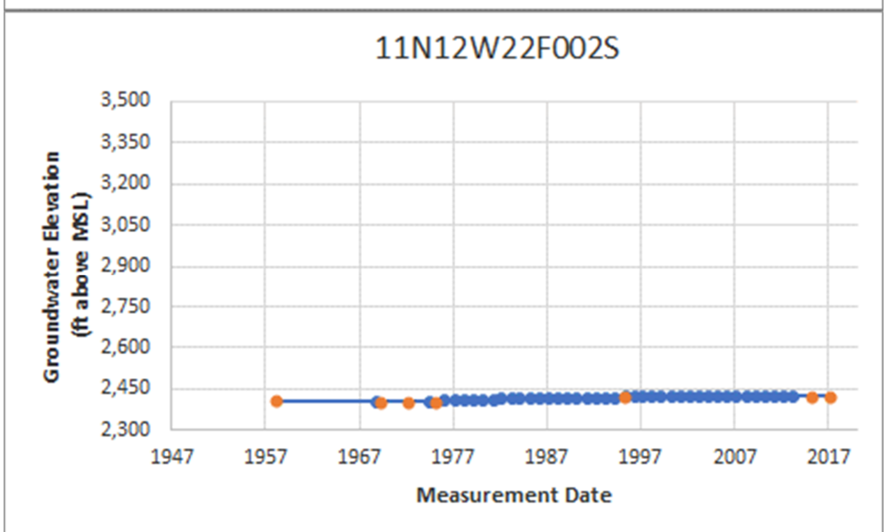
Measurement Date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3,200
3,050
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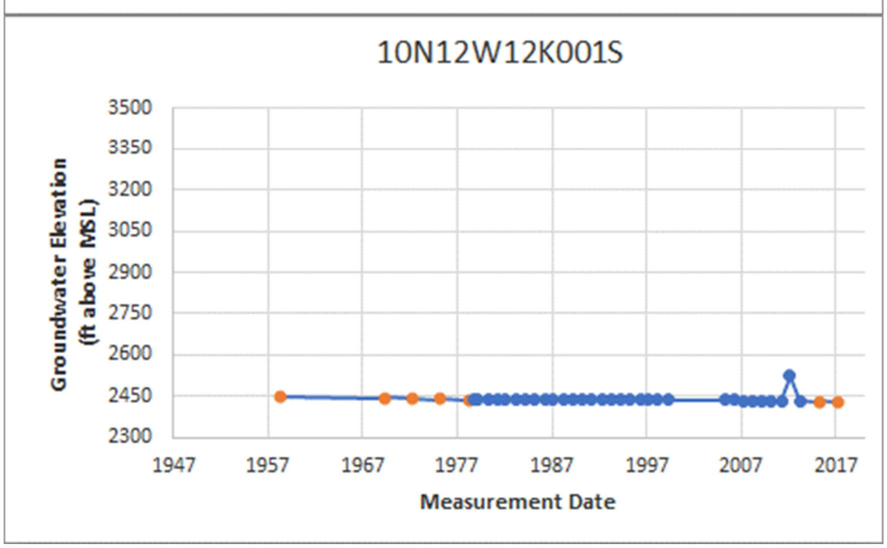
2,600
2,450
2,300
1947
1957
1967
1977
1987
1997
2007
2017
Measurement Date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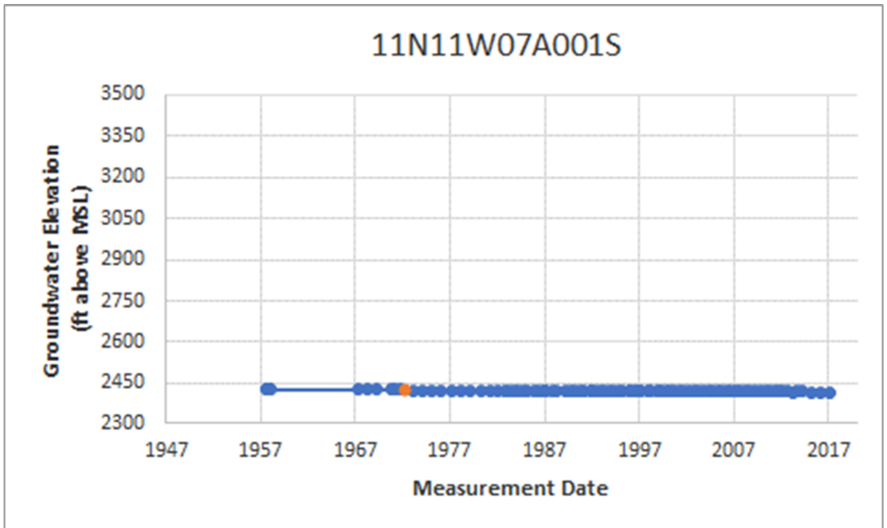
2007
2017
Measurement Date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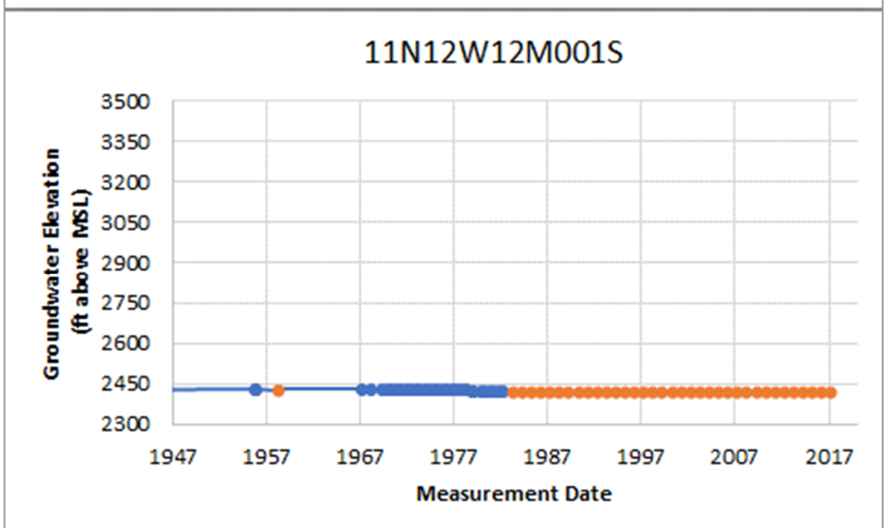
Measurement Date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1957
1967
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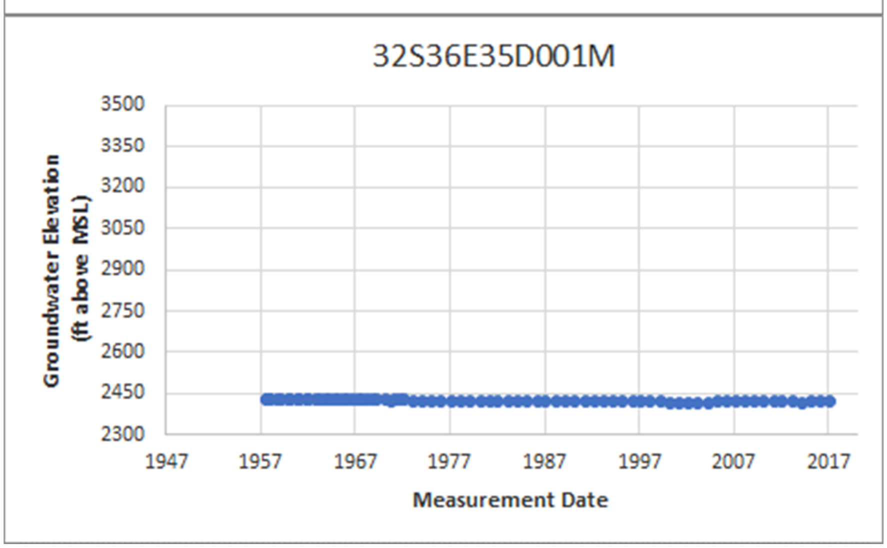
1997
2007
2017
Measurement Date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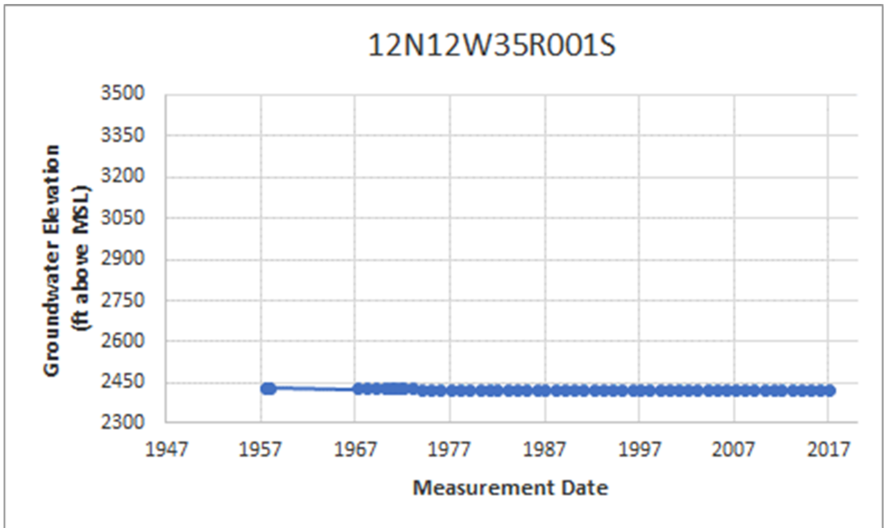
2007
2017
