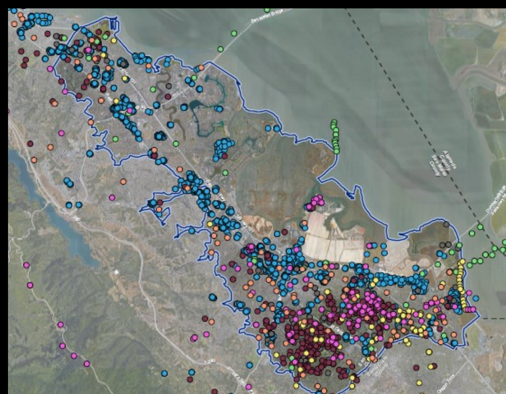
San Mateo Plain Groundwater Basin Assessment

Public Review Draft

JUNE 2018



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San Mateo Plain Groundwater Basin Assessment

DRAFT

June 2018

Prepared for:

County of San Mateo

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LIST OF ABBREVIATIONS

µS/cm	micro-siemens per centimeter
AB	Assembly Bill
ABAG	Association of Bay Area Governments
ACWD	Alameda County Water District
AF	acre-foot
AFY	acre-feet per year
ASR	aquifer storage and recovery
BAWSCA	Bay Area Water Supply and Conservation Agency
bgs	below ground surface
BMO	Basin Management Objective
BRS	Basin Ranking Score
C/CAG	City and County Association of Governments
Cal Water	California Water Service Company
CASGEM	California Statewide Groundwater Elevation Monitoring
CDPH	California Department of Public Health
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
cm/sec	centimeters per second
COC	chemicals of concern
CPUC	California Public Utilities Commission
CWC	California Water Code
CWC	Co-Operative Water Company
DEM	digital elevation model
DPR	direct potable reuse
DTSC	Department of Toxic Substances Control
DWR	California Department of Water Resources
DWSAP	Division of Drinking Water Drinking Water Source Assessment and Protection
EBMUD	East Bay Municipal Utilities District
EHS	Environmental Health Services Division
ET	evapotranspiration
ET0	reference evapotranspiration
F	Fahrenheit
ft/day	feet per day
ft2/day	square feet per day
gal/min/ft	gallons per minute per foot
GIS	Geographic Information System
gpm	gallons per minute
GRP	Groundwater Reliability Partnership
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan

GSR	Groundwater Storage and Recovery
GWMP	Groundwater Management Program
IGSM	Integrated Groundwater and Surface Water Model
IMs	Interim Milestones
iMOD	Santa Clara Valley Water District's interactive MODeling model
in/yr	inches per year
InSAR	Interferometric Synthetic Aperture Radar
IPR	indirect potable reuse
IRWM	Integrated Regional Water Management
ISG	Individual Supply Guarantee
JPA	Joint Powers Authority
LID	low impact development
LUST	leaking underground storage tank
meq/L	milliequivalents per liter
mg/L	milligrams per liter
MGD	million gallons per day
MOU	Memorandum of Understanding
MPMWD	City of Menlo Park Municipal Water District
msl	mean sea level
NAVD	North American Vertical Datum of 1988
NEBIGSM	Niles Cone and South East Bay Plain Integrated Groundwater and Surface Water Model
NGS	National Geodetic Survey
NOAA	National Atmospheric and Oceanographic Administration
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NSRS	National Spatial Reference System
PAPMWC	Palo Alto Park Mutual Water Company
PMCL	primary maximum contaminant level
ppm	parts per million
PREP	Potable Reuse Exploratory Plan
Proposition 1	Water Quality, Supply, and Infrastructure Improvement Act of 2014
RMSE	root-mean-square-error
RWQCB	San Francisco Bay Regional Water Quality Control Board
RWQCP	Palo Alto Regional Water Quality Control Plant
RWS	Regional Water System
SB	Senate Bill
SCVM	Santa Clara Valley Model
SCVWD	Santa Clara Valley Water District
SFPUC	San Francisco Public Utilities Commission
SGMA	Sustainable Groundwater Management Act
SHGCC	Sharon Heights Golf and Country Club
SLAC	SLAC National Accelerator Laboratory

SMCL	secondary maximum contaminant level
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
SMPGWM	San Mateo Plain Groundwater Flow Model
SNMP	salt and nutrient management plan
SRP	Stormwater Resource Plan
SUB	MODFLOW subsidence package
SVCW	Silicon Valley Clean Water
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	underground storage tank
UWMP	Urban Water Management Plan
VOC	volatile organic compound
WBSD	West Bay Sanitary District
WRR	Water Reclamation Requirements
WSBM	Westside Basin Model
WSIP	California Water Commission, Water Storage Investment Program
WWTP	wastewater treatment plant
Zone 7	Alameda County Flood Control and Water Conservation District, Zone 7

EXECUTIVE SUMMARY

This report summarizes efforts conducted by EKI Environment & Water Inc. (formerly Erler & Kalinowski, Inc.), Todd Groundwater, and HydroFocus, Inc. (the "Project Team") on behalf of the County of San Mateo (County) for the County's San Mateo Plain Groundwater Basin Assessment (Project). The Project was conducted by the County, with support from the Project Team, to comprehensively evaluate the San Mateo Plain Groundwater Subbasin (Basin), as defined by the California Department of Water Resources (DWR) (**Figure ES-1**). The Project is the first of its kind in the Basin, and was funded by Measures A and K (half-cent sales taxes approved by San Mateo County voters in November 2012 and November 2016, respectively, to support San Mateo County's quality of life). The Project began with Phase 1 in April 2016 and concludes with submission of this report to the County Board of Supervisors.

Figure ES-1. San Mateo Plain Groundwater Subbasin

The primary objectives of the Project as they relate to the Basin are to:

1. Increase public knowledge,
2. Evaluate hydrogeologic and groundwater conditions,
3. Identify potential impacts of sea level rise and climate change,
4. Evaluate potential impacts to groundwater quality and quantity, and
5. Develop potential groundwater management strategies.

As part of this Project, frequent public Stakeholder Workshops were conducted to engage Basin stakeholders and solicit feedback on the approach and results of the Project. Nine Stakeholder Workshops were hosted over the course of the Project. The County also held one-on-one and small group meetings with interested Basin stakeholders throughout the Project. This stakeholder engagement process is described in detail in Section 3.0.

The County has developed a website to serve as a repository for information and materials developed throughout the Project. More information about the Project can be obtained from the San Mateo Plain Project Website at: http://www.smcsustainability.org/smplain.

Basin Overview

The Basin encompasses approximately 37,708 acres[1] and is located along the eastern edge of the San Francisco Peninsula between San Francisco Bay and the Santa Cruz Mountains (**Figure ES-1**). The Basin is part of a larger regional groundwater system that includes groundwater basins in Alameda and Santa Clara Counties. A bedrock high delineates the northern end of the Basin (near Hillsborough and San Mateo) and the southern end of the Basin is generally defined by the San Mateo-Santa Clara County line, which is coincident with San Francisquito Creek. Small portions of the Basin extend into Santa Clara County.

Thirteen cities overly portions of the Basin, and land use within the Basin is almost entirely urban, supporting a total population of 292,000. There are also 13 different local water suppliers within the Basin, consisting of a combination of cities, water districts, mutual water companies, and investor-owned utilities.

Groundwater production within the Basin for potable and non-potable supply is relatively limited, as the primary water supply source since the 1960s has been imported Hetch Hetchy water. Groundwater levels have increased since the 1960s and currently the Basin is in a relatively full and stable condition. However, available data indicate that during historical periods of high groundwater production, groundwater levels in the Basin dropped significantly and negative impacts including seawater intrusion and subsidence were observed. The recent historic drought, coupled with renewed interest in groundwater development within the Basin, has increased local interest in better understanding the Basin and evaluating the extent to which increased groundwater development can be pursued, while mitigating potential negative impacts, or "undesirable results."

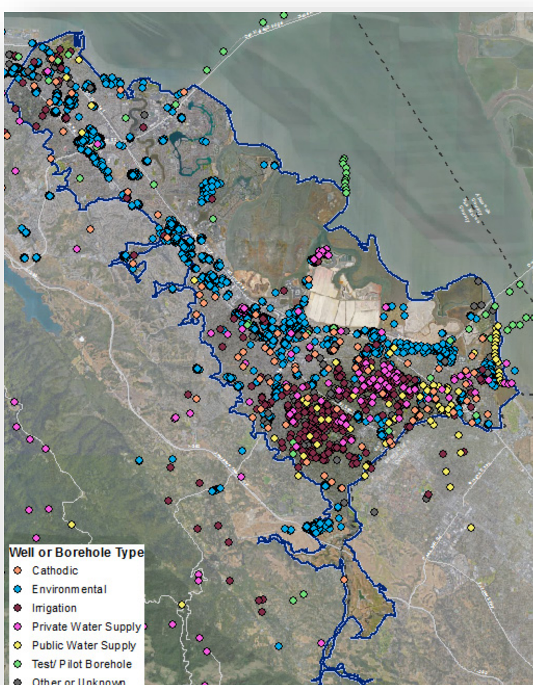


Figure ES-2. Wells and Boreholes with Available Data

Review and Compilation of Existing Data

A major emphasis of the Project is to assemble and analyze the available data for the Basin to support subsequent detailed studies of Basin characteristics and interactions. Data collected to date include: geology, soils, groundwater levels and quality, topography, climate, surface hydrology, water use and wastewater production, land cover/use, and political/jurisdictional subdivisions within the

[1] Basin area is based on the June 2014 Final CASGEM Groundwater Basin Prioritization Results.

Basin. These data have been compiled, as appropriate, into a comprehensive Microsoft Access database and related ESRI ArcGIS geodatabase (together, the "Project database") that is used to support the technical analyses being conducted as part of this Project (**Figure ES-2**). Basin-specific data developed as part of this Project have been made publicly available in the form of geospatial map "layers" and tabular data on the County's virtual data sharing site "San Mateo County GIS Open Data" located at http://data-smcmaps.opendata.arcgis.com/ (search: "groundwater" or "San Mateo Plain").

The data collection effort consolidated a significant amount of data for the Basin, including well construction records for more than 3,700 wells and boreholes, nearly 60,000 water level measurements, and over 500,000 analytical chemistry records (see **Table ES-1, Figure ES-2**). The vast majority of water level and water quality data are associated with shallow wells located at current or historical chemical contamination cleanup and investigation sites throughout the Basin. As shown on **Figure ES-3**, over 90 percent of the available water level data were from shallow wells that are less than 50 feet deep. In general, the majority of the geologic, water level, and water quality data that span both shallow and deeper aquifer zones in the Basin are limited to the southern portion, focused largely around the Menlo Park, Atherton, and East Palo Alto areas.

Table ES-1. Available Groundwater Data

Type of Data	Data Availability
Well and Borehole Records	~3,800 wells/boreholes
Wells with Screened Interval Data	~1,100 wells
Water Level Measurements	59,000+ records from ~2,500 wells
Analytical Chemistry Data	500,000+ records from ~1,900 wells
Aquifer Test Data	48 wells

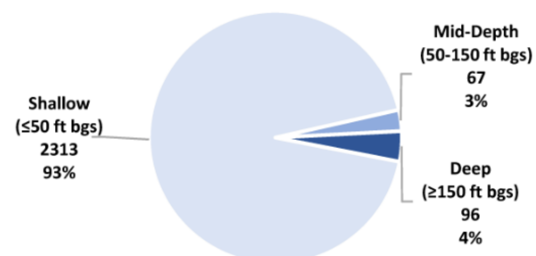


Figure ES-3. Depth of Wells Within the Basin With One or More Water Level Measurements

Basin Water Quality

In order to understand the general water quality and any significant variations or trends within the Basin, available water quality data were analyzed spatially, vertically, and temporally. In general, groundwater within the Basin was found to be of sufficient quality for municipal and irrigation supply, albeit with some level of treatment potentially required depending on the well location, depth, and intended use of the produced water.

Total dissolved solids (TDS) data, summarized on **Figure ES-4**, provide a general representation of inorganic water quality throughout the Basin. In general, deep wells are characterized by lower TDS concentrations than shallower wells. Many of the shallow wells exceed the recommended California drinking water standard, or recommended secondary maximum contaminant level

(SMCL, based on consumer-acceptance), for TDS of 500 milligrams per liter (mg/L), with several wells exceeding 2,000 mg/L; the upper secondary consumer-acceptance-based MCL is 1,000 mg/L. However, time series data exhibit generally stable trends in TDS and chloride over the past 30 years in both shallow and deep wells, indicating that water quality is not being significantly degraded.

Most wells have concentrations exceeding the SMCLs for iron (0.3 mg/L) and manganese (0.05 mg/L), suggesting that elevated concentrations of these naturally occurring constituents may be ubiquitous and require treatment for municipal use. Detections of other potential constituents of concern were limited, spatially variable and primarily focused in the shallow zone (e.g., at known chemical remediation sites).

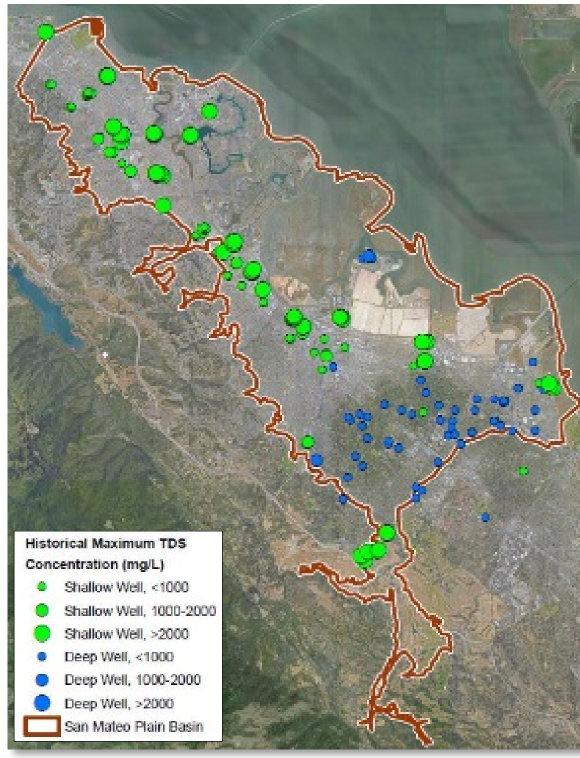


Figure ES-4. TDS Concentrations

Groundwater quality was also evaluated using geochemical plotting techniques to discern groundwater similarities and potential sources, and to evaluate any time trends for wells that would illustrate, for example, progressive seawater intrusion. In general, the Trilinear and Schoeller diagrams prepared for this study show that Basin groundwater quality reflects the varying influence and interaction of groundwater sources of recharge (including local stream and rainfall recharge, imported Hetch Hetchy water and return flow, and near-shore seawater intrusion in the shallow zone), plus the potential influence of groundwater released from local sediments. The evaluation further showed that available data for specific wells tends to cluster, revealing no significant variations or trends over time.

Hydrogeologic Conceptual Model

A hydrogeologic conceptual model was developed to characterize the Basin geology and flow system (i.e., interactions of groundwater with other water sources within the Basin and with neighboring basins). The Basin is bounded by the Santa Cruz Mountains on the west, by the Westside Basin on the north, by the Santa Clara Subbasin to the south, and by the Niles Cone and East Bay Plain Subbasins across San Francisco Bay to the east. The principal groundwater-bearing formations of the Basin are unconsolidated to semi-consolidated Quaternary-aged alluvium composed of gravel, sand, silt, and clay. In general, based on the depth to bedrock and the ground surface elevation, the alluvium is thinner in the higher elevations in the western part of the Basin and thickens towards San Francisco Bay. Various alluvial structures were deposited by streams draining the uplands. The most significant, and most studied, alluvial fan was formed by San

Francisquito Creek in the southern part of the Basin and is commonly referred to as the "San Francisquito Cone."

Regional groundwater flow within the Basin is generally from west-southwest to east-northeast, from the edge of the Santa Cruz Mountains towards the San Francisco Bay. Eight geologic cross-sections, including two longitudinal cross-sections and six lateral cross-sections, were constructed to depict the thickness and distribution of alluvial aquifer sediments and to delineate the hydrostratigraphy within the Basin. In addition, two regional cross-sections were constructed to illustrate the connections between the Basin and the adjacent groundwater basins. A sample lateral cross-section, covering the southern portion of the Basin, is provided as **Figure ES-5.** The cross-sections generally show interbedded fine- and coarse-grained layers; this aquifer and aquitard framework reflects the dynamic depositional environment and affects groundwater flow paths, providing a form of protection against sea water intrusion and vertical migration of contamination. In general, the groundwater system is unconfined in the higher elevations, and confined or semiconfined by thicker Bay Mud sequences at lower elevations closer to San Francisco Bay.

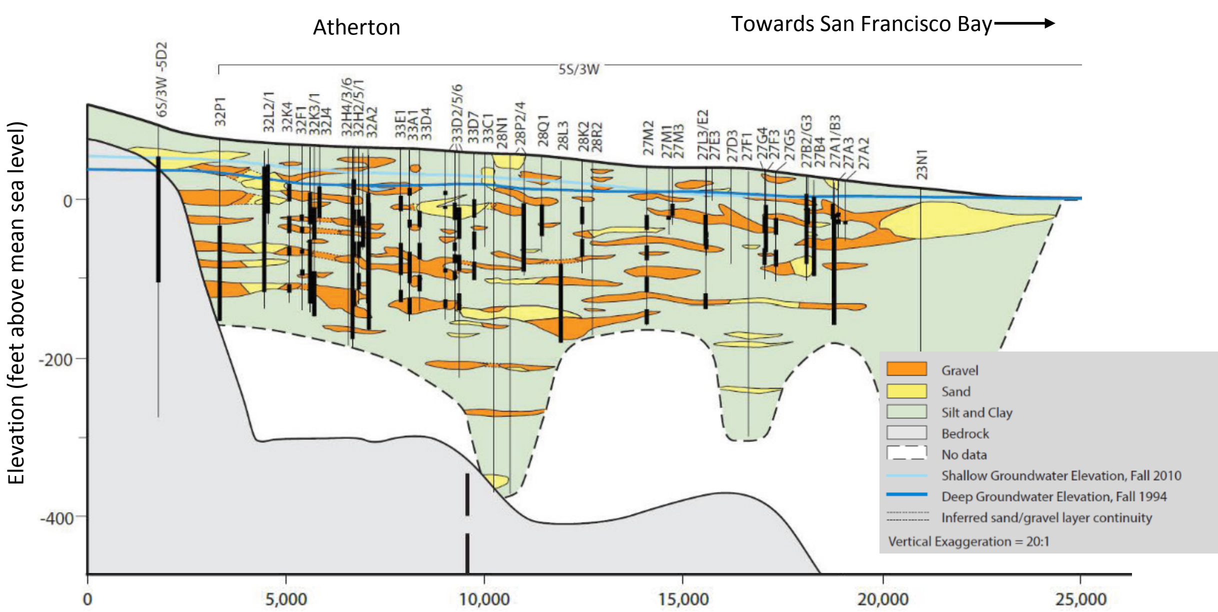


Figure ES-5. Sample Basin Cross-Section

Basin Water Balance

A water balance was developed to describe and quantify the current inflows to and outflows from the Basin. As summarized in **Table ES-2**, inflows and outflows to the Basin average about 7,900 acre-feet per year (AFY) under current land and water use conditions. The largest sources of recharge are deep percolation of rain and applied irrigation water in irrigated areas, deep percolation of rain in non-irrigated areas, percolation from creeks, and water pipe leaks.

Table ES-2. Water Balance Summary

Parameter	Estimated Water Balance (AFY)	
	Average	Plausible Range
Inflows		
Dispersed Recharge	4,800	3,300 to 9,000
Stream Percolation	1,300	800 to 2,000
Bedrock Inflow	600	100 to 1,000
Santa Clara Subbasin	1,200	500 to 2,000
Seawater intrusion	0	0
Total Inflow	**7,900**	**--**
Outflows		
Wells	3,500	2,100 to 5,700
Riparian Evapotranspiration	100	50 to 150
Seepage to Sewers, Creeks, and Tidal Wetlands	3,600	2,500 to 5,300
Outflow to San Francisco Bay	500	300 to 1,000
Westside Basin	200	-100 to 200
Total Outflow	**7,900**	**--**

The largest outflows are subsurface outflow to creeks and into and beneath San Francisco Bay, groundwater pumping for water supply, and groundwater infiltration into sewers. The balance between total inflows and total outflows reflects an assumption that there is no long-term change in storage; this assumption is supported by the fact that available water level data show that the Basin is currently in a stable and relatively "full" condition. Subsurface outflow was estimated as the residual in the water balance and was divided between groundwater discharge to creeks and wetlands and groundwater discharge to or beneath San Francisco Bay.

San Mateo Plain Groundwater Flow Model

The San Mateo Plain Groundwater Flow Model (SMPGWM) was developed to quantify water balances, hydrologic interconnections, and hydrologic responses to changes in recharge, pumping, climate, and sea level. The SMPGWM used as its starting point the existing Bay Area Water Supply and Conservation Agency (BAWSCA) Strategy Groundwater Model, which was then re-parameterized and calibrated using newly available information extracted from other existing groundwater models in the region and detailed Basin-specific information from the Project database. The SMPGWM simulates transient conditions during the period 1992 through 2015, because the largest set of water level measurement data is available for this period and because the time period overlaps the simulation periods of the numerical models used for the adjacent groundwater basins.

The SMPGWM was calibrated by adjusting aquifer storage properties (specific storage) to match seasonal and longer-term trends in measured water levels to obtain satisfactory agreement between model-calculated and measured water levels, and to generally corroborate the Basin Water Balance.

The SMPGWM utilizes a regional grid that captures hydraulically-connected portions of adjacent basins, thereby enabling the model to characterize groundwater flow throughout the San Francisco Bay Area in a way that could not be achieved solely with local models. The vertical distribution of water-bearing and non-water-bearing sediment deposits is represented in the SMPGWM by six model layers. Texture maps, such as that shown on **Figure ES-6**, were constructed for each model layer based on lithologic descriptions from boring logs, and provide the basis for representing spatial variability in horizontal and vertical hydraulic conductivity in the model.

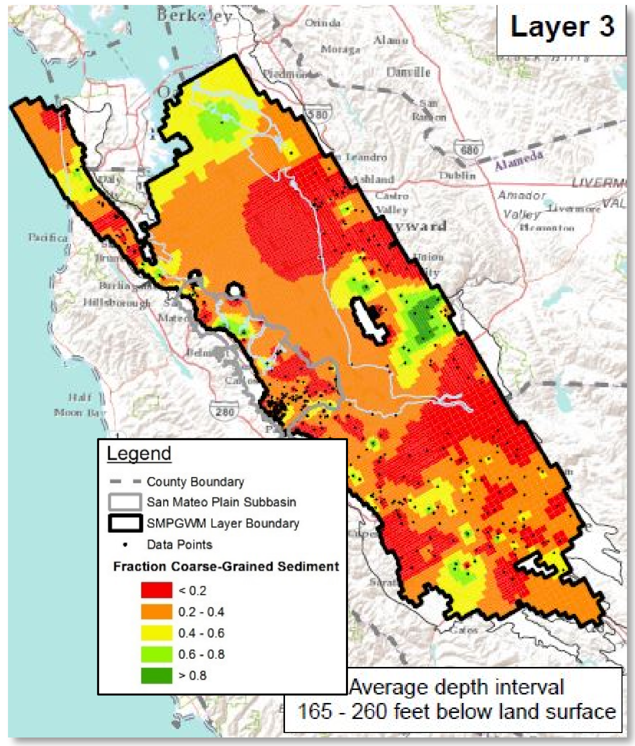


Figure ES-6. SMPGWM Layer 3 Texture Map

The model-calculated water balance for the Basin estimates that inflows and outflows to the Basin total 7,800 AFY, which is 100 AFY less than the Basin water balance described in Section 7.0 and summarized in **Table ES-2**. The difference does not indicate a model deficiency, but rather reflects, among other things, the use of different time periods and differences in the apportionment of subsurface flows across Basin boundaries by the two methods.

Evaluation of the Risk of Potential Undesirable Results

Currently conditions in the Basin are stable; however, the data indicate that, in the past, higher groundwater pumping rates in the Basin resulted in some negative impacts to the Basin (e.g., land subsidence and seawater intrusion). A qualitative analysis was therefore conducted to assess the potential impacts to groundwater quantity and quality within the Basin, in the event that future groundwater recharge decreases and/or groundwater pumping increases beyond an as-of-yet determined sustainable threshold. The qualitative risk analysis considered the Basin's vulnerability to the following undesirable results:

- *Decline in Groundwater Levels and Storage* – The risk of a chronic decline in water levels and groundwater storage is believed to be low due to (a) the availability of Hetch Hetchy water, and (b) the environmental review and permitting process required for new production wells.

- *Land Subsidence* – Land subsidence has occurred in the Basin historically. However, as long as future water levels are not drawn down below historical low levels, it is anticipated that the risk of inelastic (irreversible) land subsidence is minimal.
- *Seawater intrusion* – Seawater intrusion has occurred in adjacent basins and represents a threat to the Basin. While current groundwater levels are high enough to mitigate the risk for seawater intrusion, the risk would increase if water levels in the deep aquifer were to fall below sea level and sea water was able to migrate into the deep aquifer.
- *Impacts to Interconnected Surface Water* – An analysis of surface water-groundwater interactions in the Basin suggests that increased use of groundwater in the Basin could potentially affect baseflow in certain, hydraulically-coupled sections of San Francisquito and San Mateo Creeks, with potential implications for certain listed aquatic species such as steelhead trout.
- *Salt and Nutrient Loading* – The largest source of salt loading to the Basin is likely irrigation, although use of low-TDS Hetch Hetchy water for irrigation minimizes the impact. The effects of landscape fertilization on nutrient loading have been observed in the form of elevated nitrate concentrations detected in some Basin wells.
- *Point-Source Contamination* – Point-source contamination exists within the Basin and is addressed through remediation efforts required by regulatory drivers and oversight.
- *Cross-Contamination between Shallow and Deep Aquifers* – Migration of contaminants from the shallow aquifer to the deep aquifer can occur where cross-connecting wells allow movement from shallow to deeper zones and where sediments are dominated by coarser material. Potential cross-connecting wells have been documented in the southwestern portion of the Basin near Menlo Park and Atherton.
- *Sea Level Rise* – The threat of seawater intrusion can be exacerbated not only by reduced aquifer recharge or increased groundwater pumping, but by sea level rise as well. This remains an issue to be monitored closely as additional groundwater development occurs in the Basin over time, coupled with anticipated climate change impacts.

Based on this qualitative analysis, there is the possibility for undesirable results to occur in the Basin with changes in pumping conditions.

Initial Evaluation of Basin Management Options

One of the ways to address and/or mitigate the potential to incur the undesirable results discussed above is to conduct proactive groundwater basin management.

Groundwater basin management is generally composed of two components: (1) institutional management, and (2) physical management. *Institutional* management refers to the governance structures, laws, and policies that define how groundwater is managed within a basin. *Physical* management refers to the projects and programs that are implemented within a basin to achieve certain management objectives (e.g., operation of injection/extraction wells to create a hydraulic barrier against seawater intrusion).

Given the recent drought, the local interest in groundwater development, and the passage of the Sustainable Groundwater Management Act of 2014 (SGMA), one of the objectives of this Project was to better understand what groundwater management options were being employed in other similarly sized and used basins throughout California, and what relevance, if any, such approaches had for the Basin.

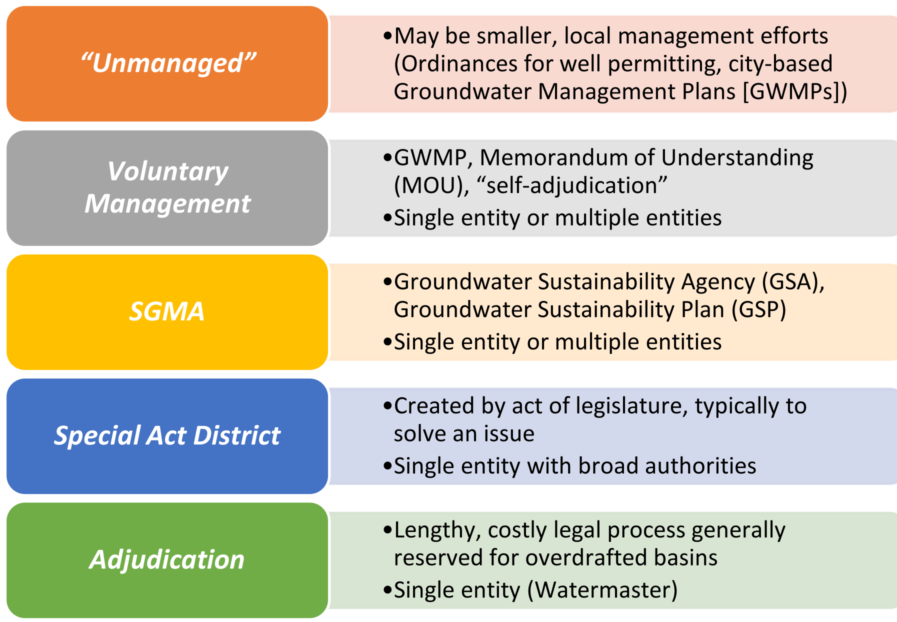


Figure ES-7. Inventory of Groundwater Management Strategies Used throughout California

As part of this evaluation, various institutional groundwater management options were inventoried – everything from unmanaged to basin adjudication, with local examples presented, as applicable (see **Figure ES-7**). For example, groundwater is managed actively in each of the adjacent groundwater basins, and these different management approaches were examined for potential relevance to the Basin. Two of the adjacent basins, the Niles Cone Subbasin across the San Francisco Bay to the east and the Santa Clara Subbasin to the south, are managed by Special Act Districts that have exclusive groundwater management authority within their basins under SGMA. The East Bay Plain Subbasin, also across the Bay to the east, is voluntarily managed by the East Bay Municipal Utility District and the City of Hayward. The most directly relevant analogues to the Basin are the Westside Basin and several smaller basins throughout California wherein entities within a basin have partnered to voluntarily manage groundwater, in large part to avoid undesirable results or to support the development of managed aquifer recharge projects.

The physical management options identified in this initial analysis similarly were intended to present the full spectrum of options that may (or may not) be applicable to the Basin. Various elements of physical management options were inventoried, including water sources, delivery methods, recharge options, pumping regulations, and options to protect groundwater quality. Some of these options were more quantitatively evaluated using the SMPGWM and the associated constraints analysis, as described below. Additional work and coordination are needed to better understand the extent to which any of the identified physical management solutions would be viable or desired by entities within the Basin, or the extent to which they can be developed as regional and multi-benefit projects.

Scenario Evaluations Using the San Mateo Plain Groundwater Flow Model

The SMPGWM was employed to evaluate the effects of various changes on groundwater conditions, specifically to quantify the risks of undesirable results and/or the benefit of the potential groundwater management options identified above and in Sections 9.0 and 10.0.

The Project Team utilized significant feedback received from stakeholders and consideration of the overall Project objectives to develop a set of four scenarios to model. The scenarios represent a stepwise approach that allows for evaluation of incremental effects relative to the "baseline" condition, and are illustrated on **Figure ES-8**. Parameterizations for each scenario were developed to reflect reasonable potential conditions. These scenarios were informed by projections of future conditions resulting from climate change, including sea level rise projected by the National Research Council (NRC, 2012) and seawater inundation due to sea level rise predicted by the California Ocean Protection Council (2013). Constraints analyses were also performed to identify areas of the Basin with high potential for being used for potential future groundwater pumping (**Figure ES-9**) and high potential for effective recharge projects.

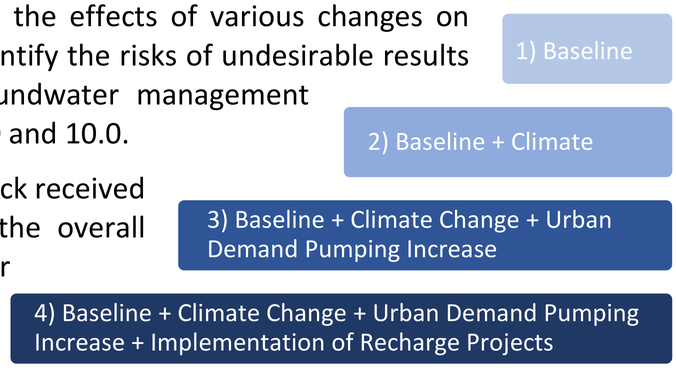


Figure ES-8. Scenarios Evaluated using the SMPGWM

Model results indicate relatively stable groundwater level trends for the four modeled scenarios. Increased pumping demand under Scenario 3 represents a more stressed condition than the other scenarios, and results in the greatest decrease in groundwater levels; however, even locations within the area of focused increased pumping show a decrease of only about 15 feet over 25 years.

The model-calculated water budget results indicate an annual change in storage for the four modeled scenarios of between 0 and -200 AFY. This amount does not suggest a significant level of overdraft. Even under the most "stressed" condition (Scenario 3), where pumping for urban water supply is nearly doubled relative to current conditions, the Basin does not exhibit a substantial long-term decrease in storage that would indicate overdraft conditions, because of the recharge that occurs across Basin boundaries. A change in storage of -200 AFY represents about 2.5 percent of the total annual water budget and less than 0.02 percent of total storage.

Due to its location directly adjacent to San Francisco Bay, the potential for salt water/seawater intrusion exists and there is historical evidence that it has occurred in the Basin. Under the stressed conditions of Scenario 3, the groundwater levels at the low point (end of) the simulation period include large areas with groundwater levels below sea level, which may create conditions conducive to migration of seawater into the Basin. It is, however, uncertain whether the water quality in the deep aquifer zone that enters the Basin from the east is saline or not, and the shallow zone retains a condition of net outflow to the east due to seepage. It is therefore possible that the Basin could operate under conditions where groundwater levels dip below sea level, either temporarily or more continuously, without resulting in "significant and unreasonable" seawater intrusion.

The SMPGWM includes the ability to simulate land subsidence. However, results indicate a negligible amount of subsidence for all scenarios. While parameterization of the subsidence package is challenging due to uncertainty in pre-consolidation heads and elastic and inelastic storage coefficients, these results should be considered qualitative, yet they indicate that land subsidence is likely not a major concern under simulated conditions, given that such inelastic subsidence has previously occurred in the Basin.

None of the scenarios modeled indicated a significant change in the amount of inflow to the Basin from recharge from creeks, including San Francisquito Creek, San Mateo Creek, and the multiple smaller creeks. San Francisquito Creek is a primary source of recharge to the Basin, but most leakage from the creek to the aquifer occurs in the upper reaches of the creek. In these areas, the water table is below the bottom of the streambed and hydraulically disconnected from water flowing in the creek. As such, the leakage rate under these conditions is determined by the water level in the creek, the elevation of the bottom of the streambed, and the hydraulic conductivity of the streambed deposits beneath the creek and is not sensitive to changes in the water table. Therefore, these preliminary results suggest that impacts of groundwater management/ development activities, if sited and managed appropriately, are not likely to be significant.

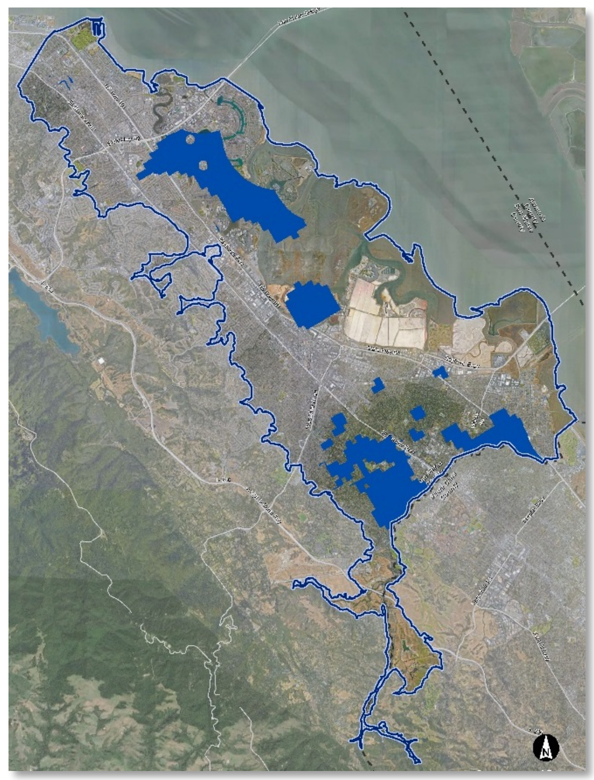


Figure ES-9. Example Constraints Analysis – Areas of Potential Increased Groundwater Production

While the modeled scenario results indicated relatively sustainable groundwater conditions under the modeled scenarios, this evaluation does not substitute for the more refined analysis of potential impacts that is necessary on a project-by-project basis as part of an environmental review and project development process.

Potential Future Activities

Groundwater basins in California are subject to the requirements of SGMA if they are designated by DWR as a Medium or High priority basin. The initial basin priorities were based upon the California Statewide Groundwater Elevation Monitoring (CASGEM) Basin Prioritization Process, which was completed in June 2014. As part of this process, DWR assigned a priority ranking of Very Low, Low, Medium, or High to each of the 517 groundwater basins in California. At this time, DWR determined that groundwater use within the Basin was lower than the 2,000 AFY threshold to be considered Low, Medium, or High priority ("the groundwater reliance exemption") and ranked it as a Very Low priority basin, exempting it from mandatory SGMA compliance.

In May 2018, DWR issued an addendum to the Bulletin 118 Interim Update, which included draft, updated basin priority rankings. The addendum proposed changing the Basin's priority ranking from Very Low to Medium priority. Based on the currently available schedule, these priority rankings are expected to be finalized by the California Water Commission in October 2018 following a 60-day comment period. Depending on the final outcome of the proposed DWR priority rankings, the Basin may no longer be subject to the groundwater reliance exemption and could be formally reprioritized as a Medium priority basin. If adopted, such a reprioritization would mean that the Basin would be subject to the requirements of SGMA, which will include, among other things, the establishment of one or more Groundwater Sustainability Agencies (GSAs) by October 2020 and the development of a basin-wide Groundwater Sustainability Plan (GSP) by October 2023. In the event that this occurs, this Report can serve as the foundation for the development of a GSP.

The Basin does not currently have a Monitoring Entity that monitors groundwater levels and is not participating in the CASGEM program. Compliance with CASGEM is potentially an important consideration for the Basin in the future (especially if it is formally re-prioritized as Medium priority) and could be an important first step in setting the Basin up for long-term sustainable management and funding. Among other things, one or more agencies would have to assume responsibility as a Monitoring Entity and establish a data collection, storing, and sharing framework that would satisfy DWR requirements.

Recognizing the importance and benefits of CASGEM compliance, the County hosted a meeting in January 2018 to discuss the matter with representatives of stakeholder agencies within the Basin and in the surrounding basins. Based on the initial feedback from meeting attendees and follow-up discussions with the remaining entities, there is strong interest among agencies in the Basin for some form of collaboration towards achieving CASGEM compliance.

Multiple agencies in the Basin are evaluating and planning for the increased use of recycled water. A result of this planning process may be a comprehensive response to salt and nutrient loading in the Basin through the development of a salt and nutrient management plan (SNMP). Water recycling provides benefits of a locally-managed supply and reliability during drought. It also allows the replacement of high quality, imported water with non-potable water for landscaping and other non-potable uses. However, use of recycled water in lieu of surface water or local groundwater source entails salt and nutrient loading. Recognizing this, the SWRCB developed its Recycled Water Policy, which requires the development of an SNMP. An SNMP would include, among other things, a description of a conceptual hydrogeologic model, identification of all salt and nutrient sources, assessment of salt and nutrient loading, analysis of fate and transport, evaluation of the assimilative capacity of local groundwater for key constituents, and identify implementation measures to monitor and manage salt and nutrient loading. This Report can serve as a foundation to support the development of an SNMP for the Basin.

1.0 INTRODUCTION

On behalf of the County of San Mateo (County), EKI Environment & Water, Inc. (formerly Erler & Kalinowski, Inc.), Todd Groundwater, and HydroFocus, Inc. (the "Project Team") have prepared this San Mateo Plain Groundwater Basin Assessment (Report) to summarize the efforts and results of the San Mateo Plain Groundwater Basin Assessment (Project). The Project was conducted by the County, with the support of the Project Team, to comprehensively evaluate the San Mateo Plain Groundwater Subbasin (Basin), as defined by the California Department of Water Resources (DWR) (**Figure 1-1**). The Project was funded by Measures A and K, a half-cent sales taxes approved by San Mateo County voters in November 2012 and November 2016, respectively, to ensure San Mateo County's quality of life.

The primary objectives of the Project as they relate to the Basin were to:

1. Increase public knowledge,
2. Evaluate hydrogeologic and groundwater conditions,
3. Identify potential impacts of sea level rise and climate change,
4. Evaluate potential impacts to groundwater quality and quantity, and
5. Develop potential groundwater management strategies.

The Project was performed in three phases, consisting of a comprehensive review and analysis of existing data and preparation of a Preliminary Report (Phase 1), a targeted effort to fill data gaps and refine the analysis (Phase 2), and an evaluation of different basin condition scenarios and an update of the Preliminary Report based on new information and analysis (Phase 3). As part of the Phase 1 and 2 efforts, the Project Team prepared a series of technical memoranda and a Preliminary Report that collectively formed the foundation for this Report, including:

- Technical Memorandum #1: Review, Compilation, and Presentation of Available Data and Key Data Gaps (19 August 2016)
- Technical Memorandum #2: Initial Basin Conceptual Model (31 August 2016)
- Technical Memorandum #3: San Mateo Plain Groundwater Flow Model (28 October 2016)
- Technical Memorandum #4: Initial Evaluation of Basin Management Options (27 September 2016)
- Technical Memorandum #5: Results of Phase 2 Data Collection and Analysis (16 February 2018)
- Technical Memorandum #6: Results of Scenario Evaluations Performed Using Groundwater Modeling (19 April 2018)
- San Mateo Plain Groundwater Basin Assessment Preliminary Report (Preliminary Report): http://www.smcsustainability.org/download/energy-water/groundwater/Final-Phase-1-Report.pdf (January 2017)

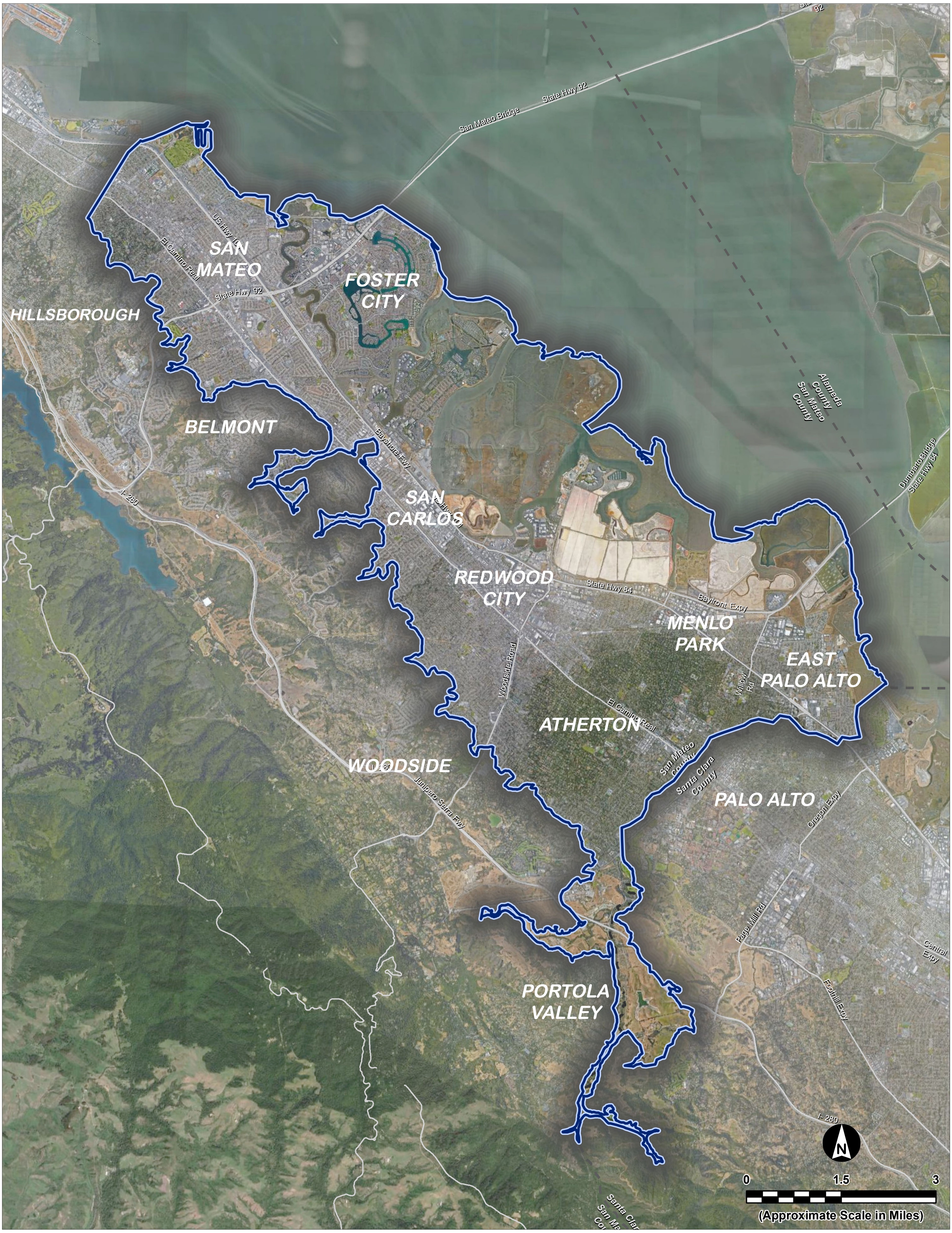
The results presented herein provide a comprehensive evaluation of the Basin, given the availability of existing data. This Report is organized as follows:

- **Section 2.0** provides an overview of the Basin;

- **Section 3.0** summarizes the close involvement of Basin stakeholders in the Project;
- **Section 4.0** provides an overview of the data collection and compilation efforts conducted as part of Phase 1;
- **Sections 5.0 through 7.0** provide a thorough conceptualization of the Basin, including a water quality analysis, hydrogeologic conceptual model, and water balance;
- **Section 8.0** presents the development of a numerical groundwater flow model (the SMPGWM) for the Basin and region;
- **Section 9.0** discusses the potential for undesirable results to occur within the Basin;
- **Section 10.0** presents an overview of groundwater management options;
- **Section 11.0** describes the application of SMPGWM in the evaluation of potential future groundwater use and management scenarios;
- **Section 12.0** summarizes the conclusions from the successful completion of the Project; and
- **Section 13.0** provides key references and sources.

Additional information related to the Project is available at the Project website at: http://www.smcsustainability.org/smplain.

Groundwater data collected and compiled throughout this Project are available on County's virtual data sharing site "San Mateo County GIS Open Data located at: https://data-smcmaps.opendata.arcgis.com/datasets?q=san%20mateo%20plain%20subbasin.



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Legend

- San Mateo Plain Subbasin
- County Boundary
- Major Road

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Aerial imagery: Google Earth Pro, accessed 19 April 2016.

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San Mateo Plain Groundwater Subbasin

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 1-1

2.0 BASIN OVERVIEW

The San Mateo Plain Groundwater Subbasin, shown on **Figure 1-1**, is one of four subbasins of the Santa Clara Valley Groundwater Basin, as defined by DWR. The Basin encompasses approximately 37,708 acres and is located along the eastern edge of the San Francisco Peninsula between San Francisco Bay and the Santa Cruz Mountains.[2] The Basin occupies a structural trough that is filled with unconsolidated alluvial sediments. At the northern end of the Basin (near Hillsborough and San Mateo), bedrock is present at shallow depths between the Coast Ranges and Coyote Point, a bedrock hill at the San Francisco Bay shoreline. The southern end of the Basin is defined by the San Mateo-Santa Clara County line. The line follows San Francisquito Creek, which flows more or less down the middle of its alluvial fan.

The total population within the Basin is approximately 292,000. As shown on **Figure 2-1**, there are 13 cities and unincorporated areas in the two counties overlying portions of the Basin. Land use is almost entirely urban, as discussed further in Section 6.1.4. Parts of the historical tidal marshes were diked, filled, and converted to urban uses as early as 1873, based on the earliest detailed and reliable topographic map available (State Geological Survey of California, 1873). However, even today large areas remain as marshes or salt evaporation ponds. Urban land uses extend westward from the coastal plain into the upland parts of the local watersheds.

There are 13 water suppliers within the Basin,[3] consisting of a combination of cities, water districts, mutual water companies and investor-owned utilities (see **Figure 2-2)**. Groundwater production within the Basin for potable and non-potable supply has been relatively limited for the last several decades, as the primary water supply source has been Hetch Hetchy water purchased from the San Francisco Public Utilities Commission (SFPUC) and accessed via the Regional Water System (RWS). The only municipal water suppliers within the Basin that currently utilize groundwater as a potable supply source are two mutual water companies that are located in the southern portion of the Basin: the Palo Alto Park Mutual Water Company (PAPMWC) and the O'Connor Tract Co-Operative Water Company (O'Connor Tract CWC). Some institutions and private landowners within the Basin also use groundwater for domestic or landscape irrigation purposes, particularly in the southern portion of the Basin. The water balance presented in Section 7.0 estimates that total groundwater production within the Basin is currently about 2,300 acre-feet per year (AFY).

As shown on **Figure 2-3**, 12 wastewater agencies collect and treat wastewater within the Basin. Currently, the City of Redwood City is the only major user of tertiary-treated recycled water

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[2] Minor changes to the southern Basin boundary were made by DWR in the Bulletin 118 – Interim Update, in Fall 2016. The figures and information herein are based on the original Basin boundaries.

[3] If California Water Service Bear Gulch District and California Water Service Mid-Peninsula District are counted separately, there are 14 water suppliers within the Basin.

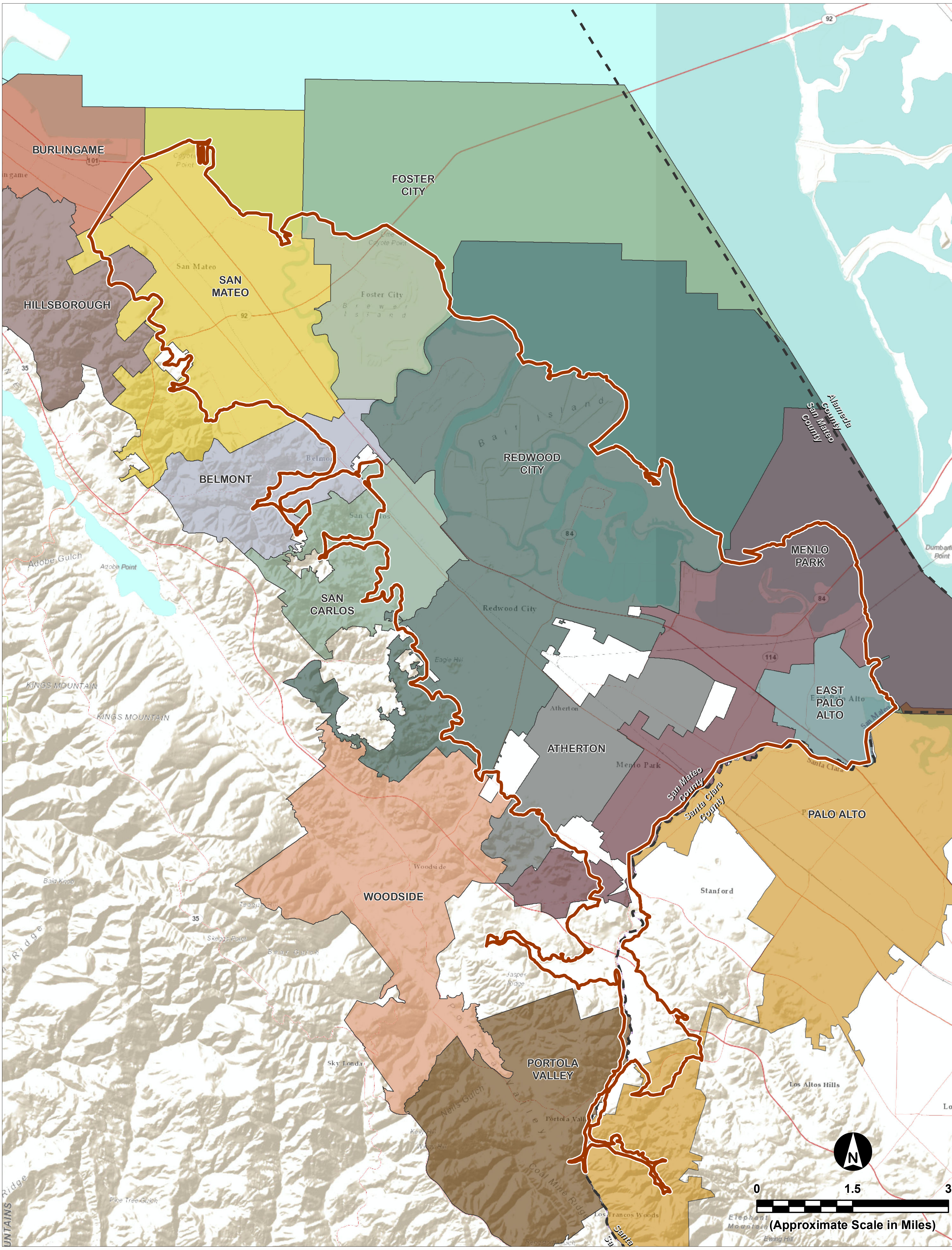
within the Basin, although numerous entities are considering expanding the use of recycled water within the Basin, even potentially for direct and/or indirect potable reuse (DPR/IPR).

Groundwater pumping in the Basin is presently much less than it was in the past. The general history of pumping began with negligible amounts prior to 1850, increasing with population growth and development until the 1960s, after which most users switched to newly available imported water supplies (i.e., Hetch Hetchy water). Historical information indicates that during these past periods of high groundwater production, groundwater levels in the Basin dropped significantly and negative impacts such as salt-water intrusion and land subsidence were observed.

As described herein, groundwater levels have increased since the 1960s and currently the Basin is in a stable condition (i.e., groundwater inflows are roughly equivalent to groundwater outflows). The recent historic drought, coupled with renewed interest in groundwater development within the Basin, has increased local interest in better understanding the Basin and evaluating the extent to which increased groundwater development can be pursued, while mitigating potential negative impacts, or "undesirable results."[4]

[4] Section 10721(w) of the Sustainable Groundwater Management Act of 2014 defines "undesirable results" as one or more of the following effects caused by groundwater conditions occurring throughout the basin:

(1) 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 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.
(2) Significant and unreasonable reduction of groundwater storage.
(3) Significant and unreasonable seawater intrusion.
(4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
(5) Significant and unreasonable land subsidence that substantially interferes with surface land uses.
(6) Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.



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Legend

San Mateo Plain Subbasin

County Boundary

Cities

- Atherton
- Belmont
- Burlingame
- East Palo Alto
- Foster City
- Hillsborough
- Menlo Park
- Palo Alto
- Portola Valley
- Redwood City
- San Carlos
- San Mateo
- Woodside

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.

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Jurisdictional Boundaries

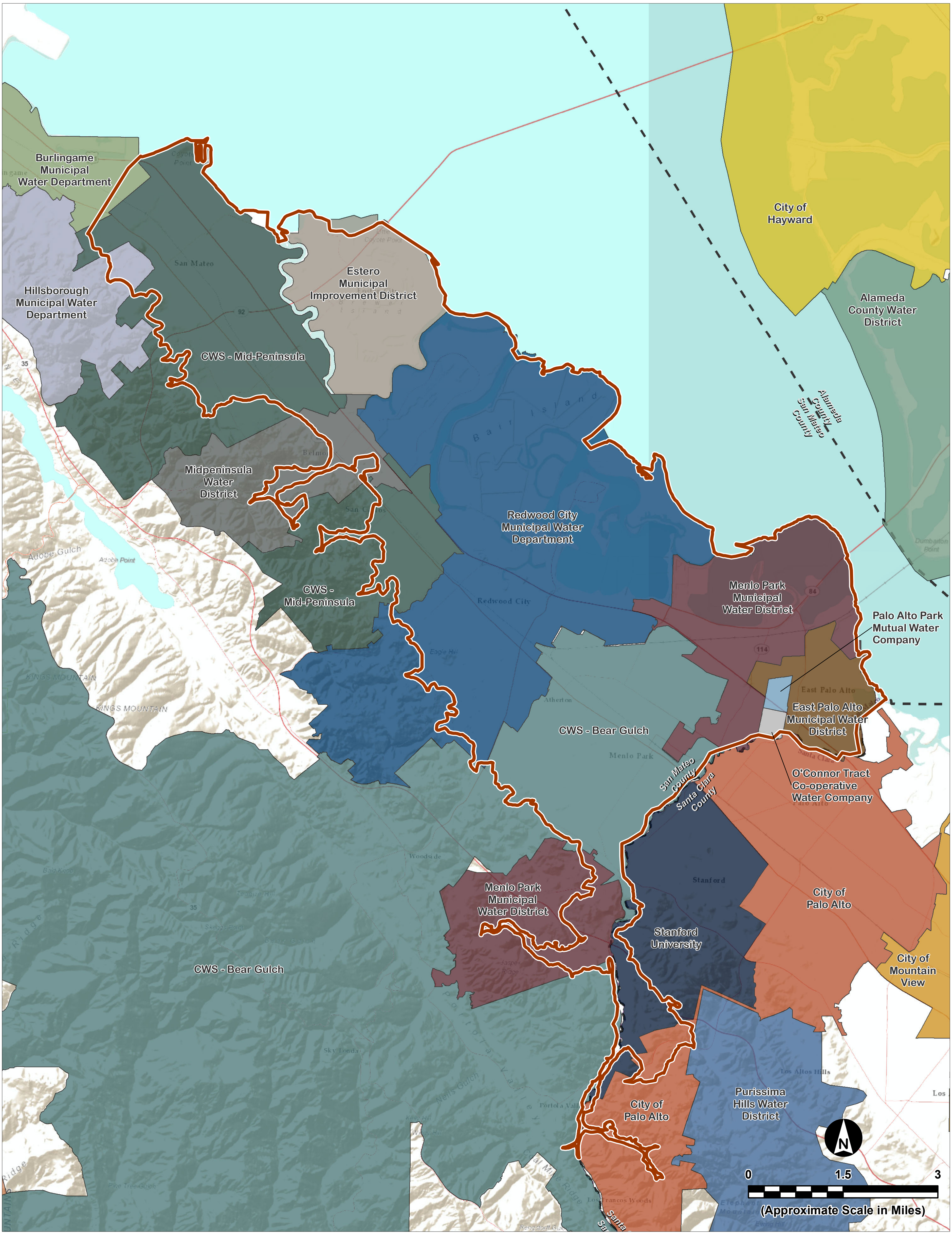
San Mateo Plain Groundwater Subbasin

San Mateo County, California

June 2018

EKI B60024.00

Figure 2-1



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Legend

San Mateo Plain Subbasin

County Boundary

Water Service Areas

- Alameda County Water District
- Burlingame Municipal Water Department
- CWS - Bear Gulch
- CWS - Mid-Peninsula
- City of Hayward
- City of Mountain View
- City of Palo Alto
- Coastside County Water District
- East Palo Alto Municipal Water District
- Estero Municipal Improvement District
- Hillsborough Municipal Water Department
- Menlo Park Municipal Water District
- Midpeninsula Water District
- O'Connor Tract Co-operative Water Company
- Palo Alto Park Mutual Water Company
- Purissima Hills Water District
- Redwood City Municipal Water Department
- Stanford University

Notes

1. All locations are approximate.

Abbreviations

CWS = California Water Service Company
SFPUC = San Francisco Public Utilities Commission

Sources

1. Water Service Areas: SFPUC, CWS, and City of Menlo Park, obtained 5 May 2016.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.

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Water Supply Agencies
San Mateo Plain Groundwater Subbasin
San Mateo County, California
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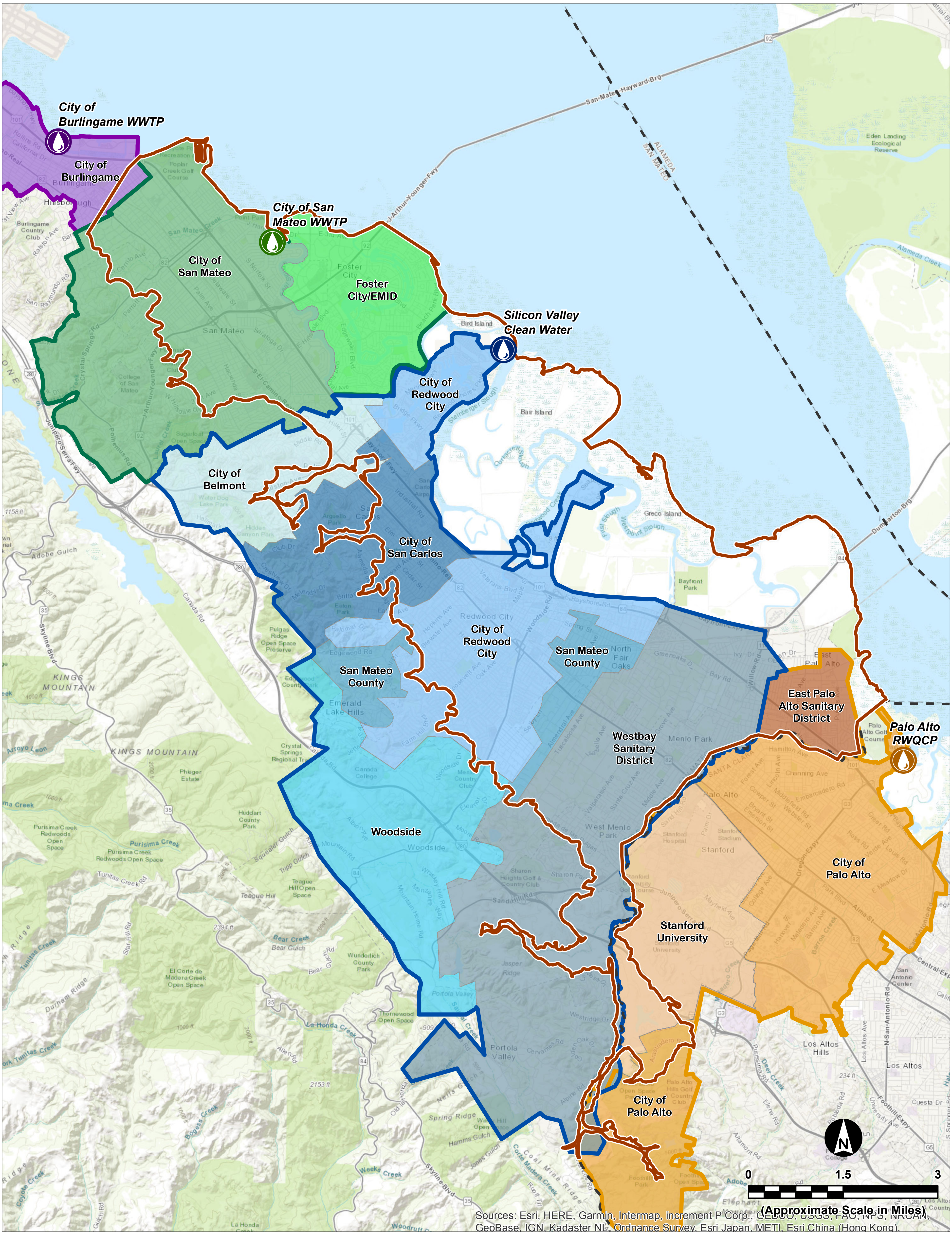
Figure 2-2



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Legend

San Mateo Plain Subbasin

County Boundary

Treatment System Service Area

- Silicon Valley Clean Water
- City of San Mateo WWTP
- Palo Alto RWQCP
- City of Burlingame WWTP

Sanitary Sewer Collection Agency

- City of Belmont
- City of Redwood City
- City of San Carlos
- San Mateo County
- Westbay Sanitary District
- Woodside
- City of San Mateo
- Foster City/EMID
- City of Palo Alto
- East Palo Alto SD
- Stanford University
- City of Burlingame

Notes

1. All locations are approximate.
2. Only agencies that overlie a portion of the San Mateo Plain Subbasin are shown.

Abbreviations

EMID = Estero Municipal Improvement District
RWQCP = Regional Water Quality Control Plant
SD = Sanitary District
WWTP = Wastewater Treatment Plant

Sources

1. Treatment system and sanitary sewer collection agencies were compiled based on multiple publically available resources and should be considered approximate.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.

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Wastewater Treatment and Collection Agencies

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
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Figure 2-3

3.0 STAKEHOLDER ENGAGEMENT

As part of Project development, the County worked closely with Basin stakeholders to better understand local and Basin-wide groundwater conditions, as well as current and projected groundwater use. Given the current focus on groundwater, locally and statewide, the County also engaged with Basin stakeholders to assess what interest and opportunities exist to increase coordination to collect additional data within the Basin and to collectively ensure the long-term sustainability of the groundwater resource. A summary of the stakeholder outreach conducted and the input received through this process is presented below.

3.1 Stakeholder Workshops

A series of stakeholder workshops were held as part of Project development to broadly solicit input from key Basin stakeholders and the public and to provide an opportunity for interested stakeholders to be informed of the Project activities. These "workshops" were widely attended over the course of the Project, and were provided coincident with key Project milestones. All meeting materials are available on the Project website: http://www.smcsustainability.org/smplain.

Stakeholder Workshop #1 (17 May 2016) served to formally introduce the Project, and included a detailed overview of the Project objectives, scope and schedule. Participants were then broken out into small groups to provide input on three important topics:

- Potential issues and opportunities within the Basin;
- Prioritization of Project objectives; and
- Data gap filling.

The results of these breakout sessions were then distilled by the Project Team (see **Appendix A**), presented back out to the group at Stakeholder Workshop #2, and are broadly summarized as follows:

- Several water sources were identified that could potentially provide enhanced groundwater recharge, including recycled water and stormwater. Participants acknowledged that additional work needs to be done to assess the quality and availability of these sources, and other potential constraints (e.g., public acceptance).
- Significant interest was expressed for multiple-benefit projects, wherein a single project will benefit multiple users and entities. For example, a stream restoration project may augment groundwater recharge, provide enhanced fish habitat, and reduce streambank erosion. As another example, an indirect potable reuse (IPR) or direct potable reuse (DPR) project could augment groundwater supplies, reduce the risk of seawater intrusion, and provide for wastewater disposal.

- There was strong support for the idea of establishing partnerships and exploring regional solutions within the Basin and across Basin boundaries. Participants expressed that this approach could increase the likelihood of receiving funding and provide economies of scale.
- Several stakeholders stressed the importance of integrating resource use and resource protection, including surface water, groundwater, and recycled water. For example, the opinion was expressed that the Project should emphasize the important role of groundwater in supporting ecosystems. At the same time, it was widely acknowledged that local groundwater development is critical to ensuring a reliable emergency and supplemental water supply.
- Participants were supportive of the technical emphasis of the Project, and placed high value on the development of foundational information for the Basin, including a comprehensive basin conceptual model, water balance and numerical model to better understand Basin conditions and function.
- Many points of contact were identified for agencies and groups in the Basin and beyond. The general impression from the participants was that filling data gaps is a high priority task, and that data sharing across jurisdictional boundaries will be key to achieving this objective.

Stakeholder Workshop #2 (7 September 2016) included a technical presentation of the data gathering and assimilation that had been completed to date, the preliminary basin hydrogeologic conceptual model and water balance, and a discussion of the historical and potential future risks to groundwater quality and quantity (i.e., undesirable results) related to groundwater extraction, groundwater contamination, and other issues. Key data gaps were identified and participants were generally encouraged to continue to provide input and support in addressing those data gaps.

Stakeholder Workshop #3 (21 November 2016) included a presentation of the numerical groundwater modelling effort completed to date, as well as a discussion to assess potential scenarios that could be modeled in the future to assess potential Basin vulnerabilities to things like climate change and sea level rise.

Stakeholder Workshop #4 (6 December 2016) included a presentation of the potential groundwater management options, as well as breakout sessions to assess potential interest or ideas regarding physical or institutional management options for the Basin. Participants were split into small groups to discuss the following questions:

1) What do you think are the most important issues to focus on when we think about "groundwater management options"?

2) Do you envision groundwater management occurring within the Basin?
    - What potential actions or options seem feasible to you?
    - What actions or options should be prioritized?
    - What limitations do you believe exist?

The results of these breakout sessions were then distilled by the Project Team (see **Appendix A**), presented back out to the group at Stakeholder Workshop #5, and are broadly summarized as follows:

- Participants expressed a high interest in the development of a better technical understanding of the Basin and the collection of more and higher quality data.
- Participants also expressed great interest in additional Basin-wide and regional coordination and collaboration, including the formation of advisory committees (from voluntary to more formalized/proactive management) and a goal of enhancing coordination, outreach, and messaging.
- Participants also expressed interest in identifying potential funding and cost-sharing opportunities, including the potential for coordinated project-based management and funding.

Stakeholder Workshop #5 (31 January 2017) included a comprehensive summary of the work completed during Phase 1, and the findings and results from the effort, as documented in the January 2017 Preliminary Report. The presentation also included a discussion of the data gaps identified during Phase 1, and the anticipated efforts to fill data gaps during Phase 2. During this discussion, the Project Team also asked stakeholder to assist identifying opportunities for partnerships to obtain additional data to address identified data gaps.

Stakeholder Workshop #6 (17 August 2017) included a presentation of the data-gathering efforts conducted as part of Phase 2 of the Project. New data obtained and shared during this workshop included: a) water levels measured in deep wells across the Basin, when access could be obtained, b) additional well data and water level measurements compiled from pre-Geotracker, hard copy reports associated with environmental remediation sites, c) field measurements of stream flows, and d) stable isotope analysis of creek water samples. Status updates on the conversion of the numerical model to a transient model and planned additional data gathering efforts were also given, and the objectives of Project Phase 3 were presented.

Participants were split into small groups and asked to discuss potential Basin use scenarios that could be modeled during Phase 3 of the project. Specifically, participants were asked:

- Scenario Priority: Within your group, identify potential scenarios within the Basin to model. Discuss and rank which scenarios you think should be the highest priority for model development in Phase 3.

- Scenario Assumptions: Choose one of your group's top two scenarios and discuss how you would model that scenario. What are the key factors that would change relative to current conditions (provide reference sources)? Where would these changes occur within the Basin? How significantly would they change from current conditions? Over what time period would the changes happen?

Each group was asked to share out the results of their discussion during Workshop #6. At Workshop #7, the results of the breakout session were summarized and the Project Team shared how the stakeholder input gathered was reflected in the four scenarios modeled. Participant input is summarized below:

- Scenario Priority: The top three scenarios based on participant rankings were: 1) increased groundwater pumping, 2) stormwater recharge projects, and 3) climate change. Participants cited the timeframe of implementation of currently planned projects and policy changes and the opportunity to determine if factors will affect sustainability of the Basin as the bases for these prioritizations.
- Scenario Assumptions: Participants identified the western portions of Basin as areas for potential stormwater recharge and the southern and eastern portions of the Basin as areas for potential groundwater pumping. Participants also suggested that these changes may occur generally over next approximately 20 years (i.e., by 2040).

Stakeholder Workshop #7 (9 November 2017) included a presentation of completed Phase 2 data gathering efforts, an update on modeling activities, and updates of the current status of statewide and local SGMA activities. The for scenarios selected to be modeled during Phase 3 were presented, and the Project Team's approach to defining the scenarios were shared with stakeholders. Representatives for each of the adjacent groundwater basins (Westside Basin, East Bay Plain Subbasin, Niles Cone Subbasin, and the Santa Clara Subbasin) provided updates of SGMA-related activities being conducted and planned in their areas.

Stakeholder Workshop #8 (17 April 2018) focused on the results of the Phase 3 scenario modeling efforts. The presentation included a review of the model development and conversion process (i.e., from steady-state to transient), the various analyses that were used to inform the model development and refinement, and the modeled changes in groundwater conditions resulting from each of the four potential-groundwater-use scenarios.

Stakeholder Workshop #9 (anticipated in June 2018) will be conducted following the publication of this report. The presentation will include a comprehensive summary of the work completed for the Project, and the findings presented herein.

There was significant participation by workshop attendees and a wide variety of ideas expressed (see **Appendix A** for a transcription of input provided by the attendees). The input received from participants during the Workshops and breakout sessions was used to guide efforts by the County and the Project Team throughout the Project.

3.2 Agency-Specific Meetings and Presentations

County staff, in some cases supported by the Project Team, have also been actively engaged in a series of meetings with individuals and entities from a range of interests within and proximate to the Basin. In addition, County staff have made several presentations to regional groups and City Councils regarding the Project. The County's stakeholder outreach efforts over the course of the Project are summarized in **Table 3-1**, and have amounted to over 50 meetings and presentations.

The meetings and presentations have primarily been informational – the County has described the Project objectives, scope and schedule, and asked for any data or information that could support the scientific analysis or future collaborations for data gap filling. Several agencies have expressed an openness to sharing information with the County in support of this Project, and many agencies have provided the County with data (e.g., Bay Area Water Supply and Conservation Agency [BAWSCA], Alameda County Water District [ACWD], Santa Clara Valley Water District [SCVWD], East Bay Municipal Utility District [EBMUD], O'Connor Tract CWC, SLAC National Accelerator Laboratory [SLAC], Redwood City, Silicon Valley Clean Water [SVCW], to name a few). Similar to what was expressed in Stakeholder Workshop #4, still others have expressed interest in participating in a larger regional effort to better understand or manage groundwater through collection of additional data (e.g., groundwater levels through the California Statewide Groundwater Elevation Monitoring [CASGEM] program) and other collaborative efforts.

While the Project has concluded, the County plans to continue its outreach with all interested parties into the future, as appropriate.

Table 3-1. Summary of Individual and Small-Group Stakeholder Outreach Meetings

Agency	Date of Meeting with Staff	Date of Council/Board/Public Presentation
Atherton, Town of	4-Aug-16, 16-May-17	31-Aug-17
Belmont, City of	22-Jul-16	27-Feb-18
East Palo Alto, City of	--	1-Nov-16
Foster City, City of	28-Jul-16	--
Hillsborough, Town of	24-Aug-16	--
Menlo Park, City of	16-Jun-16	13-Sep-16
Palo Alto, City of	25-Jan-16	--
Portola Valley, Town of	13-Jul-16	10-Aug-16
Redwood City, City of	6-Oct-16	--
San Mateo, City of	27-Sep-16, 26-Jan-18	--
San Mateo Sustainability Commission	--	11-May-17
Mid-Peninsula Water District	6-Jul-16	--
San Francisco Public Utilities Commission	18-Aug-16, 13-Apr-17, 28-Apr-17	--
Santa Clara Valley Water District	28-Aug-15, 20-Nov-15	--
Stanford University	9-Aug-16	--
California Water Service Co. - Bear Gulch District	16-Sep-16	--
California Water Service Co. - Mid-Peninsula District	16-Sep-16	--
Silicon Valley Clean Water	12-Jul-16, 20-Oct-16	--
Mid-Peninsula Regional Open Space District	23-Sep-16	--
San Francisquito Creek Joint Powers Authority	7-Jul-16, 13-Apr-17	--
Alameda County Water District	11-Aug-16	--
San Francisco Regional Water Quality Control Board	19-Jul-16	--
SLAC National Accelerator Laboratory	20-Jul-16	--
Westside Basin Partners	7-Dec-15	--
Bay Area Water Supply and Conservation Agency	4-May-15, 18-May-15, 28-Feb-17, 31-Aug-17	6-Aug-15, 1-Dec-16
San Mateo Plain Groundwater Reliability Partnership	--	22-Mar-17
West Bay Sanitary District	12-Sep-17	--
C/CAG Water Coordinating Committee	--	17-Jan-18
San Mateo County Water Coordination Committee “Challenges and Opportunities for Water Management in San Mateo County” Forum	30-Mar-18	--
Various Entities Regarding San Francisquito Creek	10-Feb-17 to 17-Mar-17	--
Various Land Use and Water Agencies Regarding Ongoing Groundwater Monitoring	12-Jan-18	--
Various Owners of Deep Wells	21-Apr-17 to 8-Sep-17	--

4.0 REVIEW AND COMPILATION OF AVAILABLE DATA

The Project Team compiled a variety of data related to the natural and anthropogenic features of the Basin, including, but not limited to: geology, soils, groundwater levels and quality, topography, climate, surface hydrology, water use and wastewater production, land cover/use, and political/jurisdictional subdivisions within the Basin. These data were assimilated, as appropriate, into a single, comprehensive Microsoft Access database and related ESRI ArcGIS geodatabase (together the "Project database") that were used to support the technical analyses conducted as part of this Project. The Project database will be made available to the public for general use and benefit at Project completion.

4.1 Data Sharing and Public Access

On 29 January 2013, the County Board of Supervisors directed County staff to develop an Open Data policy to transition towards an "Open Government" through the democratization of data. The effort set out to redefine resident/government interactions so that government can be transparent and accountable about use of taxpayer money, more participatory by engaging residents to add collective value to government, and more collaborative through the use of innovative tools and methods. As part of this policy, the County is committed to make available datasets compiled as part of the Project, as appropriate. The datasets were uploaded onto the County's data sharing website "San Mateo County GIS Open Data" and made available through the Project website.

The Project was managed through a joint effort by the County's Office of Sustainability and Environmental Health Services, a division of the County's Health System Department, both of which work to support the County's data sharing initiative. The website developed as part of this Project served as a key public outreach and coordination tool for this Project and will continue to serve as a public data repository to support future work within the Basin.

4.1.1 San Mateo Plain Project Website

The San Mateo Plain Project Website, located at http://smcsustainability.org/smplain was initially launched in Spring 2016 to serve as the key public source for information about the Project. This website was developed and is maintained and updated regularly by County staff, and serves as a repository for information and materials such as:

- Stakeholder workshop agendas and presentations;
- Project status updates;
- Graphics illustrating Project findings;
- Access to the Project's Datasets on the San Mateo County GIS Open Data website (see below);
- Contact information for the Project; and

- The January 2017 San Mateo Plain Groundwater Basin Assessment Preliminary Report (Preliminary Report).

4.1.2 Open Data Portal

Basin-specific data developed as part of this Project have been and will continue to be made publicly available, as appropriate and viable, in accordance with the County's Open Data policy. Data in the form of geospatial map "layers" and tabular data were made available through the County's virtual data sharing site "San Mateo County GIS Open Data" located at https://data-smcmaps.opendata.arcgis.com/datasets. These datasets can be accessed via the search function on the San Mateo County GIS Open Data site using the project name and/or keywords (e.g. "San Mateo Plain"). The Project website also includes links directly to the Project datasets and data visualizations (e.g. maps, charts, etc.). The goals of this effort are to provide the data as a resource for future efforts in the Basin as well as fulfill the County's Open Data policy to make the County more transparent and participatory.

4.2 Data Collection and Compilation

Data collection for the Project was necessarily an iterative process. This section describes the types of data that were gathered from April 2016 through January 2018 and assimilated into the Project database from a variety of sources and meeting certain criteria information. Several significant gaps in the currently available data were identified as part of Phase I and addressed to the extent feasible within the Project scope during Phase 2.[5] These data gaps were documented in the Preliminary Report.

4.2.1 Data Types

As described below, data were compiled in support of the various technical analyses that are being conducted as part of this Project.

- *Water balance assessment (Section 7.0)* Data compiled generally included watershed areas, surface water channel locations and types, historical precipitation records, evapotranspiration rates, stream flow measurements, soil type and distribution, impervious surface percentage, records/estimates of historical groundwater extraction rates, historical water deliveries by water purveyors, and historical flows to wastewater systems.

- *Conceptual and numerical groundwater basin models (Sections 5.0, 6.0,and 8.0)* Data compiled generally included groundwater level measurements, subsurface geology and

[5] During Phase 2, additional data were collected and added to the database, and data in the database were refined based on new information, including consolidation of duplicate well entries, refinement of well construction data (screen intervals and depths), and other changes.

lithology, locations and depths of groundwater monitoring and supply wells, aquifer pump test data, water quality analytical data, and key inputs to numerical groundwater models developed for adjacent basins (e.g., pumping locations and rates, hydraulic conductivity data, and recharge estimates).

- *Assessment of potential undesirable results related to groundwater conditions (Section 9.0)* Data compiled generally included locations and status of regulated chemical release sites, and previous studies and reports on land subsidence, sea level rise, and seawater intrusion.

- *Evaluation of groundwater management options (Section 10.0)* Data compiled generally included the jurisdictional areas of water, land use, and wastewater agencies, inventories of key water-related infrastructure, and information on groundwater management approaches in adjacent basins.

- *Scenario Evaluations using the SMPGWM (Section 11.0)* Data compiled for this analysis included projections of key climate change impacts and a synthesis of the results from the prior report sections.

The County has established guidelines for geospatial data which facilitate consistency in data shared among County users and with the public through open data portals. Geospatial data generated through Project Team efforts (e.g., maps and the underlying ArcGIS shapefiles), conform to these standards. Specifically, data generated as part of this effort are georeferenced to the North American Datum 1983 (NAD83) State Plane Zone 3 horizontal datum and the shapefiles include embedded metadata that document the data sources and limitations.

4.2.2 Data Sources

The Project is relying on data from a wide variety of sources, including online databases, historical records, studies and assessments done by others, and past work by Project Team members. Key sources of data reviewed and compiled as a part of the Project are summarized in **Table 4-1** by major Project component. As data were gathered throughout the phases of this Project, new information was incorporated into the Project database to support analysis conducted by the Project Team and others.

4.2.3 Data Limitations

The data used in this Project, particularly data from wells and boreholes, were collected for a variety of reasons, often the original intended purpose of a well influences not only the type of data available for the well, but also the quality and degree of accuracy of such data. For example, lithological information recorded in a DWR well completion report for a well installed for the purposes of irrigating landscape for a single-family home are typically not as detailed and accurate as that of a well drilled for purposes of municipal supply. Particularly when working with semi-subjective information such as logged lithological data, it should also be considered that different professionals looking at the same material in the same vicinity may interpret the material differently.

The majority of the available water level and chemistry data used for this Project were obtained from the State Water Resources Control Board (SWRCB) Geotracker website. Similar to the lithologic information mentioned above, data obtained from Geotracker has an inherent degree of potential error or bias. Geotracker is a relatively new system, beginning in 2001. While chemical data reported in Geotracker would be expected to be of sufficient quality for their intended purposes (e.g., preliminary assessment of site conditions), selected data may not meet more stringent quality assurance/quality control standards, such as those for drinking water quality sampling purposes.[6] Additionally, not all water level data obtained from Geotracker are reported relative to a standard vertical datum (e.g., North American Vertical Datum of 1988 [NAVD]). While adequate for assessing water levels and flow directions on a local site-wide basis, when considered on a regional basis, water levels reported relative to a local datum would be expected to have a greater inherent degree of error.

4.2.4 Data Selection Criteria

As discussed above and shown in **Table 4-1**, a wide range of data were compiled from many different sources, necessitating systematic prioritization and screening. Data meeting certain criteria were prioritized over others, depending on the level of effort required to process and compile the data, and the relative value added by the dataset. For example, if well data were already available in an electronic database format, then all relevant data were assimilated into the Project database (e.g., well construction information, all associated lithologic, water level and water quality data, etc.). However, if data were in a less accessible format and required hand-entry, use and incorporation of such data was prioritized based on its overall value to the Project in terms of the availability of similar data and/or critical areas of analysis (e.g., data entry related to deep wells was prioritized over that from shallow wells). A description of how the data were added to the Project database for certain key elements is provided below.

- *<u>Well construction and lithologic information</u>:* An existing database developed by a Project Team member,[7] with information current through approximately 2012, was used as the foundation for the Project database. Project Team members then added selected,

[6] For example, data obtained from Geotracker may include: grab groundwater samples collected from well locations during well installation; water samples not properly preserved (e.g., natural carbonate material causing metals to precipitate out of solution); and analyses performed out of holding times. In addition, dissolved metals and total metals results are not distinguishable based on the Geotracker system, and for many sites only dissolved metals concentrations may be available.

[7] The working database was created on the foundation of a well information database developed by HydroFocus over the course of many years, which aggregated well construction and water level measurement data for wells throughout the Basin. The working database developed by HydroFocus included data obtained from local, State, and Federal agencies, and private consultants, as well as data extracted from available reports and documents including DWR Well Completion Reports (informally known as driller's logs).

additional data from prior project work conducted in the Basin. Next, the Project Team obtained additional well construction and lithologic information from DWR Well Completion Reports (for which the County submitted a request to DWR for all records within the Basin area) and County Environmental Health well permitting records. From these two additional sources, information for wells or boreholes deeper than 100 feet that were located in areas of particular interest (i.e., wells located within 1,000 feet of the selected cross-section transects) were added to the Project well database for use by the Project Team. In total, lithologic, and well construction information was added to the comprehensive foundational dataset by the Project Team for 36 wells from these sources. Well construction data were also added for additional wells with relevant data.

- *Water quality data:* The Project Team also incorporated chemical analytical data from several sources, amounting to over 700,000 records of water quality and chemical data that were added to the database. These data include concentration data for over 500 unique chemical analytes, although individual wells were typically sampled for a smaller subset of chemicals. The water quality assessment focused on the following constituents, which are relevant to use of water for potable and irrigation supply in this region, and to characterization of the aquifer system:

  - Arsenic
  - Bicarbonate
  - Boron
  - Calcium
  - Carbonate
  - Chloride
  - Chromium
  - Iron
  - Magnesium
  - Manganese
  - Nitrate (as nitrogen or nitrate)
  - Phosphorous/ Phosphate
  - Potassium
  - Sodium
  - Sulfate
  - Total Dissolved Solids (TDS)

  In addition, information on water quality contamination impacts originating from point-source sites, most notably impacts from leaking underground storage tank (LUST) sites and former industrial/commercial sites, was compiled in the Project database. These data were used in support of the assessment of potential undesirable results (i.e., whether there has been significant and unreasonable degraded water quality, including the migration of contaminant plumes, that impair water supplies within the Basin).

- *Water level and aquifer pump test data:* Water level data were compiled from the available sources, including existing Project Team databases and hand-entered from reports for environmental cleanup sites active during the pre-GeoTracker website period.[8] In total, the Project Team added nearly 80,000 water level measurements from nearly 3,000 locations and data from 83 pumping tests from over 50 locations to the database.

4.2.5 Well and Borehole Data Working Database

All of the above data related to groundwater wells and soil boreholes, including well construction information, lithologic information, water quality analytical data, and measurements of water level elevations were compiled into a working relational database in Microsoft Access.[9] The working database was then queried to conduct analysis and to generate many of the figures, results, and geospatial map layers that are presented in Sections 5.0 through 8.0 and are made available through the San Mateo County GIS Open Data website.

Data in the Project database are tracked using key identification fields, including data source, the party responsible for adding data, modifications to data added by others, and a unique list of well names used as a key field for all files and analyses. The Project Team established these protocols to maintain a high-integrity record and data tracking throughout the Project.

4.3 Summary of Available Data and Identification of Key Data Gaps

The Project database currently contains information for more than 4,900 wells located in and proximate to the Basin, including well construction information, water level measurements, chemical analysis, and/or aquifer test data.[10] **Figure 4-1** shows the locations of the available well and borehole data that have been incorporated into the Project database. The wells shown on **Figure 4-1** and described further below include those that once existed, but have since been destroyed, as well as those that are not currently in active use. Information is available from a substantial number of locations throughout the Basin, but as discussed below, data relevant to specific temporal or spatial evaluations can be scarce. Notably, few data are available along the eastern and western boundaries of the Basin, as well as the southern tail portion of the Basin around San Francisquito Creek, Los Trancos Creek, and Felt Lake. Data also tend to be more

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[8] The SWRCB GeoTracker website was brought online in 2001 and is used for reporting of data for regulated environmental cleanup sites overseen by RWQCBs and local agencies such as the San Mateo County Groundwater Protection Program (SMC-GPP). SMC-GPP staff were aware that significant water level data were available for cleanup sites within the Basin from monitoring and reporting conducted during the pre-GeoTracker era. SMC-GPP staff and an SFPUC intern (intern time donated by SFPUC), compiled and digitized available water level data from these older reports. Through this effort, approximately 13,000 measurements from approximately 700 wells were compiled for the time period 1986 to 2009.

[9] It should be noted that the working database being used by the Project Team is not intended to capture all possible information for all wells and boreholes in the region, but rather the data considered to be most useful in conducting the Basin assessment.

[10] The total number of individual wells within the Basin may be overestimated, as records from electronically available sources, in particular the SWRCB Geotracker database, have not been fully reconciled to database entries created based on DWR Well Completion Reports. Some overlap between these two sources is present in the working database, but has not been quantified.

heavily concentrated in the southern portion of the Basin around Atherton, Menlo Park, and East Palo Alto. The number of available records for specific types of data are summarized in **Table 4-2**, below.

Table 4-2. Summary of Available Well and Borehole Data

Parameter	Located Within the Basin	Located Near the Basin
Well and Borehole Records	3,765 wells/boreholes	1,216 wells/boreholes
Wells with Screened Interval Data	1,091 wells	500 wells
Water Level Measurements	59,438 records from 2,476 wells	20,405 records from 418 wells
Analytical Chemistry Data	503,076 records from 1,910 wells	214,558 records from 491 wells
Aquifer Test Data	49 wells	8 wells

The wells and boreholes incorporated into the Project database were originally installed for a wide variety of purposes, over a number of years. **Figure 4-2** shows the general types of wells and boreholes present throughout the Basin, including those used for environmental monitoring and water supply purposes.

Table 4-3 below shows a breakdown of the available well or borehole data by type. The majority of wells and boreholes in the available dataset were created for environmental investigation and monitoring purposes. The significant representation of environmental wells in the dataset is largely due to the volume of data available from the SWRCB Geotracker website. Wells in the Basin that were constructed for environmental monitoring or remediation purposes tend to be shallow, typically completed to less than 50 feet below ground surface (bgs).

Table 4-3. Summary of Well and Borehole Type for Locations within the Basin

Type	Number of Wells and Boreholes
Cathodic Protection	78
Environmental	2,988
Irrigation	269
Private Supply	108
Public Supply	83
Test/Pilot Borehole	52
Other	187
Total	**3,765**

For the purposes of initial evaluation and screening of available data for the Basin conceptual model analyses, wells and boreholes were classified as shallow (50 feet bgs or shallower), mid-depth (from 50 to 150 feet bgs), and deep (greater than or equal to 150 feet bgs). Where exact borehole or well depth was not known, this classification was assumed based on the available well type. For example, monitoring wells, which are largely associated with environmental remediation sites, were assumed to be shallow and irrigation wells were assumed to be deep. These well depths categories are used in the data summaries presented below, but it should be noted that these designations are not strictly based on the geologic characteristics or defined water bearing zones in the Basin.

4.3.1 Coded Lithologic Data

Figure 4-3 shows the wells and boreholes for which lithologic data have been manually coded based on information reported in DWR Well Completion Reports or other sources. Because this is a time-intensive process, deeper wells and those in particular locations of interest were prioritized for inclusion in the Project Team's analysis. As shown on **Figure 4-3**, coded lithologic data are available for a total of 325 wells within the Basin and approximately 60 wells outside of the Basin, including wells and boreholes located to the east of the Basin in San Francisco Bay. Of the wells located within the Basin with coded lithologic data, 217 extend to 150 feet bgs or deeper. Of these, 54 wells are deeper than 300 feet bgs. The majority of these deep wells are located in the southern portion of the Basin, in the vicinity of Atherton, where numerous private wells have been installed for irrigation purposes.

4.3.2 Water Level Measurements

Figure 4-4a shows wells where at least one water level measurement is available. **Table 4-4** below shows the number of individual water level measurements available for wells within the Basin by year and well depth. Shallow wells with water level data are located throughout the Basin, generally associated with current or historical contamination sites. Conversely, deeper wells with water level data are primarily located in the southern portion of the Basin. Most of the water level measurements are from shallow wells, and the data are primarily available from recent years (i.e., since 2000). Fewer measurements are available prior to 1990, which necessarily limits our understanding of historical groundwater levels and conditions.

Table 4-4. Summary of Available Water Level Measurements from Wells Located Within the Basin by Decade

Well Depth[1]	Number of Water Level Measurements by Year							Total
	Pre-1960	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2017	
Shallow <50 ft bgs	1	7	--	355	10,073	31,790	14,875	57,101
Mid-Depth 50-150 ft bgs	--	3	22	18	670	298	208	1,219
Deep >150 ft bgs	4	13	54	19	843	110	75	1,118
Total	**5**	**23**	**76**	**392**	**11,586**	**32,198**	**15,158**	**59,438**

1) Where the exact well depth is not known, depths were assumed based on the criteria described in Section 4.3.

Figure 4-4b shows wells for which an extended period of water level measurements is available and **Table 4-5** below shows a breakdown of well depth by period of available water level measurements. Of the 2,476 wells within the Basin with water level measurements, measurements for approximately 750 wells span a period of greater than 10 years. However, only sixteen of those wells with extended water level records are deeper than 150 feet bgs, with the longest period ranging from 1972 to 2017, and consisting of only one measurement subsequent to 1977 (i.e., a 40-year data gap). This relative lack of time series groundwater elevation data in the deep aquifer limits our ability to quantitatively evaluate historical groundwater conditions and to understand the relationships between water levels, historical precipitation rates, water quality trends and the like.

Table 4-5. Summary of Wells with Available Water Level Measurements Located Within the Basin by Duration of Available Data

Well Depth [1]	Period Monitored [2]		
	Less than 5 years	5 to 10 years	Greater than 10 years
Shallow <50 ft bgs	1,047	578	688
Mid-Depth 50-150 ft bgs	34	16	17
Deep >150 ft bgs	73	7	16
Total	**1,154**	**601**	**721**

1) Where the exact well depth is not known, depth categories were assumed based on the criteria described in Section 4.3.
2) Period monitored is based on the first available measurement and last available measurement for a given well; wells were not necessarily monitored on a consistent basis throughout this time period.

4.3.3 Aquifer Test Results

Figure 4-5 shows the locations of wells for which aquifer test data are available. These data include measured transmissivity, hydraulic conductivity, specific capacity, and storativity values, and were compiled from a variety of published reports, dating back to 1963. One or more of these values are available for 49 wells within the Basin and an additional eight wells located south of the Basin. Of the wells in the Basin, aquifer test data are only available for 19 wells extending 150 feet bgs or deeper. Aquifer test data collected from shallow wells was generally associated with testing for remediation purposes (e.g., assessing viability of groundwater extraction to remove chemical contaminants). The majority of this testing was performed in the southern portion of the Basin, in the vicinity of Redwood City, Menlo Park, and East Palo Alto.

4.3.4 Chemical and Water Quality Data

Figure 4-6 shows the locations of wells and boreholes for which chemical analytical data are available. The majority of these data were compiled from the SWRCB Geotracker website, which is comprised of sites investigated and monitored for environmental contamination. As such, much of the chemical data available are for anthropogenic contamination chemicals, such as solvents and petroleum products released to the environment. These data are available for shallow wells across much of the Basin. Chemical data for deep wells is primarily limited to the southern portion of the Basin, in the vicinity of Atherton, Menlo Park, and East Palo Alto.

For purposes of the Basin assessment, water quality parameters refer to naturally occurring chemical constituents and properties of groundwater, such as natural anions and cations, selected metals, and measurements of total dissolved solids (TDS) and specific conductance. **Figures 4-7a** and **4-7b** show the locations of wells that have been sampled and analyzed for one or more of the following general water quality parameters:

- Arsenic
- Bicarbonate
- Boron
- Calcium
- Carbonate
- Chloride
- Chromium
- Iron
- Magnesium
- Manganese
- Nitrate (as nitrogen or nitrate)
- Phosphorous/ Phosphate
- Potassium
- Sodium
- Sulfate
- TDS

As can be seen on **Figure 4-7a** some water quality data are available for shallow groundwater wells in the northern and central portions of the Basin, but few data are available in the southern portion of the Basin. Conversely, water quality data for deep wells is primarily limited to wells in the southern portion of the Basin, in the Menlo Park, Atherton, and East Palo Alto areas. **Table 4-6**, below, shows the number of wells within the Basin for which one or more groundwater samples has been analyzed for each water quality parameter. While over 500 shallow wells and over 60 deep wells within the Basin have been analyzed for at least one of these parameters, few wells have been analyzed for all of the typical water quality parameters, and even fewer have such data available from multiple sampling events.

Of the water quality parameters listed above, the parameter with the largest available dataset is TDS, with 385 wells within the Basin having been analyzed for TDS at least once. However, as can be seen on **Figure 4-7b**, only about 20 percent of these wells have been sampled repeatedly for TDS over a time period of more than one year, and only 12 wells have been monitored over a period greater than 10 years. For these wells, the earliest sampling period ranges from 1949 to 1961 and the longest period ranges from 1985 to 2016. Time series records for other water quality parameters are even sparser. As with the water level data, the relative lack of time series water quality data limits our ability to understand the interactions between water quality parameters, as well as the relationships between water quality and other factors such as historical pumping and water levels.

Table 4-6. Summary of Number of Wells within the Basin Sampled for Selected Water Quality Parameters

Parameter	Well Depth(1)			Total
	<50 feet bgs	50-150 feet bgs	>150 feet bgs	
Arsenic	89	2	14	**105**
Bicarbonate Alkalinity as CACO3	83	1	14	**98**
Bicarbonate as HCO3	25	--	1	**26**
Boron	--	2	37	**39**
Calcium	40	--	38	**78**
Carbonate Alkalinity as CACO3	82	--	2	**84**
Carbonate as CaCO3	9	--	1	**10**
Carbonate as CO3	18	1	1	**20**
Chloride	102	4	62	**168**
Chromium, total	83	1	17	**101**
Ferrous Iron	55	1	--	**56**
Hardness as CaCO3	8	--	22	**30**
Iron	153	1	37	**191**
Magnesium	39	2	52	**93**
Manganese	96	2	39	**137**
Nitrate	77	2	44	**123**
Nitrogen, Kjeldahl, Total	20	--	--	**20**
Nitrogen, Nitrate (as N)	129	2	11	**142**
Orthophosphate	22	1	1	**24**
Phosphorus, Total (as P)	15	--	--	**15**
Phosphorus, Total Orthophosphate (as P)	5	--	4	**9**
Phosphorus, Total Orthophosphate (as PO4)	11	--	--	**11**
Potassium	32	2	39	**73**
Sodium	39	--	38	**77**
Specific Conductance	19	2	39	**60**
Sulfate	158	6	42	**206**
Total Dissolved Solids	318	5	62	**385**

1) Where the exact well depth is not known, well depth was assumed based on the criteria described in Section 4.3, above.

Table 4-1

Sources of Key Data for the San Mateo Plain Groundwater Basin Assessment

Data Item	Description	Data Type	Source
General Project Use			
San Mateo Plain Subbasin boundary	State-delineated basin boundary, per DWR Bulletin 118	Geospatial	DWR CASGEM Online System – Public Portal, http://www.water.ca.gov/groundwater/casgem/online_system.cfm, accessed 2 November 2015.
San Mateo County boundary	San Mateo County	Geospatial	County of San Mateo Information Services GIS Data Download, Jurisdictional Boundaries dataset http://isd.smcgov.org/gis-data-download, accessed 12 April 2016.
Adjacent County boundaries	California county boundaries	Geospatial	California county boundaries layer cnty24k09_1_line.shp, developed by U.S. Bureau of Reclamation, CA Department of Conservation, CA Department of Fish and Game, CA Department of Forestry and Fire Protection.
City boundaries, within San Mateo County	Boundaries of incorporated cities, County-wide	Geospatial	County of San Mateo Information Services GIS Data Download, Jurisdictional Boundaries dataset http://isd.smcgov.org/gis-data-download, accessed 12 April 2016.
Palo Alto city boundary	Palo Alto city boundary, not a part of San Mateo County	Geospatial	Santa Clara County Planning Office GIS Data, http://gisdata.sccplanning.opendata.arcgis.com/, accessed May 2016.
Water purveyor service areas	Service area boundaries of retail water agencies in the Basin	Geospatial	Service area shapefile, provided by BAWSCA on 5 May 2016.
Wastewater treatment and collection agencies	Approximate service area boundaries for sanitary sewer agencies and waste water treatment plant locations in the Basin	Geospatial	Compiled based on several sources including Silicon Valley Clean Water service area map, http://www.svcw.org/facilities/sitePages/wastewater%20conveyance.aspx and city boundary shapefiles.
Conceptual and Numerical Basin Models			
DWR Well Information	Records for approximately 3,450 wells (existing and destroyed) located in San Mateo County	Scanned hard copy records	DWR Well Information Request, response received April 2016.
County well permit records	Records of boreholes and well permits in San Mateo County; significant overlap with DWR-provided information	Scanned hard copy records	Provided by San Mateo County Department of Environmental Health, May and June 2016.
Well construction, water level, and chemical analytical data	Records for groundwater wells and boreholes in San Mateo County in and near the Basin	Tabular	SWRCB Geotracker ESI Data, http://geotracker.waterboards.ca.gov/data_download_by_county.asp, data accessed 6 September 2017.
Well construction, water level, and lithologic data	Records for approximately 1,950 groundwater wells and boreholes located in San Mateo County	Tabular	Well information database developed by HydroFocus prior to the start of the Project, incorporating data obtained from local, state, and federal agencies, private consultants, reports and other documents including DWR Well Completion Reports.

Table 4-1
Sources of Key Data for the San Mateo Plain Groundwater Basin Assessment

Data Item	Description	Data Type	Source
Chemical analytical data	Chemical analytical data for wells in San Mateo County	Tabular	SWRCB GAMA Data Download, http://geotracker.waterboards.ca.gov/gama/data_download.asp, data accessed 5 September 2017.
Water level data	Records for wells and water level measurements for environmental wells collected prior to Geotracker reporting requirements	Tabular	Provided by San Mateo County Groundwater Projection Division based on Pre-Geotracker environmental reports, July 2017.
Water level data	Measurements for selected deep wells located within the Basin, collected by County and EKI.	Tabular	Measurements made by San Mateo County staff and EKI staff during 2017.
Aquifer test data	Empirically derived aquifer storage and hydraulic conductivity values	Report documents	Bechtel Environmental, Inc., 1988, Final Site Investigation Report for the Rohm and Hass Redwood City Facility and prepared for Rohm and Haas California, Inc. May 1988.
			California Department of Water Resources, 1968, Evaluation of Ground Water Resources South Bay Volume I: Fremont Study Area. Bulletin No. 118-1. August 1968.
			Delta Environmental Consultants, Inc., 1995, Remediation System Effectiveness, Hydrogeologic Assessment and Proposed Remediation Clean-up Levels Beacon Station No. 591 595 Willow Road Menlo Park, California. September 15, 1995.
			Einarson, Fowler & Watson and Henshaw Associates, 1998, Draft Comprehensive RCRA Facility Investigation Report Romic Environmental Technologies Corporation East Palo Alto, California. Prepared for Romic Environmental Technologies Corporation. April 28, 1998.
			Erler & Kalinowski, Inc., 1997, Remedial Investigation Report 3695-3723 Haven Avenue Menlo Park, California. April 21, 1997.
			Erler & Kalinowski, Inc., 2006, Summary of Preliminary Investigation of Groundwater Extraction Opportunities Redwood City Industrial Saltworks, LLC City of Redwood City, California.
			Erler & Kalinowski, Inc., 2014, Report on Drilling, Construction, and Testing of the Pad D Test Well. Prepared for City of East Palo Alto Community Development Department. October 11, 2014.
			Fio JL and Leighton DA, 1995, Geohydrologic Framework, Historical Development of the Ground-Water System, and General Hydrologic and Water-Quality Conditions in 1990, South San Francisco Bay and Peninsula Area, California. U.S. Geological Survey Open-File Report 94-357, 46 p.

Table 4-1
Sources of Key Data for the San Mateo Plain Groundwater Basin Assessment

Data Item	Description	Data Type	Source
Aquifer test data (continued)			HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
			Kennedy/Jenks Consultants, 2006, Report on Well Installation and Groundwater Monitoring. Prepared for Praxair Inc, May 5, 2006. http://geotracker.waterboards.ca.gov/esi/uploads/geo_report/3337954461/T0608146836.PDF.
			SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem), April 30, 2002.
			SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem)., April 30, 2002.
			Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010.
			Sokol, Daniel, 1963, The Hydrogeology of the San Francisquito Creek Basin, San Mateo and Santa Clara Counties, California. Dissertation, Stanford University. December 1963.
			Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
Water Balance Assessment			
Watershed boundaries	Boundaries of watersheds of major streams crossing the Basin, including tributary headwater areas and minor watersheds along the coastal plain that drain directly to San Francisco Bay	Geospatial	Creek and watershed maps of the Bay Area, published by Oakland Museum of California in paper and GIS format. Downloaded from http://explore.museumca.org/creeks/GIS/, on April 25, 2016.
Water purveyor monthly deliveries	2004-2015 data of monthly deliveries by BAWSCA member agencies	Tabular	BAWSCA annual reports, tabular data provided by BAWSCA staff, May 2016.
WWTP daily inflows	Daily inflows for 2011-2014 for San Mateo WWTP and the six SVCW pumping stations	Tabular	Provided by San Mateo WWTP and SVCW staff, May 2016.
Rainfall isohyetal map	Contours of average annual rainfall based on 1940-1970	Geospatial, report	Rantz, S.E., 1971, Mean Annual Precipitation and Precipitation Depth-Duration-Frequency Data for the San Francisco Bay Region, California, U.S. Geological Survey (USGS) Open-File Report 3019-12., USGS, Menlo Park, CA, 1:500,000 scale map, Text, 23 p.

Table 4-1
Sources of Key Data for the San Mateo Plain Groundwater Basin Assessment

Data Item	Description	Data Type	Source
Rainfall daily time series	Daily rainfall 1940-2016 based on Redwood City gage with missing record estimated by correlation with San Mateo, Palo Alto and other nearby gages	Tabular	National Climatic Data Center database, downloaded from https://www.ncdc.noaa.gov/cdo-web/ on April 28, 2016.
Reference evapotranspiration daily time series	Daily ETo from CIMIS Union City, Fremont, San Jose and Woodside stations, 1987-2016.	Tabular	California Irrigation Management Information System (CIMIS) operated by Calif. Department of Water Resources. Download from on-line database, http://www.cimis.water.ca.gov/, on April 29, 2016
Stream flow daily time series	Period of record for 7 historical and current gages	Tabular	U.S. Geological Survey NWIS on-line databases, on April 29, 2016.
Synoptic stream flow measurements	Measured or estimated flow at 12 locations on five creeks	Tabular	Observations and measurements by Todd Groundwater on May 5, 2016.
Historical maps	Detailed maps covering the Basin area from 1873 and 1903	Geospatial	David Rumsey Map Collection. Downloaded and georeferenced images, http://www.davidrumsey.com/, in April 2016
Soils map	Soil survey mapping units classified by available water capacity, minimum vertical permeability, and hydrologic group	Geospatial	Soil survey geographic database (SSURGO) soil survey database and shapefiles downloaded from Natural Resources Conservation Service's Web Soil Survey web tool, http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
High-resolution aerial photography	Ortho-rectified seamless aerial imagery sufficiently detailed to evaluate impervious area, tree canopy and irrigated areas	Geospatial	National Agriculture Imagery Program (NAIP), imagery from 2010.
Maps of impervious area	30-m spectral-analyzed raster map of total impervious area	Geospatial	National Land Cover Data Set, http://www.mrlc.gov/nlcd2011.php, accessed in April 2016.
	Maps of impervious cover within San Mateo County watersheds developed from digitizing aerial photographs	Geospatial	Scanned and georeferenced summary maps from: STOPPP 2002. Characterization of Imperviousness and Creek Channel Modifications for Seventeen Watersheds in San Mateo County. Prepared by EOA, Inc. for the San Mateo Countywide Stormwater Pollution Prevention Program. January 1, 2002.
Evaluation of Groundwater Management			
Special districts	Descriptions of roles, responsibilities, and locations of special districts in San Mateo County	Website	Local Government Directory, San Mateo County Local Agency Formation Commission website, http://lafco.smcgov.org/local-government-directory, accessed April - June, 2016.
Groundwater production	Current groundwater production volumes and plans for future groundwater use	Report documents	2015 Urban Water Management Plans from water purveyors overlying the San Mateo Plain Subbasin and adjacent basins, accessed June - August 2016.
Current groundwater management	San Mateo County well ordinance	Governing body documents	Chapter 4.68 of the San Mateo County Ordinance Code, as amended by Ordinance No. 4023 in January 2001.

Table 4-1
Sources of Key Data for the San Mateo Plain Groundwater Basin Assessment

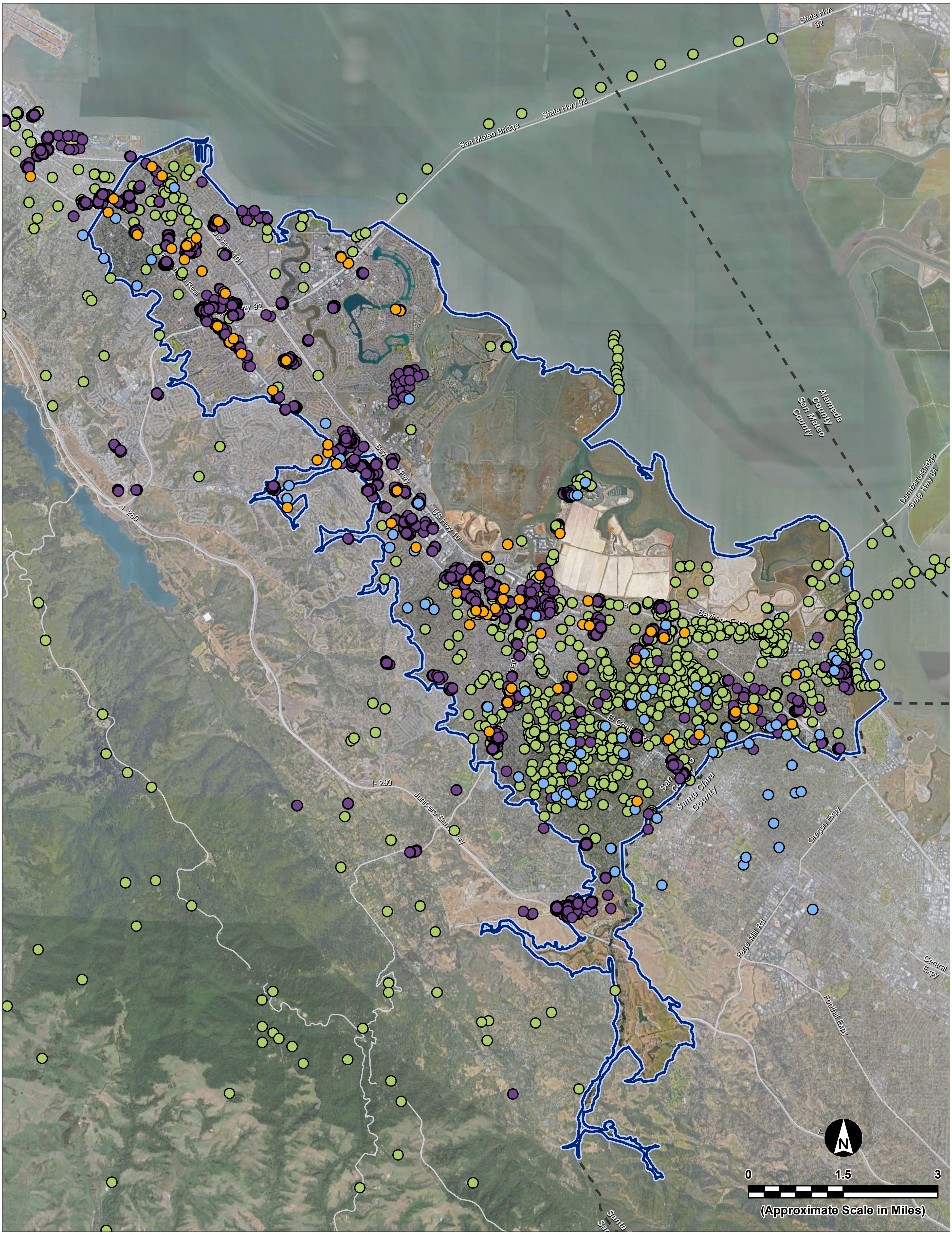
Data Item	Description	Data Type	Source
	Resolutions in support of sustainable groundwater management in the San Francisquito Creek area	Governing body documents	Resolutions by the governing bodies of the cities of East Palo Alto, Menlo Park, Palo Alto, Atherton, and Portola Valley, and Santa Clara Valley Water District and San Mateo County, signed September 2014.
	Groundwater Management Plan for the City of East Palo Alto	Report documents	Todd Groundwater, 2015, Groundwater Management Plan for City of East Palo Alto. August 2015.
CASGEM compliance	CASGEM regulations	State regulations & guidance	Senate Bill x7-6, http://www.leginfo.ca.gov/pub/09-10/bill/sen/sb_0001-0050/sbx7_6_bill_20091106_chaptered.html, accessed May 2016.
SGMA compliance	SGMA legislation	State regulations & guidance	Sustainable Groundwater Management Act, amended 3 September 2015.
	GSA formation notifications	Website	DWR GSA Formation Table, http://www.water.ca.gov/groundwater/sgm/gsa_table.cfm, accessed June - August 2016.
	GSA eligibility	State regulations & guidance	Correspondence with Jessica Bean (SWRCB), 30 June 2016.
	GSP regulations	State regulations & guidance	Groundwater Sustainability Plan Emergency Regulations, adopted 16 May 2016.
	GSP regulations guidance document	State regulations & guidance	DWR, Sustainable Groundwater Management Program - GSP Emergency Regulations Guide, July 2016.
Management in adjacent basins	Groundwater management plans	Report documents	City of San Bruno, California Water Service Company, City of Daly City, and San Francisco Public Utilities Commission, *South Westside Basin Groundwater Management Plan* , July 2012
		Report documents	East Bay Municipal Utilities District, *South East Bay Plain Subbasin Groundwater Management Plan* , March 2013.
		Report documents	Santa Clara Valley Water District, *2012 Groundwater Management Plan,* 2012. Santa Clara Valley Water District, *2016 Groundwater Management Plan, Santa Clara and Llagas Subbasins,* November 2016.
		Report documents	San Francisco Public Utilities Commission, *North Westside Basin Groundwater Management Plan* , April 2005.

Table 4-1
Sources of Key Data for the San Mateo Plain Groundwater Basin Assessment

Data Item	Description	Data Type	Source
Management in adjacent basins (continued)	Groundwater management policies, ordinances, resolutions, and agreements	Local agency documents	Alameda County Water District, *Groundwater Management Policy* , amended 22 March 2001.
		State regulations & guidance	Chapter 1942 of the Statutes of 1961, *Replenishment Assessment Act of the Alameda County Water Distric* t, amended, 18 September 1974.
		State regulations & guidance	Senate Bill No. 133, An act to add Article 9.3 to Chapter 1 of Part 5 of Division 12 of the Water Code, relating to the Alameda County Water District, 11 October 2009.
		Local agency documents	Alameda County Water District, *Ordinance No. 2010-01, An Ordinance of the Alameda County Water District to Regulate Wells, Exploratory Holes, and Other Excavations Within the Cities Of Fremont, Newark, And Union City,* 9 December 2010.
		Local agency documents	City of San Bruno, California Water Service Company, City of Daly City, and San Francisco Public Utilities Commission*, Westside Basin Groundwater Storage and Recovery Agreement,* 2014.
	GSA formation	Local agency documents	San Francisco Public Utilities Commission, *Resolution No. 15-0071* , 10 March 2015.
		Local agency documents	East Bay Municipal Utilities District, *Staff Report - Adopt a Resolution to become a Groundwater Sustainability Agency for the East Bay Plain Groundwater Subbasin* , 9 August 2016.
	GSP preparation	Local agency documents	City of San Bruno, Resolution No. 2016-XX, *Resolution Authorizing The City Manager To Execute A Contract For Preparation of the Groundwater Sustainability Plan with Rmc Water And Environment in an Amount not to Exceed $118,903 And Appropriating $7,500 From The Water Capital Fund* , 12 January 2016.

<u>Abbreviations:</u>
"BAWSCA" = Bay Area Water Supply and Conservation Agency
"CASGEM" = California Statewide Groundwater Elevation Monitoring
"CIMIS" = California Irrigation Management Information System
"DWR" = California Department of Water Resources
"ESI" = Electronic Submittal of Information
"ETo" = reference evapotranspiration
"GAMA" = Groundwater Ambient Monitoring and Assessment Program
"GSA" = Groundwater Sustainability Agency
"NWIS" = National Water Information System
"GSP" = Groundwater Sustainability Plan
"SCVWD" = Santa Clara Valley Water District
"SGMA" = Sustainable Groundwater Management Act
"SVCW" = Silicon Valley Clean Water
"SWRCB" = State Water Resources Control Board
"WWTP" = Waste Water Treatment Plant

<u>Note:</u>
This table summarizes the primary and key sources of data compiled and used by the Project Team through January 2017.



Legend

San Mateo Plain Subbasin

County Boundary

Major Road

Well or Borehole Information Source

- Compiled by County/SFPUC Intern (Note 2)
- Compiled from Well Logs and Recent Reports (Note 3)
- Compiled from Electronic Sources (Note 4)
- Previously Compiled by HydroFocus (Note 5)

Abbreviations

GAMA = Groundwater Ambient Monitoring and Assessment Program
SFPUC = San Francisco Public Utilities Commission
SWRCB = California State Water Resources Control Board

Notes

1. All locations are approximate.
2. San Mateo County staff and an SFPUC intern, compiled and digitized available water level data from pre-GeoTracker era (approx. 2001 and earlier) site cleanup reports.
3. Includes records requested and reviewed during Phase 1 and additional logs identified and reviewed during Phase 2.
4. Electronic sources compiled include the SWRCB GAMA and Geotracker online databases.
5. Includes records previously recieved and compiled by Hydrofocus through approximately 2012.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Aerial imagery: Google Earth Pro, accessed 19 April 2016.

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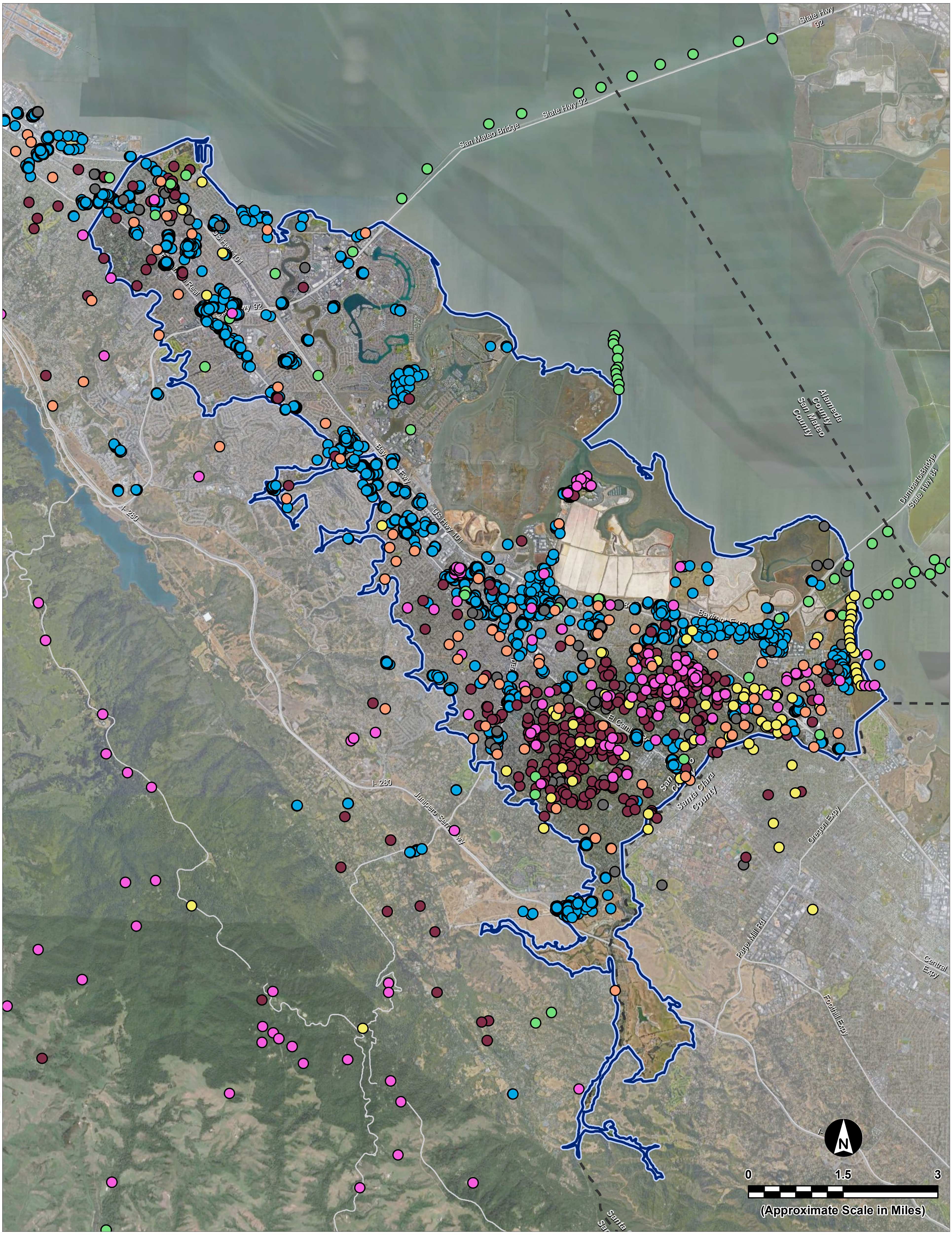
Available Wells and Boreholes by Information Source

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 4-1



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Legend

San Mateo Plain Subbasin

County Boundary

Major Road

Well or Borehole Type

- Cathodic
- Environmental
- Irrigation
- Private Water Supply
- Public Water Supply
- Test/ Pilot Borehole
- Other or Unknown

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Aerial imagery: Google Earth Pro, accessed 19 April 2016.

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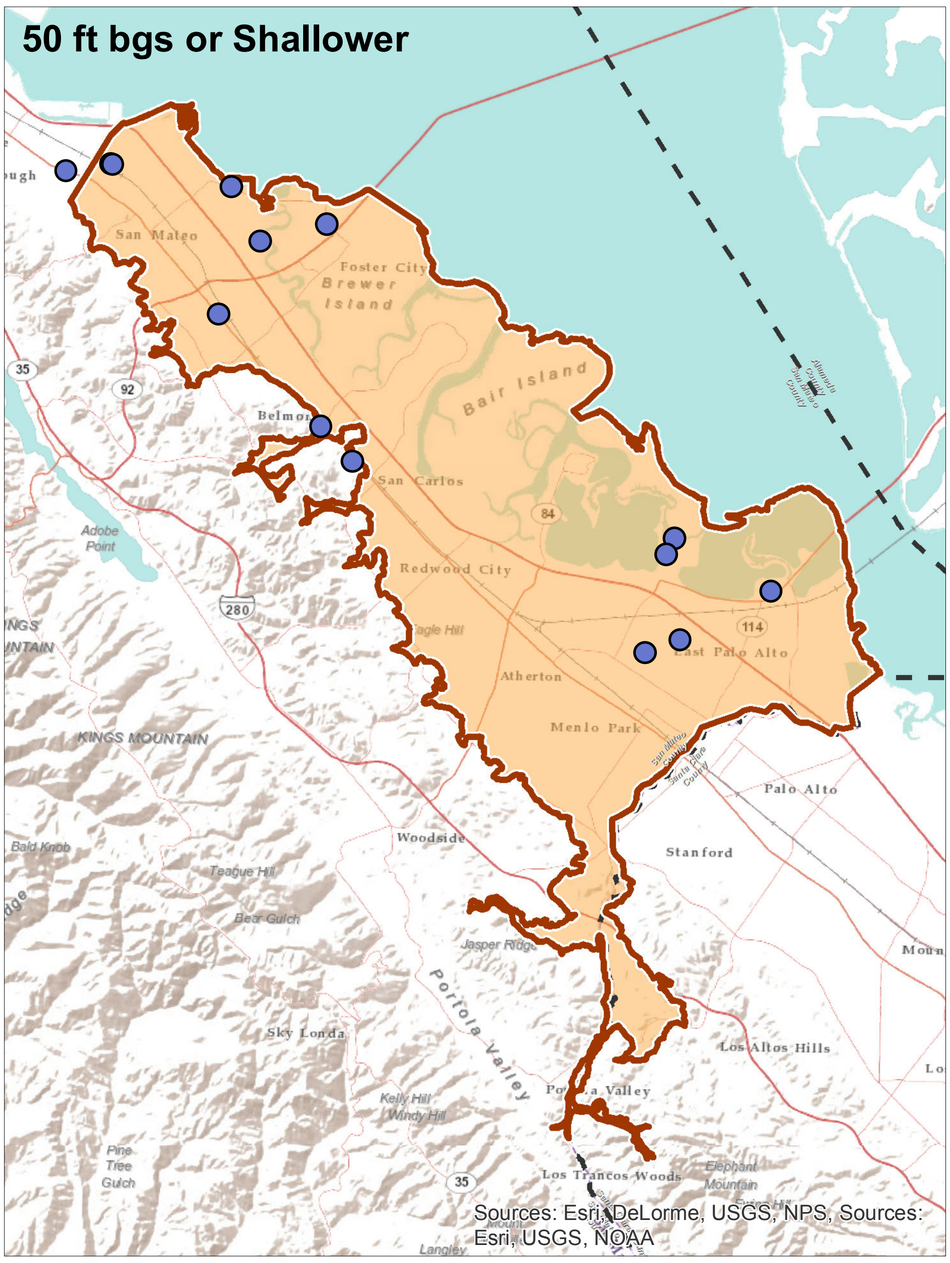
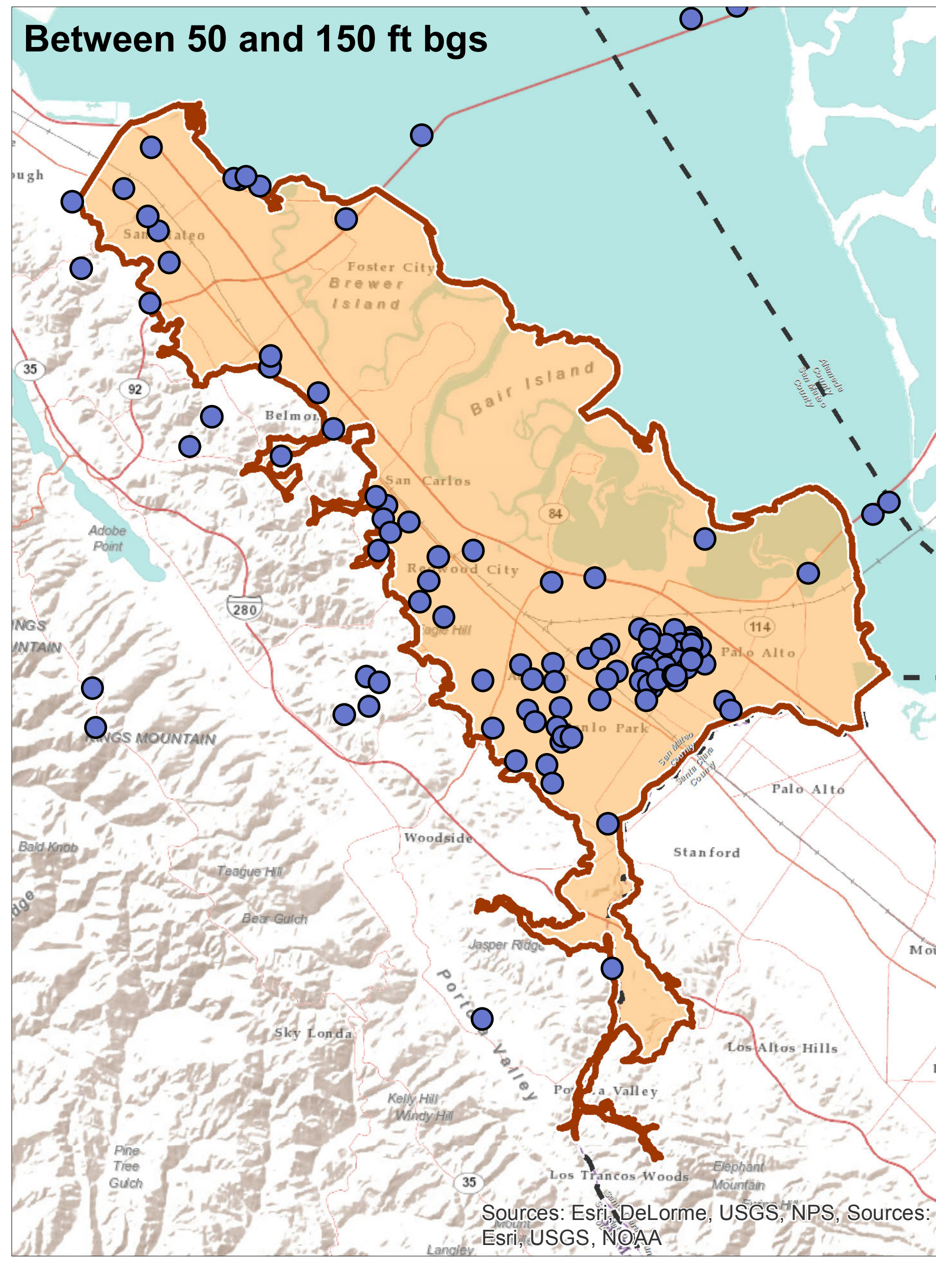
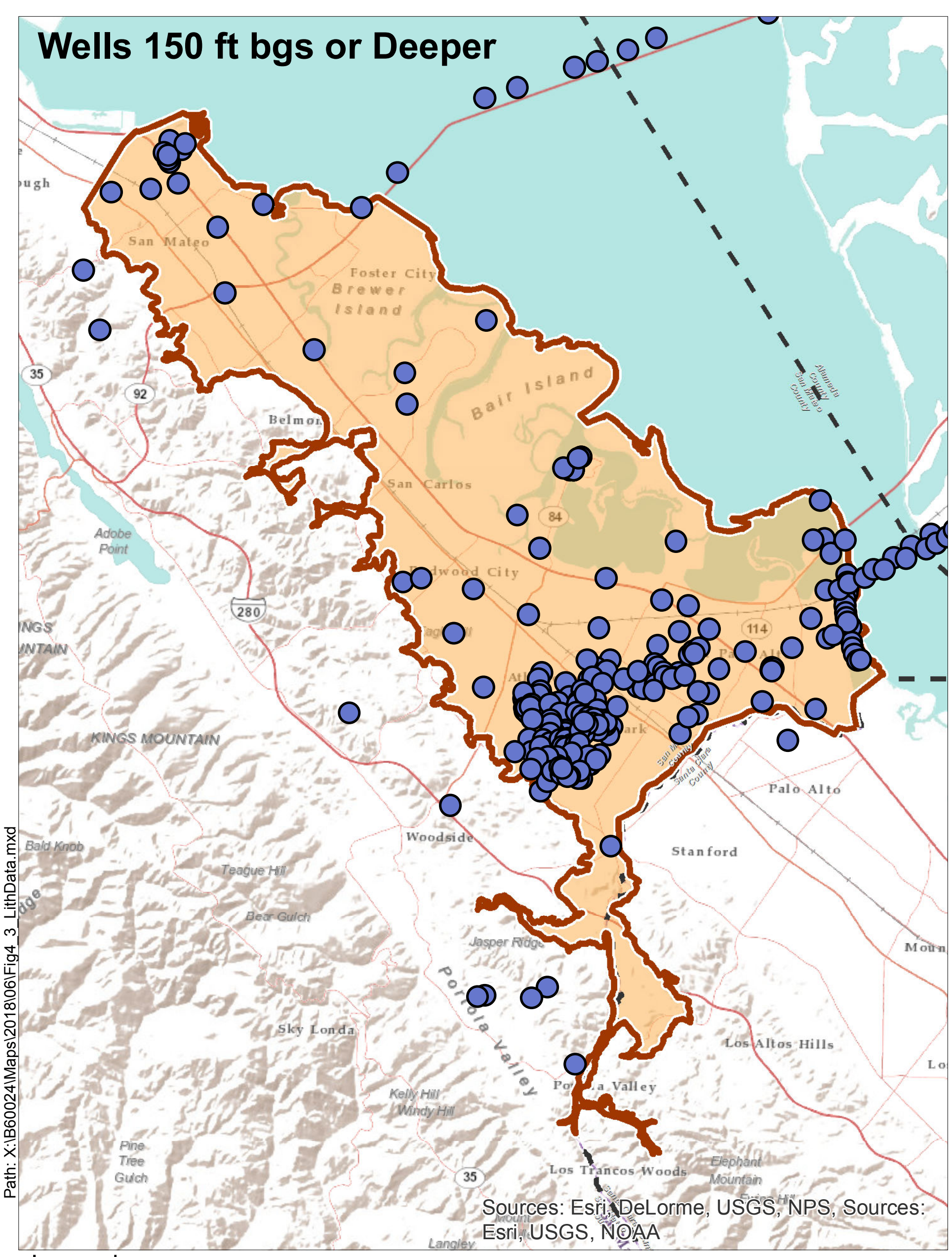
Available Wells and Boreholes by Type

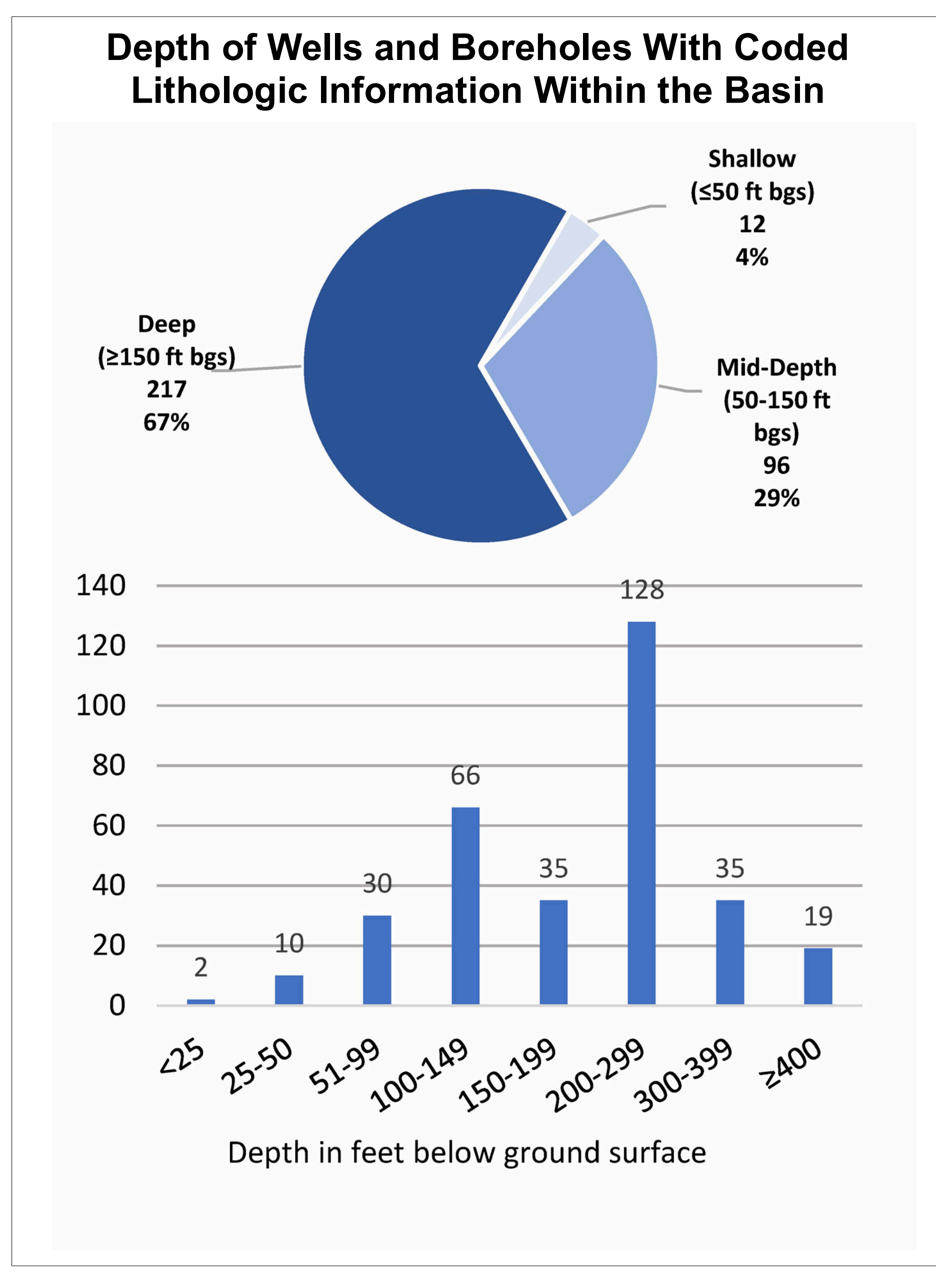
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 4-2









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Legend

- San Mateo Plain Subbasin
- County Boundary
- Well or Borehole Location

Abbreviations

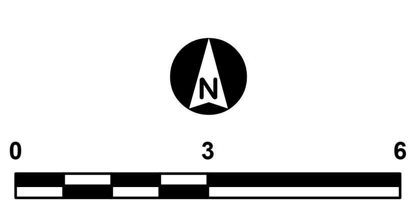
ft bgs = feet below ground surface

Notes

1. All locations are approximate.
2. The charts above summarize information for locations within the Basin only.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.



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Wells and Boreholes With Coded Lithologic Information

San Mateo Plain Groundwater Subbasin

San Mateo County, California

June 2018

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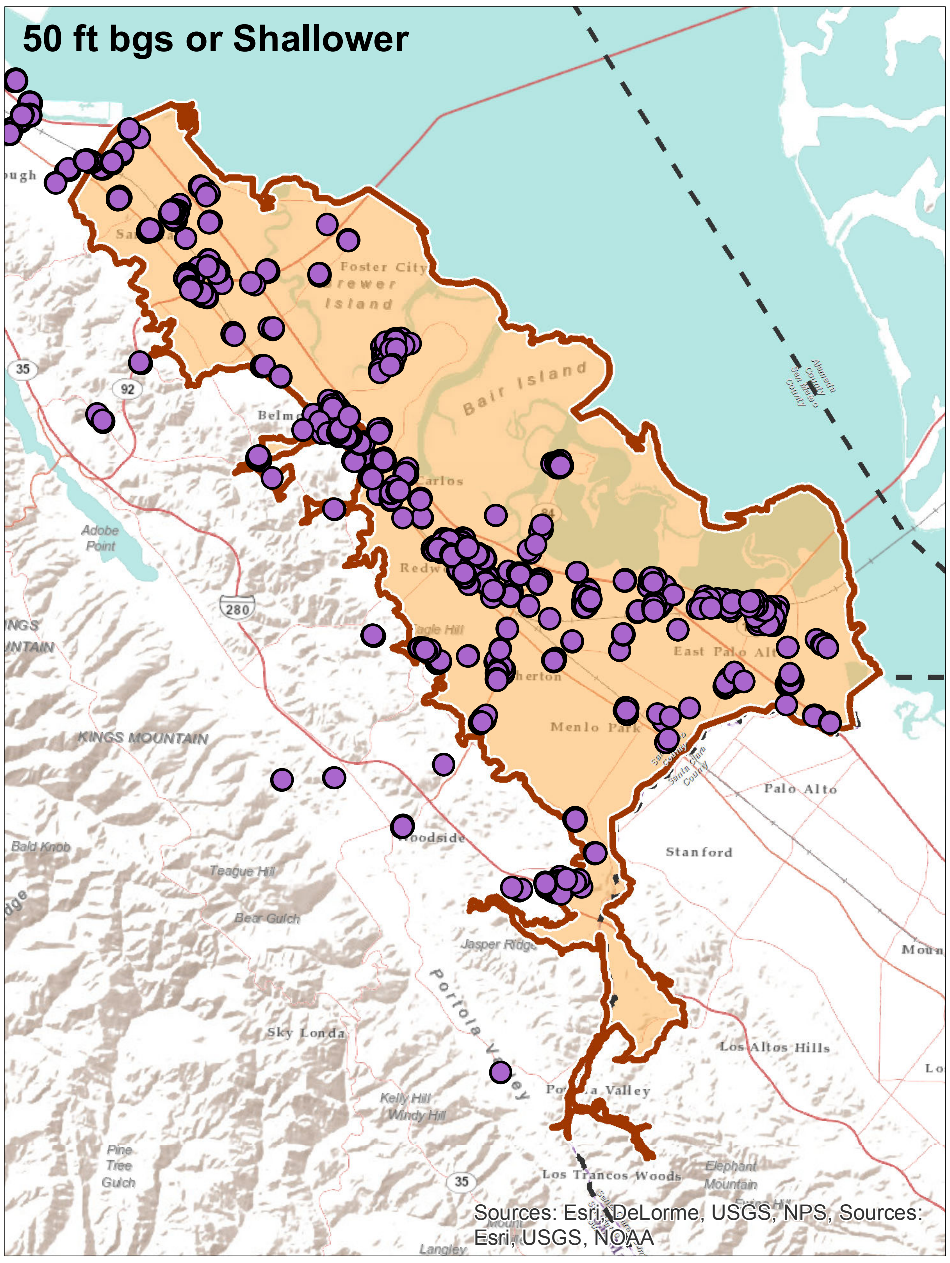
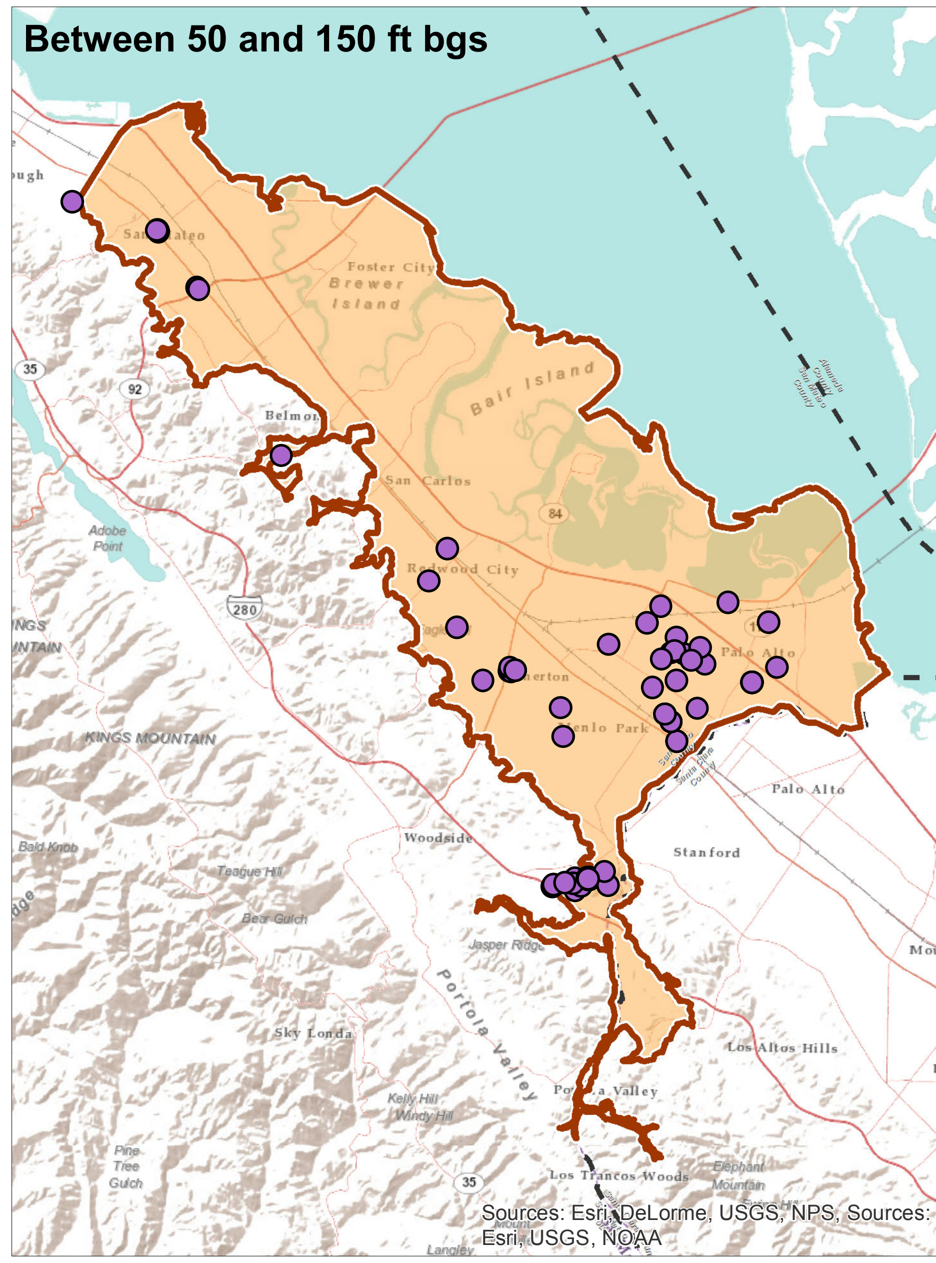
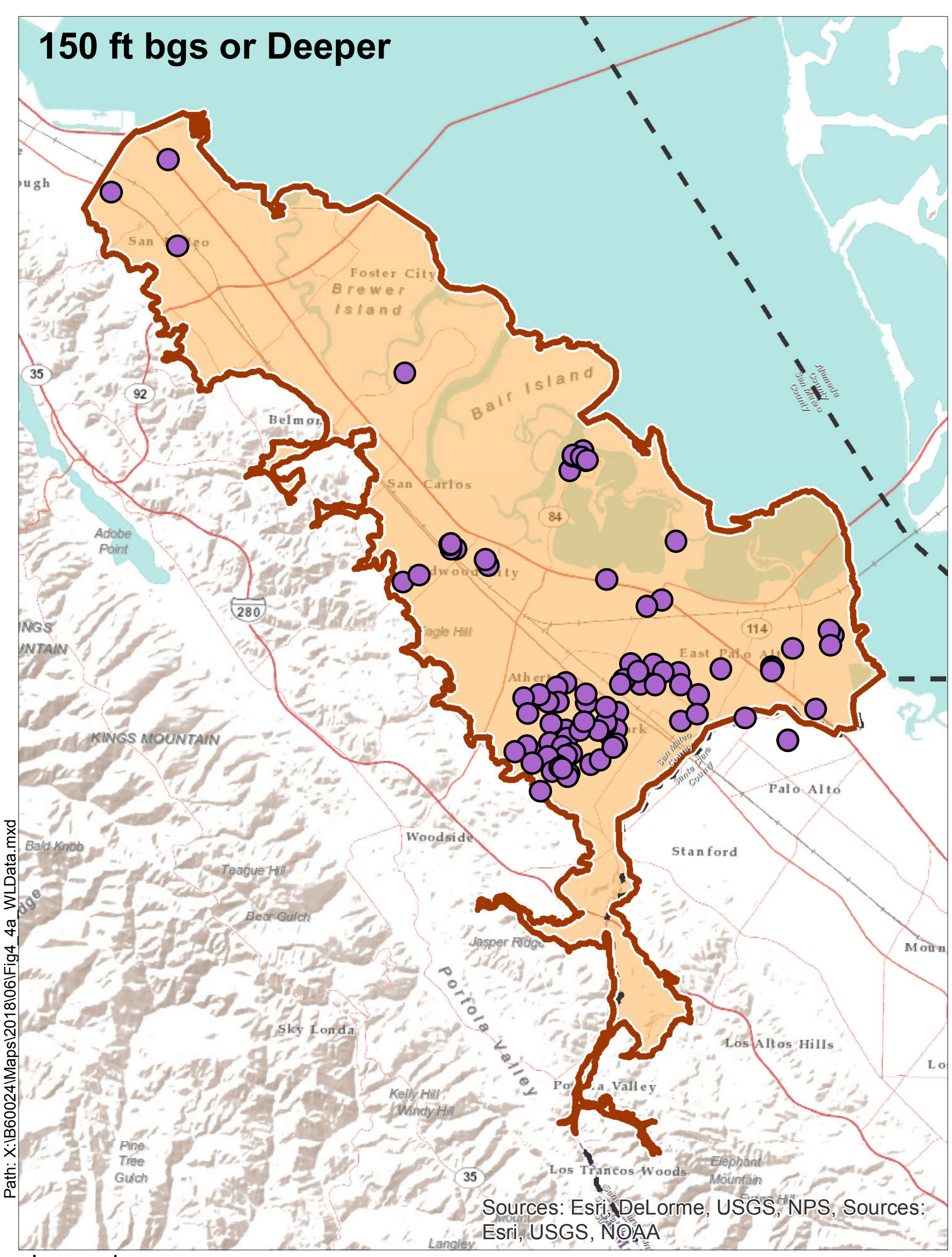
Figure 4-3







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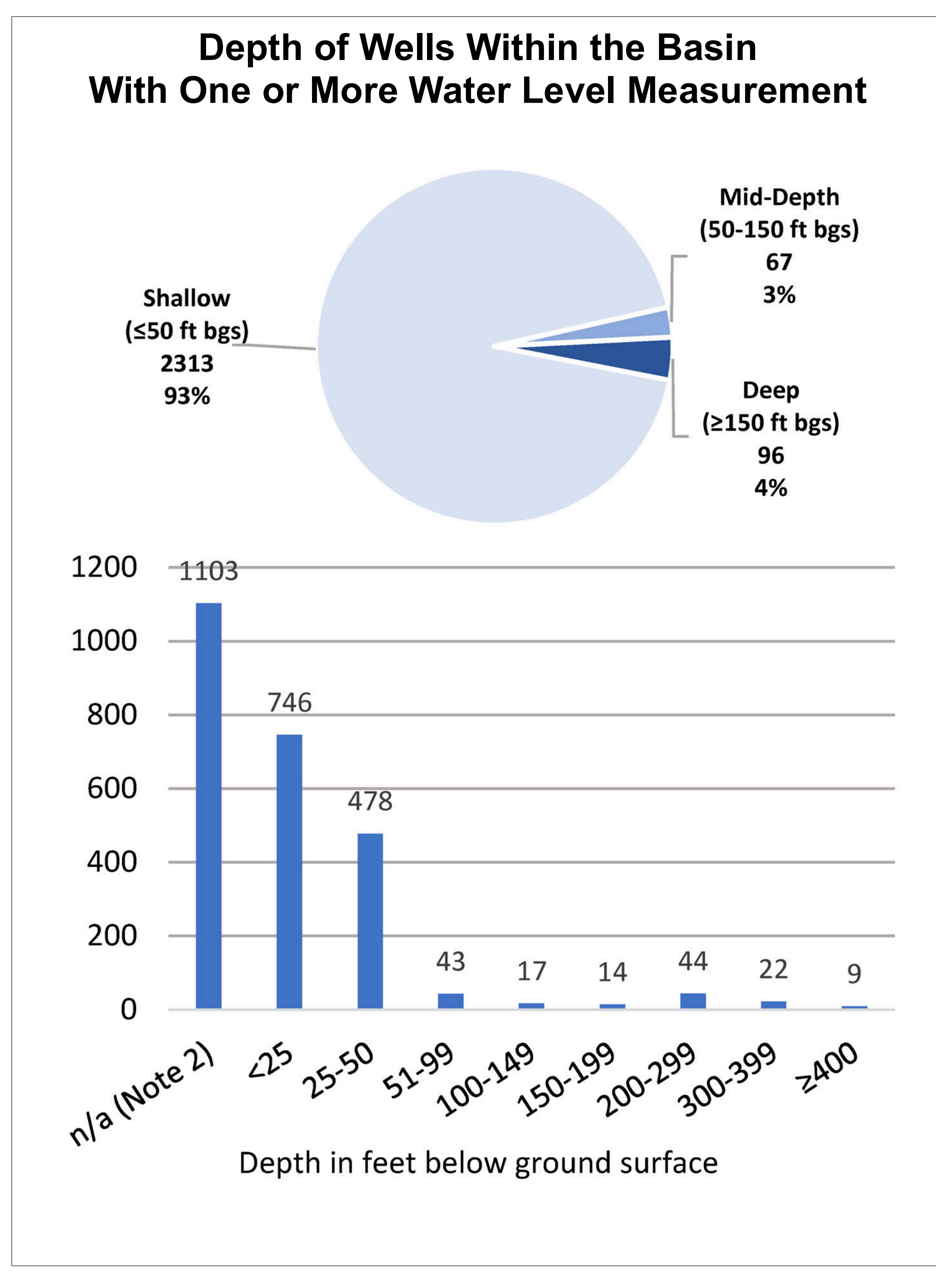

Legend

- San Mateo Plain Subbasin
- County Boundary
- Well Location

Abbreviations

ft bgs = feet below ground surface
n/a = not available

Notes

1. All locations are approximate.
2. Well depth category (i.e., shallow, mid-depth, or deep) is assumed based on well type for locations where depth is not coded in the Project database.
3. The charts above summarize information for locations within the Basin only.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.

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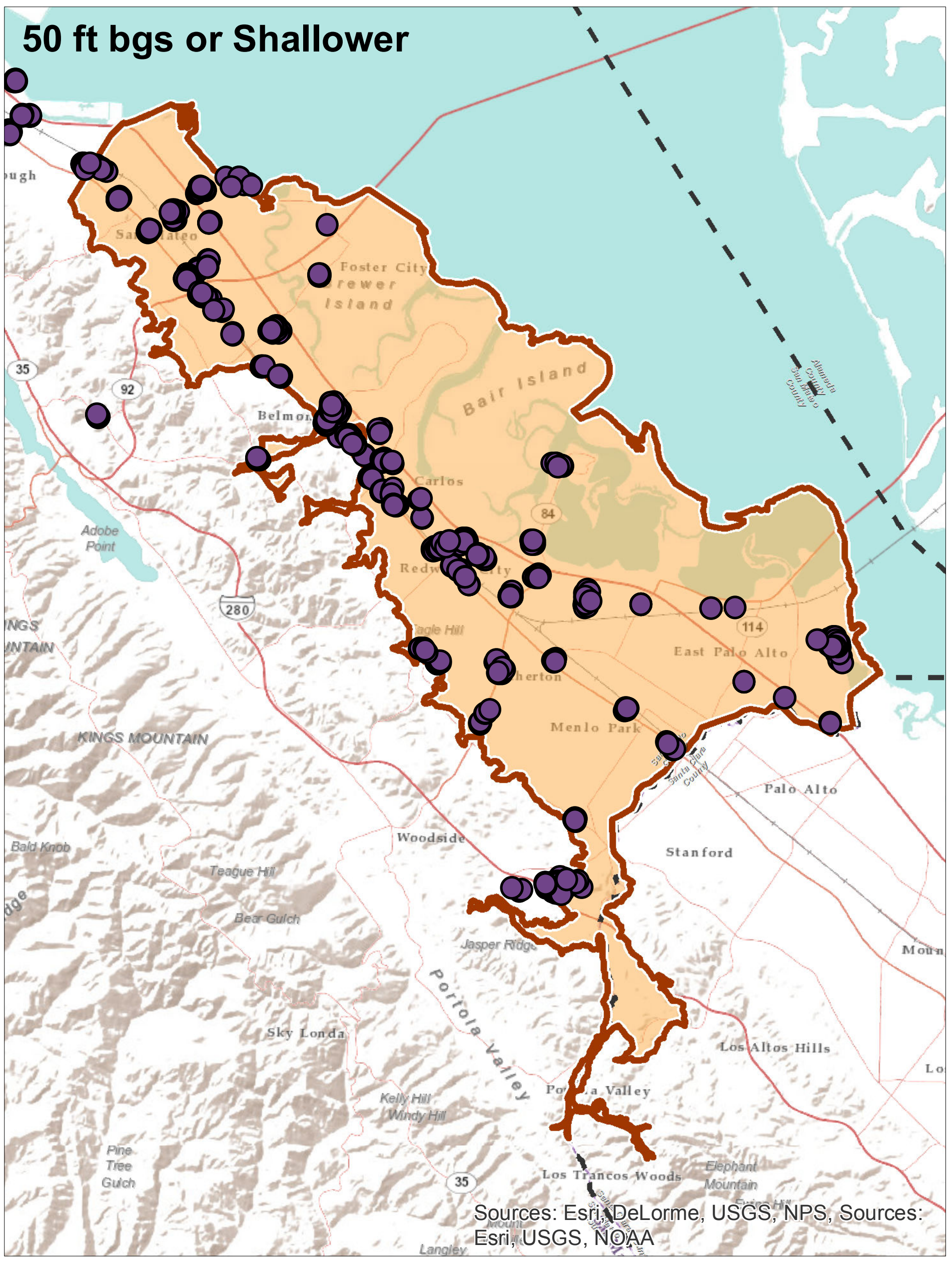
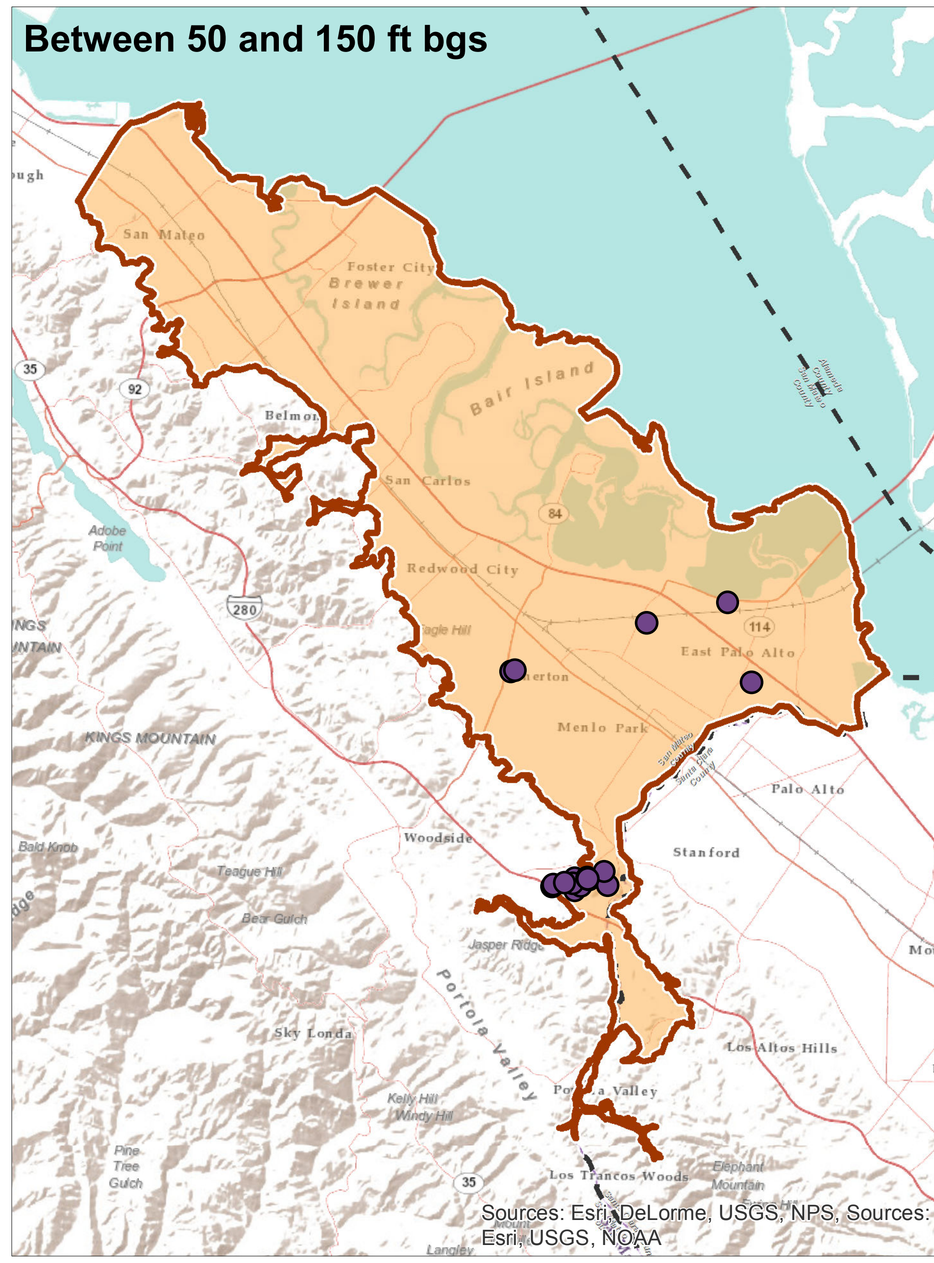
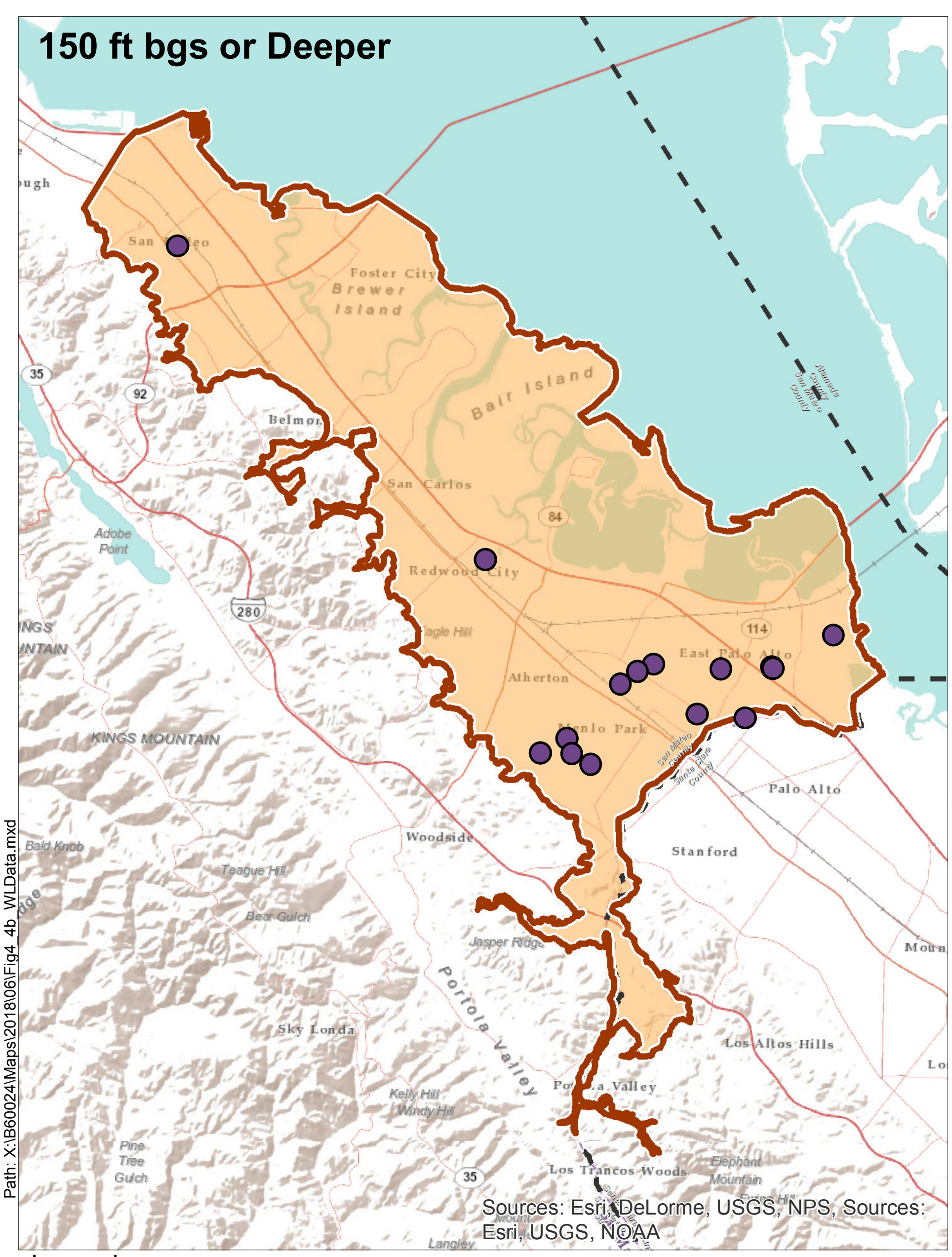
Wells with Available Water Level Measurements

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

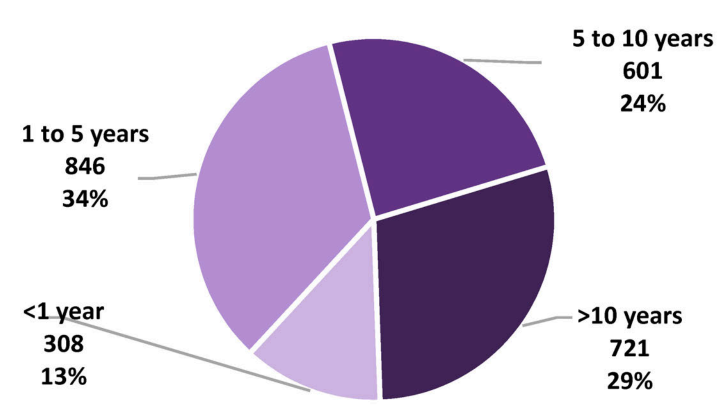
Figure 4-4a

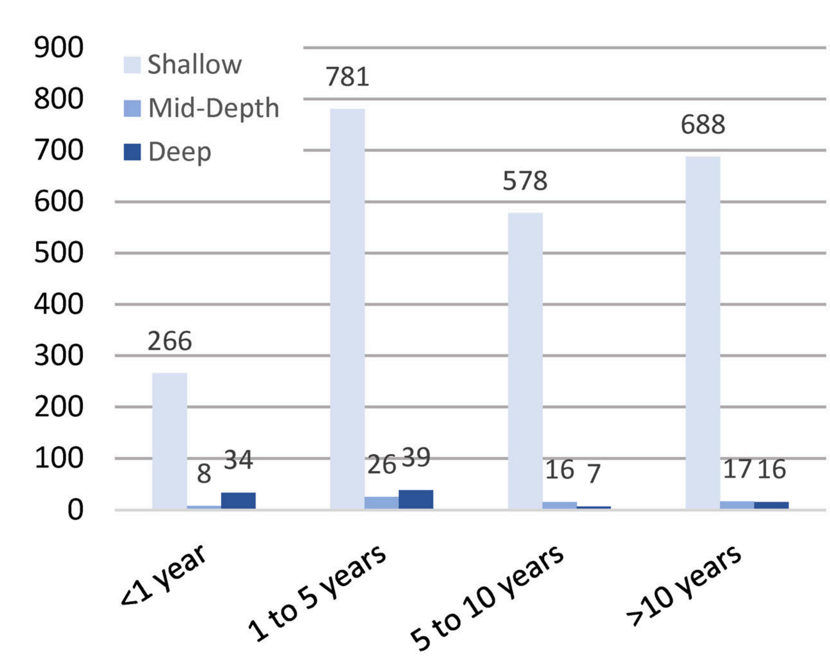






Water Level Measurement Periods For Wells Within the Basin





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Legend

San Mateo Plain Subbasin

County Boundary

Well Location

Abbreviations

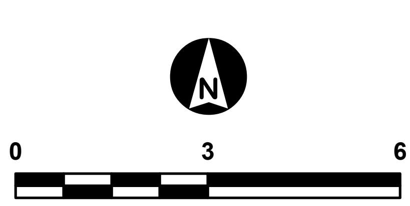
ft bgs = feet below ground surface

Notes

1. All locations are approximate.
2. Well depth category (i.e., shallow, mid-depth, or deep) is assumed based on well type for locations where depth is not coded in the Project database.
3. The charts above summarize information for locations within the Basin only.
4. Water level measurement period is based on the first and last available measurements. Wells were not necessarily monitored on a consistent basis throughout this time period.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.



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Wells with Water Level Measurements Spanning a Greater than 10-Year Period

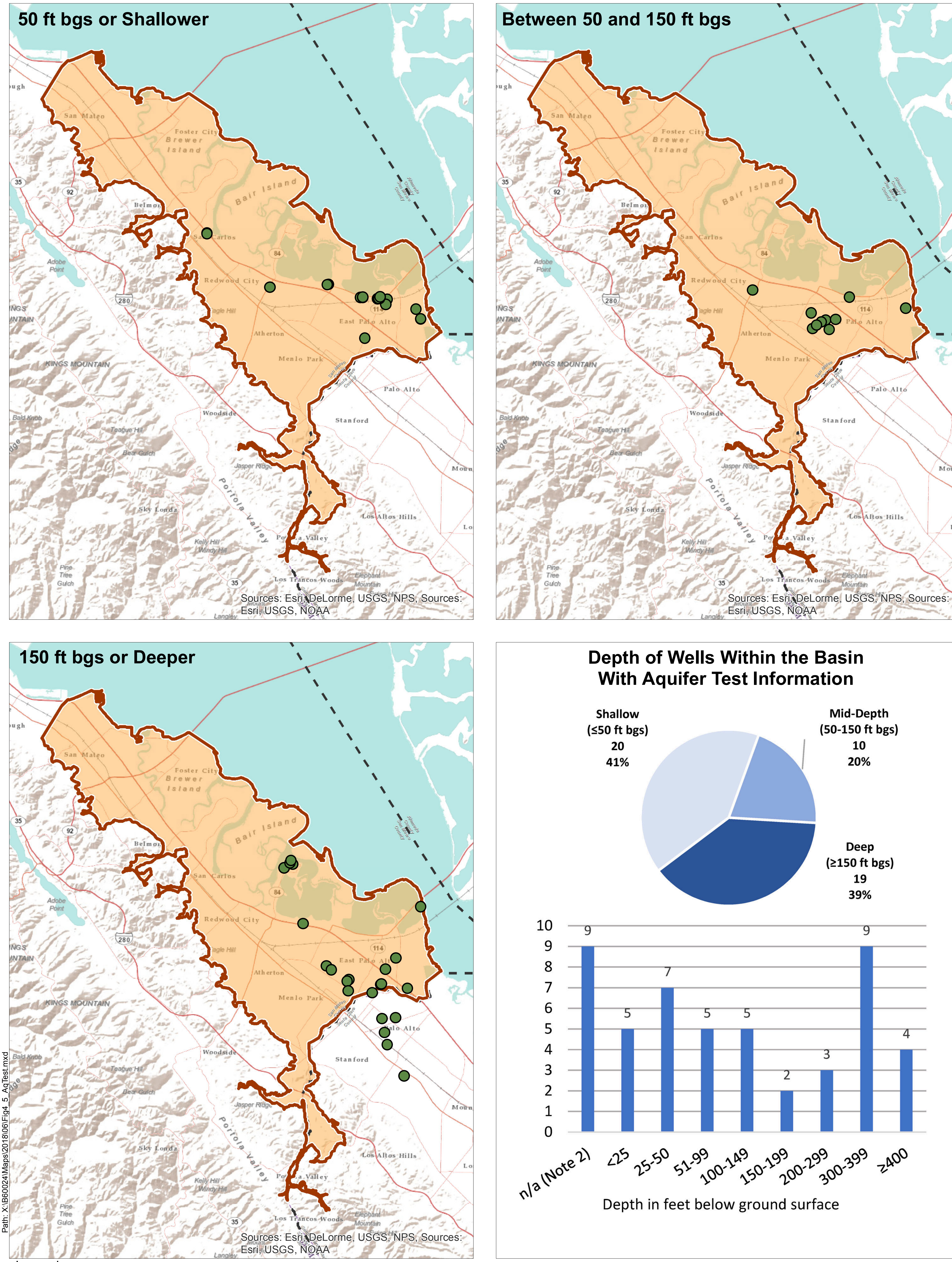
San Mateo Plain Groundwater Subbasin

San Mateo County, California

June 2018

EKI B60024.00

Figure 4-4b



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Legend

- San Mateo Plain Subbasin
- County Boundary
- Well Location

Abbreviations

ft bgs = feet below ground surface
n/a = not available

Notes

1. All locations are approximate.
2. Well depth category (i.e., shallow, mid-depth, or deep) is assumed based on well type for locations where depth is not coded in the Project database.
3. The charts above summarize information for locations within the Basin only.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.

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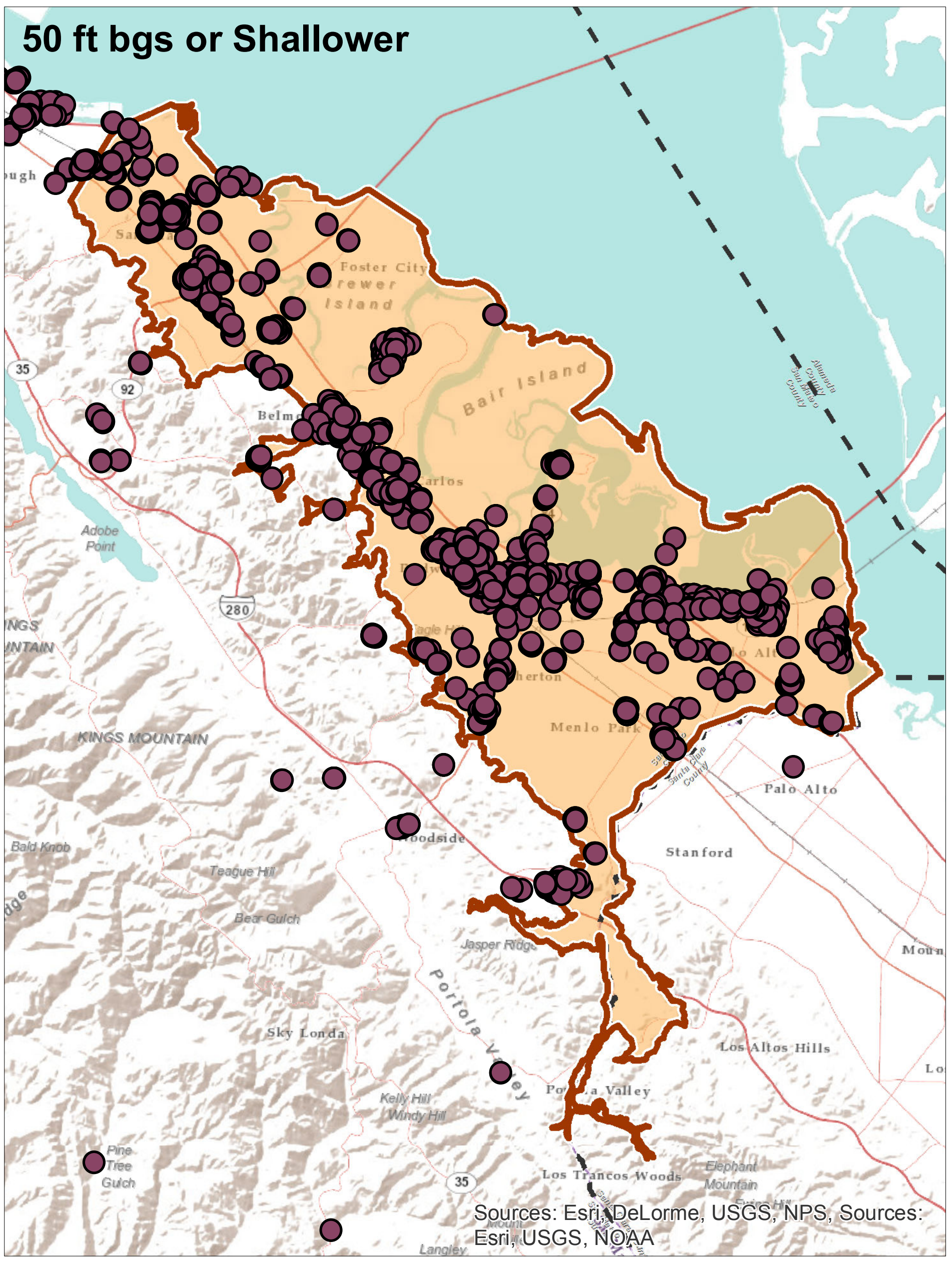
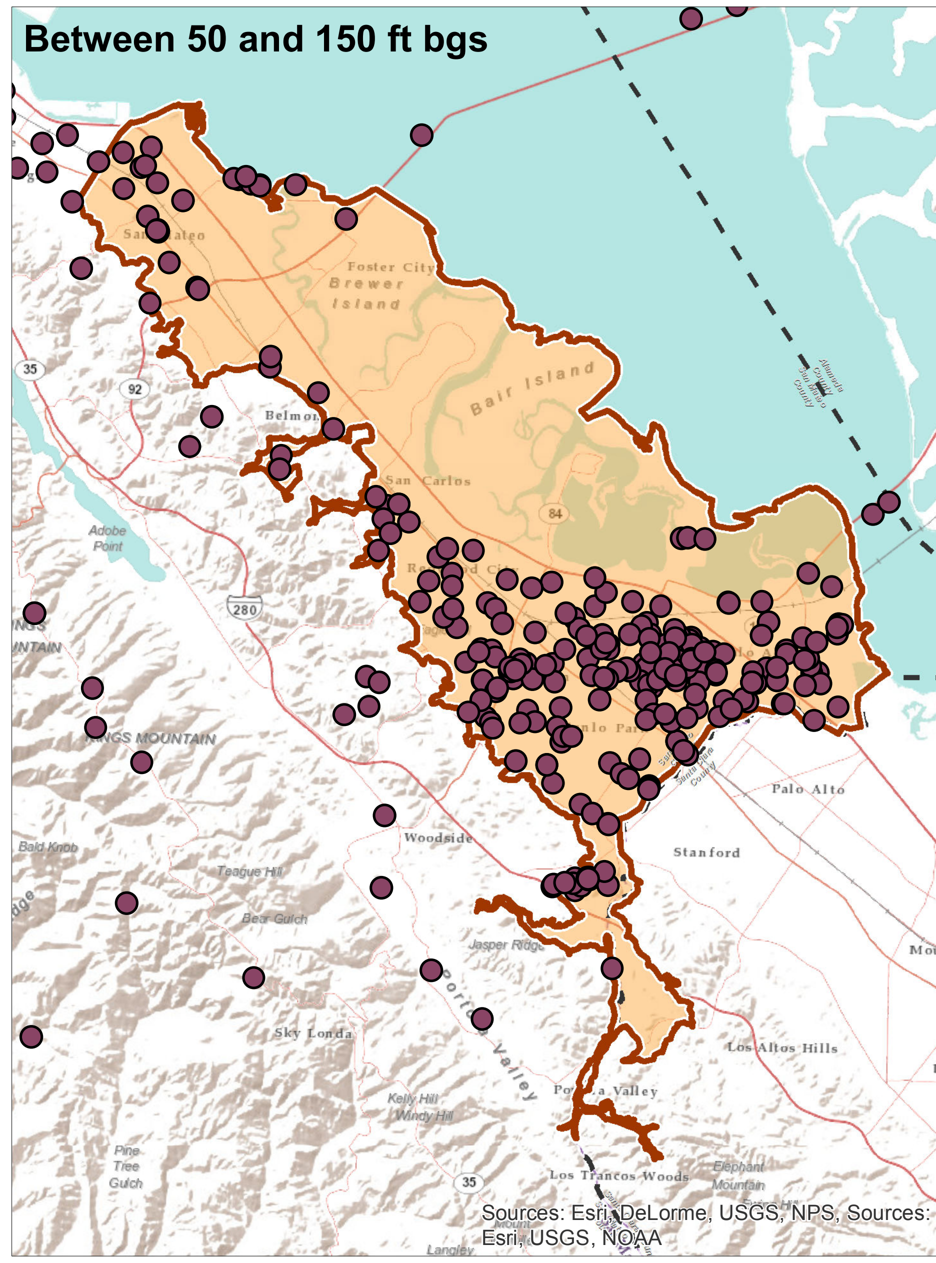
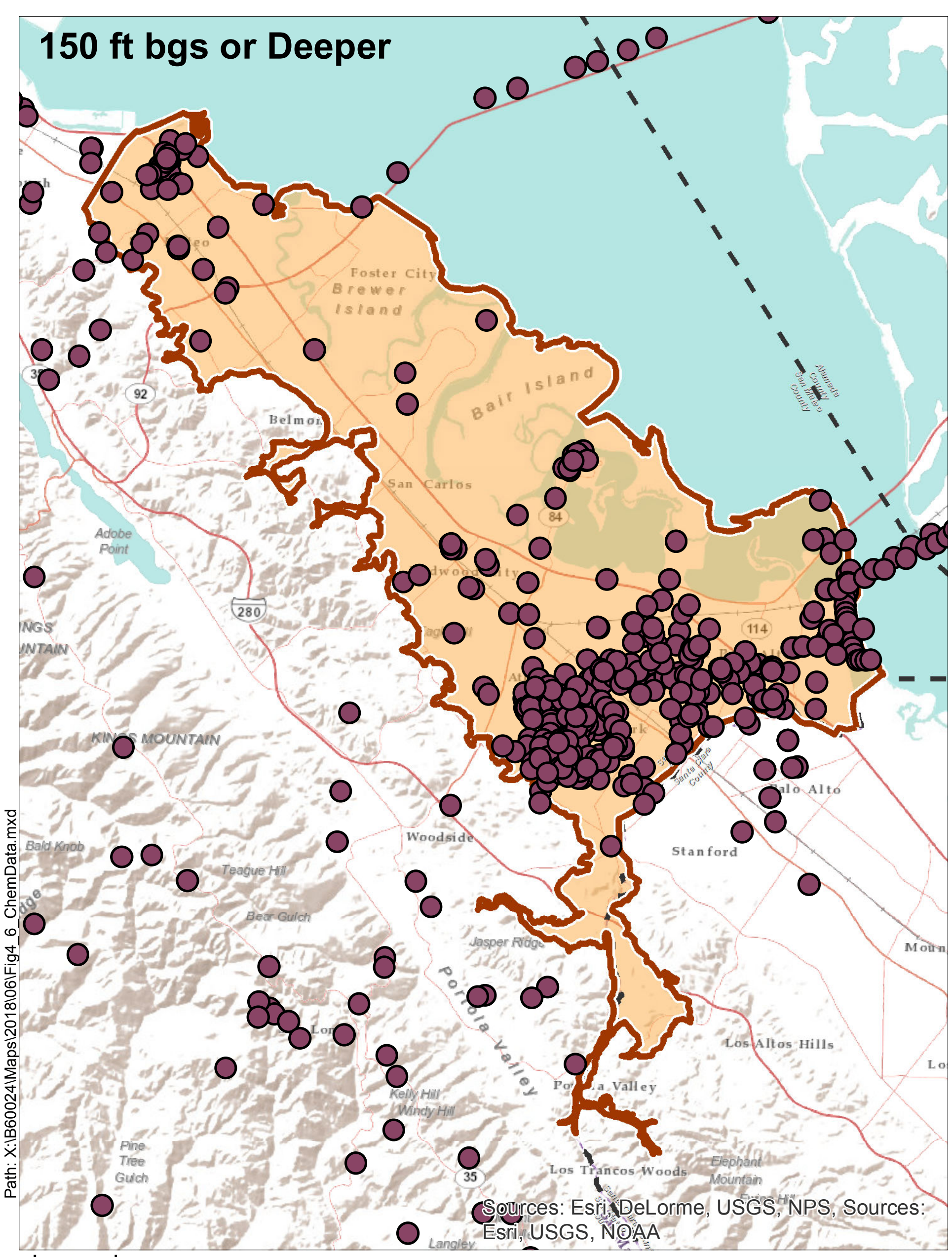
Wells with Available Aquifer Testing Results
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 4-5







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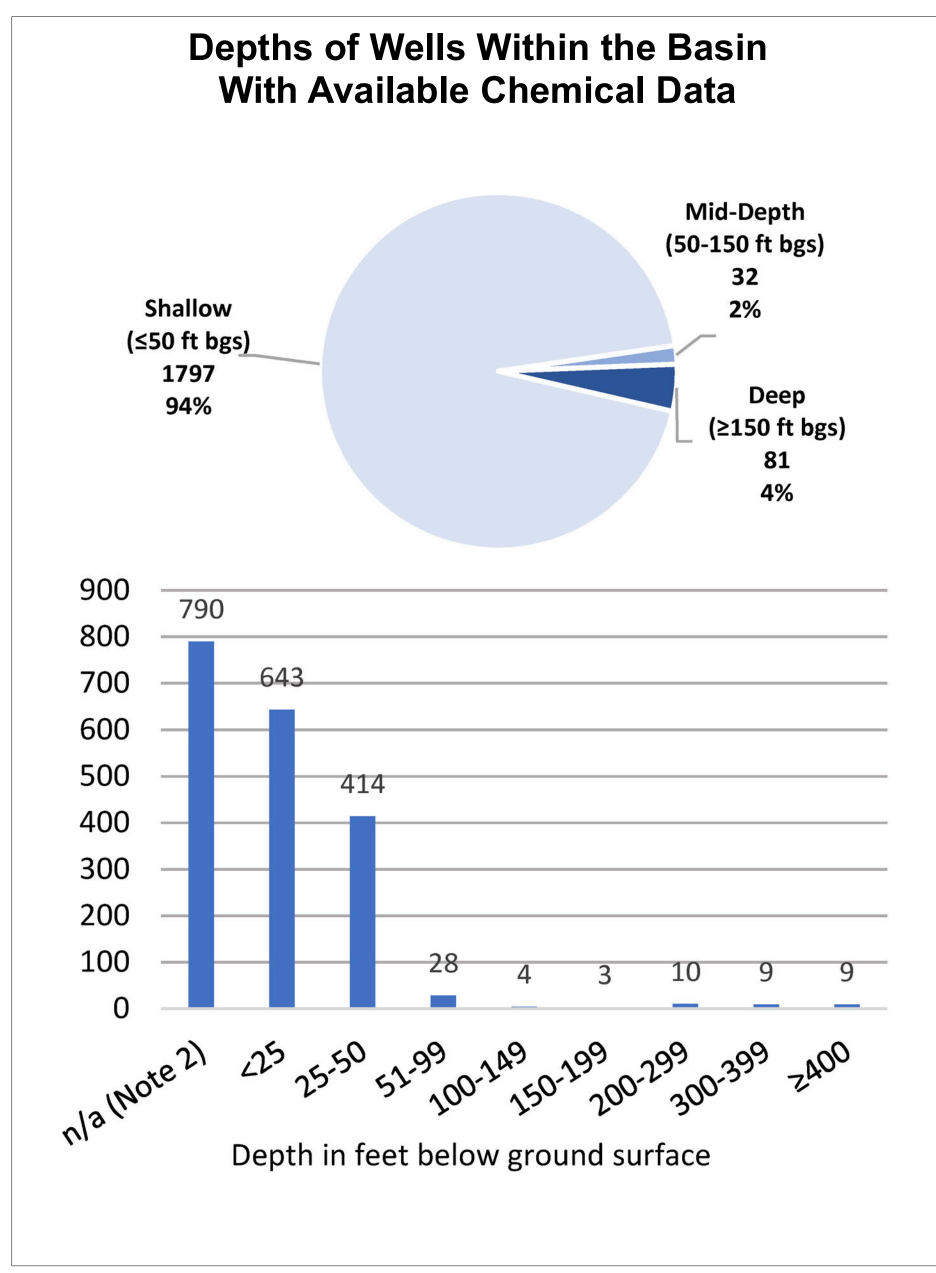

Legend

- San Mateo Plain Subbasin
- County Boundary
- Well Location

Abbreviations

ft bgs = feet below ground surface
n/a = not available

Notes

1. All locations are approximate.
2. Well depth category (i.e., shallow, mid-depth, or deep) is assumed based on well type for locations where depth is not coded in the Project database.
3. The charts above summarize information for locations within the Basin only.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.