Measurement Date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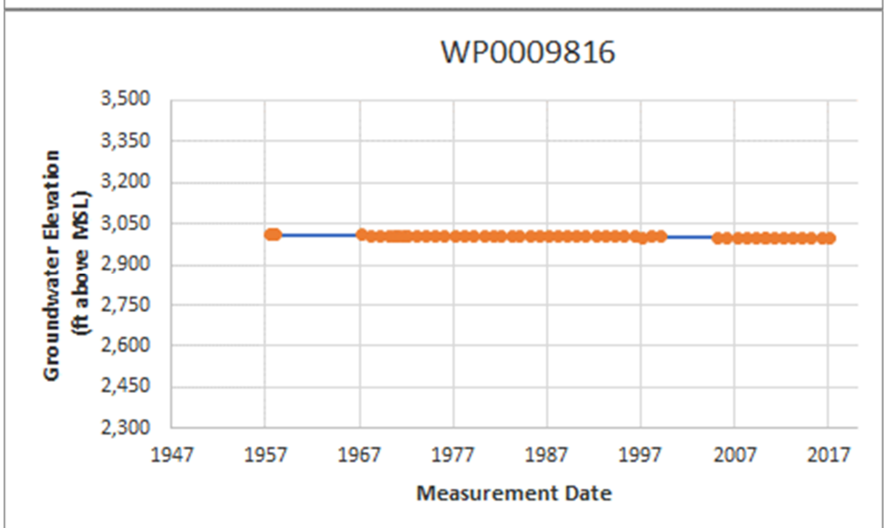
Measurement Date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1967
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1997
2007
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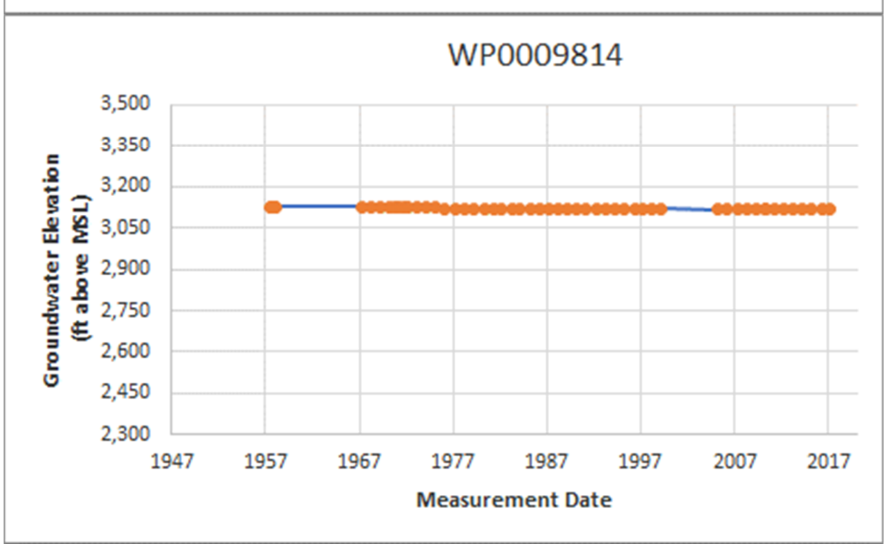
Measurement Date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2007
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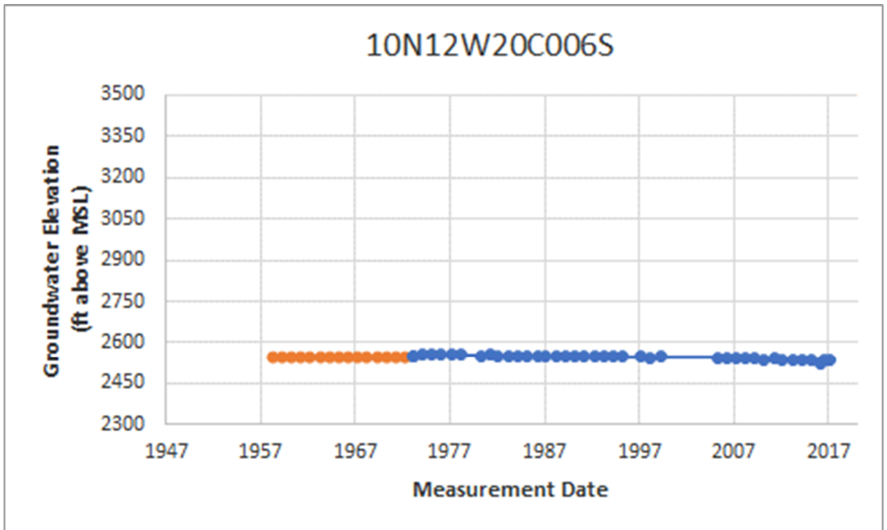
Measurement Date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1987
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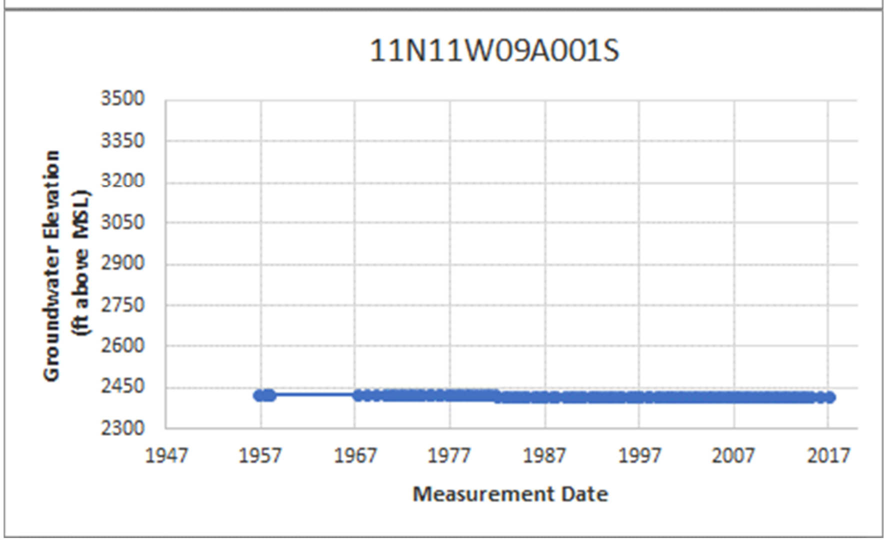
2017
Measurement Date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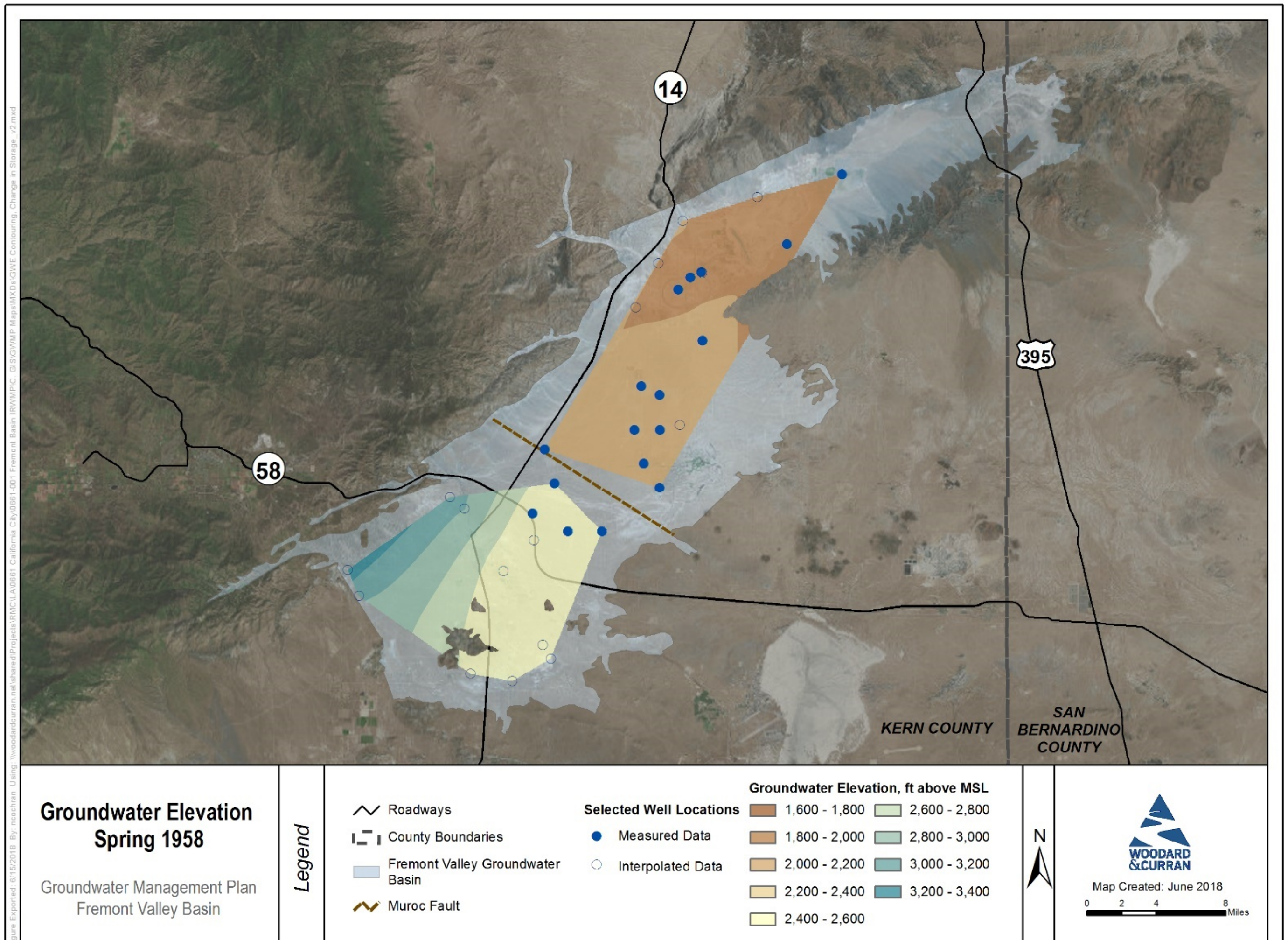
2600
2450
2300
Groundwater Elevation
(ft above MSL)
1947
1957
1967
1977
1987
1997
2007
2017
Measurement Date