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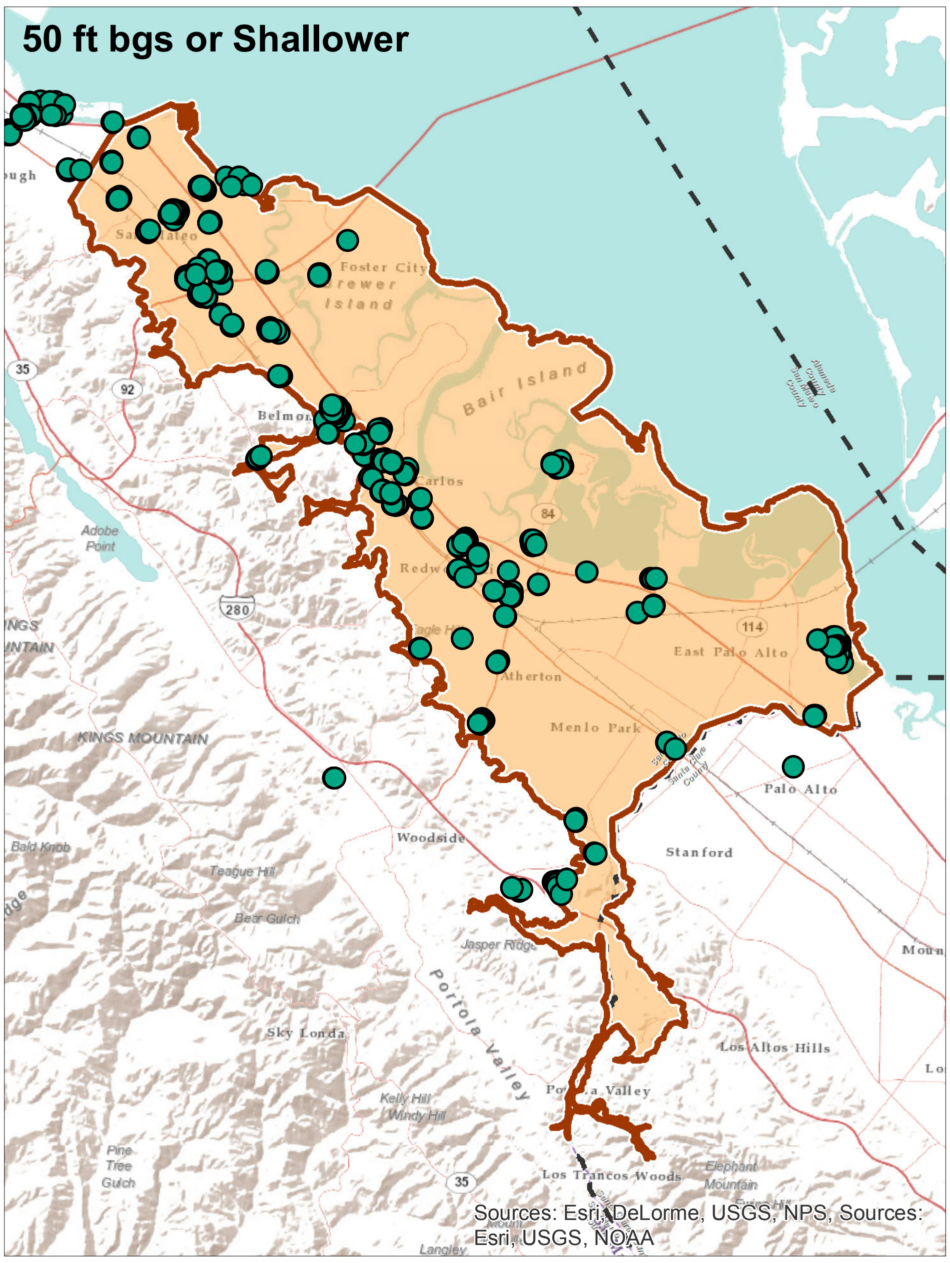
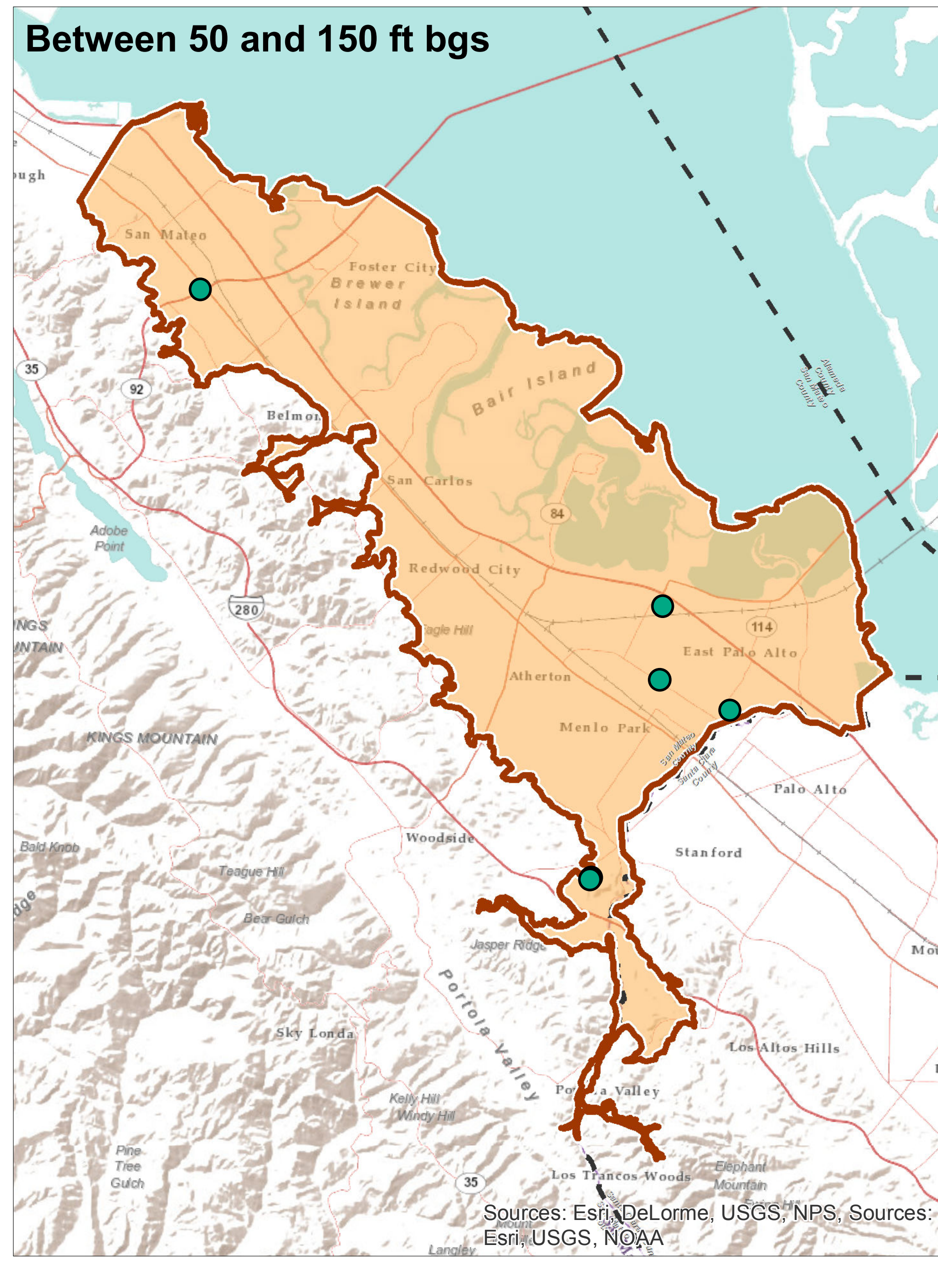
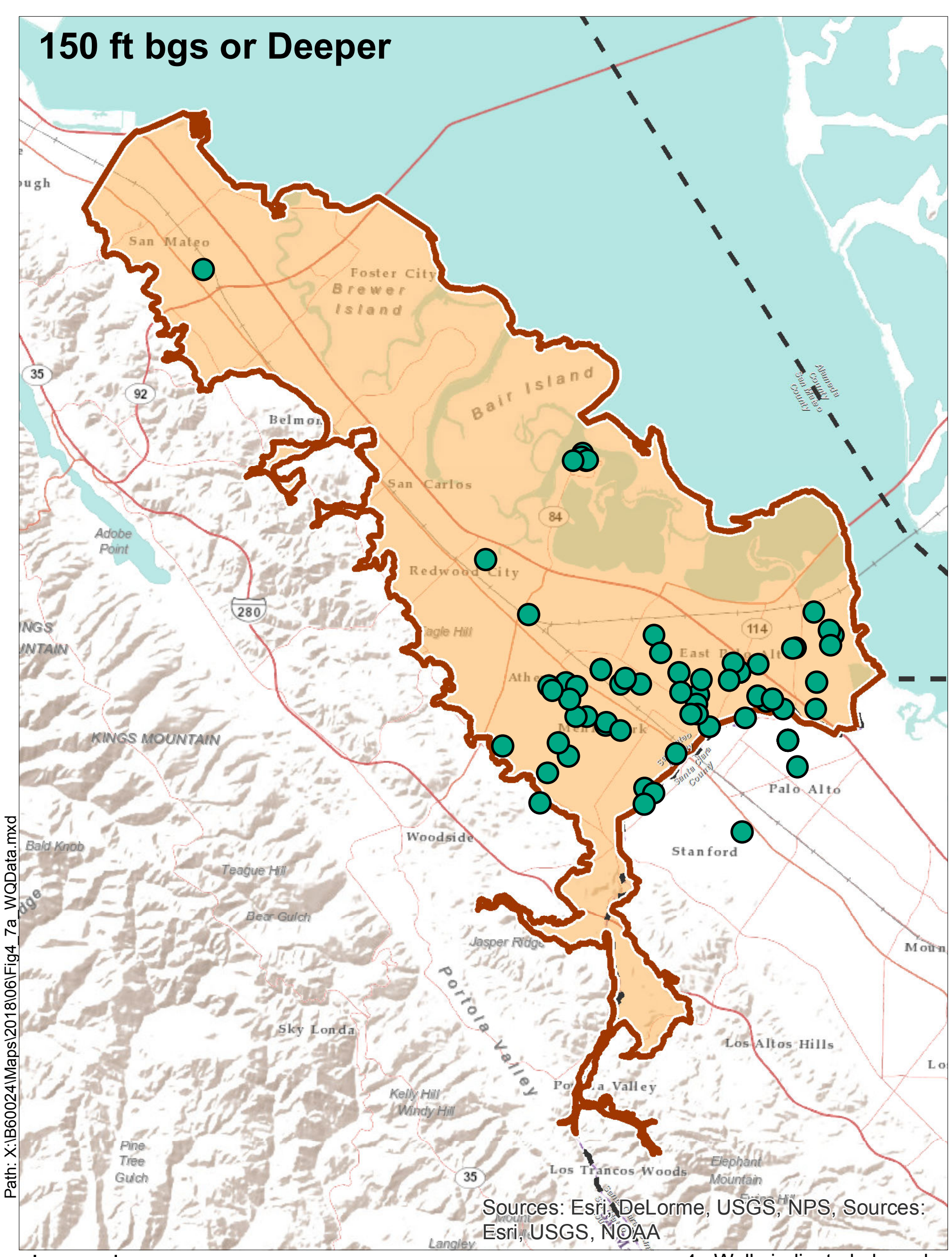
Wells with Available Chemistry Data

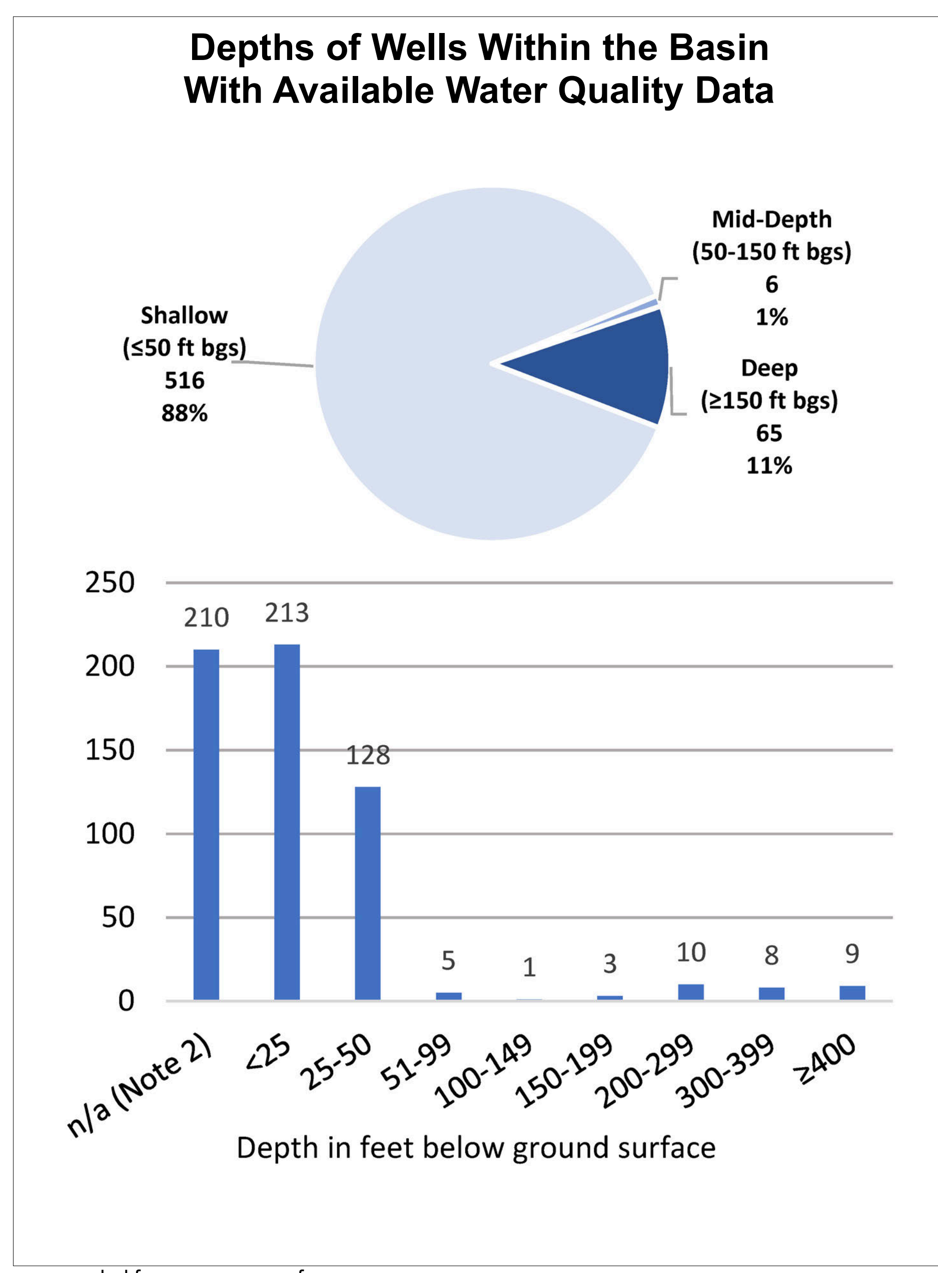
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 4-6









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Legend

San Mateo Plain Subbasin

County Boundary

Well Location

Abbreviations

ft bgs = feet below ground surface

n/a = not available

Notes

1. All locations are approximate.
2. Well depth category (i.e., shallow, mid-depth, or deep) is assumed based on well type for locations where depth is not coded in the Project database.
3. The charts above summarize information for locations within the Basin only.
4. Wells indicated above have been sampled for one or more of the following water quality parameters: arsenic, bicarbonate, boron, calcium, carbonate, chloride, chromium, iron, magnesium, manganese, nitrate (as nitrogen or nitrate), potassium, sodium, sulfate, and/or total dissolved solids (TDS).

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.

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HYDROFOCUS INC. Solutions for Land and Water Resources

Wells Sampled for Selected Water Quality Parameters

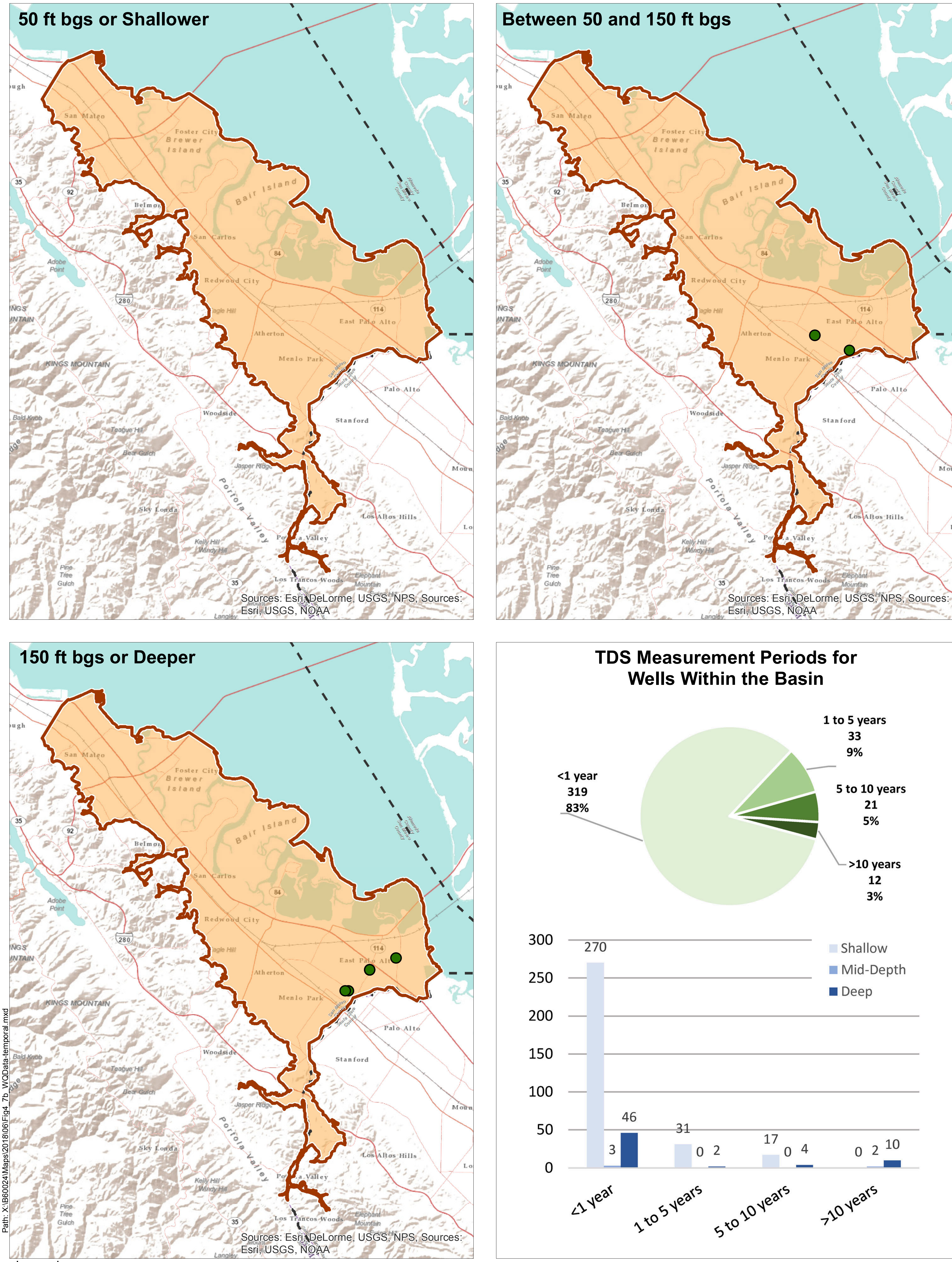
San Mateo Plain Groundwater Subbasin

San Mateo County, California

June 2018

EKI B60024.00

Figure 4-7a



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Legend

- San Mateo Plain Subbasin
- County Boundary
- Well Location

Abbreviations

ft bgs = feet below ground surface
TDS = total dissolved solids

Notes

1. All locations are approximate.
2. Well depth category (i.e., shallow, mid-depth, or deep) is assumed based on well type for locations where depth is not coded in the Project database.
3. The charts above summarize information for locations within the Basin only.
4. TDS sampling time period is based on the first and last available sample. Wells were not necessarily monitored on a consistent basis throughout this time period.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.

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Wells Sampled for TDS Spanning a Greater than 10-Year Period

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 4-7b

5.0 BASIN WATER QUALITY EVALUATION

This section provides an overview of groundwater quality conditions within the Basin, including Basin-wide distributions of TDS, chloride, nitrate, and other selected parameters, plus a focused discussion of water types/sources and factors affecting groundwater quality. Information is also provided regarding the hazardous waste release sites that have been identified in the Basin and other potential risks to Basin water quality.

5.1 Spatial Distribution, Vertical Distribution, and Trends of Key Parameters

As documented in Section 4.0, the Project database incorporates water quality data from multiple sources, including SWRCB and RWQCB online databases (e.g., Geotracker), San Mateo County records, and previous studies. Data from production wells are directly relevant to the suitability of local groundwater for municipal use, while data from monitoring wells (most of which are shallow) are useful in defining shallow groundwater quality that could affect deep groundwater. Data from existing monitoring wells also can be used to assess the suitability of these monitoring wells for basin management purposes, for example, as sentry wells for seawater intrusion.

For the inorganic groundwater quality evaluations, maps of shallow and deep well concentrations and time-concentration charts of selected general parameters were developed using available data. For the geochemical and water type evaluations (Section 5.2), a subset of analytical results was evaluated using selected water quality samples with a complete set of anions and cations and with selected trace elements.

5.1.1 Total Dissolved Solids

TDS (the sum total concentration of dissolved anions and cations in water) is used as a general representation of inorganic water quality. Measured TDS concentrations reflect the effects of many water quality influences, including dissolution of elements in soils and aquifer materials as recharged surface water passes through these materials, surface sources (e.g., nitrate from fertilizer), and subsurface sources (e.g., mixing with deep groundwater sources). For drinking water, the "recommended" secondary maximum contaminant level (SMCL) for TDS is 500 milligrams per liter (mg/L), the "upper" SMCL is 1,000 mg/L and the "short term" SMCL is 1,500 mg/L (see Table 64449-B of California Regulations Related to Drinking Water). An SMCL is a drinking water standard based on aesthetics, such as taste and odor, whereas a primary maximum contaminant level (PMCL) is a drinking water standard based on health concerns.

Figure 5-1 provides a map illustrating TDS concentrations across the Basin. The map presents the maximum historical concentration for wells with TDS results.[11] The TDS data for shallow wells (generally less than 50 feet in total depth) cover the southern, central, and northern portions of the Basin, while TDS data for deep wells are essentially limited to wells in the southern portion of the Basin.

In general, deep wells are characterized by lower maximum TDS concentrations than shallower wells. Many of the shallow wells have maxima exceeding the TDS SMCL, with several wells exceeding 2,000 mg/L. Only a few deep wells produce water with TDS concentrations exceeding the SMCL.

Figure 5-1 also shows time-concentration graphs for two sets of wells with relatively long, complete records, the PAPMWC and O'Connor Tract CWC wells in the southern portion of the Basin. The PAPMWC wells are characterized by current TDS concentrations between approximately 400 and 600 mg/L. The TDS trends for the PAPMWC wells are shown from as early as 1985, and generally are stable. The O'Connor Tract CWC wells generally are characterized by TDS concentrations between 400 and 500 mg/L and also exhibit stable trends. TDS time-concentration data for other wells in the Basin are limited.

The PAPMWC wells are located in relatively close proximity to one another but screened over different depth intervals. This provides an opportunity to consider the vertical distribution of TDS. In brief, these wells are progressively screened in deeper zones with increasing well numbers: well 002 at 60 to 67 feet bgs, 003 at 194 to 285 feet bgs, 004 at 219 to 279 feet bgs, 005 at 247 to 251 feet bgs, and 006 at 248-440 feet bgs. As shown on **Figure 5-1**, the generally lower TDS concentrations are associated with the deeper wells. This relationship is not shown in the O'Connor Tract CWC wells, which have a wide range of multiple screen depths.

5.1.2 Chloride

Along with TDS, chloride concentrations often are used as an indicator of overall groundwater salinity, and of seawater intrusion, for example from San Francisco Bay.[12] The SMCL for chloride is 250 mg/L.

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[11] In some areas, wells are close together and a high maximum concentration value may plot over a smaller value and obscure it.

[12] An important water quality issue is the potential for seawater intrusion, which has occurred historically in the southern portion of the Basin. In brief, seawater intrusion occurred in the early 20th century in the Palo Alto and East Palo Alto areas. Using 100 mg/L chloride concentrations as an indicator, seawater intrusion was mapped as far inland as the vicinity of El Camino Real (see Iwamura, 1980). Importation of Hetch Hetchy supplies allowed reduction of local groundwater pumping and restoration of groundwater levels that reversed the seawater intrusion. Later investigators indicated lingering effects of the degradation (for example, in eastern Atherton; see Metzger and Fio, 1997) and also distinguished local sediments as another potential source of high chloride concentration in groundwater (Metzger, 2002).

Figure 5-2 is a map showing chloride concentrations across the Basin; the distribution is similar to the TDS concentration distribution because chloride typically constitutes a significant portion of TDS. **Figure 5-2** also shows time-concentration plots. Chloride concentrations in the O'Connor Tract CWC and PAPMWC wells have relatively stable trends, with concentrations generally less than 100 mg/L chloride. Similar to TDS, the PAPMWC deepest well (006) has the lowest chloride concentration, generally below 50 mg/L.

Time-concentration data also are available from several monitoring well groups located on contamination sites or adjacent to San Francisco Bay and the salt ponds. Chloride data were examined to ascertain evidence for seawater intrusion. The plots are not shown here, because the data are highly variable, represent specific local conditions, and may not be appropriate indicators for regional groundwater conditions. Variability noted in the data includes extremely high chloride concentrations (possibly indicating salt pond brine), markedly different trends in adjacent wells, and rapid and dramatic concentration changes. In considering the use of existing monitoring wells in a regional groundwater monitoring program, the specific site conditions, individual wells, sampling methods/protocols, and available data would need to be evaluated.

Potential use of existing monitoring wells for basin management monitoring (e.g., sentry wells) is possible. In fact, monitoring well RP W-101, located in a strategic near-shore location in East Palo Alto, has been included as a sentry well for the East Palo Alto groundwater monitoring program, which is being implemented as part of its Groundwater Management Plan (GWMP). While this well has been sampled only recently according to monitoring program protocols, the data so far appear representative and accurate.

5.1.3 Nitrate

Elevated nitrate in groundwater typically derives from surface or near-surface sources, including fertilizer use from historical agriculture or from landscaping, and wastewater sources such as historical septic tanks and leaking sewers. Natural nitrate (as NO_3) background concentrations are generally considered to be 10 mg/L or less (Todd, 1980); the PMCL for nitrate as NO_3 is 45 mg/L.

Figure 5-3 illustrates nitrate concentrations across the Basin. There are several wells with elevated nitrate in the Atherton area; one is relatively shallow and two are deep. While recognizing that the data are not evenly distributed (potentially suggesting patterns where none exist), the elevated nitrate apparently coincides with the verdant and dense landscaping visible on the aerial photograph base map. This suggests potential intensive fertilization at the ground surface and the ability for water impacted by nitrate to percolate or migrate downward to deep zones.

Figure 5-3 also shows time concentration graphs for nitrate. The relatively deep O'Connor Tract CWC and PAPMWC wells have not been impacted by high levels of nitrate. The relatively low and steady nitrate concentrations in these wells suggest that the background concentration for area groundwater is around 5 mg/L.

5.1.4 Iron and Manganese

Iron and manganese are inorganic constituents in groundwater that derive primarily from geologic sources. They often are considered together because of their similar geochemical characteristics and occurrence in groundwater. Iron in groundwater can be attributed to minerals associated with iron oxyhydroxide coatings on sand and gravel and with iron-containing (ferruginous) clays (Parsons, et al. 2012). Elevated iron and manganese may occur when wells are screened in clay horizons (Todd, 1980). Moreover, elevated concentrations can result in similar problems, for example bacterial clogging of well screens and staining of plumbing and laundry. The SMCLs for iron and manganese are 0.3 mg/L and 0.05 mg/L, respectively.

Figure 5-4 shows the respective areal distributions of iron and manganese concentrations, which are similar. Most wells have iron and manganese concentrations exceeding the SMCL, suggesting that elevated iron and manganese concentrations may be ubiquitous in the Basin.

5.2 Groundwater Quality Parameters for Water Source Evaluation

This study included a focused review to identify general mineral water types and to evaluate potential water sources affecting groundwater quality. For this review, 14 wells were selected that have data from a recent sampling event with complete major cation and anion 'suites' necessary for water source evaluation and with available data on selected trace elements.

5.2.1 Summary of Major Cation and Ion Data

Table 5-1 is a summary of the recent analyses with complete major cations and anions and with selected trace ions for groundwater samples from five monitoring wells and nine municipal wells in the Basin. **Figure 5-5** shows the locations of the wells. Four of the five monitoring wells (MW-6B-10 and MW-FE2B-10; MW-2 and MW-4) are located at two sites east of the Bayshore Highway near the salt flats, and RP W-101 is a monitoring well for the Rhone-Poulenc site located near the East Palo Alto Baylands Nature Preserve. The nine municipal wells are located in south Menlo Park and East Palo Alto. Of these, two wells are owned by O'Connor Tract CWC and five are owned by PAPMWC. The Gloria Way well is an East Palo Alto production well currently undergoing rehabilitation and reactivation, and Pad D is an East Palo Alto test well.

The database was queried for water quality records including all major cations (calcium, magnesium, sodium, and potassium) and major anions (bicarbonate and carbonate,[13] chloride,

[13] At typical near-neutral values of pH, dissolved bicarbonate is the dominant ion; carbonate is listed for completeness.

sulfate, and nitrate). These samples also were selected for available data on trace ions including arsenic, boron, total chromium, iron, manganese, and phosphorous/phosphate. Values for TDS are also listed. All analytes were either reported in mg/L or parts per million (ppm), or in micrograms per liter (µg/L) or parts per billion (ppb) converted to mg/L. Where nitrate was reported as nitrate-nitrogen (N), it was recalculated as nitrate-NO_3.

The upper portion of **Table 5-1** presents the most recent complete ion analyses. As indicated, the recent samples range from 2004 to 2016; 87 additional historical records with complete major ions in the database were evaluated to discern factors affecting groundwater quality and trends. Regulatory drinking water standards are provided for comparison (Marshack, 2015) including California and Federal PMCLs and SMCLs. Values for groundwater shown in bold are at or exceed a regulatory limit for drinking water.

The lower portion of **Table 5-1** shows water quality data for representative surface water samples which allows for comparison of surface water and groundwater water quality. The results of this comparison are discussed in the Section 5.2.2 below. The water quality data include San Francisquito Creek surface water (Metzger, 2002), which can be considered representative of local stream recharge and to a degree, local rainfall recharge. Hetch Hetchy imported surface water supply is provided as a five-year average. This water can represent recharge by leakage from water supply pipelines and to a lesser degree, landscape irrigation returns, which are altered by precipitation/dissolution processes in the unsaturated zone, including interaction with soil amendments and fertilizers. Averaged San Francisco Bay water samples represent salt water. While estimated in the water balance to be a minor recharge source through leaking sewers, local wastewater effluent also is represented.

Lastly, it must be recognized that some sediments underlying the Basin, most notably fine-grained layers of marine origin, likely contain some connate water that was incorporated at the time of deposition and is being released to pumping wells, causing elevated TDS and chloride. This phenomenon was noted previously in the United States Geological Survey (USGS) study of San Francisquito Creek (Metzger, 2002).

5.2.2 Trilinear and Schoeller Diagrams

Groundwater quality was evaluated using geochemical plotting techniques to discern groundwater similarities and potential sources. In general, the Trilinear and Schoeller diagrams prepared for this study show that groundwater quality reflects the varying influence and interaction of groundwater sources of recharge (including local stream and rainfall recharge, Hetch Hetchy water and return flow, and near-shore seawater intrusion in the shallow zone), plus the potential influence of groundwater released from local sediments. In addition, as part of a Basin-wide monitoring program, such diagrams can assist with tracking and understanding potential changes to groundwater conditions, such as seawater intrusion. Each diagram is described below, along with initial observations.

Figure 5-6 is a Trilinear (Piper) diagram used to compare and classify water types. Cation (calcium, magnesium, and sodium + potassium) concentrations in milliequivalents per liter (meq/L) are expressed as a percentage of total cations on the left side triangle and anion (carbonate + bicarbonate, sulfate, chloride + nitrate) concentrations in meq/L are plotted on the right side triangle. The cation-anion plot is then projected onto a central diamond-shaped area, which combines both cation and anion distribution. Water samples with similar geochemistry will generally group together, allowing identification of sources of recharge. The Trilinear diagram includes plotted points for the fourteen wells and four surface water sources provided in **Table 5-1**.

Focusing on the diamond-shaped portion of **Figure 5-6**, salient features of the Trilinear diagram include the following:

- Most of the groundwater points are loosely grouped in the center of the diamond and in the vicinity of the points for San Francisquito Creek, Hetch Hetchy, and wastewater effluent; most do not plot closely to the point representing San Francisco Bay water.
- The points for groundwater wells PAPMWC—006 and the Pad D Test well plot together.
- The Gloria Way Well is more saline than most wells.
- Monitoring well MW-6B-10 is relatively saline and MW-FE2B-10, a near-shore well with high TDS, plots close to San Francisco Bay.

For context, the USGS also prepared a Trilinear diagram for its study of San Francisquito Creek (Metzger, 2002). This study involved defining groundwater recharge sources, including (1) San Francisquito Creek and Lake Lagunita, and (2) San Francisco Bay water. Metzger also included residential tap water (imported water from Hetch Hetchy) that was used to represent residential irrigation. Using somewhat different wells than those used in this study, the USGS Trilinear diagram separated water sources into three distinctive groups: (1) samples similar to surface water, (2) samples with increasing bicarbonate and decreasing sulfate concentration, and (3) samples from deep aquifers affected by cation exchange reactions. Using the Trilinear diagram and other analyses, Metzger arrived at findings paraphrased below:

- Groundwater from the upper zone of the deep aquifer (and away from the Bay) is similar to surface water samples. The quality is characterized by combinations of groundwater from the shallow aquifer and lower zone of the deep aquifer.
- Chloride may be elevated in shallow groundwater near San Francisco Bay where extensive deposits of Bay Mud occur. Bay water intrusion may be the source of elevated chloride in some wells.
- Away (inland) from the Bay, shallow groundwater may resemble surface water because of short infiltration times.
- In the deep aquifer zones, marine sediments are present in partly consolidated bedrock underlying the deep aquifer. In these zones, mineral dissolution processes may be a

source of elevated chloride (as opposed to San Francisco Bay water intrusion). This groundwater also would be noticeably affected by cation exchange in clays, e.g., calcium for sodium. Metzger confirmed this with trace elements (boron, bromide, and iodide) that are not routinely included in water quality analyses.

Figures 5-7a and **5-7b** are Schoeller (water source) diagrams, which present the major cations and anions in terms of meq/L as concentrations on a logarithmic scale. (Trilinear diagrams show solutes that are normalized as *percentages* of meq/L). Schoeller diagrams can effectively reveal water sources in situations where groundwater solute sources are indistinguishable from surface water solute sources except at very high concentration levels. **Figure 5-7a** shows plots only for potential water sources, including the high-concentration signature of San Francisco Bay water, low-concentration signature of Hetch Hetchy water, and intermediate San Francisquito Creek and wastewater effluent signatures. The wastewater signature indicates higher concentrations than Hetch Hetchy water (its predominant source prior to use) with relatively higher sodium and chloride, as is expected from municipal use. **Figure 5-7b** shows the water source signatures plus the plots for groundwater from the 14 wells. Most of the groundwater plots are relatively bunched, indicating relatively similar, and mixed, sources of recharge. The following are notable on **Figure 5-7b**:

- The plots for groundwater samples from production wells are clustered indicating similar sources.
- Samples from RP W-101, Gloria Way and PAPMWC 006 wells have signatures with somewhat elevated chloride concentrations, suggesting chloride derived from local sediments.
- The plot of San Francisco Bay water is mirrored by the water source signature of monitoring well MW-FE2B-10, a well with elevated TDS (see **Table 5-1**) and a saline plot on the Trilinear, indicating that it is influenced by salt water.
- The plot of monitoring well MW-6B-10 tracks with other groundwater samples.

The evaluation of groundwater quality data using Trilinear and Schoeller diagrams did not completely explain groundwater sources for each well. Nonetheless, the evaluation indicates that groundwater in production wells is a combination of water from various sources, including rainfall and streamflow, returns from Hetch Hetchy and groundwater with relatively high chloride that was incorporated at the time of sedimentary deposition. Saltwater intrusion appears to have affected monitoring well MW-FE2B-10, which is located near the salt flats.

In addition to the above, Trilinear and Schoeller diagrams were prepared to identify any time trends for wells with a series of complete analyses of major cations and anions over time. Time trends could illustrate, for example, progressive seawater intrusion. The evaluation conducted for this study showed that available data for specific wells tends to cluster, revealing no significant variations over time.

5.2.3 Other Selected Groundwater Quality Parameters

Additional groundwater quality parameters of interest include arsenic, boron, chromium, and phosphorous/phosphate. Available data are relatively sparse and unevenly distributed; nonetheless, some general observations can be made.

Arsenic, which has a PMCL of 0.01 mg/L, warrants sampling and analysis if local groundwater is developed for drinking water purposes. The database includes samples from over 100 wells (see Section 4.0) that have been analyzed for arsenic; these were reviewed in terms of concentrations relative to the PMCL and geographic distribution. The review indicated that elevated arsenic is associated with contamination sites; data from drinking water wells indicated that arsenic concentrations were below detection limits or the current PMCL. If elevated arsenic were naturally-occurring, it would be detected in association with elevated iron (O'Day, 2006; Welch, et al., 2006); this review did not establish such a pattern for the Basin.

Boron does not have an established drinking water standard, but has a California notification level of 1.0 mg/L because of potential adverse effects to pregnant women and unborn children. Boron also is significant to landscape irrigation use of groundwater, given that some plants are sensitive to as little as 0.5 mg/L. Samples analyzed for boron are available from about 40 wells in the database, and reflect samples from wells in the San Francisquito Cone. All but a few samples are lower than 0.35 mg/L, indicating no significant issue.

Total chromium is a potential indicator of chromium-VI, a potential carcinogen. The Federal PMCL for total chromium is 0.5 mg/L and the California PMCL for chromium-VI is 0.01 mg/L. Total chromium analyses are available for about 100 shallow and deep wells throughout the Basin. Review of the available data suggests that elevated chromium is associated with contamination sites. In deep wells, total chromium concentrations since 1988 have been low (less than 0.005 mg/L) or not detected. Available data indicate that chromium-VI concentrations are non-detect or below the PMCL at drinking water supply wells.

Phosphorous/phosphate is an indicator of excessive fertilizer use and wastewater impacts. Common in detergents, it is frequently a component of sewage (Hem, 1989). Phosphorous/phosphate has implications mostly for surface water habitat. Naturally occurring phosphates are not very mobile in soil (Hem, 1989) and typically occur in groundwater in only trace amounts. Very few analyses are available for Basin groundwater, and most represent shallow wells (e.g., at gas stations).

5.3 Point-Source Contamination

While regulations exist under federal, state, and local laws that govern the transport, handling, storage, and use of chemicals, historical practices have in some cases resulted in the release of chemicals of concern (COCs) into the environment. These occurrences of groundwater contamination are known as point sources and are typically related to certain overlying commercial or industrial land uses. Most common among these point source contamination sites are current or former gasoline service stations which contain(ed) underground storage tanks (USTs) for liquid hydrocarbon fuels that have leaked their contents into the surrounding soil and underlying groundwater. Other land uses that have, in some instances, resulted in contamination impacts to underlying groundwater include dry cleaners, industrial facilities using chemical solvents (ranging from auto body shops to semiconductor factories), and landfills. Leaks from sanitary sewer pipes or septic tanks can also result in groundwater contamination.

Point source contamination sites that have been identified through field investigation, often spurred by reports of a release or in the context of due diligence investigations during real property transactions or at the request of the RWQCB, often become "regulated sites," whose further investigation and remediation is conducted under the oversight of one or more agencies. These agencies include the RWQCB, the California Environmental Protection Agency Department of Toxic Substances Control (DTSC), the USEPA or the San Mateo County Environmental Health Department under its Groundwater Protection Program. Typically, following initial discovery, site investigations are conducted to assess the nature and extent of the impact, and to inform the development and implementation of remediation plans, if needed. Investigations often entail installation of monitoring points/wells, collection and analysis of soil, groundwater, and/or soil vapor samples, and application of hydrogeologic knowledge to develop a conceptual model of the particular release and contamination. Remedial efforts can include excavation of contaminated soil, extraction, and treatment of contaminant mass from the subsurface using groundwater and/or soil vapor extraction wells, and in situ remedies involving injection of remediation compounds to affect/promote degradation of the contaminants into less harmful substances. Additionally, engineering and/or institutional land use controls may be implemented at the site to protect site occupants or workers from exposure to contaminants. Sites that have been adequately remediated to the point where they no longer pose a threat to public health or the beneficial use(s) of the groundwater resource may be "closed" by the oversight agency either with or without ongoing land use controls.

In the Basin, a total of 781 regulated sites have been identified in the SWRCB's GeoTracker system. Of these, 156 are currently open (meaning active remediation or monitoring is still occurring) and 633 are closed. The distribution of sites by type within the subbasin is shown in **Table 5-3**.

As shown, the much higher proportion of the Geotracker-listed Cleanup Program Sites that remain open (i.e., 114 out of 206 sites, or 55 percent) compared to LUST Cleanup Sites that remain open (i.e., 38 out of 541 sites, or 6.5 percent) illustrates the relative difficulty in remediating the Cleanup Program Sites, which typically include chlorinated solvents, compared to the LUST Cleanup Sites, which generally involve hydrocarbon contamination.

Table 5-3. Summary of Geotracker-Listed Point Source Contamination Sites by Type and Open/Closed Status

Site Type	Open Sites	Closed Sites	Total
Cleanup Program Sites	114	92	206
Leaking Underground Storage Tank (LUST) Cleanup Sites	38	541	579
Land Disposal Sites	4	--	4
Total	**156**	**633**	**784**

Figure 5-8a shows the distribution of open sites within the Basin that have groundwater listed as an affected media, grouped by case type (i.e., Cleanup Program Site, LUST Cleanup Site, or Land Disposal Site). **Figure 5-8b** shows the same set of sites, grouped by contaminant class (i.e., metals, petroleum hydrocarbons, chlorinated volatile organic compounds, or inorganics). Both figures show that most of these sites are located in the narrow band between Highway 101 and El Camino Real, coincident with current and historical commercial and industrial land uses. The distribution of open sites by City is summarized in **Table 5-4** below.

Table 5-4. Distribution of Open Sites by City

City	Number of Open Sites
Redwood City	45
San Mateo	38
San Carlos	27
Menlo Park	16
East Palo Alto	19
Belmont	7
Foster City	3
Burlingame	1
Portola Valley	0
Atherton	0
Hillsborough	0

Most point source contamination is released into the environment at the land surface or at relatively shallow depths within the subsurface. Downward gravity-driven migration through the vadose zone can cause contaminants to enter the saturated (groundwater) zone, from which point they may migrate along with the prevailing groundwater flow (advection), spread laterally and vertically due to pore-scale velocity variations (dispersion), diffuse into lower concentration zones (diffusion), sorb onto the solid aquifer matrix (sorption), and/or degrade by biotic or abiotic processes into other compounds (degradation). The fate of any given chemical released into the subsurface is controlled by chemical properties (e.g., density, solubility, soil/water/vapor partitioning coefficients) and site-specific hydrogeologic properties (e.g., groundwater levels and gradients, soil hydraulic properties, geochemical conditions, presence of fine-grained layers that could impede migration, etc.), as well as the size, duration, and timing of the release.

As discussed in subsequent sections, the geology of the Basin consists of alluvial fan and alluvial plain sediments that exhibit patterns of alternating fine- and coarse-grained deposits. The more permeable coarse-grained deposits tend to transmit water horizontally under the regional hydraulic gradients, while the less permeable fine-grained deposits tend to inhibit vertical groundwater flow. This anisotropy in permeability of the Basin sediments generally causes contaminant plumes to favor horizontal rather than vertical migration. Therefore, point source contamination originating at or near the land surface is generally limited in vertical extent to the upper one or two coarse-grained layers in the vicinity of the release site, rarely penetrating below depths of approximately 50 feet bgs.

Table 5-1
Available Recent Water Quality Data: Major and Trace Ions

Well Type	Well Database Identifier/Name		Well Screens feet bgs: Top	Well Screens feet bgs: Bottom	Sample Date	Cations: Calcium	Cations: Magnesium	Cations: Sodium	Cations: Potassium	Anions: Bicarbonate	Anions: Carbonate	Anions: Chloride	Anions: Sulfate	Anions: Nitrate as N	Anions: Nitrate as NO_3	Trace Ions: Arsenic	Trace Ions: Boron	Trace Ions: Chromium (total)	Trace Ions: Iron	Trace Ions: Manganese	Trace Ions: Phosphorus/ [Phosphate]	Total Dissolved Solids
						Concentrations in mg/L																
Monitoring	SL18322742_MW-6B-10		NA	NA	12/19/2006	19.8	19.3	97.8	11	44.7	NA	50.9	20.4	NA	13.7	NA	NA	NA	ND	ND	NA	246
Monitoring	SL18322742_MW-FE2B-10		NA	NA	12/19/2006	25.1	76.8	733	12.3	668	NA	**578**	174	NA	1.74	NA	NA	NA	ND	0.293	NA	**2,330**
Monitoring	T0608100661_MW-2		NA	NA	12/30/2014	130	100	330	70	670	NA	370	**510**	2.7	(11.95)	NA	NA	NA	**1.00**	NA	NA	**2,000**
Monitoring	T0608100661_MW-4		NA	NA	03/26/2014	30	10	13	1.8	46	NA	20	8.6	1.6	(7.08)	NA	NA	NA	**19.0**	NA	NA	180
Monitoring	RP W-101		158.3	178.3	04/21/2016	120	28	130	5.3	240	NA	380	29	NA	NA	NA	NA	NA	ND	**0.370**	NA	**2,300**
Municipal	4110019-001	O'Connor	NA	NA	11/24/2015	61	15	79	1.9	270	NA	98	62	3.6	(5.93)	ND	0.00024	NA	ND	**0.050**	NA	510
Municipal	4110019-002	O'Connor	NA	NA	11/24/2015	66	15	59	2	300	NA	54	55	(0.5)	2.2	ND	NA	ND	ND	**0.15**	NA	460
Municipal	4110020-002	PAPMWC	60	67	06/05/2012	120	29	54	1.5	335	NA	51	80	4.1	(18.94)	NA	0.00019	NA	ND	**0.069**	NA	557
Municipal	4110020-003	PAPMWC	194	285	09/03/2014	45	15	110	NA	229	NA	100	45	0.49	(2.17)	NA	0.18	NA	NA	NA	NA	445
Municipal	4110020-004	PAPMWC	NA	NA	11/24/2004	60	18	89	2.4	200	NA	95	57	6	(26.55)	ND	0.22	NA	0.15	ND	NA	470
Municipal	4110020-005	PAPMWC	219	279	06/05/2012	60	17	99	2.2	234	NA	79	52	4.8	(21.24)	ND	ND	NA	ND	ND	NA	439
Municipal	4110020-006	PAPMWC	247	251	09/08/2015	23	9.2	120	0.8	238	NA	64	32	NA	NA	NA	NA	NA	0.086	0.065	NA	375
Municipal	Gloria Way	City of East Palo Alto	258	323	04/08/2016	53	24	220	1.1	250	NA	340	31	NA	NA	NA	NA	NA	**1.20**	**0.180**	NA	840
Municipal	Pad D-Test Well	City of East Palo Alto	170	525	04/08/2016	12	4.9	120	ND	270	NA	44	16	NA	NA	NA	NA	NA	0.27	0.039	NA	380
Regulatory Drinking Water Requirements:						Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Carbonate	Chloride	Sulfate	Nitrate as N	Nitrate as NO_3	Arsenic	Boron	Chromium (total)	Iron	Manganese	Phosphorus/ Phosphate	Total Dissolved Solids
						Concentrations in mg/L																
						None	None	None	None	None	None	250: CS-R 500: CS-U	250: CS-R 500: CS-U	10: CP, EP	45: CP, EP	0.01: CP, EP	1.0: NL	0.05: CP	0.3: CS	0.05 CS	None	500: CS-R 1,000: CS-U
Site Designation	Site Name				Sample Date(s)	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Carbonate	Chloride	Sulfate	Nitrates as N	Nitrates as NO_3	Arsenic	Boron	Chromium (total)	Iron	Manganese	Phosphorus/ Phosphate	Total Dissolved Solids
						Concentrations in mg/L																
Surface Water	San Francisquito Creek				04/30/1997	74	31.75	44	2.25	265	217.5	54.5	123.5	NA	NA	NA	0.24	NA	<0.003	0.003	[0.04]	482
Surface Water	Hetch Hetchy Treated				2012-2016	6.45	1.70	8.30	0.50	28.80	NA	5.70	8.60	0.2	(28.79)	0.00059	0.037	0.00010	0.0424	0.0031	2.0	(77.18)
Surface Water	San Francisco Bay: Stations 24-30				04/11/196-05/18/2016	307.51	958.60	8,048.79	297.88	94.07	NA	14,448.4	2,024.70	NA	NA	0.002	3.63	0.006	1.07	0.054	NA	{26,230.97}
Surface Water	Effluent				2014-2015	26	10.5	75.5	NA	166*	NA	82	22*	NA	NA	NA	0.23	NA	NA	NA	8.05	433

Abbreviations:

"<" = less than
"bgs" = below ground surface
"mg/L" = milligrams per liter or parts per million (ppm).
"Monitoring well" = <50 feet bgs
"Municipal well" = >150 feet bgs
"NA" = not analyzed or data not available.
"ND" = not detected at analytical method limit.
"O'Connor" = O'Connor Tract Cooperative Water Company
"PAPMWC" = Palo Alto Park Mutual Water Company and City of East Palo Alto

Notes:

a) Nitrate reported as N recalculated as Nitrate-NO3 or if reported as NO3 recalculated as N: calculated values are in parentheses ( ). Values rounded to nearest 0.10 mg/L.
b) * Bicarbonate and sulfate estimated.
c) Values in brackets [ ] for phosphate analysis.
d) Values in brackets { } for calculated Total Dissolved Solids.
e) Values in bold (for wells only) are at or exceed a regulatory limit for drinking water.
f) Regulatory Requirements: CP = California (CA) Primary Maximum Contaminant Level (MCL); CS = CA Secondary MCL; CS-R = CA Recommended Secondary MCL; CS-U = CA Upper Secondary MCL;
NL = CA Notification Level; EP = U.S. EPA Primary MCL; EHA = U.S. EPA Health Advisory Level

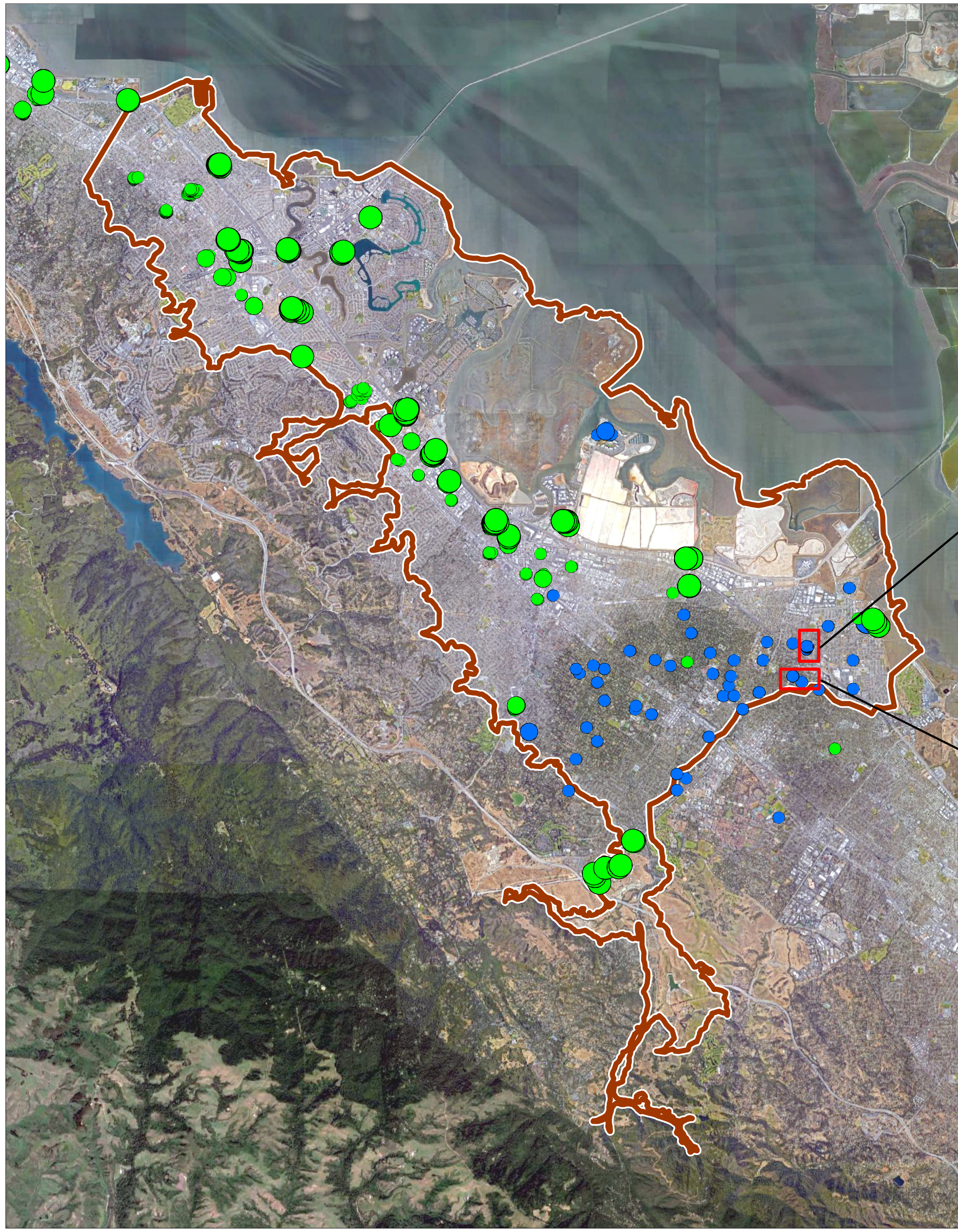
Sources:

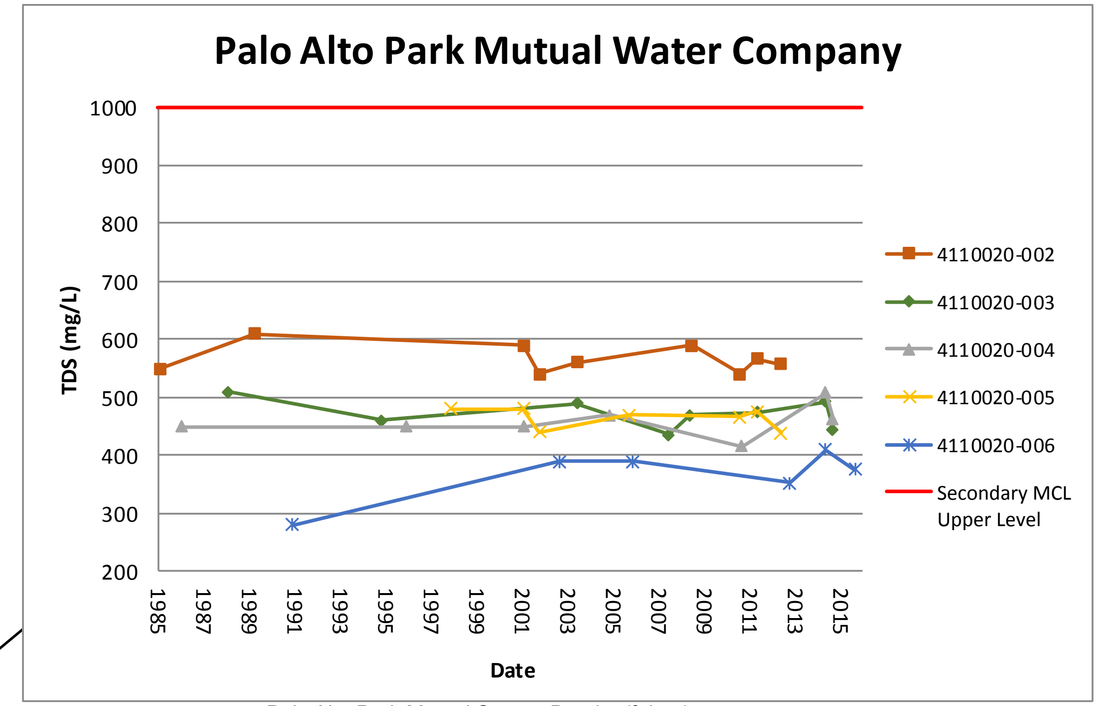
Wells: SMP well database
Surface Water: Hetch-Hetchy Reservoir treated water 5 year average from SFPUC data: Dr. Jean Debroux, Kennedy Jenks Consultants written communication.
San Francisco Bay average salinity data: USGS (2016); major ions from Hem (1989) and Murray (2004). Trace element data from SFEI&ASC (2016). Effluent data from RMC (2015).
San Francisquito Creek surface water data for upper to lower creek four station average from Metzger (2002).
Regulatory Requirements: Marshack (2015).

Table 5-2
Cation-Anion Balance for Water Quality Analyses

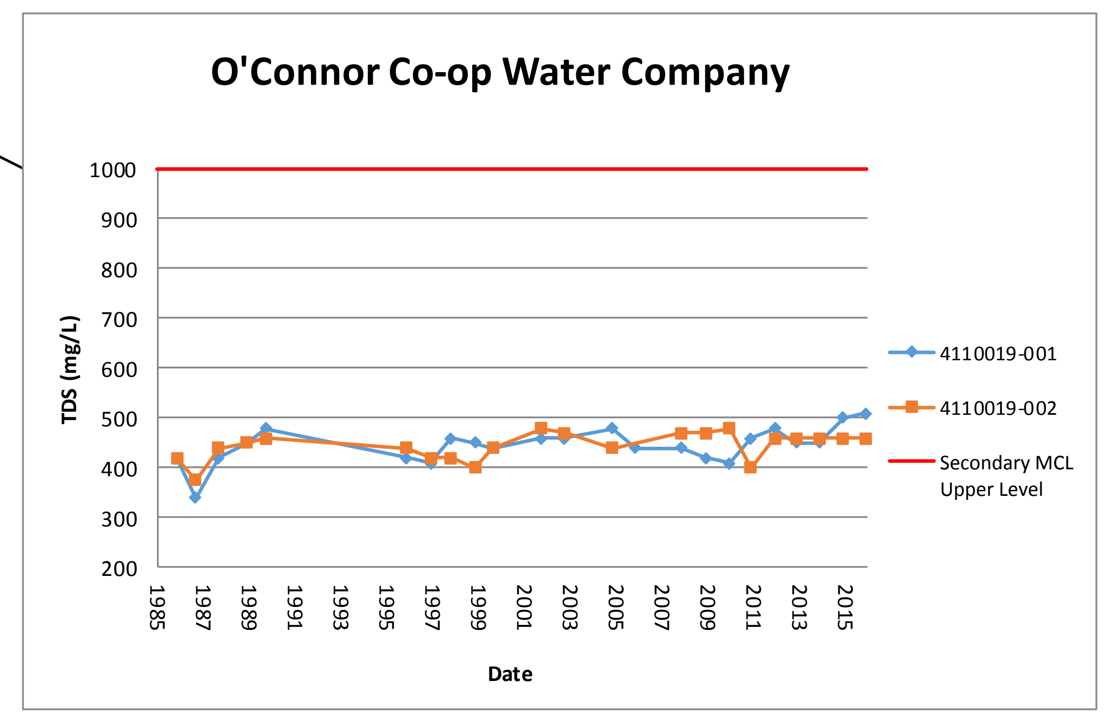
Well Type	Well Database Identifier/Name		% Balance (Error)
Monitoring	SL18322742_MW-6B-10		43.30*
Monitoring	SL18322742_MFE2B10		12.55*
Monitoring	T0608100661_MW2		–2.17
Monitoring	T0608100661_MW4		29.06*
Monitoring	RP-W-101		-3.96
Municipal	4110019-001	O'Connor	-5.90
Municipal	4110019-002		-3.18
Municipal	4110020-002	PAPMWC	9.54
Municipal	4110020-003		4.85
Municipal	4110020-004		5.59
Municipal	4110020-005		7.80
Municipal	4110020-006		5.75
Municipal	Gloria Way		-0.23
Municipal	Pad D		1.91
Site Designation	**Site Name**		**% Balance (Error)**
Surface Water	San Francisquito Creek		2.80
Surface Water	Hetch-Hetchy Treated		-2.40
Surface Water	San Francisco Bay		0.19
Surface Water	Effluent		-2.10

Notes:
* Exceeds recommended balance error of ±10 percent; based on Hem (1989) and Hounslow (1995).





Palo Alto Park Mutual Screen Depths (ft bgs)
4110020-002: 60-67
4110020-003: 194-195, 219-235, 249-257, 269-285
4110020-004: 219-279
4110020-005: 247-251
4110020-006: 248-260, 290-300, 340-366, 378-388, 424-440



O'Connor Co-op Water Company Screen Depths (ft bgs)
4110019-001: 181-372, 396-489, 508-532
4110019-002: 72-90, 172-178, 184-200, 217-223, 233-237, 242-245, 252-265, 282-291

0 2 4
Miles

N

Legend

Historical Maximum TDS Concentration (mg/L)

- Shallow Well, <1000
- Shallow Well, 1000-2000
- Shallow Well, >2000
- Deep Well, <1000
- Deep Well, 1000-2000
- Deep Well, >2000
- San Mateo Plain Basin

Abbreviations:
TDS: Total Dissolved Solids
MCL: Maximum Contaminant Level
mg/L: milligrams per liter

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TDS in Groundwater

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 5-1

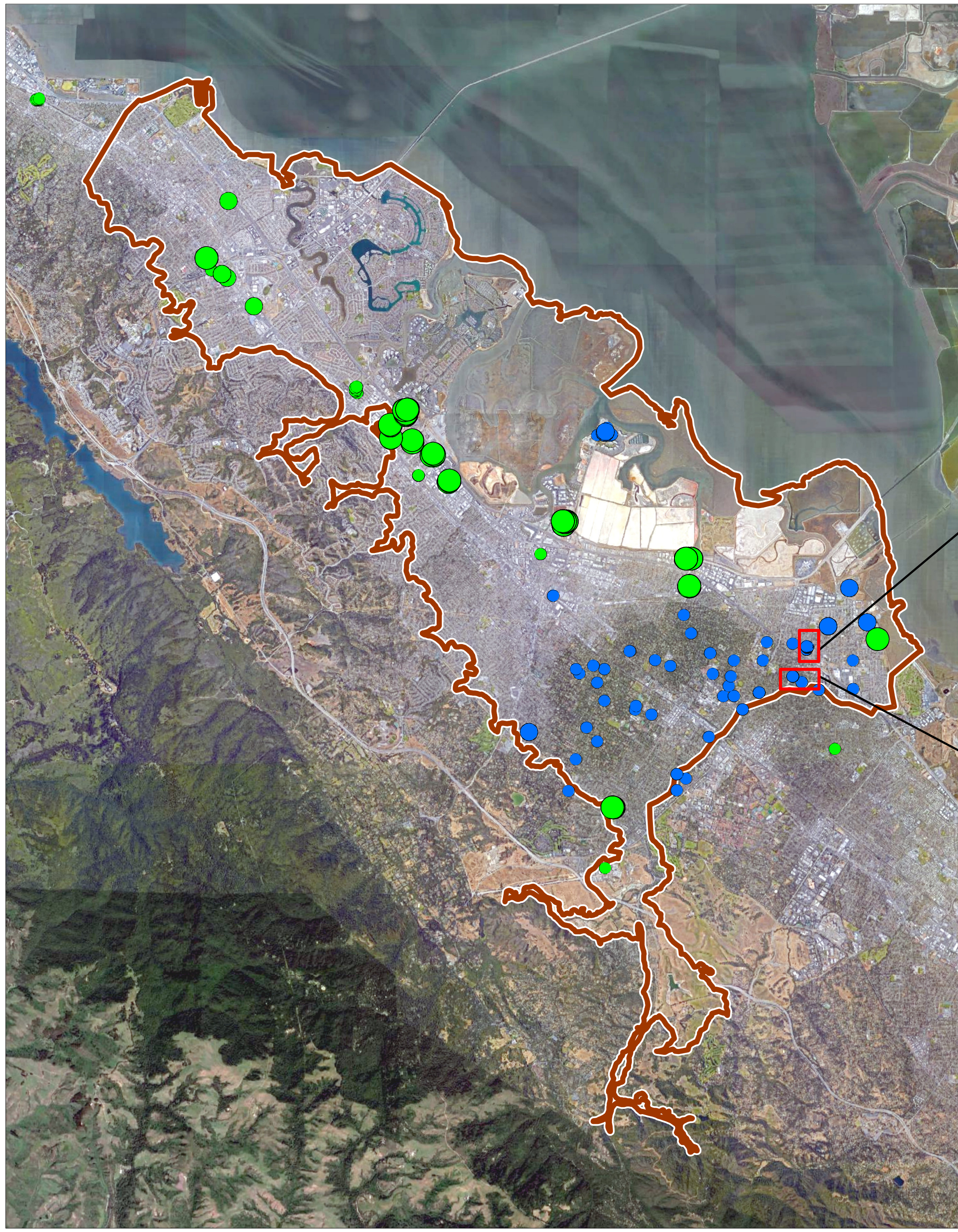
0 2 4
Miles

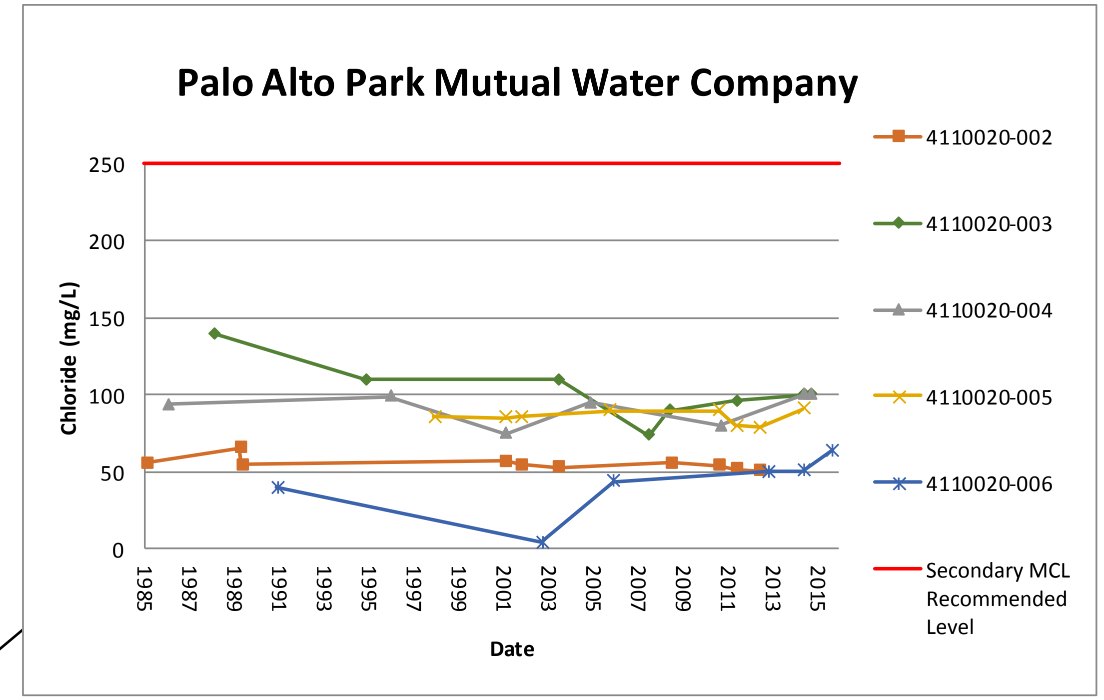
Legend

Historical Maximum Chloride Concentration (mg/L)

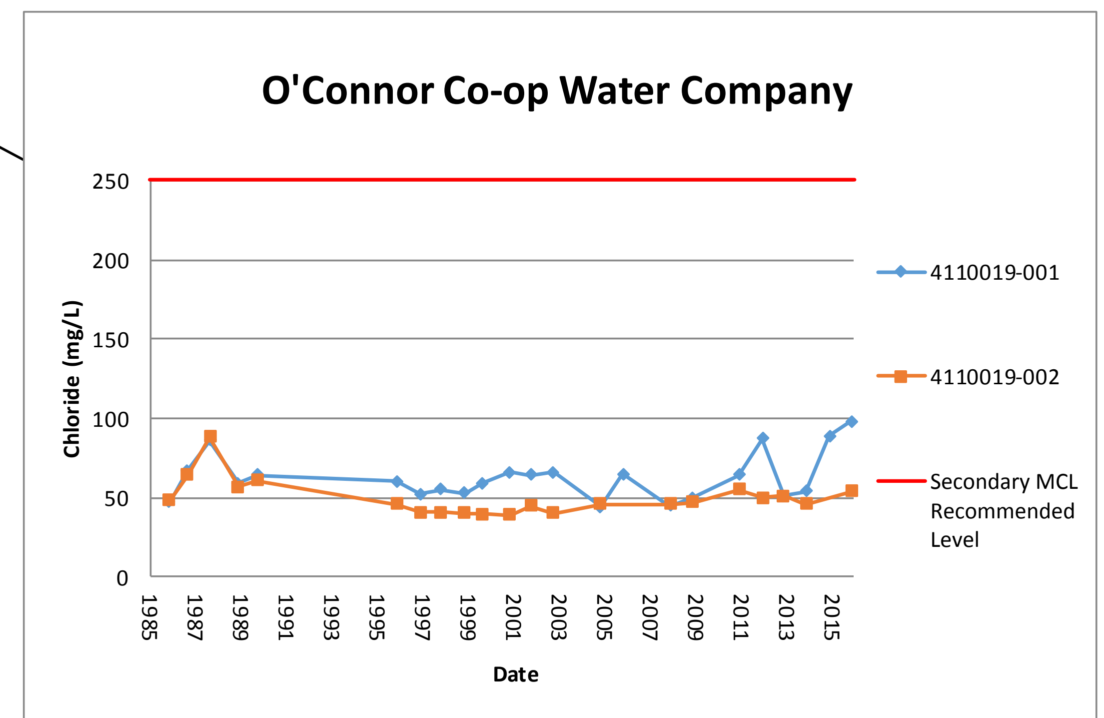
- Shallow Well, <250
- Shallow Well, 250-500
- Shallow Well >500
- Deep Well, <250
- Deep Well, 250-500
- Deep Well, >500
- San Mateo Plain Basin

Abbreviations:
MCL: Maximum Contaminant Level
mg/L: milligrams per liter





Palo Alto Park Mutual Screen Depths (ft bgs)
4110020-002: 60-67
4110020-003: 194-195, 219-235, 249-257, 269-285
4110020-004: 219-279
4110020-005: 247-251
4110020-006: 248-260, 290-300, 340-366, 378-388, 424-440



O'Connor Co-op Water Company Screen Depths (ft bgs)
4110019-001: 181-372, 396-489, 508-532
4110019-002: 72-90, 172-178, 184-200, 217-223, 233-237, 242-245, 252-265, 282-291

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Chloride in Groundwater

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 5-2

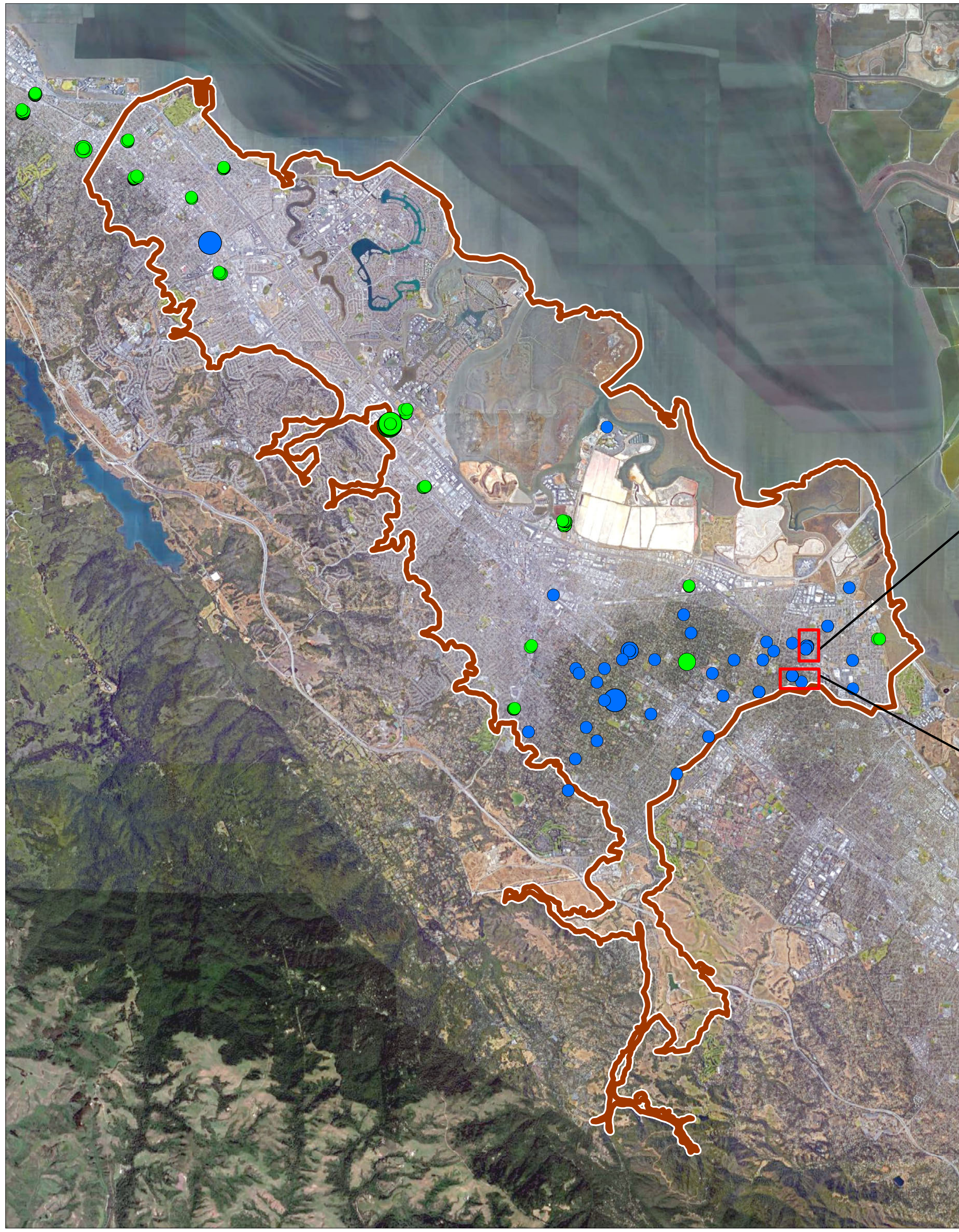
Legend

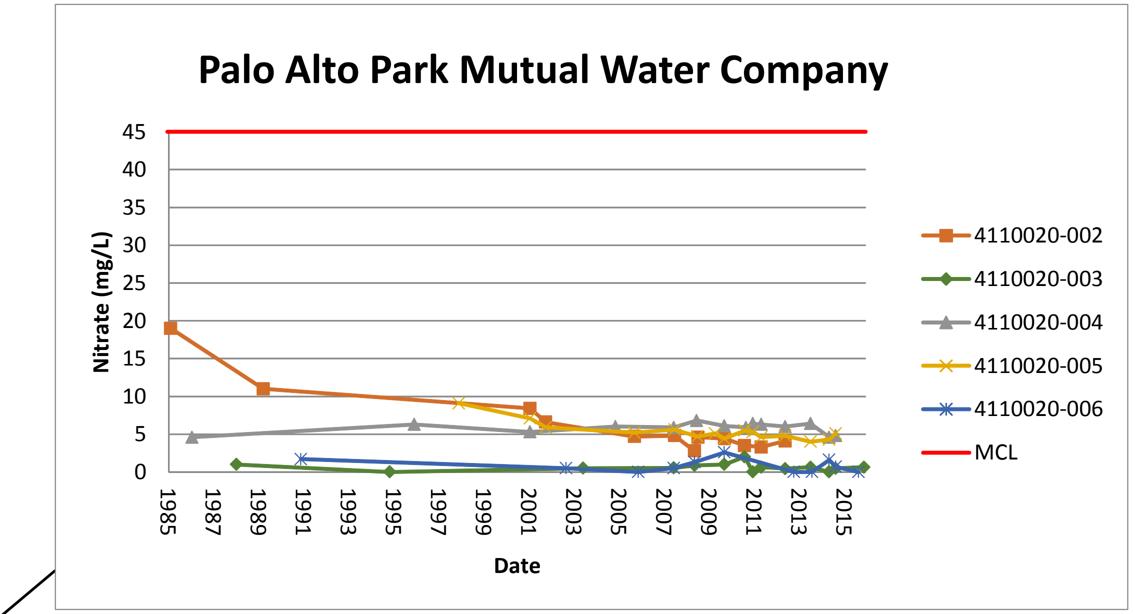
Historical Maximum Nitrate as NO3 Concentration (mg/L)

- Shallow Well, <45
- Shallow Well, 45-90
- Shallow Well, >90
- Deep Well, <45
- Deep Well, 45-90
- Deep Well, >90
- San Mateo Plain Basin

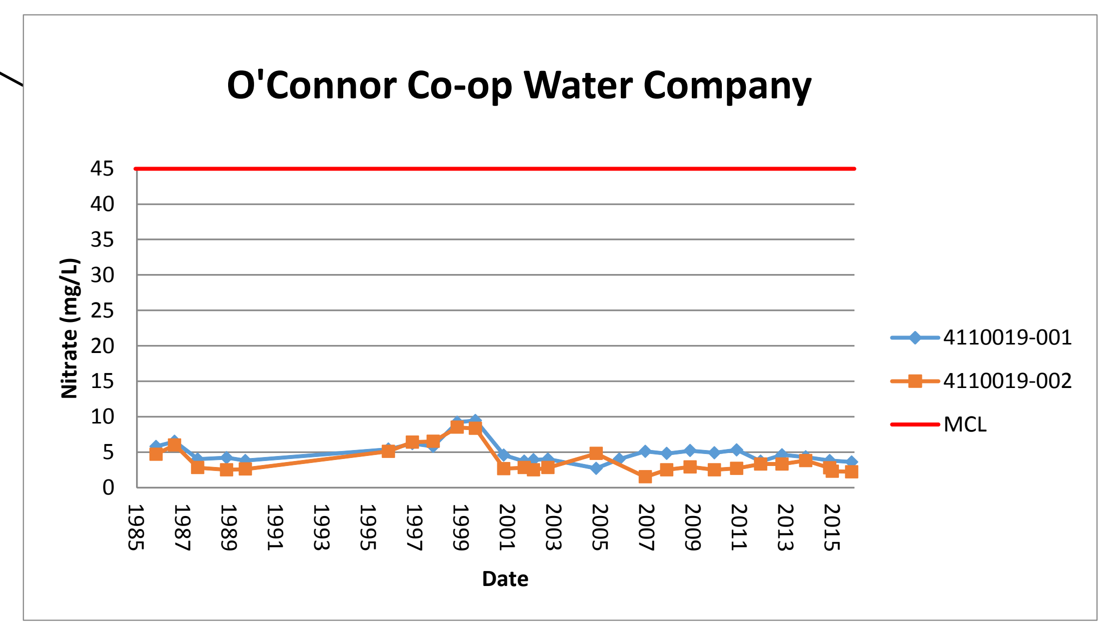
Abbreviations:
MCL: Maximum Contaminant Level
mg/L: milligrams per liter

*Non-Detect values plotted as 0 mg/L





Palo Alto Park Mutual Screen Depths (ft bgs)
4110020-002: 60-67
4110020-003: 194-195, 219-235, 249-257, 269-285
4110020-004: 219-279
4110020-005: 247-251
4110020-006: 248-260, 290-300, 340-366, 378-388, 424-440



O'Connor Co-op Water Company Screen Depths (ft bgs)
4110019-001: 181-372, 396-489, 508-532
4110019-002: 72-90, 172-178, 184-200, 217-223, 233-237, 242-245, 252-265, 282-291

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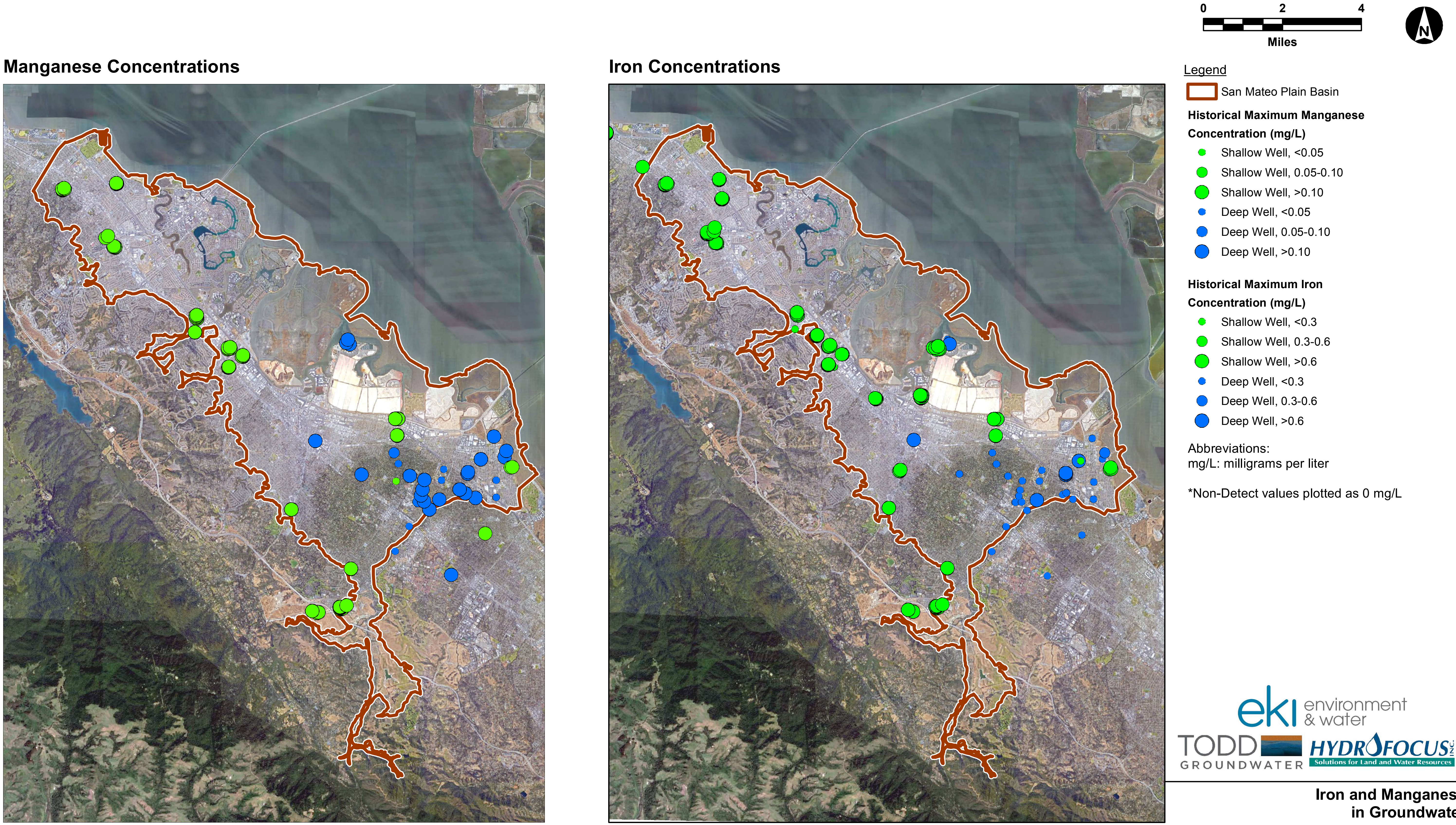
Nitrate in Groundwater

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

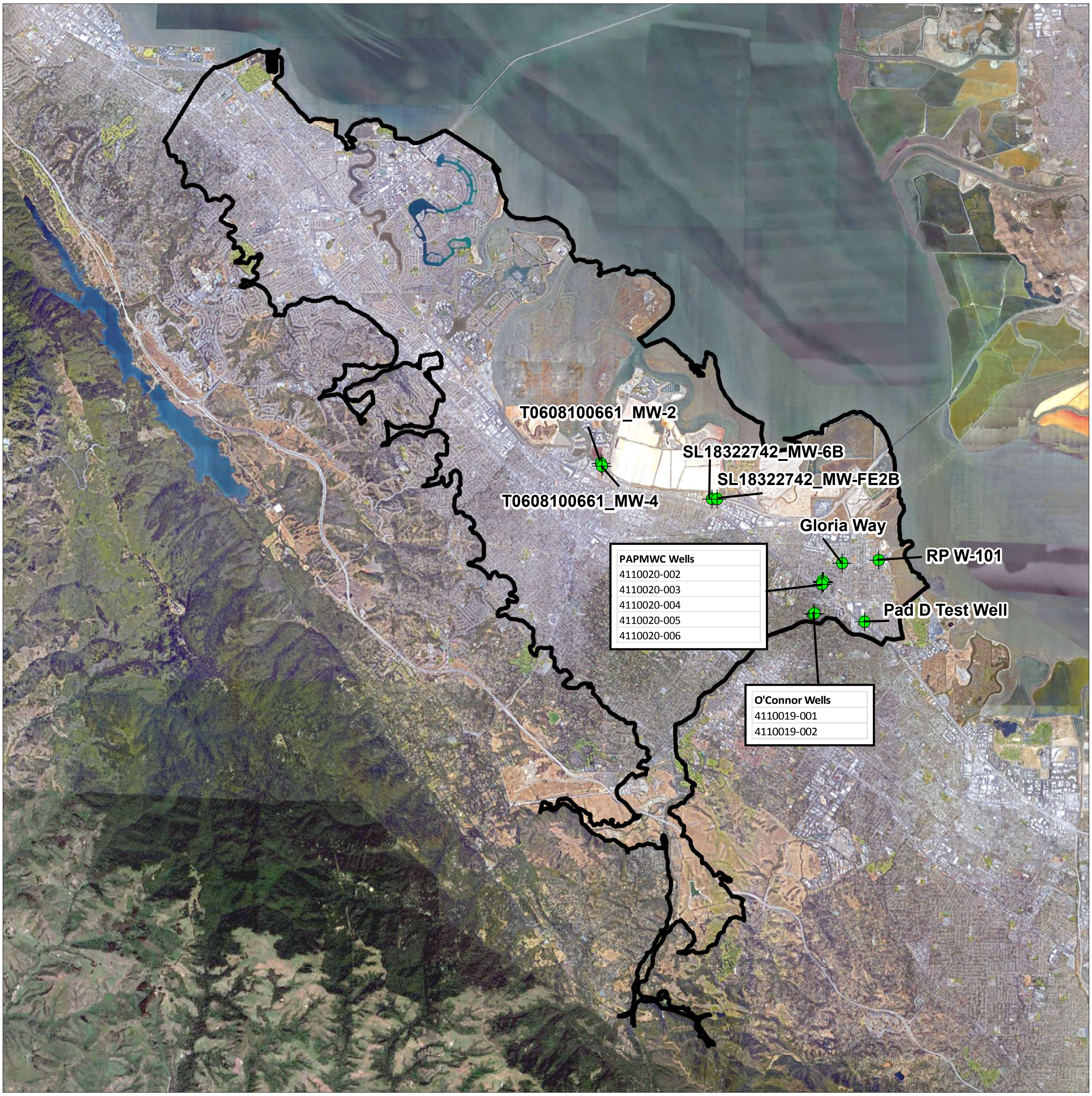
Figure 5-3



Iron and Manganese in Groundwater

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 5-4



Legend

San Mateo Plain Basin

0 2.5 5

Miles

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Locations of Wells with Complete Data on Major Cations and Anions

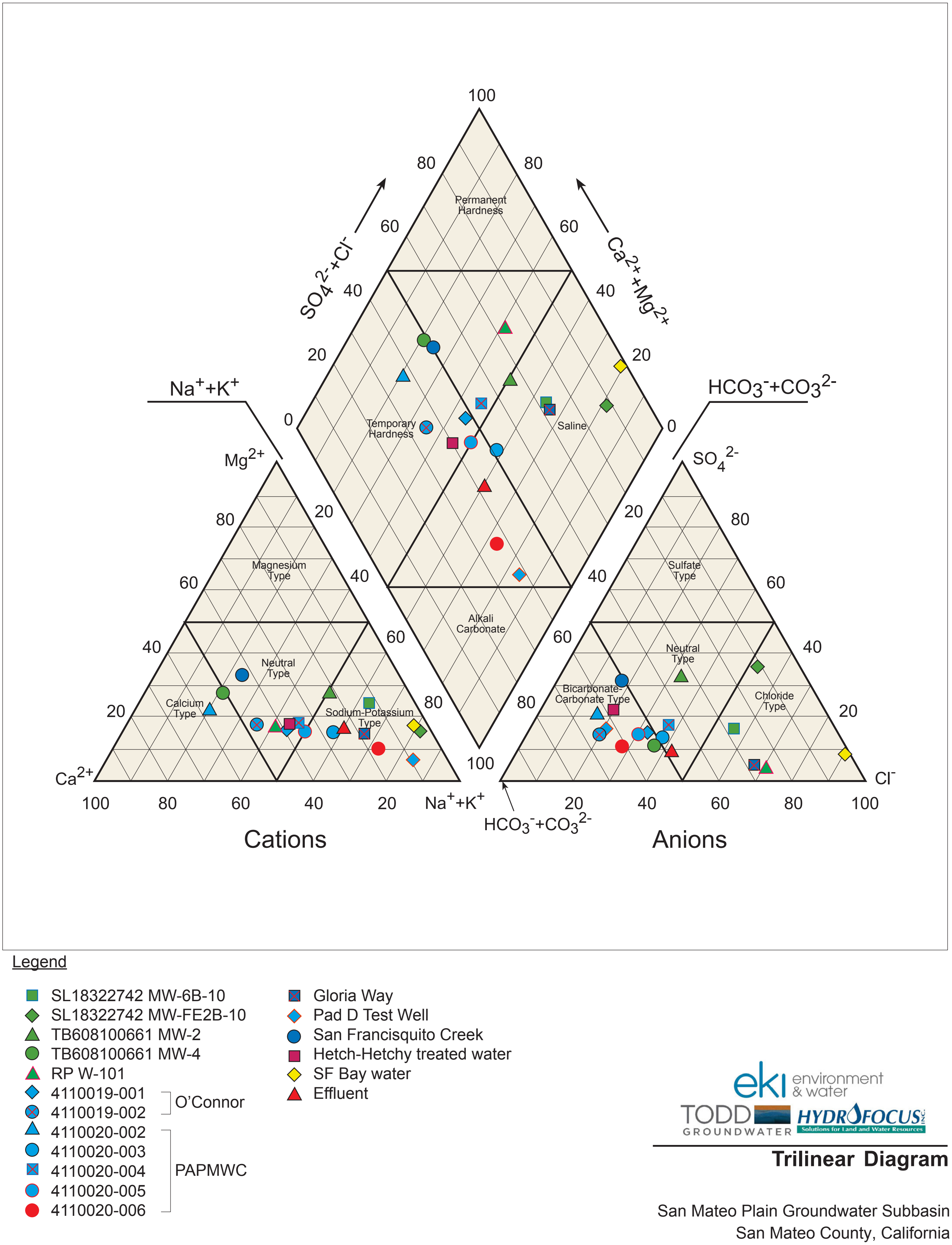
San Mateo Plain Groundwater Subbasin

San Mateo County, California

June 2018

EKI B60024.00

Figure 5-5



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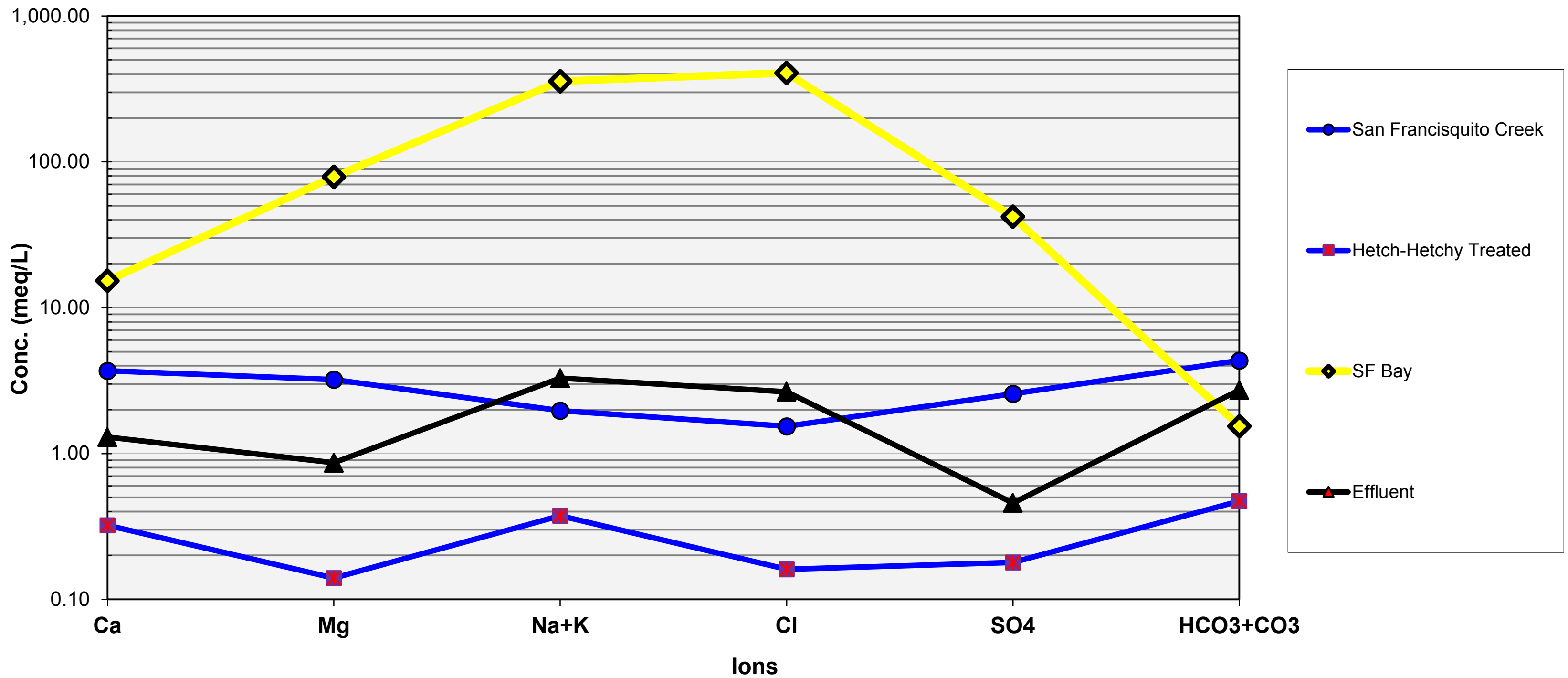
Trilinear Diagram

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 5-6



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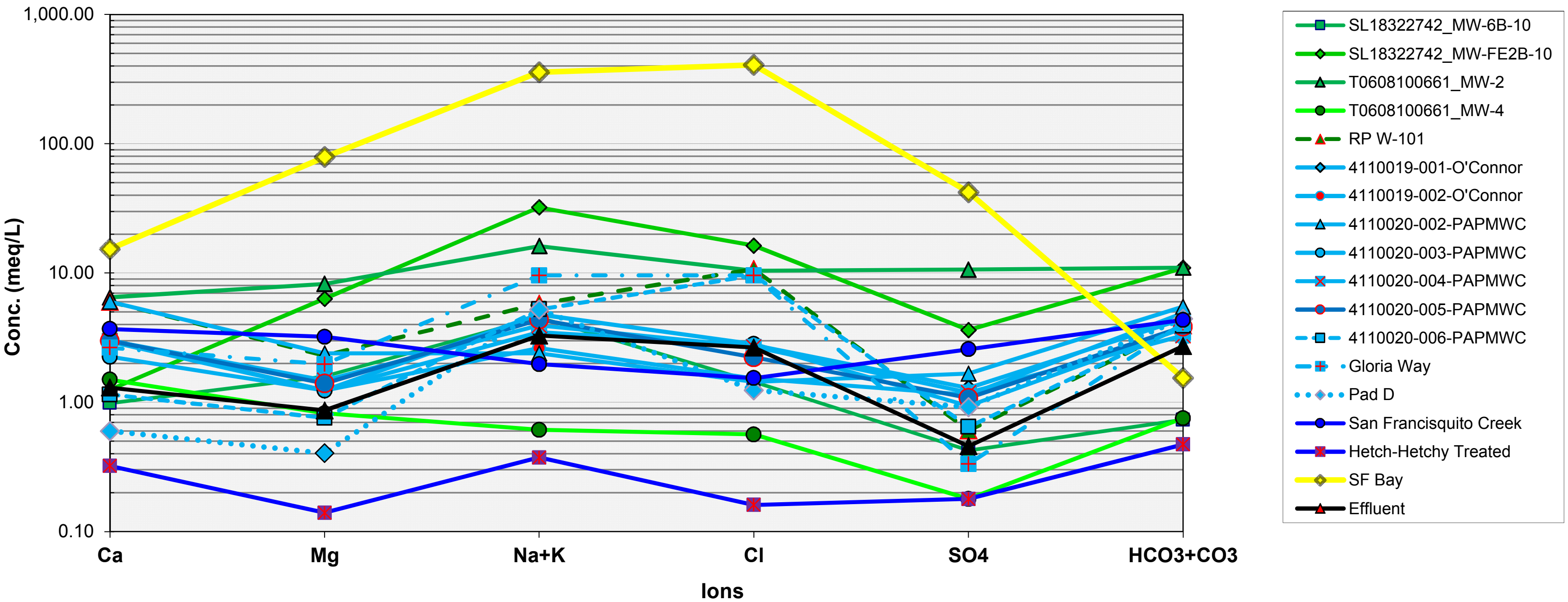
Schoeller Water Source Diagram

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 5-7a



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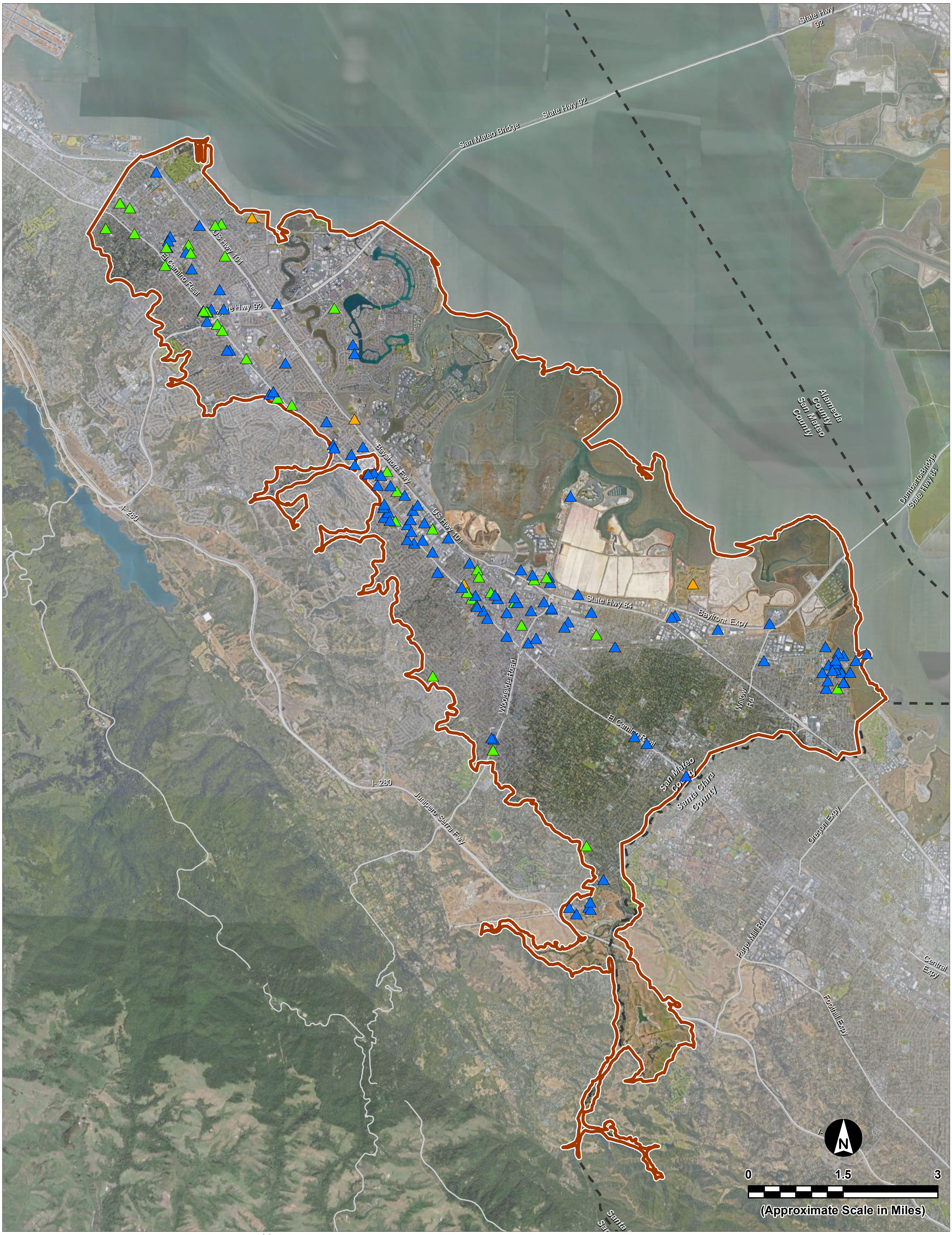
Schoeller Water Source Diagram

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 5-7b



Path: X:\B60024\Maps\2018\06\Fig5_8a_PtSourceContamSites.mxd

Legend

San Mateo Plain Subbasin

County Boundary

Major Road

Notes

1. All locations are approximate.
2. Sites shown are from the State Water Resources Control Board Geotracker Database and are indicated as having groundwater as a potentially affected media and have a current status of "Open".

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Aerial imagery: Google Earth Pro, accessed 19 April 2016.
3. Geotracker site data: http://geotracker.waterboards.ca.gov/data_download.asp, accessed 25 April 2018.

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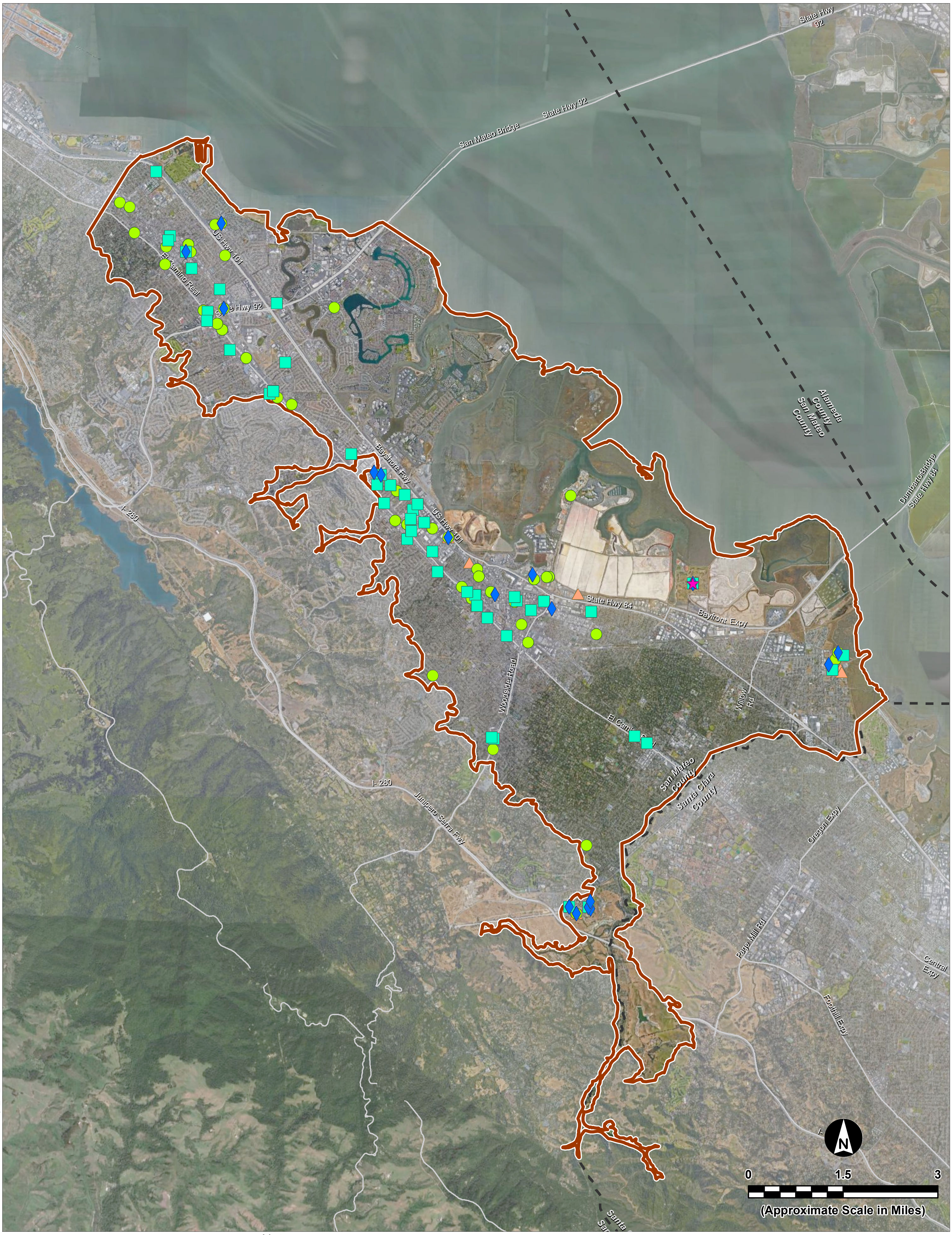
HYDROFOCUS INC. Solutions for Land and Water Resources

Point-Source Contamination Sites
By Case Type

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 5-8a



Path: X:\B60024\Maps\2018\06\Fig5_8b_PtSourceContamSites.mxd

Legend

- San Mateo Plain Subbasin
- County Boundary
- Major Road

Chemical of Concern ("COC")

- Metals
- Petroleum Hydrocarbons
- Chlorinated VOCs
- Inorganics
- Other

Notes

1. All locations are approximate.
2. Sites shown are from the State Water Resources Control Board Geotracker Database and are indicated as having groundwater as a potentially affected media and have a current status of "Open".

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Aerial imagery: Google Earth Pro, accessed 19 April 2016.
3. Geotracker site data: http://geotracker.waterboards.ca.gov/data_download.asp, accessed 25 April 2018.

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Point-Source Contamination Sites By Contaminant Class

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 5-8b

6.0 HYDROGEOLOGIC CONCEPTUAL MODEL

A hydrogeologic conceptual model is a description of the physical setting and characteristics of a basin that influence the groundwater system, including geology, aquifers, hydrology, climate, land use, and conditions at the basin boundaries. The hydrogeologic conceptual model serves as a foundation for further hydrogeologic analysis including development of water budgets and numerical groundwater flow models, and provides the physical context for planning and management efforts such as development of monitoring programs.

The San Mateo Plain Groundwater Subbasin, shown on **Figure 6-1**, is one of four subbasins of the Santa Clara Valley Groundwater Basin, as defined by DWR. The other three subbasins are the East Bay Plain, the Niles Cone, and the Santa Clara Subbasins. The Basin is designated by DWR as basin number 2-9.03 (DWR, 2004). Portions of the surrounding subbasins are shown on **Figure 6-1**, along with portions of the Westside Basin (DWR 2-35), which is adjacent to the Basin to the north.

The USGS has conducted several groundwater investigations addressing the southern portion of the Basin and the northern portion of the Santa Clara Subbasin (e.g., Oliver, 1990; Fio and Leighton, 1995; Metzger, 2002). The 2002 USGS investigation focused on surface water-groundwater interactions along San Francisquito Creek and, for the purposes of the investigation, defined a San Francisquito Creek alluvial fan groundwater basin, called the "San Francisquito Cone", which overlies portions of San Mateo and Santa Clara counties as shown on **Figure 6-1**. The work described herein builds off of these previous efforts by extending the area of investigation to the entire Basin and by compiling and incorporating a significant amount of new information, as discussed in Section 4.0.

6.1 Basin Setting

6.1.1 Topography

The Basin is located along the eastern edge of the San Francisco Peninsula between San Francisco Bay and the Santa Cruz Mountains, which occupy the central axis of the peninsula. The Basin consists of unconsolidated alluvial sediments underneath a coastal plain. A broad band of flat intertidal marshland is present along the Bay shore, reflecting the gradual rise in sea level since the last ice age. Along the inland edge of the coastal plain, bedrock hills ascend to the west. The inland edge of the Basin roughly follows the 100-foot elevation contour. The width of the coastal plain between the historical marshes and the bedrock hills ranges from zero near Belmont – where a bedrock ridge projects east from the main mountain range – to five miles at the south end of the Basin where San Francisquito Creek flows over a prominent alluvial fan (coterminous with the USGS-defined San Francisquito Cone Subbasin; see **Figure 6-1**). Alluvial deposits extend an additional five miles up the creek along the valley carved by the creek into the lower slopes of the Coast Ranges.

The easternmost ridge of the Coast Ranges follows the east side of the San Andreas Fault and has crest elevations of generally 500-700 feet msl. Two of the local watersheds draining into the subbasin (i.e., the watersheds of San Mateo Creek and San Francisquito Creek) extend west of this ridge and up to the main crest of the Coast Range, at elevations of 1,600-2,200 feet above mean sea level (msl) (**Figure 6-2)**. The remaining creek watersheds drain only the eastern slope of the easternmost ridge.

At the northern end of the Basin near Hillsborough and San Mateo, bedrock is present at shallow depths between the Coast Ranges and Coyote Point, a bedrock hill at the San Francisco Bay shoreline. The south end of the Basin is generally defined by the San Mateo-Santa Clara County line. The line follows San Francisquito Creek, which flows more or less down the middle of its alluvial fan. As discussed further below in Section 6.2.6, the county line is not a hydrogeologic boundary, and groundwater can move freely across it.

6.1.2 Climate

The climate on the Bay side of San Mateo County is Mediterranean, with wet winters and dry summers. Average annual precipitation increases from about 14 inches per year (in/yr) at the Bay shoreline to about 42 in/yr along the crest of the main Coast Range ridge. **Figure 6-3** is an isohyetal map showing contours of average annual precipitation (Rantz, 1971). Two other isohyetal maps were reviewed for this study (Rantz, 1969; SCVWD, 1989), and were less consistent with local rain gauge data and less realistic in delineating the effect of mountains on rainfall distribution. Based on 85 years of precipitation records from Redwood City, the lowest annual rainfall during the period from 1931 to 2016 was 7.28 inches in water year 1976, and the highest was 42.19 inches in water year 1983.[14] Precipitation falls almost exclusively as rain, and on average 85 percent of annual rainfall occurs during November through March.

Maximum air temperatures average 81 degrees Fahrenheit (F) in July through August, and minimum air temperatures average 40 degrees F in December through January. The diurnal temperature range is 19 degrees in mid-winter increasing to 25 degrees in mid-summer. Temperature is one of several factors that determine the evaporative demand and the consumptive use of water by plants for transpiration. Evapotranspiration (ET) is the variable that specifically indicates plant water requirements and is derived from solar radiation, air temperature, wind speed and relative humidity. Reference evapotranspiration (ET_0) is the ET of an extensive well-watered turf. The California Irrigation Management Information System (CIMIS) operates several hundred climate stations throughout California and records daily ET_0 in an on-line database (http://wwwcimis.water.ca.gov/). ET_0 is one of the variables used in the water balance analysis for this study to simulate groundwater recharge and irrigation demand. Only one CIMIS station has ever operated in San Mateo County, in the Town of Woodside. The

[14] Water years are defined as extending from 1 October of the preceding calendar year to 30 September of the current calendar year. Missing record at the Redwood City rain gage was estimated by correlation with the Burlingame, San Francisco International Airport and Palo Alto gages.

period of record from the Woodside station was only three years (1991-1994), but by correlation with CIMIS stations in Fremont, Union City and San Jose, a complete record of daily ET_0 for water years 1987-2015 was constructed, which is representative of conditions in the coastal plain portion of the Basin. The spatial pattern of ET_0 in San Mateo County is complex because of cool marine air and fog west of the Coast Range ridge and a smaller marine influence near San Francisco Bay. The statewide map of ET_0 zones developed by CIMIS shows the San Mateo Plain in Zone 8 and higher elevations along the Coast Ranges in Zone 3. By using the ratios of average monthly ET_0 for the two zones, a daily time series of ET_0 in the upper elevations of the San Mateo Plain creek watersheds was developed.

6.1.3 Watersheds and Surface Water Features

Eleven major watersheds overlie the Basin, as well as a number of small areas along the eastern edge of the Basin that drain directly to San Francisco Bay (**Figure 6-2**). The watershed boundaries were delineated by the Oakland Museum of California (Sowers, 2004; Tillery et al., 2007). In this delineation, Pulgas and Greenwood Creeks are combined into a single watershed, as are Redwood Creek and Arroyo Ojo de Agua. All but two of the watersheds originate east of the San Andreas Fault and are relatively small. Most of the creek channels have been straightened and converted to concrete channels where they cross the Basin, which limits the interaction of surface water and groundwater (see **Figure 6-2**).

The San Mateo Creek and San Francisquito Creek watersheds include large areas west of the San Andreas Fault. Their watersheds are three to thirty times larger than those of the other creeks and include areas of much higher rainfall. Consequently, stream flows and geomorphic power have been much greater over geologic time for those two streams, and the difference is reflected in the texture of the alluvial fan deposits where those creeks leave the mountains and cross the coastal plain to the Bay.

Crystal Springs Dam has controlled runoff from approximately 84 percent of the San Mateo Creek watershed since 1888. Flow in the reach of San Mateo Creek that crosses the Basin consisted almost entirely of runoff from the small watershed area downstream of the dam until 2015, when dry-season releases from the dam were increased to benefit steelhead trout habitat. Searsville Dam partially controls runoff from 32 percent of the San Francisquito Creek watershed. Thus, flow along the reach that crosses the Basin is still substantially unregulated. Flooding in the lower reaches of San Francisquito Creek has been a problem, and the flood of 1998 led to the formation of the San Francisquito Creek Joint Powers Authority, which is implementing measures to reduce flood damage.

Table 6-1 lists basic descriptive information for each watershed that contributes to the Basin, compiled from various watershed studies, the Regional Water Quality Control Board's Basin Plan and data assembled for this study (SFRWQCB, 2015a). **Figures 6-4** through **6-6** show the lengths of natural, engineered and underground channels in the main Basin area, the tidal marsh area, and the upland area, respectively, of each watershed. Underground channels are those shown on **Figure 6-2** and include major storm drains as well as buried creek channels. As shown on **Figures 6-4** through **6-6**, with the exception of San Francisquito Creek, the creeks within the Basin are predominantly underground or engineered.

Only natural channels have significant bed permeability and opportunity for percolation of stream flow. There are about 28.5 miles of natural channel in the non-tidal part of the Basin. About one-third of this total length is in the narrow alluvial valley that extends from the main Basin into the uplands area beneath San Francisquito Creek. Stream percolation in that area is more likely to re-emerge into the creek as summer base flow than to supply significant groundwater inflow to the plain area, because the creek crosses the Pulgas Fault near the point where it enters the Basin and stream flow measurements have documented little net percolation upstream of the fault (Metzger, 2002). Of the remaining 18.6 miles of natural channel in the non-tidal part of the Basin, 62 percent is along San Mateo and San Francisquito Creeks. There are 116.7 miles of natural channel in the upland parts of the local watersheds, where percolation losses in winter similarly tend to re-emerge as base flow in summer rather than flow via the subsurface to the groundwater Basin (see Section 7.2.6 for additional discussion). None of the mapped creek channels in the tidal marsh part of the Basin are natural. Tidal sloughs were not included as creek channels in the mapping. They contain brackish water and are at the same elevation as San Francisco Bay. With respect to the groundwater basin they function as a constant-head boundary and location of groundwater discharge, just like the Bay.

6.1.4 Land Uses

A map of Basin land uses is shown as **Figure 6-7.** For the purpose of water balance analysis, land uses in the Basin and tributary watershed areas were delineated on the basis of variables relevant to hydrology: impervious area, irrigated area, vegetation type, and the density of water and sewer pipe networks. Eleven land use categories were used: four types of natural cover (grass, brush, trees, and open water), three types of residential (rural, “typical” and “lush”—the latter classification included larger lots and more irrigation), large irrigated areas (golf courses, cemeteries, and some parks), commercial, industrial, and vacant. Delineation was done through visual inspection of seamless, georeferenced, high-resolution aerial imagery (National Agricultural Imagery Program, 2010). Supplemental corroboration of variations in impervious cover was obtained by comparing the photos with the 2011 National Land Cover Database raster image of percent impervious cover (Homer et al., 2015).

As shown on **Figure 6-7**, land use in the Basin is almost entirely urban and has been developed for many decades. Parts of the historical tidal marshes were diked, filled, and converted to urban uses as early as 1873, which was the date of the earliest detailed and reliable topographic map (State Geological Survey of California, 1873). Even today, however, large areas remain as marshes or salt evaporation ponds. Residential land uses extend westward from the coastal plain into the uplands parts of the local watersheds. As an exception, the San Mateo Creek watershed upstream of Crystal Springs Dam is completely undeveloped. The SFPUC manages the watershed for potable water supply and keeps it in a pristine natural condition. Remote parts of the San

Francisquito Creek watershed west of Interstate 280 are largely undeveloped but include some low-density residential development.

6.2 Hydrogeologic Setting and Groundwater Conditions

6.2.1 Regional Geology

The Basin is located in the southwestern region of the San Francisco Bay, which itself is a structural depression between the Diablo Ranges on the east and the Santa Cruz mountains on the west. The mountain ranges are composed of older consolidated sedimentary and igneous rocks, where groundwater storage and flow are generally limited to fractures. Surface streams have flowed from the mountains and deposited sedimentary debris as alluvial fans and flood plains. These alluvial deposits compose the major aquifers of the region.

Geologic maps of the Basin include the USGS geologic maps for the San Mateo Quadrangle (Brabb et al., 1998) among others, and the California Department of Conservation Geologic Map of California (2010). **Figure 6-8** is a geologic map of the rock types present at the ground surface within and adjacent to the Basin based on the California Department of Conservation map. The bedrock formations within the Santa Cruz mountain watersheds draining to the Basin include several Cretaceous-aged (around 65 to 140 million years) to Tertiary-aged (around 2.6 to 65 million years) rock types, including mélange (predominantly greywacke sandstone, siltstone, and shale), greenstone including altered basaltic rocks, greenish-grey to bluish-green serpentinite, and chert and shale. These formations have been lithified and altered over geologic time to the degree that they have very little original or primary porosity or permeability. However, secondary fractures in these rocks contain limited amounts of groundwater.

The principal groundwater-bearing formations of the Basin are unconsolidated to semi-consolidated Quaternary-aged (less than 2.6 million years) alluvium composed of gravel, sand, silt, and clay. The alluvium present within the Basin originated primarily from erosion of the rocks in the Santa Cruz Mountains, and transportation of sediment via streams and deposition as alluvial/fluvial sedimentary deposits. Sediments from the Santa Clara Valley streams and from the East Bay (Niles Cone and Alameda Creek) may also have been transported and deposited in the southern and eastern portions of the Basin and/or interfingered with sedimentary layers originating from the west, especially under San Francisco Bay. During the Pleistocene, rising and falling sea levels caused alternating periods of continental (alluvial) and marine (bay) sediments, resulting in layers of coarse- and fine-grained sediments.

The Quaternary alluvium formation mapped on **Figure 6-8** represents the upper portions of the alluvial aquifer and roughly corresponds to the Basin boundary (**Figure 1-1**). Groundwater is also present in the older Santa Clara Formation of Plio-Pleistocene age underlying the Quaternary alluvium deposits. The Santa Clara Formation is composed of gravel, sand, silt, and clay, and is difficult to distinguish from the overlying Quaternary alluvium because both geologic units are similar in nature.

The depositional settings, composition, and thickness of the Basin's alluvial aquifer are further discussed below.

6.2.2 Structural Geologic Setting

The Basin is located in the Coast Range Physiographic Province, a region characterized by northwest-trending faults, mountain ranges, and valleys. Lateral movement along the San Andreas, Hayward, and Calaveras faults and down warping of the area between the fault zones formed a structural trough occupied by the San Francisco Bay (DWR, 1967). During the Pleistocene, the San Francisco Bay depression became connected to the Pacific Ocean during four inter-glacial episodes. Sea level rise increased the base level of streams resulting in deposition of silt and clay within the Bay. As sea level declined, the base level fell and streams draining the mountains eroded channels into the silts and clays and laid down coarser material such as sands and gravels (Fio and Leighton, 1995).

In 1990, the USGS mapped the bedrock elevation in San Mateo County (Hensolt and Brabb, 1990). These bedrock elevation contours are primarily based on information from borehole logs: 215 that extend to bedrock and 58 that do not extend to bedrock (Hensolt and Brabb, 1990). The bedrock elevation contours from this map were digitized and are illustrated on **Figure 6-9**. These bedrock elevations are also shown as a surface on the geologic cross-sections, which are described below in Section 6.2.3.

Four faults mapped by the California Department of Conservation (2010) intersect at least a portion of the Basin (**Figure 6-8**). Three of these faults, the San Jose, Palo Alto, and the Stanford faults, are Late Quaternary age concealed faults with a northwest to southeast orientation in the southern region of the Basin. These faults extend to the southeast into the Santa Clara Subbasin. There is also a short (approximately one-mile-long), unnamed northwest to southeast trending fault mapped by the California Department of Conservation that is parallel to the western edge of the Basin near Belmont Creek. In addition, Metzger (2002) identifies the Pulgas (**Figure 6-2**), San Francisquito, and Atherton faults in the southwestern corner of the Basin, near Atherton. These are not mapped and labelled as such by the California Department of Conservation, but may be part of the Stanford Fault system. The faults mapped by the California Department of Conservation are also identified on the cross-sections, described below in Section 6.2.3.

In general, bedrock in the western region of the Basin reaches an elevation of approximately 100 feet msl and dips to the east. The gradient of the bedrock slope is relatively uniform in the western portion of the Basin and reaches a depth of approximately 300 feet below msl in the center of the Basin. The bedrock surface in the central and eastern regions of the Basin undulates, forming both highs and depressions.

Bedrock highs, composed of erosional remnants of the Franciscan assemblage (Hensolt and Brabb, 1990), are present throughout the Basin. In the northeastern corner of the Basin, bedrock crops out and forms Coyote Point. Additional bedrock highs in the Basin remain below the unconsolidated material, including one southeast of Coyote Point that rises to an elevation of approximately 100 feet below msl and another in the central part of the Basin near Redwood Shores that rises to approximately 300 feet below msl. There are two significant bedrock depressions: one in the central part of the Basin just north of Redwood Shores which extends to more than 700 feet below msl and one in the southeastern corner of the Basin near East Palo Alto that extends to approximately 1,300 feet below msl.

6.2.3 Hydrostratigraphy

6.2.3.1 Hydrogeologic Setting

Groundwater flow within the Basin is generally from west-southwest to east-northeast, from the edge of the Santa Cruz Mountains to San Francisco Bay. Groundwater is present in both the Santa Clara Formation and the Quaternary alluvial deposits, although Quaternary alluvium is the primary water bearing formation (DWR, 2004). In general, based on the depth to bedrock and the ground surface elevation, the alluvium is thinner in the higher elevations in the western Basin and thickens towards San Francisco Bay.

Various alluvial fan structures were deposited by streams draining the uplands. The most significant, and most studied, alluvial fan was deposited in the southern part of the Basin by San Francisquito Creek, and is most commonly known as the San Francisquito Cone (USGS, 2002). Other smaller streams in the Basin that drain the uplands include Atherton Creek, Cordilleras Creek, Pulgas Creek, Belmont Creek, Laurel Creek, and San Mateo Creek (see **Figure 6-2**). The streams meandered through time, especially at the flatter and lower elevations closer to the San Francisco Bay, and formed interfingered and laterally discontinuous layers of gravel, sand, and clay material (SFRWQCB, 2003). The deposits are a heterogeneous mixture of fine- and coarse-grained materials, which make it difficult to distinguish aquifers and aquifer boundaries.

Continental deposition of alluvium during the Plio-Pleistocene and Quaternary periods was accompanied by periods of sea level transgression (rise) and regression (fall), associated with periods of climatic warming and cooling, respectively. During periods of sea-level rise, the paleo San Francisco Bay inundated a larger area between the Santa Cruz and Diablo Range Mountains, and fine-grained silt and clay layers were deposited over broad areas. The uppermost sequence of fine-grained material around the perimeter of the South Bay and in the eastern portion of the Basin is commonly referred to as the “Bay Mud” aquitard. This aquitard is of low permeability, as much as 100- to 200-feet thick near the Bay perimeter, and is one of a series of confining layers that impede vertical flow of groundwater. This is evidenced by the historical and current presence of artesian wells in some downgradient portions of the Basin (Section 6.2.5). However, the Bay Mud aquitard does not appear to be regionally continuous, as incised sand channel deposits are present in many areas of the Basin.

During sea level regressions, much of the area currently occupied by San Francisco Bay was dry, and coarser-grained alluvium was deposited, including stream channel deposits that incised the previously-deposited finer-grained material. The resulting sedimentary sequence includes interbedded fine- and coarse-grained layers reflecting those dynamic depositional environments. This aquifer and aquitard framework affects groundwater flow. In general, the groundwater system is unconfined in the higher elevations, and confined or semiconfined at lower elevations closer to San Francisco Bay.

6.2.3.2 Cross-Section Development

Eight geologic cross-sections (A-A' through H-H') were constructed to characterize the thickness and distribution of alluvial aquifer sediments and to delineate the hydrostratigraphy within the Basin. These eight localized cross-sections were developed using detailed stratigraphic information from boreholes across the Basin. In addition, two regional cross-sections were constructed to illustrate the connections between the Basin and the adjacent groundwater basins; these are discussed further in Section 6.2.6.

Cross-section transect locations were chosen based on available well data and in order to provide lithologic coverage throughout the Basin. **Figure 6-10** illustrates well locations throughout the Basin, based on the data sources and assimilation described in Section 4.0.

Cross-section transect locations are shown on **Figure 6-11** and the cross-sections are presented on **Figures 6-12a** through **6-19**. As shown on **Figure 6-11**, cross-sections A-A' and B-B' are oriented longitudinally, along the length of the Basin from approximately northwest to southeast, and cross-sections C-C', D-D', E-E', F-F', G-G', and H-H' are oriented laterally, across the Basin from approximately southwest to northeast.

As described in Section 4.0, a texture database approach was used to construct the cross-sections utilizing the ESRI ArcHydro module[15] for ArcGIS. Most of the geologic texture data are from a database developed by the USGS as part of a hydrogeologic study of the South San Francisco Bay and Peninsula Bay (Fio and Leighton, 1995; Leighton et al., 1995), with additional data added by the Project Team from DWR Well Completion Reports and other sources that were reviewed as part of this Project and other prior work.

The lithology in the database is shown on the cross-sections at the same detail for which it was described on the drillers' reports. For example, the well log for the well located in Township 5 south, Range 3 west, and Section 22, shown on cross-section B-B', describes a gravel layer from a depth of 100 to 102 feet bgs. Consequently, a two-foot gravel layer is included in the texture

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[15] The ArcHydro module allows import and three-dimensional plotting of geologic data from boreholes, topological surfaces (including land surface, bedrock contact elevation, and water table surfaces). ArcHydro analysis tools include projection of borehole and surface data along cross-sections at selected orientations for analysis and geologic correlation.

database and shown on the cross-section at this corresponding location and depth. The quality of the lithologic descriptions in the well logs varies, and therefore, lithology was not described at a two-foot scale at each well. However, the detail provided on each drillers' report is preserved in the texture database and on the cross-sections.

Screened intervals are shown on cross sections as dark shading. The screened interval information is from the database developed for the hydrogeologic study of the South San Francisco Bay and Peninsula Bay, as described above, and from DWR well completion reports. Most of the screens are within or straddle sands or gravels, while portions of some well screens are in silts and clays. In some cases, the screened interval of a well appears to include bedrock. In a few cases, the well completion report confirmed that the driller did in fact install screen in bedrock. In other cases, the bedrock surface might not have been precisely interpolated between control points, or projection of the well log to the cross-section line might have created the appearance of screens extending into bedrock.

Lithologic correlations shown on the cross-sections were based on texture. The cross-sections honor the texture information on the drillers' reports and the lithologic database at the well locations. Between well locations, relatively thick gravel and sand bodies were assumed to be more continuous and more likely to be interconnected than relatively thin gravel and sand layers.

The geologic cross-sections also utilized ground surface, water table, and bedrock contact elevation surfaces. Ground surface elevations were generated from the National Elevation Dataset developed by the USGS. The bedrock surface shown on the cross-sections is based on a bedrock elevation map developed by the USGS (Hensolt and Brabb, 1990). The bedrock elevation contours were digitized and interpolated to create a two-dimensional bedrock elevation surface throughout the Basin. The bedrock elevation surface cut by each transect is shown on the cross-sections. Minor revisions to the bedrock elevation surface were made in places where the bedrock elevation at the wells differed from the map. Groundwater level surfaces for both shallow (<50 feet deep) and deep wells are shown on the cross-sections for two different time periods: 1994 and 2010. Groundwater level surfaces are based on groundwater contour maps described in Section 6.2.5.

It should be noted that the vertical scale is exaggerated for both the local and regional cross-sections in order to better illustrate the thin coarse and fine-grained layers. For purposes of cross-section development and grouping shallow and deep water levels, wells deeper than 50 feet were considered to be deep, and all other wells were considered to be shallow.

6.2.3.3 Hydrogeologic Framework

As described below, the cross-sections depict the general hydrogeologic framework within the Basin.

Longitudinal Cross-sections

Cross-section A-A' (**Figures 6-12a, 6-12b,** and **6-12c**) spans the western side of the Basin from northwest to southeast. The bedrock surface is deep in the northern and southern regions of the section and shallow in the center of the section. The bedrock surface in the northern region of the Basin along this location is approximately 400 feet bgs and in the southern region of the Basin is approximately 375 feet bgs. Depth to bedrock in the central portion of the west side of the Basin is very shallow, within 50 feet of ground surface.

As shown on cross-section A-A' (**Figures 6-12a** and **6-12b**), the northern portion of the Basin contains layers of sand and gravel that range from thin lenses to thicker zones up to 75 feet thick. The shallower coarse deposits are dominated by gravel relative to sand, while sand lenses are more prevalent at greater depths. In particular, there is a thick (approximately 75 feet) layer of sand close to the base of the bedrock depression. These sand layers were likely deposited by the San Mateo Creek alluvial system. Permeable zones near the ground surface may allow groundwater-creek interactions, as described in Section 7.0. The coarse deposits thin to the south and silts and clays become more dominant.

As illustrated on cross-section A-A' (**Figure 6-12a**), there is a large area without lithologic information between approximately San Mateo Creek and Laurel Creek. The central portion of the Basin reflects the thin deposits and shallow depth to bedrock of the Basin's higher elevations. The lithology in this region is dominated by silts and clays, and only a few thin sand lenses are present. The thinner and less-prevalent sand units in this area may have originated from lower-energy streams in the middle portions of the Basin, as compared with the higher-energy San Francisquito Creek and San Mateo Creek systems.

The southwestern region of the Basin (**Figures 6-12a** and **6-12c**) is dominated by thin lenses of coarse material, primarily gravel. These lenses were likely deposited by the Atherton Creek alluvial system and reflect meandering paleochannel deposits. Thicker layers of gravel and sand are evident in the southernmost portion of the Basin near the north-facing wall of the local bedrock depression beneath Atherton. These thicker units were likely deposited by the larger San Francisquito Creek alluvial system. Permeable zones near the ground surface may allow groundwater-creek interactions, as observed during USGS monitoring of San Francisquito Creek and as described in Section 7.0. San Francisquito Creek forms the southern boundary of the Basin in this cross-section.

Cross-section B-B' (**Figure 6-13**) spans the southern two-thirds of the eastern side of the Basin. Bedrock along the eastern side of the Basin is deeper than along the western side, reflecting the bedrock dip direction from west to east. Bedrock elevation along this section ranges from a low of approximately 700 feet below msl in the northern part of the section to approximately 900 feet below msl in the southern edge of the Basin. Bedrock elevation rises to an elevation of approximately 300 feet below msl in the center of the section. Lithologic information in the northern part of the section is sparse, but lenses of sand and gravel, with a predominance of sand, are evident.

Thicker deposits of sand and gravel are deposited against the north-facing wall of the bedrock depression in the vicinity of cross-section E-E'. The southern region of the Basin is dominated by thin layers of sand and gravel in the vicinity of the Atherton Creek alluvial system and thicker layers of sand and gravel along the southern basin boundary in the vicinity of San Francisquito Creek. Silts and clays, however, are more predominant in the southern region of cross-section B-B' than along the southwestern edge of the Basin (cross-section A-A'). This is consistent with the alluvial depositional environment. As streams flow from the apex of the San Francisquito Cone toward San Francisco Bay, they lose energy and the sediment load becomes finer. Therefore, alluvial deposits generally become finer with distance downstream.

Cross-section B-B' extends slightly beyond the edge of the Basin and includes two deep wells: the Hale Well, owned by the City of Palo Alto near the edge of the Basin, and the Eleanor Well, installed by SCVWD south of the Basin. Lithology in these two wells confirm that depth to bedrock is more than 900 feet, as mapped by Hensolt and Brabb (1990), and contains thick layers (up to approximately 150 feet) of sand and gravel in a bedrock depression approximately 500 feet below msl.

Wells on these longitudinal cross sections are, in general, screened at shallower depths in the southern region of the Basin. The Hale Well, which has multiple screen intervals to a depth of approximately 800 feet, is an exception.

<u>*Lateral Cross-sections*</u>
Six cross-sections illustrate the lithology across the Basin, from the hills to the Bay. These cross-sections are described below, in order from the northern to the southern end of the Basin.

Cross-section C-C' (**Figure 6-14**) illustrates the hydrostratigraphy along the northern end of the Basin. Bedrock slopes from close to ground surface at an elevation of approximately 75 feet msl on the western boundary of the Basin into a bedrock depression in the center of the Basin at an elevation of approximately 400 feet below msl. Bedrock on the flanks of Coyote Point rises near the eastern edge of the Basin to approximately 125 feet below msl and then drops off again towards the Bay. Based on available driller's logs, the lithology in this area contains layers of sand and gravel deposits in the upper 200 feet which are over 100 feet thick in places, consistent with the thicker sand and gravel beds illustrated in the northern region of cross-section A-A'. The presence of the well screens within the thick sand and gravel layers in this portion of the Basin indicates that groundwater may be pumped from supply wells at moderate rates. Presuming that thick sand and gravel layers are more likely to be areally extensive, then the presence of these layers also suggests potential hydraulic connection between the San Mateo and Westside groundwater basins. However, finer-grained aquifer materials may predominate just north of the Basin boundary, as discussed in Section 6.2.5.

Cross-section D-D' cuts across the central part of the Basin and roughly follows the Belmont Creek drainage (**Figure 6-15**). Bedrock dips from west to east, from slightly below ground surface in the west to approximately 650 feet below msl at the edge of the Basin and Bay. Well 5S/4W-1C1, in the center of the Basin, is described in the well log as having a 250-foot thick sand layer that was deposited on top of the bedrock surface, and is screened primarily within this sand layer. Few other wells are located in this area and the presence and continuity of this thick sand unit presently cannot be confirmed. Closer to the Bay, this thick sand deposit becomes inter-bedded with clay and silt deposits. This pattern of deposits is consistent with an alluvial depositional system and deposition of mud during high sea level periods.

Cross-section E-E' (**Figure 6-16**) crosses at approximately the center of the Basin and roughly follows the Cordilleras Creek drainage. Bedrock elevation is near the ground surface at the western edge of the Basin and slopes to an elevation of approximately 600 feet below msl in the central region of the Basin. Bedrock then rises to an elevation of approximately 300 feet below msl on the eastern side of the Basin and then dips down towards the edge of the Basin and the Bay. Wells in the western and central portions of the Basin are less than 200 feet deep and illustrate a predominance of silt and clay deposits. A thick gravel layer near the surface in the western section was likely deposited by the Cordilleras Creek alluvial system, while a deeper thick sand layer in the center of the section represents an older and finer-grained alluvial deposit. There is no lithologic information in the center of the Basin below a depth of approximately 175 feet bgs. The wells along the eastern region of the section are deeper and show layers of sand and gravel deposits that are relatively thin at the surface and thicken with depth. These wells are screened primarily in these deeper and thicker sand and gravel layers.

Cross-section F-F' (**Figure 6-17**) crosses the Basin slightly north of the San Francisquito Cone. Bedrock is near the surface at the western edge of the Basin and slopes with undulations towards the Bay. Bedrock reaches an elevation of approximately 500 feet below msl at the edge of the Basin. Lithologic data along this section are relatively sparse, but show that the western and eastern regions of the section are dominated by silts and clays. Well 5S/3W-28C1 is slightly more than 1,000 feet from the section (the general criterion for well inclusion) but was included to provide some coverage in the central portion of the section. Lithology at this well illustrates layers of gravel and sand extending from the ground surface to close to the bedrock surface. Based on the one available deep well, sand and gravel deposits in the eastern region of the Basin are thinner and less prevalent than in the center of the Basin.

Cross-section G-G' (**Figure 6-18**) crosses the Basin through the northern portion of the San Francisquito Cone and contains a high density of wells and lithologic data. Bedrock is near ground surface at the western edge of the Basin and dips towards the Bay with undulations. Bedrock is deepest in the eastern portion of the Basin, reaching a depth of approximately 700 feet bgs. The western portion of the section contains numerous coarse-grained lenses dominated by gravel, and most of the wells are screened in, or through, more than one of these lenses. The density of the coarse-grained lenses decreases slightly to the east and the prevalence of silts and clays increase. There is less lithologic data in the eastern region of the section, but available data show that sediments in the eastern region are finer grained and wells are screened at deeper depths than in the western region. The coarse deposits along the eastern edge of the Basin are thinner and predominantly sand relative to gravel. The section illustrates the increasing prevalence of fine-grained material from west to east along the alluvial depositional system.

Cross-section H-H’ (**Figure 6-19**) crosses the Basin through the middle of the San Francisquito Cone, between Atherton Creek and the San Francisquito Creek. Bedrock is at a depth of approximately 75 feet bgs at the western edge of the Basin and slopes steeply to the east, reaching an elevation of approximately 1,100 feet below msl in the eastern region of the Basin. Sand and gravel layers are present throughout, but their frequency decreases from west to east reflecting an increase in silts and clays. In general, wells are screened at shallower depths in the western portion of the section. The coarse layers are thicker and appear more continuous than the coarse layers slightly to the north on section G-G’, likely because the San Francisquito Creek alluvial system is larger than the Atherton Creek system and this location is closer to the mouth of the alluvial valley. The sand and gravel lenses are thinner close to the edge of the Basin and the Bay.

<u>*Summary*</u>

The cross-sections document bedrock dipping from west to east, from slightly below ground surface along the western margins of the Basin to hundreds of feet or even over 1,000 feet below msl at the Bay. The alluvium reaches a maximum thickness of up to 1,300 feet below msl at the southern end of the Basin. Bedrock along the eastern part of the Basin, particularly in the north near cross-section C-C’ and in the central part of the Basin near cross-section E-E’, rises to form the walls of deep sedimentary basins.

The cross-sections also reveal heterogeneous coarse and fine deposits associated with alluvial depositional systems and Bay deposits. The eastern portions of the Basin are dominated by silts and clays with lenses and layers of gravel and silt. Fining upwards sequences, which are a signature characteristic of alluvial deposits, are present throughout the Basin as layers of gravel overlain by sand overlain by silt and clay. As the streams that drain the hills flow from west to east, they lose energy and deposit progressively finer material. This is illustrated by a greater frequency of coarse grained layers and lenses in the western portion of the Basin. The frequency of coarse deposits decreases from west to east giving way to more sand lenses and finer deposits. The thickness of discreet sand layers also generally decreases to the east. In general, well screens are shallower in the western portion of the Basin.

The cross-sections show that the gravel and sand deposits in the northern and southern areas of the Basin are thicker than in the center of the Basin. The deposits in the southern region of the Basin in the vicinity of San Francisquito Cone are lenticular as a result of meandering paleochannels. Sand and gravel deposits south of Atherton Creek, near the southern boundary of the Basin, are thicker and likely were deposited by the larger San Francisquito Creek alluvial system. Permeable zones near the ground surface near San Mateo Creek, San Francisquito Creek, and the smaller creeks allow groundwater-creek interactions, as described in Section 7.0. There is also evidence throughout the Basin of thick coarse deposits at the base of the alluvial sequence within the bedrock depressions.

6.2.3.4 Lithologic Textures

The cross-sections show the interbedded nature of the fine and coarse material throughout the Basin and indicate a higher percentage of fine grained material (silts and clays) in the eastern portions. To provide a more comprehensive evaluation of the lithologies throughout the Basin, geologic texture data at the locations in the texture database were incorporated into the study. Textures refer to the proportions or percentages of gravel, sand, and silt and clay within a geologic unit and can indicate areas of higher or lower permeability. In general, higher percentages of coarse-grained material (i.e., gravel and sand) result in higher permeability, allowing groundwater to be more easily transmitted through the unit.

Texture maps were developed based on the percentage of coarse-grained material at the approximately 390 well locations in the texture database. The texture maps were developed based on the depth-averaged fraction of coarse grained material at each well location in accordance with USGS methodology (Leighton et al., 1995). Sediments that were primarily gravel or sand were assumed to be 100 percent coarse grained and sediments that were primarily silt or clay were assumed to be 0 percent coarse grained.

Texture maps showing the percentage of coarse grained material at each well are illustrated on **Figures 6-20a** and **6-20b**. The maps show coarse percentages at different depth intervals (in 50-foot 'slices'), and for the system as a whole. **Figure 6-20a** shows the coarse percent of the entire depth of each well and from 0 to 50 feet bgs, 50 to 100 feet bgs, and 100 to 150 feet bgs. **Figure 6-20b** shows the coarse percent from 150 to 200 feet bgs, 200 to 250 feet bgs, 250 to 300 feet bgs, and below 300 feet bgs. If a well does not reach the depth represented on the map, it is not shown. Therefore, the number of wells shown on each map decreases with depth.

A texture map showing the percentage of coarse material for the entire depth of each well is illustrated on the upper left panel of **Figure 6-20a**. This map is biased by the variable depths of the wells, and in some cases shallow wells may exhibit significant coarse or fine material percentages that are not reflective of the entire alluvial system at those locations. However, the map shows that the Basin is dominated by fine-grained materials (i.e., coarse percent less than 50 percent). The well locations with coarse percentages greater than 50 percent are in the southwestern region of the Basin in the vicinity of the Atherton Creek and San Francisquito Creek drainages, along the western edge of the Basin at higher elevations, and in the northern region of the Basin. Most of the wells in the eastern region of the Basin are constructed in fine-grained material (i.e., coarse-grained percent less than 50 percent). This is consistent with the lithology shown on the cross-sections.

By comparing the texture map of the upper 50 feet (**Figure 6-20a**, upper right panel) to the texture map below 300 feet (**Figure 6-20b**, lower right panel), it is evident that the coarse material is more evenly distributed throughout the Basin at the surface (0 to 50 feet bgs) than at depth (below 300 feet bgs). In the southwestern region of the Basin, the upper 50 feet shows many wells that have coarse percentage over 50 percent while only two wells in this region show similar percentages of coarse material below a depth of 300 feet. The northern end of the Basin is the coarsest region of the Basin at a depth below 300 feet. This is consistent with the thick sand layers in the bedrock depression illustrated on cross-section C-C'.

Table 6-2 shows the percentages of wells on each map that are either fine grained (0 to 50 percent coarse) or coarse grained (50 to 100 percent coarse). The percentage of wells with coarse grained material increases with depth from the surface (0 to 50 feet bgs) to a depth of 200 to 250 feet bgs, with the exception of 100 to 150 feet bgs. The interval from 100 to 150 feet bgs is the finest-grained of all the intervals shown on **Figures 6-20a** and **6-20b**; 93 percent of the wells are in fine-grained material. The interval from 200 to 250 feet is the coarsest grained interval; 23 percent of the wells are in coarse-grained material.

Table 6-2. Percentage of Wells with Fine- and Coarse-Grained Textures

Well Texture	Depth Interval (feet bgs)							
	>0	0 - 50	50 - 100	100 - 150	150 - 200	200 - 250	250 - 300	>300
Fine Grained (0% to 50% Coarse)	91%	88%	83%	93%	80%	77%	84%	87%
Coarse Grained (50% to 100% Coarse)	9%	12%	17%	7%	20%	23%	16%	13%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

6.2.4 Aquifer Hydraulic Properties

Aquifer hydraulic properties are used to quantify the potential productivity and storage characteristics of water-bearing units. Hydraulic conductivity is a function of the aquifer material's intrinsic permeability and controls the rate at which water can move through the medium under a given hydraulic gradient. Transmissivity is equal to the hydraulic conductivity multiplied by the average saturated thickness of the aquifer, and is the rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient. Storativity is the volume of water an aquifer releases from or takes into storage per unit surface area of aquifer per unit change in hydraulic head. Specific capacity is the rate at which water is produced by a well per foot of drawdown (drop in water level) over a specified period of pumping.

Aquifer test data were compiled from previous studies and are presented in **Table 6-3**. Aquifer hydraulic properties are available from testing at 51 wells located in the southern portion of the Basin and at four wells in the northern portion of Santa Clara Subbasin, immediately south of the southern Basin boundary. Aquifer test data include estimates of hydraulic conductivity (K), transmissivity (T), specific capacity and storativity based on pump tests, recovery tests, and slug tests. A summary of the number of data points, minimum, maximum, geometric mean and median values are provided in **Table 6-4** below. **Figures 6-21** and **6-22** illustrate hydraulic conductivity and transmissivity values. Hydraulic property values at USGS well

005S003W34H001, presented in **Table 6-3** are orders of magnitude higher than the rest of the data and are not included on the figures or in **Table 6-4** below.

Table 6-4. Aquifer Test Data Summary

Value	Transmissivity, T (ft^2/day)	Hydraulic Conductivity, K (ft/day)	Specific Capacity (gal/min/ft)	Storativity
Count	59	40	31	16
Minimum	1.3	0.5	0.8	2.5E-05
Maximum	14,583	310	54.5	1.7E-01
Geometric Mean	330	13	7.6	2.1E-03
Median	493	13	6.0	3.4E-03

Hydraulic conductivity values are within the expected range for aquifer materials. The minimum end of the range (0.5 feet per day (ft/day) or 1.8×10^{-4} centimeters per second (cm/s)) is representative of silty sands while the maximum end of the range (310 ft/day or 0.11 cm/s) is representative of clean sands and gravels (Todd and Mays, 2005). The geometric mean and median values (13 ft/day or 4.6×10^{-3} cm/s) are representative of clean sands (Todd and Mays, 2005). As presented on **Figure 6-21**, the highest values of hydraulic conductivity (greater than 50 ft/day) are located within and to the east of the San Francisquito Cone and along San Francisquito Creek. The hydraulic conductivity data are highly variable within a geographic region. For example, there are several wells within San Francisquito Cone with values of hydraulic conductivity that bracket both the lowest and highest ends of the range. This variability is consistent with the heterogeneity of the alluvial deposits.

Values of transmissivity range from 1.3 to 14,583 ft^2/day, with a geometric mean of 330 ft^2/day and median of 493 ft^2/day. As presented on **Figure 6-22**, the pattern of transmissivity values is relatively similar to the hydraulic conductivity data. The highest transmissivity values (greater than 1,000 ft^2/day) are in the southernmost region of the Basin, on and to the east of San Francisquito Cone, along San Francisquito Creek. The lowest transmissivity values are in wells north of San Francisquito Cone and in the eastern portion of the Basin adjacent to the Bay.

Storativity values are available at 16 wells and range from 0.000025 to 0.17, with a geometric mean of 0.0021 and median of 0.0034. The highest values are representative of unconfined conditions while the geometric mean and median values are indicative of confined conditions. This is consistent with the presence of both confined and unconfined conditions in the Basin.

Values of specific capacity provided in **Table 6-3** range from 0.8 to 54.5 gallons per minute per foot (gal/min/ft), with a geometric mean of 7.6 gal/min/ft and median of 6.0 gal/min/ft. Specific capacity data are often used to evaluate well performance or estimate transmissivity. Most wells with available specific capacity data also include estimates of transmissivity.

6.2.5 Groundwater Levels and Flow

An evaluation of Basin groundwater levels and flow was conducted using available water level data. Available water level data include discrete measurements of monitoring and production wells in San Mateo County, along with additional long-term and nested well groundwater elevation data from wells just across the southern Basin boundary in Palo Alto. Groundwater elevation contour maps were prepared using data from shallow (less than or equal to 50 feet deep) and deep wells, and hydrographs of water levels over time were constructed and evaluated. In general, long-term records of water level data for shallow wells and recent data for deep wells in the Basin are relatively limited.

6.2.5.1 Groundwater Contours

Groundwater level data for shallow and deep wells were contoured for four time periods. The most complete set of basin-wide water level data for deep wells is from fall 1994, and the most complete basin-wide data set for shallow wells is from fall 2010. Groundwater elevations were contoured for both shallow and deep wells for both historical time periods (fall 1994 and fall 2010) and for the most recently available data (fall 2016 and summer 2017). A few non-contemporaneous water level measurements were added in order to augment the sparse water level data used to develop the contour maps; these additional data are flagged on the maps.

Fall 1994

The groundwater elevation map based on fall 1994 shallow water level measurements is presented on **Figure 6-23**. Groundwater elevations in the southern part of the Basin are limited to wells near San Francisco Bay and are less than 5 feet msl. Groundwater elevations in the northern part of the Basin range from approximately 10 to 15 feet in the west to less than 5 feet msl in the east. Shallow water level data are not available in the central portion of the Basin. Based on the contours, groundwater flows towards the Bay, from southwest to northeast. The shallow horizontal hydraulic gradient in the north is approximately 0.0019 ft/ft. Groundwater levels in the shallow wells near the Bay are known to be tidally influenced (Ninyo & Moore, 2016).

Deep groundwater elevations measured in fall 1994 are presented as **Figure 6-24**. Groundwater elevations range from approximately 50 feet msl in the western edge of the San Francisquito cone to less than 5 feet msl in the southeastern region of the Basin. Groundwater elevations in the central and northern regions of the Basin are sparse and range from 10 to 15 feet msl to less than 5 feet msl. Groundwater flow is from west to the east towards the San Francisco Bay. The deep horizontal hydraulic gradient in the vicinity of San Francisquito Cone is approximately 0.0024 ft/ft. The contour irregularity in this region may be due to deep well pumping or the presence of thin discontinuous aquifer zones. The deep groundwater contour surface is also shown on the cross-sections, as described previously in Section 6.2.3.

Fall 2010

Shallow groundwater elevations measured in fall 2010 are illustrated on **Figure 6-25**. Values are too numerous to show on the map and are documented in **Table 6-5**. The water level measurements are spread out throughout the Basin and show groundwater elevations ranging from approximately 50 feet msl in the western region of the San Francisquito Cone to approximately sea level in the northeastern region of the Basin. Similar to 1994, flow direction is from west to east. The shallow horizontal hydraulic gradients range from approximately 0.0021 ft/ft in the north to 0.0027 ft/ft in the south. Shallow groundwater exhibits a steep gradient in the vicinity of the San Francisquito Cone. Shallow groundwater levels east of the San Francisquito Cone appear to be higher in 2010 than in 1994. This shallow groundwater contour surface is also shown on the cross-sections, as described previously in Section 6.2.3.

Deep groundwater elevations measured in fall 2010 are illustrated on **Figure 6-26**. Deep water levels are sparse and range from 10 to 15 feet msl in the southern Basin to approximately sea level near the San Francisco Bay, both north of the Basin boundary and in the southeastern Basin. Based on the measurements, groundwater flow is from the west to the east towards San Francisco Bay. The deep horizontal hydraulic gradient in the central region of the Basin is approximately 0.0008 ft/ft. A deep well at the Romic site in East Palo Alto near the Bay exhibits water levels that are above sea level (artesian) (Arcadis, 2015).

Fall 2016 and Spring 2017

Additional groundwater contour maps were created for fall 2016 and spring 2017. Groundwater contour maps for both shallow and deep wells were included. New data was included for wells measured by the County, East Palo Alto monitoring program wells, City of Palo Alto wells, and Geotracker data.

Shallow groundwater levels in fall 2016 are shown on **Figure 6-27** and spring 2017 are shown on **Figure 6-28**. The shallow groundwater levels for these time periods are similar to the 2010 water levels shown on **Figure 6-25**. In the southern part of the Basin, groundwater elevations in fall 2016 decreased from about 60 feet msl near the inland edge of the Basin in Atherton to less than 5 feet near the tidal marshes, indicating groundwater flow toward the Bay. A similar pattern was present near San Mateo in the northern part of the Basin, except that the highest measured water levels near the inland edge of the Basin were less than 20 feet. By spring 2017 shallow groundwater levels had risen in most wells in San Mateo County, shifting the groundwater elevation contours slightly toward the Bay. Near San Francisquito Creek the single well controlling the contouring experienced 8-foot rise in water level, possibly resulting from creek recharge. Water levels farther upstream along San Francisquito Creek were assumed to have risen 10 to 12 feet since fall 2016, and the contours were drawn accordingly.

Deep groundwater levels are shown for fall 2016 on **Figure 6-29** and spring 2017 on **Figure 6-30**. In fall 2016 groundwater flow was generally slightly west of north in the area located just south of the Basin. Water levels decreased from about 75 feet msl near the upper end of Stevens Creek to 10 feet msl near the lower end of San Francisquito Creek (see **Figure 6-2** for creek locations).

The closed water-level contour farther up San Francisquito Creek encircles a water-level depression associated with Stanford irrigation wells. The spring 2017 groundwater level contour map shows the same general pattern of groundwater flow in Santa Clara County, except that water levels recovered near the Stanford wells. The spring map includes data from the southern part of the Basin. Those water levels indicate a groundwater flow direction from the inland edge of the Basin toward San Francisco Bay. Groundwater elevations decreased from about 40 feet msl to less than 10 feet msl along that flow path.

6.2.5.2 Hydrographs

Groundwater levels are also presented as hydrographs at select wells throughout the Basin. Hydrographs for shallow and deep wells are illustrated on **Figures 6-31** and **6-32**. Hydrographs were selected for wells located throughout the Basin, as much as possible, and with long water level histories. The well screen interval is noted on the hydrograph, if available.

Shallow well hydrographs (**Figure 6-31**) are presented for six wells: three in the northwestern region of the Basin, one along the northeastern edge of the Basin, and two in the central region of the Basin. These wells depict groundwater levels over an approximate 15-year history, from late 2001 to early 2016. The three wells clustered in the northwestern region of the Basin, whose hydrographs are shown on the left side of **Figure 6-31**, have groundwater elevations that range from sea level to about 20 feet msl. Water levels in these wells are cyclic, with annual fluctuations of 5 to 10 feet. Two of these northwestern wells show generally stable long-term water levels between 2001 and 2012, followed by declines of approximately 2 to 5 feet between 2012 and early 2016, most likely associated with the drought. Water levels in well T0608100572_MW-21 showed a somewhat more consistent declining trend over the same period, declining from approximately 15 feet msl in 2001 to slightly below sea level in late 2015. The majority of this decline occurred during the drought period from 2012 through 2015.

Water levels in the shallow well along the northeastern Basin boundary and the two shallow wells in the central region of the Basin are lower than in northwestern Basin. Water levels in these wells are also cyclic, but the annual fluctuations are much less - two to three feet at most. Elevations over the last 15 years show mixed trends: slight downwards trend in the southernmost central well (T0608191816_MW-6), slight upwards trend in the northernmost central well (T0608100346_MW-2), and no discernable trend along the northeastern edge of the Basin.

Figure 6-32 shows hydrographs for four deep wells in the Basin, all in the southern portion of the Basin. The time period and duration of water level records at these wells vary. As described above, shallow groundwater shows cyclic fluctuations. The deep wells in the southern Basin also show similar cyclic patterns and illustrate that groundwater elevations are higher in the western Basin than in the eastern Basin. The deep well in the center of San Francisquito Cone (006S003W04C001) has a short water level record, from about 1992 to 1996, with water levels that fluctuate between about 10 to 23 feet msl. Water levels at the Romic RW-16D well, along the southeastern Basin boundary, exhibit a cyclic pattern with fluctuations of about 4 to 5 feet and elevations ranging from sea level to about 10 feet msl between 2001 to 2014, occasionally reaching artesian conditions. Hydrographs for the remaining two deep wells shown in the center portion of the Basin (USGS well 5S/3W-34H1 and the Hale Well) are shown in greater detail on **Figure 6-33**.

Figure 6-33 shows hydrographs for a USGS well (5S/3W-34H1) and the Hale Well, both located near the southern Basin boundary. The USGS well is located in the Basin, slightly north of the boundary, while the Hale Well is located slightly south of the Basin. The well locations are shown on the shallow and deep well hydrograph figures (**Figures 6-31** and **6-32**). Water levels in the Hale Well illustrate how much groundwater levels have increased in the last 55 years. Water levels in the Hale Well rose almost 150 feet between the early 1960s and the late 1970s, from approximately 130 feet below msl to approximately 15 to 20 feet above msl. After the late 1970s, the water levels became relatively stable, fluctuating between approximately sea level and 25 feet msl. There are some anomalously high and low water levels during this time. Water levels at the USGS well are similar during the period of overlap, from about 1977 to 1995. Water levels in the Hale well dropped around 15 feet during the drought period between approximately 2010 and 2014, but then rebounded about 5 feet in 2015. As described in more detail below in Section 6.2.6, the water level similarity across the Basin boundary indicates that the Basin is hydrologically connected to the northern region of the Santa Clara Subbasin.

Water levels in SCVWD's Eleanor Pardee Park nested well cluster, located in Palo Alto slightly south of the Basin boundary, are shown on **Figure 6-34**. Water levels in the four separate monitoring wells (which are screened at different depth intervals) are monitored at high temporal frequency by the SCVWD. These high-frequency and depth-discrete records allow for examination of short-term water level fluctuations in each well and a comparison of water level behavior at different depths. The largest fluctuations were observed in the shallowest well. Water level elevations in the deeper wells are progressively greater than those in the shallow wells, indicating an upward vertical gradient in this area.

6.2.6 Bay Mud Hydraulic Conductivity Evaluation

Water levels in wells located near San Francisco Bay are influenced by cyclic water level changes in San Francisco Bay influenced by ocean tides that range in frequency. The predominant tidal fluctuations are the semi-diurnal/semi-daily (every 12 hours and 25 minutes) and diurnal/daily cycles (every 24 hours and 50 minutes). The resulting pressure waves from the tides are transmitted through the underlying bay mud sediments and shallow water bearing zone to produce water level fluctuations in wells. Additional factors that can influence well water levels include barometric pressure changes, rainfall, and groundwater extractions. We measured water level changes in monitoring wells in response to ocean tides, and analyzed the timing and magnitude of the response to estimate the water storage properties of the shallow aquifer and the vertical hydraulic conductivity of the bay mud.

6.2.6.1 Water Level Data

A pressure transducer was installed in monitoring well RW-14B located at the former Romic Environmental Technologies Corporation Site, located at 2081 Bay Road in East Palo Alto (**Figure 6-35**). At this site, the bay mud is estimated to be approximately 15 to 16 feet thick. RW-14B is 42 feet deep, with a screened interval of 25 to 40 feet below land surface, and therefore falls beneath the bay mud and within the shallow aquifer corresponding to San Mateo Plain Groundwater Flow Model (SMPGWM) layer 1 (see Section 8.0; Arcadis G&M, Inc., 2001). The transducer recorded changes in the height of the water column at 6-minute intervals, which were converted to groundwater elevation based on the corresponding depth to water and surveyed measuring point elevation (Ninyo & Moore, 2016).

The water level of the Bay is recorded at the Redwood City National Oceanic and Atmospheric Administration (NOAA) station[16] in 6-minute intervals and referenced to mean sea level. The reported bay water levels were converted to NAVD-88 using the benchmark at the Dumbarton Bridge.[17] **Figure 6-36** shows the Bay tide and monitoring well water level elevations for the measurement period (11 September 2017 to 20 October 2017). The raw data shown on **Figure 6-36** was then filtered to remove most of the major daily and semi-daily tidal effect using 24-hour moving averages (Serfes, 1991), leaving the water level response to longer wavelengths presumed to be in response to barometric pressure changes, groundwater discharge to the Bay, and groundwater extractions from the aquifer by wells; the filtered data are also plotted on **Figure 6-36** and show the longer-term groundwater trends during the data collection period. We subtracted the filtered response (the long-term trends) from the raw data to approximately isolate the water level changes due solely to the semi-diurnal and diurnal tidal cycle (**Figure 6-36**). The water storage and transmitting properties of the shallow water bearing sediments were then estimated by analyzing the isolated tidal response that was recorded in the measured groundwater levels.

6.2.6.2 Specific Storage

The "tidal method" applied herein assumes that pressure waves are damped exponentially as they progress away from San Francisco Bay through the shallow water-bearing zone. Assuming one-dimensional flow through a confined aquifer, the tidal method allows estimation of the storage coefficient from the observed time lag and calculated tidal efficiency (Carr and Van Der Kamp, 1969; Shuai et. al., 2017). An apparent time lag of 48 minutes between the peaks of the Bay tide and monitoring well water levels was calculated, and then the apparent tidal efficiency (TE_{app}) was estimated as the ratio of the standard deviations of the monitoring well and tidal water levels per Erskine (1991). The true tidal efficiency (TE_{true}), which conceptually is the efficiency at a location immediately adjacent to the Bay, is calculated using the following equation cited by Carr and Van Der Kamp (1969):

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[16] https://tidesandcurrents.noaa.gov/waterlevels.html?id=9414523
[17] https://www.ngs.noaa.gov/Tidal_Elevation/diagram.xhtml?PID=HT0308&EPOCH=1983-2001

$$TE_{true} = TE_{app} \times e^{\left[T_L \times \left(\frac{2\pi}{t_O}\right)\right]}$$

where

T_L is the time lag, in days; and,
t_o is the period of fluctuation, which is about 0.52 days for the semi-diurnal tidal cycle.

Specific storage is calculated directly from TE_{true}:

$$S_s = \frac{\theta \beta \varsigma}{(1 - TE_{true})}$$

where

S_s is specific storage, per foot of aquifer (ft^{-1});
Θ is the porosity of the sediments (assumed 76-percent);[18]
β is the compressibility of the water (2.1×10^{-8} lb/ft^2); and
ς is the specific weight of water (62.4 lb/ft^3).

Using the tidal data, monitoring well data, and the equation above, the calculated value for S_s is 1×10^{-6} ft^{-1}.

6.2.6.3 Vertical Conductivity of the Bay Mud

In the SMPGWM, head-dependent flow boundaries (denoted as general-head boundaries) allow for the exchange of water between San Francisco Bay and the underlying groundwater. The model-calculated groundwater level is determined as a function of the specified water level external to the general-head boundary (in this case, the reported measured water level in the Bay), and the specified water-transmitting properties of the Bay bottom sediments (the vertical conductivity of the "bay mud"). Using the measured bay water levels, the vertical conductivity of the bay mud was estimated by adjusting its value to match the measured monitoring well water levels.

Our analysis employed the superposition[19] modeling approach to calibrate model-calculated water levels in response solely to the tidal cycle. The principal advantage of superposition is that

[18] Average measured porosity from mud core samples collected near the bay in East Palo Alto. HydroFocus, Inc., 2005, "Geotechnical Analysis of Soil Sediments in Abandoned Wells."
[19] The "theory of superposition" states that solutions to the parts of a complex problem can be added to solve the composite problem. Superposition can therefore be utilized to isolate the effect of one stress from all other stresses

it isolates the effect of the tides from all other factors that influence water levels, and is therefore consistent with our use of the filtering approach and isolated tidal data and groundwater water level response. In the superposition approach, recharge and pumping in the model are all set to zero, and the specified six-minute filtered bay water levels simulate the isolated cyclic fluctuation of the Bay tides.

The specific storage of model layer 1 was set equal to the value estimated from the tidal efficiency ($1x10^{-6}$ ft^{-1}), and a trial-and-error approach was used to adjust the specified bay mud vertical conductivity represented by the general-head boundary conductance. **Figure 6-37** shows the comparison between model-calculated and measured water levels, which was greatly improved by reducing the bay mud conductivity from 0.025 feet per day (ft/d) to 0.0015 ft/d (a reduction of more than one order of magnitude). Upon completion of parameter estimation/calibration, discrepancies between model-calculated water levels and measured water levels still exist. These are likely attributed primarily to model discretization (i.e., the area and depth intervals of the model cells are fairly large relative to the site-specific conditions represented by the monitoring well) and real-world aquifer heterogeneity (i.e., the actual thickness and extent of fine- and coarse-grained sediments between the Bay water and monitoring well) that are only approximated by the model.

6.2.7 Basin Boundaries

The Basin is bounded on the west by the Santa Cruz Mountains, on the east by the San Francisco Bay and Niles Cone Subbasin, on the north by the Westside Basin, and on the south by the Santa Clara Subbasin (see **Figure 6-1**). In general, groundwater and surface water inflow occurs across the western boundary into the Basin. Under current conditions, the only onshore Basin boundary with net outflow is the northern boundary. Groundwater outflow also occurs through the eastern boundary through aquifer zones extending under the Bay. Groundwater inflow or outflow can occur through the northern and southern boundaries, depending on recharge and pumping conditions along and adjacent to the boundaries.

Regional cross-sections were developed to evaluate the hydrogeologic inter-connections between the Basin and the neighboring groundwater basins and subbasins. These cross-sections are conceptualized, and do not show lithologic layering in high detail, but do illustrate the potential inter-connections between the adjacent groundwater basins. **Figure 6-38** is a longitudinal cross-section extending from the Westside Basin to the north, through the Basin, and into the Santa Clara Subbasin to the south. This cross-section is aligned along local cross-section A-A’ (**Figures 6-12a** through **6-12c**) and is connected to an existing cross-section across the southern Westside Basin prepared by the SFPUC (2014) and an existing cross-section of the

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operating in a basin. (Reillym Franke, Bennett, 1987). In modeling practice, superposition is implemented by setting initial water levels equal; constant (or fixed) water-level boundaries are all specified equal to the initial water levels so that the hydraulic gradient along the boundary is initially zero; and background prescribed stresses representing existing conditions are removed.

northern Santa Clara Subbasin prepared by the DWR (DWR, 1975). Note that the detailed stratigraphy illustrated on local cross-section A-A’ was generalized on this schematic cross-section, and the broad sand zones illustrated on the regional sections may be more accurately described as layered coarse and fine packages with individual layers on the scale of feet or tens of feet, rather than the thick zones illustrated.

Figure 6-39 is a transverse cross-section extending from the Basin eastward across San Francisco Bay and into the Niles Cone Subbasin. This cross-section is aligned along local cross-section H-H’ (**Figure 6-19**) and extends across the Bay to the Niles Cone and illustrates lithologic data provided by the ACWD. This cross-section also includes lithologic data from a series of submarine borings drilled by the SFPUC as a part of the Bay Division pipeline project.

6.2.7.1 Western Basin Boundary

The western boundary of the Basin roughly coincides with the contact between the unconsolidated alluvial deposits and the Santa Cruz Mountains. The boundary is uneven, with alluvial aquifer fingers stretching to the west within stream channel drainages. As shown on the lateral cross-sections (**Figures 6-14** through **6-19**), very thin deposits of unconsolidated material are present near the Basin boundary. The depth to bedrock illustrated on the cross-sections is generally based on the ground surface elevation digital elevation model (DEM) and the Hensolt and Brabb (1990) bedrock elevation map. Based on the logged thickness of alluvium in boreholes and elevations of the bedrock surface where it rises near the boundary, the alluvium pinches out to the west as is represented on the USGS and California Department of Conservation geologic maps. Longitudinal cross-section A-A’ (**Figures 6-12a** through **6-12c**) skirts the edge of the Basin in the north-central part of the Basin and illustrates bedrock cropping west of the Basin boundary.

The nature and distribution of groundwater-bearing bedrock fractures along the western Basin boundary has not been characterized. However, subsurface inflow to the Basin via bedrock fractures was estimated in the water budget (Section 7.0).

6.2.7.2 Eastern Basin Boundary

The eastern boundary of the Basin is defined by DWR as the margin of San Francisco Bay. However, as illustrated on the cross-sections, the coarse deposits extend laterally to the eastern boundary of the Basin and presumably beneath at least a portion of San Francisco Bay. The conceptual regional cross-section extending from the Basin to the Niles Cone Subbasin (**Figure 6-39**) illustrates this likely extension of the aquifer zones. Niles Cone aquifers also presumably extend to the west beneath the San Francisco Bay, potentially all the way to the Basin.

Based on review of the available data, the permeable aquifer zones associated with the Niles Cone appear thicker and more continuous than those in the Basin, likely reflecting the greater potential energy of Alameda Creek, which formed the Niles Cone and drains a significantly larger watershed[20] and accordingly, has a greater capacity to transport and deposit thick and continuous gravel and sand layers. On this basis, the Niles Cone sediments may extend farther across San Francisco Bay than those originating in the Basin. However, the degree of inter-connection between the Basin and Niles Cone aquifer system is not well characterized. As illustrated on the conceptual regional cross-section, soil borings drilled along the alignment of the SFPUC cross-bay pipeline provide lithologic information in the upper 200 feet of sediments beneath the Bay, but no deeper lithologic data are available. Sand layer aquifer zones in both the Basin and Niles Cone Subbasins appear to thin as they approach the Bay, and some sand zones appear to pinch out near and beneath the Bay. This may indicate that the aquifer transmissivity and connectivity is limited to certain relatively thick and continuous aquifer zones. However, some degree of connection was indicated based on the results of a pumping test conducted by DWR in 1963. During this test, wells 5S/2W-18D1 and 5S/2W-18E3, located near the western landing of the Dumbarton Bridge, were pumped at a combined rate of 580 gallons per minute (gpm) for a period of eight days, and drawdown of 3 feet was observed in well 5S/2W-21L1, located in the middle of the Bay between the groundwater basins (DWR, 1967).

Because the groundwater flow direction in the Basin under current conditions is generally from west to east, groundwater flows from the Basin east under the Bay. The amount of groundwater outflow through the eastern boundary along the Bay shoreline was estimated for the Basin water budget (Section 7.3).

6.2.7.3 Northern Basin Boundary

The northern boundary of the Basin is represented as the boundary between the Basin and the Westside Basin. According to DWR, this boundary is based on a bedrock high that separates the two basins (DWR, 2006). This bedrock high is presumably the same bedrock ridge that surfaces at Coyote Point in the northeast corner of the Basin. However, based on the bedrock elevation map discussed above and as shown on cross-section C-C' (**Figure 6-14**), this bedrock ridge does not extend to the groundwater surface in the area between the foothills and Coyote Point, and therefore likely does not form a complete boundary to groundwater flow. The western edge of Coyote Point is slightly more than a mile from the western boundary of the Basin.

As shown on cross-section C-C' (**Figure 6-14**), the northern edge of the Basin is the narrowest and shallowest part of the Basin. The east-west length of the northern boundary is less than two miles, and the thickness of the alluvium along cross-section C-C', slightly south of the boundary, is very thin along the western portion, thickening to approximately 400 feet in the center of the Basin. As shown on cross-section A-A', there are discrete sand and gravel layers that likely extend to and across the Basin boundary into the Westside Basin. However, borehole data in the southernmost portions of the Westside Basin indicate that predominantly fine-grained deposits (silts and clays) overlying shallow bedrock are present just north of the Basin boundary (**Figure 6-**

[20] San Francisquito Creek drains an area of approximately 109 square kilometers, and Alameda Creek drains an area of approximately 1,813 square kilometers (Leidy, 2007).

38). Farther north in the Westside Basin, the alluvium thickens, and some boreholes contain Upper Merced Formation sediments in the lower portions of the Basin.

The groundwater flow direction in the area of the Basin boundary is generally from the west to the east, (i.e., parallel to the Basin boundary). Groundwater may move across the Basin boundary in response to groundwater pumping on either side of the boundary. However, groundwater flow rates across the Basin boundary are limited by the relatively thin aquifer thickness and predominantly fine-grained deposits along and north of the Basin boundary.

6.2.7.4 Southern Basin Boundary

San Francisquito Creek forms the southern boundary of the Basin. However, alluvial aquifer deposits are thickest within the Basin along the southern boundary due to a deep bedrock depression extending to approximately 1,300 feet below msl. As shown on the conceptual regional cross-section (**Figure 6-38**) and local cross-section B-B’ (**Figure 6-13**), which extends beyond the southern Basin boundary, there are layers of coarse material that are likely continuous across the boundary.

Water level data provide further evidence that the southern region of the Basin is hydrologically connected to the northern region of the Santa Clara Subbasin and that the southern Basin boundary is not a barrier to groundwater flow (**Figures 6-27** to **6-30)**. As shown on **Figure 6-33**, USGS well 34H1, located within the Basin immediately north of the boundary, is approximately 4,100 feet northwest of the Hale Well, located immediately south of the Basin boundary. As illustrated, water level trends at these wells are similar from 1977 to 1995, the period of overlap, suggesting both sides of the Basin boundary are influenced by local and regional recharge and discharge sources.

6.2.8 Subsidence History

Land subsidence occurs when groundwater level declines significantly reduce the fluid pressure in the pores of the aquifer system. This results in compression of clay materials and the sinking of the land surface. Land subsidence can exacerbate flooding and damage infrastructure.

Subsidence includes both an elastic and inelastic component. Elastic deformation occurs when sediments compress as pore pressure decreases, and then subsequently expand as pore pressure increases. Inelastic compaction results only when the sediments are compressed beyond their previous maximum stress (preconsolidation stress). The preconsolidation stress, or the effective stress threshold at which inelastic compaction begins, generally is exceeded when groundwater levels decline past historic low levels. In these stress ranges, the materials can compress inelastically, and the compaction and subsequent land subsidence are largely permanent and irreversible, despite any subsequent water level recovery. The dual nature of both elastic and irreversible inelastic consolidation is described by Poland in his studies of historical subsidence in the South Bay and East Palo Alto areas (Poland, 1971). This compression may be partially recoverable if pressures rebound, but the recovery is rarely of the same magnitude as the initial compression. Because of the greater compressibility of fine-grained sediments, areas having an abundance of fine-grained sediments, such as in the eastern portions of the Basin near the Bay, are more susceptible to land subsidence than the western areas with greater proportions of relatively incompressible sand and gravel.

In the first half of the 20th century, portions of the Santa Clara Valley subsided as much as 13 feet as a result of groundwater over-pumping. Similarly, in the southern portions of the Basin prior to the 1960s, groundwater levels were well below sea level; these lowered groundwater levels induced subsidence of the aquifer system. Land subsidence of more than two feet was measured in East Palo Alto between 1934 and 1967 (Poland and Ireland, 1988). Subsidence in the Atherton area during the same period was reportedly between 0.1 and 0.5 foot (Metzger, 1997).

The subsidence observed in the basins during the 20th century was halted with development of surface water sources and/or improved groundwater management. Reduced groundwater pumping, along with artificial recharge initiated by the SCVWD[21] allowed depressed groundwater levels to recover in the Santa Clara Subbasin. This is reflected in the hydrograph for the Hale Well located in the northern portion of the Santa Clara Subbasin (**Figure 6-33**). Groundwater elevations in the Hale Well reached a low elevation of -140 feet msl in 1962, but have increased since that time. Long-term water levels records are more limited for the Basin, but it is known that the static water level in a well drilled in Atherton in 1950 was about -23 feet msl. The PAPMWC Well No. 5 had a static groundwater level of -31 feet msl when drilled in 1950. Since the importation of Hetch Hetchy water to the Basin, groundwater levels have increased to above sea level (see **Figures 6-23** to **6-30** and **6-33**).

Because of the economic cost of subsidence, the SCVWD and USGS/NOAA initiated a program of surveying the Santa Clara Valley and adjacent counties to determine its extent. NOAA's National Geodetic Survey (NGS) maintains and provides access to the National Spatial Reference System (NSRS), a consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States. The foundational elements of the NSRS include a series of survey benchmarks. **Figure 6-40** shows the locations of USGS/NOAA benchmarks in and adjacent to the Basin, and **Table 6-6** provides information on these benchmarks.

Additional benchmarks are monitored by SCVWD, and several municipalities and other agencies within the Basin. East Palo Alto installed five permanent survey benchmarks in 2014 and is surveying them bi-annually to monitor for land subsidence as part of the implementation of its recently-adopted GWMP.

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[21] Mitigation measures by the SCVWD in the late 1960s and early 1970s have stopped and even reversed subsidence in the Santa Clara Subbasin. These measures have included provision of surface water supplies in lieu of groundwater, artificial recharge of the groundwater basin through stream channels and recharge basins, and careful monitoring and management of groundwater levels to avoid further subsidence.

Satellite Interferometric Synthetic Aperture Radar (InSAR) has also been used to monitor subsidence in the Basin and region. InSAR is a relatively new technique allowing measurement and mapping of changes on the Earth's surface as small as a few millimeters. To evaluate seasonal and multi-year deformation patterns in the Santa Clara Valley, the USGS used European Observation Satellites (EOS) 5-year InSAR data from September 1992 through August 1997. The data showed small amounts (5 to 10 millimeters) of regional uplift that corresponded with water-level recovery throughout the Santa Clara Valley. An 8-month interferogram (January to August 1997) showed seasonal subsidence of about 30 millimeters near San Jose that corresponded to about a 10-meter decline in water levels. In the Palo Alto and East Palo Alto area, significantly smaller seasonal declines were noted (Galloway, et al., 2000; Bawden, et al., 2003). A 12-month interferogram of the Santa Clara Valley area for the period from March 2015 to March 2016 showed less than 0.2 inches (the lowest end of the range of displayed data) for the northern Santa Clara Subbasin proximal to the southern end of the Basin, suggesting that subsidence within the Basin was negligible during that time period (Farr, et al., 2016).

Table 6-1
Watershed and Creek Characteristics

Atherton Flood Channel				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	1,685	2,150	444	4,279
Uplands	1,188	199	115	1,502
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	0.1	3.1	20.1	23.3
Reservoirs	**Year Built**	**Area (acres)**	**Storage (acre-feet)**	**Description**
Bear Gulch	n.a.	15	660	Stores local runoff and imported water for public supply.
Water Quality				
Beneficial Uses (b,c)	WARM,WILD, REC-1, REC-2			
Belmont Creek				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	104	214	26	344
Uplands	1,037	554	116	1,707
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	1.4	0.2	3.7	5.3
Water Quality[6,7]				
TDS	Specific conductance 690-1,660 µS/cm			
Pollutants	Exceeded trigger threshold for bioassessment, chlorine, secondary chemistry, and pathogen indication in 2013			
Beneficial Uses (b,c)	WARM,WILD, REC-1, REC-2			
Borel Creek				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	316	446	83	845
Uplands	347	356	48	751
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	1.1	1.2	6	8.3
Water Quality				
Beneficial Uses (b,c)	WARM,WILD, REC-1, REC-2			
Cordilleras Creek				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	522	288	50	860
Uplands	1,814	359	133	2,306
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	1.3	0.4	2.3	3.9
Water Quality[5]				
TDS	Specific conductance 406-1,024 µS/cm, hardness 220-440 mg/L during 2004-2006.			
Pollutants	No organophosphorus pesticides detected			
Beneficial Uses (b,c)	WARM,WILD, REC-1, REC-2			
Laurel Creek				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	197	321	47	565
Uplands	1,139	651	148	1,938
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	0.9	0.7	3.2	4.8
Water Quality[7]				
Pollutants	Exceeded trigger threshold for pathogen indicators in 2012.			
Beneficial Uses (b,c)	WARM,WILD, REC-1, REC-2			

Table 6-1
Watershed and Creek Characteristics

Leslie Creek				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	276	276	61	613
Uplands	30	30	7	67
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	0	0.1	3.6	3.7
Water Quality				
Beneficial Uses (b,c)	WARM,WILD, REC-1, REC-2			
Poplar Creek				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	213	183	50	446
Uplands	27	14	7	48
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	0	0	1.6	1.6
Water Quality				
Beneficial Uses (b,c)	--			
Pulgas/Greenwood Creeks				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	189	314	43	546
Uplands	848	499	114	1,461
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	1.3	0.9	5.6	7.8
Water Quality[7]				
Pollutants	1 (of 1) copper sample exceeded water quality objective of 13 µg/L.			
Beneficial Uses (b,c)	WARM,WILD, REC-1, REC-2			
Redwood Creek/Arroyo Ojo de Agua				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	1,585	1,545	376	3,506
Uplands	1,637	1,120	350	3,107
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	1	4	19.8	24.8
Water Quality[7]				
Pollutants	Redwood Creek exceeded trigger threshold for bioassessment and secondary chemistry in 2013. Arroyo Ojo de Agua exceeded trigger threshold for bioassessment, chlorine, and pathogen indicators in 2012.			
Beneficial Uses (b,c)	WARM,WILD, REC-1, REC-2			

Table 6-1
Watershed and Creek Characteristics

San Francisquito Creek				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	3,307	996	310	4,613
Uplands	20,982	983	1,038	23,003
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	9.7	1.8	6.4	17.9
Reservoirs	**Year Built**	**Area (acres)**	**Storage (acre-feet)**	**Description**
Searsville Lake	1890	36	1,300	90% of storage capacity filled with sediment.
Felt Lake	1929	47	n.a.	Stores diversions from Los Trancos Creek for Stanford water supply.
Water Quality[7]				
Pollutants	Exceeded trigger threshold for continuous water quality and pathogen indicators, 2012-2013			
Beneficial Uses (b,c)	COLD, MIGR, SPWN, WARM, WILD, REC-1, REC-2			
San Mateo Creek				
Area (acres)	**Pervious**	**Connected Impervious**	**Disconnected Impervious**	**Total**
In-basin (a)	274	314	71	659
Uplands	18,956	620	401	19,977
Channel Type	**Natural**	**Engineered**	**Underground**	**Total**
Length (miles) (a)	1.9	0.3	2.6	4.8
Reservoirs	**Year Built**	**Area (acres)**	**Storage (acre-feet)**	**Description**
Crystal Springs Reservoir	1888	1,092	57,910	Stores local runoff and Hetch-Hetchy water for SFPUC.
San Andreas Lake	1868	550	19,000	Ditto.
Water Quality[4,7]				
TDS	Specific Conductance 268-1,242 µS/cm Feb-Apr 2004; 198-456 µS/cm in 2013.			
Pollutants	Organophosphorous pesticides were not detected during study in 2005.			
Beneficial Uses (b,c)	FRSH, COLD, MIGR, RARE, SPWN, WARM, WILD, REC-1, REC-2			

Abbreviations:

"cfs" = cubic feet per second
"SFPUC" = San Francisco Public Utilities Commision
"µg/L" = microgram per liter
"µS/cm" = microsiemens per centimeter

Notes:

a "In-basin" watershed areas and channel lengths are for the part of the watershed overlying the San Mateo Plain basin excluding the tidal marshland subarea. Includes tributaries and tributary storm drains if they were mapped by Sowers (2004) or Tillery and others (2007).

b Beneficial uses of San Mateo Plain creeks listed in the Basin Plan are:
"COLD" = cold fresh water habitat
"FRSH" = fresh water replenishment
"MIGR" = fish migration
"RARE" = habitat for rare or endangered species
"REC-1" = water contact recreation
"REC-2" = non-contact recreation
"SPWN" = fish spawning
"WARM = warm fresh water habitat
"WILD" = wildlife habitat

c Water quality objectives for San Mateo Plain creeks listed in the Basin Plan are:

Water Quality Objectives for Inland Surface Waters[1]				
Bacteria				
	Beneficial Use	Fecal Coliform (NPN/100 mL)	Total Coliform (NPN/100 mL)	Enterococcus (NPN/100 mL)
	REC-1	Geometric mean < 200	Median < 240	Geometric mean < 35
		90th percentile < 400	No sample > 10,000	No sample > 104
	REC-2	Mean < 2,000	--	--
		90th percentile < 4,000	--	--
Dissolved Oxygen	7 mg/L minimum for cold water habitat and 5 mg/L for warm water habitat			
pH	6-5 to 8.5			

See Basin Plan Section 3.3 for narrative discussion of water quality objectives

Table 6-3
Aquifer Test Data

Well Name	Date	T (ft2/day)	K (ft/day)	Specific Capacity (gal/min/ft)	Storativity	Method	Source
005S003W27L004		1,069.4	26.7	4.0		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
005S003W27L006		243.0	3.5	0.9		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
1 (Howard)		222.9	3.2	0.8		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
005S002W18E003				7.0		Recovery Test, Recovery Method	California Department of Water Resources, 1968, Evaluation of Ground Water Resources South Bay Volume I: Fremont Study Area. Bulletin No. 118-1. August 1968.
005S002W18E003					5.0E-04	Drawdown Test, Most Reasonable Average	California Department of Water Resources, 1968, Evaluation of Ground Water Resources South Bay Volume I: Fremont Study Area. Bulletin No. 118-1. August 1968.
006S003W10L001	April 1960				5.0E-02	Pump Test, Theis Method	Sokol, Daniel, 1963, The Hydrogeology of the San Francisquito Creek Basin, San Mateo and Santa Clara Counties, California. Dissertation, Stanford University. December 1963.
006S003W11B001	19-Apr-62				1.3E-03	Pump Test, Theis Method	Sokol, Daniel, 1963, The Hydrogeology of the San Francisquito Creek Basin, San Mateo and Santa Clara Counties, California. Dissertation, Stanford University. December 1963.
006S003W01D001							Fio JL and Leighton DA, 1995, Geohydrologic Framework, Historical Development of the Ground-Water System, and General Hydrologic and Water-Quality Conditions in 1990, South San Francisco Bay and Peninsula Area, California. U.S. Geological Survey Open-File
005S003W21G001		5,941.3	121.3	22.2		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
EPA Gloria		616.9	22.9	2.3		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
005S003W27D002		1,604.2	80.2	6.0		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
005S003W27F002		8,020.8	200.5	30.0		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
005S003W27G002		1,336.8	13.2	5.0		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
005S003W27G004		274.2	6.9	1.0		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
005S003W27H005		381.9	9.5	1.4		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.

Table 6-3
Aquifer Test Data

Well Name	Date	T (ft2/day)	K (ft/day)	Specific Capacity (gal/min/ft)	Storativity	Method	Source
005S003W27L003		1,336.8	22.3	5.0		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
Bayport Well 1		35.8				72 hour Pumping Test, Drawdown	Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010
Bayport Well 1		88.0				72 hour Pumping Test, Recovery	Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010
Bayport Well 1		48.9				8 hour Pumping Test, Recovery	Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010
Beacon MW-4			10.0				Delta Environmental Consultants, Inc., 1995, Remediation System Effectiveness, Hydrogeologic Assessment and Proposed Remediation Clean-up Levels Beacon Station No. 591 595 Willow Road Menlo Park, California. September 15, 1995
Bohannon MW-3 (02)		966.3	107.0				Erler & Kalinowski, Inc., 1997, Remedial Investigation Report 3695-3723 Haven Avenue Menlo Park, California. April 21, 1997.
Bohannon MW-5B	November 1996	948.2	95.0		6.4E-04		Erler & Kalinowski, Inc., 1997, Remedial Investigation Report 3695-3723 Haven Avenue Menlo Park, California. April 21, 1997.
EPA Pad D Test Well		880.0				Pump test, Step-drawdown	Erler & Kalinowski, Inc., 2014, Report on Drilling, Construction, and Testing of the Pad D Test Well. Prepared for City of East Palo Alto Community Development Department. October 11, 2014.
EPA Pad D Test Well		896.0				Pump test, Constant rate	Erler & Kalinowski, Inc., 2014, Report on Drilling, Construction, and Testing of the Pad D Test Well. Prepared for City of East Palo Alto Community Development Department. October 11, 2014.
LW MWC-1			190.0				HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
LW MWF1-1			310.0				HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
Menlo Park Corp Yard Well	April 6, 2017			36.6		2 hour Constant Rate Pumping Test	Luhdorff & Scalmanini Consulting Engineers, 2017, City of Menlo Park Corp Yard Well Construction and Testing Summary, May 2017.
Menlo Park Corp Yard Well	April 6, 2017			35.1		2 hour Constant Rate Pumping Test	Luhdorff & Scalmanini Consulting Engineers, 2017, City of Menlo Park Corp Yard Well Construction and Testing Summary, May 2017.
Menlo Park Corp Yard Well	April 6, 2017			32.4		2 hour Constant Rate Pumping Test	Luhdorff & Scalmanini Consulting Engineers, 2017, City of Menlo Park Corp Yard Well Construction and Testing Summary, May 2017.

Table 6-3
Aquifer Test Data

Well Name	Date	T (ft2/day)	K (ft/day)	Specific Capacity (gal/min/ft)	Storativity	Method	Source
Menlo Park Corp Yard Well	April 10, 2017			33.7		12 hour Constant Rate Pumping Test	Luhdorff & Scalmanini Consulting Engineers, 2017, City of Menlo Park Corp Yard Well Construction and Testing Summary, May 2017.
MW-7D	11/16/2005	1.3	1.3			Pumping Test, Theis Method	Kennedy/Jenks Consultants, 2006, Report on Well Installation and Groundwater Monitoring. Prepared for Praxair Inc, May 5, 2006. http://geotracker.waterboards.ca.gov/esi/uploads/geo_report/3337954461/T0608146836.PDF
MW-8D	11/22/2005	1.9	0.6			Pumping Test, Theis Method	Kennedy/Jenks Consultants, 2006, Report on Well Installation and Groundwater Monitoring. Prepared for Praxair Inc, May 5, 2006. http://geotracker.waterboards.ca.gov/esi/uploads/geo_report/3337954461/T0608146836.PDF
O'Conner Tract #1				45.0			Erler & Kalinowski, Inc., 2006, Summary of Preliminary Investigation of Groundwater Extraction Opportunities Redwood City Industrial Saltworks, LLC City of Redwood City, California. Technical Memorandum from Anona Dutton and Jeff Shaw to Mark Kehke, John
O'Conner Tract #2				5.0			Erler & Kalinowski, Inc., 2006, Summary of Preliminary Investigation of Groundwater Extraction Opportunities Redwood City Industrial Saltworks, LLC City of Redwood City, California. Technical Memorandum from Anona Dutton and Jeff Shaw to Mark Kehke, John
O'Conner Tract #1		12,833.3	118.8	48.0		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
O'Conner Tract #2		1,336.8	17.8	5.0		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
Pacific Shores (1)	8/28/2001	529.2			2.5E-05	2001 Pumping Test, Drawdown	Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010
Pacific Shores (1)		403.0				2001 Pumping Test, Recovery	Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010
Pacific Shores (2)	9/1/2001	511.2			9.8E-05	2001 Pumping Test, Drawdown	Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010
Pacific Shores (2)		427.6				2001 Pumping Test, Recovery	Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010
Pacific Shores No. 1		787.0					Erler & Kalinowski, Inc., 2006, Summary of Preliminary Investigation of Groundwater Extraction Opportunities Redwood City Industrial Saltworks, LLC City of Redwood City, California. Technical Memorandum from Anona Dutton and Jeff Shaw to Mark Kehke, John
Pacific Shores No. 2		418.0					Erler & Kalinowski, Inc., 2006, Summary of Preliminary Investigation of Groundwater Extraction Opportunities Redwood City Industrial Saltworks, LLC City of Redwood City, California. Technical Memorandum from Anona Dutton and Jeff Shaw to Mark Kehke, John

Table 6-3
Aquifer Test Data

Well Name	Date	T (ft2/day)	K (ft/day)	Specific Capacity (gal/min/ft)	Storativity	Method	Source
Pacific Shores No. 3		115.0					Erler & Kalinowski, Inc., 2006, Summary of Preliminary Investigation of Groundwater Extraction Opportunities Redwood City Industrial Saltworks, LLC City of Redwood City, California. Technical Memorandum from Anona Dutton and Jeff Shaw to Mark Kehke, John
Pacific Shores No. 3	9/15/2001	694.2			9.8E-04	2001 Pumping Test, Drawdown	Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010
Pacific Shores No. 3		165.8				2001 Pumping Test, Drawdown	Smith DW, Porter V, Manley W, Remy T, Stanin PS, Young VJ, 2010, Water Group Summary Report for the Saltworks Proposal in Redwood City, CA. Prepared for the Hart Howerton, Ltd. And the City of Redwood City. January 22, 2010
Palo Alto Hale St. 3		5,881.9	17.8	22.0			Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
Palo Alto Matadero		483.8	0.5	1.8		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
Palo Alto Park MWC #7		974.8	13.2	3.6		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
Palo Alto Peer's Park	19-May-61				1.9E-04	Pump Test, Theis Method	Sokol, Daniel, 1963, The Hydrogeology of the San Francisquito Creek Basin, San Mateo and Santa Clara Counties, California. Dissertation, Stanford University. December 1963.
Palo Alto Peer's Park		1,951.7	2.8	7.3			Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
Palo Alto Rinconada		4,597.3					Fio JL and Leighton DA, 1995, Geohydrologic Framework, Historical Development of the Ground-Water System, and General Hydrologic and Water-Quality Conditions in 1990, South San Francisco Bay and Peninsula Area, California. U.S. Geological Survey Open-File
Palo Alto Rinconada		8,822.9	25.8	33.0			Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
Palo Alto Seale		359.5					Fio JL and Leighton DA, 1995, Geohydrologic Framework, Historical Development of the Ground-Water System, and General Hydrologic and Water-Quality Conditions in 1990, South San Francisco Bay and Peninsula Area, California. U.S. Geological Survey Open-File
Raychem R-1		1,940.4	12.0			Slug Test 1986	HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
Raychem R-18			3.0			Slug Test 2002	HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
Raychem R-19		14.0				Pumping Test, Jacob Method	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem)., April 30, 2002.
Raychem R-19		4.6				Recovery Test, Jacob Method	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem)., April 30, 2002.