APPENDIX B: GROUNDWATER ELEVATION CONTOUR MAPS

Figure B-1: Spring 1958 Groundwater Elevation Contours



Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources:** DWR Bulletin 118, ESRI, DeLorme, USGS, NPS, NOAA, Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure B-2: Spring 1969 Groundwater Elevation Contours

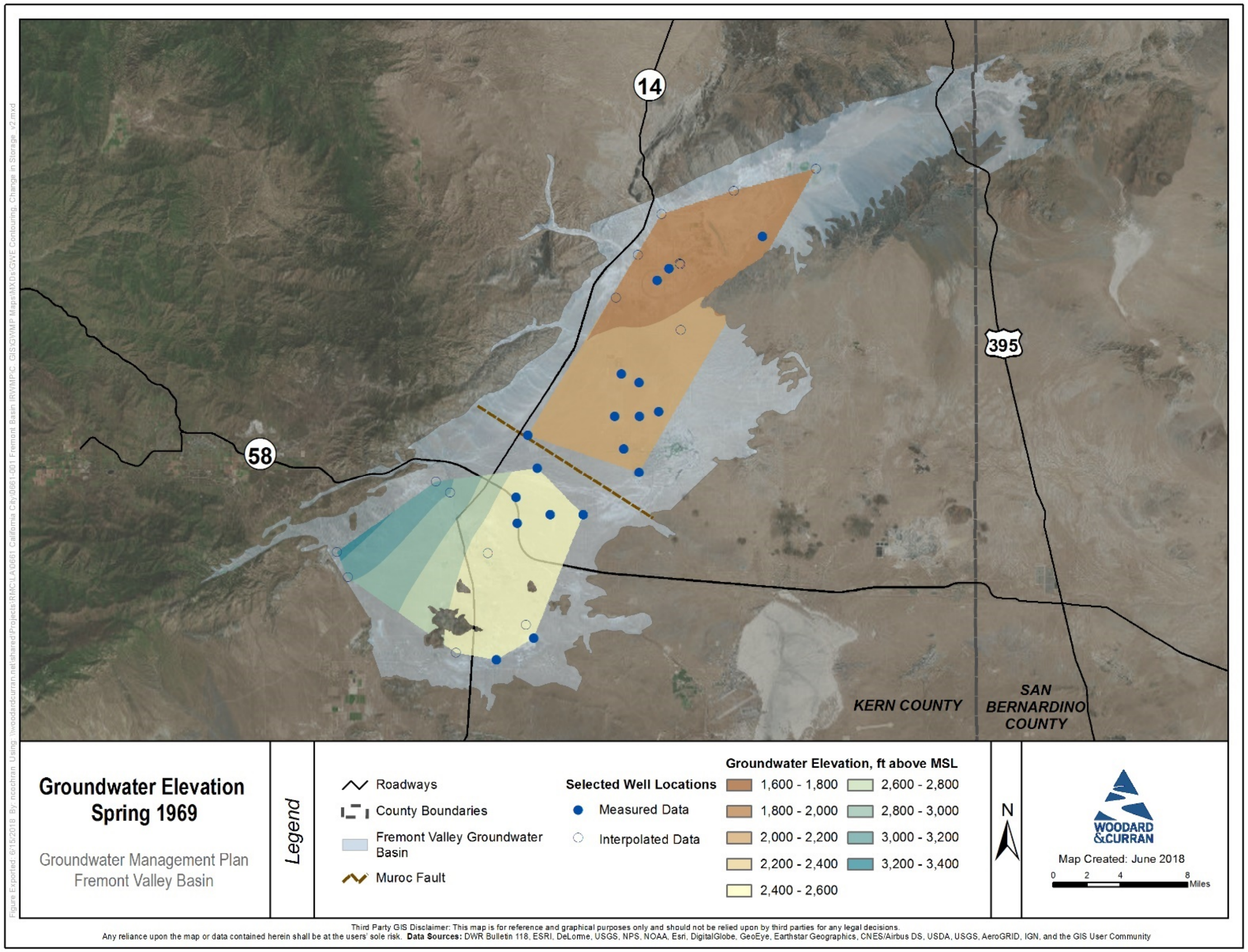