Table 6-3
Aquifer Test Data

Well Name	Date	T (ft2/day)	K (ft/day)	Specific Capacity (gal/min/ft)	Storativity	Method	Source
Raychem R-19	April 2002	1,065.6			4.0E-03	Slug Test	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem), April 30, 2002.
Raychem R-19			15.0			Recovery Test 2002	HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
Raychem R-19			1.0			Recovery Test 2002	HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
Raychem R-20		492.9				Pumping Test, Jacob Method	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem)., April 30, 2002.
Raychem R-20		344.1				Recovery Test, Jacob Method	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem)., April 30, 2002.
Raychem R-20			4.0			Recovery Test 2002	HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
Raychem R-38			6.0			Slug Test 2002	HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
Raychem R-48		3.7				Pumping Test, Jacob Method	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem)., April 30, 2002.
Raychem R-48		5.6				Recovery Test, Jacob Method	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem)., April 30, 2002.
Raychem R-48	April 2002	132.5			4.0E-03	Slug Test	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem), April 30, 2002.
Raychem R-49		334.8				Pumping Test, Jacob Method	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem)., April 30, 2002.
Raychem R-49		753.3				Recovery Test, Jacob Method	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem)., April 30, 2002.
Raychem R-49	April 2002	4,464.0			6.0E-03	Slug Test	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem), April 30, 2002.
Raychem R-53	April 2002	14,400.0			3.0E-03	Slug Test	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem), April 30, 2002.
Raychem R-59	April 2002	8.6			1.7E-01	Slug Test	SCS Engineers, 2002, Full-Scale Aquifer Testing Tyco Electronics (Former Raychem), April 30, 2002.
RH RW-4X	September 1987	26.0	6.0		1.5E-02		Bechtel Environmental, Inc., 1988, Final Site Investigation Report for the Rohm and Hass Redwood City Facility and prepared for Rohm and Haas California, Inc. May 1988
RH RW-9D	September 1987	4.0	0.8		3.8E-03		Bechtel Environmental, Inc., 1988, Final Site Investigation Report for the Rohm and Hass Redwood City Facility and prepared for Rohm and Haas California, Inc. May 1988
RH RW-9S	September 1987	63.0	12.3	11.2	6.4E-03		Bechtel Environmental, Inc., 1988, Final Site Investigation Report for the Rohm and Hass Redwood City Facility and prepared for Rohm and Haas California, Inc. May 1988
Romic RW-2C		47.0	8.0	3.4			Einarson, Fowler & Watson and Henshaw Associates, 1998, Draft Comprehensive RCRA Facility Investigation Report Romic Environmental Technologies Corporation East Palo Alto, California. Prepared for Romic Environmental Technologies Corporation. April 28, 19

Table 6-3
Aquifer Test Data

Well Name	Date	T (ft2/day)	K (ft/day)	Specific Capacity (gal/min/ft)	Storativity	Method	Source
Romic RW-3B		6.0	0.8	0.8			Einarson, Fowler & Watson and Henshaw Associates, 1998, Draft Comprehensive RCRA Facility Investigation Report Romic Environmental Technologies Corporation East Palo Alto, California. Prepared for Romic Environmental Technologies Corporation. April 28, 19
RP M-1			15.0				HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
RP M-3			41.0				HydroFocus, Inc., 2003, Groundwater-Flow System Description and Simulated Constituent Transport, Raychem/Tyco Electronics Site 300-315 Constitution Drive, Menlo Park, CA. November 21, 2003.
St. Patricks Seminary No. 3		14,583.3	132.6	54.5		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
St. Patricks Seminary 35D2		4,491.7	22.5	16.8		Pump Test	Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.
St. Patricks Seminary No. 3				5.4			Erler & Kalinowski, Inc., 2006, Summary of Preliminary Investigation of Groundwater Extraction Opportunities Redwood City Industrial Saltworks, LLC City of Redwood City, California. Technical Memorandum from Anona Dutton and Jeff Shaw to Mark Kehke, John
USGS 005S003W34H001		106,944.4	2,138.9	400.0			Todd Engineers, Kennedy/Jenks Consultants, and ESA, 2012, Gloria Way Water Well Production Alternatives Analysis & East Palo Alto Water Security Feasibility Study. November, 2012.

Table 6-5
Shallow Groundwater Level Data, Fall 2010

ID	Well Name	Water Level Elev. (ft NAVD88)	ID	Well Name	Water Level Elev. (ft NAVD88)	ID	Well Name	Water Level Elev. (ft NAVD88)	ID	Well Name	Water Level Elev. (ft NAVD88)
1	L10003734871_DW-1	4.84	**56**	SL18390810_MW-2A	8.12	**111**	T0608100037_MW-1	10.36	**166**	T0608100205_PZ6	0.85
2	L10003734871_DW-2	6.61	**57**	SL18390810_MW-3	7.64	**112**	T0608100037_MW-10	6.64	**167**	T0608100211_MW-10	25.55
3	L10003734871_K-1	5.55	**58**	SL18390810_MW-4	7.79	**113**	T0608100037_MW-11	6.24	**168**	T0608100211_MW-4	24.83
4	L10003734871_K3-PZ	5.39	**59**	SL18390810_MW-5	7.58	**114**	T0608100037_MW-5	11.51	**169**	T0608100211_MW-5	25.56
5	L10003734871_K3-R	9.92	**60**	SL18390810_R-1	8.37	**115**	T0608100037_MW-6	10.46	**170**	T0608100237_MW-10	(3.97)
6	L10003734871_K-4	4.89	**61**	SL18390810_R-2	7.87	**116**	T0608100037_MW-7	9.35	**171**	T0608100237_MW-4	(5.02)
7	L10003734871_MW-3	3.64	**62**	T0608100025_MW-1	2.73	**117**	T0608100037_MW-8	10.37	**172**	T0608100237_MW-5	(4.12)
8	L10003734871_MW3-1R	4.29	**63**	T0608100025_MW-3A	(1.24)	**118**	T0608100037_MW-9	8.31	**173**	T0608100237_MW-7	(5.01)
9	L10003734871_MW3-2R	4.77	**64**	T0608100025_MW-4	2.68	**119**	T0608100038_MW-2	2.05	**174**	T0608100237_MW-8	(3.66)
10	L10003734871_MW-4	4.93	**65**	T0608100028_A-1	6.55	**120**	T0608100038_MW-3	0.98	**175**	T0608100237_MW-9	(4.06)
11	L10003734871_MW-4P	5.03	**66**	T0608100028_A-10	6.79	**121**	T0608100038_MW-4	0.47	**176**	T0608100297_E-1	15.11
12	L10003734871_P-2A	5.78	**67**	T0608100028_A-11	5.93	**122**	T0608100038_MW-5	1.41	**177**	T0608100297_MW-1	15.34
13	L10003734871_P3-PZ	4.74	**68**	T0608100028_A-12	4.54	**123**	T0608100038_MW-6	1.28	**178**	T0608100297_MW-10	12.77
14	L10003734871_P3-R	4.70	**69**	T0608100028_A-13	4.19	**124**	T0608100040_MW-1R	1.51	**179**	T0608100297_MW-11	15.05
15	L10003734871_P-4	8.56	**70**	T0608100028_A-2	6.68	**125**	T0608100040_MW-2R	2.77	**180**	T0608100297_MW-2	14.56
16	L10003734871_P5-1-PZ	2.80	**71**	T0608100028_A-3	6.70	**126**	T0608100040_MW-4R	4.74	**181**	T0608100297_MW-3	14.35
17	L10003734871_P5-1R	2.82	**72**	T0608100028_A-4	6.61	**127**	T0608100040_MW-5R	2.32	**182**	T0608100297_MW-4	14.91
18	L10003734871_P-6	5.84	**73**	T0608100028_A-6	6.20	**128**	T0608100040_MW-6R	1.93	**183**	T0608100297_MW-5	14.46
19	L10003734871_P-7	7.18	**74**	T0608100028_A-7	6.30	**129**	T0608100040_MW-8D	1.82	**184**	T0608100297_MW-6	14.03
20	L10003734871_P-8	3.21	**75**	T0608100028_A-8	6.34	**130**	T0608100040_MW-8S	1.70	**185**	T0608100297_MW-7	15.16
21	L10003734871_PZ-2	5.23	**76**	T0608100028_ASW-1	5.00	**131**	T0608100042_MW-1	2.53	**186**	T0608100297_MW-9	14.60
22	L10003734871_PZ-2P	4.55	**77**	T0608100028_ASW-2	5.06	**132**	T0608100042_MW-3	2.22	**187**	T0608100338_MW-10	10.16
23	L10003734871_PZ-3A	4.11	**78**	T0608100028_EW-1	6.83	**133**	T0608100042_MW-4	1.47	**188**	T0608100338_MW-11	11.53
24	L10003734871_PZ-3B	3.86	**79**	T0608100028_EW-11	6.40	**134**	T0608100042_MW-5	2.14	**189**	T0608100338_MW-12	10.40
25	L10003734871_PZ-3C	3.37	**80**	T0608100028_EW-5	6.43	**135**	T0608100042_MW-6	0.31	**190**	T0608100338_MW-13	12.13
26	L10003734871_S-2	16.59	**81**	T0608100030_EW-1	56.17	**136**	T0608100042_MW-7	1.51	**191**	T0608100338_MW-3	12.09
27	L10003734871_S-3A	10.39	**82**	T0608100030_EW-2	57.22	**137**	T0608100042_MW-8	1.84	**192**	T0608100338_MW-4	10.64
28	L10003734871_S-4A	12.17	**83**	T0608100030_MW-1	58.66	**138**	T0608100042_MW-9	2.52	**193**	T0608100338_MW-5	10.91
29	L10003734871_S-5	10.32	**84**	T0608100030_MW-12D	51.84	**139**	T0608100069_MW-16	22.62	**194**	T0608100338_MW-6	9.77
30	L10003734871_UPG-2	2.94	**85**	T0608100030_MW-16A	57.71	**140**	T0608100069_MW-17	23.48	**195**	T0608100338_MW-7	11.38
31	SL0608101750_MW-1	48.11	**86**	T0608100030_MW-17	57.29	**141**	T0608100078_MW-1	4.43	**196**	T0608100338_RW-1	15.57
32	SL0608101750_MW-2	48.41	**87**	T0608100030_MW-18	56.91	**142**	T0608100078_MW-2	4.05	**197**	T0608100338_RW-2	11.22
33	SL0608101750_MW-3	47.32	**88**	T0608100030_MW-19	57.54	**143**	T0608100078_MW-3	3.97	**198**	T0608100338_RW-3	11.84
34	SL0608101750_MW-4	46.54	**89**	T0608100030_MW-1S	58.66	**144**	T0608100078_MW-4	4.32	**199**	T0608100338_RW-4	10.46
35	SL0608101750_SMW-6	47.51	**90**	T0608100030_MW-20	56.82	**145**	T0608100078_MW-5	4.02	**200**	T0608100342_MW-13	2.74
36	SL0608148082_P-10U	4.51	**91**	T0608100030_MW-2A	57.73	**146**	T0608100078_MW-6	3.99	**201**	T0608100342_MW-14	3.12
37	SL0608148082_P-11L	4.44	**92**	T0608100030_MW-3	58.84	**147**	T0608100078_MW-7	3.91	**202**	T0608100342_MW-15	2.96
38	SL0608148082_P-12U	4.60	**93**	T0608100030_MW-4	57.27	**148**	T0608100124_MW-1	143.27	**203**	T0608100342_MW-16	3.32
39	SL0608148082_P-13L	4.57	**94**	T0608100030_MW-5	57.03	**149**	T0608100124_MW-15	147.92	**204**	T0608100346_BW	4.94
40	SL0608148082_P-8U	4.33	**95**	T0608100030_MW-6	56.21	**150**	T0608100124_MW-16	145.02	**205**	T0608100346_MW-10	2.42
41	SL0608148082_P-9L	4.12	**96**	T0608100030_MW-7	55.76	**151**	T0608100124_MW-8	144.71	**206**	T0608100346_MW-11	2.41
42	SL0608148082_W-139(A)	4.46	**97**	T0608100034_EW-1	2.92	**152**	T0608100197_MW-1	3.89	**207**	T0608100346_MW-12	4.07
43	SL0608148082_W-140(B)	4.57	**98**	T0608100034_MW-10	3.35	**153**	T0608100197_MW-2	3.50	**208**	T0608100346_MW-13	3.78
44	SL0608148082_W-141(C)	4.30	**99**	T0608100034_MW-1A	2.53	**154**	T0608100205_EW1	0.78	**209**	T0608100346_MW-14	4.20
45	SL0608184452_MW-1	48.11	**100**	T0608100034_MW-2	3.14	**155**	T0608100205_MW2	0.81	**210**	T0608100346_MW-15	5.28
46	SL0608184452_MW-2	48.41	**101**	T0608100034_MW-3	2.95	**156**	T0608100205_MW3A	0.78	**211**	T0608100346_MW-2	4.54
47	SL0608184452_MW-3	47.32	**102**	T0608100034_MW-4	2.82	**157**	T0608100205_MW4	1.08	**212**	T0608100346_MW-3	4.41
48	SL0608184452_MW-4	46.54	**103**	T0608100034_MW-5	3.35	**158**	T0608100205_MW5B	1.54	**213**	T0608100346_MW-4	4.71
49	SL0608184452_SMW-6	47.51	**104**	T0608100034_MW-7	2.84	**159**	T0608100205_MW6	0.46	**214**	T0608100346_MW-5	4.83
50	SL18390810_IP-1	8.01	**105**	T0608100034_MW-8	2.72	**160**	T0608100205_MW7	0.78	**215**	T0608100346_MW-6	4.99
51	SL18390810_IP-2	7.86	**106**	T0608100034_MW-9	2.72	**161**	T0608100205_PZ1	0.80	**216**	T0608100346_MW-7	4.01
52	SL18390810_IP-3	7.83	**107**	T0608100037_EW-1	11.68	**162**	T0608100205_PZ2	0.77	**217**	T0608100346_MW-8	3.35
53	SL18390810_IP-4	7.77	**108**	T0608100037_EW-2	14.11	**163**	T0608100205_PZ3	0.78	**218**	T0608100346_MW-9	4.94
54	SL18390810_IP-5	7.73	**109**	T0608100037_EW-3	11.45	**164**	T0608100205_PZ4	(0.02)	**219**	T0608100346_RW-1	3.57
55	SL18390810_IP-6	7.47	**110**	T0608100037_EW-4	10.32	**165**	T0608100205_PZ5	0.78	**220**	T0608100346_SP-1	3.98

Table 6-5
Shallow Groundwater Level Data, Fall 2010

ID	Well Name	Water Level Elev. (ft NAVD88)	ID	Well Name	Water Level Elev. (ft NAVD88)	ID	Well Name	Water Level Elev. (ft NAVD88)	ID	Well Name	Water Level Elev. (ft NAVD88)
221	T0608100449_MW-2	(0.11)	275	T0608100669_OBS-3	3.04	329	T0608100987_MW-2TM	4.28	383	T0608129773_MW-6	5.19
222	T0608100509_MW-16	22.62	276	T0608100726_EX-1	11.66	330	T0608100987_MW-2TS	(2.27)	384	T0608129773_MW-7	4.96
223	T0608100509_MW-17	23.48	277	T0608100726_EX-2	11.56	331	T0608100987_MW-3TM	0.22	385	T0608129773_MW-8	4.93
224	T0608100539_MW15A	3.69	278	T0608100726_EX-3	11.45	332	T0608100987_MW-3TS	(2.25)	386	T0608144190_MW-1	16.61
225	T0608100539_MW15C	3.52	279	T0608100726_OB-1	11.70	333	T0608100987_MW-4TS	0.72	387	T0608144190_MW-2	15.30
226	T0608100539_MW15D	5.25	280	T0608100726_OB-2	11.81	334	T0608100987_MW-5TS	2.17	388	T0608144190_MW-3	15.36
227	T0608100539_MW15E	6.73	281	T0608100726_OB-3	12.52	335	T0608100987_WTS-MW1	(0.78)	389	T0608144190_MW-4	14.91
228	T0608100539_MW15F	3.03	282	T0608100726_X-10A	8.53	336	T0608100987_WTS-MW2	1.20	390	T0608144190_MW-5	15.43
229	T0608100539_MW15G	2.71	283	T0608100726_X-10B	8.55	337	T0608100987_WTS-MW3	(2.65)	391	T0608144190_MW-7	14.59
230	T0608100539_MW15H	1.83	284	T0608100726_X-11A	8.30	338	T0608100996_MW-1	6.10	392	T0608146836_MW-11	2.88
231	T0608100539_MW15I	3.58	285	T0608100726_X-11B	7.27	339	T0608100996_MW-2	4.92	393	T0608146836_MW-12	2.93
232	T0608100539_MW15J	2.80	286	T0608100726_X-11C	7.76	340	T0608100996_MW-3	4.18	394	T0608146836_MW-14	3.22
233	T0608100539_MW15K	2.81	287	T0608100726_X-12R	11.79	341	T0608100996_MW-4	3.41	395	T0608146836_MW-16D	2.70
234	T0608100539_MW15LA	7.22	288	T0608100726_X-13	11.48	342	T0608100996_MW-5	4.04	396	T0608146836_MW-18D	2.77
235	T0608100539_MW15LB	2.85	289	T0608100726_X-15	7.60	343	T0608100996_MW-6	3.80	397	T0608146836_MW-4	2.93
236	T0608100539_MW15MA	7.16	290	T0608100726_X-15C	(2.73)	344	T0608100996_MW-7	4.21	398	T0608146836_MW-5D	2.91
237	T0608100539_MW15MB	1.63	291	T0608100726_X-16	5.72	345	T0608100996_MW-8	3.22	399	T0608146836_MW-6	2.64
238	T0608100539_MW15NA	7.01	292	T0608100726_X-16C	6.31	346	T0608100996_MW-9	2.86	400	T0608146836_MW-7D	2.39
239	T0608100539_MW15NB	4.33	293	T0608100726_X-2	12.75	347	T0608101011_EW-1	48.24	401	T0608159805_MW-1	8.14
240	T0608100539_MW15OA	5.88	294	T0608100726_X-4	12.17	348	T0608101011_EW-2	42.72	402	T0608159805_MW-2	8.11
241	T0608100539_MW15OB	2.45	295	T0608100726_X-5	9.96	349	T0608101011_EW-3	44.81	403	T0608159805_MW-3	8.16
242	T0608100539_MW15PA	6.47	296	T0608100726_X-6	9.85	350	T0608101011_EW-4	47.65	404	T0608160745_MW-1	12.94
243	T0608100539_MW15PB	3.63	297	T0608100726_X-7	13.75	351	T0608101011_MW-1	44.74	405	T0608160745_MW-2	12.93
244	T0608100539_MW15QA	6.42	298	T0608100726_X-8	8.26	352	T0608101011_MW-10	38.66	406	T0608160745_MW-3	12.70
245	T0608100539_MW15QB	3.34	299	T0608100735_MW-1	41.81	353	T0608101011_MW-11	38.43	407	T0608160745_MW-4	12.98
246	T0608100539_OB1	2.75	300	T0608100735_MW-10	42.19	354	T0608101011_MW-2	44.74	408	T0608160745_MW-5	13.28
247	T0608100539_OB3	2.86	301	T0608100735_MW-11	46.26	355	T0608101011_MW-3	39.48	409	T0608173943_MW1	(3.02)
248	T0608100539_OB4	4.05	302	T0608100735_MW-12	47.50	356	T0608101011_MW-4	38.59	410	T0608173943_MW2	(3.00)
249	T0608100539_OB5	3.92	303	T0608100735_MW-13	46.81	357	T0608101011_MW-5	39.95	411	T0608173943_MW3	(2.92)
250	T0608100588_MW-1	7.65	304	T0608100735_MW-2	41.61	358	T0608101011_MW-6	41.10	412	T0608173943_MW4	(3.05)
251	T0608100588_MW-10	7.83	305	T0608100735_MW-3	43.73	359	T0608101011_MW-7	42.21	413	T0608179970_MW-1	1.68
252	T0608100588_MW-2	7.60	306	T0608100735_MW-4	41.97	360	T0608101011_MW-8	39.82	414	T0608196925_MW-3	7.66
253	T0608100588_MW-3	7.95	307	T0608100735_MW-5	43.45	361	T0608101011_MW-9	38.28	415	T0608196925_MW-4	7.58
254	T0608100588_MW-5	8.89	308	T0608100735_MW-6	42.59	362	T0608101097_MW-11	6.87	416	T0608196925_MW-5	7.55
255	T0608100588_MW-6	6.97	309	T0608100735_MW-7	34.68	363	T0608101107_MW-1	8.70	417	T0608196925_MW-6	7.46
256	T0608100588_MW-8	8.08	310	T0608100735_MW-8	45.99	364	T0608101107_MW-2	8.43	418	T0608196925_MW-7	7.43
257	T0608100591_MW-1	4.96	311	T0608100735_MW-9	42.59	365	T0608101107_MW-3	8.75	419	T0608196925_MW-8	7.56
258	T0608100591_MW-2	5.08	312	T0608100800_MW-1	16.57	366	T0608101115_MW-10	4.24	420	T0608196925_MW-9	7.81
259	T0608100591_MW-4	4.71	313	T0608100800_MW-2	15.44	367	T0608101115_MW-11	4.14	421	T0608197062_MW1	5.70
260	T0608100591_MW-5	4.81	314	T0608100800_MW-3	16.51	368	T0608101115_MW-12	2.77	422	T0608197062_MW2	5.06
261	T0608100591_RW-1	4.83	315	T0608100800_MW-4	14.65	369	T0608101115_MW-13	2.71	423	T0608197062_MW3	5.92
262	T0608100661_MW-2	5.38	316	T0608100852_S-1	8.64	370	T0608101115_MW-14	2.82	424	T0608197062_MW4	5.39
263	T0608100661_MW-3	5.48	317	T0608100852_S-2	8.05	371	T0608101115_MW-4	4.50	425	T0608198726_MW-1	168.70
264	T0608100661_MW-4	4.94	318	T0608100852_S-3A	(0.06)	372	T0608101115_MW-5	4.13	426	T0608198726_MW-2	169.38
265	T0608100661_MW-5A	4.66	319	T0608100852_S-4	(0.35)	373	T0608101115_MW-6	3.65	427	T0608198726_MW-3	171.13
266	T0608100661_MW-6	2.79	320	T0608100852_S-5	2.43	374	T0608101115_MW-7	4.65	428	T0608198726_MW-4	168.76
267	T0608100661_MW-7	5.03	321	T0608100852_S-6	8.43	375	T0608101115_MW-8	6.24	429	T0608198726_MW-5	168.49
268	T0608100661_P-2	5.51	322	T0608100852_S-7	8.36	376	T0608101115_MW-9	4.26	430	T0608198726_MW-6	170.35
269	T0608100669_EX-1	2.99	323	T0608100967_MW-1	12.29	377	T0608101468_MW-01	4.48	431	T10000000880_MW-1	31.40
270	T0608100669_MW-3	3.11	324	T0608100967_MW-2	12.17	378	T0608101468_MW-02	5.60	432	T10000000880_MW-2	31.98
271	T0608100669_MW-4	3.07	325	T0608100967_MW-3	11.82	379	T0608101468_MW-03	3.54	433	T10000000880_MW-3	31.44
272	T0608100669_MW-5	2.95	326	T0608100967_MW-4	12.17	380	T0608126581_MW-1	31.78			
273	T0608100669_MW-6	3.00	327	T0608100987_MW-1A	(2.13)	381	T0608129773_MW-4	5.00			
274	T0608100669_OBS-2	3.07	328	T0608100987_MW-1TM	3.64	382	T0608129773_MW-5	5.39			

Table 6-6
Benchmark Data

ID	Long	Lat	Name	County	Datum	Elevation	Elevation Datum	First Received	Last Received	Last Condition
1	-122.22222	37.47389	100 SM CO	SAN MATEO	NAD 83	7.63	NAVD 88	UNK	1967	MARK NOT FOUND
2	-122.20361	37.51639	12 PPC	SAN MATEO	NAD 83	1.08	NAVD 88	UNK	1967	GOOD
3	-122.21611	37.48889	208 CADH	SAN MATEO	NAD 83	2.4	NAVD 88	1953	1976	GOOD
4	-122.19917	37.48722	211 CAHD	SAN MATEO	NAD 83	2.35	NAVD 88	1953	1960	MARK NOT FOUND
5	-122.19111	37.41861	219 L SFWD	SAN MATEO	NAD 83	52.7	NAVD 88	UNK	1988	GOOD
6	-122.19111	37.41861	219 R SFWD	SAN MATEO	NAD 83	52.13	NAVD 88	UNK	1967	GOOD
7	-122.21081	37.50208	4.29 RC	SAN MATEO	NAD 83	2.77	NAVD 88	UNK	20041120	GOOD
8	-122.21086	37.50799	941 4508 C TIDAL	SAN MATEO	NAD 83	3.57	NAVD 88	1997	20110602	GOOD
9	-122.205	37.51389	941 4523 TIDAL 3	SAN MATEO	NAD 83	2.02	NAVD 88	UNK	1976	GOOD
10	-122.31389	37.55889	A 110 RESET 1972	SAN MATEO	NAD 83	4.68	NAVD 88	1972	1972	MONUMENTED
11	-122.20611	37.51583	A 390 CASLC	SAN MATEO	NAD 83	2.35	NAVD 88	UNK	1967	GOOD
12	-122.17861	37.48667	A 554	SAN MATEO	NAD 83	3.27	NAVD 88	1956	20080426	MARK NOT FOUND
13	-122.14417	37.48444	A 592	SAN MATEO	NAD 83	2.52	NAVD 88	1940	1954	GOOD
14	-122.14417	37.48444	A 592 RESET 1960	SAN MATEO	NAD 83	3.01	NAVD 88	1960	1965	GOOD
15	-122.22306	37.47028	A 876	SAN MATEO	NAD 83	10.51	NAVD 88	1954	20070203	MARK NOT FOUND
16	-122.32199	37.5608	AA 110	SAN MATEO	NAD 83	11.64	NAVD 88	1932	20030810	GOOD
17	-122.2058	37.51491	ALIEN	SAN MATEO	NAD 83	42.2	NAVD 88	1982	1983	GOOD
18	-122.20598	37.51455	ALIEN RM 1	SAN MATEO	NAD 83	42.2	NAVD 88	1982	1985	GOOD
19	-122.26222	37.57389	B 25 CAHD	SAN MATEO	NAD 83	4.48	NAVD 88	UNK	1986	MARK NOT FOUND
20	-122.26222	37.57389	B 33 CAHD	SAN MATEO	NAD 83	5.09	NAVD 88	UNK	1960	GOOD
21	-122.26194	37.57361	B 34 CAHD	SAN MATEO	NAD 83	5.09	NAVD 88	UNK	1960	GOOD
22	-122.26222	37.57361	B 35 CAHD	SAN MATEO	NAD 83	5.09	NAVD 88	UNK	1986	MARK NOT FOUND
23	-122.26222	37.57361	B 37 CAHD	SAN MATEO	NAD 83	4.97	NAVD 88	UNK	1986	MARK NOT FOUND
24	-122.26222	37.57361	B 39 CAHD	SAN MATEO	NAD 83	4.97	NAVD 88	UNK	1960	GOOD
25	-122.26222	37.57389	B 41 CAHD	SAN MATEO	NAD 83	5	NAVD 88	UNK	1960	GOOD
26	-122.15528	37.46944	B 554	SAN MATEO	NAD 83	8.02	NAVD 88	1956	1977	GOOD
27	-122.34488	37.57997	B 814	SAN MATEO	NAD 83	10.1	NAVD 88	1952	1986	GOOD
28	-122.22639	37.46111	B 876	SAN MATEO	NAD 83	15.96	NAVD 88	1954	20070203	MARK NOT FOUND
29	-122.30444	37.54222	BB 110 C OF SM	SAN MATEO	NAD 83	7.32	NAVD 88	1932	1967	GOOD
30	-122.27029	37.51185	BELMONT WATER MAIN VENT SPIPE	SAN MATEO	NAD 83		NAVD 88	UNK	1969	SEE DESCRIPTION
31	-122.21858	37.49511	BILLS YARD	SAN MATEO	NAD 83	3.1	NAVD 88	1983	20041120	MARK NOT FOUND
32	-122.27932	37.57343	BLOCK 2	SAN MATEO	NAD 83	3.3	NAVD 88	1983	1983	MONUMENTED
33	-122.26265	37.57259	BRIDGE	SAN MATEO	NAD 83	5	NAVD 88	1930	1948	SEE DESCRIPTION
34	-122.3694	37.59213	BURLINGAME COOP CORS ARP	SAN MATEO	NAD 83		NAVD 88			
35	-122.29806	37.53889	C 110	SAN MATEO	NAD 83	7.77	NAVD 88	1932	1956	MARK NOT FOUND
36	-122.18806	37.42306	C 151	SAN MATEO	NAD 83	47.06	NAVD 88	1933	1967	GOOD
37	-122.24869	37.51223	CARLPORT	SAN MATEO	NAD 83	0.7	NAVD 88	1987	19920619	GOOD
38	-122.25367	37.51507	CARLPORT AZ MK	SAN MATEO	NAD 83	1.5	NAVD 88	1987	19920619	GOOD
39	-122.20511	37.51685	CEMENT PLANT SQUARE BIN	SAN MATEO	NAD 83		NAVD 88	1931	1931	MONUMENTED
40	-122.31374	37.59211	COYOTE POINT YACHT HARB DBCN 5	SAN MATEO	NAD 83		NAVD 88	1980	1980	FIRST OBSERVED
41	-122.31362	37.59304	COYOTE POINT YACHT HARB DBCN 4	SAN MATEO	NAD 83		NAVD 88	1980	1980	FIRST OBSERVED
42	-122.31303	37.59371	COYOTE POINT YACHT HARB LT 2	SAN MATEO	NAD 83		NAVD 88	1980	1980	FIRST OBSERVED

Table 6-6
Benchmark Data

ID	Long	Lat	Name	County	Datum	Elevation	Elevation Datum	First Received	Last Received	Last Condition
43	-122.31438	37.59139	COYOTE POINT YACHT HARB DBCN 7	SAN MATEO	NAD 83		NAVD 88	1980	1980	FIRST OBSERVED
44	-122.3142	37.59239	COYOTE POINT YACHT HARB DBCN 6	SAN MATEO	NAD 83		NAVD 88	1980	1980	FIRST OBSERVED
45	-122.31316	37.59278	COYOTE POINT YACHT HARB DBCN 3	SAN MATEO	NAD 83		NAVD 88	1980	1980	FIRST OBSERVED
46	-122.31255	37.59347	COYOTE POINT YACHT HARB LT 1	SAN MATEO	NAD 83		NAVD 88	1980	1983	GOOD
47	-122.3148	37.59171	COYOTE POINT YACHT HARB DBCN 8	SAN MATEO	NAD 83		NAVD 88	1980	1980	FIRST OBSERVED
48	-122.317	37.58839	COYOTE PT YCHT HBR FR RNG LT	SAN MATEO	NAD 83	7	NAVD 88	1983	1983	FIRST OBSERVED
49	-122.31818	37.58689	COYOTE PT YCHT HBR REAR RNG LT	SAN MATEO	NAD 83	9.9	NAVD 88	1983	1983	FIRST OBSERVED
50	-122.28889	37.53056	D 110 RESET 1936	SAN MATEO	NAD 83	4.78	NAVD 88	1936	1976	GOOD
51	-122.19083	37.42444	D 151	SAN MATEO	NAD 83	45.75	NAVD 88	1933	1988	GOOD
52	-122.14167	37.46028	D 554	SAN MATEO	NAD 83	8.18	NAVD 88	1956	20041023	MARK NOT FOUND
53	-122.14167	37.46028	D 554 RESET 1958	SAN MATEO	NAD 83	6.93	NAVD 88	1958	20041023	MARK NOT FOUND
54	-122.205	37.51417	D 591 CASLC	SAN MATEO	NAD 83	1.95	NAVD 88	1940	1958	GOOD
55	-122.20389	37.51722	D 995	SAN MATEO	NAD 83	3.2	NAVD 88	1965	1976	GOOD
56	-122.12983	37.49814	DUM RM 5	SAN MATEO	NAD 83	4.01	NAVD 88	1971	1971	MONUMENTED
57	-122.27694	37.52194	E 110	SAN MATEO	NAD 83	10.91	NAVD 88	1932	1976	GOOD
58	-122.27694	37.52194	E 110 RESET	SAN MATEO	NAD 83	11.76	NAVD 88	1993	1993	MONUMENTED
59	-122.19892	37.48731	E 1122 RESET 1966	SAN MATEO	NAD 83	3.73	NAVD 88	1966	20040220	GOOD
60	-122.1925	37.41333	E 151	SAN MATEO	NAD 83	53.33	NAVD 88	1933	20030908	MARK NOT FOUND
61	-122.29861	37.55667	E 476	SAN MATEO	NAD 83	1.8	NAVD 88	1951	1956	MARK NOT FOUND
62	-122.13444	37.45611	E 554	SAN MATEO	NAD 83	5.76	NAVD 88	1956	1967	GOOD
63	-122.26	37.5075	E 7	SAN MATEO	NAD 83	8.63	NAVD 88	UNK	1984	GOOD
64	-122.26667	37.51389	F 110	SAN MATEO	NAD 83	7.61	NAVD 88	UNK	1956	MARK NOT FOUND
65	-122.192	37.39994	F 151 RESET 1965	SAN MATEO	NAD 83	80.05	NAVD 88	1965	20090107	GOOD
66	-122.29889	37.55667	F 476	SAN MATEO	NAD 83	1.67	NAVD 88	1951	1956	MARK NOT FOUND
67	-122.19183	37.38619	F 591	SAN MATEO	NAD 83	111.43	NAVD 88	1940	20090106	GOOD
68	-122.22778	37.48481	F 7 RESET	SAN MATEO	NAD 83	4.2	NAVD 88	1940	20090111	GOOD
69	-122.25222	37.50083	G 110	SAN MATEO	NAD 83	5.9	NAVD 88	1932	1976	GOOD
70	-122.25294	37.5013	G 110 RESET	SAN MATEO	NAD 83	5.97	NAVD 88	1992	200209	GOOD
71	-122.19156	37.39439	G 151	SAN MATEO	NAD 83	90.91	NAVD 88	1933	20090106	GOOD
72	-122.29583	37.55333	G 476	SAN MATEO	NAD 83	1.81	NAVD 88	1951	1956	MARK NOT FOUND
73	-122.29583	37.55333	G 476 RESET 1969	SAN MATEO	NAD 83	2.36	NAVD 88	1969	1971	GOOD
74	-122.2025	37.37556	G 591	SAN MATEO	NAD 83	149.06	NAVD 88	1940	1967	GOOD
75	-122.26282	37.57287	GUANO ISLAND RESET	SAN MATEO	NAD 83	3.47	NAVD 88	1968	200209	GOOD
76	-122.26298	37.57299	GUANO ISLAND RM 6	SAN MATEO	NAD 83	4.91	NAVD 88	1967	1986	GOOD
77	-122.235	37.48806	H 110	SAN MATEO	NAD 83	5.31	NAVD 88	UNK	1948	MARK NOT FOUND
78	-122.19583	37.38111	H 151	SAN MATEO	NAD 83	129.54	NAVD 88	UNK	1950	MARK NOT FOUND
79	-122.32984	37.55975	H 386	SAN MATEO	NAD 83	13.76	NAVD 88	1936	20030810	GOOD
80	-122.19382	37.40582	H 591	SAN MATEO	NAD 83	66.88	NAVD 88	1940	1967	GOOD
81	-122.17052	37.44732	H 7	SAN MATEO	NAD 83	22.79	NAVD 88	1910	20030220	GOOD
82	-122.31411	37.5705	H 875	SAN MATEO	NAD 83	4.12	NAVD 88	1954	1986	GOOD
83	-122.22828	37.49463	HARBOR	SAN MATEO	NAD 83	260.7	NAVD 88	1957	1967	SEE DESCRIPTION
84	-122.28624	37.54278	HIGHWAY	SAN MATEO	NAD 83	3	NAVD 88	1930	1958	SEE DESCRIPTION

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Benchmark Data

ID	Long	Lat	Name	County	Datum	Elevation	Elevation Datum	First Received	Last Received	Last Condition
85	-122.22583	37.48972	J 110 RESET	SAN MATEO	NAD 83	4.23	NAVD 88	1989	1989	MONUMENTED
86	-122.13778	37.49028	J 175	SAN MATEO	NAD 83	2.57	NAVD 88	1934	1954	GOOD
87	-122.13639	37.49167	J 175 RESET 1960	SAN MATEO	NAD 83	2.63	NAVD 88	1960	1965	GOOD
88	-122.32806	37.58472	J 476	SAN MATEO	NAD 83	3.69	NAVD 88	1951	1967	GOOD
89	-122.36528	37.58889	J 553	SAN MATEO	NAD 83	4.72	NAVD 88	1956	20120905	GOOD
90	-122.16546	37.47523	K 1121	SAN MATEO	NAD 83	5.36	NAVD 88	1960	20041023	GOOD
91	-122.30861	37.55167	K 476	SAN MATEO	NAD 83	3.47	NAVD 88	1951	1956	MARK NOT FOUND
92	-122.23	37.48667	K 875 CASLC	SAN MATEO	NAD 83	4.43	NAVD 88	1954	20030706	GOOD
93	-122.21032	37.50764	KAO	SAN MATEO	NAD 83	3.9	NAVD 88	1985	1985	MONUMENTED
94	-122.20694	37.41556	KG RIVET 29	SAN MATEO	NAD 83	88.48	NAVD 88	UNK	1965	GOOD
95	-122.20611	37.41611	KG RIVET 30	SAN MATEO	NAD 83	87.98	NAVD 88	UNK	1965	GOOD
96	-122.20528	37.41694	KG RIVET 31	SAN MATEO	NAD 83	87.49	NAVD 88	UNK	1965	GOOD
97	-122.23285	37.54728	KPO RAD STA E TOWER	SAN MATEO	NAD 83		NAVD 88	1934	1986	GOOD
98	-122.23485	37.5469	KPO RAD STA W TOWER	SAN MATEO	NAD 83		NAVD 88	1934	1958	SEE DESCRIPTION
99	-122.23972	37.49111	L 1121	SAN MATEO	NAD 83	6.31	NAVD 88	1960	1976	GOOD
100	-122.31056	37.57278	L 476	SAN MATEO	NAD 83	4.32	NAVD 88	1951	1976	GOOD
101	-122.25611	37.51361	L 875	SAN MATEO	NAD 83	3.82	NAVD 88	1954	1984	GOOD
102	-122.20843	37.51384	LSS 37	SAN MATEO	NAD 83	2.9	NAVD 88	1991	1991	MONUMENTED
103	-122.22601	37.54459	LSS 38	SAN MATEO	NAD 83	3	NAVD 88	1991	1991	MONUMENTED
104	-122.30417	37.54556	M 1121	SAN MATEO	NAD 83	4.71	NAVD 88	1960	1972	POOR
105	-122.29528	37.57083	M 476	SAN MATEO	NAD 83	4.49	NAVD 88	1951	1976	GOOD
106	-122.25222	37.51333	M 875 RESET 1960	SAN MATEO	NAD 83	1.29	NAVD 88	1960	1967	GOOD
107	-122.19628	37.53457	MARSH	SAN MATEO	NAD 83	2.5	NAVD 88	1925	1983	GOOD
108	-122.31179	37.54959	MATEO	SAN MATEO	NAD 83	6.6	NAVD 88	1957	1961	SEE DESCRIPTION
109	-122.31197	37.54909	MATEO 2	SAN MATEO	NAD 83	7	NAVD 88	1961	1975	GOOD
110	-122.17194	37.47917	N 110	SAN MATEO	NAD 83	0.89	NAVD 88	1932	20080419	GOOD
111	-122.28028	37.57056	N 476	SAN MATEO	NAD 83	3.29	NAVD 88	1951	1956	MARK NOT FOUND
112	-122.27389	37.56917	N 553 RESET 1962	SAN MATEO	NAD 83	2.47	NAVD 88	1962	1988	MARK NOT FOUND
113	-122.19403	37.41246	N 875 RESET	SAN MATEO	NAD 83	55.9	NAVD 88	1994	20030908	GOOD
114	-122.16161	37.47219	P 875	SAN MATEO	NAD 83	6.72	NAVD 88	1954	20031225	GOOD
115	-122.12977	37.49791	P 888=DUM RESET	SAN MATEO	NAD 83	2.6	NAVD 88	1930	1979	MARK NOT FOUND
116	-122.24368	37.49328	PALO ALTO BASE A RM 3	SAN MATEO	NAD 83	7.65	NAVD 88	1958	20050901	MARK NOT FOUND
117	-122.24335	37.49304	PALO ALTO BASE A RM 2	SAN MATEO	NAD 83	7.57	NAVD 88	1932	20050901	GOOD
118	-122.24327	37.49323	PALO ALTO BASE STA A	SAN MATEO	NAD 83	7.29	NAVD 88	1932	1975	MARK NOT FOUND
119	-122.26121	37.50822	PALO ALTO NW BASE RM 3	SAN MATEO	NAD 83	8.98	NAVD 88	1936	1984	GOOD
120	-122.26314	37.50983	PALO ALTO NW BASE RM 4	SAN MATEO	NAD 83	7.59	NAVD 88	1936	1964	MARK NOT FOUND
121	-122.31139	37.55639	PIPE 1 CAHD	SAN MATEO	NAD 83	3.19	NAVD 88	UNK	1956	MARK NOT FOUND
122	-122.25333	37.50194	PIPE 11 CAHD	SAN MATEO	NAD 83	6.25	NAVD 88	UNK	1954	MARK NOT FOUND
123	-122.24861	37.49778	PIPE 12 CAHD	SAN MATEO	NAD 83	6.63	NAVD 88	UNK	1956	MARK NOT FOUND
124	-122.24472	37.49472	PIPE 13	SAN MATEO	NAD 83	7.04	NAVD 88	UNK	1956	MARK NOT FOUND
125	-122.23944	37.49056	PIPE 14 CAHD	SAN MATEO	NAD 83	6.96	NAVD 88	UNK	1956	MARK NOT FOUND
126	-122.22028	37.48778	PIPE 16 CAHD	SAN MATEO	NAD 83	2.23	NAVD 88	UNK	1954	MARK NOT FOUND

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Benchmark Data

ID	Long	Lat	Name	County	Datum	Elevation	Elevation Datum	First Received	Last Received	Last Condition
127	-122.20472	37.4875	PIPE 19 CAHD	SAN MATEO	NAD 83	2.65	NAVD 88	UNK	1956	MARK NOT FOUND
128	-122.30889	37.55139	PIPE 2 CAHD	SAN MATEO	NAD 83	4.11	NAVD 88	UNK	1956	MARK NOT FOUND
129	-122.16889	37.47694	PIPE 24 CAHD	SAN MATEO	NAD 83	5.2	NAVD 88	UNK	1956	MARK NOT FOUND
130	-122.30278	37.54389	PIPE 3 CAHD	SAN MATEO	NAD 83	4.38	NAVD 88	UNK	1956	MARK NOT FOUND
131	-122.29639	37.53694	PIPE 4 A CAHD	SAN MATEO	NAD 83	8.31	NAVD 88	UNK	1956	MARK NOT FOUND
132	-122.29444	37.535	PIPE 4 B CAHD	SAN MATEO	NAD 83	8.39	NAVD 88	UNK	1956	MARK NOT FOUND
133	-122.30056	37.54083	PIPE 4 CAHD	SAN MATEO	NAD 83	6.5	NAVD 88	UNK	1956	MARK NOT FOUND
134	-122.285	37.52833	PIPE 5 CAHD	SAN MATEO	NAD 83	10.3	NAVD 88	UNK	1956	MARK NOT FOUND
135	-122.28139	37.52556	PIPE 6 CAHD	SAN MATEO	NAD 83	13.96	NAVD 88	UNK	1956	MARK NOT FOUND
136	-122.27333	37.51917	PIPE 7 CAHD	SAN MATEO	NAD 83	11.87	NAVD 88	UNK	1956	MARK NOT FOUND
137	-122.26944	37.51611	PIPE 8 CAHD	SAN MATEO	NAD 83	9.44	NAVD 88	UNK	1956	MARK NOT FOUND
138	-122.26306	37.51111	PIPE 9 CAHD	SAN MATEO	NAD 83	5.78	NAVD 88	1947	1956	MARK NOT FOUND
139	-122.15962	37.47433	PLATFORM	SAN MATEO	NAD 83	3	NAVD 88	1931	1931	MONUMENTED
140	-122.31942	37.59129	POINT SAN MATEO	SAN MATEO	NAD 83	14	NAVD 88	1925	1986	GOOD
141	-122.31953	37.59112	POINT SAN MATEO 2	SAN MATEO	NAD 83	14	NAVD 88	1968	1977	SEE DESCRIPTION
142	-122.31954	37.59117	POINT SAN MATEO RM 2	SAN MATEO	NAD 83	17.06	NAVD 88	1932	1967	MARK NOT FOUND
143	-122.31809	37.59132	POINT SAN MATEO RM 6	SAN MATEO	NAD 83	4.1	NAVD 88	1983	1983	MONUMENTED
144	-122.31691	37.59129	POINT SAN MATEO RM 7	SAN MATEO	NAD 83	4.1	NAVD 88	1983	1983	MONUMENTED
145	-122.23619	37.53728	PRESS TEMP	SAN MATEO	NAD 83	6.6	NAVD 88	UNK	1985	GOOD
146	-122.1525	37.46778	Q 110	SAN MATEO	NAD 83	7.15	NAVD 88	1932	1954	GOOD
147	-122.15306	37.46844	Q 110 RESET 1954	SAN MATEO	NAD 83	6.27	NAVD 88	1954	20040220	GOOD
148	-122.20694	37.51444	Q 875	SAN MATEO	NAD 83	2.76	NAVD 88	1954	1967	GOOD
149	-122.26694	37.51417	Q 887	SAN MATEO	NAD 83	7.02	NAVD 88	1948	1976	GOOD
150	-122.14139	37.46167	R 110	SAN MATEO	NAD 83	7.29	NAVD 88	UNK	1948	MARK NOT FOUND
151	-122.24921	37.50445	R 887 RESET 1967	SAN MATEO	NAD 83	3.29	NAVD 88	1967	20020124	GOOD
152	-122.21667	37.44	R 888	SAN MATEO	NAD 83	36.36	NAVD 88	1948	1960	GOOD
153	-122.23386	37.54711	RADIO STATION KNBC TALL MAST	SAN MATEO	NAD 83		NAVD 88	UNK	1986	GOOD
154	-122.17559	37.4937	RAVEN	SAN MATEO	NAD 83	29.2	NAVD 88	1981	1985	GOOD
155	-122.1756	37.4936	RAVEN RM 3	SAN MATEO	NAD 83	29.1	NAVD 88	1981	1981	MONUMENTED
156	-122.17567	37.49364	RAVEN RM 4	SAN MATEO	NAD 83	29.1	NAVD 88	1981	1981	MONUMENTED
157	-122.13244	37.48567	RAVENSWOOD PT SUBSTA N GABLE	SAN MATEO	NAD 83		NAVD 88	UNK	1958	SEE DESCRIPTION
158	-122.21082	37.51215	RAZ 4	SAN MATEO	NAD 83	3.1	NAVD 88	1991	1991	MONUMENTED
159	-122.20519	37.51773	RAZ 6	SAN MATEO	NAD 83	2.3	NAVD 88	1991	1991	MONUMENTED
160	-122.2049	37.51619	REDWOOD CITY CEMENT WKS E STK	SAN MATEO	NAD 83		NAVD 88	UNK	1985	MARK NOT FOUND
161	-122.22965	37.48699	REDWOOD CITY COURTHOUSE DOME	SAN MATEO	NAD 83		NAVD 88	1931	20101011	GOOD
162	-122.22483	37.49192	REDWOOD CITY FRANK TANNERY STK	SAN MATEO	NAD 83		NAVD 88	UNK	1988	MARK NOT FOUND
163	-122.22671	37.48742	REDWOOD CITY TALL TRANSM TOWER	SAN MATEO	NAD 83		NAVD 88	UNK	1958	SEE DESCRIPTION
164	-122.22482	37.49173	REDWOOD CITY TANK	SAN MATEO	NAD 83		NAVD 88	1931	1958	SEE DESCRIPTION
165	-122.19913	37.52529	REDWOOD CREEK DAYBEACON 11	SAN MATEO	NAD 83	5.4	NAVD 88	1983	20041120	GOOD
166	-122.21601	37.50624	REDWOOD CREEK DAYBEACON 21	SAN MATEO	NAD 83	5.9	NAVD 88	1983	20041120	GOOD
167	-122.20496	37.52083	REDWOOD CREEK LIGHT 13	SAN MATEO	NAD 83	6.2	NAVD 88	1991	1991	FIRST OBSERVED
168	-122.20659	37.51761	REDWOOD CREEK LIGHT 15	SAN MATEO	NAD 83	6.2	NAVD 88	1991	1991	FIRST OBSERVED
169	-122.19225	37.53333	REDWOOD CREEK LIGHT 7	SAN MATEO	NAD 83	7.8	NAVD 88	1983	1983	FIRST OBSERVED
170	-122.19387	37.53358	REDWOOD CREEK LIGHT 8	SAN MATEO	NAD 83	6.9	NAVD 88	1983	20041120	GOOD

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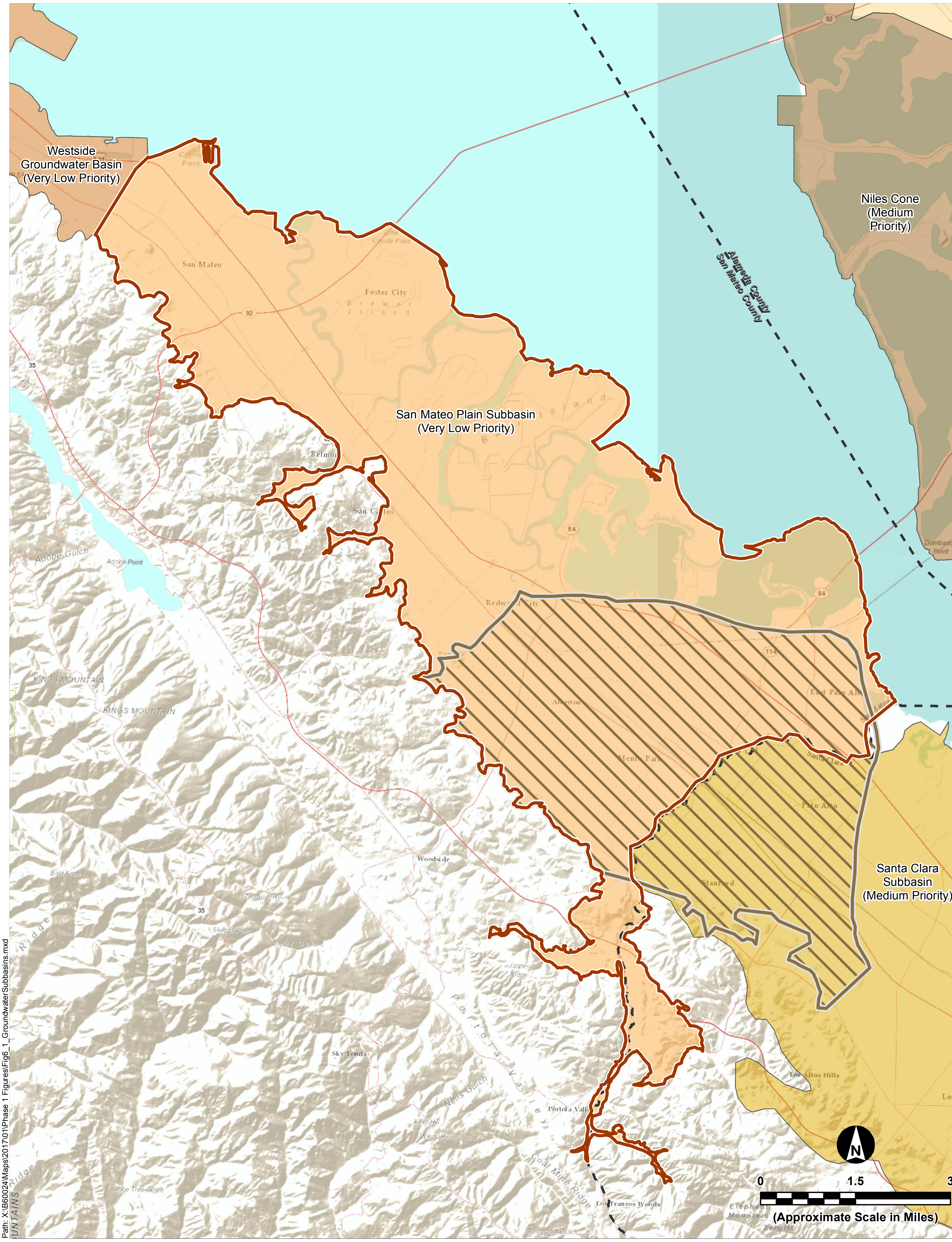
Benchmark Data

ID	Long	Lat	Name	County	Datum	Elevation	Elevation Datum	First Received	Last Received	Last Condition
171	-122.1946	37.52856	REDWOOD CREEK LIGHT 9	SAN MATEO	NAD 83	7.2	NAVD 88	1983	20041120	GOOD
172	-122.19619	37.5291	REDWOOD CREEK LIGHT 10	SAN MATEO	NAD 83	7.1	NAVD 88	1983	1983	FIRST OBSERVED
173	-122.20048	37.52578	REDWOOD CREEK LIGHT 12	SAN MATEO	NAD 83	7.1	NAVD 88	1983	1983	FIRST OBSERVED
174	-122.20496	37.52081	REDWOOD CREEK LIGHT 13	SAN MATEO	NAD 83	8.3	NAVD 88	1983	1983	FIRST OBSERVED
175	-122.20601	37.52168	REDWOOD CREEK LIGHT 14	SAN MATEO	NAD 83	7.9	NAVD 88	1983	20041120	GOOD
176	-122.20659	37.51763	REDWOOD CREEK LIGHT 15	SAN MATEO	NAD 83	7.4	NAVD 88	1983	20041120	GOOD
177	-122.20918	37.51702	REDWOOD CREEK LIGHT 16	SAN MATEO	NAD 83	7.5	NAVD 88	1983	1983	FIRST OBSERVED
178	-122.2122	37.51341	REDWOOD CREEK LIGHT 18	SAN MATEO	NAD 83	7.9	NAVD 88	1983	20041120	GOOD
179	-122.21356	37.50956	REDWOOD CREEK LIGHT 20	SAN MATEO	NAD 83	7.1	NAVD 88	1983	20041120	GOOD
180	-122.20453	37.52448	REDWOOD CREEK N SIDE TRANSM TR	SAN MATEO	NAD 83		NAVD 88	1931	1976	GOOD
181	-122.20164	37.52284	REDWOOD CREEK S SIDE TRANSM TR	SAN MATEO	NAD 83		NAVD 88	1931	1976	GOOD
182	-122.21011	37.5045	S 1076	SAN MATEO	NAD 83	1.72	NAVD 88	1967	20041120	MARK NOT FOUND
183	-122.25992	37.57468	SAN MATEO BRIDGE TRANSM TWR 20	SAN MATEO	NAD 83		NAVD 88	UNK	1960	SEE DESCRIPTION
184	-122.26319	37.57172	SAN MATEO BRIDGE TRANSM TWR 21	SAN MATEO	NAD 83		NAVD 88	1955	1960	SEE DESCRIPTION
185	-122.20425	37.41651	SLAC_BARD_CN2002 CORS ARP	SAN MATEO	NAD 83		NAVD 88			
186	-122.20425	37.41651	SLAC_BARD_CN2002 CORS L1	SAN MATEO	NAD 83		NAVD 88			
187	-122.21306	37.49167	T 984	SAN MATEO	NAD 83	2.1	NAVD 88	1964	1976	GOOD
188	-122.22556	37.48972	TANNERY CASLC	SAN MATEO	NAD 83	4.56	NAVD 88	1958	1967	GOOD
189	-122.31838	37.58964	TIDAL 1	SAN MATEO	NAD 83	4.77	NAVD 88	1945	20130318	GOOD
190	-122.24167	37.50111	TIDAL 1 1931	SAN MATEO	NAD 83	2.54	NAVD 88	UNK	1967	GOOD
191	-122.31869	37.58986	TIDAL 2	SAN MATEO	NAD 83	4.61	NAVD 88	1945	1967	GOOD
192	-122.18186	37.52043	TIP 1931	SAN MATEO	NAD 83	2	NAVD 88	1931	1958	SEE DESCRIPTION
193	-122.24853	37.54925	TRANSMISSION TOWER 7	SAN MATEO	NAD 83		NAVD 88	1931	1983	POOR
194	-122.22773	37.53755	TRANSMISSION TOWER 9	SAN MATEO	NAD 83		NAVD 88	1931	1983	GOOD
195	-122.25112	37.55071	TRANSMISSION TOWER 8	SAN MATEO	NAD 83		NAVD 88	1931	1983	POOR
196	-122.29694	37.5375	U 984	SAN MATEO	NAD 83	9.69	NAVD 88	1964	1976	GOOD
197	-122.18285	37.45364	UU 110	SAN MATEO	NAD 83	22.51	NAVD 88	1932	20080407	GOOD
198	-122.12789	37.49927	V 150	SAN MATEO	NAD 83	6.11	NAVD 88	1933	1965	GOOD
199	-122.1633	37.46649	VETERANS HOSPITAL TANK	SAN MATEO	NAD 83		NAVD 88	1931	1944	SEE DESCRIPTION
200	-122.34483	37.58076	VV 109	SAN MATEO	NAD 83	9.4	NAVD 88	1932	20090111	POOR
201	-122.33833	37.5775	W 109	SAN MATEO	NAD 83	9.83	NAVD 88	1932	1986	GOOD
202	-122.15089	37.48047	W 150	SAN MATEO	NAD 83	3.01	NAVD 88	1933	1960	GOOD
203	-122.25222	37.51694	W 887	SAN MATEO	NAD 83	0.93	NAVD 88	1948	1965	MARK NOT FOUND
204	-122.28167	37.57083	WHB 4	SAN MATEO	NAD 83	3.52	NAVD 88	1960	1976	MARK NOT FOUND
205	-122.24401	37.53246	WINDMILL	SAN MATEO	NAD 83		NAVD 88	1931	1958	SEE DESCRIPTION
206	-122.19228	37.51778	WOODEN WINDMILL VERTICAL VANE	SAN MATEO	NAD 83		NAVD 88	1931	1931	MONUMENTED
207	-122.3275	37.57139	X 109	SAN MATEO	NAD 83	8.16	NAVD 88	1932	1986	GOOD
208	-122.29611	37.53639	X 553 RESET 1964	SAN MATEO	NAD 83	8.07	NAVD 88	1964	1976	GOOD
209	-122.14975	37.48182	X572 RESET	SAN MATEO	NAD 83	2.82	NAVD 88	UNK	200209	GOOD
210	-122.33917	37.57194	XX 109	SAN MATEO	NAD 83	15.1	NAVD 88	1932	1967	GOOD
211	-122.32673	37.56941	Y 109	SAN MATEO	NAD 83	8.65	NAVD 88	1932	1986	GOOD

Table 6-6
Benchmark Data

ID	Long	Lat	Name	County	Datum	Elevation	Elevation Datum	First Received	Last Received	Last Condition
212	-122.16256	37.45397	Y 150	SAN MATEO	NAD 83	17.82	NAVD 88	1933	20080416	GOOD
213	-122.21667	37.44	Y 151	SAN MATEO	NAD 83	36.7	NAVD 88	1933	1953	MARK NOT FOUND
214	-122.23917	37.49944	Y 553	SAN MATEO	NAD 83	2.6	NAVD 88	1956	1967	GOOD
215	-122.20161	37.43159	Z 151 RESET 1971	SAN MATEO	NAD 83	40.72	NAVD 88	1971	20070609	GOOD
216	-122.21306	37.49	Z 553	SAN MATEO	NAD 83	2.57	NAVD 88	1956	1976	GOOD
217	-122.15444	37.4725	Z 591 RESET	SAN MATEO	NAD 83	4.99	NAVD 88	1971	20030205	MARK NOT FOUND
218	-122.15444	37.4725	Z 591 RESET 1974	SAN MATEO	NAD 83	4.98	NAVD 88	1974	20030205	MARK NOT FOUND



Path: X:\B60024\Maps\2017\01\Phase 1 Figures\Fig6_1_GroundwaterSubbasins.mxd

Legend

- San Mateo Plain Subbasin
- San Francisquito Cone
- County Boundary

Groundwater Basins and Subbasins

- 2-35: Westside Basin
- 2-9.01: Niles Cone Subbasin
- 2-9.02: Santa Clara Subbasin
- 2-9.03: San Mateo Plain Subbasin
- 2-9.04: East Bay Plain Subbasin

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. San Francisquito Cone: Metzger, 2002, *Streamflow Gains and Losses along San Francisquito Creek and Characterization of Surface-Water and Ground-Water Quality, Southern San Mateo and Northern Santa Clara Counties, California 1996-97*, U.S. Geological Survey (USGS) Water-Resources Investigations Report 02-4078, USGS, Sacramento, CA, 49 p.
3. Basemap: Esri's World Reference and World Terrain Base, accessed 21 December 2016.
4. CASGEM priority ranking from June 2014 Basin Prioritization Process.

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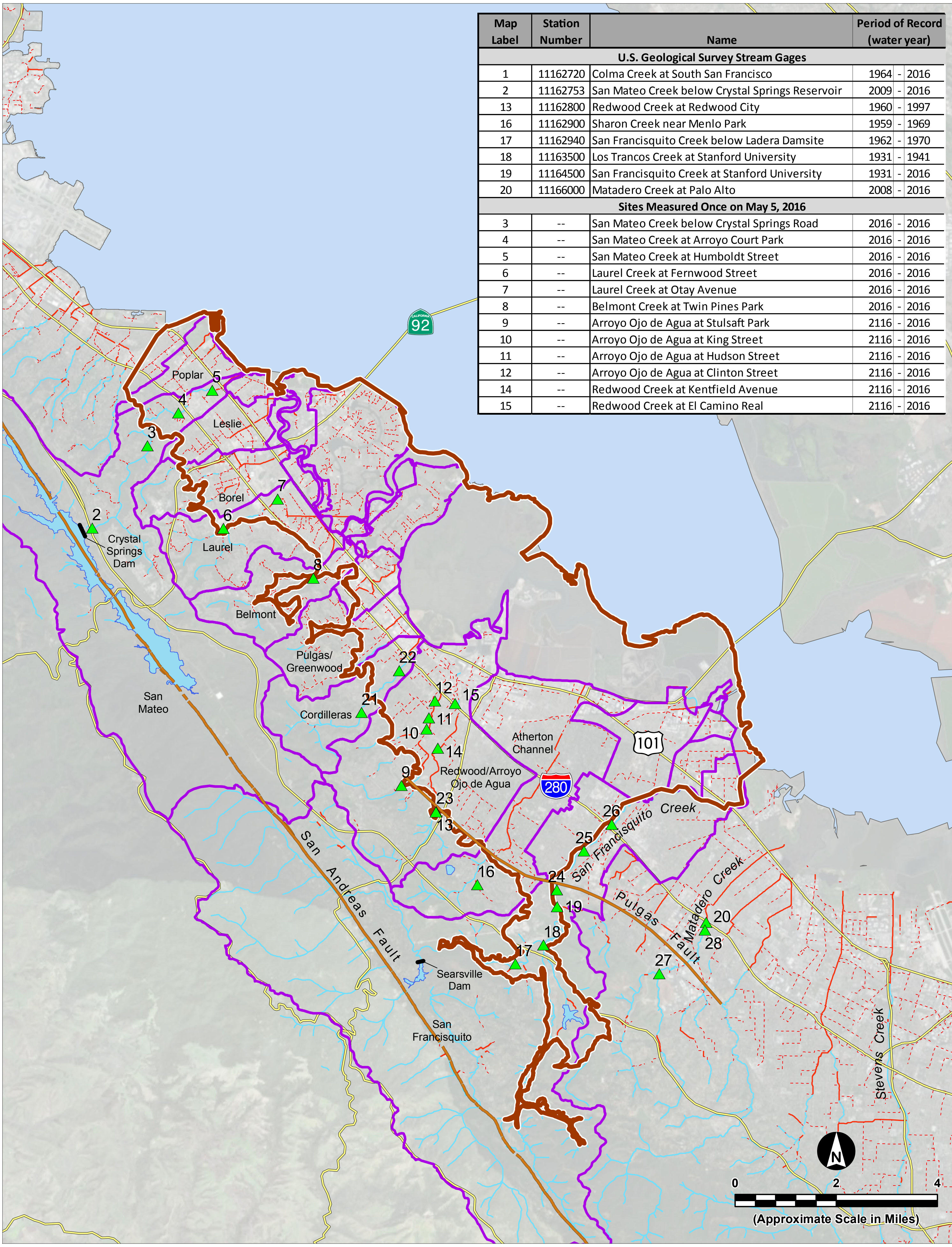
Groundwater Subbasins
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 6-1



Map Label	Station Number	Name	Period of Record (water year)		
U.S. Geological Survey Stream Gages					
1	11162720	Colma Creek at South San Francisco	1964	-	2016
2	11162753	San Mateo Creek below Crystal Springs Reservoir	2009	-	2016
13	11162800	Redwood Creek at Redwood City	1960	-	1997
16	11162900	Sharon Creek near Menlo Park	1959	-	1969
17	11162940	San Francisquito Creek below Ladera Damsite	1962	-	1970
18	11163500	Los Trancos Creek at Stanford University	1931	-	1941
19	11164500	San Francisquito Creek at Stanford University	1931	-	2016
20	11166000	Matadero Creek at Palo Alto	2008	-	2016
Sites Measured Once on May 5, 2016					
3	--	San Mateo Creek below Crystal Springs Road	2016	-	2016
4	--	San Mateo Creek at Arroyo Court Park	2016	-	2016
5	--	San Mateo Creek at Humboldt Street	2016	-	2016
6	--	Laurel Creek at Fernwood Street	2016	-	2016
7	--	Laurel Creek at Otay Avenue	2016	-	2016
8	--	Belmont Creek at Twin Pines Park	2016	-	2016
9	--	Arroyo Ojo de Agua at Stulsaft Park	2116	-	2016
10	--	Arroyo Ojo de Agua at King Street	2116	-	2016
11	--	Arroyo Ojo de Agua at Hudson Street	2116	-	2016
12	--	Arroyo Ojo de Agua at Clinton Street	2116	-	2016
14	--	Redwood Creek at Kentfield Avenue	2116	-	2016
15	--	Redwood Creek at El Camino Real	2116	-	2016

Legend

- Flow measurement stations

Creek channel types

- Creek (natural)
- Engineered Channel
- Underground pipe or culvert
- Watersheds

Sources
north of Redwood Creek: Sowers (2004);
south from Redwood Creek: Tillery and others (2007).

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Watersheds and Creeks

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
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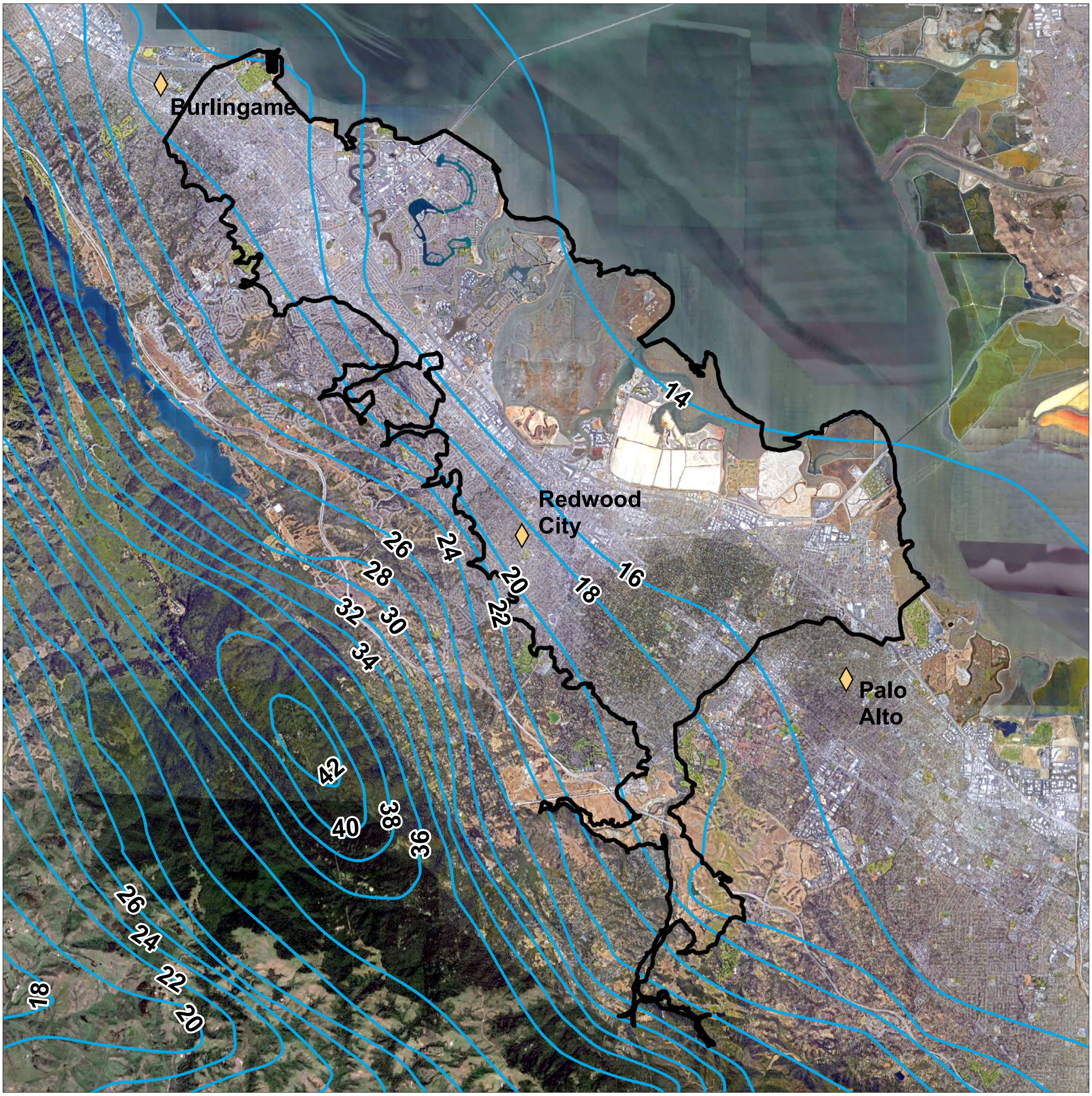
Figure 6-2



Legend

Average annual rainfall (inches)

Rainfall measurement station

San Mateo Plain Basin

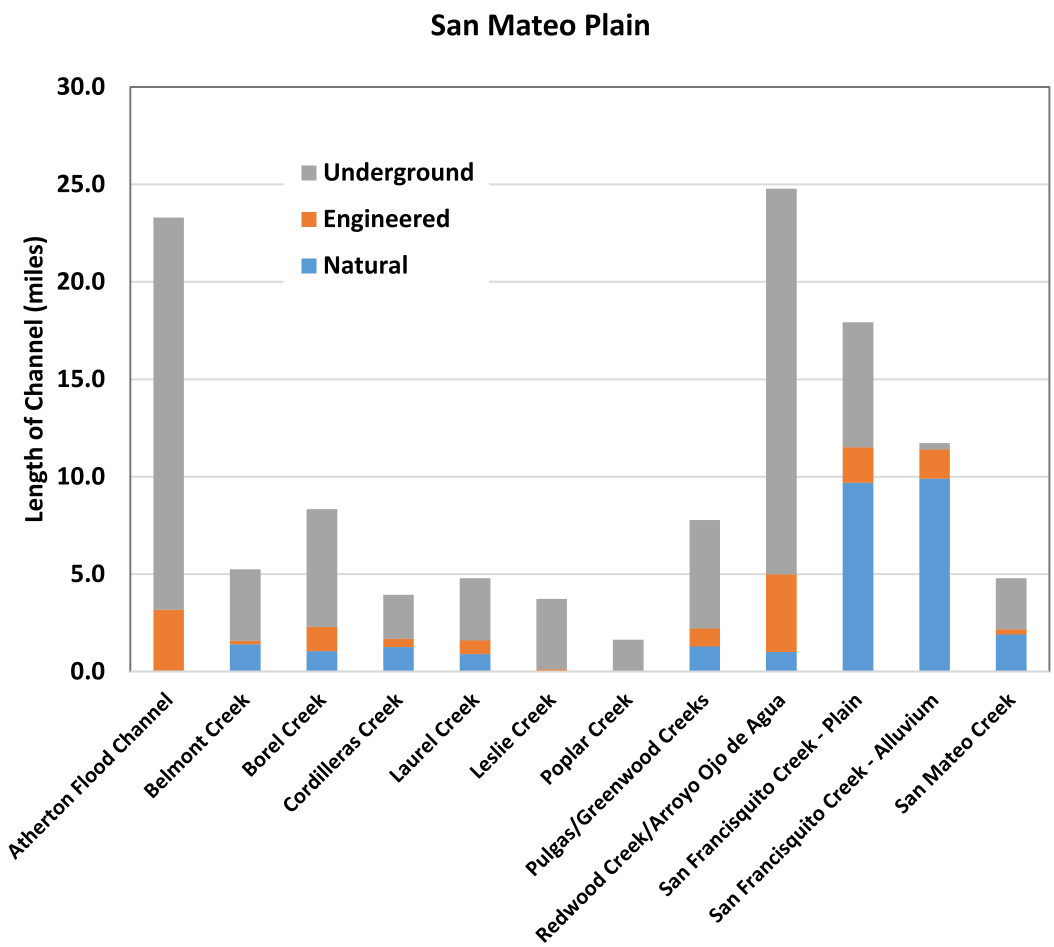
Sources
Rantz, 1971.

0 2.5 5
Miles

Contours of Average Annual Rainfall

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-3



SAN MATEO PLAIN				
Creek	Length of Channel (miles)			
	Natural	Engineered	Underground	TOTAL
Atherton Flood Channel	0.1	3.1	20.1	**23.3**
Belmont Creek	1.4	0.2	3.7	**5.3**
Borel Creek	1.1	1.2	6.0	**8.3**
Cordilleras Creek	1.3	0.4	2.3	**3.9**
Laurel Creek	0.9	0.7	3.2	**4.8**
Leslie Creek	0.0	0.1	3.6	**3.7**
Poplar Creek	0.0	0.0	1.6	**1.6**
Pulgas/Greenwood Creeks	1.3	0.9	5.6	**7.8**
Redwood Creek/Arroyo Ojo de Agua	1.0	4.0	19.8	**24.8**
San Francisquito Creek - Plain	9.7	1.8	6.4	**17.9**
San Francisquito Creek - Alluvium	9.9	1.5	0.3	**11.7**
San Mateo Creek	1.9	0.3	2.6	**4.8**
TOTAL	**28.5**	**14.2**	**75.3**	**118.0**

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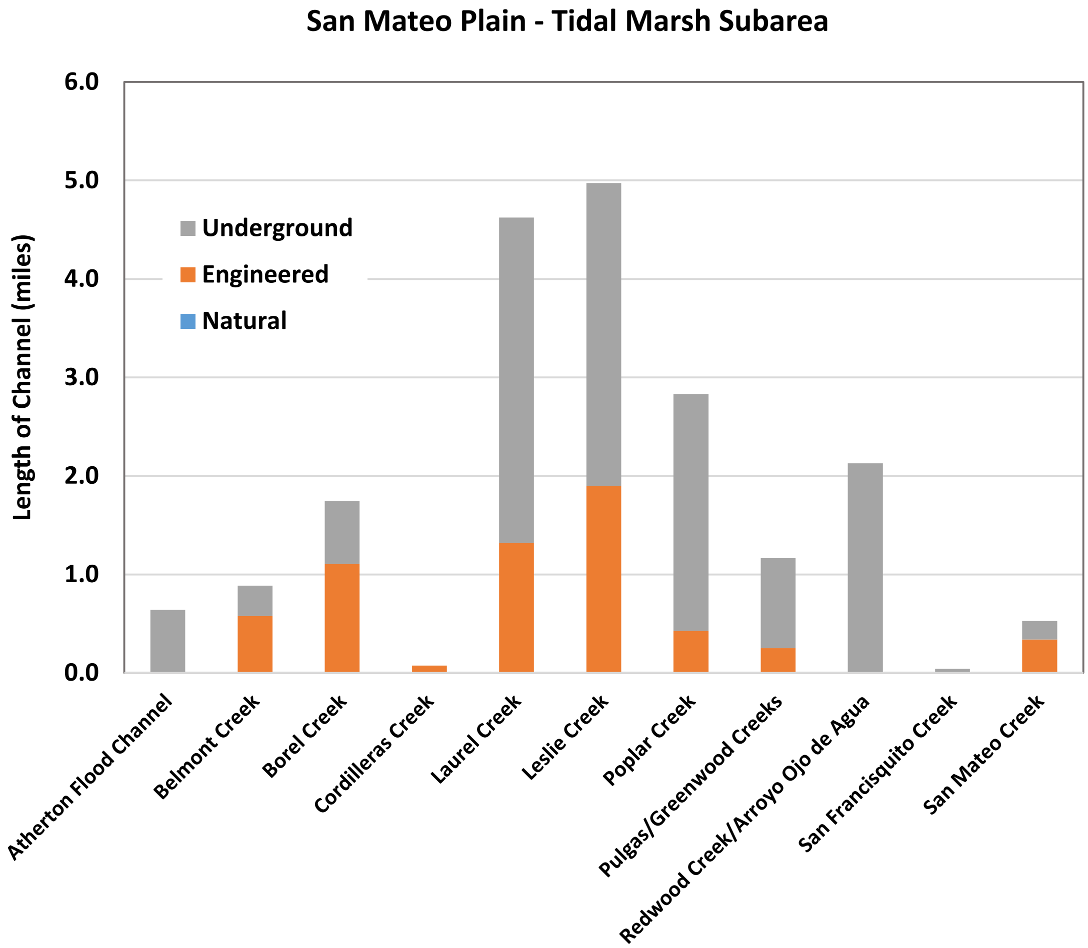
Lengths of Natural, Engineered and Underground Stream Channels in the Non-Tidal Part of San Mateo Plain Basin

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-4



SAN MATEO PLAIN - TIDAL MARSH SUBAREA				
Creek	Length of Channel (miles)			
	Natural	Engineered	Underground	TOTAL
Atherton Flood Channel	0.0	0.0	0.6	0.6
Belmont Creek	0.0	0.6	0.3	0.9
Borel Creek	0.0	1.1	0.6	1.7
Cordilleras Creek	0.0	0.1	0.0	0.1
Laurel Creek	0.0	1.3	3.3	4.6
Leslie Creek	0.0	1.9	3.1	5.0
Poplar Creek	0.0	0.4	2.4	2.8
Pulgas/Greenwood Creeks	0.0	0.3	0.9	1.2
Redwood Creek/Arroyo Ojo de Agua	0.0	0.0	2.1	2.1
San Francisquito Creek	0.0	0.0	0.0	0.0
San Mateo Creek	0.0	0.3	0.2	0.5
TOTAL	**0.0**	**6.0**	**13.6**	**19.6**

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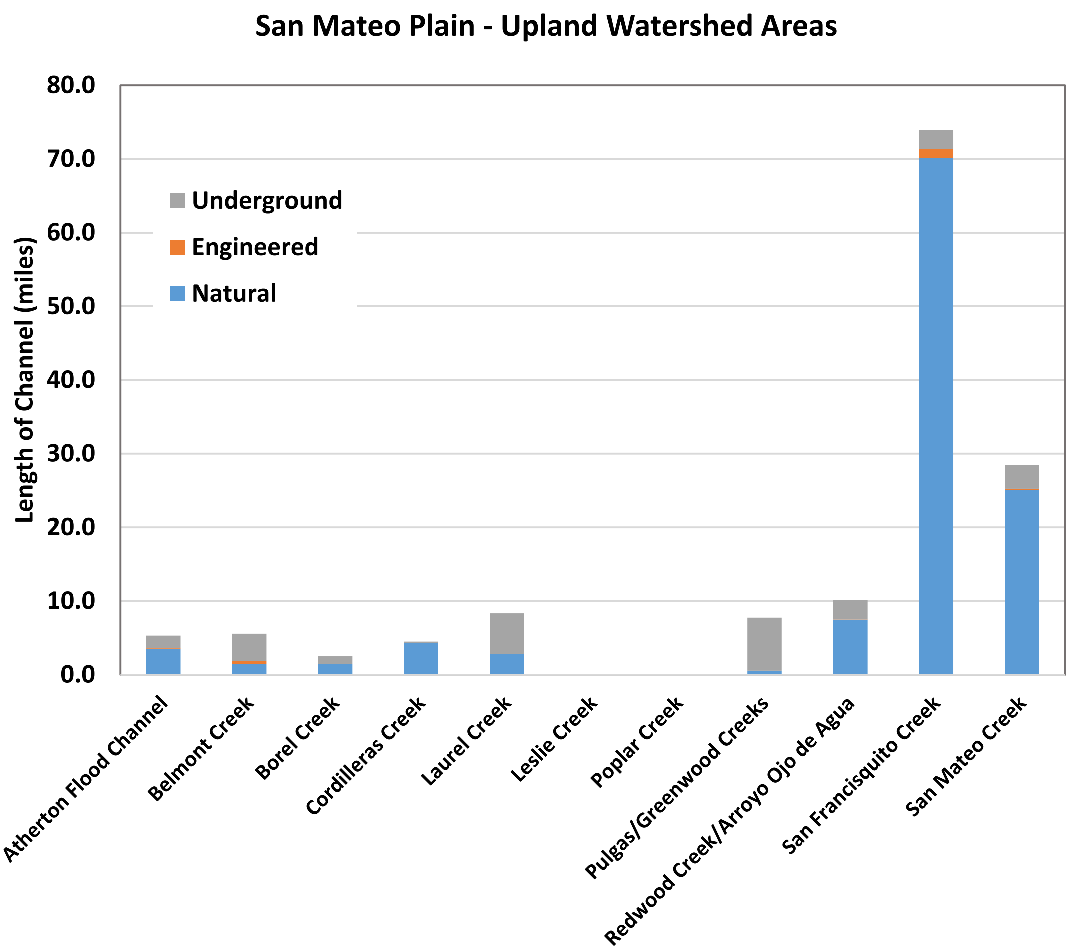
Lengths of Natural, Engineered and Underground Stream Cahnnels in the Tidal Marsh Subarea

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-5



SAN MATEO PLAIN - UPLAND WATERSHED AREAS				
Creek	**Length of Channel (miles)**			
	Natural	**Engineered**	**Underground**	**TOTAL**
Atherton Flood Channel	3.5	0.1	1.7	5.3
Belmont Creek	1.5	0.4	3.7	5.6
Borel Creek	1.4	0.0	1.0	2.5
Cordilleras Creek	4.3	0.0	0.2	4.5
Laurel Creek	2.8	0.0	5.5	8.3
Leslie Creek	0.0	0.0	0.0	0.0
Poplar Creek	0.0	0.0	0.0	0.0
Pulgas/Greenwood Creeks	0.6	0.0	7.2	7.7
Redwood Creek/Arroyo Ojo de Agua	7.4	0.1	2.7	10.1
San Francisquito Creek	70.1	1.3	2.6	73.9
San Mateo Creek	25.1	0.2	3.3	28.5
TOTAL	**116.7**	**1.9**	**27.8**	**146.5**

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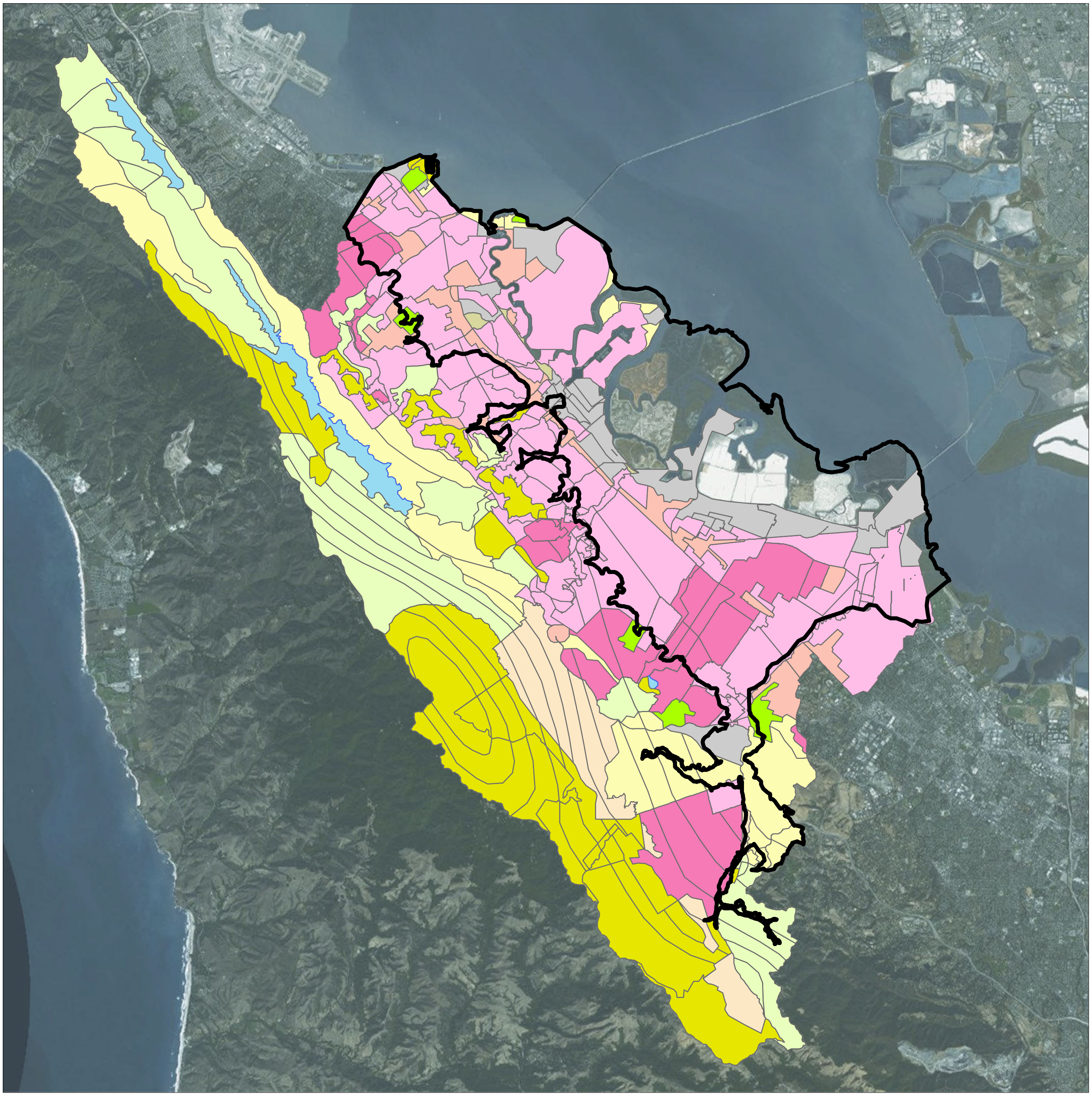
Lengths of Natural, Engineered and Underground Stream Channels in the Uplands Watershed Areas

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-6



Legend

San Mateo Plain Basin

Land use

- NV1 natural - grassland
- NV2 natural - brush
- NV3 natural - trees
- NW open water
- RR rural residential
- UC urban commercial
- UI urban industrial
- UL1 irrigated turf
- UR1 urban residential
- UR2 urban residential - lush
- UV urban vacant

<UMD>Note</UND>

1. Land use delineations are based on visual inspection high-resolution aerial imagery according to the National Agricultural Imagery Program (2010) method.

N

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Miles

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Land Use

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
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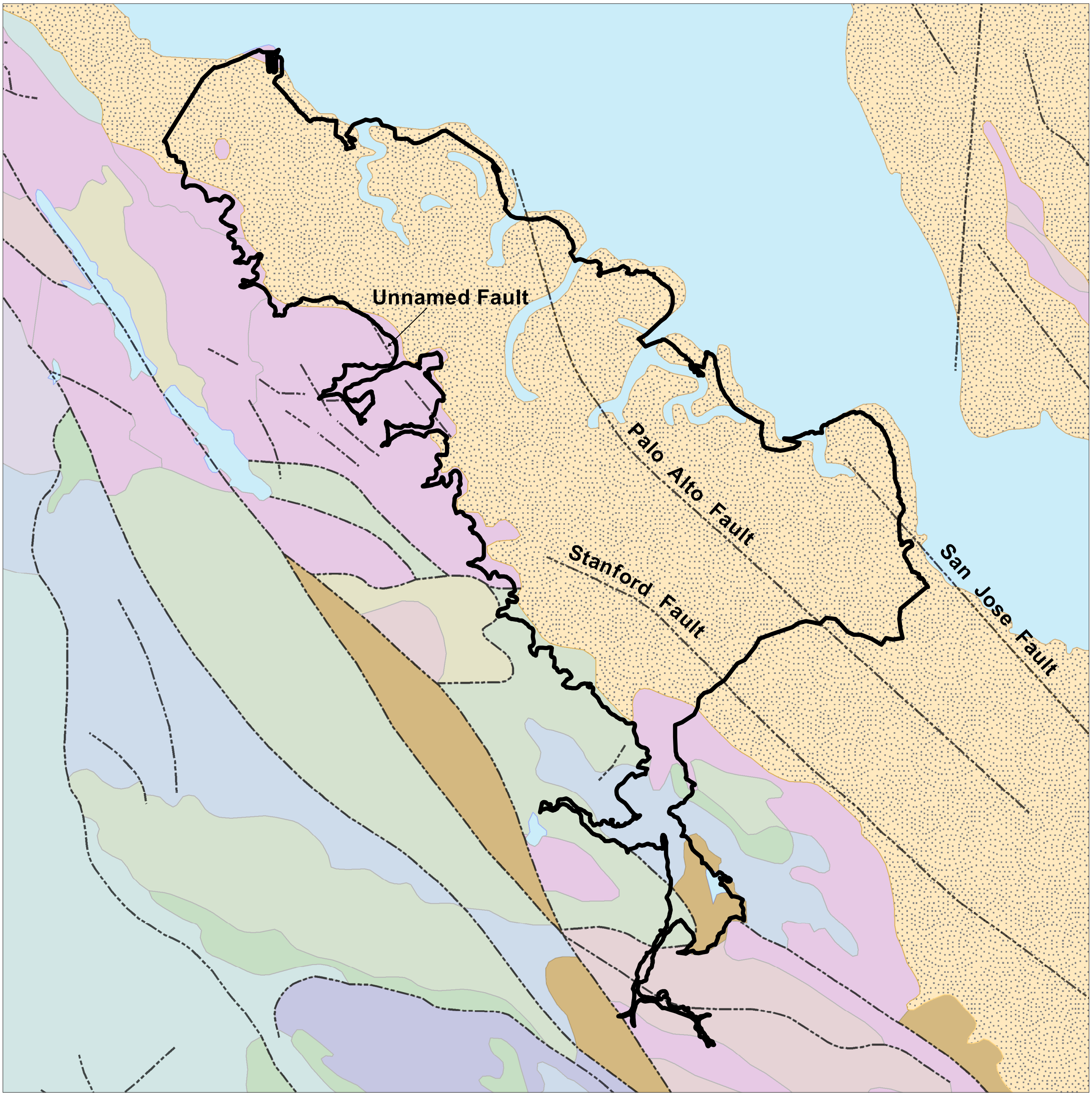
Figure 6-7



Legend

- San Mateo Plain Basin
- Fault
- Quaternary Alluvium
- Pliocene continental sedimentary rocks
- Pliocene marine sedimentary rocks
- Miocene marine sedimentary rocks
- Oligocene marine sedimentary rocks
- Eocene marine sedimentary rocks
- Cretaceous Marine sedimentary and metasedimentary rocks
- Mesozoic granite and quartz monzonite
- Mesozoic metavolcanic rocks
- Mesozoic plutonic rocks
- Tertiary Volcanic Rocks
- Water

Sources

Based on the California Department of Conservation Geologic Map of California (2010)

0 2.5 5

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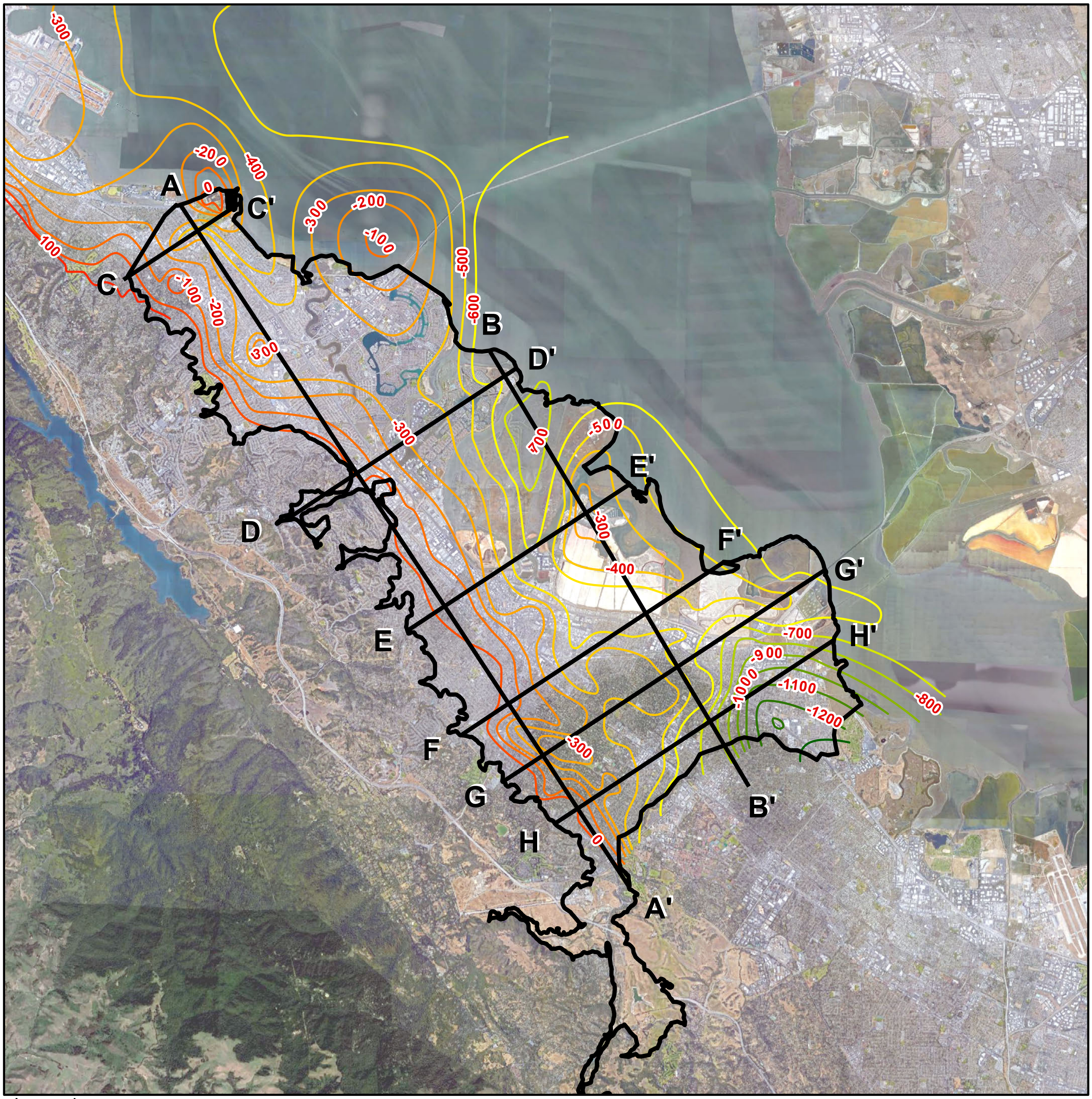
Geologic Map

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-8



Legend

Section Line

Bedrock elevation contour, ft msl (100 foot contour interval)

Notes

Bedrock elevation contours based on Hensolt and Brabb, 1990

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Bedrock Elevation Map

N

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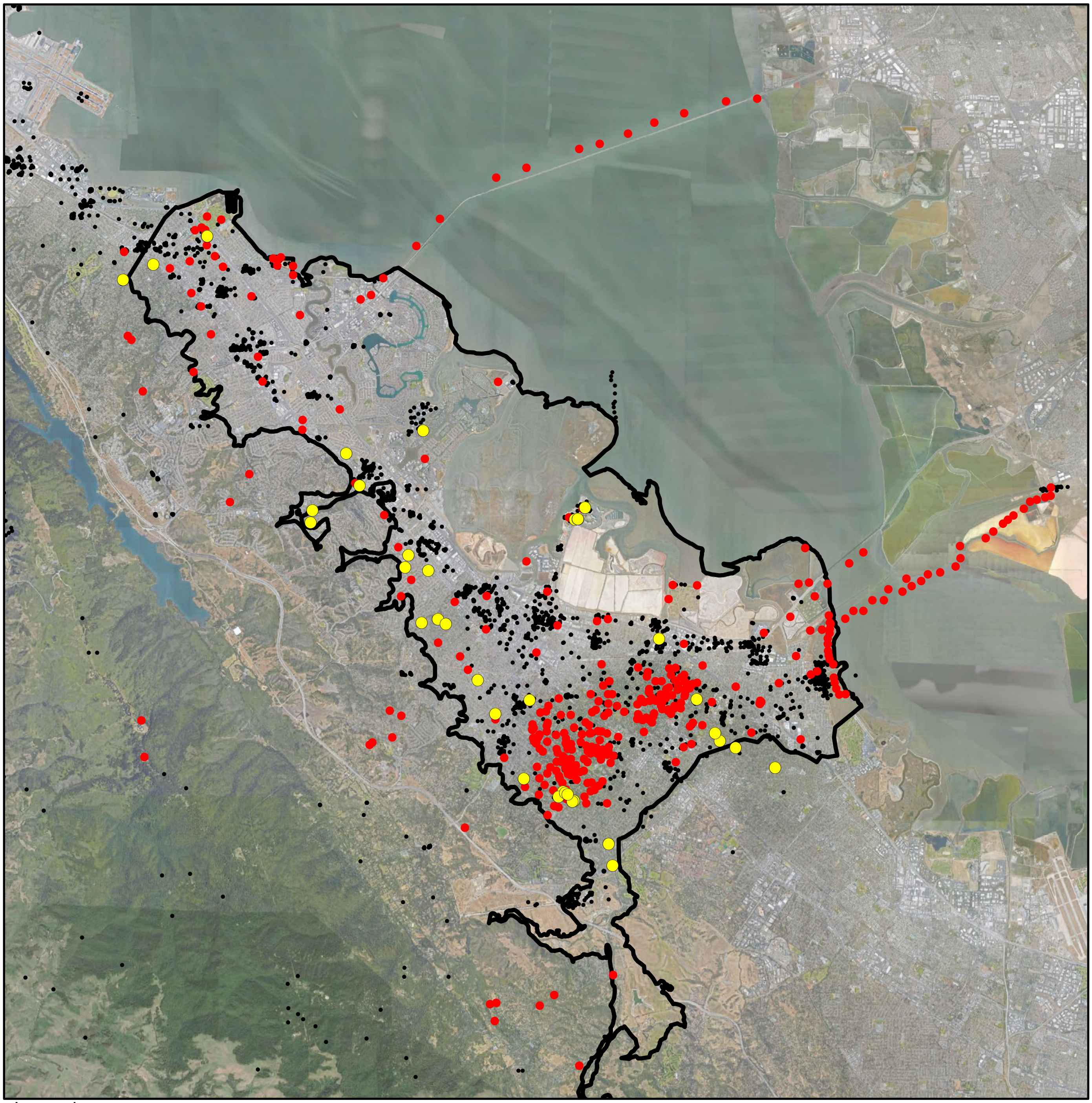
Miles

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-9



Legend

- Todd Coded Wells
- Original Texture Database Wells
- Database Wells

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Study Area Wells

San Mateo Plain Groundwater Subbasin
San Mateo County, California
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Figure 6-10

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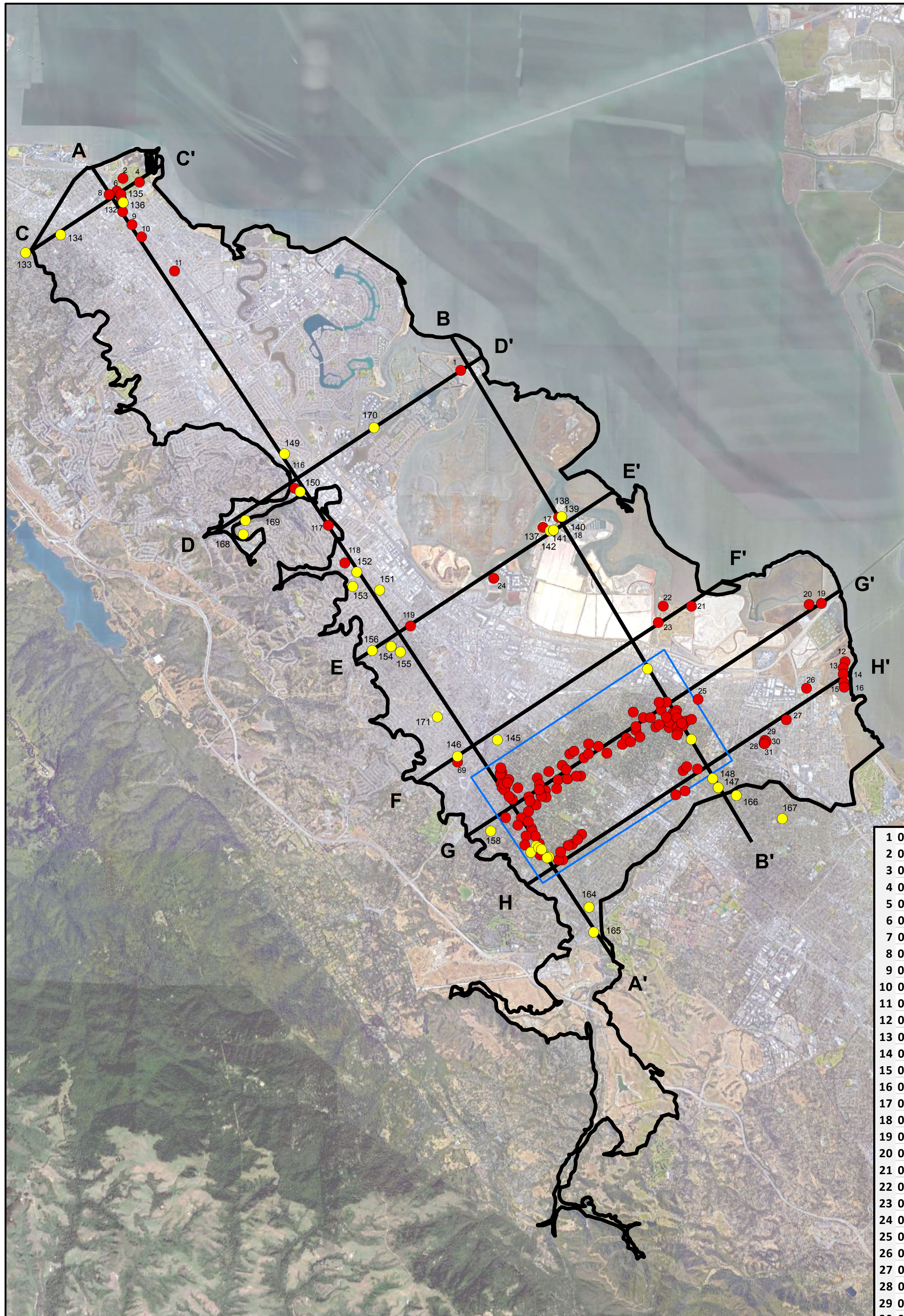
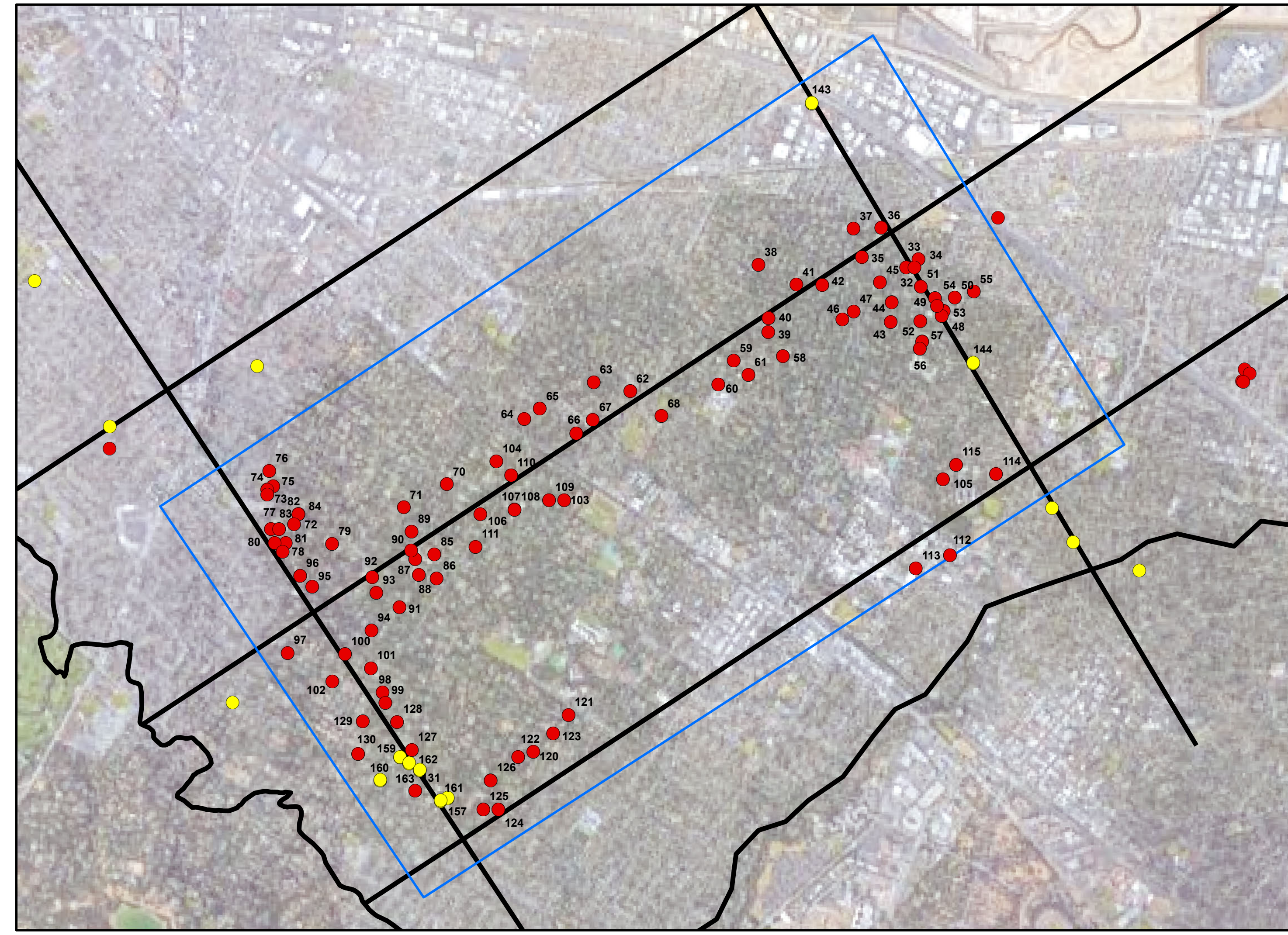
Miles





State Well Numbers

1	004S003W31B01	31	005S003W25M06	61	005S003W27M03	91	005S003W32J04	121	006S003W04C02	151	005S004W13F01
2	004S004W17F01	32	005S003W27A01	62	005S003W28K02	92	005S003W32K01	122	006S003W04C03	152	005S004W13D01
3	004S004W17K01	33	005S003W27A02	63	005S003W28L03	93	005S003W32K03	123	006S003W04C05	153	005S004W13E01
4	004S004W17K02	34	005S003W27A03	64	005S003W28N01	94	005S003W32K04	124	006S003W04E01	154	005S004W24G01
5	004S004W17K03	35	005S003W27B02	65	005S003W28P02	95	005S003W32L01	125	006S003W04E02	155	005S004W24G02
6	004S004W17L01	36	005S003W27B03	66	005S003W28P04	96	005S003W32L02	126	006S003W04E03	156	005S004W23F01
7	004S004W17L02	37	005S003W27B04	67	005S003W28Q01	97	005S003W32P01	127	006S003W05A01	157	006S003W05H01
8	004S004W17L03	38	005S003W27D03	68	005S003W28R02	98	005S003W32Q01	128	006S003W05A02	158	006S003W05D01
9	004S004W20B02	39	005S003W27E02	69	005S003W30Q01	99	005S003W32Q02	129	006S003W05B02	159	006S003W05A01
10	004S004W20H01	40	005S003W27E03	70	005S003W32A01	100	005S003W32Q03	130	006S003W05B03	160	006S003W05G01
11	004S004W21P01	41	005S003W27F01	71	005S003W32A02	101	005S003W32Q04	131	006S003W05H01	161	006S003W05H02
12	005S002W19F02	42	005S003W27F03	72	005S003W32C03	102	005S003W32Q05	132	004S004W17Q01	162	006S003W05H03
13	005S002W19L01	43	005S003W27G01	73	005S003W32D01	103	005S003W33C01	133	004S004W19M01	163	006S003W05H04
14	005S002W19L02	44	005S003W27G02	74	005S003W32D02	104	005S003W33D02	134	004S004W19G01	164	006S003W09B01
15	005S002W19L03	45	005S003W27G03	75	005S003W32D03	105	005S003W33D03	135	004S004W17Q01	165	006S003W09G01
16	005S002W19P01	46	005S003W27G04	76	005S003W32D04	106	005S003W33D04	136	004S004W17Q01	166	005S003W35G02
17	005S003W08H06	47	005S003W27G05	77	005S003W32E01	107	005S003W33D05	137	005S003W08J01	167	005S003W36P01
18	005S003W09E08	48	005S003W27H03	78	005S003W32E02	108	005S003W33D06	138	005S003W09E01	168	005S004W10L01
19	005S003W13J01	49	005S003W27H04	79	005S003W32F01	109	005S003W33D07	139	005S003W09E02	169	005S004W10F01
20	005S003W13J02	50	005S003W27H05	80	005S003W32F03	110	005S003W33D09	140	005S003W09J02	170	005S004W01C01
21	005S003W15J01	51	005S003W27H06	81	005S003W32F04	111	005S003W33E01	141	005S003W09J03	171	005S003W30F01
22	005S003W15K01	52	005S003W27H07	82	005S003W32F05	112	005S003W34H01	142	005S003W09J04		
23	005S003W15Q01	53	005S003W27H08	83	005S003W32F06	113	005S003W34H04	143	005S003W22L01		
24	005S003W18H01	54	005S003W27H09	84	005S003W32F07	114	005S003W35D01	144	005S003W26M01		
25	005S003W23N01	55	005S003W27H10	85	005S003W32H01	115	005S003W35D02	145	005S003W29M01		
26	005S003W24Q01	56	005S003W27J01	86	005S003W32H02	116	005S004W02N01	146	005S003W30Q01		
27	005S003W25F01	57	005S003W27J02	87	005S003W32H03	117	005S004W11K01	147	005S003W35G01		
28	005S003W25M03	58	005S003W27L03	88	005S003W32H04	118	005S004W14A01	148	005S003W35C01		
29	005S003W25M04	59	005S003W27M01	89	005S003W32H05	119	005S004W24A01	149	005S004W03H01		
30	005S003W25M05	60	005S003W27M02	90	005S003W32H06	120	006S003W04C01	150	005S004W11D01		

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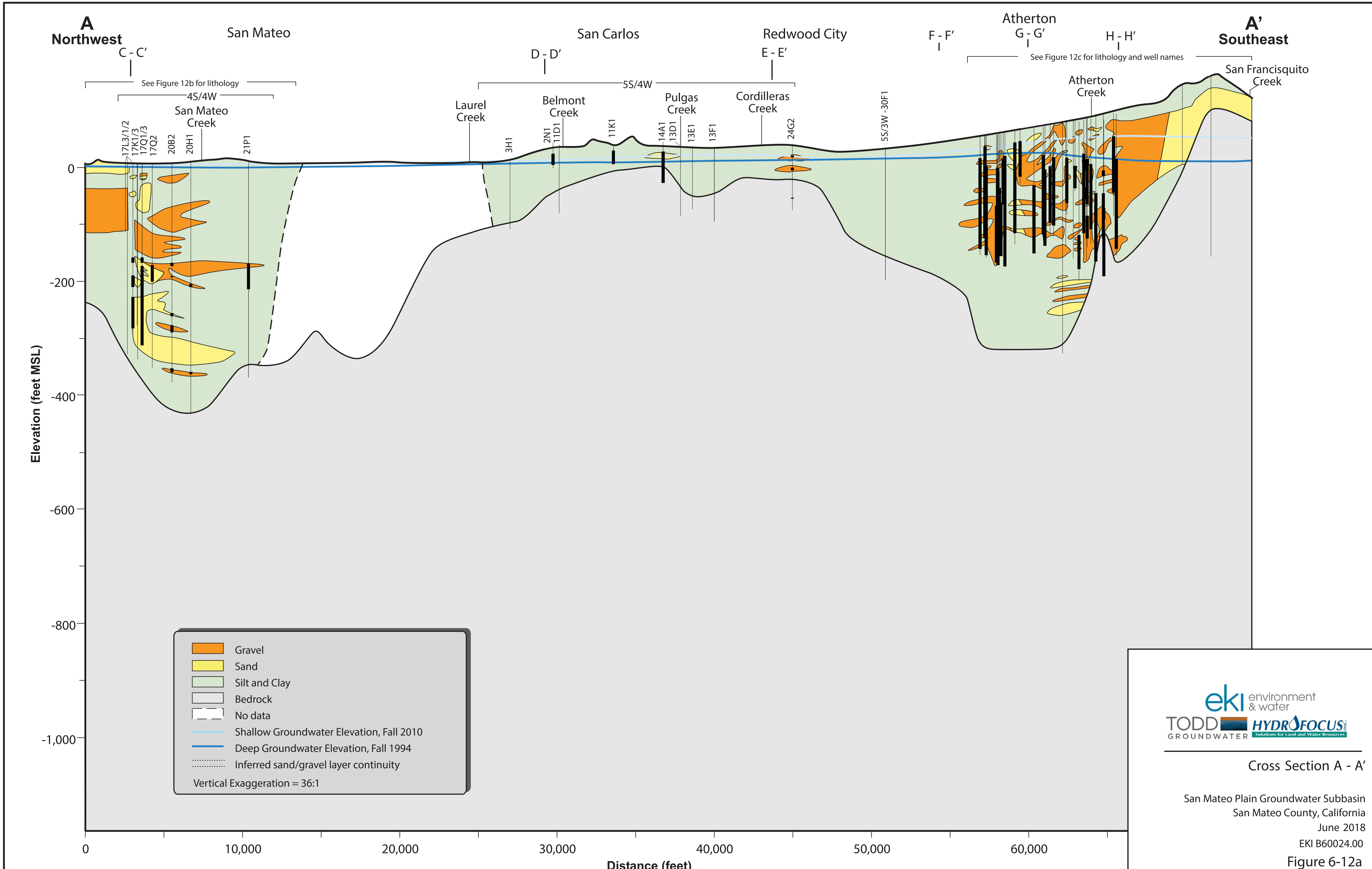
Cross Section Transects with Well Locations

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

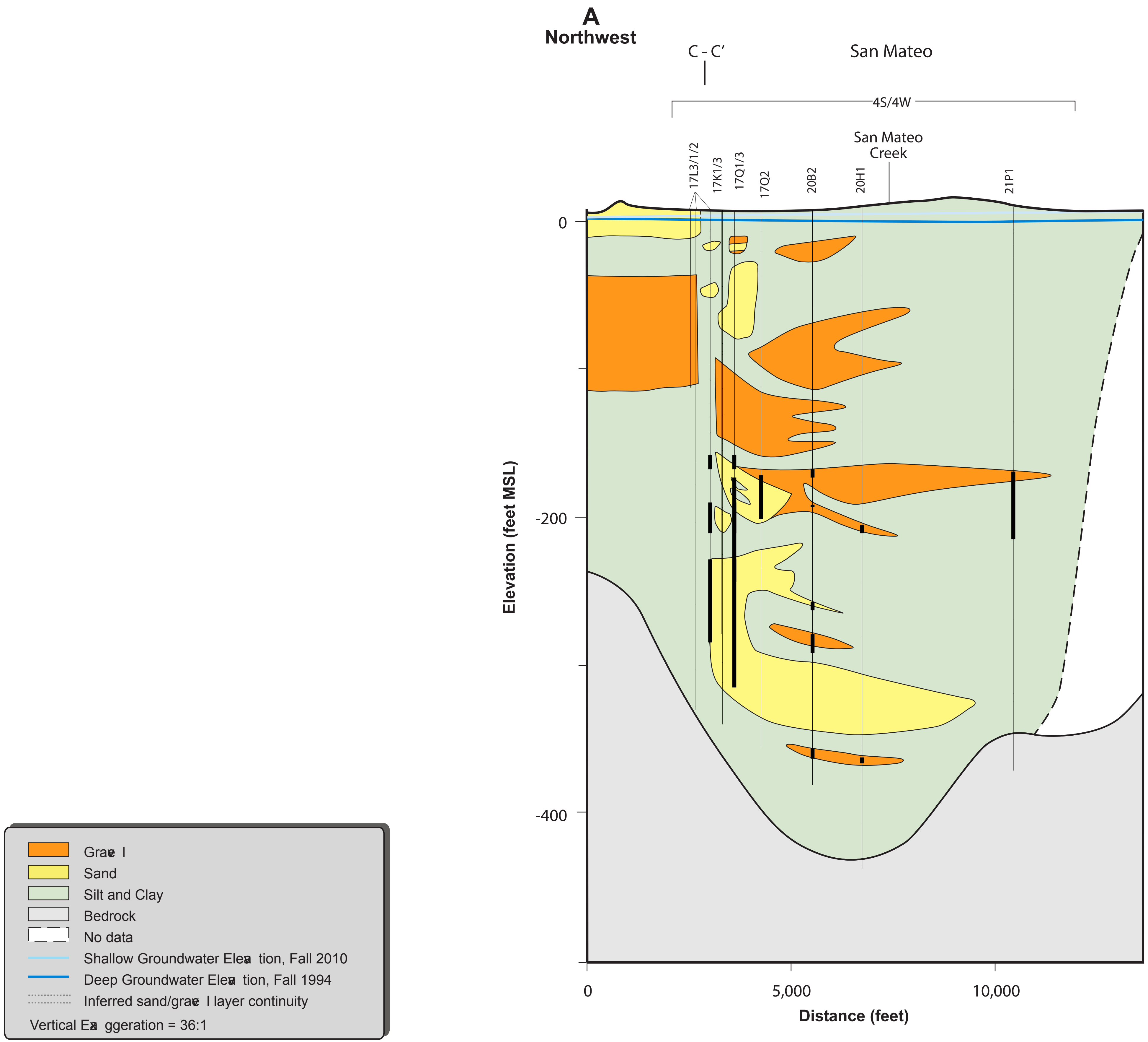
Figure 6-11



Cross Section A - A'

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-12a



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Cross Section A - A'

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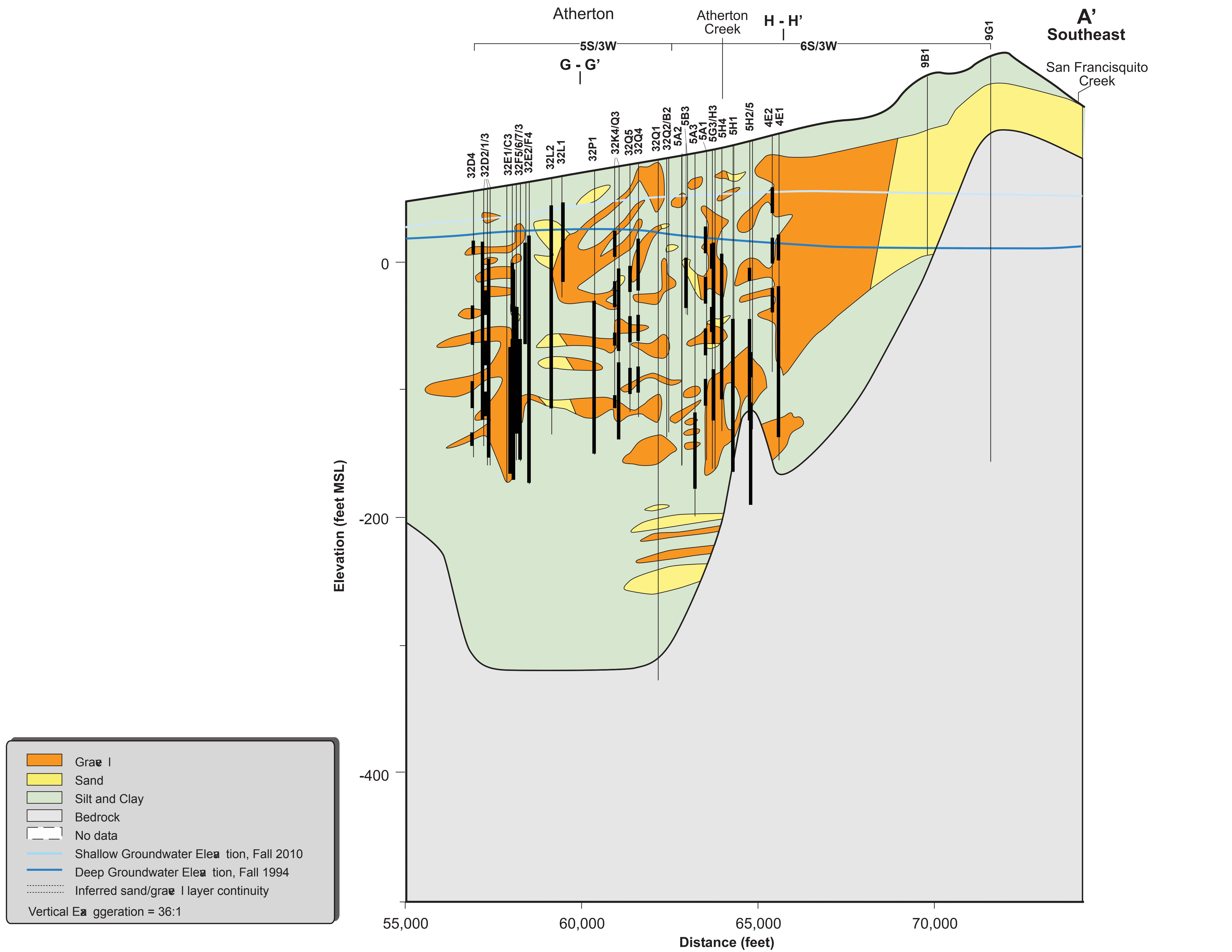
EKI B60024.00

Figure 6-12b



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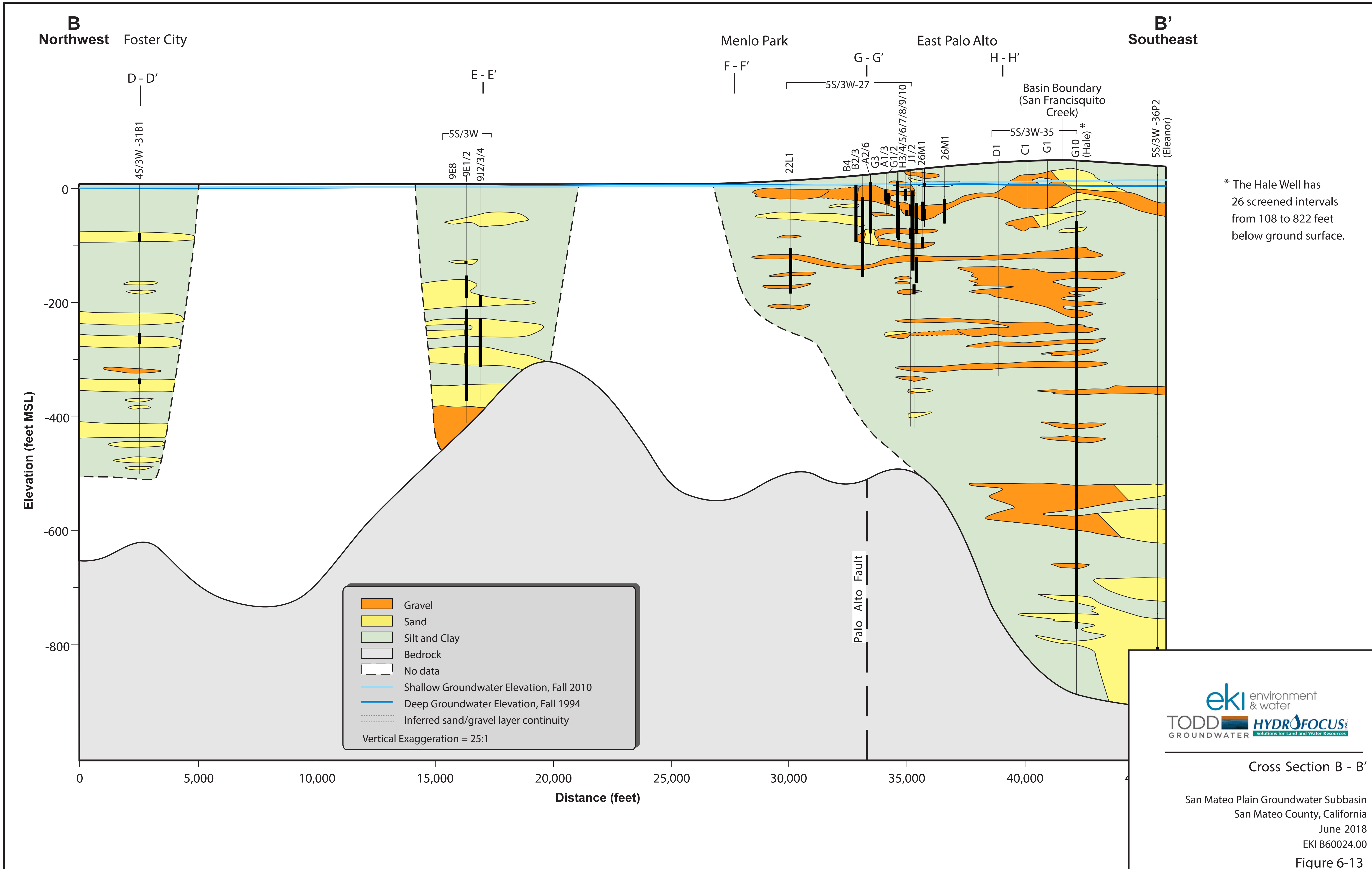
TODD GROUNDWATER
HYDROFOCUS INC. Solutions for Land and Water Resources

Cross Section A - A'

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-12c



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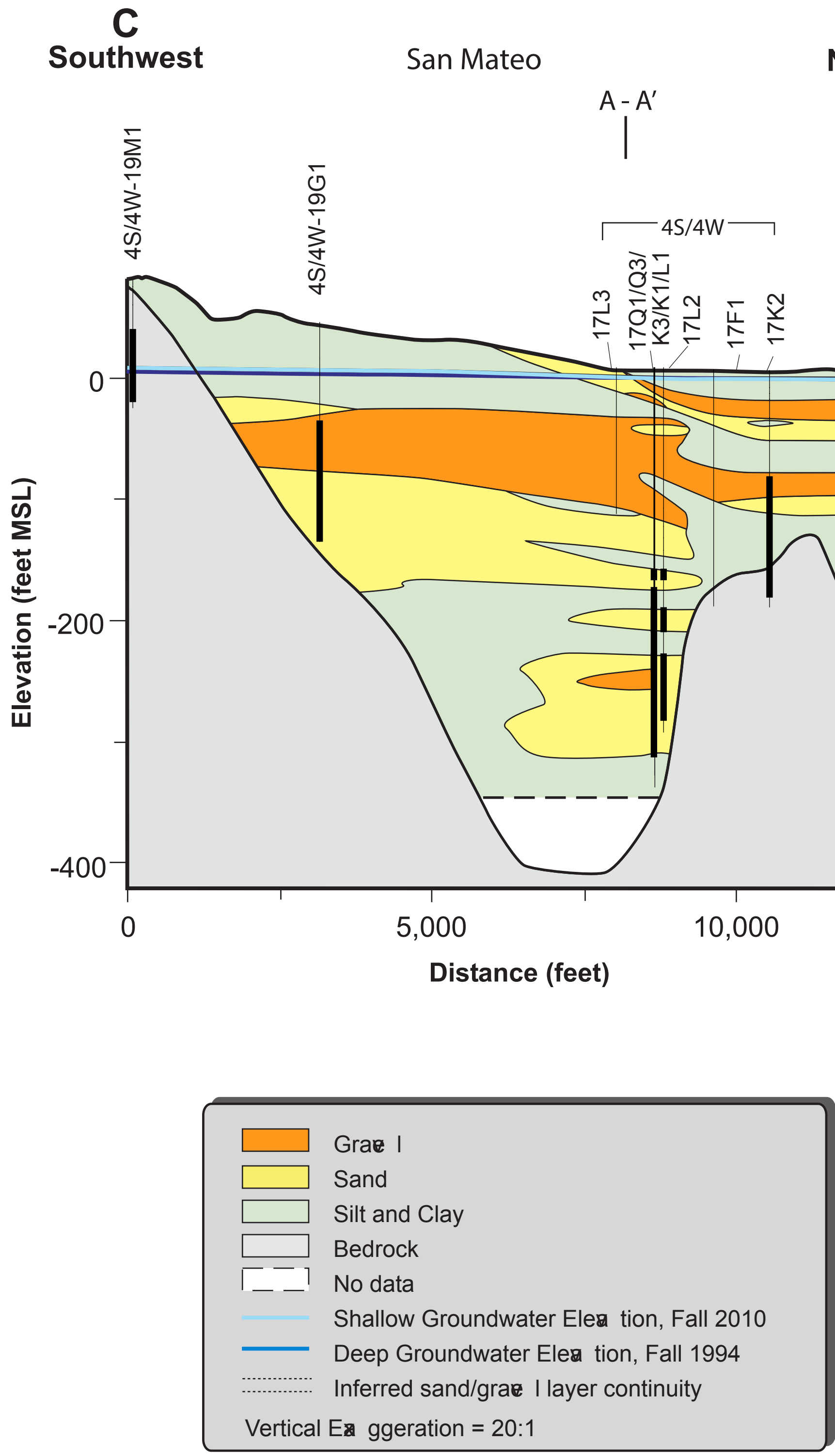
HYDROFOCUS Solutions for Land and Water Resources

Cross Section B - B'

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-13



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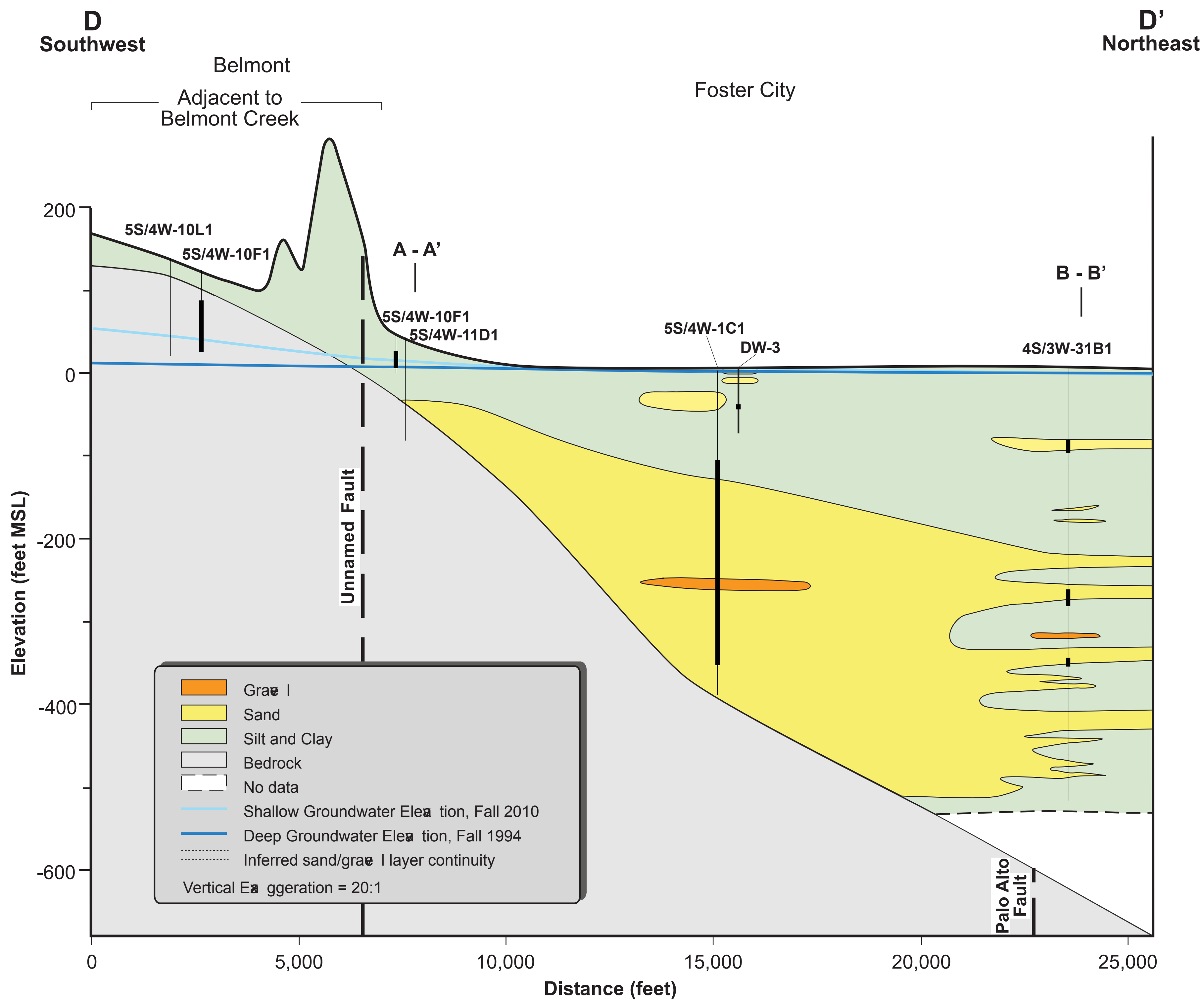
TODD GROUNDWATER

HYDROFOCUS Solutions for Land and Water Resources

Cross Section C - C'

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-14



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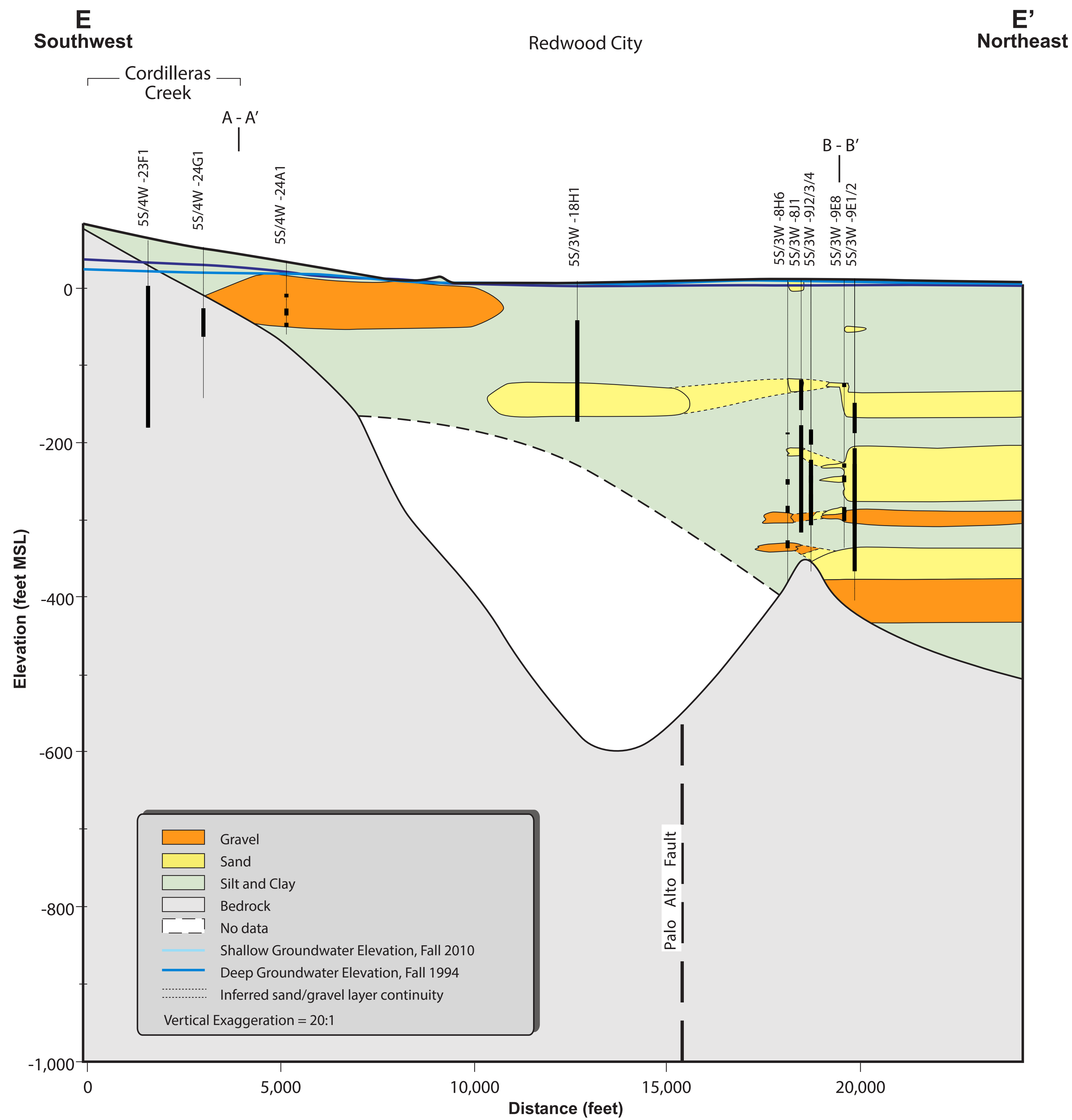
Cross Section D - D'

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-15



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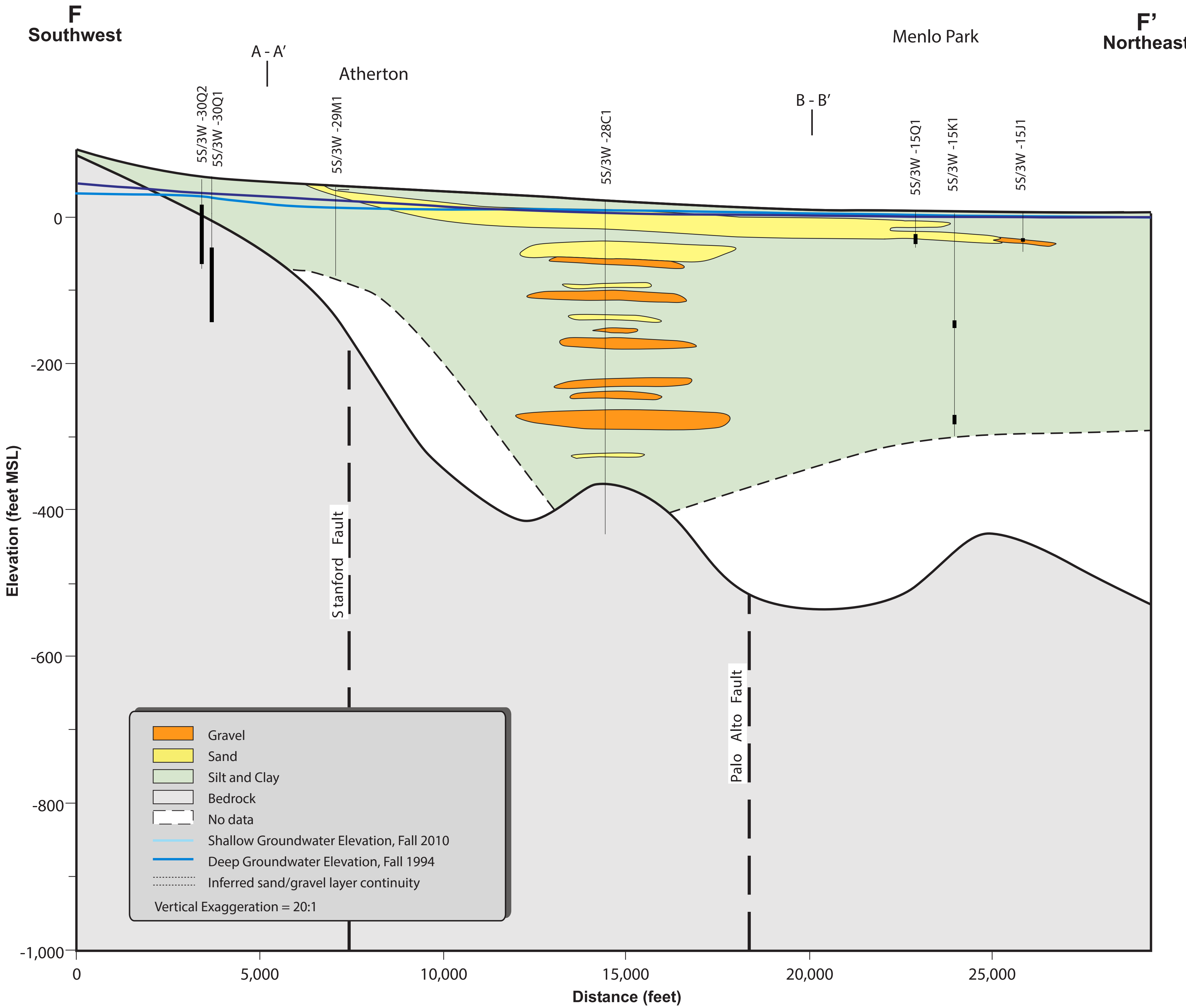
HYDROFOCUS

Cross Section E - E'

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-16



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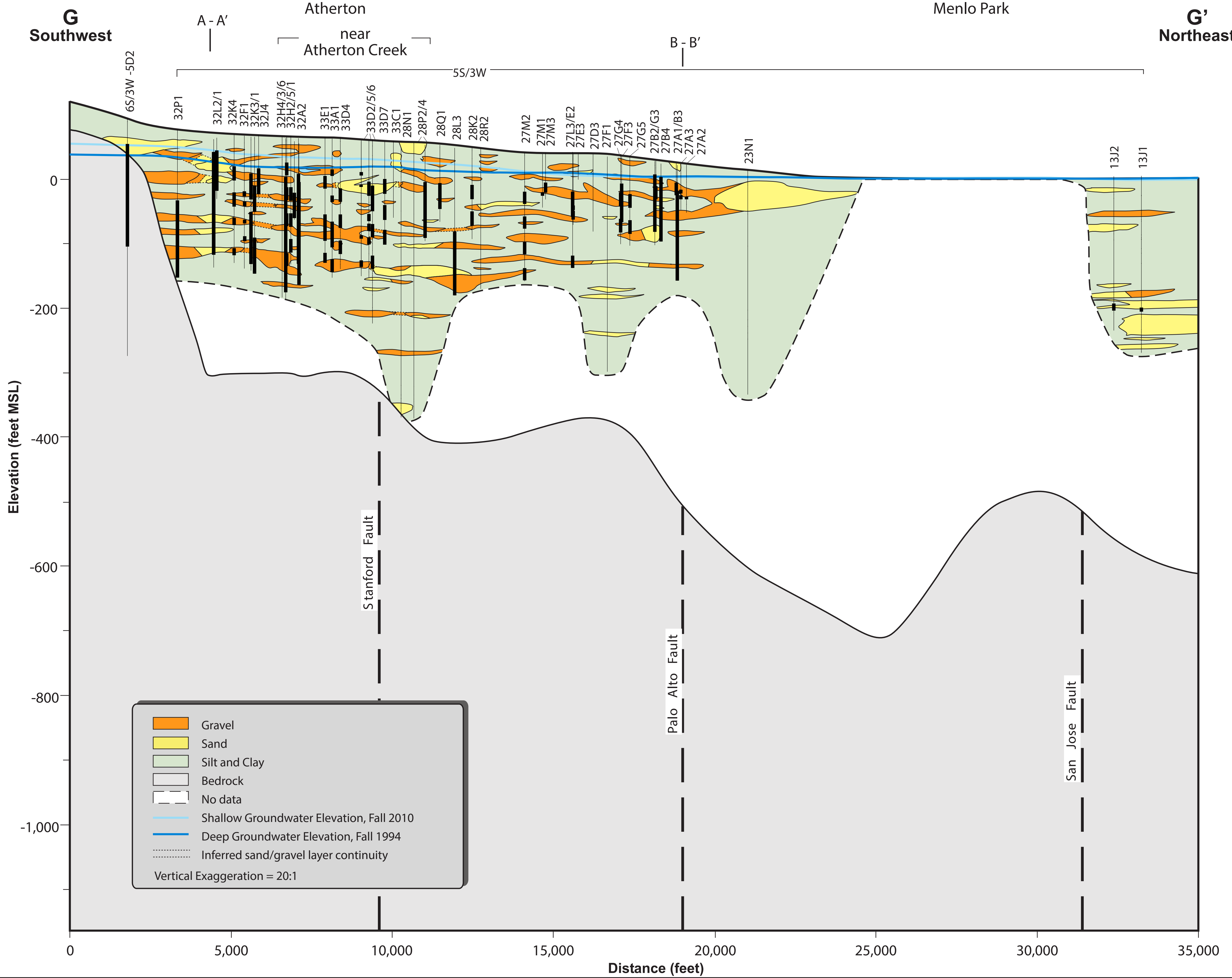
HYDROFOCUS Solutions for Land and Water Resources

Cross Section F - F'

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

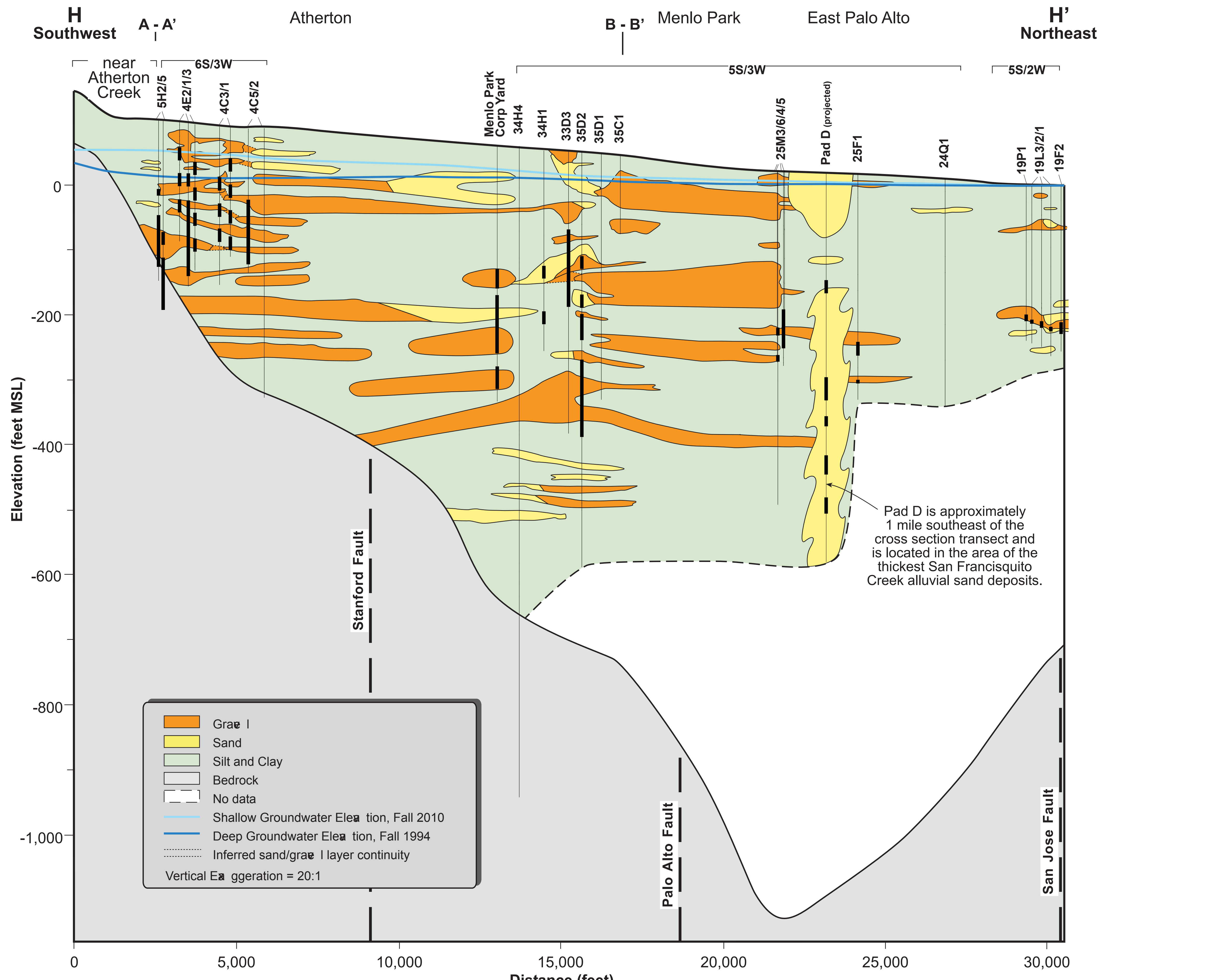
Figure 6-17



Cross Section G - G'

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-18



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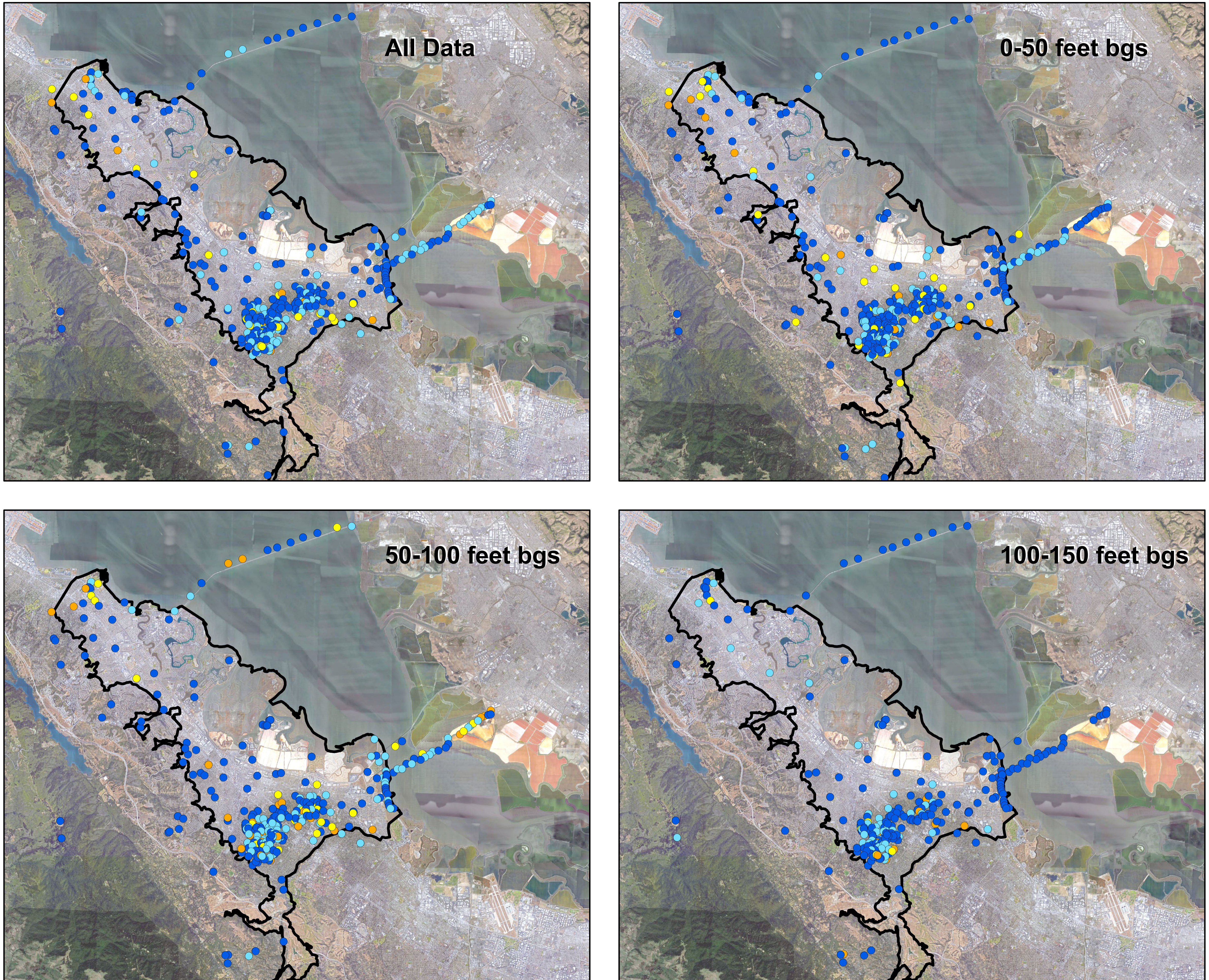
HYDROFOCUS INC. Solutions for Land and Water Resources

Cross Section H - H'

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-19



0 2 4
Miles

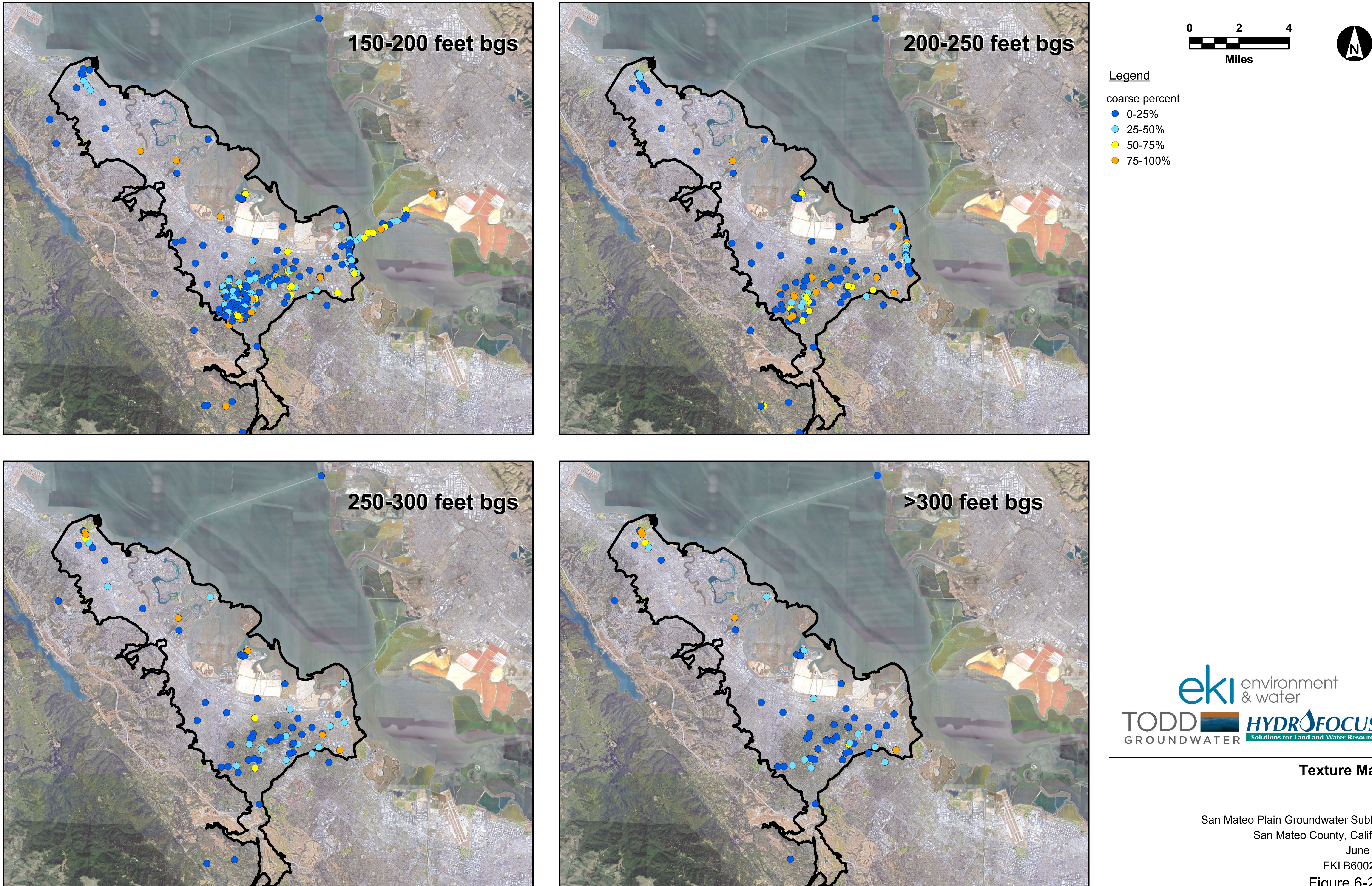
Legend

coarse percent
- 0-25%
- 25-50%
- 50-75%
- 75-100%

Texture Maps

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

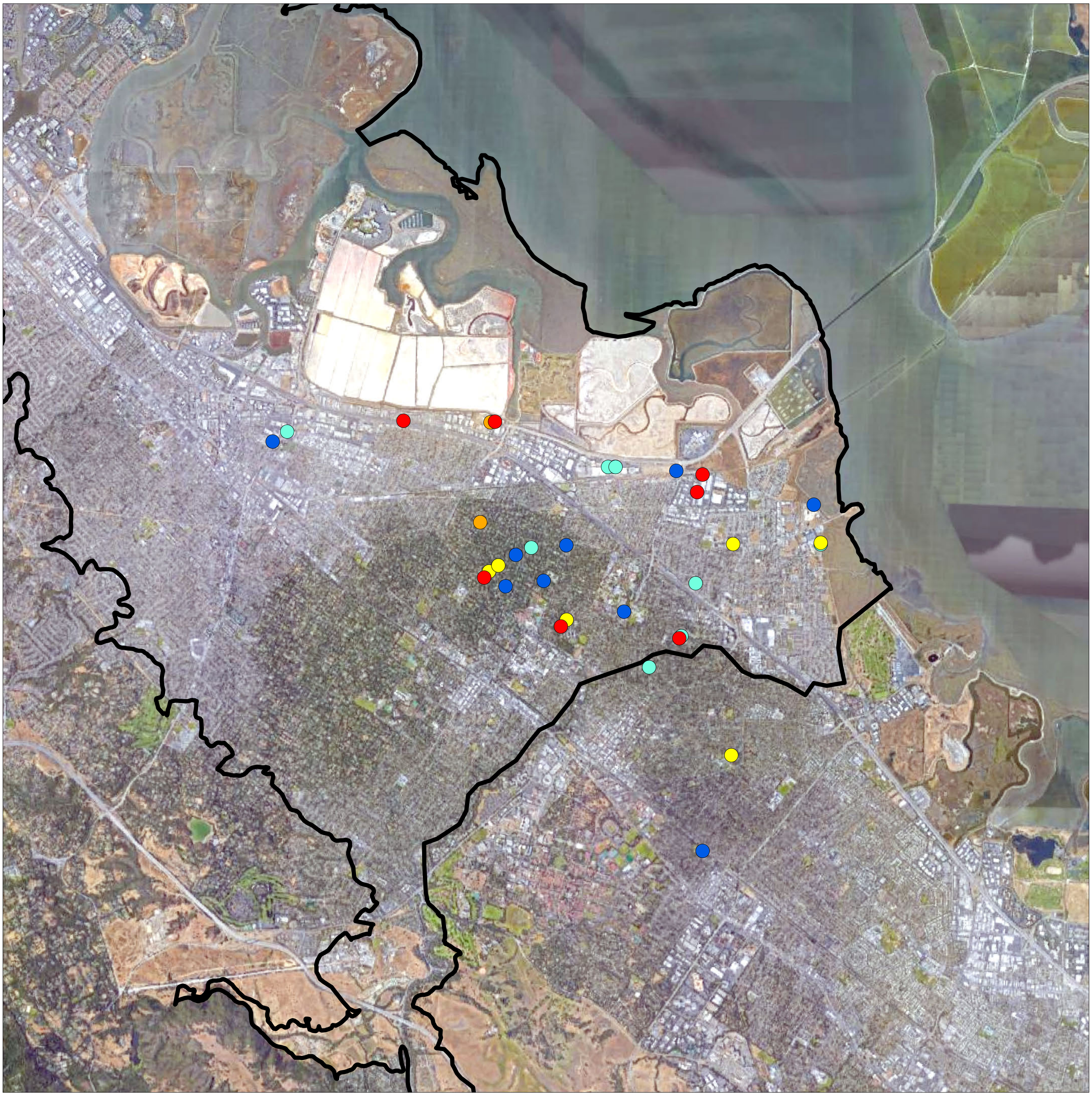
Figure 6-20a



Texture Maps

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-20b



Legend

Hydraulic Conductivity (ft/day)

- 0-10
- 10-20
- 20-50
- 50-100
- 100-400
- San Mateo Plain Basin

0 1 2
Miles

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Hydraulic Conductivity Values

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 6-21

Legend

Transmissivity
(ft²/day)

- 0-100
- 100-500
- 500-1,000
- 1,000-10,000
- 10,000-15,000
- San Mateo Plain Basin

0 1 2
Miles

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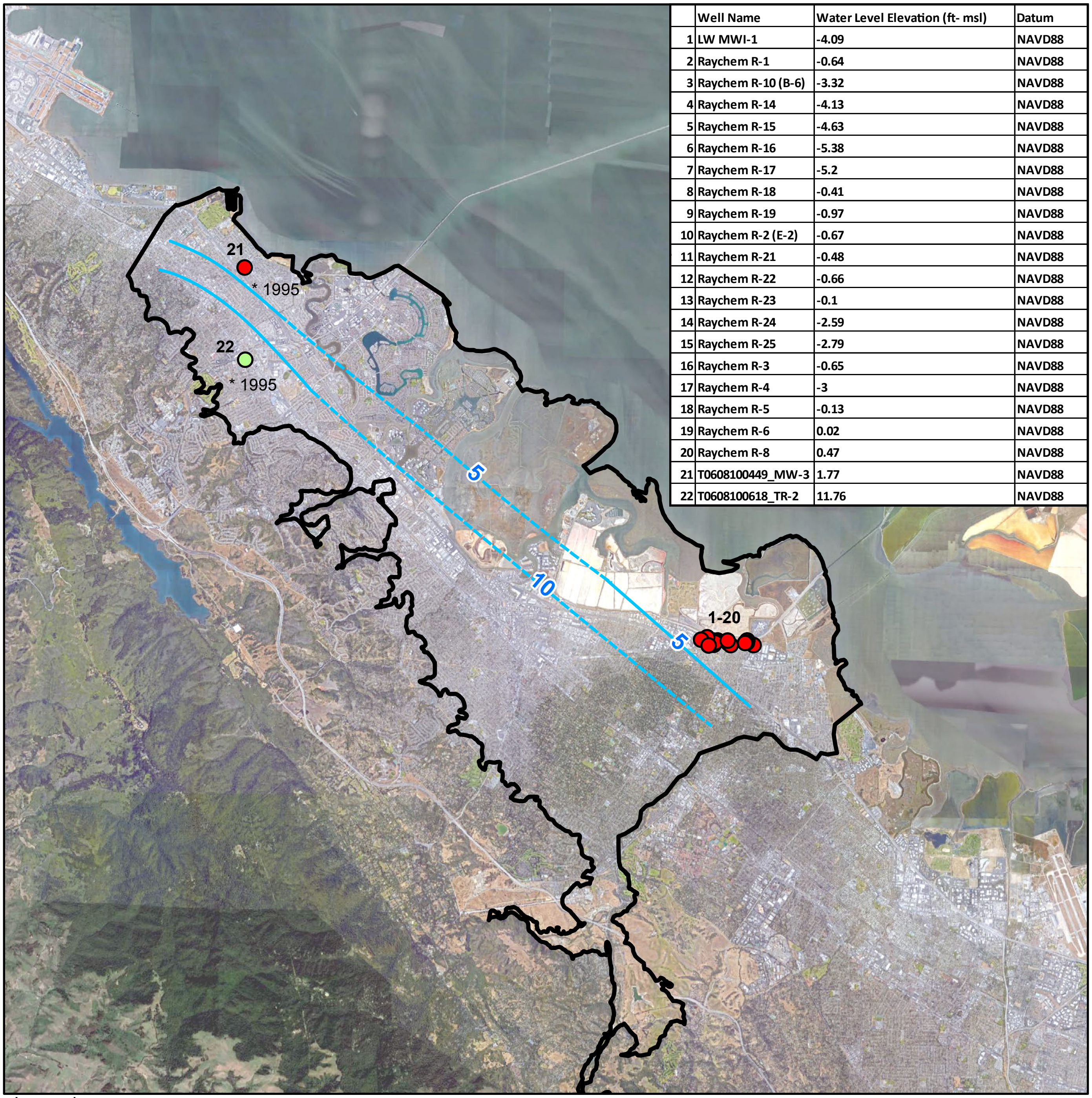
HYDROFOCUS INC. Solutions for Land and Water Resources

Transmissivity Values

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-22



	Well Name	Water Level Elevation (ft- msl)	Datum
1	LW MWI-1	-4.09	NAVD88
2	Raychem R-1	-0.64	NAVD88
3	Raychem R-10 (B-6)	-3.32	NAVD88
4	Raychem R-14	-4.13	NAVD88
5	Raychem R-15	-4.63	NAVD88
6	Raychem R-16	-5.38	NAVD88
7	Raychem R-17	-5.2	NAVD88
8	Raychem R-18	-0.41	NAVD88
9	Raychem R-19	-0.97	NAVD88
10	Raychem R-2 (E-2)	-0.67	NAVD88
11	Raychem R-21	-0.48	NAVD88
12	Raychem R-22	-0.66	NAVD88
13	Raychem R-23	-0.1	NAVD88
14	Raychem R-24	-2.59	NAVD88
15	Raychem R-25	-2.79	NAVD88
16	Raychem R-3	-0.65	NAVD88
17	Raychem R-4	-3	NAVD88
18	Raychem R-5	-0.13	NAVD88
19	Raychem R-6	0.02	NAVD88
20	Raychem R-8	0.47	NAVD88
21	T0608100449_MW-3	1.77	NAVD88
22	T0608100618_TR-2	11.76	NAVD88

Legend

Water Level Elevation Contour (ft-msl)

Water Level Elevation Contour- Speculative (ft-msl)

San Mateo Plain Basin

Shallow Well Water Level Elevation Fall 1994 (ft-msl)

- <5
- 5-10
- 10-15
- 15-20
- >20

* Water level measured in fall of noted year

0 2.5 5

Miles

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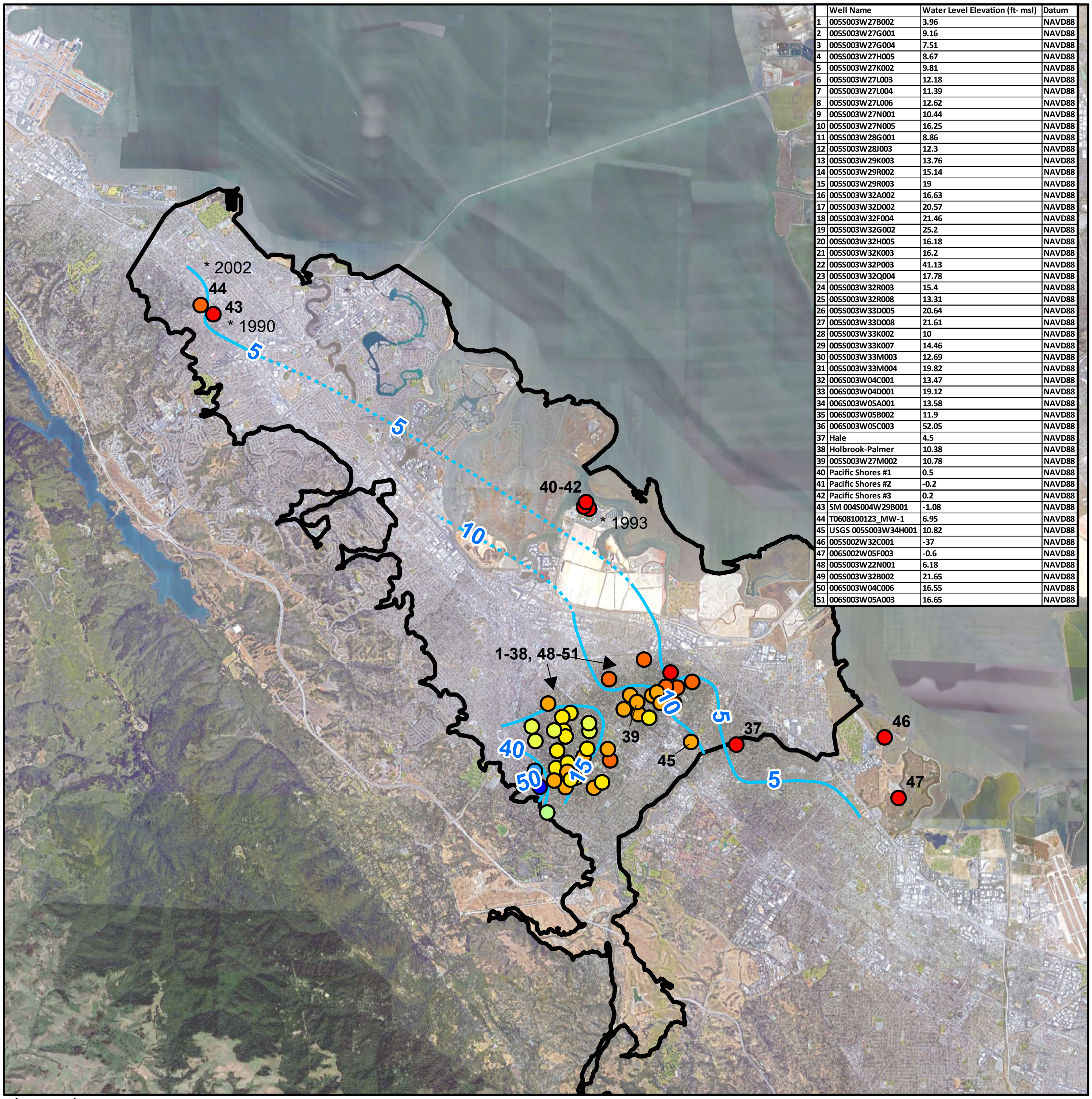
TODD GROUNDWATER

HYDROFOCUS INC. Solutions for Land and Water Resources

Fall 1994 Shallow Well Groundwater Elevation

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-23



	Well Name	Water Level Elevation (ft- msl)	Datum
1	005S003W27B002	3.96	NAVD88
2	005S003W27G001	9.16	NAVD88
3	005S003W27G004	7.51	NAVD88
4	005S003W27H005	8.67	NAVD88
5	005S003W27K002	9.81	NAVD88
6	005S003W27L003	12.18	NAVD88
7	005S003W27L004	11.39	NAVD88
8	005S003W27L006	12.62	NAVD88
9	005S003W27N001	10.44	NAVD88
10	005S003W27N005	16.25	NAVD88
11	005S003W28G001	8.86	NAVD88
12	005S003W28J003	12.3	NAVD88
13	005S003W29K003	13.76	NAVD88
14	005S003W29R002	15.14	NAVD88
15	005S003W29R003	19	NAVD88
16	005S003W32A002	16.63	NAVD88
17	005S003W32D002	20.57	NAVD88
18	005S003W32F004	21.46	NAVD88
19	005S003W32G002	25.2	NAVD88
20	005S003W32H005	16.18	NAVD88
21	005S003W32K003	16.2	NAVD88
22	005S003W32P003	41.13	NAVD88
23	005S003W32Q004	17.78	NAVD88
24	005S003W32R003	15.4	NAVD88
25	005S003W32R008	13.31	NAVD88
26	005S003W33D005	20.64	NAVD88
27	005S003W33D008	21.61	NAVD88
28	005S003W33K002	10	NAVD88
29	005S003W33K007	14.46	NAVD88
30	005S003W33M003	12.69	NAVD88
31	005S003W33M004	19.82	NAVD88
32	006S003W04C001	13.47	NAVD88
33	006S003W04D001	19.12	NAVD88
34	006S003W05A001	13.58	NAVD88
35	006S003W05B002	11.9	NAVD88
36	006S003W05C003	52.05	NAVD88
37	Hale	4.5	NAVD88
38	Holbrook-Palmer	10.38	NAVD88
39	005S003W27M002	10.78	NAVD88
40	Pacific Shores #1	0.5	NAVD88
41	Pacific Shores #2	-0.2	NAVD88
42	Pacific Shores #3	0.2	NAVD88
43	SM 004S004W29B001	-1.08	NAVD88
44	T0608100123_MW-1	6.95	NAVD88
45	USGS 005S003W34H001	10.82	NAVD88
46	005S002W32C001	-37	NAVD88
47	006S002W05F003	-0.6	NAVD88
48	005S003W22N001	6.18	NAVD88
49	005S003W32B002	21.65	NAVD88
50	006S003W04C006	16.55	NAVD88
51	006S003W05A003	16.65	NAVD88

Legend

Water Level Elevation Contour (ft-msl)

Water Level Elevation Contour- Speculative (ft-msl)

San Mateo Plain Basin

Deep Well Water Level Elevation Fall 1994 (ft msl)

- <5
- 5-10
- 10-15
- 15-20
- 20-25
- 25-30
- 30-35
- 35-40
- 40-45
- 45-50
- \>50

* Water level measured in fall of noted year

0 2.5 5

Miles

N

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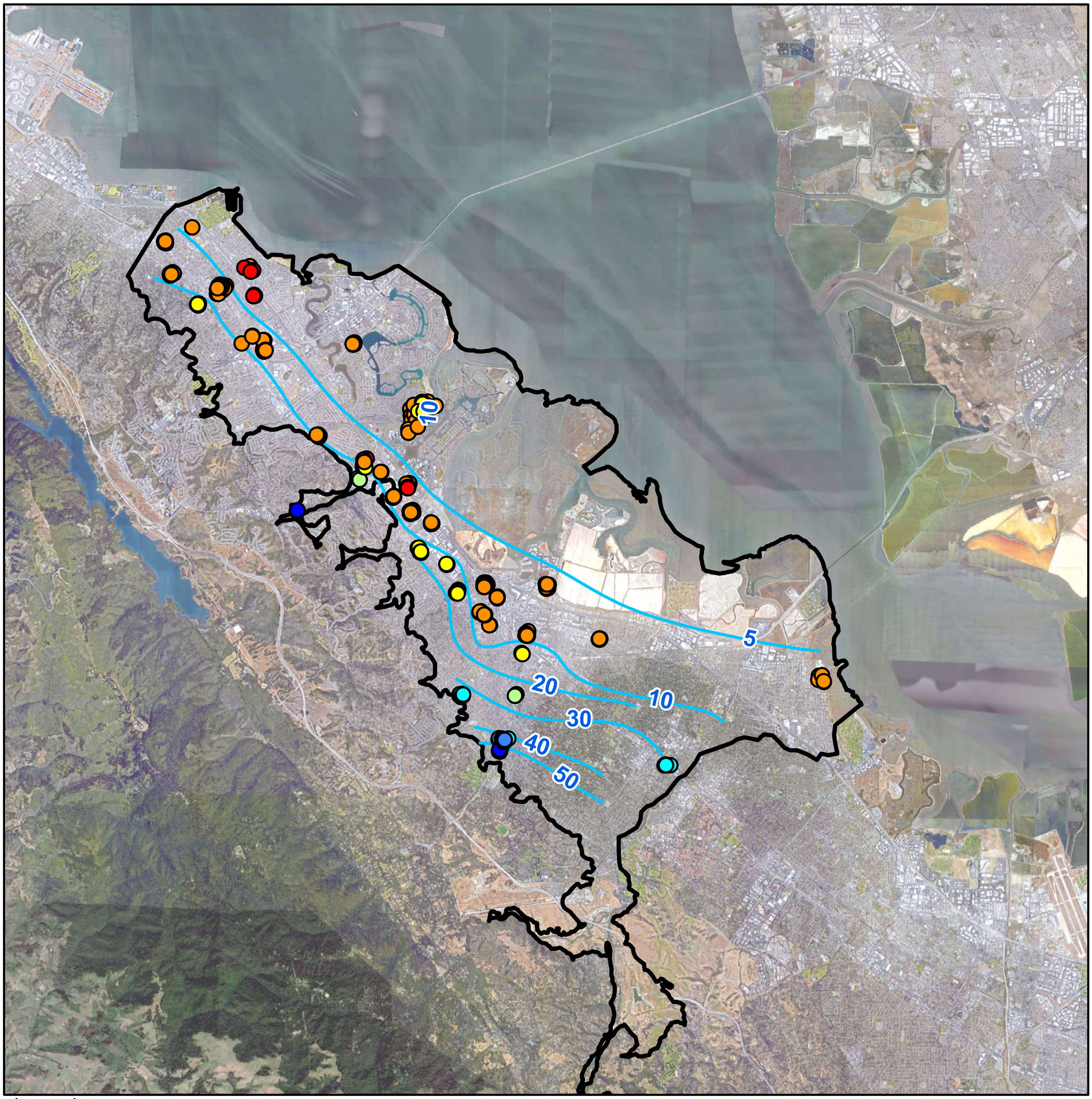
HYDROFOCUS INC. Solutions for Land and Water Resources

Fall 1994 Deep Well Groundwater Elevation

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-24



Legend

Water Level Elevation Contour (ft-msl)

San Mateo Plain Basin

Shallow Well Water Level Elevation Fall 2010 (ft msl)

- <0
- 0-10
- 10-20
- 20-30
- 30-40
- 40-50
- >50

0 2.5 5

Miles

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HYDROFOCUS INC. Solutions for Land and Water Resources

Fall 2010 Shallow Well Groundwater Elevation

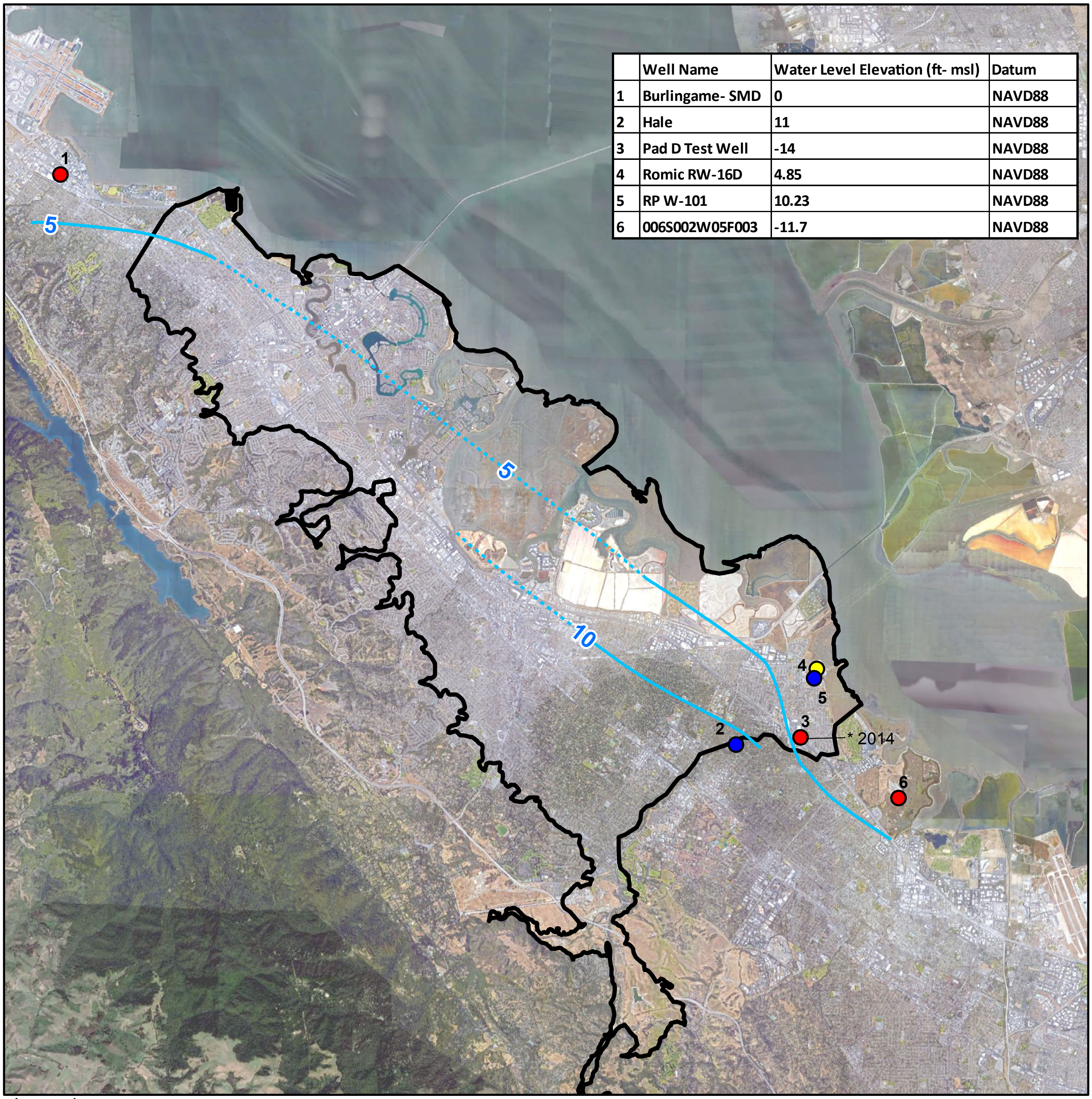
San Mateo Plain Groundwater Subbasin

San Mateo County, California

June 2018

EKI B60024.00

Figure 6-25



	Well Name	Water Level Elevation (ft- msl)	Datum
1	Burlingame- SMD	0	NAVD88
2	Hale	11	NAVD88
3	Pad D Test Well	-14	NAVD88
4	Romic RW-16D	4.85	NAVD88
5	RP W-101	10.23	NAVD88
6	006S002W05F003	-11.7	NAVD88

Legend

Water Level Elevation Contour (ft-msl)

Water Level Elevation Contour- Speculative (ft-msl)

San Mateo Plain Basin

Deep Well Water Level Elevation Fall 2010 (ft msl)

- <0
- 0-5
- 5-10
- 10-15

* Water level measured in noted year

N

0 2.5 5

Miles

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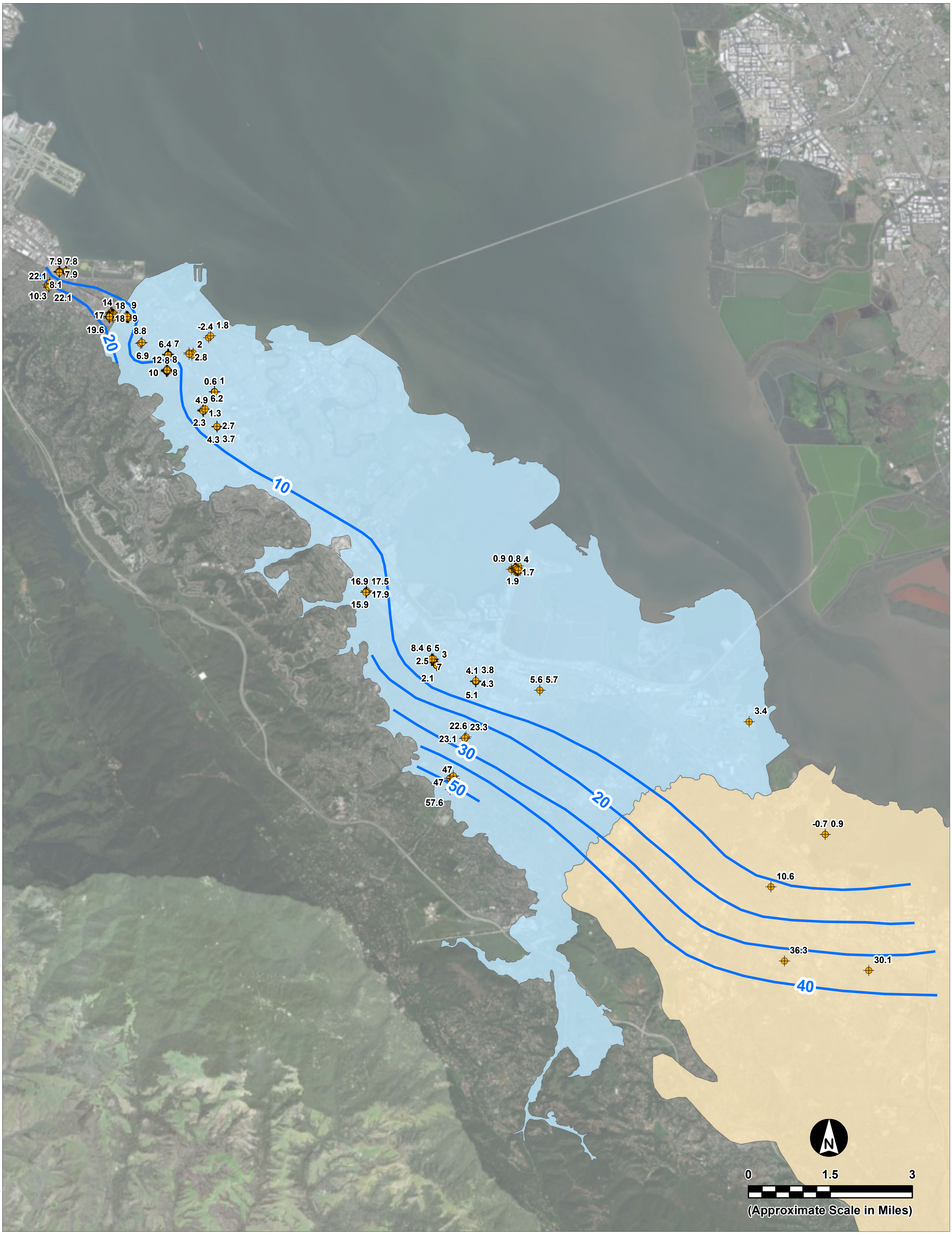
TODD GROUNDWATER

HYDROFOCUS INC. Solutions for Land and Water Resources

Fall 2010 Deep Well Groundwater Elevation

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-26



Path: T:\Projects\San Mateo Basin Assessment 78001\GIS\Maps\Phase 2 Figures\Fig 6-29 ShallowFall2016.mxd

Legend

- Water Level Elevation (ft-msl)
- Groundwater Contour

Groundwater Basin

- Santa Clara Valley
- San Mateo Plain

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Fall 2016 Shallow Well Groundwater Elevation

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-27

Path: T:\Projects\San Mateo Basin Assessment 78001\GIS\Maps\Phase 2 Figures\Fig 6-30 ShallowSpring-Summer2017.mxd