Figure B-3: Spring 1972 Groundwater Elevation Contours

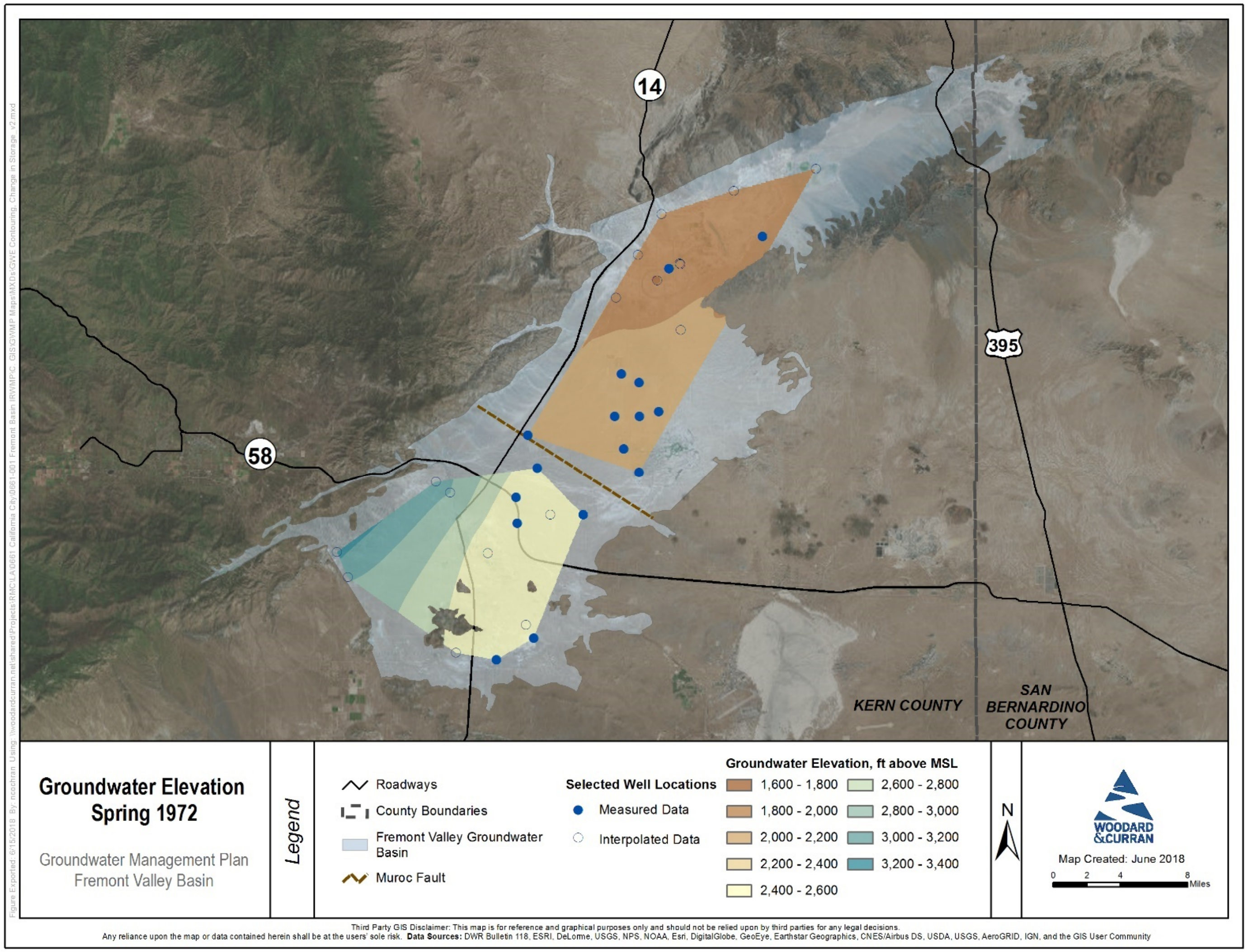


Figure B-4: Spring 1975 Groundwater Elevation Contours

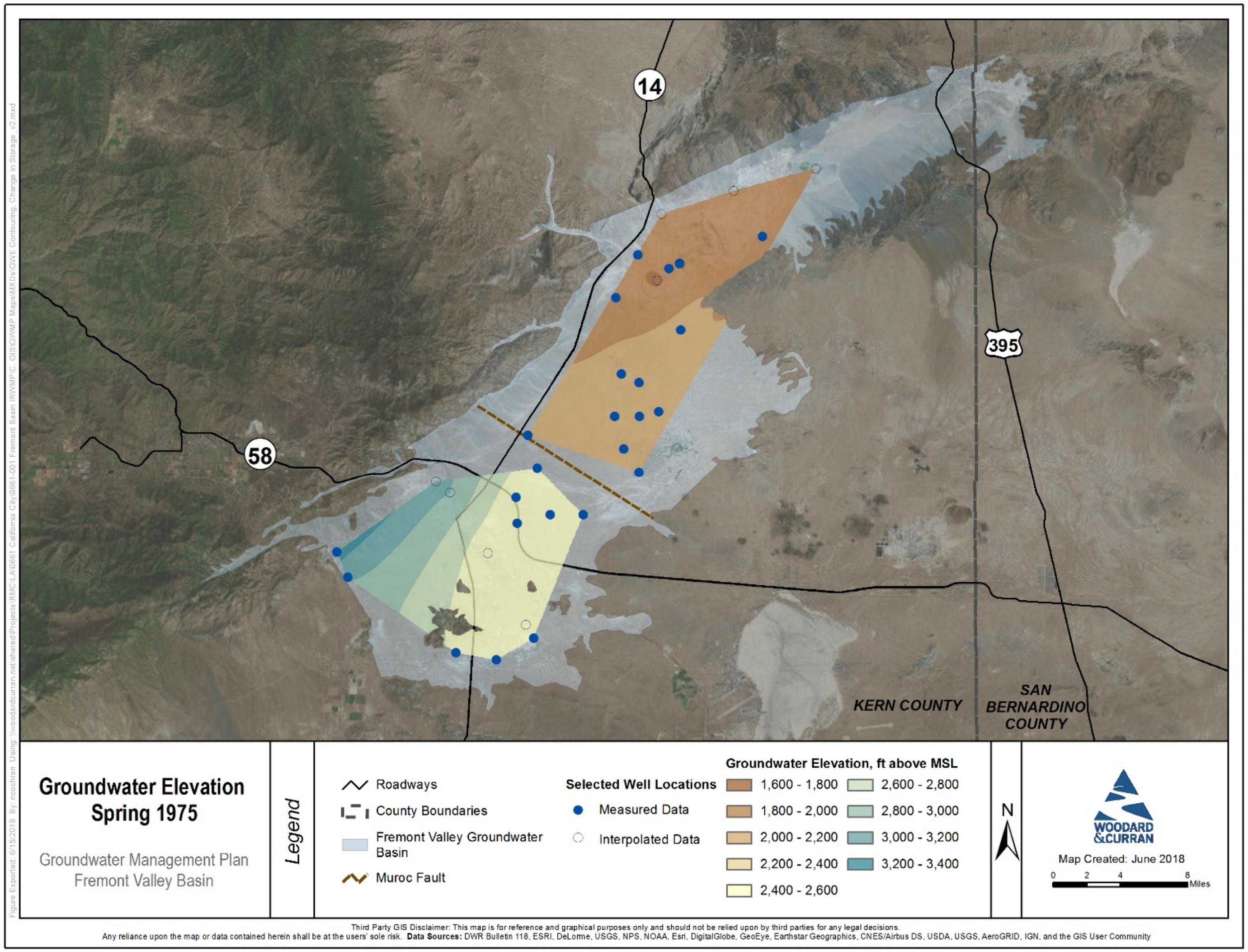


Figure B-5: Spring 1978 Groundwater Elevation Contours

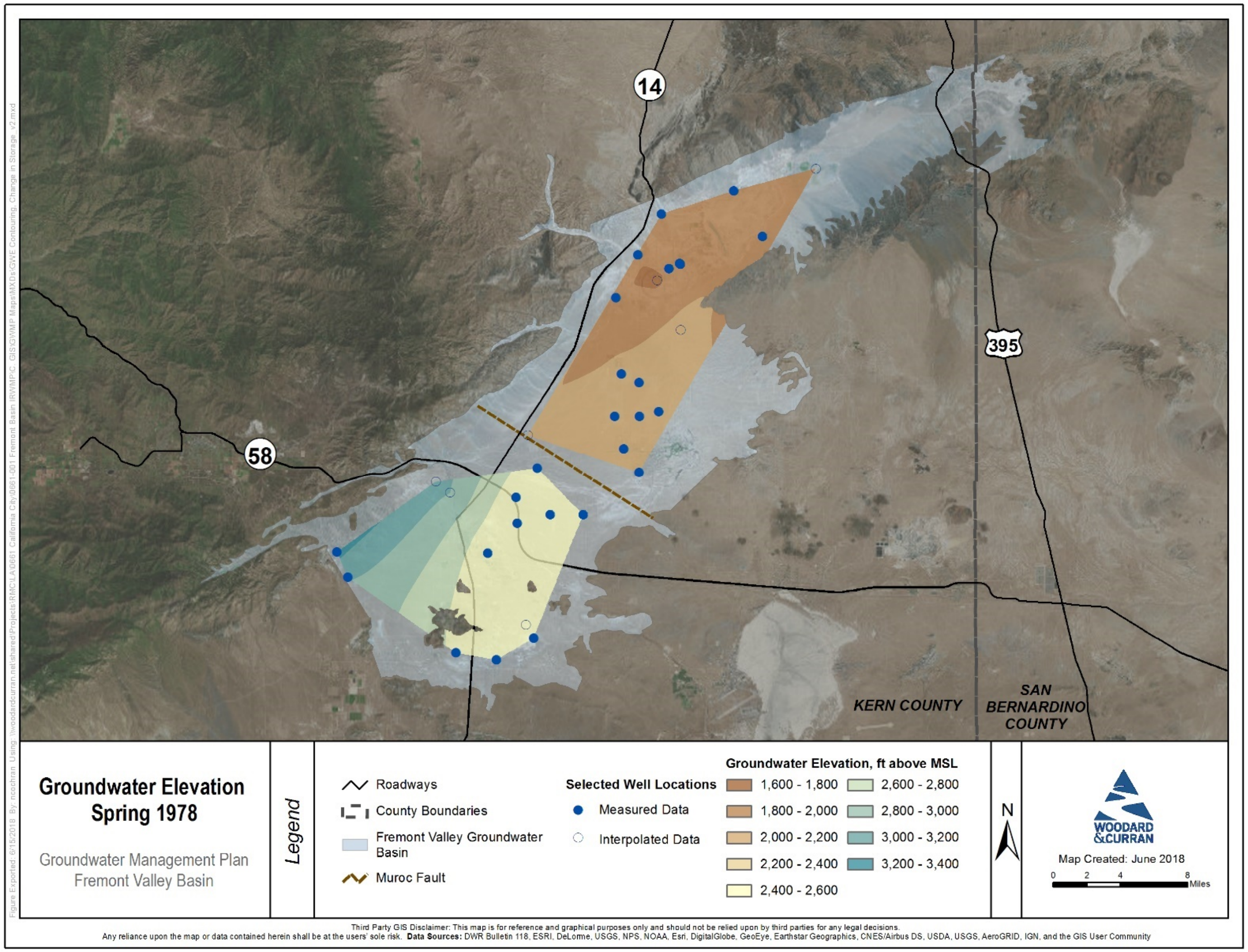


Figure B-6: Spring 1980 Groundwater Elevation Contours

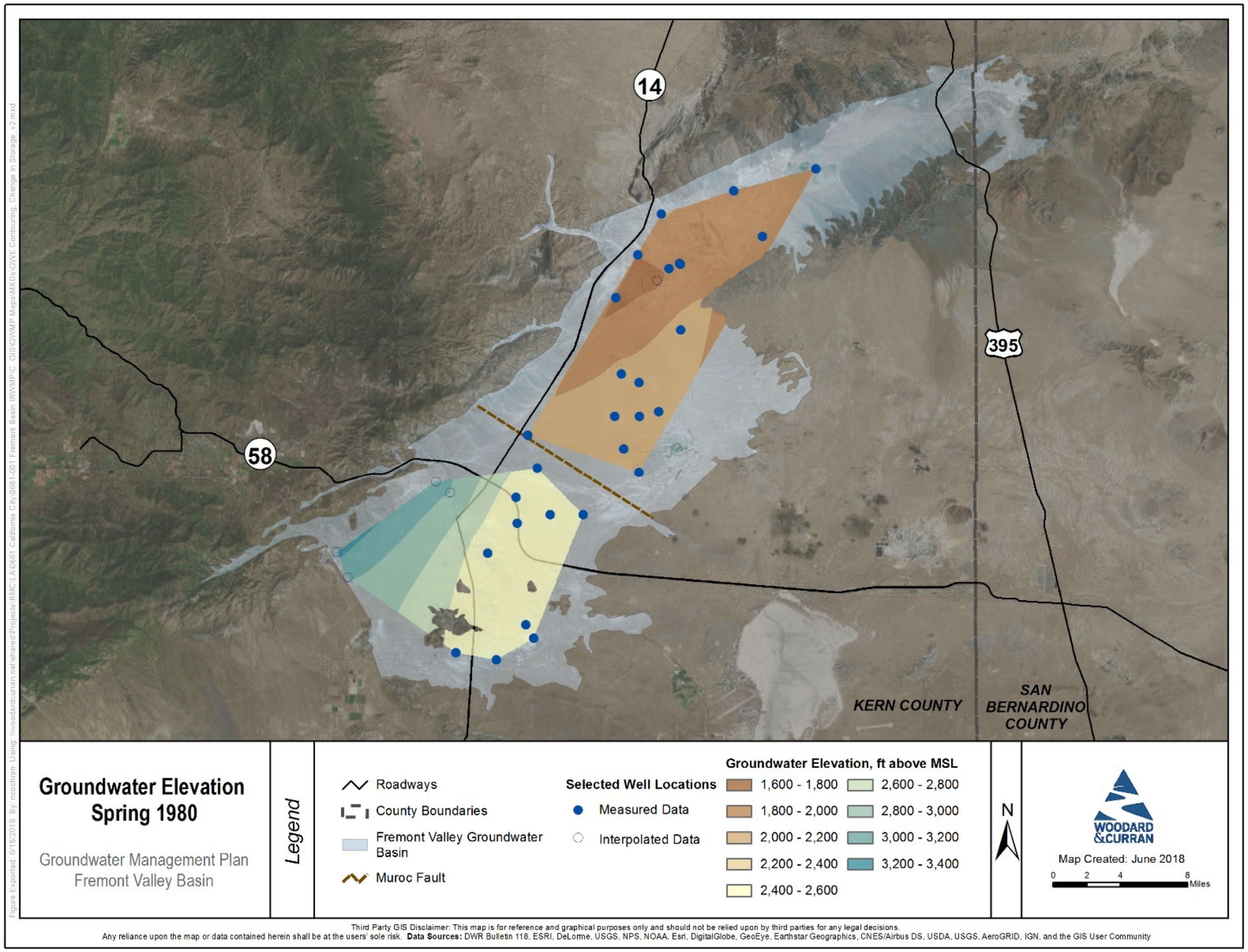


Figure B-7: Spring 1981 Groundwater Elevation Contours

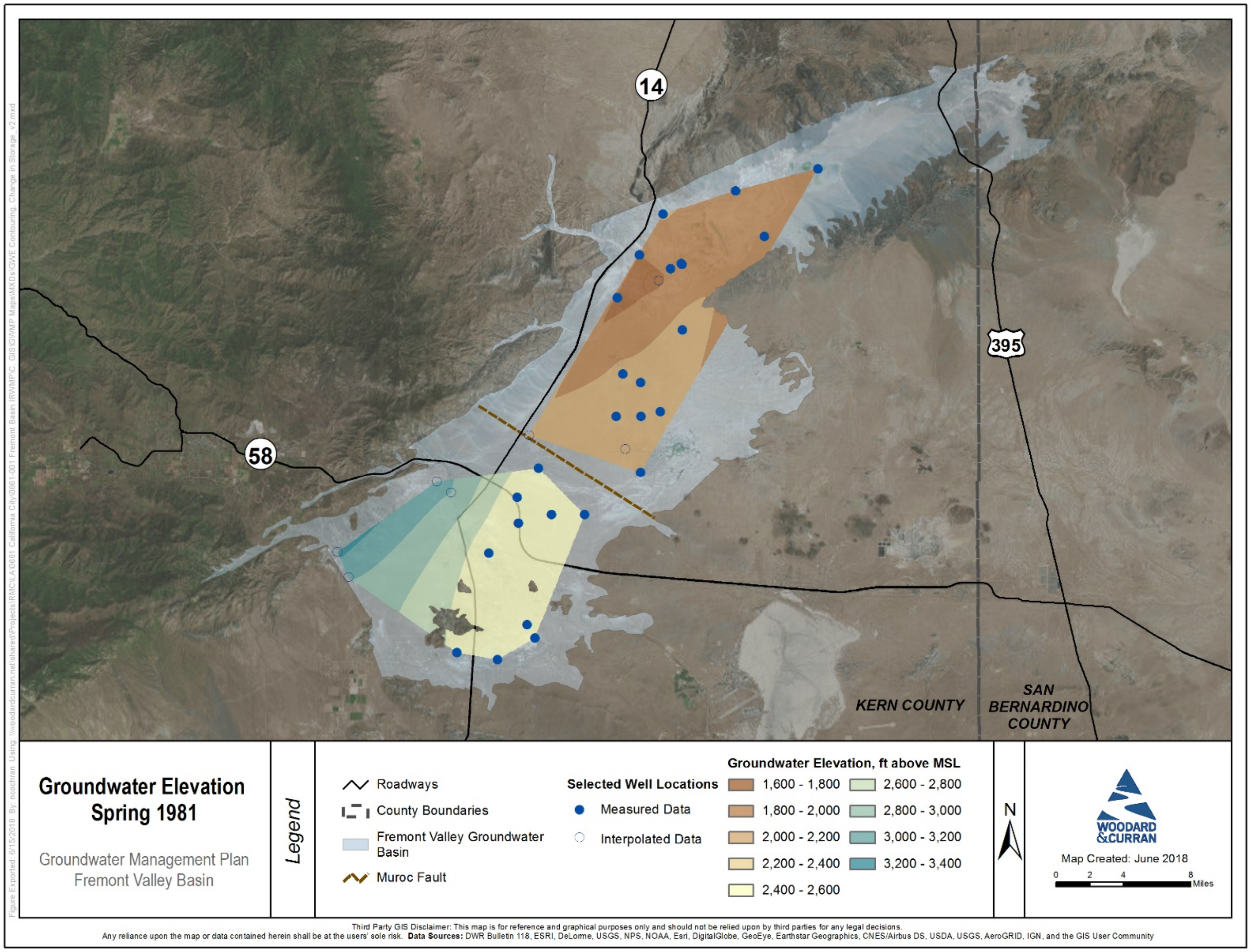


Figure B-8: Spring 1983 Groundwater Elevation Contours

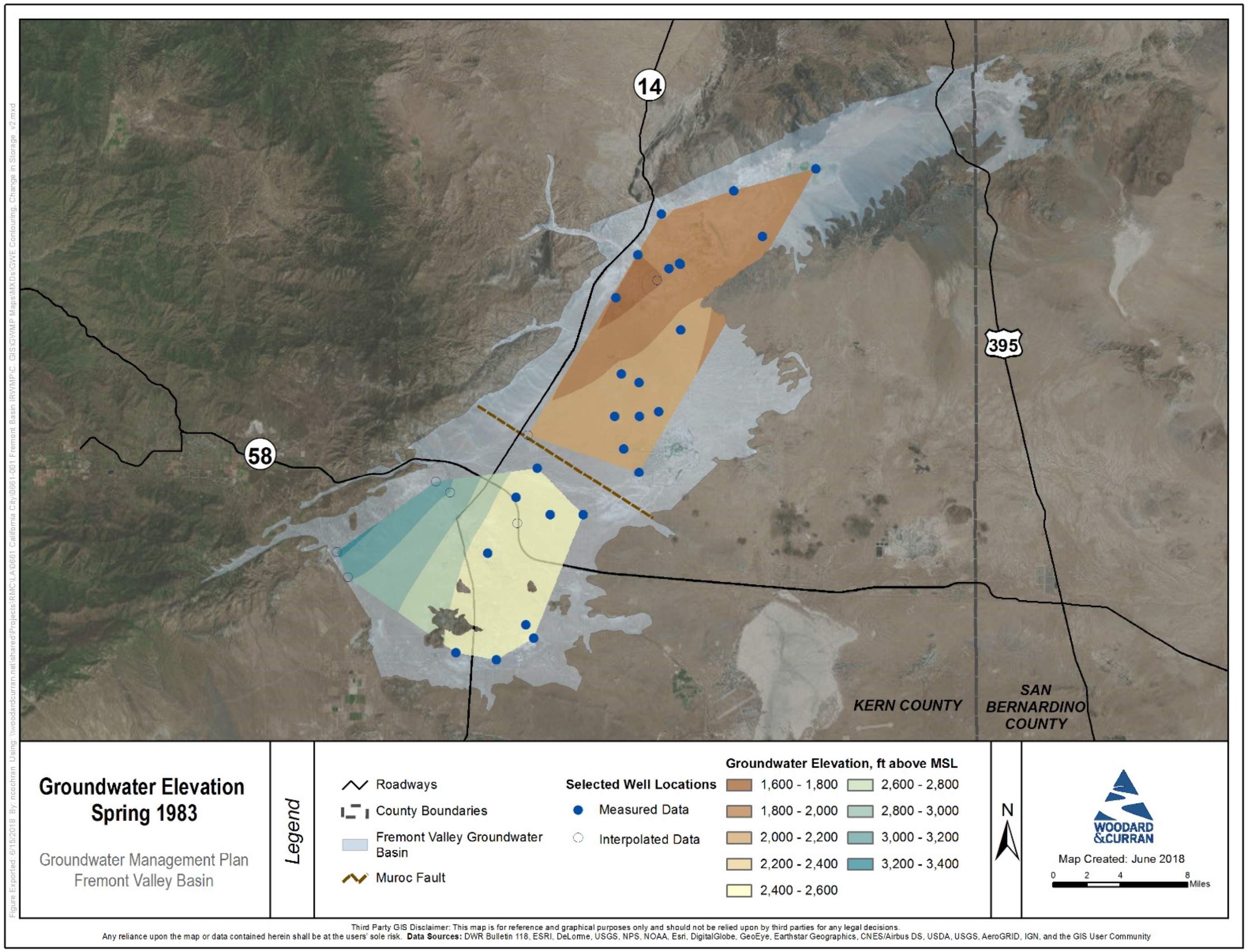


Figure B-9: Spring 1985 Groundwater Elevation Contours

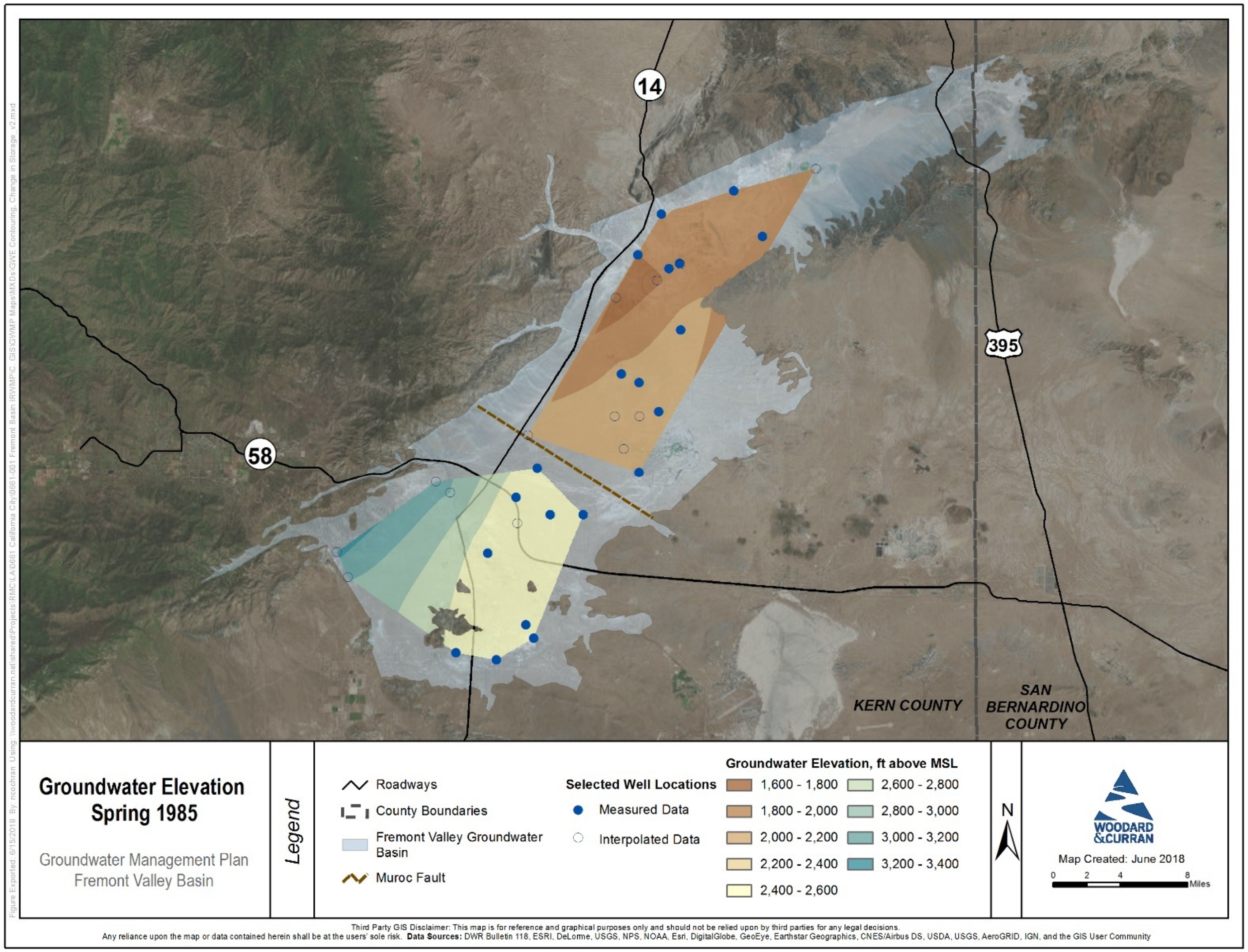


Figure B-10: Spring 1987 Groundwater Elevation Contours