Legend

- Water Level Elevation (ft-msl)
- Groundwater Contour

Groundwater Basin

- Santa Clara Valley
- San Mateo Plain

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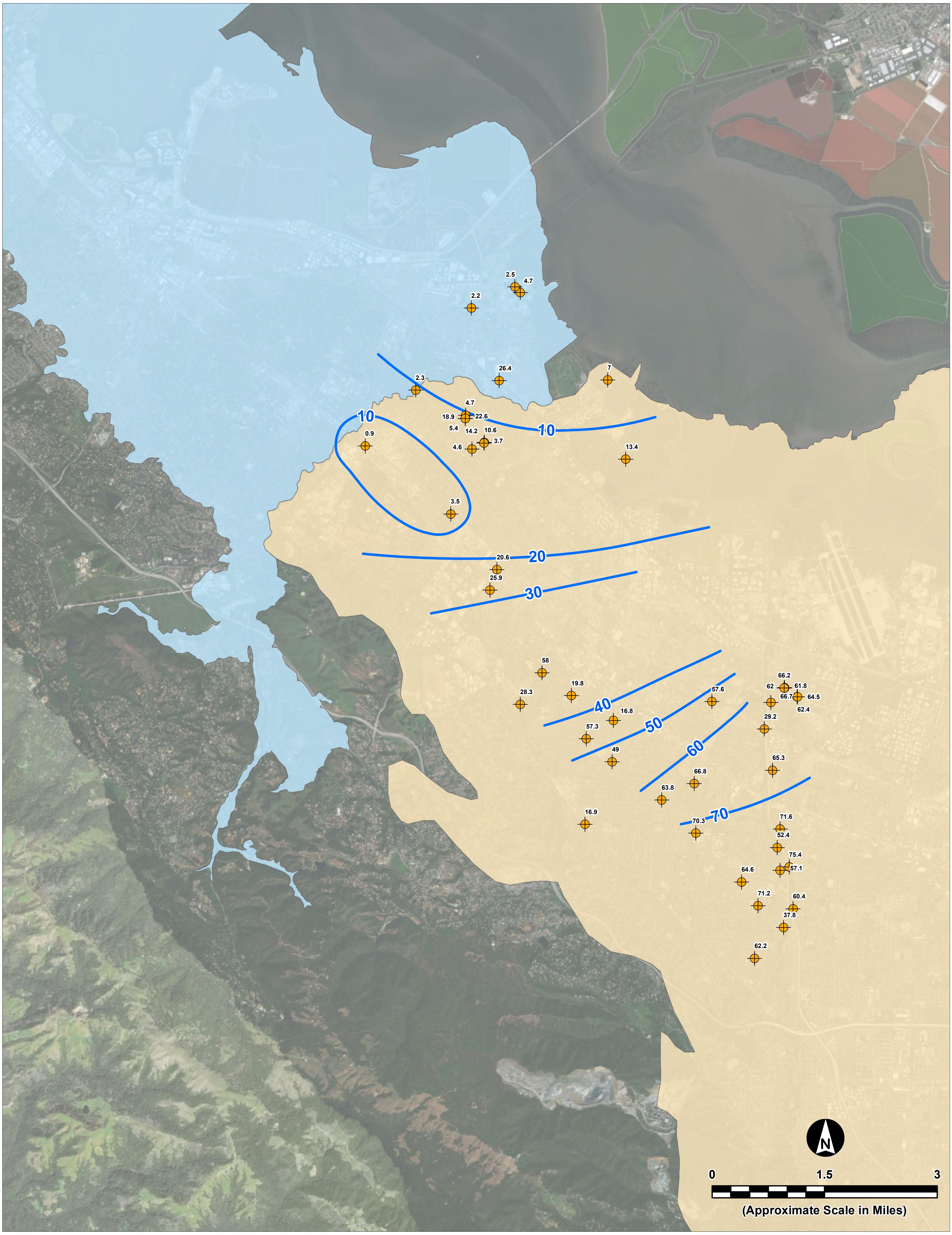
HYDROFOCUS INC. Solutions for Land and Water Resources

Spring/Summer 2017 Shallow Well Groundwater Elevation

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-28



Legend

Water Level Elevation (ft-msl)

Groundwater Contour

Groundwater Basin

Santa Clara Valley

San Mateo Plain

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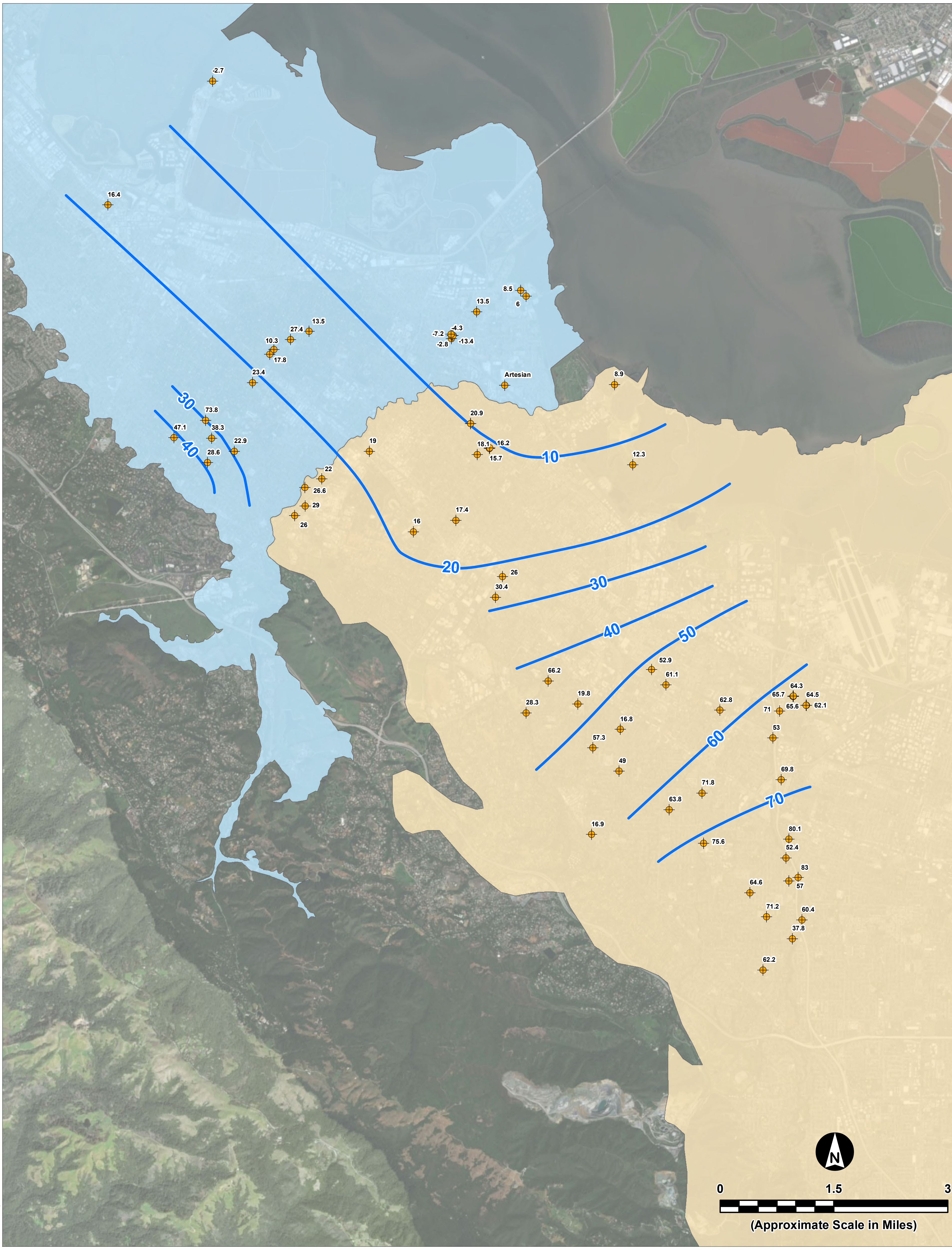
Fall 2016 Deep Well Groundwater Elevation

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-29



Path: T:\Projects\San Mateo Basin Assessment 78001\GIS\Maps\Phase 2 Figures\Fig 6-28 DeepSpring-Summer2017WL.mxd

Legend

- Water Level Elevation (ft-msl)
- Groundwater Contour

Groundwater Basin

- Santa Clara Valley
- San Mateo Plain

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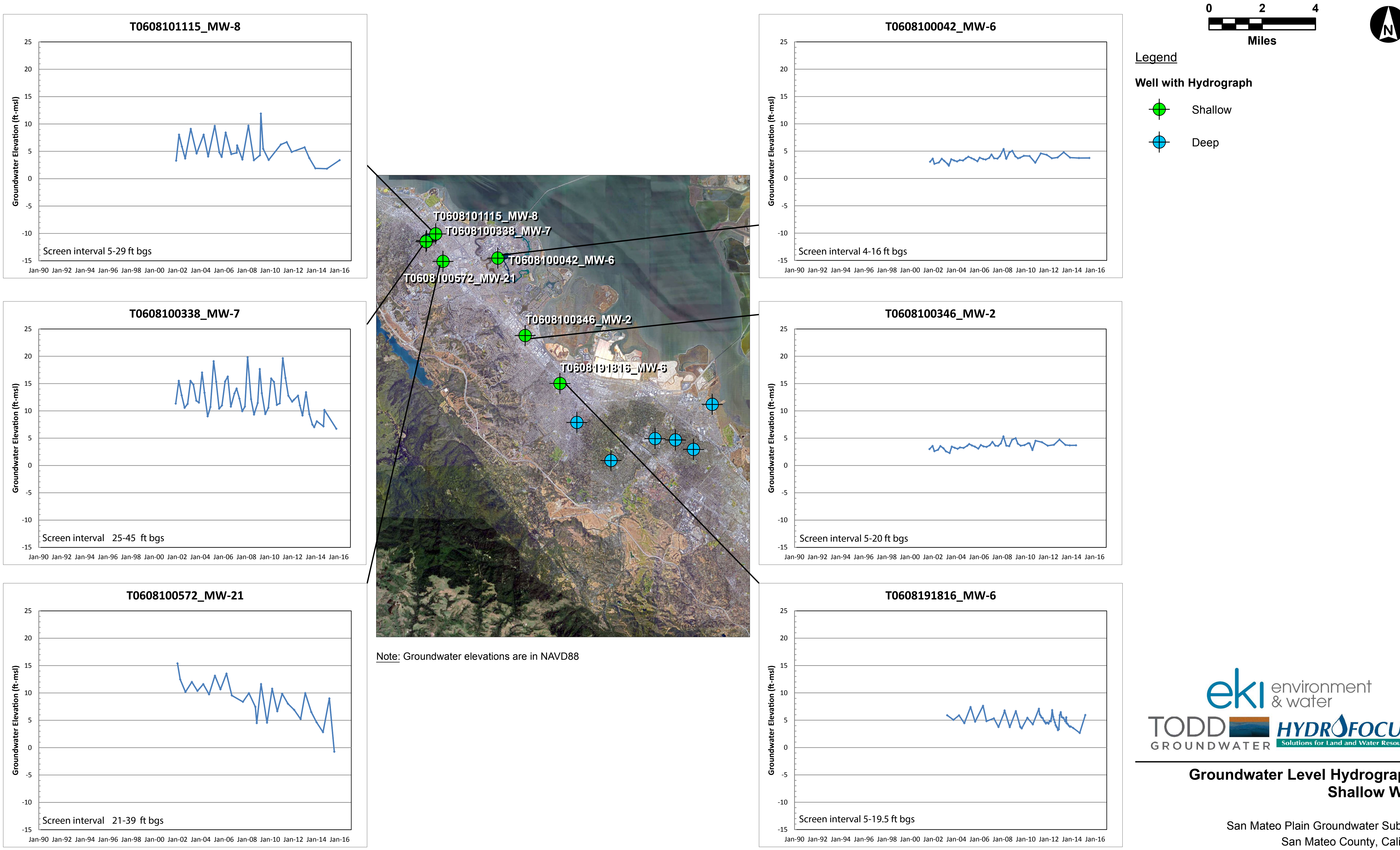
Spring/Summer 2017 Deep Well Groundwater Elevation

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 6-30



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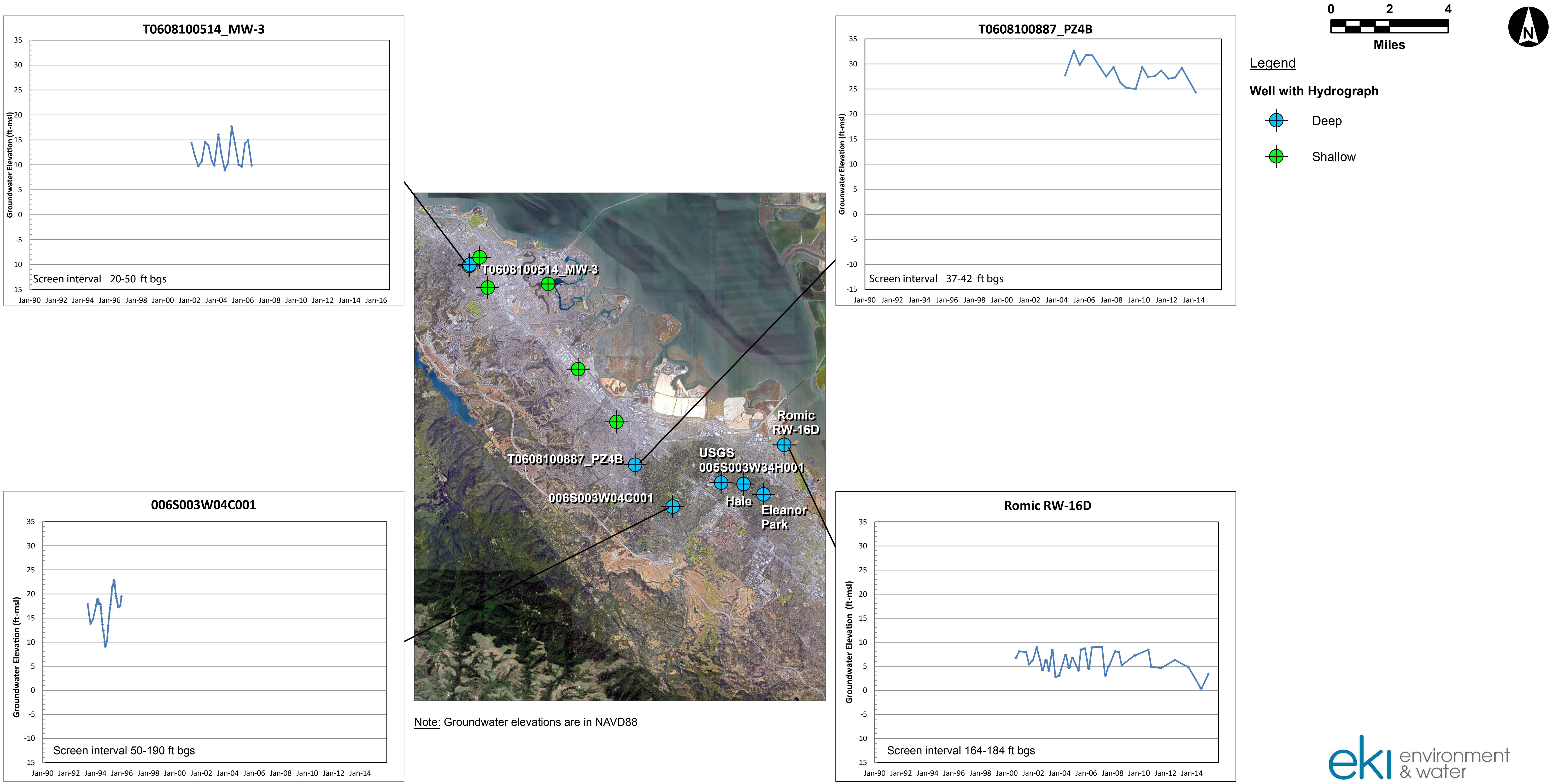
Groundwater Level Hydrographs, Shallow Wells

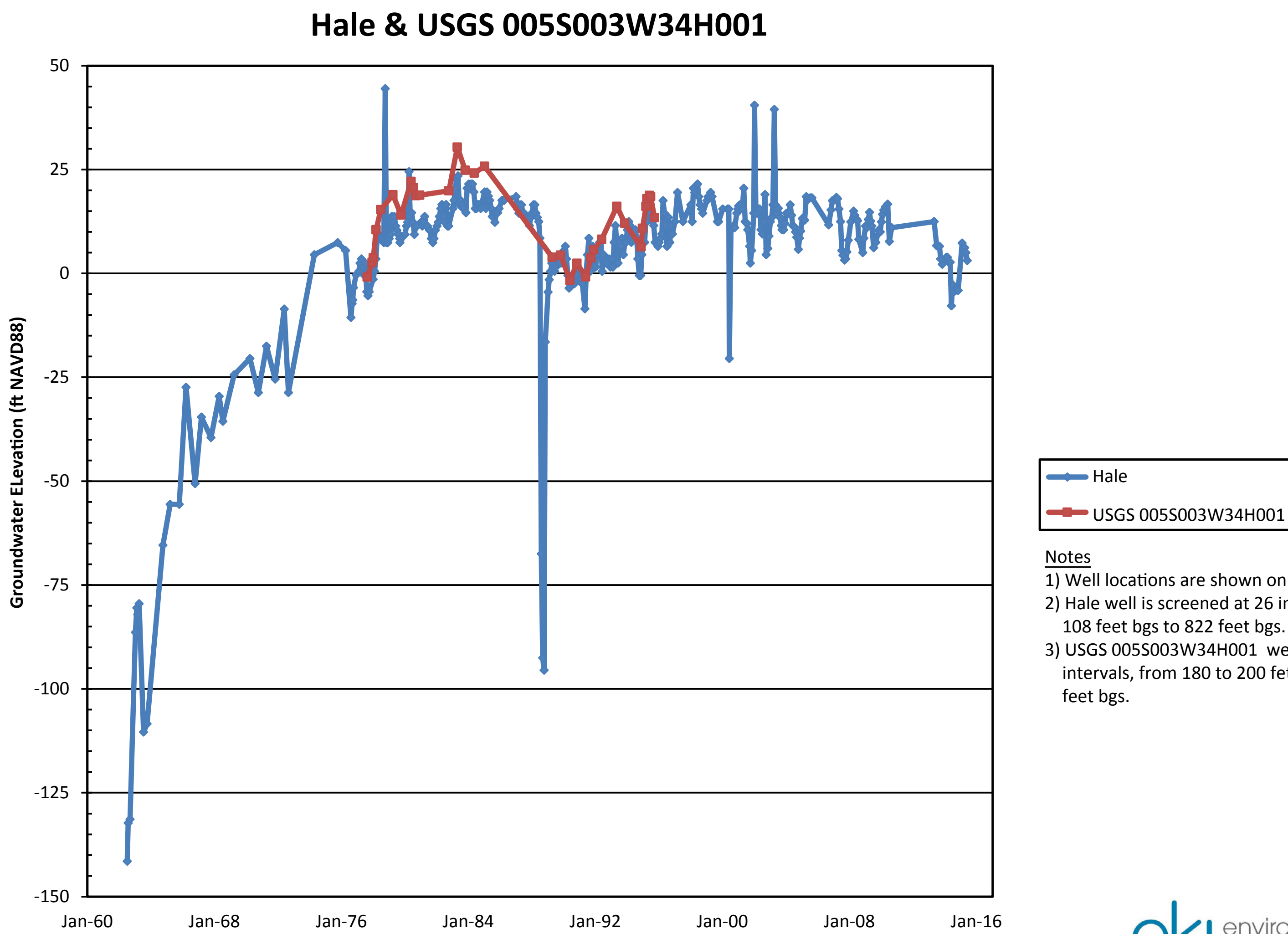
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 6-31



Note: Groundwater elevations are in NAVD88

Groundwater Level Hydrographs, Deep Wells

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 6-32



Notes
1) Well locations are shown on Figure 6-28.
2) Hale well is screened at 26 intervals ranging from 108 feet bgs to 822 feet bgs.
3) USGS 005S003W34H001 well is screened at twi intervals, from 180 to 200 fet bgs and 250 to 270 feet bgs.

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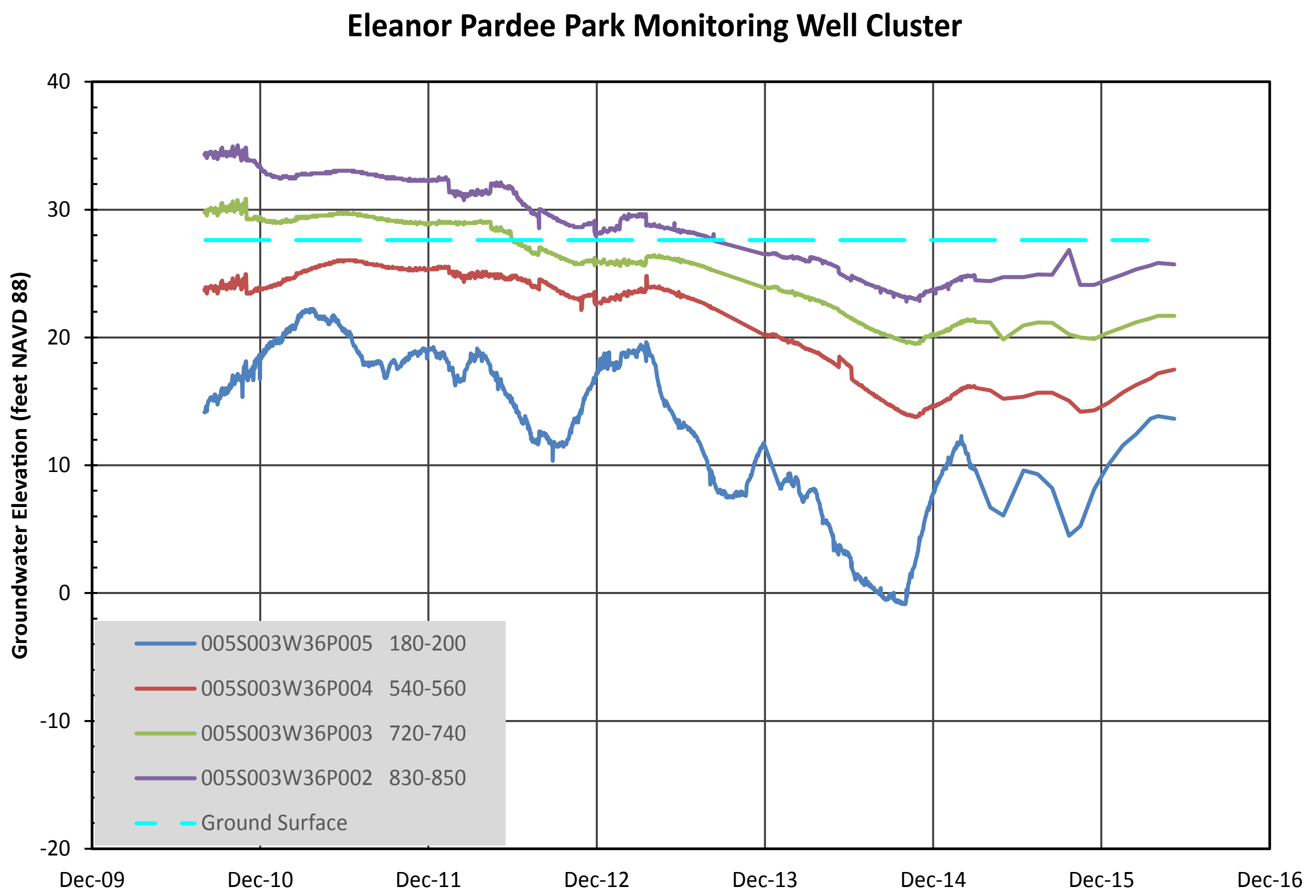
Groundwater Level Hydrographs, Hale Well and 34H1

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-33



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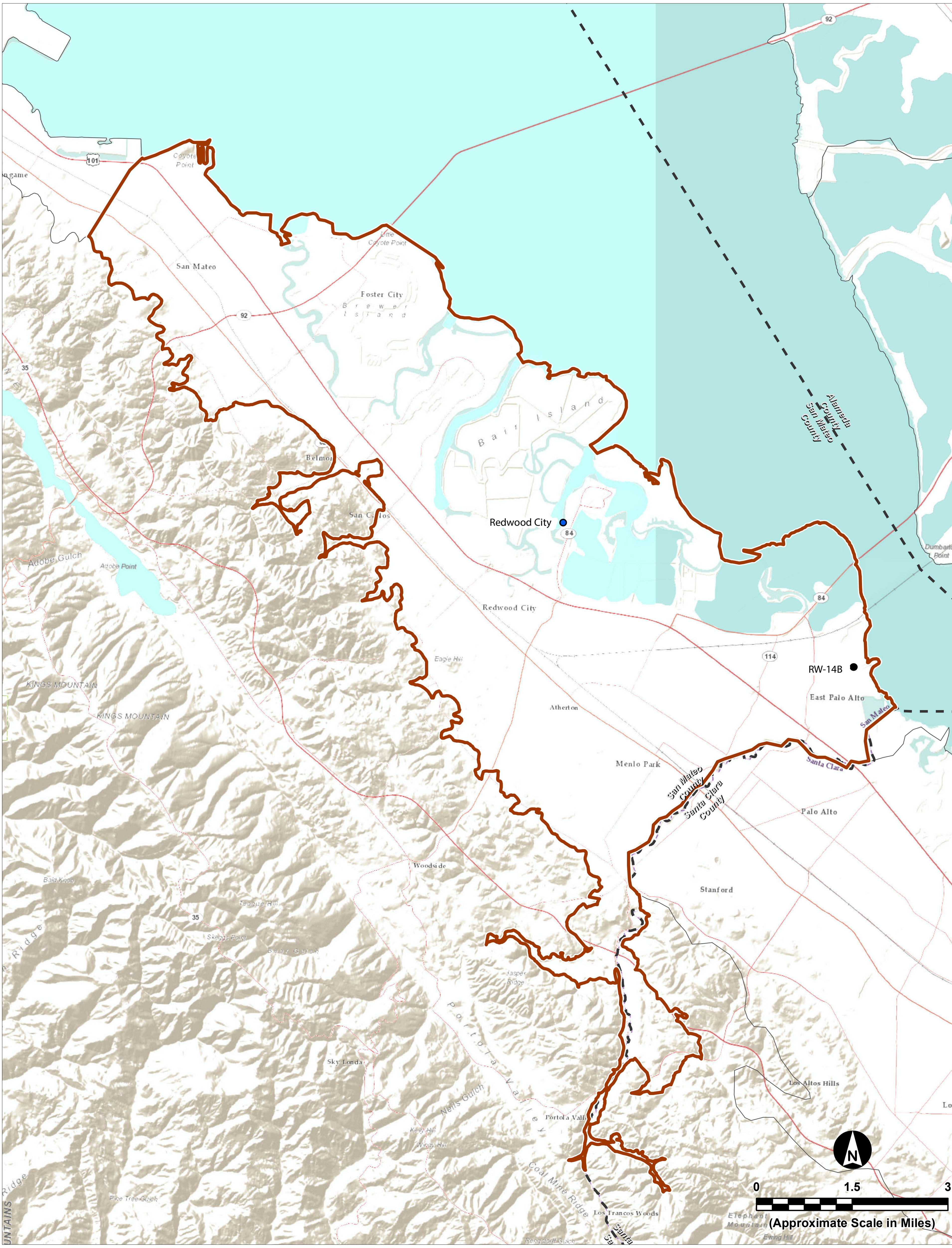
Groundwater Level Hydrographs, Eleanor Park Well Cluster

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-34



Path: P:\Projects\5075-2_San Mateo Plain GW\GIS\Maps\Report Figures\Fig2-1_Bay Mud Study Location.mxd

Legend

- Monitoring Well
- NOAA Station
- San Mateo Plain Subbasin
- County Boundary

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 2 January 2018.

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Monitoring Well and Bay Tide Station

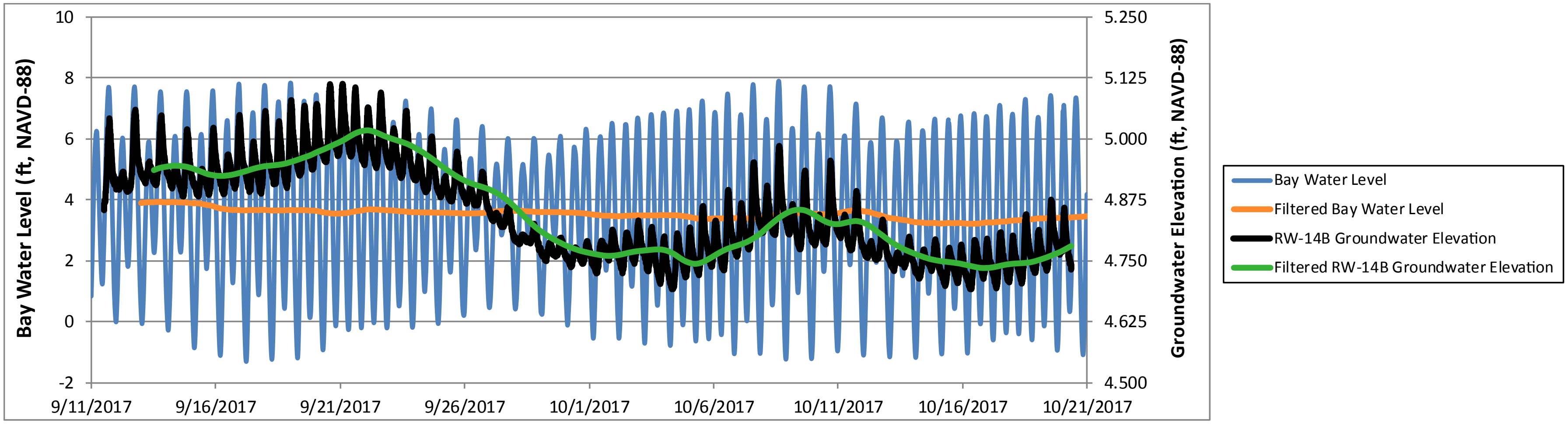
San Mateo Plain Groundwater Subbasin

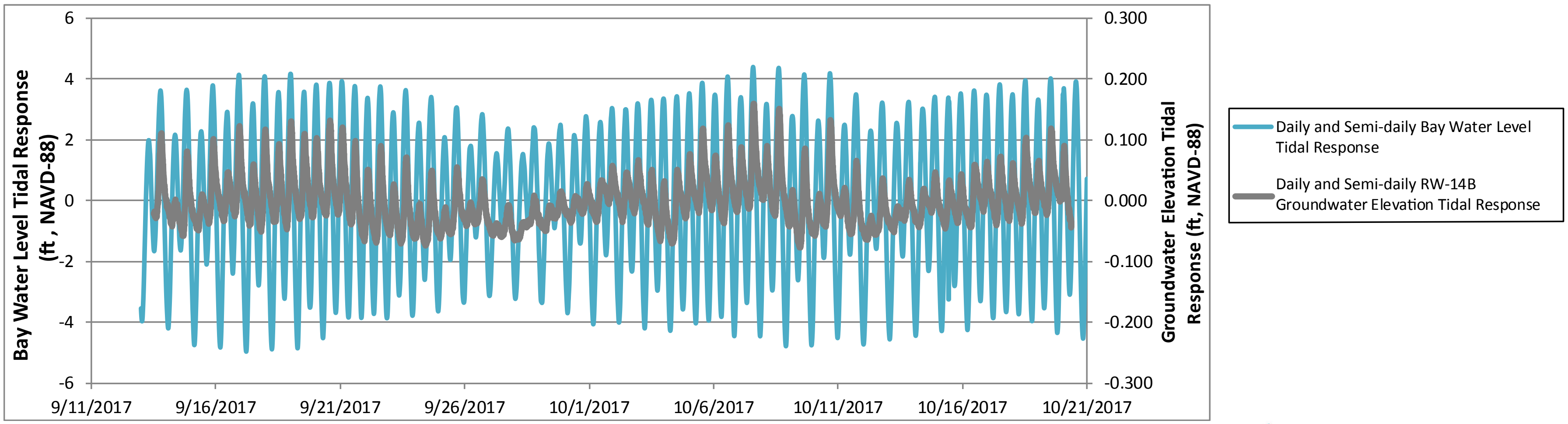
San Mateo County, California

June 2018

EKI B60024.00

Figure 6-35





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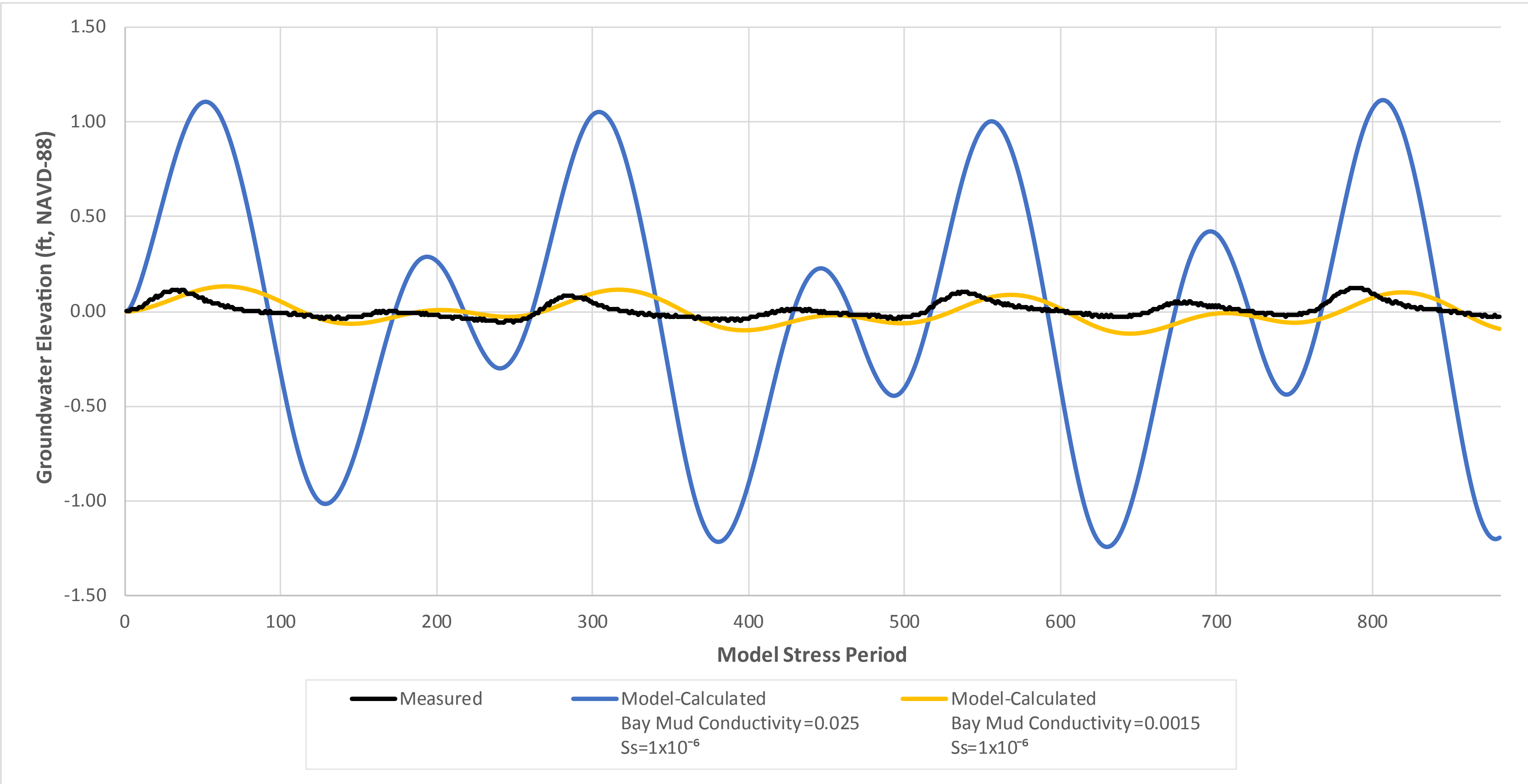
Bay Water Level and RW-14B Groundwater Elevation Data

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-36



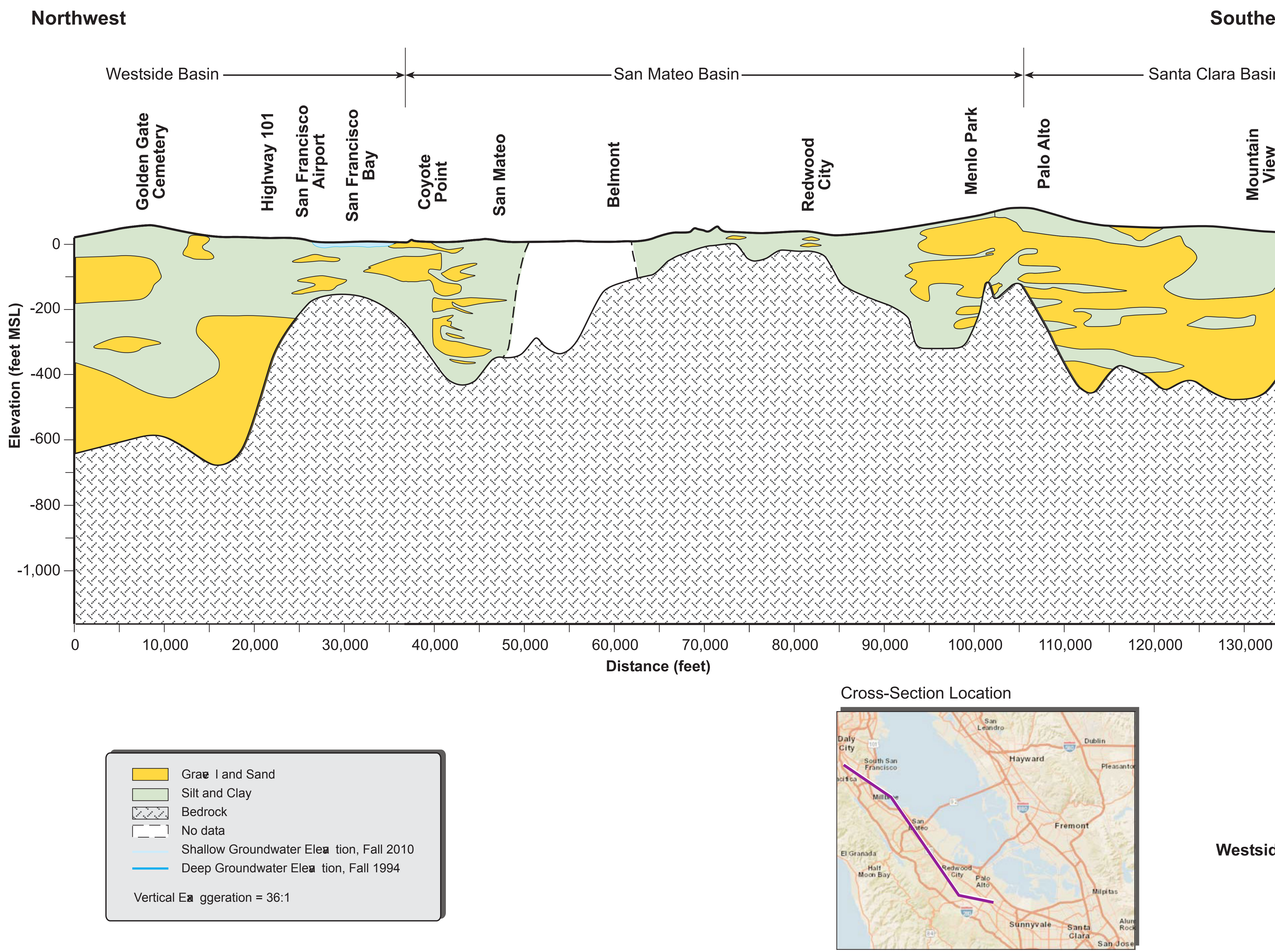
Notes

1. Measured groundwater elevation is the isolated tidal response.

Measured and Model-Calculated Tidal Response

San Mateo Plain Groundwater
Basin San Mateo County, California
June 2018
EKI B60024.00

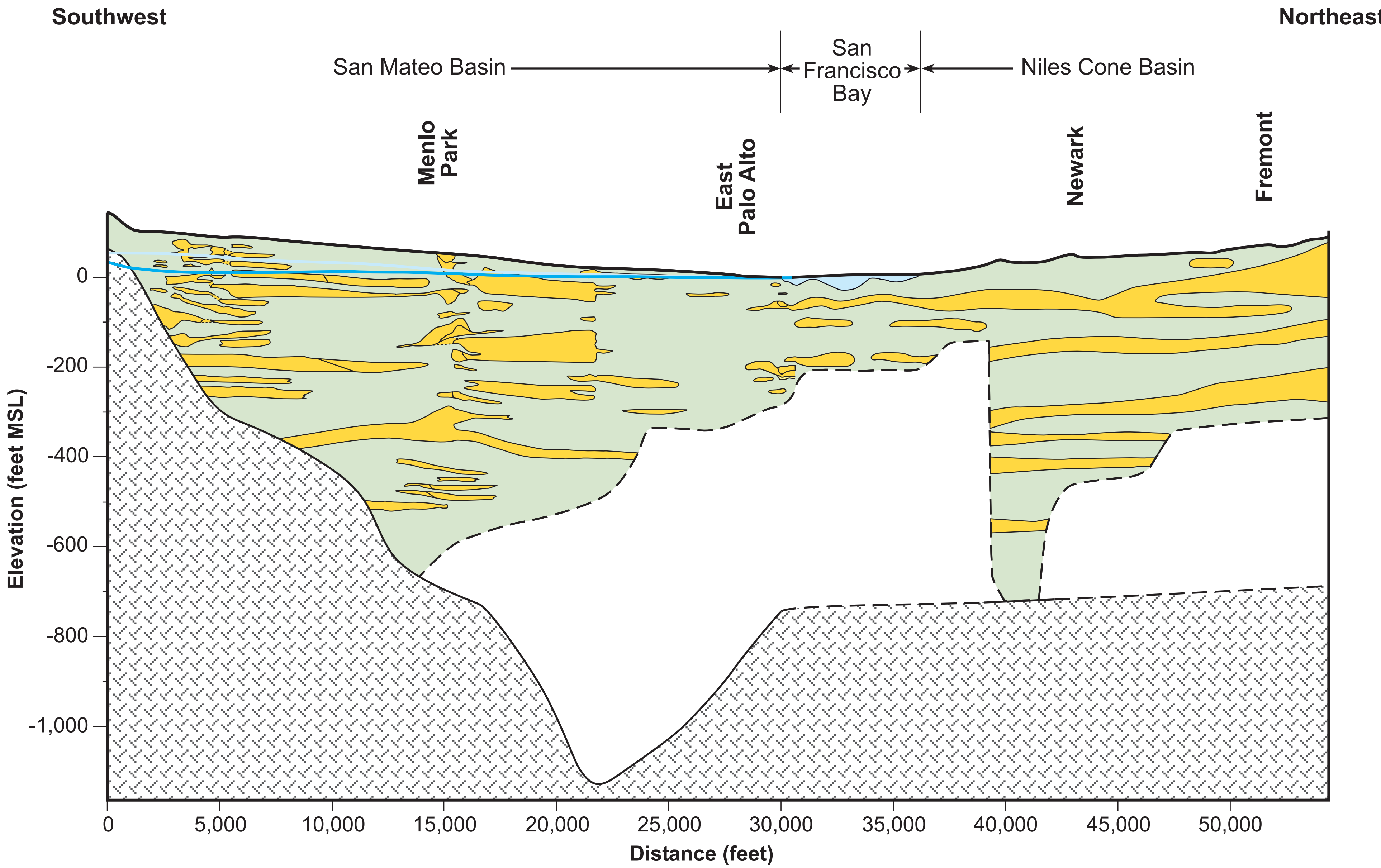
Figure 6-37



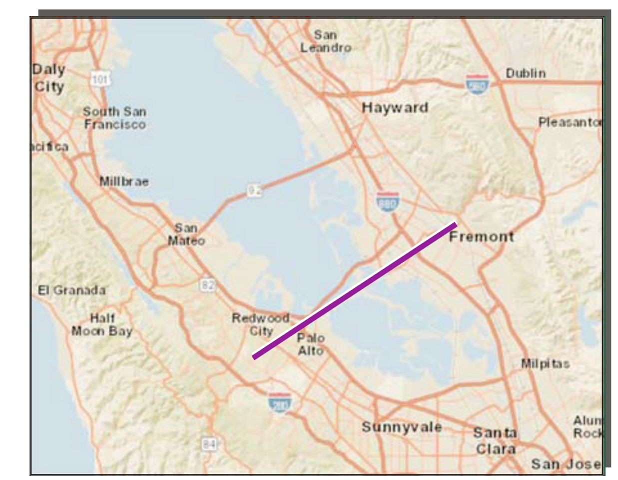
Schematic Cross Section
Westside, San Mateo, Santa Clara Basins

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-38



Cross-Section Location



Grae l and Sand
Silt and Clay
Bedrock
No data
Shallow Groundwater Elea tion, Fall 2010
Deep Groundwater Elea tion, Fall 1994

Vertical Ea ggeration = 20:1

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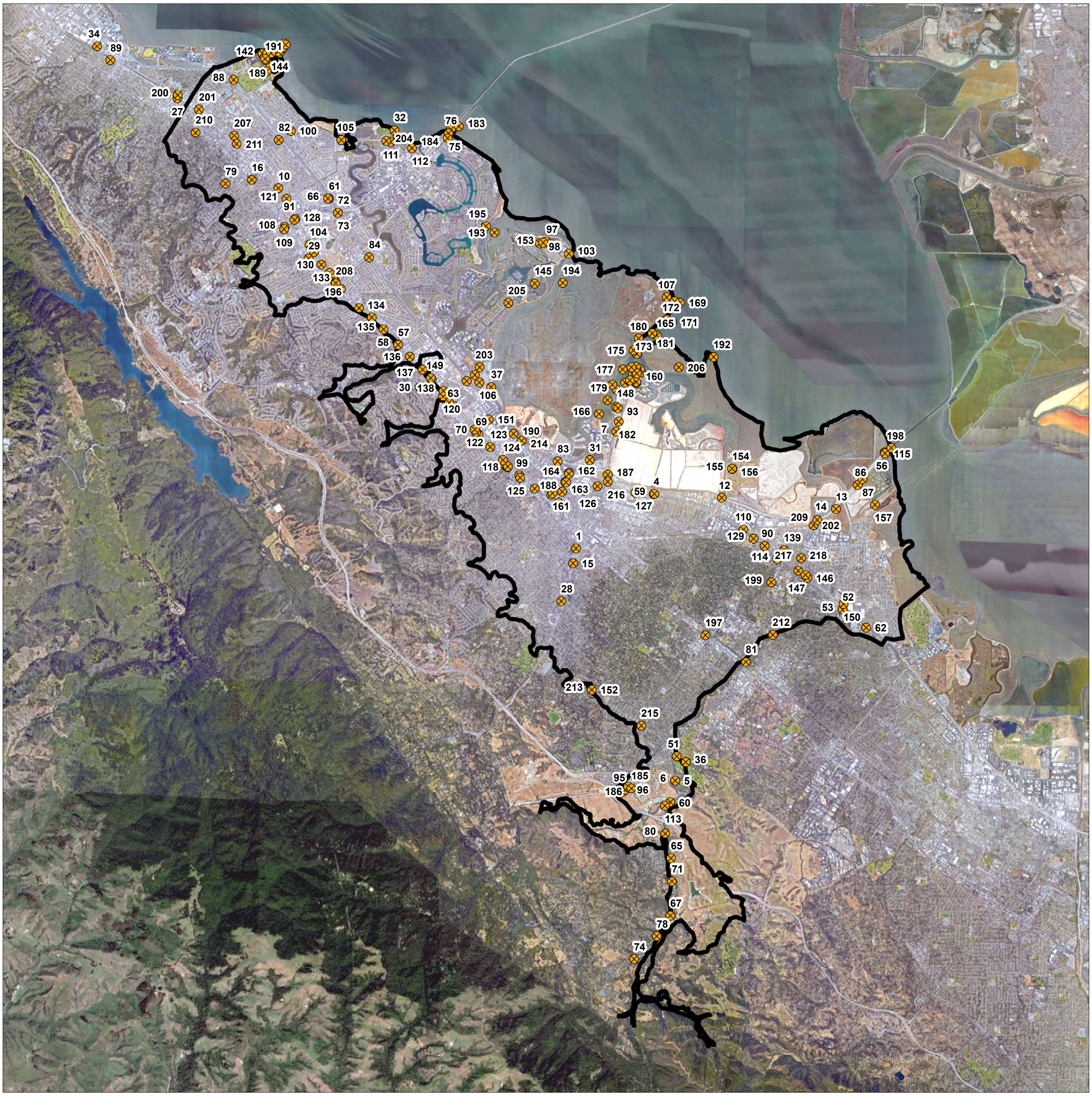
Schematic Cross Section
San Mateo and Niles Cone Basins

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-39



Legend

USGS Benchmark

San Mateo Plain Basin

0 2.5 5

Miles

USGS Benchmark Locations

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 6-40

7.0 BASIN WATER BALANCE

7.1 Methodology

An average annual water balance for the Basin was developed by quantifying individual inflows and outflows reflecting both natural processes and the effects of urbanization. A variety of methods was used to quantify the individual Basin inflows and outflows, as described in the following sections, including use of a recharge simulation model that produced estimates of rainfall recharge, irrigation and irrigation return flow. The recharge simulation model calculated those estimates for numerous small recharge zones and also allocated recharge from pipe leaks to the zones. The details of the recharge zone delineation and hydrologic process simulation are described below, as well as the ways in which this analytical water balance model was coordinated with development of the SMPGWM.[22] Additional documentation is provided in **Appendix B**.

7.1.1 Study Area

The recharge simulation model was applied to the entire watershed area of all streams that cross the Basin in addition to the Basin area itself. This provided the option of estimating stream flow and subsurface flow entering the Basin based on water balance calculations for tributary watershed areas. It also enabled correct accounting for mass balance in water service areas and wastewater sewer areas, many of which extend beyond the Basin boundary into tributary watershed areas.

A total of 377 individual recharge zones were delineated, of which 168 were in the Basin and 209 were in tributary upland watersheds. The zones were delineated by overlaying the geographic distributions of the following factors in GIS:

- *Groundwater basin*. The Basin was divided into four subareas for this variable, as shown on **Figure 7-1**. From the Bay inland, these four subareas are: the tidal marsh areas as of 1873, the portion of the Basin located inland of tidal marshes as of 1873, the upper San

[22] A water balance is also produced as part of the SMPGWM, described in Section 8.0. The two water balances were used to inform each other and were to some extent jointly calibrated. The SMPGWM requires up-front estimates of fixed inflows and outflows that are not affected by groundwater levels (i.e., rainfall recharge, pipe leaks, bedrock inflow, and pumping from wells). The estimates of the flows described in the water balance described in this section were used as inputs into the SMPGWM. Conversely, head-dependent flows—which vary depending on groundwater levels—are best estimated using the SMPGWM. These include: stream percolation where the water table is close to the stream bed elevation; groundwater seepage into sewers, storm drains, and marshes; and groundwater flows across the northern, eastern, and southern Basin boundaries. Estimates of these head-dependent flows were obtained from the SMPGWM and included in the water balance described in this section. In the process of calibrating the SMPGWM, it was found that reducing recharge near the Bay (within a plausible range of uncertainty in the original recharge estimates) improved simulation results.

Francisquito Creek alluvium, and the upland areas in tributary watersheds underlain by bedrock.

- *Watersheds***.** The delineation of watersheds within the Basin is shown on **Figure 6-2**. This variable was used primarily for subtotaling recharge results by watershed.
- *City boundaries*. The boundaries of cities and unincorporated areas are shown on **Figure 2-1**. A small portion (154 acres) of Burlingame extends into the Basin, but was not addressed specifically; hydrologic characteristics were extrapolated from the neighboring City of San Mateo. This variable was used primarily for subtotaling recharge results by city.
- *Water purveyor service areas*. Thirteen water purveyors deliver water to retail customers in the Basin. Their service areas are shown on **Figure 2-2**. Water use data for individual purveyors was used to estimate groundwater recharge from water and sewer pipe leaks and to check the estimate of simulated water use for irrigation. Developed areas not served by one of the purveyors were assigned to a "rural residential" category. Recharge zones within each service area were assigned pipe leak recharge rates based on the area and density of development in the zone relative to the average density for the service area.
- *Wastewater collection areas*. Flow data are available for six of the thirteen sewer service areas shown overlying the Basin on **Figure 2-3**. The three northernmost areas flow to the City of Burlingame and City of San Mateo Wastewater Treatment Plants (WWTPs) while the ten southern areas flow to the SVCW or Palo Alto WWTPs. This map was used primarily for subtotaling recharge results by sewer service area. The majority of wastewater within the Basin flows to either the City of San Mateo or SVCW WWTPs.
- *Land use*. Land use categories and a map of land use relative to hydrologic characteristics (**Figure 6-7**) were discussed in Section 6.1.4.
- *Rainfall*. Some of the recharge zones delineated on the basis of the foregoing variables were quite large and spanned a wide range of annual rainfall. These large zones were divided along rainfall isohyets **(Figure 6-3)** to span a range of no more than two inches per year of average annual rainfall.

Intersecting these variables in GIS resulted in hundreds of small sliver polygons where similar polygon edges among the various layers did not quite match up. Polygons less than about five acres in size were merged with adjoining larger polygons.

7.1.2 Study Period

The primary objective of the water balance task was to develop an estimate of the average annual Basin-wide groundwater balance under current land use and water use conditions. The various sources of data used to develop the water balance have different periods of record and/or monitoring intervals. For some variables, such as bedrock inflow, attempting to develop a historical time series with monthly or even annual time steps would be speculative at best, and long-term average rates were used for all time periods. The recharge simulation model simulates rainfall, interception, runoff, evapotranspiration, irrigation, and deep percolation on a daily basis. The two transient input data sets are rainfall and ET_0. For this study, complete daily time series were developed for water years 1984-2015 by correlation among stations. The 1985-2015 time period was selected because it was a period of long-term average rainfall and included both droughts and wet periods. The cumulative departure plot of annual rainfall at Redwood City shown on **Figure 7-2** indicates three sub-intervals within the simulation period during which average rainfall approximately equaled the long-term average of 18.69 inches: 1984-2011, 1991-2015 and 1997-2013.

7.2 Basin Inflows

The estimated average annual water balance of the Basin under current land and water use conditions is shown in **Table 7-1**, with itemized inflows listed in the top half and outflows in the bottom half. The assumptions, data and calculations used to quantify each flow item are described in the following sections.

7.2.1 Rainfall Percolation

Each recharge zone was divided into three land cover categories expressed as percentages of the total zone area: impervious, irrigated, and non-irrigated. In non-irrigated areas, rainfall is the only source of soil moisture. Rainfall infiltration into the soil was calculated by subtracting interception and runoff losses from rainfall. Interception ranged from 0.00 inch for industrial and vacant areas with little vegetative cover to 0.08 inch for land uses with predominantly tree cover (Maidment, 1993). This loss was applied to each day in which rainfall occurred. Rainfall was extrapolated to individual zones from the Redwood City gauge[23] based on the ratio of average annual rainfall at the zone location to average annual rainfall at the gauge. Runoff was calculated using a stepwise linear function. Runoff was assumed to be zero below a specified threshold of daily rainfall, above which a specified percentage of the additional rainfall was assumed to infiltrate. Infiltration was also capped at a maximum daily amount, with any excess rainfall becoming runoff. Runoff thresholds ranged from 0.2 inch in industrial areas to 0.8 inch on turf areas. For any excess rainfall, infiltration ranged from 70 percent in industrial areas to 92 percent in residential areas. Infiltration was capped at 3 inches per day. The values of these parameters were taken from a similar analysis of recharge in the Santa Clara Subbasin, where a dense network of stream gauges allowed more accurate calibration of recharge parameters (Todd, 2016).

The amount and type of impervious area strongly influence rainfall recharge. Total impervious area can be divided into "connected" and "disconnected" categories, which have opposite effects on rainfall recharge. Impervious areas are "connected" if runoff flows to a storm drainage system consisting of gutters, pipes and concrete channels that remove runoff from the Basin with little

[23] National Oceanic and Atmospheric Administration, Redwood City Station (47339).

opportunity for infiltration. Connected impervious areas decrease groundwater recharge. Impervious areas are "disconnected" if runoff flows to adjacent pervious soils and largely infiltrates. These areas tend to increase groundwater recharge because the runoff is focused into a relatively small pervious area, where the additional infiltration tends to rapidly saturate the soil moisture profile and initiate deep percolation below the root zone. Common examples include patios, walkways, sidewalks, and roof downspouts that discharge to landscaping.

Various methods are available to measure either total or connected impervious percentage of an urban area, each with their own limitations. Several of these methods have been applied to the Basin by others or for this study. The percent total impervious area in 17 San Mateo County watersheds was estimated by the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) (SMCWPPP, 2002) by delineating subareas with specific land uses on aerial photographs and assigning impervious percentages from tables compiled by the Association of Bay Area Governments (ABAG). For some categories, the impervious percentage was obtained by digitizing all impervious surfaces on a single block from high-resolution aerial photographs. The derivation of the ABAG percentages was not discussed, and as with all remote-sensing methods, tree canopy can interfere with the delineation of impervious surfaces. There are also variations among different areas with the same land use and difficulties identifying land use from aerial photographs. This method obtains an estimate of total impervious area.

Spectral analysis of reflected light for each pixel of a satellite image can also be used to estimate impervious area. The National Land Cover Dataset contains the estimated impervious percentage for 30 by 30-meter grid cells covering the entire continental United States (http://www.mrlc.gov/nlcd2011.php). This method produces estimates of total impervious area. The method applies spectral "fingerprints" developed from the statistical distributions of wavelengths in "training" areas. Errors arise from differences in spectral patterns between the training areas and the area of interest, and the method does not detect impervious areas beneath tree canopy (Xian, 2016). For example, total impervious area in residential areas with many mature trees such as Hillsborough and Atherton would tend to be underestimated relative to impervious percentage in other parts of the Basin. Inspection of individual pixel values in the Basin revealed a large degree of variability among adjacent pixels within areas that would be classified as having the same land use; however, averaging over an independently-delineated land use area could provide a reasonable estimate of total impervious area.

Connected and disconnected impervious areas cannot be differentiated using remote sensing methods. The amount of connected impervious area can be estimated if stream flow data are available for rainfall runoff from an urban catchment. In this approach, all runoff during small rain storms is assumed to be from impervious areas, and the volume of runoff for the storm event (usually one to three days using daily data) is compared with the volume of rainfall. There are no suitable stream gauges in the Basin, but several are present in the Santa Clara Subbasin; in addition, the Colma Creek gauge in South San Francisco is suitable. For a groundwater model of the Santa Clara Subbasin, rainfall and runoff for about 20 small storm events were calculated for four urban catchments. Land use within the catchments was delineated from aerial photographs, and the connected impervious percentages for each land use were adjusted by calibration to obtain the best possible match between simulated and gauged runoff across all of the catchments and storm events (Todd, 2016). Those percentages were used as initial estimates for the same land uses in the Basin.

For this study, land uses within the developed part of the Colma Creek watershed were delineated, and the linear relationship between rainfall and runoff for a range of small storm events indicated that connected impervious area covered 68 percent of the developed watershed area. Matching this overall average with percentages by land use (residential, commercial, and vacant) required values much higher than the ones obtained from the Santa Clara Subbasin analysis, for reasons that are not clear.

A significant limitation of the stream gaging method is that it measures only runoff to streams, not runoff to sanitary sewers. In at least one part of the Basin, the sanitary sewer system receives a substantial percentage of impervious area runoff. A flow survey of 36 subareas in the sewer collection area for the San Mateo WWTP found that the percent of rainfall entering the sanitary sewer system ranged from 2 to 88 percent of the rain falling on the entire sewered area—not just the impervious part of the sewered area (West Yost Associates, 2016). The area-weighted average over the entire sewered area was approximately 20 percent of total rainfall. This indicates that the amount of runoff entering the sanitary sewer system was of the same order of magnitude as runoff to streams. Because rainfall inflow reflects the design and age of the sewer system, the results for the San Mateo WWTP do not necessarily apply to other areas of the Basin.

Table 7-2 summarizes the estimates of total and connected impervious area by land use category and lists the values used in the recharge simulation model for this study. Unfortunately, the large disparity among the various estimates provided only minimal guidance for selecting values to use in the simulation program. Where possible, values near the middle of the range of estimates were selected, and logical relationships were imposed, such as increasing percent impervious from rural residential to normal residential to commercial and industrial.

The recharge simulation model simulates soil moisture storage as a "bathtub" with a maximum storage capacity equal to the plant root depth multiplied by the available water capacity of the soil (which is texture-dependent). A range of available water capacity typical of sandy to clay loams (0.11 to 0.19 inch per inch) was assigned to recharge zones based on a partial soils map. Almost the entire Basin is classified as "orthents" or urban soils that are disturbed and for which key physical parameters are not specified in the soil survey. Root depth represented an average over the vegetated area given the estimated mix of plant types and the root distribution beneath and between individual plants. Most urban irrigation is for lawns, for which a root depth of 18 inches was assumed. For non-irrigated vegetation in urban areas a root depth of 72 inches was assumed. For areas of non-irrigated natural vegetation, root depths were assumed to be 48 inches for grassland, 72 inches for brush, and 84 inches for trees.

Water consumed by plant transpiration was simulated by multiplying daily ET_0 by a crop coefficient that reflects the difference in water use between the vegetation and the reference well-watered turf (which defines ET_0). In winter, when rainfall infiltration exceeds evapotranspiration, soil moisture increases. When simulated soil moisture exceeds the soil moisture storage capacity, the excess is assumed to become deep percolation. In tributary watersheds, the deep percolation accrues to shallow groundwater storage that flows laterally and becomes stream base flow. For zones overlying the Basin, all of the deep percolation was assumed to become groundwater recharge. Average annual rainfall recharge on in-Basin non-irrigated lands and from disconnected impervious areas were estimated to be 910 AFY and 1,710 AFY, respectively. Calibration of the SMPGWM was improved by decreasing dispersed recharge by 32 percent overall. Accordingly, the estimate of recharge from impervious runoff was decreased by half to 900 AFY (rounded) to reflect consumption of infiltrated water by plants and runoff from pervious soils during large storm events. This value was subsequently decreased to improve calibration of the recharge simulation model, as discussed below. Rain also contributes to recharge on irrigated lands but is smaller than recharge from deep percolation of applied irrigation water.

7.2.2 Irrigation Deep Percolation

When simulated soil moisture in irrigated areas falls below a specified percentage, the recharge simulation model assumes an irrigation event occurs. Irrigation is assumed to fully replenish soil moisture storage. Because of non-uniformity of application, however, irrigation is not 100 percent efficient. There are losses to mist evaporation, overspray onto impervious surfaces and deep percolation beneath the root zone. Deep percolation results from non-uniform application of water with typical sprinkler layouts. In order to fully replenish soil moisture throughout the irrigated area, some locations will receive more than enough water, and the excess usually becomes deep percolation. Because of the small, irregular shapes of typical irrigation zones in residential and commercial settings, sprinkler overspray and runoff are common. An overall efficiency of 70 percent was assumed for residential and commercial land uses, meaning only 70 percent of the applied water is actually transpired by plants. Studies have found that even lower efficiencies are common (Baum and others, 2005; Xiao and others, 2007; Kumar and others, 2009). One-third of the non-consumed water—or 10 percent of applied water—was assumed to become deep percolation and the remainder to run off. For larger irrigated areas irrigated professionally, an overall efficiency of 80 percent was assumed, with 15 percent becoming deep percolation.

Rainfall recharge is also relatively high in turf areas, partly because the root depth of grass is much shallower than the root depths of shrubs and trees, and partly because the soil is relatively moist at the start of the rainy season (due to prior irrigation). The recharge simulation model estimated total deep percolation of irrigation water and rainfall on the 4,400 irrigated acres in the Basin to be more than 4,000 AFY. This estimate is nearly double the estimate obtained from evaluating seasonal patterns of municipal water use by the curve separation method. In the month of minimum water use (usually February) all water use is assumed to be for indoor use, and irrigation is assumed to be zero. In northern California this assumption is reasonably accurate. Furthermore, indoor use is assumed to be constant in all months, and the additional water use in March through January is assumed to be for irrigation. Applying the curve separation calculations to monthly water use data for the eight water service areas overlying the Basin and assuming that 10 percent of applied water becomes deep percolation produced an estimate of 2,200 AFY of deep percolation. This estimate does not include deep percolation of rainfall on the irrigated soils.

The estimate of 1,800 AFY in the water balance table (**Table 7-1**) reflects a reduction to achieve total inflows equal to total outflows in the SMPGWM. In terms of physical processes, this reduction could plausibly be attributed to two causes. First, many homeowners appear to irrigate at less than the full amount associated with ET_0, as suggested by lawns that appear less than bright green in aerial photographs. Second, neither of the irrigation deep percolation estimates account for roots from trees and shrubs next to lawns that extend beneath the lawn to take advantage of the relatively abundant soil moisture. The amount of deep percolation intercepted by such roots could be substantial.

7.2.3 Water and Sewer Pipe Leaks

Water, sewer, and storm drain pipes in urban areas leak to some extent, creating a source of recharge to the underlying groundwater system. Conversely, sewer and storm drain pipes can gain flow from infiltration of groundwater where the water table is high. Leaks are often small and difficult to detect. Of the three types of pipelines, municipal water distribution systems are typically the most studied and best maintained. Leak rates are relatively high because the pipes are pressurized, but leak detection is relatively aggressive because the leakage can be a significant economic loss and because leak detection is a best management practice for water conservation. One leak detection program audited 47 California water utilities and found an average loss of 10 percent, with a range of 30 percent to less than 5 percent of the total annual flow.[24] Another study monitored water use at numerous individual residences in ten medium to large California water systems using data loggers, and it found an average leak rate of 18 percent of the delivered volume (Aquacraft, 2011). A U.S. Environmental Protection Agency (USEPA) study found that "unaccounted for water" (which includes incidental unmetered uses in addition to leaks) in the range of 10 to 20 percent of total volume delivered is normal (Lahlou, 2001).

Large water purveyors are required to update their Urban Water Management Plans (UWMPs) every five years, and recent updates include breakdowns of unaccounted for water into apparent and real losses. Apparent losses are known unmetered uses of water, such as for fire hydrants and water main flushing. All remaining unaccounted-for water is assumed to be leakage from the distribution system. For nine of the water purveyors in the Basin, estimated distribution system

[24] DWR website http://www.water.ca.gov/wateruseefficiency/leak/ accessed 2 May 2013.

leakage in 2014 ranged from 0.5 to 6.4 percent of delivered water and averaged 3.1 percent.[25] The water system leak rate is expressed as a percentage of flow because of the water-balance approach used to estimate it. However, it is actually independent of flow because the network of pressurized pipes would leak even if all faucets and other outlets were turned off.

Not all water pipe leakage becomes groundwater recharge. Because leaks generate soil moisture year-round at a slow, steady rate, it is very likely that substantial amounts of the water are intercepted by tree roots, where trees are present. While there is uncertainty in this regard, for the water balance analysis, trees were assumed to intercept one-half of the annual leakage, with the remainder becoming groundwater recharge. The estimated average annual groundwater recharge from water pipe leaks in the main part of the Basin during 2005-2014 was 900 AFY. The 2005-2014 time period was used because it reflects the most recent available data and because water pipe leaks are independent from fluctuating climatic conditions.

Sewer pipes also leak, and the volume of leakage was estimated in a two-step process. First, as described above, indoor water use was estimated by curve separation of monthly purveyor water production. Almost all water used indoors leaves the building as wastewater in drains; only about two percent is consumed (Mitchell and others, 2001). Sewer leaks receive less attention than water pipe leaks, and few studies are available in the literature. Because sewer pipes are mostly gravity flow (not pressurized), and leaks probably self-seal to some extent due to clogging by solids and biofilms, the sewer pipe leak rate was assumed to be half the water pipe leak rate. Based on these assumptions, the average annual groundwater recharge from sewer pipe leaks in the main Basin area was estimated to be 300 AFY.

7.2.4 Summary of Dispersed Recharge

The sources of recharge documented in the preceding sections are dispersed, meaning they occur to varying degrees over the entire Basin. **Figure 7-3** shows a map of average annual simulated groundwater recharge during water years 1984-2015 for each of the 377 recharge zones. The entire uplands area west of the Basin is underlain by bedrock. Deep percolation of rain, applied irrigation water and pipe leaks beneath the root zone does occur in the uplands, but that water tends to discharge as baseflow into creeks rather than flow laterally into the Basin. Some inflow probably does occur from areas immediately adjacent to the west edge of the Basin (see Section 7.2.6), but that inflow is treated separately from downward recharge in the Basin.

Based on the analysis described above, most in-Basin recharge zones have values between one and five inches per year of dispersed recharge. Variations correlate primarily with land use. Residential areas have intermediate recharge values (two to three inches per year). Lush residential areas have higher values due to greater deep percolation of applied irrigation water (three to four inches per year). Large areas of turf have still higher values for the same reason—

[25] Including Palo Alto but excluding PAPMWC, O'Connor Tract CWC, and Stanford University, which do not prepare urban water management plans.

mostly four to six inches per year but up to almost twelve inches per year. Commercial and industrial land uses have below-average rates of dispersed recharge due primarily to greater connected impervious area, and less irrigated area. Areas of natural vegetation also have low rates of dispersed recharge because plants are efficient at capturing most rainfall infiltration and because urban sources of recharge such as irrigation and pipe leaks are absent.

During calibration of the SMPGWM, simulated water levels more closely matched measured water levels when dispersed recharge was decreased from the initial estimates, particularly near the Bay. The reductions were within the range of uncertainty for those estimates. However, the estimates of deep percolation through soils and pipe leaks described above and shown in the water balance table are toward the low end of their plausible ranges.

7.2.5 Streamflow Percolation

Percolation losses have been thoroughly studied for San Francisquito Creek but not any of the other creeks that cross the Basin. Metzger (2002) monitored flow in San Francisquito Creek at 13 locations on five occasions during 1996-1997. Percolation was found to be negligible upstream of the Pulgas Fault, which in this water balance analysis forms the boundary between the main part of Basin and the "San Francisquito Creek alluvium" part of the Basin upstream of the fault. The creek consistently lost water to percolation from the Pulgas Fault to Middlefield Road, a distance of 3.3 miles. Below Middlefield Road percolation alternated between slight gains and slight losses. The estimated average annual groundwater recharge from percolation was 1,050 AFY. Stream flow measurements in 2016 and 2017 (described below) were consistent with the Metzger data and indicated that his estimate of average annual recharge remains reasonable. For this water balance analysis, half of the recharge is assumed to accrue to San Mateo County and half to Santa Clara County. In the SMPGWM, a similar amount of recharge was obtained by adjusting the creek bed permeability.

Although historical flow data are available for several other creeks in or near the Basin, there was only one gauge per creek and in all cases the gauge was located upstream of the Basin. Therefore, the flow data do not provide any indication of flow gains or losses along the reach that crosses the Basin. A one-day survey of stream flow at thirteen locations on five creeks was completed for this study on 5 May 2016. Conditions were relatively favorable for measuring flow gains and losses on that day because it was during the period of sustained base flow after the rainy season, but before the irrigation season and the confounding effects of inflow from sprinkler runoff. Repeat measurements were made under similar conditions at some of the locations on 12 June 2017. The flow observations are summarized in **Tables 7-3** and **7-4**. Due to access limitations and flow measurement challenges, flow at five locations could only be estimated visually. With the exception of San Mateo Creek, changes in flow between measurement points along each creek were within the uncertainty range of the flow measurements, indicating no detectable gain or loss of flow. The 0.3 cubic feet per second (cfs) decrease in flow along San Mateo Creek is probably greater than the measurement uncertainty. If that loss rate was sustained year-round, it would amount to 217 AFY of groundwater recharge. However, the increase in electrical conductivity between Crystal Springs Road and Gateway Park indicates that other sources of water entered the creek, so that the intervening reach was not entirely losing. At Crystal Springs Road most of the flow consisted of water imported by SFPUC released from Crystal Springs Reservoir, as indicated by the low specific conductance of 337 microsiemens per centimeter (µS/cm). Specific conductance measurements of the other creeks were consistently much higher, averaging about 1,200 µS/cm. The additional dissolved minerals could derive from local groundwater seepage, urban runoff, or a combination of both. The increase in conductance along San Mateo Creek to 680 µS/cm at Gateway Park suggests that 40 percent of the water at Gateway Park derived from groundwater inflow and/or local runoff below Crystal Springs Road.

Stream flow measurements were repeated at some of the locations on June 12, 2017, plus measurements along San Francisquito Creek and Matadero Creek in northern Santa Clara County (**Table 7-4**). Evaluating the measured flow losses along unlined creek reaches indicated that a percolation capacity of 0.3 cfs per mile was typical for small streams. For each stream, total percolation capacity equaled the per-mile capacity multiplied by the length of unlined channel. Daily unrestricted percolation was estimated as the smaller of daily stream flow and total percolation capacity. Daily flows for each stream were estimated by correlation with Redwood Creek (period of record 1960-1997) and Sharon Creek (period of record 1959-1969), based on drainage area ratio. Given current conditions of generally high groundwater levels, half of the unrestricted potential recharge was assumed to be rejected. The resulting estimates of average annual creek recharge under current groundwater conditions are 200 AFY for San Mateo Creek and 500 AFY for all other small creeks in the Basin, combined.

In order to provide additional information regarding possible groundwater-surface water exchange, stable isotopes of oxygen (oxygen-18) and hydrogen (deuterium) were sampled in San Mateo, Cordilleras, and Redwood Creeks in June 2017. Water often develops isotopic compositions (ratios of heavy to light isotopes) unique to its original source. The delta of an isotope is a measure of the ratio of stable “heavy” to “light” isotopes, and can be used to determine water’s unique isotopic signature. **Figure 7-4** is a plot of delta deuterium versus delta oxygen-18 showing the 2017 data along with data from nearby sites collected in 1997 by Metzger (2002). The point near the lower-left corner of the plot is isotopically “light” and is from a sample of local water supplies that originate from high-elevation areas in the Sierra Nevada Mountains. Data points near the upper right end of the plot are isotopically “heavy” and are from San Francisquito Creek. Those samples originate entirely from local rainfall. Groundwater samples from various depths in the San Francisquito Cone area are spread out between those end members, which reflects mixing of local and imported waters. Deep groundwater sample plots closest to the San Francisquito Creek samples, whereas the shallow groundwater sample data points plot farther down the meteoric water line toward imported water. This logically reflects greater mixing of local rainfall recharge with imported-water recharge (from leaking pipes and irrigation return flow) at shallow depths within the Basin. The creek samples from 2017 were slightly lighter than the samples from small creeks sampled in 1997 but similar to shallow groundwater samples from 1997. This suggests that base flow in the three creeks sampled in 2017 derives at least partly from shallow groundwater. The shift toward a heavier composition from the upstream site on Redwood Creek to the downstream site could reflect groundwater inflow, but it might reflect other local variations that cannot be statistically characterized with only two data points. There was very little difference in isotopic composition between the upstream and downstream points on San Mateo Creek, consistent with the negligible change in flow between those locations.

7.2.6 Subsurface Inflow

Subsurface groundwater inflow is theoretically possible along the north, east, south, and west sides of the Basin.

7.2.6.1 Northern Boundary

The northern boundary is located in an area of relatively shallow bedrock and little pumping on either side of the boundary line. Water level gradients in that area are from the mountains toward the Bay, parallel to the boundary line. Thus, groundwater flow across the boundary is presently close to zero. However, a change in pumping on either side could initiate flow in one direction or the other. The SMPGWM indicated an outflow of 100 AFY in a steady-state simulation of 1987-1995, and that value is used in the water balance table.

7.2.6.2 Southern Boundary

Like the northern boundary, the southern boundary could allow groundwater flow into or out of the Basin, depending on the intensity of pumping on either side. The best available estimate of groundwater flow across the Basin boundary beneath San Francisquito Creek comes from the SMPGWM, which accounts for variations in hydraulic conductivity and dynamically fluctuating water level gradients by depth and location along the boundary.

The calibrated SMPGWM indicates an average northward flow of 1,200 AFY. Much of this appears to be related to a pumping trough associated with the O'Connor Tract CWC and PAPMWC wells. It would be expected that up to perhaps half of the 848 AFY pumped by those users would arrive as northward flow beneath the San Francisquito Creek.

7.2.6.3 Eastern Boundary

The eastern boundary of the Basin water balance area is San Francisco Bay. Shallow and deep groundwater level contours (see **Figures 6-23** through **6-28**) and the water balance analysis indicate that flow is presently from the Basin to and/or beneath the Bay. However, increased groundwater pumping could reverse the direction of flow across this boundary and thereby initiate seawater intrusion or increased outflow from the Niles Cone Subbasin. Because flow is presently toward the Bay, this boundary is discussed in greater detail in Section 6.2.7.2.

7.2.6.4 Western Boundary

The western boundary of the Basin is the contact between the unconsolidated alluvial deposits in the Basin and fractured bedrock of the Franciscan Formation. Inflow to the Basin through bedrock fractures is possible, and two methods were used to roughly estimate the magnitude of that flow. The first method evaluated base flow in creeks that drain the bedrock area. If the volume and duration of base flow in a stream are high, it can be inferred that the bedrock in the watershed is highly fractured with substantial storage and permeability. Those same characteristics would promote subsurface inflow to the adjacent Basin. Conversely, low base flow volume and persistence indicate low storativity and permeability, and hence relatively low bedrock inflow to the Basin. The USGS operated stream gauges at various times on four local creeks whose watersheds drain only bedrock areas east of the San Andreas Fault: Redwood Creek, Sharon Creek (a tributary to Atherton Channel), Los Trancos Creek (a tributary to San Francisquito Creek) and Matadero Creek. Matadero Creek is in northern Santa Clara County and drains to the Santa Clara Subbasin, but the geologic and watershed-basin relationships are the same as for the creeks in San Mateo County. Hydrographs showing daily flows for five-year periods for each of those gauges are shown on **Figure 7-5**. The scale is cropped to show only flows less than 14 cfs. In all four watersheds, there is little base flow. Sustained flows greater than 1 cfs occur only during wet-weather periods and probably result from shallow subsurface flow through soils and weathered bedrock rather than flow through deep bedrock fractures. All of the creeks dry up fairly quickly after the rainy season ends. These base flow patterns indicate low bedrock storativity and permeability and imply that subsurface inflow to the Basin from bedrock uplands is small.

The second approach was to tabulate recharge over upland areas immediately adjacent to the Basin where groundwater gradients in the soil and weathered bedrock zone were estimated to be directly toward the Basin rather than toward a creek channel in the uplands. Recharge zones fitting this description with a combined area of 9,100 acres were identified. Simulated average annual groundwater recharge in those zones was about 600 AFY. This corresponds to about seven percent of total Basin recharge and is consistent with the baseflow data and associated inference that bedrock inflow is relatively small.

7.3 Basin Outflows

7.3.1 Groundwater Supply Pumping

Groundwater use for water supply in the Basin can be divided into three categories: public supply, irrigation, and domestic. A summary of water supply pumping is shown in **Table 7-5**. Currently, use of groundwater for public supply is limited to PAPMWC and O'Connor Tract CWC, which are two adjoining small community water systems near the border between Menlo Park and East Palo Alto (see **Figure 2-2**). As shown in the table, they are the largest and third-largest individual groundwater users and their combined annual groundwater production averages about 848 AFY. The remaining 12 rows in the upper part of the table identify individual institutional users whose use of groundwater for irrigation was confirmed by telephone or a site visit or was assumed to be ongoing. The combined production of the individual institutional users was estimated to total 741 AFY. These users were identified in previous studies (Wood, 1975; Metzger and Fio, 1997; Todd Engineers and others, 2012), but the water use estimates were revised for this study based on irrigated area measured from high-resolution aerial photographs and simulated annual applied irrigation water of 33.4 in/yr. Note that one institutional user cited in previous reports (U.S. Veterans Administration) was visited in 2017, and their wells have reportedly been inactive for years.

The lower half of the table includes estimates of groundwater use for several groups of users, mostly private irrigation wells in Hillsborough, Atherton, and nearby areas. Except for wells drilled since 1995, the user group wells and their estimated combined production of 736 AFY were taken from previous studies (Metzger and Fio, 1997; HydroFocus, Inc., 2011).

Groundwater use for potable supply at private residences is probably negligible. Available well records include only 55 wells with "domestic" as the stated use. Half of them were drilled prior to 1965, and use was likely discontinued when imported water supplies became available in the mid-1960s. Twenty-six were drilled during the 1976-1977 and 1987-1992 droughts, and another fourteen had no date. The surge in drilling activity during droughts suggests that these wells were actually for irrigation rather than potable use. Assuming that wells drilled prior to 1995 were included in the irrigation pumping estimates for the Atherton-Menlo Park area by Metzger and Fio (1997), then only the 29 wells drilled since 1995 would represent new use. Assuming those wells produced the same amount of water per well as residential irrigation wells, their production would total 55 AFY. In the table, this pumping is included in the amount for Atherton area residential irrigation wells.

Overall, groundwater production for use as water supply totals an estimated 2,300 AFY under current land use and water supply conditions.

7.3.2 Groundwater Remediation System Pumping

The San Francisco Regional Water Quality Control Board (RWQCB) issues permits to discharge treated groundwater that is pumped from groundwater contamination sites. Discharges are typically to storm drains and are permitted pursuant to the National Pollutant Discharge Elimination System (NPDES). The RWQCB conducted a search of its groundwater cleanup permit databases for NPDES/waiver permitted pump-and-treat discharges. The search found twenty-one Volatile Organic Compound (VOC)/Fuel General Permits and three Groundwater General Permits issued in the Basin, mostly subsequent to 2012 when electronic record keeping was implemented. Discharge rates or volumes were compiled from Self-Monitoring Reports, Authorization to Discharge letters and Rescission of Authorization to Discharge letters. It appears that sixteen of these permits were issued for construction dewatering that typically lasted less than one year. Pumping rates or volumes were not listed for seven permits. One permit is for long-term dewatering of a parking garage in Redwood City, where 43,301,000 gallons of treated water were pumped during 2015 and discharged to the storm sewer. For nine sites with records of groundwater production during 2014 to mid-2016, the total volume produced was 374 AF, or 150 AFY.

7.3.3 Dewatering Pumping

The RWQCB also issues NPDES permits for discharges of uncontaminated groundwater pumped for dewatering of construction sites or underground structures. Only discharges greater than 10,000 gallons per day (11.2 AFY) require a permit. RWQCB staff searched their database and found no active permits for this type of discharge within the Basin.

In some cases, dewatering water is discharged to the sanitary sewer system, in which case San Mateo County issues a permit. A search of records for 2011-2016 found eighteen permits, of which six involved groundwater (the others were mostly for draining swimming pools). The total reported discharge of groundwater was 1.2 AF, corresponding to an average annual rate of 0.3 AFY.

The amount of dewatering pumping is almost certainly larger than these records indicate. In the City of Palo Alto—where dewatering pumping is regulated by permit—pumping totaled 783 AF in 2016. The shallow water table conditions that necessitate dewatering in Palo Alto probably extend northward along most of the San Mateo Bay Plain. An estimate of dewatering pumping for the Basin was obtained from the SMPGWM, which included “drain” cells to remove groundwater close to the ground surface. That discharge is combined with discharge to tidal wetlands in the water table, and they total an estimated 3,200 AFY.

7.3.4 Use of Groundwater by Riparian and Wetland Vegetation

Some natural stream channels in the Basin have a corridor of large trees along both banks. Where the water table is within 10 to 15 feet of the ground surface, some trees (phreatophytes) can grow roots to the water table and use groundwater directly. Where the water table is too deep to reach but the stream has flow during the dry season, the trees can intercept stream percolation that would otherwise become groundwater recharge, with the same effect on the water balance as extracting water from the water table. Use of groundwater by riparian trees was estimated by measuring the area of tree canopy and estimating the amount of transpiration that is supplied by groundwater rather than rainfall. **Table 7-6** lists the length and average canopy width of corridors of trees along stream channels, as identified on aerial photographs. There is a total of 56 acres of riparian tree canopy in the Basin, counting only the north bank of San Francisquito Creek, consistent with the treatment of percolation from that waterway.

Consumptive use of groundwater was estimated by simulating a hypothetical riparian forest zone using the recharge simulation model. The zone was simulated as completely non-irrigated during 1984-2015 then re-simulated as completely irrigated. The difference in simulated actual evapotranspiration equals the amount of groundwater consumed (the water table serving as the source of “irrigation” in the simulation). Consumptive use of groundwater by this method averaged 24.6 in/yr, or 114 AFY over the entire area of riparian vegetation.

This estimate is probably high because some of the riparian trees probably do not receive all of the water they could use, either because the water table is too deep or stream flow and percolation taper off too much during the dry season. Also, some stream flow in summer derives from irrigation overspray and other human activities in the surrounding urban areas that result in potable supply water flowing to storm drains. To the extent the trees are using this source of water, their use of groundwater is overestimated. In any case, the magnitude of groundwater use by riparian vegetation is clearly small in the overall context of the Basin water balance, and a round estimate of 100 AFY is used in the water balance calculations.

The only wetlands of significant size in the Basin are the tidal wetlands along the Bay shore. The evapotranspiration needs of tidal marsh vegetation are assumed to be met by Bay water or by subsurface groundwater discharge to the Bay, which is accounted for separately in the water balance.

7.3.5 Groundwater Seepage

Groundwater in the Basin generally flows east, and if it is not intercepted by wells it leaves the Basin by seeping into sewers, creeks, tidal marshes, and San Francisco Bay. Additionally, some of the eastward flow could continue via the subsurface to the Niles Cone area. Few data are available to partition groundwater outflow among these flow paths. The approach used here combines independent estimates and flows calculated by the SMPGWM. Groundwater seepage into sewers and groundwater consumed by riparian vegetation were estimated directly from data. Groundwater seepage into the lower reaches of creeks, tidal wetlands and the Bay were taken from the SMPGWM (see Section 8.0)

Groundwater can infiltrate into sewer pipes when the water table is higher than the pipe. Sewer pipes are commonly about six feet below the ground surface. Metered daily inflows to the San Mateo WWTP and six sub-catchments that enter the SVCW WWTP were evaluated for seasonal trends that might indicate the occurrence of groundwater infiltration. In four of the seven metered catchments, small gradual declines in sewer flow occur from spring to fall. This pattern would not result from seasonal changes in water use or from infiltration of Bay water, and it is the pattern that would be expected for gradual dry-season declines in water table elevation. Hydrographs of daily inflows for the four sewer systems where declines were evident are shown on **Figure 7-6**. Annual groundwater infiltration was estimated in three steps. First, groundwater infiltration during April-November was estimated to equal the amount of flow that exceeded the minimum flow during that period, which was 814 AFY for the four service areas. Second, that estimate was increased by one-third to represent infiltration during the remaining four months of the year, during which groundwater levels are on average at least as high as during the dry season. Finally, the resulting annual estimate was increased by 20 percent to better match the estimate obtained from the head-dependent drain boundary in the SMPGWM. The increase could plausibly represent groundwater inflow still occurring at the end of the dry season (and hence also year-round) and possibly also groundwater inflow to sewer collection areas for which daily flow data are not available. The resulting estimate of groundwater seepage into sewers was 1,300 AFY. This was adjusted within the reasonable estimate range to 1,400 AFY in the water balance table to match the value in the SMPGWM.

Groundwater can also seep into creeks where their channels approach San Francisco Bay and the water table is close to the ground surface. Data are not available to detect these gains in stream flow because gauges have not ever been installed close to the Bay and because low-flow measurements are difficult due to tidal backwater and/or shallow flow depths on the flat bottoms of the concrete engineered channels. However, gauges located near the downstream ends of several large streams that cross the Santa Clara Subbasin confirmed that flows are substantially larger than at gauges farther upstream in the mid-basin area (Todd, 2016).

Water follows the path of least resistance, and longer groundwater flow paths generally have greater cumulative flow resistance than shorter ones. For that reason, it would be expected that groundwater seepage into creeks would be greater than into the tidal marshes, which would be greater than into the Bay. Results from the groundwater flow model confirm this pattern. Simulated seepage into creeks and tidal wetlands (2,200 AFY) is more than four times larger than simulated seepage into the bottom of the Bay (500 AFY).

7.3.6 Subsurface Outflow

The only onshore Basin boundary with net outflow is the northern boundary. The amount simulated by the SMPGWM is used in this water balance (200 AFY).

7.4 Change in Storage

Groundwater pumping in recent decades has been less than recharge and less than historical pumping. Under these conditions, it is reasonable to assume that the long-term change in storage is zero. Additional recharge during wet periods subsequently drains to creeks and the Bay, and decreased recharge during dry periods are counterbalanced by decreased outflows and greater retention of rainfall recharge when wetter conditions first resume. The assumption of zero net long-term change in storage is somewhat corroborated by available water-level data. Only a few wells have long-term records, but many of those show fairly flat long-term trends (see **Figures 6-31** through **6-34**). In half of the shallow wells, seasonal water-level fluctuations are one to two feet, versus five to ten feet in the other half. The hydrographs with larger seasonal fluctuations also had larger multi-year variations (three to ten feet versus two feet). The wells with larger fluctuations could be in areas with a small specific yield or could be influenced by nearby pumping wells. Seasonal fluctuations would be expected even under pre-development conditions because of the seasonality of recharge: almost all recharge occurred in winter, and the summer dry season was dominated by discharge to creeks, riparian evapotranspiration, and San Francisco Bay. Recharge is somewhat less seasonal in urbanized basins because pipe leaks are constant year-round and recharge from applied irrigation water occurs in summer, whereas rainfall and stream recharge occur in winter.

In terms of volume, fluctuations in storage are greatest near the water table, where pores between grains of sediment fill and drain as water levels rise and fall. Because of the predominantly fine-grained texture of Basin sediments, the average specific yield might be on the order of 0.10. A seasonal or multi-year water-table fluctuation of two feet over the non-tidal-marsh part of the Basin would correspond to a storage change of 3,500 acre-feet (AF).

7.5 Overview of Current Water Balance

Inflows and outflows to the Basin average about 7,900 AFY under current land and water use conditions (see **Table 7-1**). The largest sources of recharge are deep percolation of rain and applied irrigation water in irrigated areas (22 percent), deep percolation of rain in non-irrigated areas (22 percent), percolation from creeks (17 percent), and water pipe leaks (12 percent). These proportions reflect several significant effects of urbanization: pipe leaks, irrigation deep percolation, and conversion of creeks to cement-lined, engineered channels.

The largest outflows are groundwater seepage to creeks and tidal wetlands (30 percent), groundwater pumping for water supply (29 percent), groundwater infiltration into sewers (17 percent), and dewatering pumping (12 percent). The balance between total inflows and total outflows reflects an assumption that there is no long-term change in storage.

The large amount of groundwater seepage and outflow (4,300 AFY, or about 1.3 times the current amount of groundwater pumping) indicates that there is available yield to support increased pumping. However, it is likely not possible to capture all current subsurface outflow without incurring undesirable results such as land subsidence, seawater intrusion, or reduction in aquatic or riparian habitat. Avoiding those impacts will require maintaining water levels above subsidence thresholds, subsurface outflow at rates sufficient to minimize inflows of salt water from the Bay or salt ponds, and groundwater-supported base flow in creeks sufficient to support sensitive aquatic or riparian habitat.

The water balance table (**Table 7-1**) is for the main Basin area, excluding the extension of alluvium beneath San Francisquito Creek westward into the uplands area. The San Francisquito Creek alluvium part of the Basin has an area of 2,000 acres, almost all of which is covered by natural grassland. Rainfall recharge in that part of the Basin averages about 140 AFY, but most recharge is from stream percolation. In most years, winter percolation from San Francisquito Creek probably fills the underlying alluvium to a level in equilibrium with the creek elevation. During the dry season, some of the alluvial groundwater drains down the valley to the main part of the Basin. The Pulgas Fault crosses the creek at the western edge of the main Basin area and forces much of the alluvial groundwater flow into the creek (Metzger 2002). For the purposes of this study, it is assumed that baseflow recorded at the USGS gauge near that location (about 850 AFY) represents all groundwater outflow from the uplands alluvial part of the Basin to the main basin area. It contributes to stream percolation downstream of the fault, which is where it appears in the water balance table.

7.6 Water Balance Uncertainty and Variability

7.6.1 Uncertainty

Each of the values in the average annual water balance is an estimate subject to some uncertainty. A plausible range of values for each item was developed based on sensitivity analysis of the recharge simulation model, the variability of values in some data sets, and professional judgment (see **Table 7-1**). The estimated percolation of runoff from impervious surfaces onto adjacent pervious soils is quite sensitive to the estimate of disconnected impervious area. The upper end of the range of uncertainty corresponds to a doubling of disconnected impervious area in the major urban land use categories from 5 to 10 percent of overall zone area. Simulated deep percolation of rainfall in non-irrigated areas is especially sensitive to the average root depth of vegetation. Decreasing the average from 36 to 24 inches almost doubled the amount of rainfall recharge. Recharge in irrigated areas is proportional to the amount of irrigated area, which might be 20 percent greater or smaller than the original estimate. It is also very sensitive to the assumed irrigation efficiency—specifically, the part of the "inefficient" fraction that becomes deep percolation past the root zone. Increasing that fraction from 10 to 20 percent of applied water increased estimated recharge by about two-thirds. The methods used by water purveyors to estimate the overall leak rate from their distribution system is subject to metering errors and uncertainty in estimating other non-metered losses. Also, the fraction of leaked water that is intercepted by vegetation is speculative, as is the leak rate from sewer systems. The original estimates were conservatively small with respect to most of those variables; the true values are more likely larger than smaller than those estimates. For example, increasing the water pipe leak rate by two percent of delivered water for all purveyors and retaining the assumption that sewer leak rates are half as large as water pipe leak rates slightly more than doubled the estimates of groundwater recharge from those two sources.

Uncertainty in estimated recharge from San Francisquito Creek percolation is associated with the extrapolation from streamflow measured on a few dates to average annual loss rates in the original USGS study (Metzger, 2002). The plausible range of values shown in the table corresponds to a +/- 30 percent uncertainty in the average annual percolation rate. Assuming that creek recharge is split 35:65 percent between San Mateo and Santa Clara Counties instead of 50:50 percent produces the same plausible range of recharge values. For San Mateo Creek, major sources of uncertainty are possible flow measurement errors during 2016 and 2017 field surveys (perhaps +/- 20 percent) and the assumption that percolations losses throughout the year are the same as they are in May-June. It is likely that percolation losses are higher in summer and early winter when groundwater levels are lower due to pumping and/or natural seasonal recession. Percolation from the other creeks is even more uncertain due to a lack of good low-flow data. Even concrete-lined channels could gain or lose more than 0.1 cfs over a mile or two through cracks. The plausible ranges of stream recharge correspond to an uncertainty of +/- 50 percent.

Subsurface inflow from bedrock uplands is certainly greater than zero, and an upper end of the plausible range was obtained by doubling the area of uplands from which groundwater is assumed to flow directly into the Basin rather than to an upland creek channel. Seawater intrusion is almost certainly zero at present, given the prevailing eastward gradients in groundwater levels.