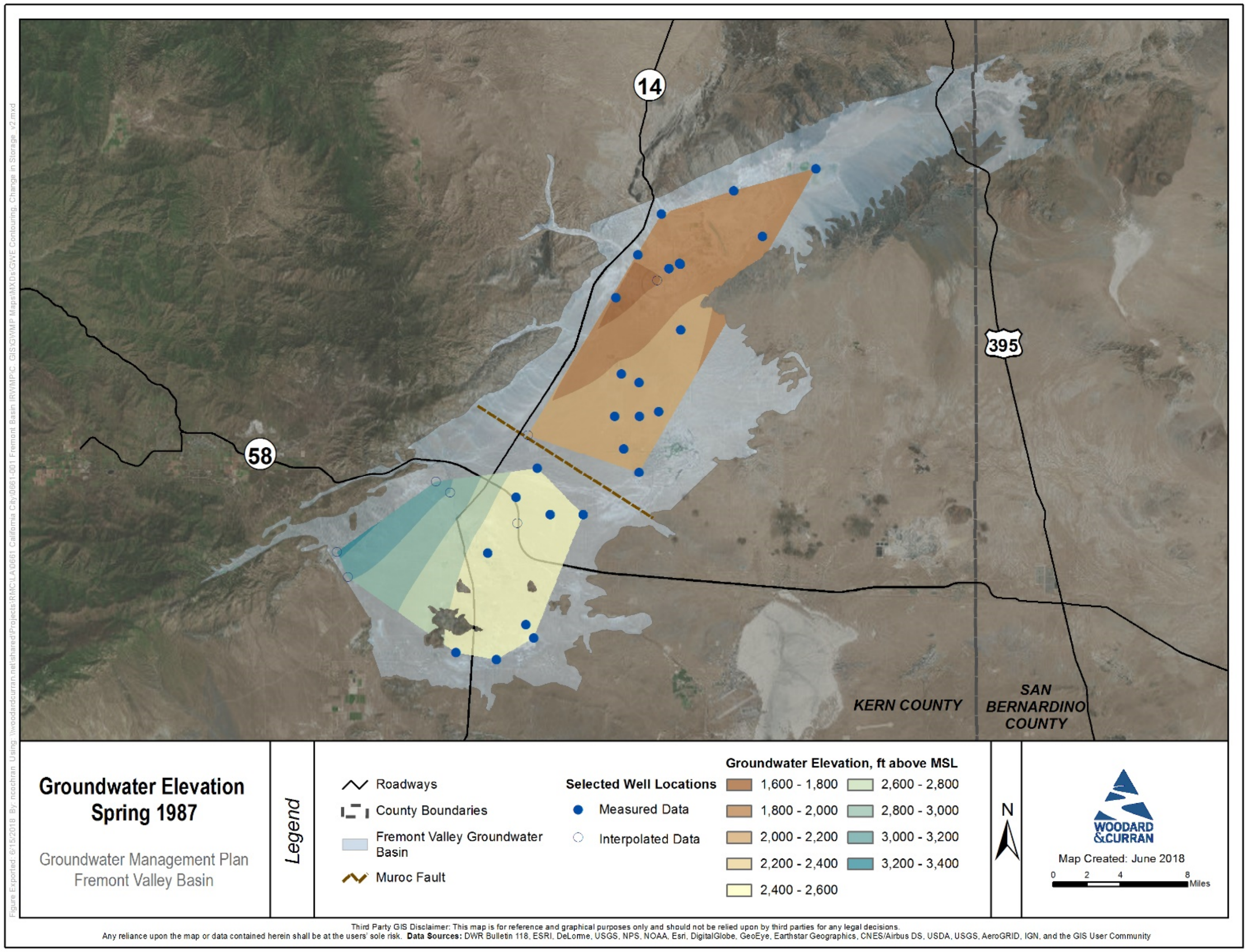


Figure B-11: Spring 1990 Groundwater Elevation Contours

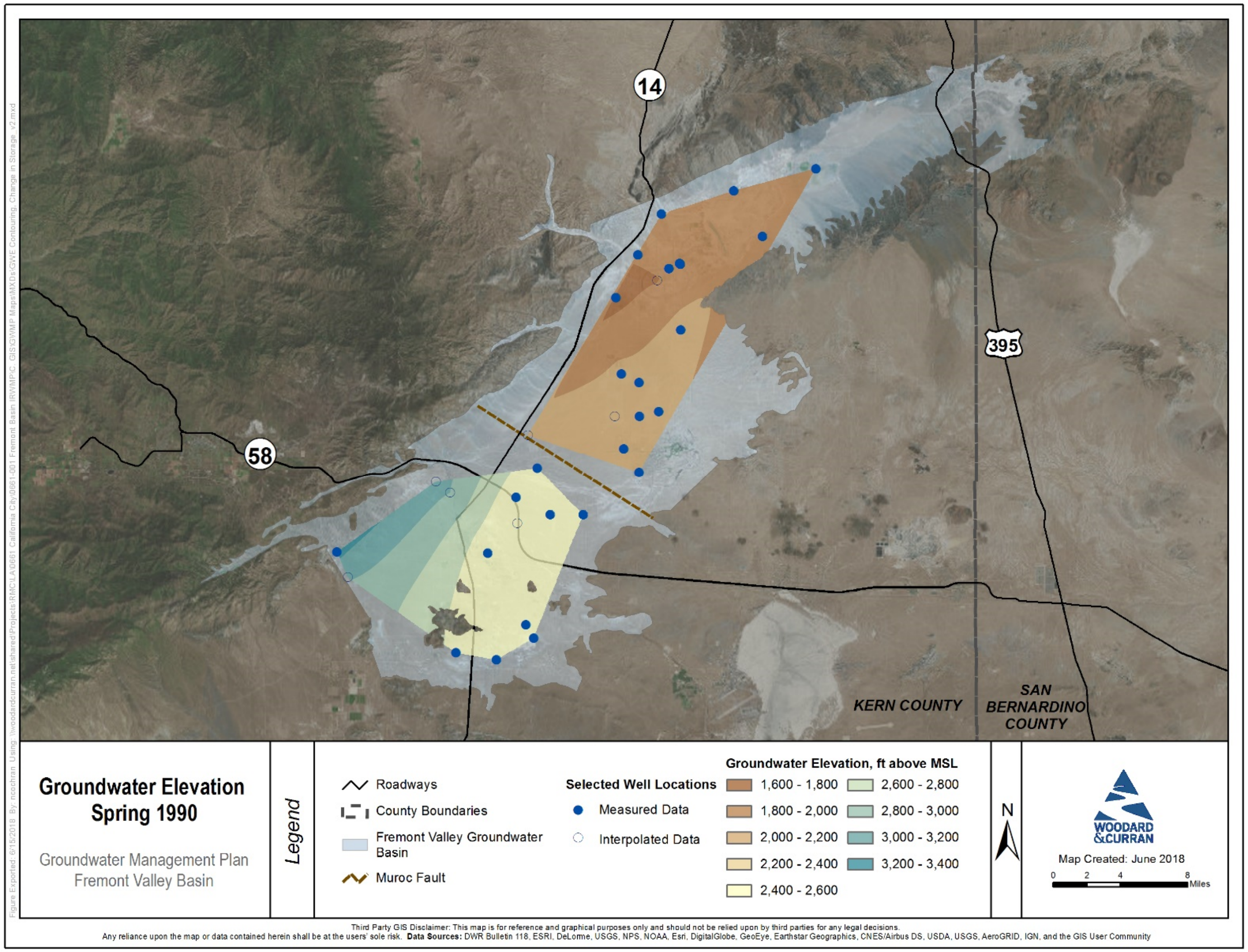


Figure B-12: Spring 1993 Groundwater Elevation Contours

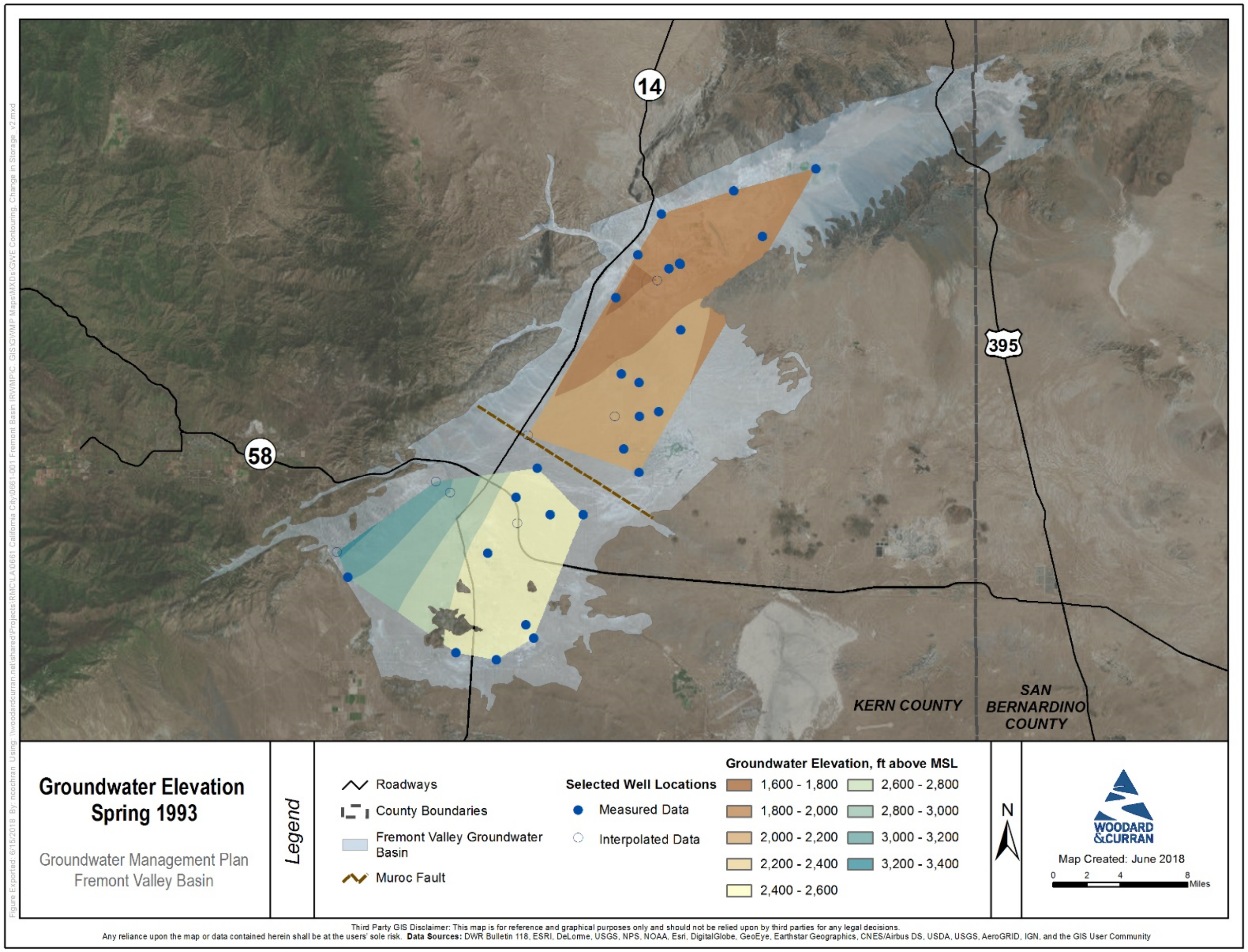


Figure B-13: Spring 1995 Groundwater Elevation Contours

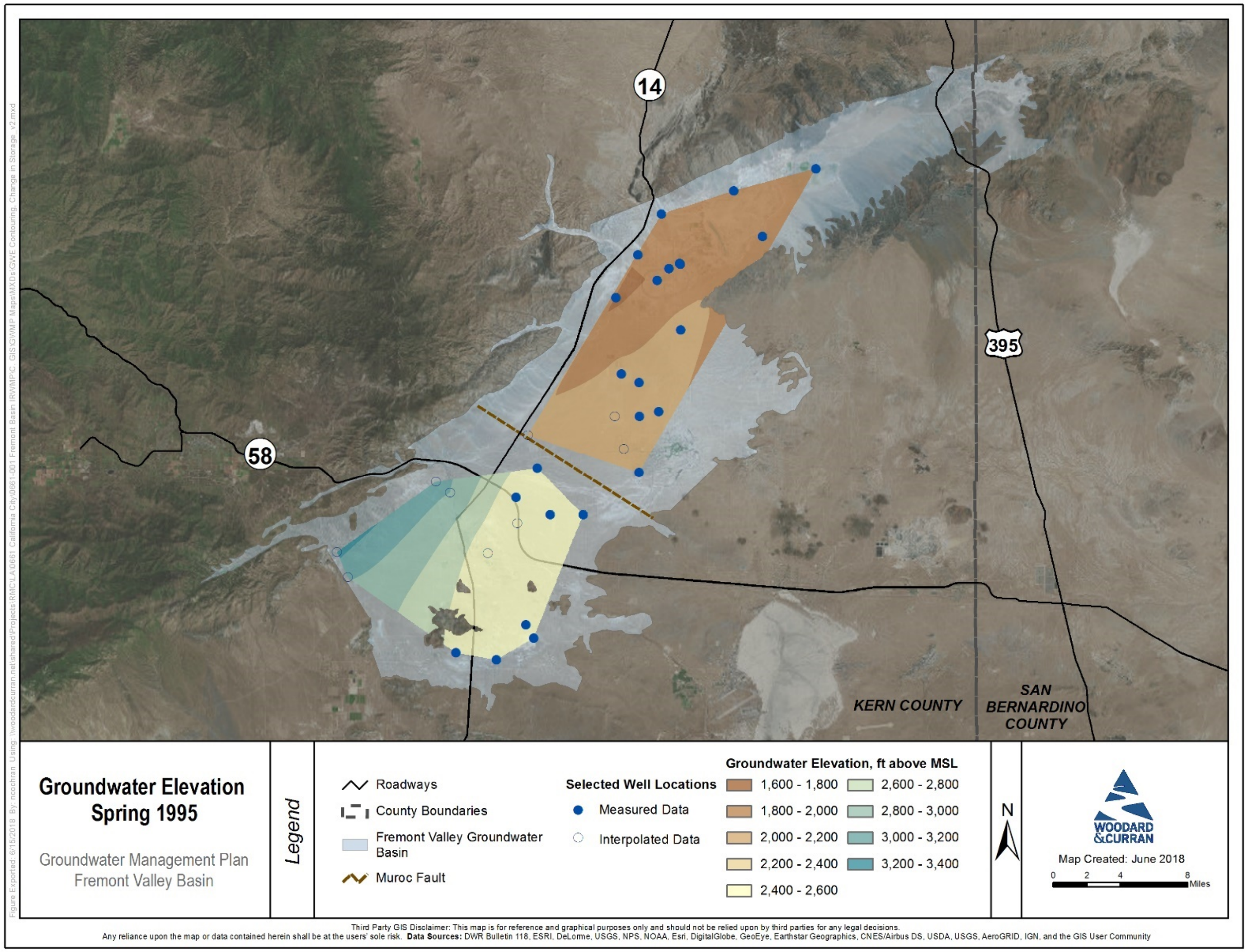


Figure B-14: Spring 1998 Groundwater Elevation Contours

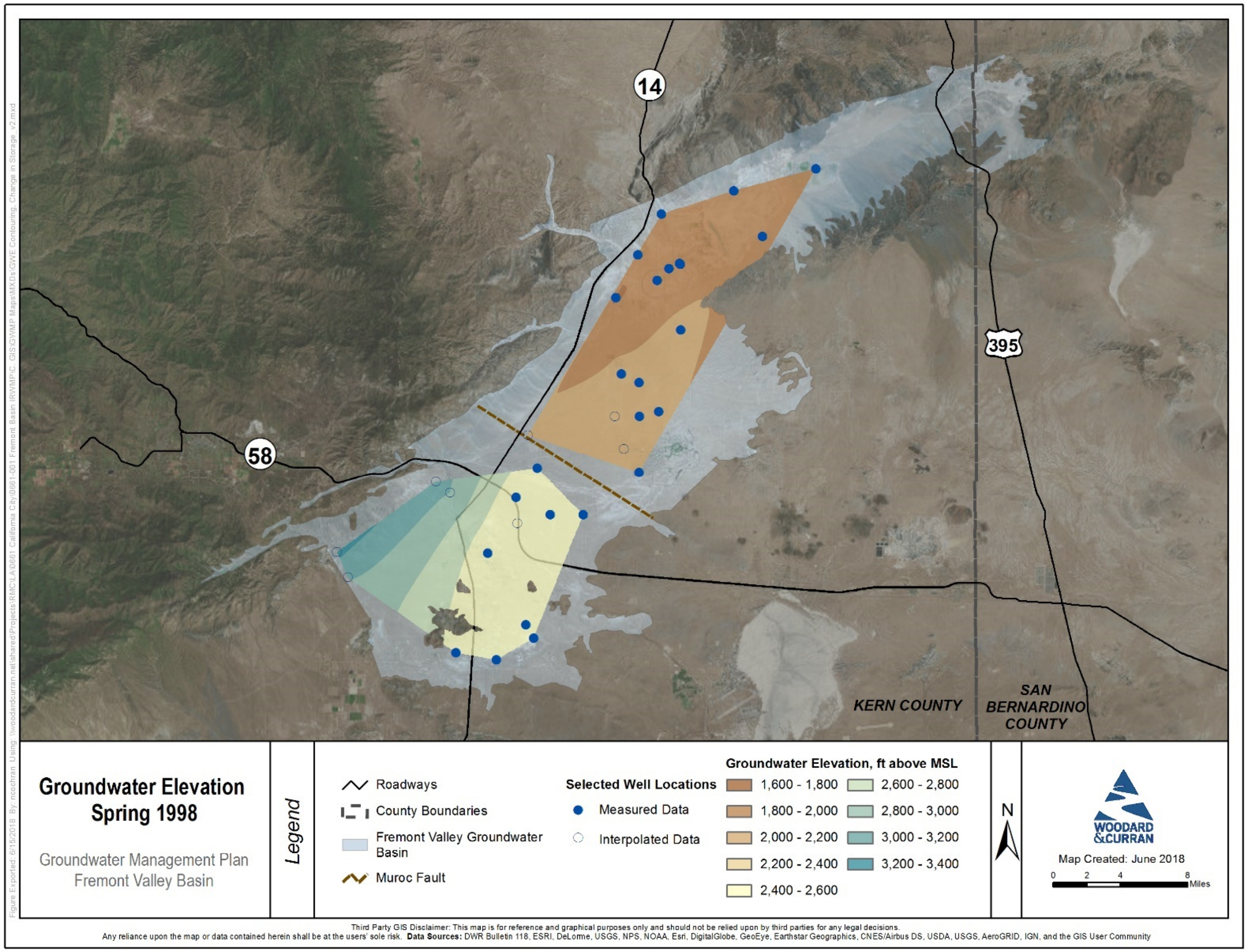


Figure B-15: Spring 2005 Groundwater Elevation Contours

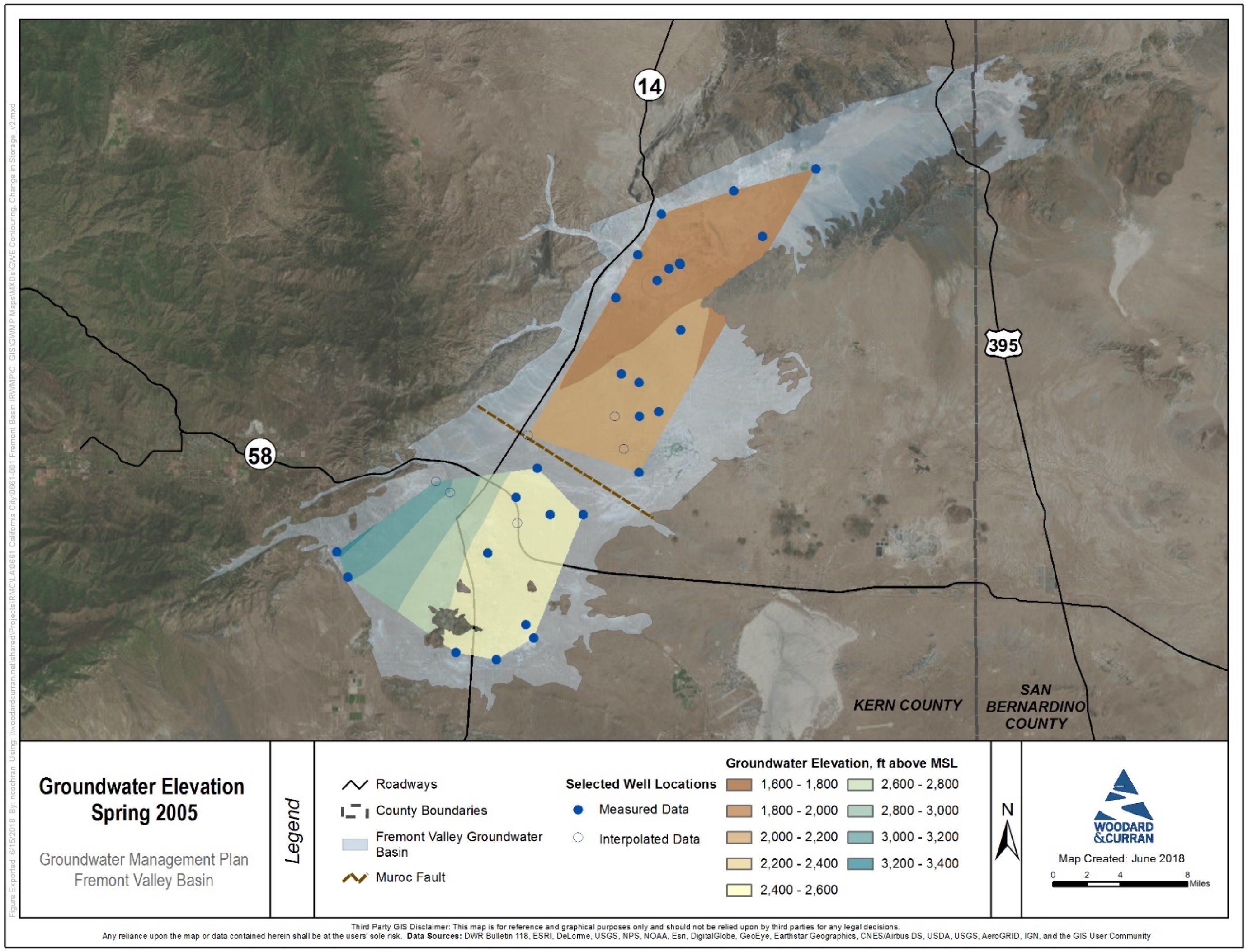


Figure B-16: Spring 2007 Groundwater Elevation Contours

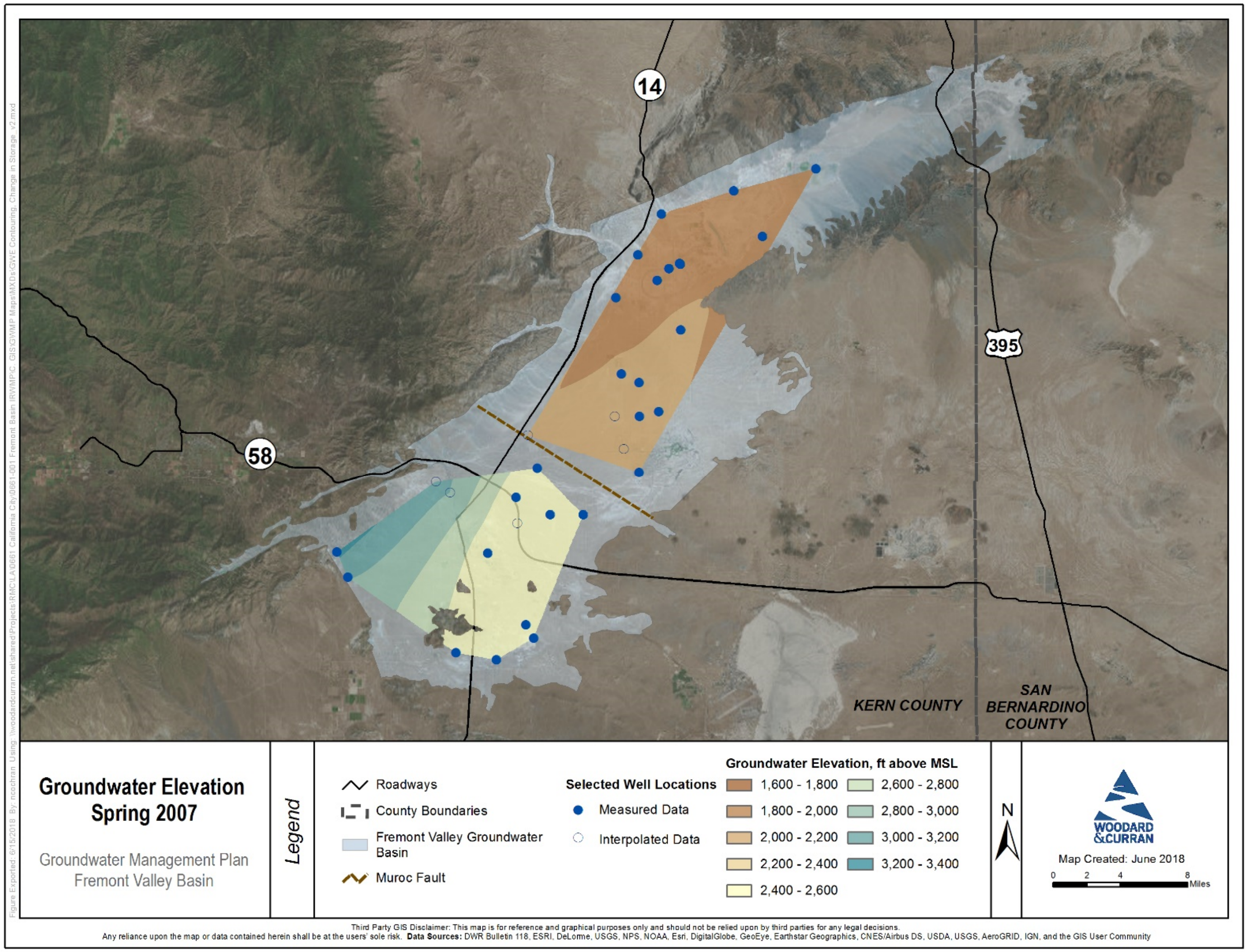


Figure B-17: Spring 2010 Groundwater Elevation Contours

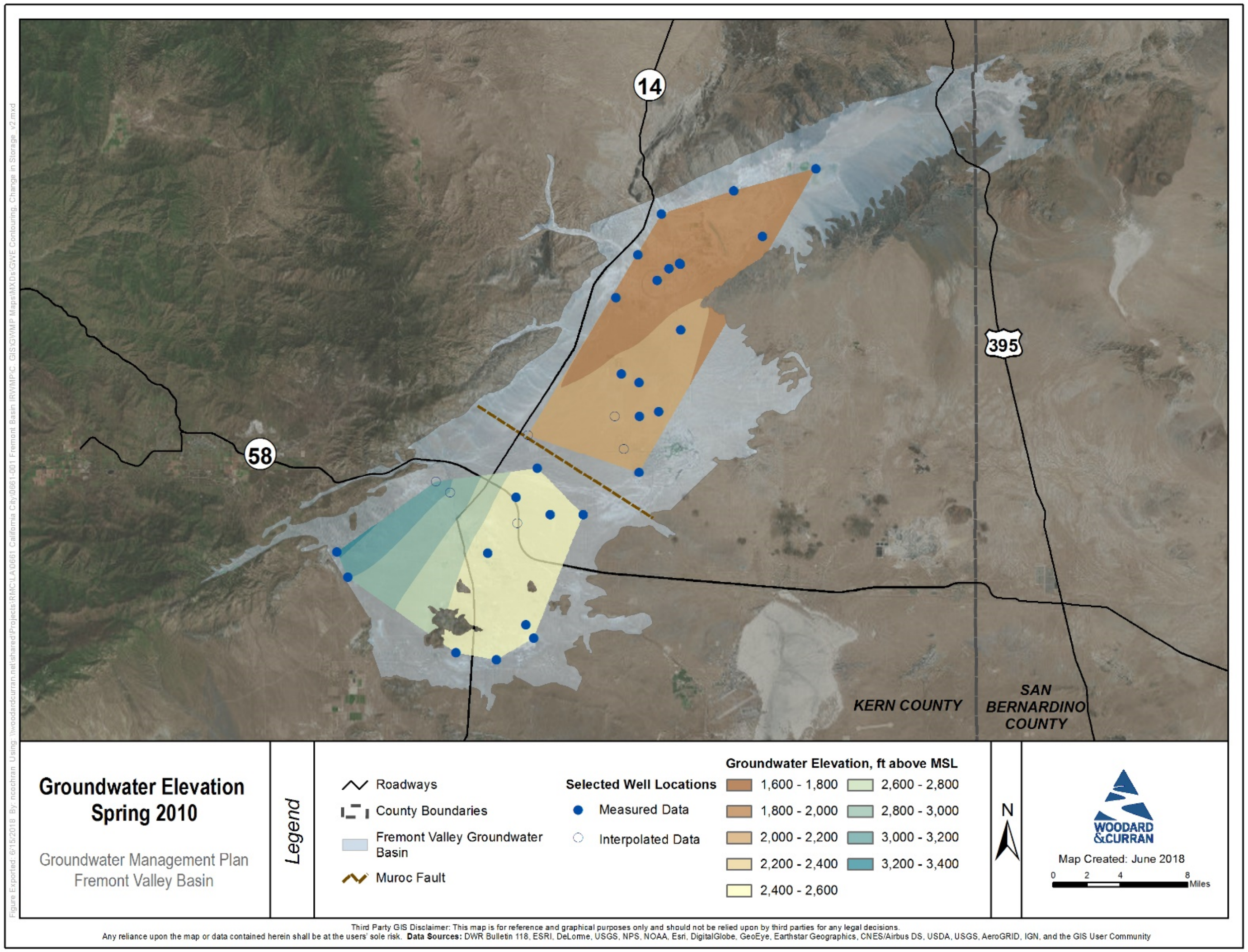


Figure B-18: Spring 2013 Groundwater Elevation Contours

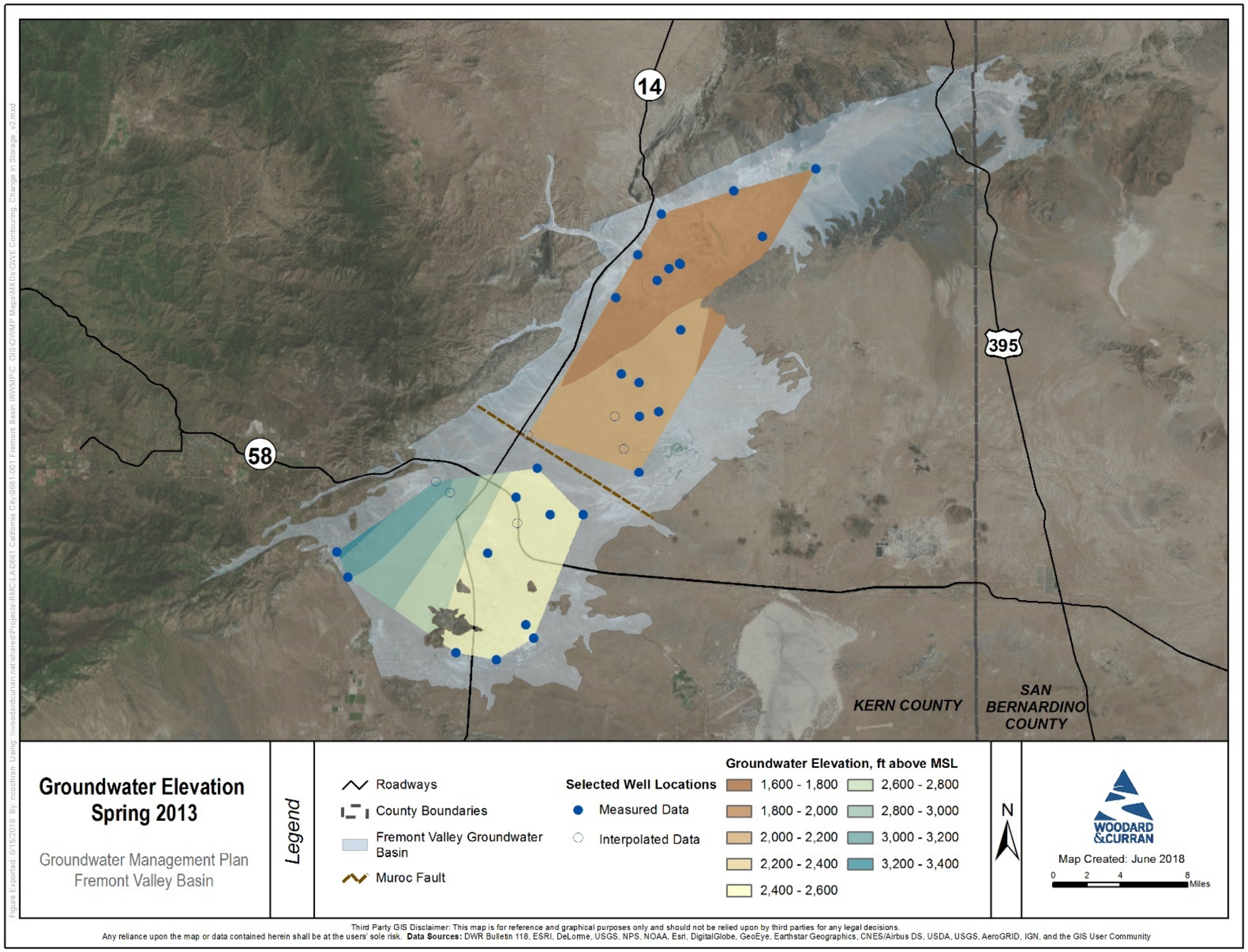


Figure B-19: Spring 2015 Groundwater Elevation Contours

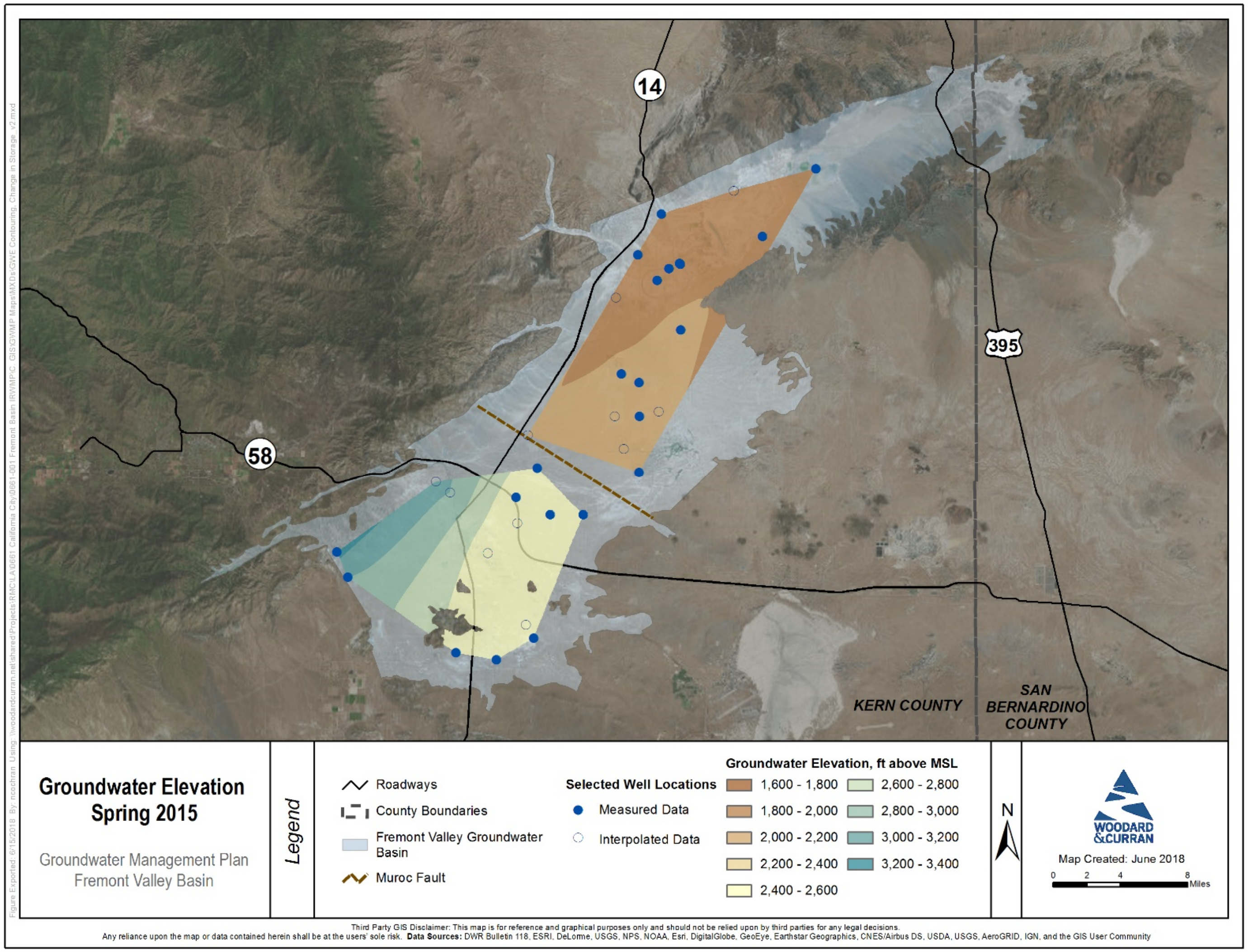
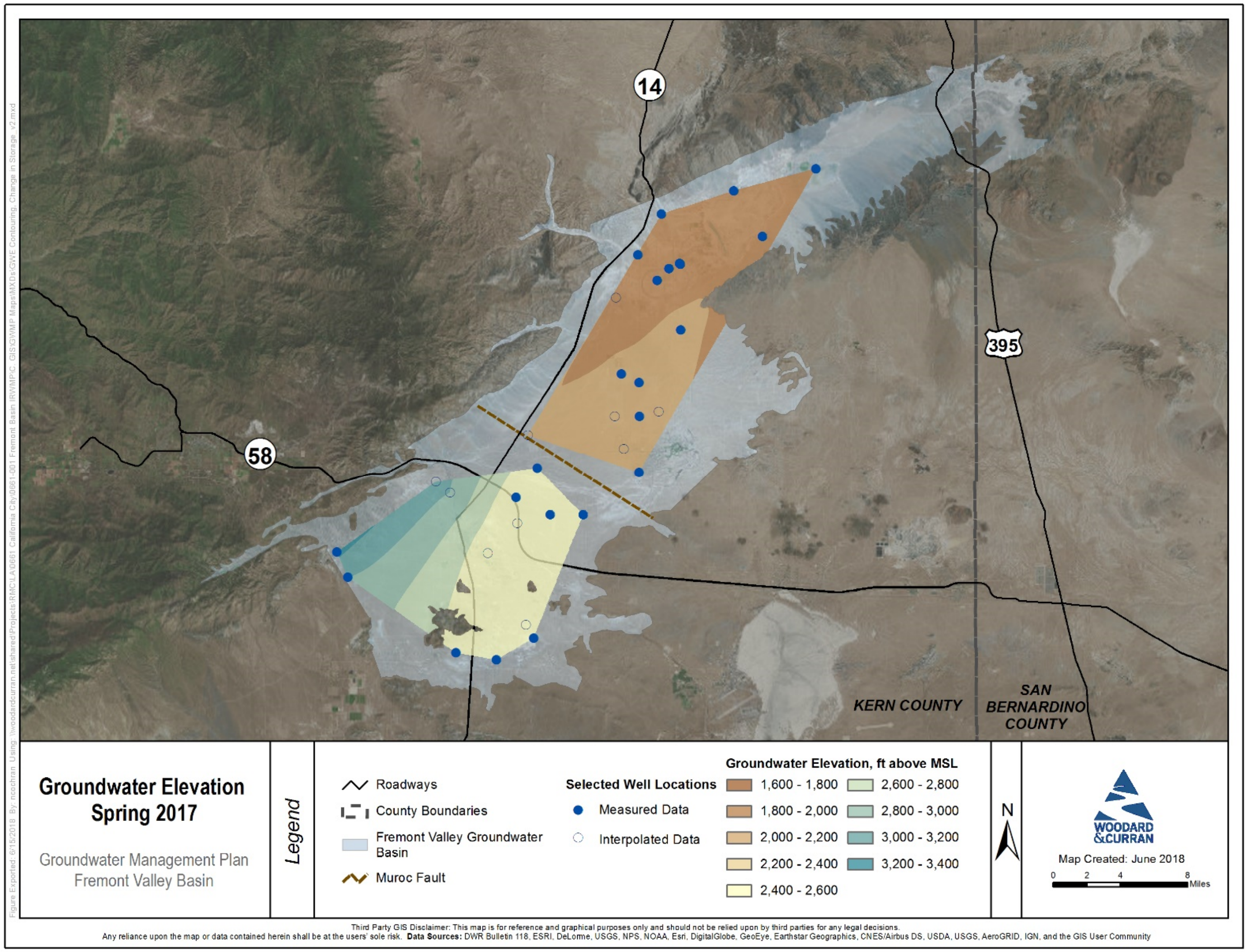


Figure B-20: Spring 2017 Groundwater Elevation Contours



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