The upper end of the plausible range of groundwater pumping for water supply assumes that the inventory of pumping overlooked two fairly large institutional users and 100 residential irrigation wells. The low end reflects the possibility that one or two institutions and numerous residential wells thought to be active are actually inactive. It is unlikely that remediation wells would be present that are not included in the RWQCB database because of the need for discharge permits. However, some of the wells in the database might have operated for less time than originally assumed. There is a large uncertainty in the amount of dewatering pumping. It is plausible that numerous below-grade structures in shallow water table areas have sump pumps for which permits were not obtained. For example, 200 structures discharging an average of 3 gpm would pump over 900 AFY of groundwater. Thus, the estimate produced by the drain function in the SMPGWM appears to be of a reasonable order of magnitude. The estimate of riparian vegetation ET is more likely to be high than low because some of the mapped trees might not have roots that reach the water table all or some of the time. Annual ET could plausibly be half the amount listed in the table. The estimate of subsurface inflow from Santa Clara County obtained from the SMPGWM is subject to uncertainties related to aquifer characteristics and model calibration. Measured water levels indicate that groundwater flow is generally parallel to the creek, but water crosses from Santa Clara County to San Mateo County where the creek bends to the south and near the PAPMWC and O'Connor Tract CWC production wells.

The uncertainty in the overall Basin water balance is speculative. The high end of the plausible range does not equal the sum of the high ends of the individual item ranges because those estimates are all independent and the probability that all errors are simultaneously high is vanishingly small. Based on the plausible ranges for most items, a reasonable estimate of overall uncertainty would be +/- 30 percent.

7.6.2 Variability

The water balance presented in **Table 7-1** represents annual flows under land and water use conditions of the past decade and averaged over a series of years when average rainfall equaled the long-term average. Some water balance items remain relatively constant from year to year, including pipe leaks, deep percolation of applied irrigation water, subsurface inflow from bedrock uplands, groundwater pumping, and evapotranspiration by riparian vegetation. Other items depend on current-year rainfall and vary substantially from year to year, including rainfall recharge, percolation from streams, and subsurface outflow to creeks and the Bay. In dry years, rainfall recharge can be close to zero; all infiltrated rainfall is retained in the root zone and later transpired by plants. The duration of stream flow is also much less in dry years, reducing the opportunity for percolation. An exception is San Mateo Creek, where low flows consist largely of water released from Crystal Springs Reservoir according to a prescribed schedule. For planning purposes, it would be reasonable to assume that in a dry year rainfall recharge is zero and percolation from streams other than San Mateo Creek is only twenty-five percent of the average annual value. This would reduce total inflow to about 5,100 AFY.

The decrease in inflow during a dry year is balanced by temporary decreases in subsurface outflow and groundwater storage. The amount by which each of those items responds to the decrease in inflow depends partly on hydrogeology and the location of decreased inflow. For planning purposes, it is reasonable to assume that half of the decrease in inflow would be absorbed by a decrease in storage and the other half would be absorbed by decreases in groundwater outflow (by a uniform percentage for all outflows). Thus, groundwater storage might decrease by 1,400 AFY, and subsurface outflows to sewers, creeks and wetlands, and San Francisco Bay might decrease by 500 AFY, 860 AFY and 180 AFY, respectively.

During wet periods, rainfall recharge and stream percolation would be above average, which would replenish the temporary decrease in groundwater storage and restore subsurface outflows to their former values. A sequence of wet years would temporarily boost all of those items to above-average values.

7.7 Historical Water Balances

Groundwater pumping in the Basin is presently much less than it was in the past. Although domestic water supply wells were present throughout the Basin, most pumping was in the San Francisquito Creek Cone area at the south end of the Basin (see **Figure 6-1)**. The general history of pumping began with negligible amounts prior to 1850, increasing with population growth and development to around 7,500 AFY in the San Francisquito Cone area in the 1960s, after which most users switched to newly available imported water supplies. As of 1913, groundwater pumping was small enough that flowing wells were still present at several locations along the edge of the tidal marsh part of the Basin (Clark, 1924). A map of the Burlingame-San Carlos area included in that report showed 26 wells, all but two of which were within 0.5 mile of El Camino Real. A map of the Redwood City-Palo Alto area showed 41 wells north of San Francisquito Creek. Groundwater levels measured in 1915 were 10 to 60 feet msl throughout the San Francisquito Cone. However, rapid groundwater development for agricultural and urban uses ensued shortly thereafter, and total groundwater production from the San Francisquito Cone reached 6,000 AFY by the mid-1920s (Lee, 1924-1926). As a result of increased pumping and below-average rainfall, groundwater levels decreased by an average of 10 feet per year during 1923-1926 in many parts of the San Francisquito Cone. Static water levels reached 25 to 40 feet below msl, pumping levels were as much as 90 feet below msl, and wells near the western edge remained dry for several years (Lee, 1924-1926). The pumping tabulations were not divided by County, but data for later periods suggests that most of the pumping occurred in Santa Clara County (Palo Alto and Stanford University).

In the 1950s, groundwater production from the San Francisquito Cone was about 7,500 AFY, 87 percent of which was in Santa Clara County. Groundwater levels in the Atherton-Menlo Park area were +15 to -15 feet msl in the early- to mid-1950s but dropped to more than 90 feet below msl in some wells during the 1959-1961 drought (Sokol, 1964). Palo Alto and Stanford University discontinued using groundwater for potable supply in 1962, although Stanford continues to pump a few hundred AFY for irrigation use (Metzger and Fio, 1997; BAWSCA 2003-20014).

An important conclusion that can be drawn from this history is that groundwater in the San Mateo County part of the San Francisquito Cone cannot be considered independently of the Santa Clara County part and vice versa. Most of the historical pumping was in Santa Clara County, but the reductions in water levels spread throughout the Cone. Clearly, historical pumping from the San Francisquito Cone at rates of 6,000 to 7,500 AFY resulted in significantly lower water levels. The recharge part of the water balance might be different than it was in the 1920s and 1960s. Countywide population increased by a factor of 1.7 from 1960 to 2015, which was presumably accompanied by an increase in urban density. This could have increased groundwater recharge from pipe leaks and possibly irrigation and/or could have increased or decreased rainfall recharge depending on the relative amounts of connected and disconnected impervious area. Assuming overall groundwater yield has not changed, then pumping in the southern part of the San Francisquito Cone might need to be less than historical maximum pumping rates to avoid undesirable impacts on groundwater and stream baseflow.

Table 7-1
Average Annual Water Balance

Inflow or Outflow	Flow Rate (AFY)[a]	Plausible Range (AFY)	Source
Inflows			
Dispersed Recharge[b]			
Rainfall - runoff from impervious areas	900	500 to 1,700	Recharge zone simulations. Runoff from impervious surfaces to adjacent pervious soils. Decreased to conform with calibrated regional groundwater model for this study.
Rainfall - nonirrigated areas	900	600 to 1,800	Recharge zone simulations.
Irrigated areas	1,800	1,400 to 3,000	Recharge zone simulations and curve separation. Includes rainfall recharge on irrigated areas. Decreased to conform with calibrated regional groundwater model for this study.
Water pipe leaks	900	600 to 2,000	Equals total water delivered to in-basin recharge zones, multiplied by adjusted %-unaccounted-for water.
Sewer pipe leaks	300	200 to 500	Sewer leak rate (as percentage of annual flow) assumed half of water pipe leak rate.
Stream percolation			
San Francisquito Creek	600	400 to 800	Average of Metzger (2002) and simulated creek percolation in regional groundwater model for this study. An equal amount assumed to flow to Santa Clara County.
San Mateo Creek	200	200 to 400	Percolation capacity at 0.4 cfs/mi is less than current perennial reservoir releases. Assume half of potential annual percolation rejected due to high water levels.
Other creeks	500	200 to 800	Filter synthetic daily flows at 0.3 cfs/mi percolation capacity. Assume half of percolation rejected.
Bedrock inflow	600	100 to 1,000	Average annual total recharge in zones adjacent to basin but not near creeks.
Groundwater inflow from the South (Santa Clara Subbasin)	1,200	500 to 2,000	Regional groundwater model for this study
Saltwater intrusion from SF Bay	0	0 to 0	Assumed. Shallow and deep water-level gradients are toward San Francisco Bay.
Total inflows[c]	**7,900**		
Outflows			
Wells			
Water supply	2,300	1,500 to 4,000	Previous studies and irrigated area x applied water.
Remediation	200	100 to 200	RWQCB NPDES permit database; 2014 to mid 2016.
Dewatering	1,000	500 to 1500	Extrapolation of records for dewatering in Palo Alto; County permits for discharges to sanitary sewer systems, 2011-2016.
Groundwater seepage to			
Riparian evapotranspiration	100	50 to 150	Riparian canopy area x groundwater evapotranspiration rate.
Sewers	1,400	900 to 2,100	Dry-season recession of SVCW and San Mateo daily flows, by pump station, plus 197 gpm infiltration year-round. Regional groundwater flow model for this study.
Creeks and tidal wetlands	2,200	1,600 to 3,200	Regional groundwater flow model for this study.
Groundwater outflow to the			
East (beneath San Francisco Bay)	500	300 to 1,000	Regional groundwater flow model for this study.
North (Westside Basin)	200	-100 to 200	Groundwater model for this study.
Total outflows[c]	**7,900**		
Storage Change			
Inflows minus outflows	**0**		Assumed zero average annual storage change. Water balance residual is outflow to creeks and Bay.

Abbreviations: AFY = acre-feet per year, WWTP = wastewater treatment plant, SVCW - Silicon Valley Clean Water, cfs = cubic feet per second, gpm = gallons per minute, mi = miles

Notes:

[a] The water balance is for the San Mateo Plain Groundwater Basin, excluding the extension of San Francisquito Creek alluvium west into the uplands. The water balance represents land and water use conditions as of 2016 during a period of average annual rainfall.

[b] These estimates of dispersed recharge were decreased by approximately 30 percent in the groundwater model, to improve calibration.

[c] Totals may not equal sum of items due to rounding.

Table 7-2
Estimates of Impervious Land Cover

Land Use Category	Source of Data and Type of Imperviousness Measured (a)								
	Santa Clara Plain Runoff (b)	ABAG Table (c)	Colma Creek Runoff (d)	San Mateo WWTP Inflow (e)	National Land Cover Database (f)	Handbook of Hydrology (g)	Selected Values for San Mateo Plain		
	Connected	*Total*	*Connected*	*Partial Connected*	*Total*		*Connected*	*Disconnected*	*Total*
Natural vegetation - grass	2	1	--	--	7	--	0	1	1
Natural vegetation - brush	--	--	--	--	1	--	0	1	1
Natural vegetation - trees	--	1	--	--	1	--	0	1	1
Open water	--	0	--	--	1	--	0	0	0
Rural residential	--	10	--	--	7	--	0	15	15
Urban residential	25	47	63	20	45	50	50	5	55
Urban residential - lush	--	--	--	--	15	20	39	6	45
Urban commercial	30	93	85	20	65	85	80	5	85
Urban industrial	30	91	--	20	61	72	80	5	85
Urban vacant	40	66	70	--	57	--	50	10	60
Large turf areas	--	3	--	--	0	--	0	5	5

Abbreviations:
"ABAG" = Association of Bay Governments
"WWTP" = wastewater treatment plant

Notes:
(a) Values in table indicate percent of total land area that is impervious.
(b) Comparison of rainfall and runoff in four catchments by Todd Groundwater (2016).
(c) ABAG table values cited in San Mateo Countywide Pollution Prevention Program (2002).
(d) Comparison of rainfall and runoff in Colma Creek watershed for this study.
(e) Comparison of rainfall and WWTP inflows by West Yost Associates (2016).
(f) Spectral analysis of satellite imagery in San Mateo basin (Homer et al., 2007). 30-meter pixel values averaged by land use.
(g) Textbook values in Handbook of Hydrology (Maidment, 1993).

Table 7-3
Stream Flow Measurements of 5 May 2016

Site	Flow (cfs)	Specific Conductance (µS/cm)	Temperature (°C)	Flow Measurement Method	Remarks
San Mateo Creek					
Below Crystal Springs Dam	1.9	--	--	USGS gage	Daily average flow recorded on 5/5/16.
Crystal Springs Road	1.9	337	13.8	Pygmy meter with top-setting rod.	About 400 ft downstream on El Cerrito Rd from Crystal Springs Road. Low conductivity indicates Hetch Hetchy water from Crystal Springs Reservoir.
Arroyo Court Park near El Camino	1.6	--	--	Visual estimate: W=7 ft, D=0.4 ft, center top V = 2 ft/s. Assume triangular xsec and mean V = 2/3 center top V.	--
Gateway Park at South Humboldt Street	1.65	680	14.8	Pygmy meter with top-setting rod.	Gravel bed at D/S end of box culvert under Humboldt and East 3rd Avenue, below Gateway Park.
Laurel Creek					
Fernwood Street	0.13	1,293	14.2	Bucket and stopwatch	Caught flow falling off concrete bridge apron. 10-quart bucket filled in average of 2.53 seconds.
Otay Avenue	0.67	1,056	15.2	Pygmy meter with top-setting rod.	50 ft upstream of bridge on Otay cul-de-sac. Shifted gravels and removed filamentous algae to create better measurement conditions.
Belmont Creek					
Twin Pines Park	0.19	1,401	--	Salt dilution	10-foot run in gravel channel.
Arroyo Ojo de Agua					
Stulsaft Park	0.32	1,051	15.9	Pygmy meter with top-setting rod.	At downstream end of park below Mitchell Way. Short run in gravel channel at point bar above property fence.
King Street (at Vera St)	Similar	--	--	Visual from road	Concrete trapezoidal channel below box ulvert under Red Morton Park. Flow is <=1 inch deep and 4-6 ft wide on flat cement bottom. Much filamentous algae. Tightly fenced to prevent access. No good way to measure this type of flow. Made visual observation through fence.
Hudson Street	Similar	--	--	Visual from road	Cement trapezoidal channel. Did not enter.
Clinton Street	Similar	--	--	Visual from road	Cement trapezoidal transitions to rectangular channel. Bottom 10 ft wide, fully covered by flow perhaps 0.3 ft deep, moving slowly. Algae focuses flow into narrow area.
Redwood Creek					
Arroyo de las Pulgas	--	--	--	--	Natural channel in Menlo Country Club. Chain link and barbed wire fence. Channel pooled upstream of road culvert so could not estimate velocity or flow through fence. Site of former USGS gage.
Kentfield Avenue	0.8	--	--	Visual from road plus floating twigs for velocity.	Trapezoidal concrete channel, tightly fenced. Bottom 7 ft wide, fully wetted. Algae focuses perhaps 80% of flow into 1.5 ft wide x 0.5 ft deep x 1.04 ft/s = 0.78 cfs
El Camino Real	Similar	--	--	Visual from road	El Camino to Maple Street concrete channel 10 ft wide on bottom, fully wetted, much algae focusing flow into narrow runs. Below Maple Street is backwater condition.

Abbreviations:
"cfs" = cubic feet per second
"D" = flow depth (feet)
"ft" = feet
"V" = velocity (feet per second)
"W" = flow top width (feet)
"USGS" = U.S. Geological Survey
"µS/cm" = microsiemens per centimeter

Table 7-4
Stream Flow Measurements of 12 June 2017

Site	Flow (cfs)	Specific Conductance (µS/cm)	Temper-ature (°C)	Flow Measurement Method	Remarks
			San Mateo Creek		
Below Crystal Springs Dam	3.69	--	--	USGS gage	Daily average flow recorded on 6/12/17.
Crystal Springs Road	3.84	283	14.2	Pygmy meter with top-setting rod.	About 400 ft downstream on El Cerrito Rd from Crystal Springs Road. Low conductivity indicates Hetch Hetchy water from Crystal Springs Reservoir.
Arroyo Court Park near El Camino Real	3.56	311	14.2	Pygmy meter with top-setting rod.	Run between pools upstream of large storm drain.
Gateway Park at South Humboldt Street	3.68	318	14.8	Pygmy meter with top-setting rod.	Gravel bed at downstream end of box culvert under Humboldt and East 3rd Avenue, below Gateway Park.
			Cordilleras Creek		
Edgewood Road	0.29	991	14.9	Pygmy meter with top-setting rod.	80 ft upstream of Edgewood Road. Bedrock in channel.
Warwick Street	0.024	1,065	15.4	Visual from road: 1 ft wide x 0.08 ft deep x 0.3 ft/s	Box culvert. Approx. 1,000 ft upstream of El Camino Real. Water sample collected from bridge by bucket and string.
			Redwood Creek		
Alameda de las Pulgas	0.25	1,152	16	Pygmy meter with top-setting rod.	Natural channel in Menlo Country Club. Chain link and barbed wire fence. Channel pooled upstream of road culvert so could not estimate velocity or flow through fence. Site of former USGS gage.
El Camino Real	0.4	1,437	21.3	Visual from road: 2 ft wide x 0.2 ft deep x 1 ft/s	Trapezoidal concrete culvert downstream of El Camino. Flow estimate was 100 ft upstream of Lathrop Street. Water quality sample obtained from bridge by bucket and string.
			San Francisquito Creek		
Sand Hill Road	4.37	922	17.7	Pygmy meter with top-setting rod.	Metzger site 4. Boulder and cattail riffle between pools 200 ft upstream of bike bridge.
San Mateo Drive bike bridge	3.63	937	19	Pygmy meter with top-setting rod.	Metzger site 5. Run by gravel bar 200 ft upstream of bike bridge.
Alma Street	2.09	937	18.6	Pygmy meter with top-setting	Metzger site 6. Run by gravel bar under railroad bridge.
			Matadero Creek		
Foothill Expressway	0.16	2,084	15.4	Pygmy meter with top-setting rod. Floating-stick velocity for part of section.	Short run by gravel bar 300 ft upstream of road. Cleared algae and focused flow.
Matadero Road	0	--	--	Visual from road.	At Josina Avenue, about 800 ft upstream of El Camino Real. Nearly continuous pools but no surface flow.

Abbreviations
- cfs = cubic feet per second
- D = flow depth (feet)
- ft = feet
- V = velocity (feet per second)
- W = flow top width (feet)
- USGS = U.S. Geological Survey
- µS/cm = microsiemens per centimeter

Table 7-5
Groundwater Production for Water Supply

Well Number	Well Name	Owner	Type of Use	Average Annual Production (AF)	Method of Estimate	Sources of Information
Individual Users						
05S03W25M002, 25M004 and 25M005	Well Nos. 3, 5 and 6	Palo Alto Park Mutual Water Co.	Small public water system	523	Production estimated by GeoMatrix and Papadopulos (1989)	OF 75-43 lists the three numbered wells. Five active wells per Todd Engineers and others (2012). Production estimated by GeoMatrix and Papadopulos (1989)
--		Peninsula Golf and Country Club	Golf course irrigation	328	Golf course area and percent irrigated estimated from high-resolution aerial photographs. Irrigated area multiplied by 33.4 in/yr applied water.	Consultant recollection from previous studies. Well use not recently confirmed with well owner.
05S03W36D001 and 36D002		O'Connor Tract Cooperative Water Co.	Small public water system	325	Metered annual production 1977-2015, with data gaps. Selected approximate average for non-drought years during 1987-2015.	Manny Nathenson e-mail (8/9/2016)
04S04W7K001 or 17L001		San Mateo City Parks and Recreation Department	Poplar Creek (Coyote Point) Golf Course	238	Lot area and percent irrigated estimated from high-resolution aerial photographs. Irrigated area multiplied by 33.4 in/yr applied water.	This study
--		CEMEX	Dust control and other indusrial uses	40	Dust control on approximately 6 acres of unpaved vehicular operation area.	This study
--	Pacific Shores No. 1	Pacific Shores office park	Irrigation	39	Lot area and percent irrigated estimated from high-resolution aerial photographs. Irrigated area multiplied by 33.4 in/yr applied water.	Consultant recollection from previous studies. Well use not recently confirmed with well owner.
04S04W29B001		San Mateo City Parks and Recreation Department	Central Park landscape irrigation	22	Lot area and percent irrigated estimated from high-resolution aerial photographs. Irrigated area multiplied by 33.4 in/yr applied water.	This study
05S03W35D002		St. Patrick's Seminary	Swimming pool and landscape irrigation	19	Lot area and percent irrigated estimated from high-resolution aerial photographs. Irrigated area multiplied by 33.4 in/yr applied water.	This study
--		City of Atherton, Holbrook-Palmer Park	Irrigation	15	Irrigated area planimetered from high-resolution aerial photographs and multiplied by 33.4 in/yr applied water.	This study
04S04W20D	Well Nos. 1 and 2	San Mateo High School	Irrigation	14	Lot area and percent irrigated estimated from high-resolution aerial photographs. Irrigated area multiplied by 33.4 in/yr applied water.	Consultant recollection from previous studies. Well use not recently confirmed with well owner.
--		U.S. Geological Survey	Assumed landscape irrigation	11	Lot area and percent irrigated estimated from high-resolution aerial photographs. Irrigated area multiplied by 33.4 in/yr applied water.	This study
04S04W20G001		San Mateo City Parks and Recreation Department	M.L. King Center and Park	6	Lot area and percent irrigated estimated from high-resolution aerial photographs. Irrigated area multiplied by 33.4 in/yr applied water.	This study
--		Menlo Park School District, Encinal Elementary School	Irrigation	6	Irrigated area planimetered from high-resolution aerial photographs and multiplied by 33.4 in/yr applied water.	This study
--		San Mateo County Center	Irrigation	2.4	Irrigated area planimetered from high-resolution aerial photographs and multiplied by 33.4 in/yr applied water.	This study

Table 7-5
Groundwater Production for Water Supply

Well Number	Well Name	Owner	Type of Use	Average Annual Production (AF)	Method of Estimate	Sources of Information
			User Groups			
--	298 active or potentially active residential wells	Private homeowners in Atherton	Landscape irrigation	562	269 wells in WRIR 97-4033 plus 29 wells drilled since 1995. Used per-house use from USGS metering in 1990s (1.9 AFY).	WRIR 97-4033, drillers logs and this study
--	43 residential irrigation wells near Atherton, in San Mateo County	Residents near Atherton	Irrigation	67	Atherton per-house use applied to each of these wells.	Todd Engineers and others (2012). Of the 100 wells estimated for San Francisquito Creek Cone areas outside Atherton, 43 were in San Mateo County.
--	6 institutional wells in Atherton	Institutions in Atherton	Irrigate landscaping and athletic fields	90	USGS-reported 1993-1995 production minus wells listed separately above. 4 wells were metered in 1993-1995.	WRIR 97-4033
--	8 private irrigation wells in Hillsborough and San Mateo	Two office park/apartment complexes and four private residences in Hillsborough and San Mateo	Irrigation	17	Lot area and percent irrigated for irrigation wells in San Mateo Plain Basin and uplands estimated from high-resolution aerial photographs. Irrigated area multiplied by 33.4 in/yr applied water.	This study
TOTAL				**2,325**		

Abbreviations: AFY = acre-feet per year, in/yr = inches per year, WRIR = Water Resources Investigations Report, OF = Open-File Report

Notes:

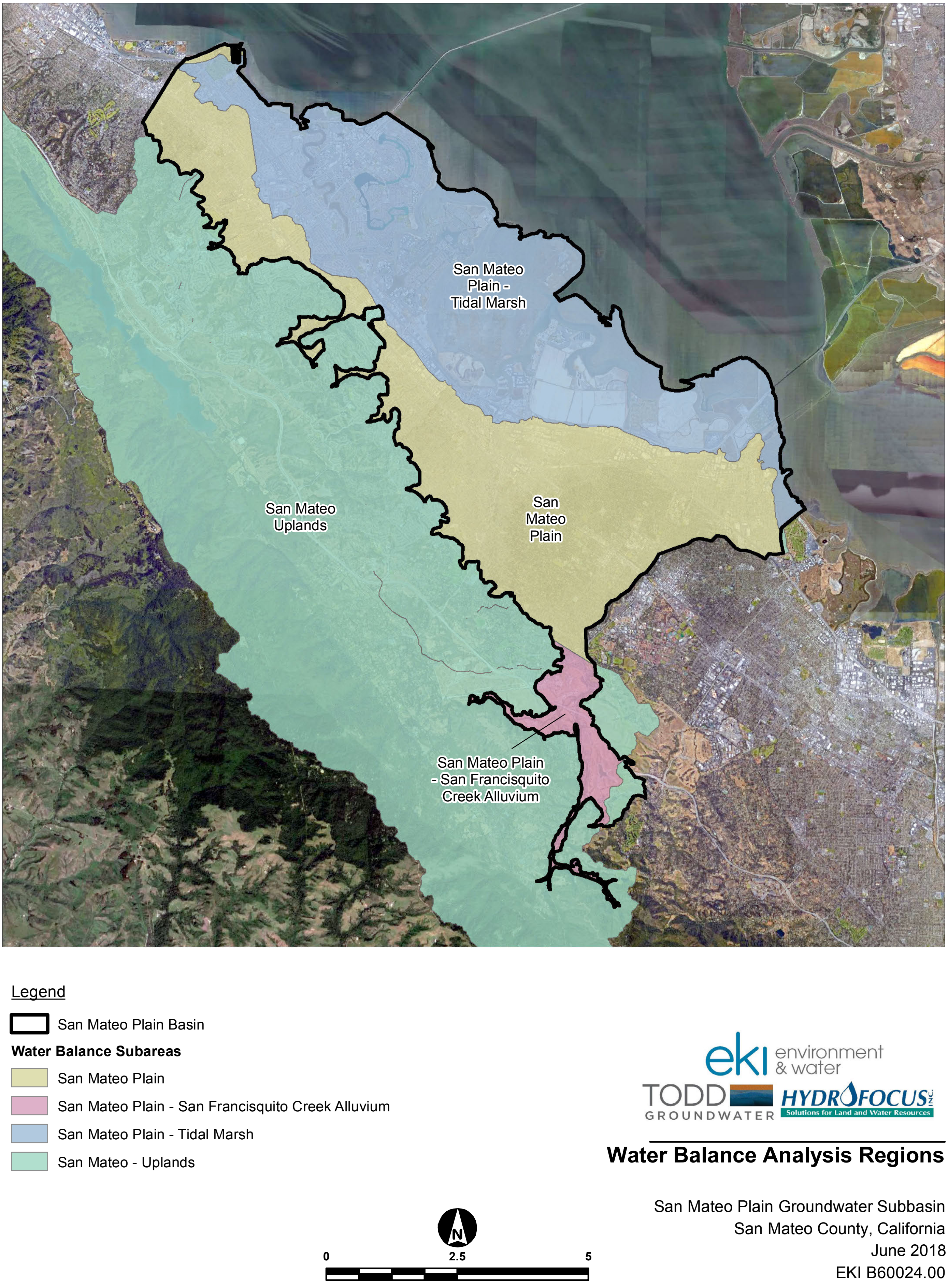
This table lists average annual production under land use conditions in 2016

Table 7-6
Consumptive Use of Groundwater by Riparian Vegetation

Creek	Riparian Forest Canopy and Water Use				
	Length (ft)	Average Width (ft)	Area (acres)	Consumptive Use of Groundwater (AFY) (a)	Reach
Belmont	2,249	80	4.1	8.5	Maywood Drive to Chula Vista Drive
Belmont	1,633	120	4.5	9.2	Twin Pines Park
Cordilleras	6,377	90	13.2	27.0	Basin boundary to El Camino Real
Cordilleras	1,810	60	2.5	5.1	El Camino Real to Hwy. 101
Laurel	2,450	80	4.5	9.2	Basin boundary to El Camino Real
Pulgas/Greenwood	4,300	80	7.9	16.2	Basin boundary to Chestnut Street
Redwood/Arroyo Ojo de Agua	2,184	70	3.5	7.2	Basin boundary to Connecticut Drive
San Mateo	6,800	100	15.6	32.0	Basin boundary to El Camino Real
San Francisquito - north side (b)	28,982	60	39.9	81.8	Junipero Serra Road to Hwy. 101
TOTAL	**35,782**	**--**	**55.5**	**113.7**	**--**

Abbreviations:
"ft" = feet
"AFY" = acre-feet per year
"Hwy" = highway

Notes:
(a) Based on average annual consumptive use of groundwater of 24.6 in/yr derived from comparison of riparian forest under "irrigated" and non-
(b) Only riparian vegetation along the north bank of the creek is included, consistent with the treatment of stream percolation.



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TODD GROUNDWATER

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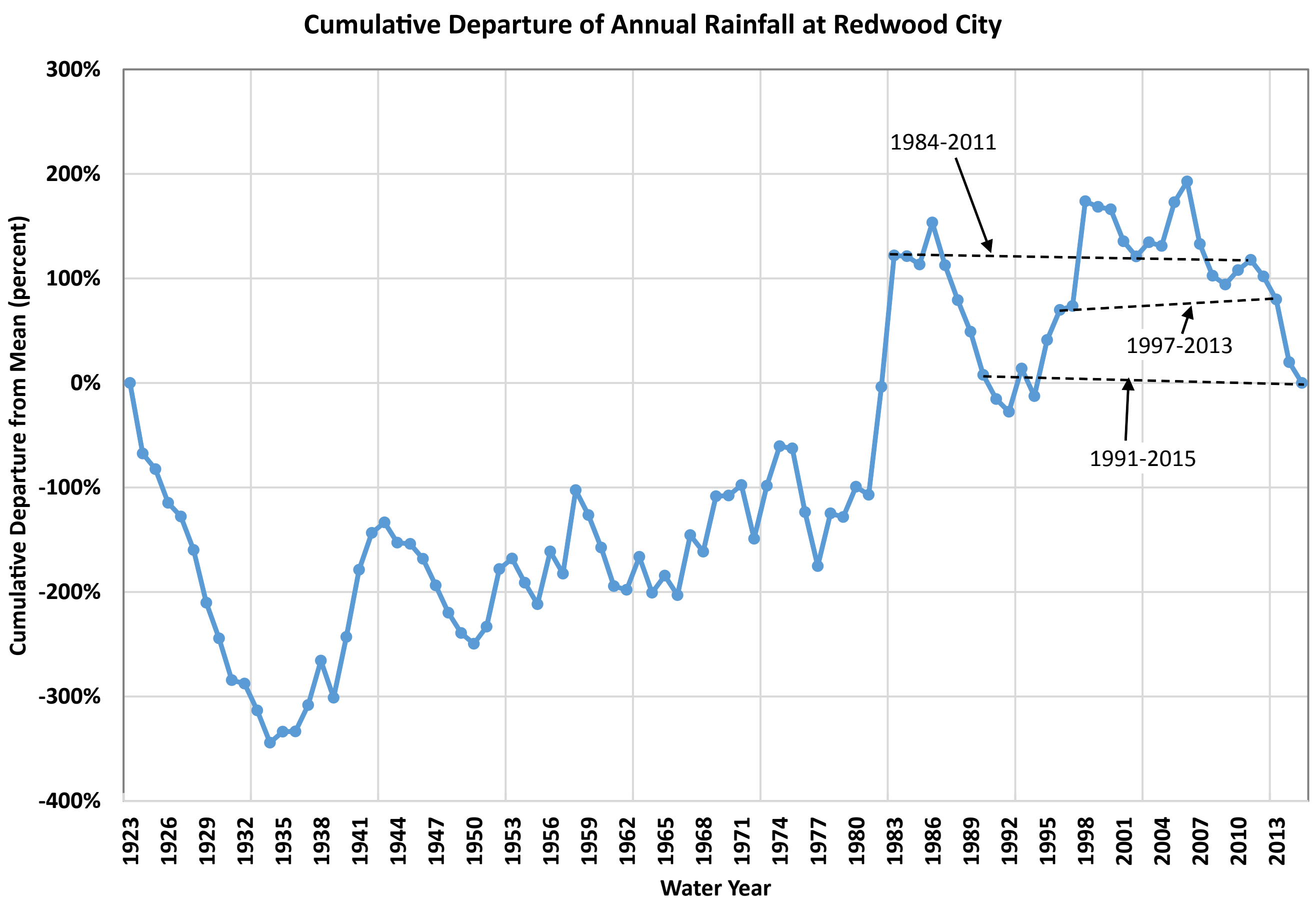
Water Balance Analysis Regions

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 7-1



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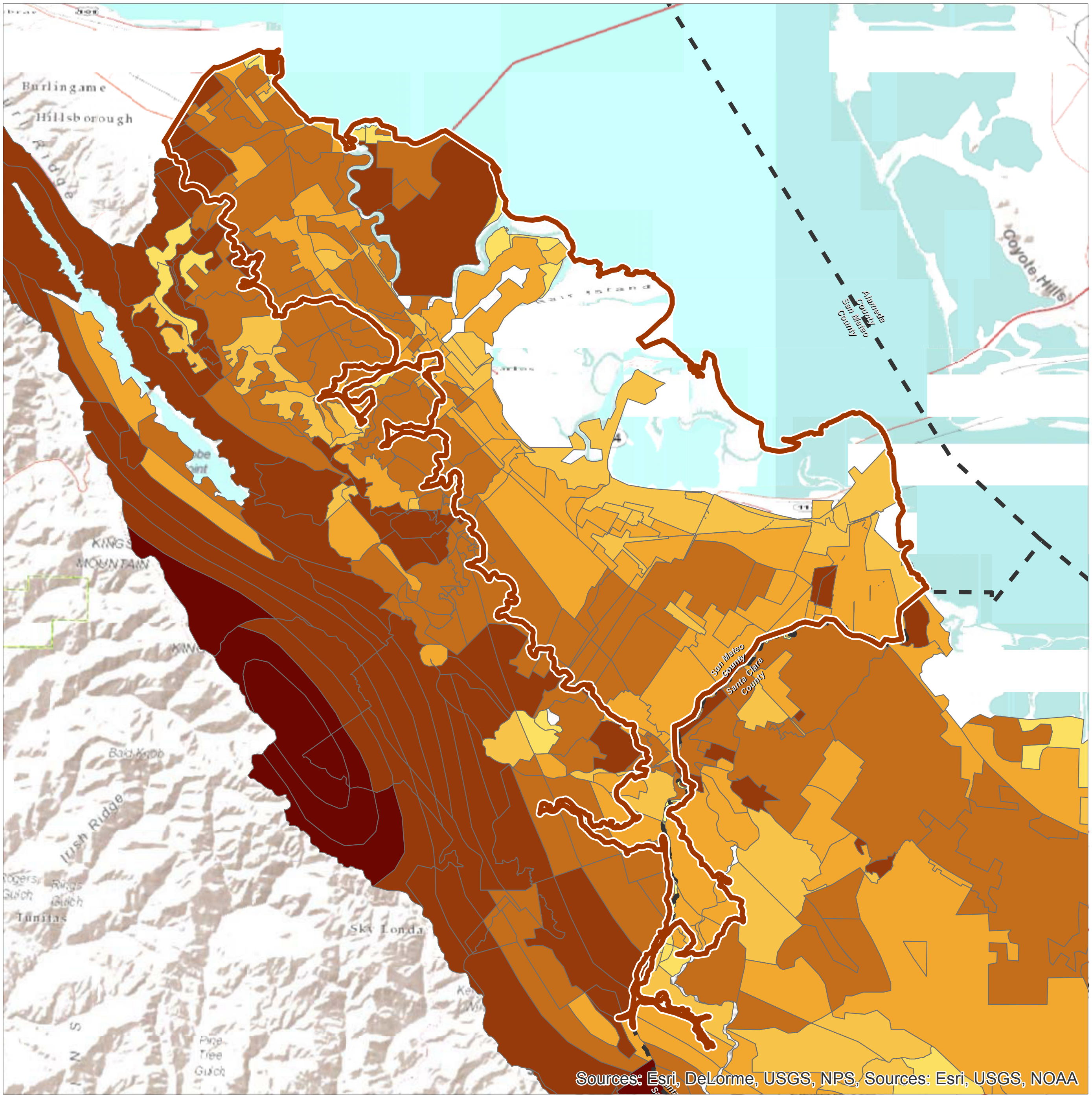
Cumulative Departure of Annual Rainfall

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 7-2



Legend

San Mateo Plain Subbasin

County Boundary

Dispersed Recharge

RechInYr

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 6
- 6 - 12

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 21 December 2017.

Abbreviations

RechInYr = average annual recharge in inches per year

0 2.5 5

Miles

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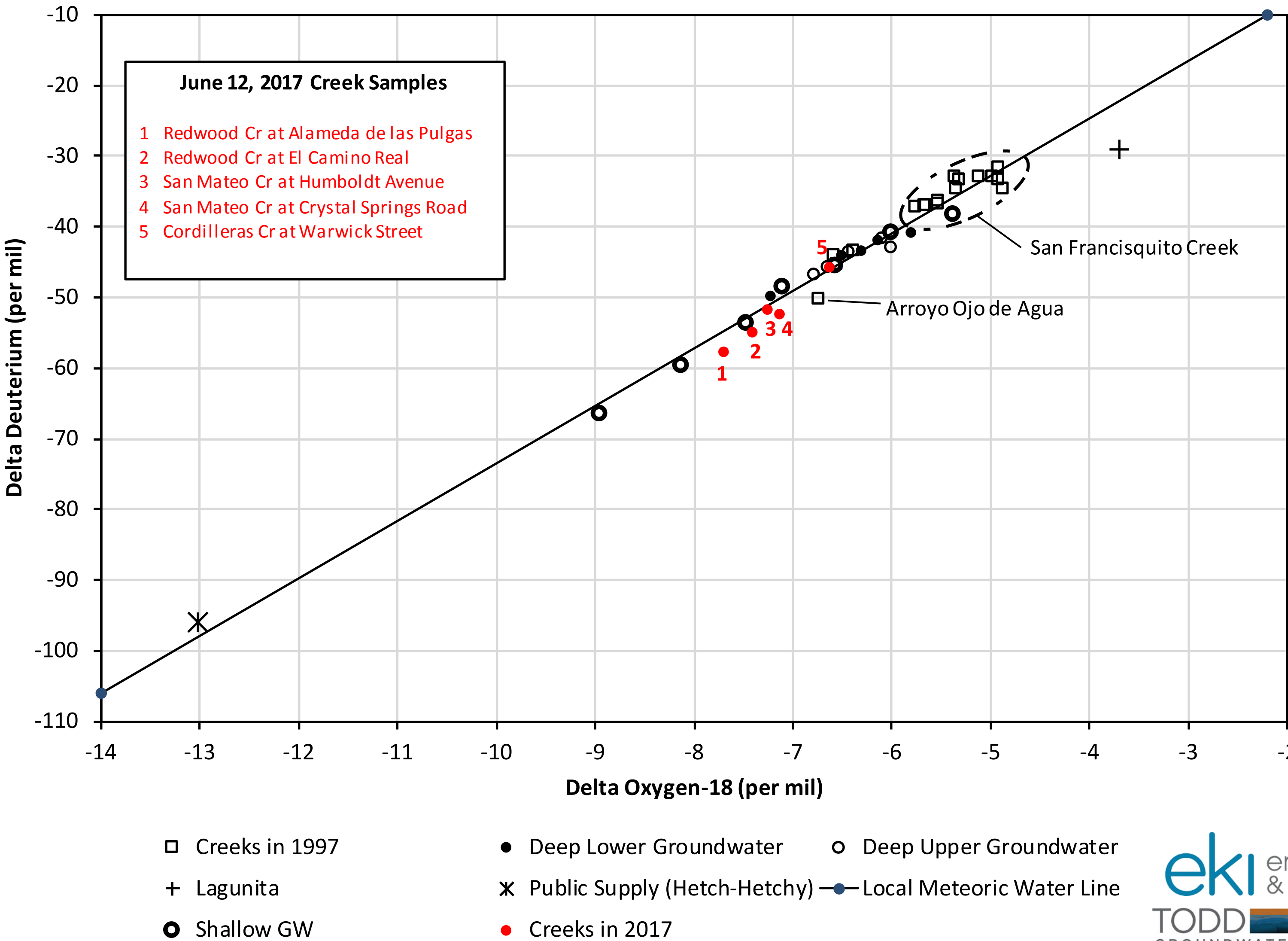
Dispersed Recharge

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 7-3



Note: All non-2017 data were collected in 1997 (Metzger, 2002).

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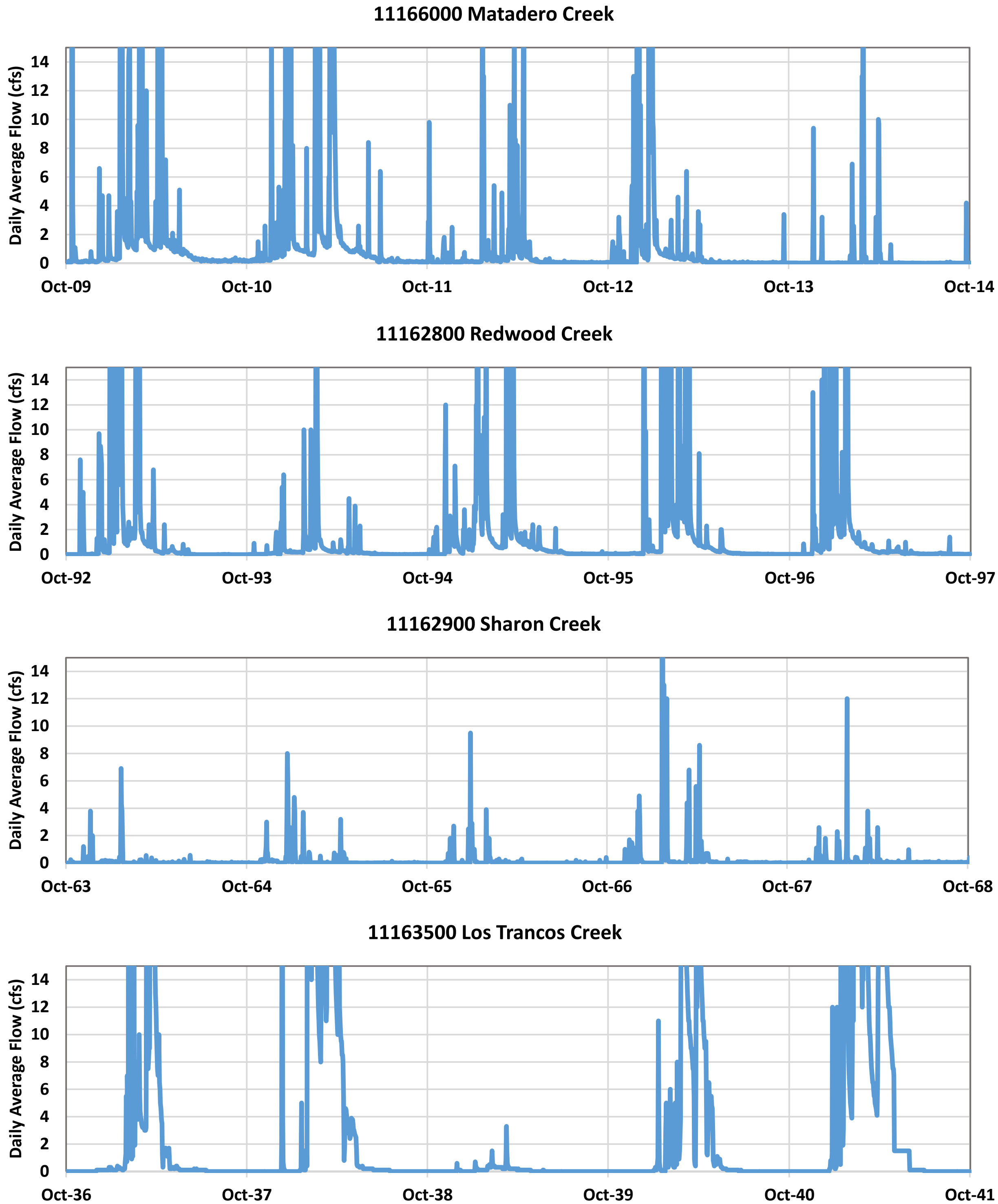
Stable Isotopes in Local Waters

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 7-4



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TODD GROUNDWATER

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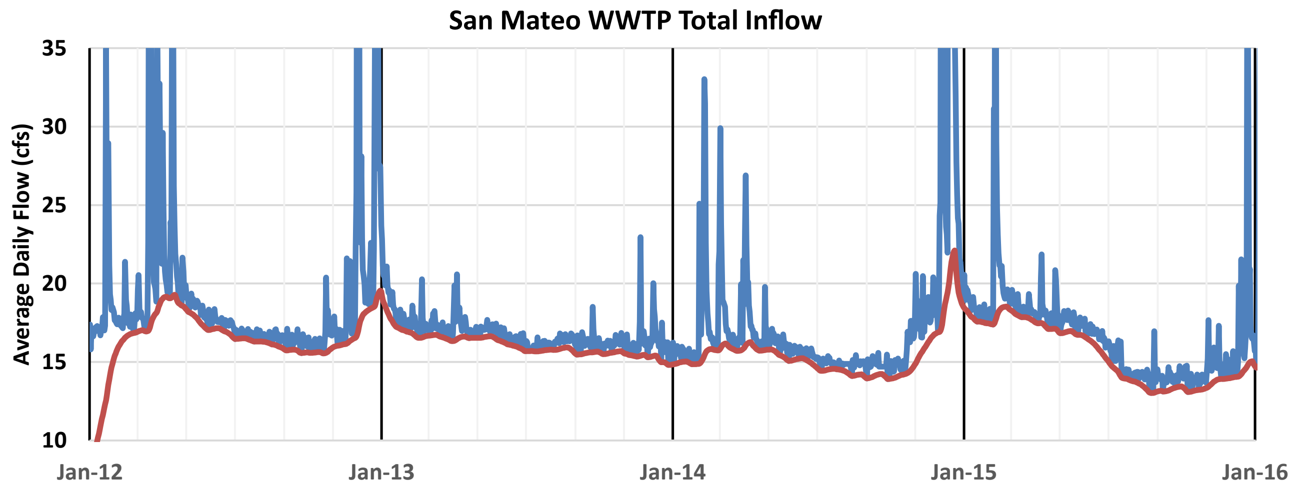
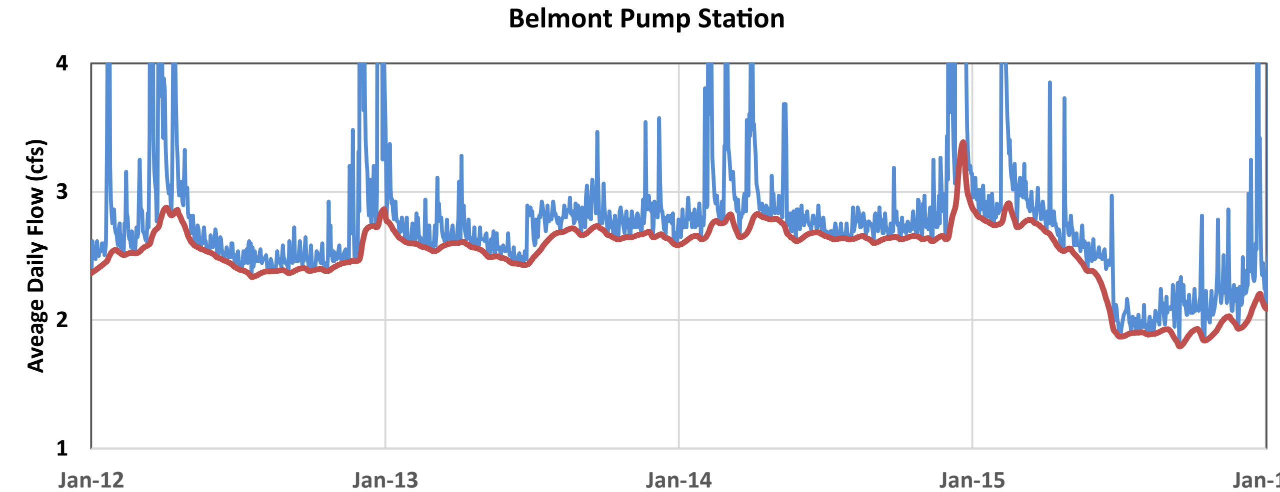
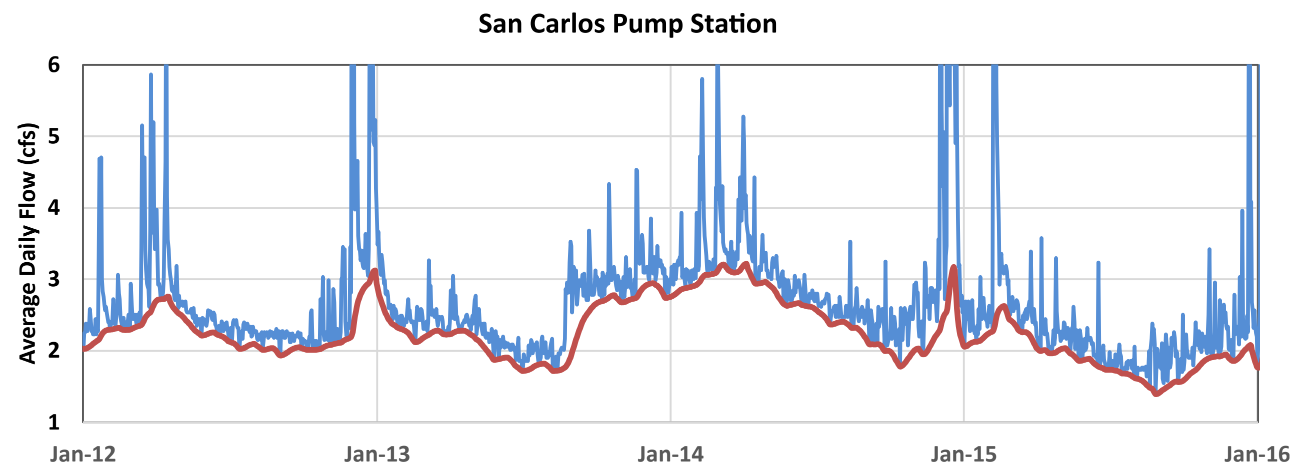
Low Flows in Four Gaged Small Creeks

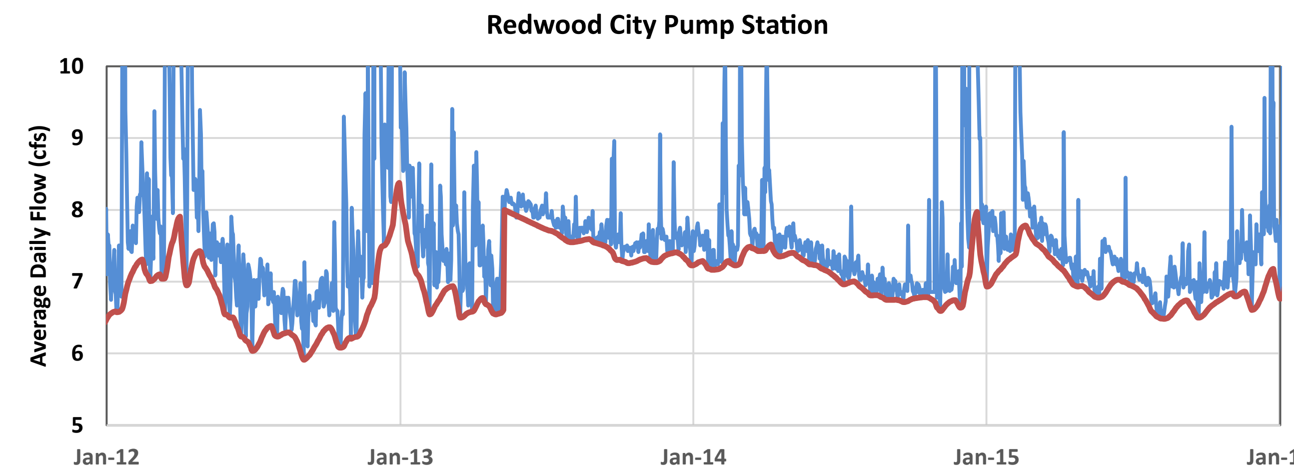
San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 7-5









	San Mateo		San Carlos		Belmont		Redwood City		TOTAL
Water Year	Base Flow Threshold (cfs)	Apr-Nov Infiltration (AF)[a]	Base Flow Threshold (cfs)	Apr-Nov Infiltration (AF)[a]	Base Flow Threshold (cfs)	Apr-Nov Infiltration (AF)[a]	Base Flow Threshold (cfs)	Apr-Nov Infiltration (AF)[a]	Apr-Nov Infiltration (AF)[a]
2010	--	--	2.9	135	2.3	46	7.9	166	**347**
2011	--	--	2.1	467	2.4	27	6.6	438	**933**
2012	14.5	891	2	90	2.4	38	6.3	136	**1,155**
2013	14.5	726	1.7	158	2.5	5	7.3	105	**994**
2014	14.5	298	2.4	117	2.6	35	6.7	204	**654**
2015	14.5	493	1.6	107	2.3	69	6.5	134	**803**
AVERAGE	--	**602**	--	**179**	--	**37**	--	**197**	**814**

Abbreviations: cfs = cubic feet per second; AF = acre-feet; GW = groundwater; Apr = April; Nov = November

Notes

a Groundwater infiltration equals base flow above the indicated threshold during April-November, except: Belmont in 2018 only tallied to June 19; Belmont in 2018 only tallied to June 24; Redwood City in 2013 only tallied May 10-September 30. Annual infiltration estimated to be at least 33 percent greater.

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Sewer Flow Hydrographs

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 7-6

8.0 SAN MATEO PLAIN GROUNDWATER FLOW MODEL

Numerical groundwater models can be used to quantitatively evaluate the hydrogeologic conditions associated with water inflows, outflows, and associated connectivity between adjacent groundwater basins. The Preliminary Report documents the Phase 1 activities related to development of the San Mateo Plain Groundwater Model (SMPGWM), including initial model construction, parameterization, sensitivity analysis, and steady-state calibration. The SMPGWM was further developed in Phase 2 of the Project. Updates to the SMPGWM during Phase 2 included:

- conversion from steady-state to transient simulation mode;
- update of the SMPGWM data sets by incorporating new aquifer parameter information and additional water level data;
- modification of boundary conditions including the use of "drains" to simulate multiple near-surface groundwater/surface water exchange processes;
- incorporation of historical pumping and dispersed recharge information;
- updated calibration against a 25-year historical water level dataset;
- incorporation of model input from existing local models (i.e., Alameda County Water District's Niles Cone and South East Bay Plain IGSM and Santa Clara Valley Water District's IMOD); and
- refinement to the model-calculated water budget.

This section documents the Phase 2 SMPGWM model development activities.

8.1 Conversion from Steady-State to Transient

The SMPGWM was expanded from steady-state to transient to simulate monthly changes in groundwater levels and storage. The expansion included an update of the SMPGWM data sets by incorporating new aquifer parameter information, additional water level data, a refined conceptual water budget, and model input from existing local models (i.e., Alameda County Water District's [ACWD] North East Bay Plain Integrated Groundwater and Surface Water Model [NEBIGSM], Santa Clara Valley Water District's [SCVWD] interactive MODeling [iMOD] model, and the Westside Basin Partner's Westside Basin Model [WSBM]).

The steady-state model simulates average conditions during the period 1987-1996, and results are assumed to represent average conditions during 1 October 1990 through 30 September 1991 (Water Year 1991). The steady-state model results for model stress period 1 are therefore utilized for the initial conditions in the transient model. Accordingly, the transient model simulates monthly conditions during Water Years 1992-2015 (stress periods 2 through 289 representing the period 1 October 1991 through 30 September 2015). Most of the water level data is available during this time period, with the greatest additions to the Project database in the 1990s and early 2000s. Further, the time period overlaps the simulation periods of the local WSBM, NEBIGSM, and iMOD models that provided recharge, pumping, and observation point data for integration and use by the SMPGWM (**Figure 8-1**). The transient simulation was utilized to estimate the spatial distribution of aquifer storage parameter values (elastic) and to refine the modeled distribution of water transmitting properties (horizontal and vertical hydraulic conductivity).

8.2 Refinement of Aquifer Parameters

As described in detail in the Preliminary Report, SMPGWM grid cells are grouped geographically into physiographic zones initially delineated by the DWR using surficial features and the origin of sediments forming the alluvium deposits (DWR, 1967). The zones were refined for this study based on available well and borehole data, local model area coverage, and groundwater level trends. As part of the Phase 2 model update, two additional physiographic zones were created within the Basin. In the updated SMPGWM, the Basin is represented by three Westside Aprons zones (3, 16 and 17) and three Bay Plain zones (9, 13, and 12) (**Figure 8-2**). The two additional zones (16 and 17) provided greater flexibility during model calibration, and refined the spatial distribution of aquifer storage properties in semi-confined and confined portions of the Basin.

Additional aquifer test data from several shallow wells located along the Basin boundary in the Westside Aprons parameter zone of the model were added to the Project database during Phase 2 of the Project. These data were included on **Figure 8-3**, which compares hydraulic conductivity data to the updated calibrated values in the SMPGWM. Additionally, the vertical conductivity representing Bay Mud in the model was set equal to 0.0015 ft/d, based on results of the tidal method analysis described in Section 6.2.6.

8.3 Refinement of Boundary Conditions

Boundary conditions mathematically reproduce the physical conditions at the edges of the groundwater system represented by the model grid. As part of the Phase 2 model update, modifications were made to drain and water-channel boundary conditions.

8.3.1 Drains

Shallow groundwater is removed from the groundwater system by infiltration into submerged sewer pipes, seepage into creek channels, riparian and wetland vegetation transpiration, evaporation from the shallow water table in exposed marshland and mudflat areas, and dewatering operations. These outflows are modeled using "drain" boundary conditions, whereby the volume and rate of groundwater discharge is determined by the water table elevation, hydraulic conductivity of the surficial sediments, the leakiness of sewer pipes, and the head loss that occurs as groundwater seeps into open channels and pipes. The distribution of drain boundary conditions between "sewer," "marsh," and "dewatering" areas was specified based on aerial photos (**Figure 8-4**).

Sewer drains were specified in urban areas of the Basin, Palo Alto, and Sunnyvale where depth to water is typically shallow. Sewer pipes are commonly about 6 feet below the ground surface, so sewer drains were assigned a drain elevation of 6 feet below land surface and the drain conductance adjusted during calibration to calculate a net outflow similar to estimated groundwater infiltration to sewers.[26]

Marsh drains were specified in Basin model cells near the Bay representing areas of tidal marsh and open water. Marsh drains were assigned a drain elevation of land surface, and the drain conductance adjusted during calibration to optimize comparisons between model-calculated and measured water levels in shallow zone wells but maintain a net outflow of water flowing in the shallow zone from the Basin to the east.

Dewatering likely occurs in the low-lying urban areas that surround the Bay where depth to water is typically less than 10 feet. In the Basin, dewatering drains were delineated where the Project data base identifies shallow sumps and dewatering wells, and where sewer drains are not already specified. The dewatering drains were assigned a drain elevation of 8 feet below land surface, and the drain conductance adjusted during model calibration to obtain a total outflow approximately equal to the estimated average annual discharge from dewatering activities within the Basin (approximately 1,000 AFY). Dewatering pumping also occurs in Palo Alto, which is located south and adjacent to the Basin. The dewatering extraction rate in Palo Alto was estimated at about 640 AFY based on a map of dewatering pumping rates. The Project database does not contain information for shallow sumps and dewatering wells in areas outside the Basin, and therefore the effect of dewatering operations in the Palo Alto area was included by reducing dispersed recharge equally for all Palo Alto model cells excluding undeveloped land areas near the Bay. Dewatering pumping likely occurs in other low-lying areas near the Bay represented by the SMPGWM, but was not included in the model and its effect on modeled Basin conditions is assumed small.

8.3.2 Channel Gains and Losses

Shallow groundwater seepage across creek beds and into creek channels represent channel gains, whereas the leakage of surface flows into the subsurface represents channel losses. Channel gains and losses were implemented in the SMPGWM using the MODFLOW stream package (STR), river package (RIV), or added directly to the dispersed recharge specified for model cells corresponding to channels (channel gains are specified as negative recharge, and channel losses are specified as positive recharge). The decision to represent the channels using either STR, RIV, or specified recharge was determined by location (either within or outside the Basin) and the significance of the channel to the Basin water budget.

Figure 8-5 shows the surface water channels represented by model cells assigned to STR, RIV, or specified recharge. Within the Basin, the two largest creeks, San Francisquito Creek and San Mateo Creek, were explicitly represented in the model using the STR boundary condition. The

[26] San Mateo Plain Groundwater Basin Assessment Stakeholder Workshop #6, 17 August 2017. http://www.smcsustainability.org/download/stakeholder_meetings/SMPStakeholderWorkshop6_20170817.pdf

RIV boundary condition was utilized to represent channels in the corresponding iMOD areas of Santa Clara Valley. The gains and losses associated with all other channels were included in specified recharge, derived from NEBIGSM results or estimated from field observations.

The STR boundary condition calculates stream gains and losses in San Francisquito and San Mateo creeks using channel inflow, channel geometry, and channel bed conductance. Monthly channel inflow was specified at the head of the modeled portion of these creeks using measured daily discharge at the USGS Stanford and San Mateo stations, respectively.[27] Measured discharge data for San Francisquito Creek were available for the entire model period, and measured data for San Mateo Creek were available only for WY 2009-2015; San Mateo Creek discharge for WY 1992-2008 was estimated from the average discharge in WY 2009-2015.

Creek channels were digitized from USGS topographic maps and overlain on the model grid to identify model cells that contain the channels. The channels were represented by model cells having mapped channel lengths greater than 10% of the cell dimensions, unless a model cell having a smaller segment length was needed to maintain continuity along the channel trace from the foothills to the Bay. The channel width of San Francisquito Creek ranged from 23 feet to 53 feet and was calculated as the average of the top and bottom channel widths estimated from previous creek modeling efforts (Sanders and Chrysikopoulos, 2004). The channel width of San Mateo Creek was assumed to be 15 feet along the entire modeled section. The channel bottom elevation of San Francisquito Creek was estimated from stream profiles prepared for development of a stream hydraulic model (Noble Consultants, 2009) and the channel bottom elevation for San Mateo Creek was estimated based on a relationship between land surface and channel bottom elevations developed using San Francisquito Creek data. The initial bed conductance estimates were calculated from the channel width, channel length, assumed hydraulic conductivity, and assumed bed sediment thickness. The bed conductance values were adjusted to match estimated creek losses as part of model calibration.

Channel conductance was calculated from the hydraulic conductivity values for the bed sediments, which were calibrated using measured water levels in nearby wells and estimated net losses of channel flows to groundwater (leakage). The majority of the stream leakage occurs along the upper and middle stream reaches where the streams lose water to the aquifer (almost 1,600 AFY for San Francisquito Creek and about 200 AFY for San Mateo Creek). Calibrated hydraulic conductivity values ranged from 0.35 ft/d to 0.08 ft/d for the upstream and downstream portions of San Francisquito Creek, respectively. Similarly, the calibrated hydraulic conductivity values ranged from 0.2 ft/d to 0.001 ft/d for upstream and downstream portions of San Mateo Creek, respectively. This relative hydraulic conductivity distribution is consistent with the reported thickness and grain sizes of channel sediment deposits in the Basin. For example, reported channel sediment deposits decrease in thickness towards San Francisco Bay, and range

[27] San Francisquito Creek at Stanford University (USGS site number 11164500) and San Mateo Creek below Crystal Springs Reservoir (USGS site number 11162753).

from relatively coarse-grained sediment in the upstream portions of San Francisquito Creek, to medium-grained alluvium and clay in the lower portions of the creek (Metzger, 2002).

The RIV boundary condition represents channels in corresponding Santa Clara Valley IMOD areas, and calculates gains and losses based on the specified monthly channel stage in each RIV cell. Each RIV model cell requires specification of the stage, elevation of the bed bottom, and bed conductance. These parameters were extracted from iMOD and integrated into the SMPGWM based on a weighted percentage of stream length falling within each SMPGWM cell. The weighting was needed to account for differences in cell dimensions between the two models, and the weights were based on relative channel length. The IMOD RIV conductance was adjusted by a factor of 6 during model calibration to match reported net flow simulated by iMOD.

8.3.3 Pumpage

Pumpage is categorized in the SMPGWM as one of three types: irrigation, public supply, or remediation. Irrigation pumpage occurs from numerous private wells, mostly located in the Atherton area, and institutional users such as schools, golf courses, and other institutions throughout the Basin. Total pumpage for irrigation was adjusted annually during the 1992-2015 simulation period based on the annual change in number of active wells, and distributed between each month of the year using evapotranspiration[28] and rainfall[29] data. Groundwater for public supply is provided by wells operated by O'Connor Tract CWC and PAPMWC. Annual pumpage was available for most years for the O'Connor Tract CWC wells, and when annual data were not available pumpage was estimated from annual water use reported by other nearby local water suppliers (BAWSCA Annual Reports). The estimated average annual pumpage for the PAPMWC wells was reported as part of the Basin water balance, which was varied based on the annual variation in the O'Connor Tract CWC pumping. Monthly water use by O'Connor Tract CWC and PAPMWC was estimated from the reported monthly water use of local water suppliers (BAWSCA, 2017b). Remediation pumping rates for 29 sites were estimated from information in the SWRCB GeoTracker database. Annual remediation pumpage was distributed equally between all months.

Groundwater pumping rates from wells within the SMPGWM domain but outside of the Basin were determined directly from local model input data, which provided well locations, extraction depth intervals, and monthly pumping rates. Monthly NEBIGSM pumpage was not available from January 2013-September 2015 for the area north of the ACWD service area boundary. Monthly pumpage for the WSBM area was not available for October 2014-September 2015. Monthly pumpage for wells located in these two areas was estimated using the average monthly pumpage from the most recent three-year period, depending on data availability. Monthly pumpage for model areas corresponding to SCVWD iMOD were available for the entire 1992-2015 period, and therefore utilized directly in the SMPGWM (Todd Groundwater, 2016). **Figure 8-6** shows the distribution of average annual pumping rates used in the steady-state model (years 1987-1996).

[28] DWR, 2012, Reference Evapotranspiration Zones, California Irrigation Management Information System.
[29] National Oceanic and Atmospheric Administration, Redwood City Station (47339).

8.3.4 Recharge

Monthly dispersed recharge for the Basin was estimated using updated results from the recharge simulation model employed to develop the Basin water balance. Monthly dispersed recharge for the period 1987-1996 was averaged and specified for the updated steady-state model (**Figure 8-7**), and the transient monthly dispersed recharge values were utilized directly for the 1992-2015 transient simulation period. The Basin water balance also included a total estimated annual average stream percolation from the small creeks (excluding San Mateo Creek and San Francisquito Creek) in the Basin of approximately 500 AFY. Annual percolation was adjusted proportionally using annual total rainfall relative to the 1992-2015 average. The small stream percolation rates were varied monthly based on reported monthly rainfall.[30] Lastly, the Basin water balance estimated 600 AFY of inflow from bedrock areas adjacent to the Basin. The bedrock inflow was applied to model cells located adjacent to the bedrock contacts and between creek channels. The modeled dispersed recharge, small stream percolation, and bedrock inflows were then summed to provide a net recharge for each SMPGWM cell representing the Basin. **Figure 8-7** shows the distribution of average annual 1987-1996 net recharge as used in the steady-state model.

Monthly recharge for model areas located outside of the Basin was determined directly from local model input data, when available. As with groundwater pumping, monthly recharge rates were not available from January 2013-September 2015 in the NEBIGSM area north of the ACWD service area, and monthly recharge for the WSBM area was not available for October 2014 to September 2015. Therefore, recharge rates in these two areas were estimated using the average monthly recharge from the most recent three-year period, depending on data availability. Monthly recharge for model areas corresponding to SCVWD iMOD were available for the entire 1992-2015 period, and therefore utilized directly in the SMPGWM. Managed recharge from Santa Clara Valley facilities were represented as injection wells, which is consistent with the approach utilized in IMOD.

8.4 Updated Model Calibration

A trial-and-error approach was used to calibrate the modeled water-transmitting and storage properties by manually adjusting the parameter values to reduce the discrepancy between model-calculated and measured water levels (the difference between modeled and measured water levels is referred to as the model error or “residuals”). The updated model calibration was completed in two steps. First, the steady-state calibration was updated to provide the spatial distribution of modeled horizontal and vertical hydraulic conductivity that reasonably matched measured median water levels during the period 1987-1996. The model-calculated steady-state water levels provided the initial water levels to the transient model for the 1991-2015 simulation period. Then the transient calibration provided the spatial distribution of modeled specific

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[30] National Oceanic and Atmospheric Administration, Redwood City Station (47339).

storage that reasonably matched the seasonality and trends in measured monthly water levels during 1991-2015.

8.4.1 Water Level Data

The measured water level data utilized to calibrate the SMPGWM were obtained from five primary sources: the Project database; the USGS National Water Information System; DWR's online water data library; ACWD monitoring reports; and various published paper sources. **Figure 8-8** shows the locations of wells where annual median water level data are utilized for the steady-state model calibration. A total of 301 wells with annual median water levels were utilized, and 69 of those wells are located within the Basin. **Figure 8-9** shows the locations of wells where monthly water levels were utilized for the transient model calibration. A total of 418 wells with monthly water levels were utilized to calibrate the transient model, and 79 of those wells are located within the Basin.

8.4.2 Steady-State Calibration Results

The adequacy of the calibration was assessed by comparing calibrated aquifer parameters to corresponding values in local models and reported field testing results, model-calculated and measured water levels in wells, the modeled groundwater-flow directions represented by water level elevation contours, and the model-calculated and estimated Basin water balance.

8.4.2.1 Aquifer Parameters

In most zones the modeled horizontal hydraulic conductivity values fall within the range of the local models, and generally in the lower range of reported aquifer tests (**Figure 8-3**). In the Westside Aprons zone, which generally corresponds to the Basin, the average modeled horizontal conductivity of the shallow aquifer (35 ft/d) is five times greater than the median field-determined value (about 7 ft/d); the horizontal conductivity value still falls within the range of field-determined values and local models. In the deep aquifer, the average modeled conductivity (10 ft/d) is about one half of the median field-determined value (about 22 ft/d), but still within the range of reported values.

The range in vertical conductivity is substantial in the SMPGWM and local models, but in general there is reasonable overlap between similar areas and depth intervals in all models (**Figure 8-10)**. The most notable differences in vertical conductivity ranges occur in the shallow aquifer in the Santa Clara Valley, where the lower limit on the calibrated SMPGWM vertical conductivity is greater than the upper limit within the SCVWD iMOD. This finding could be an indication that recharge rates are too high in the Santa Clara Valley portion of the SMPGWM, and large calibrated vertical conductivity values are required to reduce simulated mounding of the water table and flooding due to high recharge rates.[31]

8.4.2.2 Water Levels

Prior to model re-calibration, initial comparisons indicated that model-calculated water levels were consistently higher than measured water levels in shallow aquifer wells, suggesting an imbalance between recharge and discharge. The imbalance was expected because the specified hydraulic conductivity for the Bay Mud had decreased by about one order of magnitude relative to the previous model calibration, resulting in substantially reduced model-calculated groundwater discharge to San Francisco Bay. The reduction in discharge could not be adequately compensated for by changes in hydraulic conductivity for the aquifer or drains representing outflows to sewers, dewatering operations, or marsh areas. For example, the hydraulic conductivity utilized to calculate conductance for the marsh drains could be increased to remove greater volumes of water from the shallow aquifer and lower water levels. However, model testing showed that the increase in drain conductance required to achieve this response resulted in simulated inflows from the Bay to the marsh drains, which is inconsistent with the conceptual understanding of Basin groundwater moving eastward toward the Bay. Similarly, the shallow aquifer horizontal conductivity for the Bay Plain zone could be increased to move more water eastward towards the Bay. However, increasing shallow aquifer conductivity was not considered reasonable because the average SMPGWM value (19 ft/d) was already greater than most corresponding values determined from aquifer tests and utilized in local models (**Figure 8-3**). Model-calculated water levels were therefore most effectively reduced by decreasing simulated groundwater recharge.

Model testing indicated that an acceptable match was achieved between model-calculated and measured water levels after reducing dispersed recharge 70% in the Bay Plain zone. Because most of the estimated recharge in the Basin occurs near the foothills and the upper portions of the alluvial fans, the 70% reduction within the Bay Plain resulted in an overall net decrease of only about 30% in total dispersed recharge in the Basin. This level of uncertainty is not unreasonable because the recharge calculation considers a large number of input parameters, some of which have uncertain or assumed values. Typically, the most sensitive parameters are those that serve as input into the equations that allocate rainfall to soil infiltration and run-off, the assumed efficiency of irrigation practices, and the specified leakage rates from water supply and sewer lines.

Model-calculated water levels in the Basin did not substantially change as a result of the updated calibration. The model-calculated steady-state water level contours show that the SMPGWM

[31] Groundwater storage increases when modeled inflow (recharge) exceeds outflow (pumping and groundwater discharge). The steady-state assumption assumes groundwater storage does not change, and in the SMPGWM the additional recharge must therefore be compensated by an increase in groundwater discharge. Alternatively, modeled inflow can be decreased by reducing groundwater recharge.

reproduces the general regional aspects of the conceptual groundwater system (**Figures 8-11a and 8-11b**). Water levels in the shallow aquifer decrease towards San Francisco Bay, and inferred flow near San Francisquito Creek moves outward both into the Basin and into the Santa Clara Valley Subbasin. The steepest hydraulic gradients occur near the western bedrock boundary, and the gradients decrease in the lowlands and near the Bay. In the deep aquifer, water levels also decrease towards San Francisco Bay but the horizontal gradients are generally lower as a result of pumping, and there are areas where pumping creates localized water-level depressions.

Model-calculated steady-state water levels are plotted against their corresponding measured values on **Figure 8-12**. All SMPGWM data points generally fall along a line, and linear regression indicates a slope of 0.9, which is close to one (regression equation is not shown on **Figure 8-12)**. Most of the data points are clustered near the center of the plot (water level elevations between -25 and 50 feet msl), and fewer data points are available near the highest and lowest water levels. The distribution of data points that plot above and below the one-to-one line appears fairly uniform across the range in water levels, and the histogram of residuals is approximately normally distributed but shifted slightly to the right (i.e., the positive direction), indicating that model calculated water levels on average tend to be higher than measured (the median of the residuals is 1.5 feet). These general characteristics exist in both shallow and deep portions of the SMPGWM domain.

Within the Basin (lower left portion of **Figure 8-12**), most of the data points also fall along a line, and the histograms of residuals for the shallow and deep aquifer are also shifted slightly to the right indicating that model-calculated water levels have a tendency to be greater than measured.[32] The median shallow aquifer residual is 3.7 feet,[33] and the median deep aquifer residual is 2.0 feet.[34]

The root mean squared error (RMSE) calculated from the residuals of SMPGWM results is almost 17 feet (**Figure 8-12**), which represents less than 5 percent of the total range of measured water levels in the regional groundwater system (almost 400 feet). When the RMSE represents less than 10 percent of the total range of measured water levels, it suggests that the model-calculated water levels are primarily the result of the modeled hydraulic conductivity, recharge and pumping and much less influenced by model error (Anderson and Woessner, 1992). Within the

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[32] Several outliers are noted on **Figure 8-12.** In the shallow aquifer, the measured water level in one well is about 50-feet greater than calculated by the SMPGWM. This well is located at the western edge of the Basin near the bedrock contact and is only 24 feet deep. The texture map for the shallow aquifer indicates subsurface soils are predominantly fine-grained (20-percent or less coarse-grained sediment). The high-water level at this location may therefore not be representative of shallow aquifer conditions. In the deep aquifer, the measured water levels in two wells are about 25 feet greater than calculated by the SMPGWM. These two wells are also located near the bedrock contact.
[33] Median residual calculation excludes outlier wells located near the bedrock contact. *Ibid.* [32]
[34] *Ibid.* [32]

Basin, the RMSE for the shallow and deep aquifers are approximately 6 feet and about 3 feet, respectively, possibly indicating a slightly higher precision in Basin calculated water levels relative to the entire SMPGWM as measured by the RMSE.[35]

The spatial distribution of residuals in the shallow and deep aquifers is shown on **Figures 8-13a** and **8-13b** to identify potential geographic areas where model bias occurs. The residuals are both positive and negative; positive residuals indicate that model-calculated water levels are greater than measured water levels, and negative residuals indicate that model-calculated water levels are less than measured water levels. In the shallow aquifer, most Basin wells have small positive residuals with outliers occurring in wells closest to bedrock. The largest residuals in absolute value occur in the Merced Zone (north of the Basin) and in the Upper Niles Cone east of the Hayward Fault. In the deep aquifer, wells in the Basin have both negative and positive residuals that are small in value. The largest residuals also occur in areas near bedrock, and the affected wells are located in the Merced Zone, Eastside Aprons, and Westside Apron-South. In these upslope areas recharge rates are typically the greatest (**Figure 8-7**).

8.4.2.3 Updated Steady-State Water Budget

Model simulation results from the SMPGWM were used to develop water budgets for the entire SMPGWM area (i.e., a regional water budget) and for the Basin subarea. The water budgets were developed using the updated steady-state model. The SMPGWM specifies an average annual net recharge rate over this time period of about 171,000 AFY, over 60% of which (109,000 AFY) occurs in the Santa Clara Valley zones. The model also includes almost 157,000 AFY of groundwater pumped annually from the regional groundwater system. About 67% of the extracted groundwater (more than 105,000 AFY) occurs in the Westside Apron South and San Jose Plain zones. The balance between inflows and outflows results in a net discharge of almost 9,600 AFY as seepage from groundwater to the Pacific Ocean and San Francisco Bay. Most (67%) of the groundwater discharge is seepage from the shallow aquifer to San Francisco Bay (6,400 AFY). The groundwater discharge to San Francisco Bay is largely controlled by the Bay Mud conductivity, which was specified everywhere in the model as 0.0015 ft/d based on the results from the tidal method analysis performed with data from a shallow monitoring well located in East Palo Alto.

The model-calculated steady-state water budget for the Basin is summarized below in **Table 8-1.** Also shown in **Table 8-1**, for comparison, are the water balance components estimated independently as described in Section 7. Specified and model-calculated inflows total 7,800 AFY. Because the SMPGWM is a steady-state approximation of the average water balance, inflows and outflows are equal. Model-calculated outflows (7,800 AFY) include specified pumping rates estimated for all known wells (2,600 AFY), shallow zone extractions attributed to dewatering operations (1,000 AFY), head-dependent discharge attributed to seepage into sewer pipes

[35] RMSE calculations exclude outlier wells located near the bedrock contact. *Ibid.* [32]

(1,300 AFY), and discharge into channels and evapotranspiration from riparian/wetland areas of the mudflats adjacent to the Bay (2,200 AFY).

Table 8-1. Estimated Basin Water Balance and Steady-State Model-Calculated Water Budget for San Mateo Plain Groundwater Subbasin

	Estimated Basin Water Balance			Steady-State Model-Calculated Water Budget
	Average	Plausible Range		
Inflows (AFY)(1)				
Dispersed Recharge	4,800	3,300	9,000	4,700(2)
Stream Percolation				
San Francisquito Creek	600	400	800	600(3)
San Mateo Creek	200	200	400	200
Other creeks	500	200	800	500
Bedrock Inflow	600	100	1,000	600
Inflow from the South (from Santa Clara Subbasin)	1,200	500	2,000	1,200
Inflow from the East (beneath San Francisco Bay)	0	0	0	0
Total Inflows	*7,900*			*7,800*
Outflows (AFY) (1)				
Wells	2,500	1,600	4,200	2,600
Dewatering	1,000	500	1,500	1,000
Groundwater Seepage				
Riparian ET	100	50	150	2,200(4)
Creeks and Tidal Wetlands	2,200	1,600	3,200	
Sewers	1,400	900	2,100	1,300
Outflow to the East (beneath San Francisco Bay)	500	300	1,000	500
Outflow to the North (to Westside Basin)	200	-100	200	200
Total Outflows	*7,900*			*7,800*

Notes:
1) All values shown are rounded to the nearest 100 AFY.
2) Dispersed recharge calculated with the recharge simulation model was reduced 70% in the Bay Plain prior to use as input to the SMPGWM to improve model calibration, which resulted in a 32% reduction in total modeled dispersed recharge specified in the Basin.
3) The Basin boundary is aligned with San Francisquito Creek. The stream percolation inflow value reflects 50% of the total simulated leakage from the creek of approximately 1,200 AFY.
4) Model-calculated groundwater seepage outflow represents the combined flow from riparian ET and creeks and tidal wetlands.

Model calculated subsurface inflow from the Santa Clara Subbasin is 1,200 AFY. Groundwater inflow from Santa Clara Subbasin is sensitive to leakage from San Francisquito Creek due to the creek's effect on hydraulic gradients. Model-calculated leakage was 1,200 AFY, which is greater than estimated by Sokol (1964) and Metzger (2002) (650 AFY and 950 AFY, respectively), but lower than estimated from recent field observations (Section 7.2.5) along the upstream and middle sections of the creek (almost 1,600 AFY).[36] Metzger (2002) reported that measuring stream gains/losses in the middle and lower sections of San Francisquito Creek was difficult due to the inflow of urban runoff from up to 12 large storm drains.

8.4.3 Transient Results

Unlike the steady-state model, the transient model requires specification of aquifer storage properties (specific storage). The transient model was calibrated by adjusting aquifer storage properties (specific storage) to match seasonal and longer-term trends in measured water levels. The adequacy of the transient model calibration was assessed by comparing the calibrated specific storage values to corresponding values in local models and reported field testing results, and the measured changes in model-calculated and measured water levels over time.

8.4.3.1 Aquifer Parameters

The spatial distribution of specific storage was modeled using the physiographic zones (**Figure 8-2**). The specific storage value in the Bay Plain zones was based on the analysis of the measured tidal response monitoring well water levels (see Section 6.2.6). The specific storage values for other zones were obtained from local models, where available, and adjusted as part of model calibration. In most zones, calibration adjustments were minor; however, in some cases the calibrated storage values fell outside the range of values in the local models. For example, in the deeper layers of the Westside Aprons and Eastside Aprons south zones the calibrated specific storage value is two orders of magnitude greater than the specified initial values. The larger values were needed to correct for excessive seasonality in the model results for these zones – prior to the adjustment the model-calculated seasonal water level changes were too great compared to the measured changes.

As discussed above in Section 8.2, the Westside Apron physiographic zone was split into three zones representing the spatial distribution of inferred semi-confined and confined portions of the Basin (**Figure 8-2**). The delineation of semi-confined and confined zones was based on surficial geology, sediment texture maps, and water level hydrographs. As part of model calibration, the specific storage for the shallow aquifer in the Westside Aprons zone was specified as $5x10^{-4}$ based on visual comparisons between model-calculated and measured seasonal changes in water levels. In the upslope portion of the Westside Aprons (physiographic zones 16 and 17 on **Figure 8-2**), the measured seasonality in water levels is less pronounced, indicating that groundwater is less confined in these upslope areas and modeled specific storage values needed to be set higher. The specific storage was therefore increased in zones 16 and 17 from $5x10^{-4}$ to $2.5x10^{-3}$, which improved the match between model-calculated and measured water levels.

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[36] *Ibid* [26]

8.4.3.2 Water Levels

In the transient model, the discrepancies between model-calculated and measured water levels are influenced by the magnitude, location, and timing of recharge and pumping, the modeled distribution of aquifer parameters (hydraulic conductivity and specific storage), and discrepancies in specified initial water levels (the discrepancies in the steady-state calibration). Model-calculated water levels from the transient model are plotted against their corresponding measured values on **Figure 8-14**. The data points generally fall along a line and linear regression indicates a slope of 0.7 (the regression equation is not shown on **Figure 8-14)**. Model-calculated water levels tend to be slightly lower than measured (median difference between model-calculated and measured water levels is -0.7 feet). The RMSE calculated from the residuals based on all wells in the SMPGWM area is 30.7 feet (**Figure 8-14**), which is almost double the RMSE calculated for the steady-state model (17 feet). The higher RMSE represents the accumulation of discrepancies between model-calculated and measured water levels during the 25-year simulation period, especially at locations where there is a large discrepancy in initial conditions. In the transient calibration, model-calculated water levels are compared to over 27,000 measured water levels, whereas in the steady-state calibration model-calculated water levels are compared to less than 300 measured water levels.

The lower left portion of **Figure 8-14** shows the comparison of 2,455 model-calculated and measured water levels at various locations within the Basin, and most of the data points also fall along a line.[37] In the shallow aquifer, the median difference between model-calculated and measured water levels is 7.8 feet,[38] and in the deep aquifer the median difference is 1.2 feet. These positive median differences indicate that model-calculated water levels tend to be greater than measured. The RMSE for the shallow and deep aquifers are both about 7 feet.[39]

The transient model calibration was also assessed by examining hydrographs throughout the SMPGWM area (**Figures 8-15a** and **8-15b**)**.** The wells plotted in these figures were selected to represent the general range in model performance, with some selected to show comparisons between model-calculated**,** and measured water levels that are fairly good, and other locations where the comparisons can be considered relatively poor. Overall, model-calculated water levels and trends compare fairly well with measured conditions, but model performance is spatially variable. For example, in the deep aquifer there is fairly good agreement between model-calculated water levels and observed trends in the Niles Cone subarea, whereas in the Westside Aprons south and San Jose Plain subareas the comparisons are less favorable.

In the Basin, the comparisons between model-calculated and measured water level hydrographs are fairly good, but discrepancies exist (**Figure 8-15c**). In the northern portion of the Basin, model-

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[37] Several outliers are noted on **Figure 8-14**. *Ibid.* [32]
[38] Median residual calculation excludes outlier wells located near the bedrock contact. *Ibid*. [32]
[39] RMSE calculations exclude outlier wells located near the bedrock contact. *Ibid.* [32]

calculated and measured water level trends generally agree in wells W445, W448, W279 and W446, but the measured seasonal high and low levels can be more pronounced than simulated by the model (e.g., see well W445). All the observation wells in this portion of the Basin are shallow monitoring wells, with screened intervals corresponding to the upper portion of model layer 1, and the lower seasonal variability characterized by the model could indicate uncertainty in specified storage properties representing the entire thickness of the shallow aquifer. In other wells, the model-calculated trend and seasonality is reasonable but the magnitude of the water levels can be 5 to 10 feet too high (e.g., W279 and W446). These discrepancies are likely due to deficiencies in specified initial water levels represented by the uncertainty in the steady-state calibration. Similar comparisons exist in the San Francisquito Cone portion of the Basin; however, the discrepancies between model-calculated and measured water levels exist in some wells as a result of greater data uncertainty. For example, the comparison is relatively poor for well W214, which is a public supply well, and variability in measured water levels may reflect recently pumped conditions not represented by the model-calculated water levels.

8.4.3.3 Volumetric Water Budget

The annual model-calculated inflow (net recharge), outflow (extractions), and groundwater storage changes from the transient model are shown on **Figure 8-16a**, and a similar plot for the Basin is provided in **Figure 8-16b**. Groundwater storage increases when net recharge exceeds extractions, and storage decreases when recharge is less than extractions. Within the Basin, there has generally been a small decline in model-calculated and measured water levels over time (**Figure 8-15a**), corresponding with the simulated decline in groundwater storage. The average annual 1992-2015 water budget for the Basin based on results from the transient model is summarized below in **Table 8-2**. Compared to the average over the period 1987-1996 simulated by the steady-state model, total inflows in the WY 1992-2015 transient model were 300 AFY lower, including 200 AFY lower stream percolation and 200 AFY lower inflow from the Santa Clara Subbasin. Total outflows were 100 AFY lower. While specified well extractions, seepage into sewers, and discharge to channels and wetlands all increased (by 100 AFY, 100 AFY, and 300 AFY, respectively), these greater outflows lowered water levels, resulting in a 100 AFY decrease in northward subsurface outflow into the Westside Basin, and a complete capture of the 500 AFY of subsurface flow that previously (in the steady-state model) discharged eastwards out of the Basin. The difference between inflows and outflows indicated an overall modeled 200 AFY decrease in groundwater storage. To put this storage decrease in perspective, it represents at most 0.02% of the more than estimated one million AF of total water storage in the Basin.[40] It should be noted, however, that most of this water in storage is inaccessible for beneficial use owing to negative effects that would occur from excessive drawdown if it were to be pumped (e.g., potential seawater intrusion, subsidence, and de-watering of interconnected creeks and streams).

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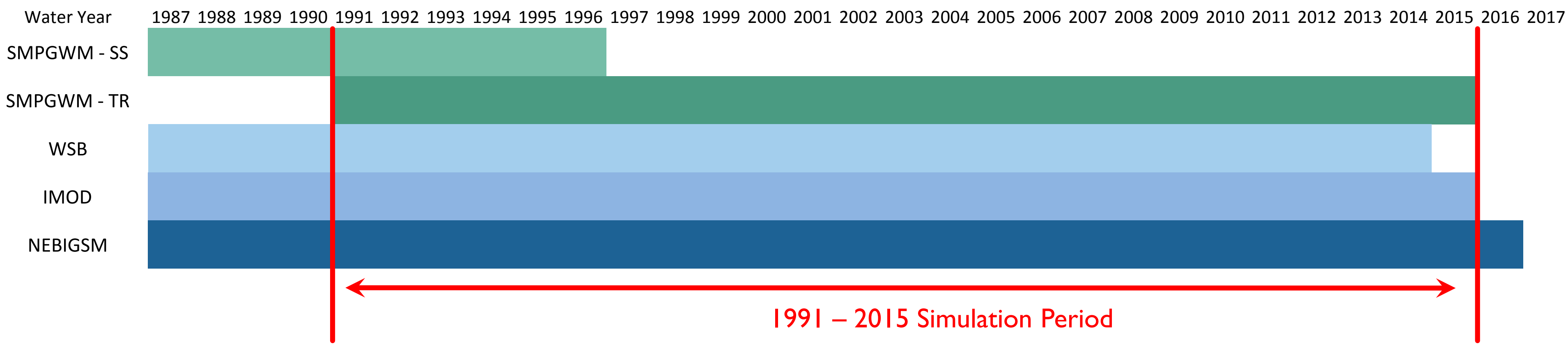
[40] The total volume of storage in the Basin was estimated using 1987-1996 water levels from the steady-state simulation and assuming a specific yield of 10%.

Table 8-2. Steady-State and Transient Model-Calculated Water Budgets for San Mateo Plain Groundwater Subbasin

	Model-Calculated Water Budgets	
	Steady-state (WY 1991)	**Transient Average (WY 1992-2015)**
	Inflows (AFY)[1]	
Dispersed Recharge	4,700	4,700
Stream Percolation		
San Francisquito Creek	600[2]	400[2]
San Mateo Creek	200	200
Other creeks	500	500
Bedrock Inflow	600	600
Inflow from the South (from Santa Clara Subbasin)	1,200	1,100
Inflow from the East (beneath San Francisco Bay)	0	0
Total Inflows	*7,800*	*7,500*
	Outflows (AFY)[1]	
Wells	2,600	2,700
Dewatering	1,000	1,000
Groundwater Seepage		
Riparian ET	2,200[3]	2,500[3]
Creeks and Tidal Wetlands		
Sewers	1,300	1,400
Outflow to the East (beneath San Francisco Bay)	500	0
Outflow to the North (to Westside Basin)	200	100
Total Outflows	*7,800*	*7,700*
	Change in Storage (AFY)	
Storage Change	NA	-200[4]

Notes:
1) All values shown are rounded to the nearest 100 AFY.
2) The Basin boundary is aligned with San Francisquito Creek. The stream percolation inflow value reflects 50% of the total simulated leakage from the creek.
3) Model-calculated outflow represents the combined flow from the two estimated water budget components.
4) Storage change determined by balance of total inflow and outflow.



SMPGWM – SS	San Mateo Plain Groundwater Model – Steady State (Water Years 1987-1996)
SMPGWM – TR	San Mateo Plain Groundwater Model - Transient (Water Years 1992-2015)
WSB	Westside Basin Model (Water Years 1959-2014)
IMOD	Santa Clara Valley Water District Model (Water Years 1985-2015)
NEBIGSM	Niles Cones and South East Bay Plain IGSM (Water Years 1965-2016)

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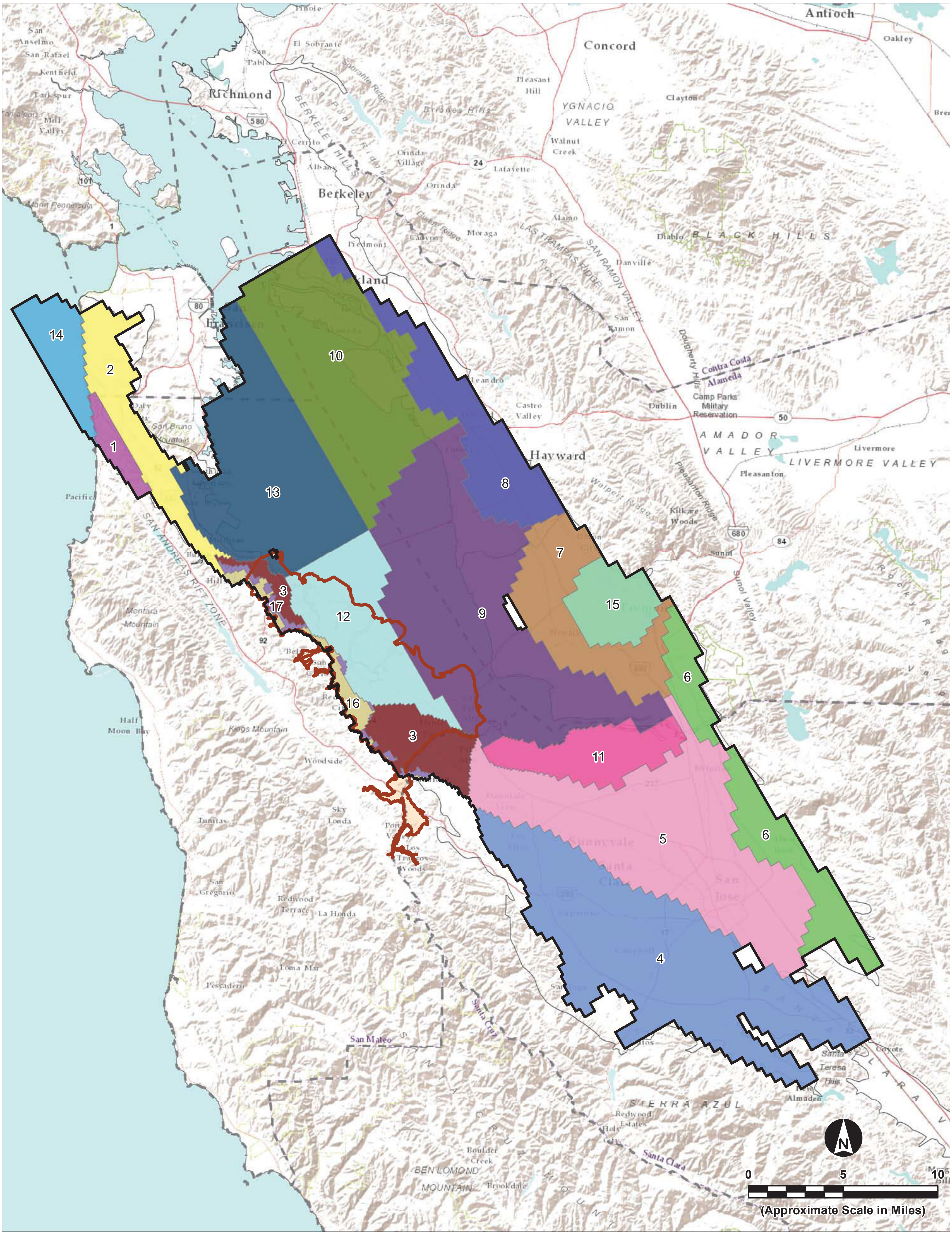
Model Simulation Periods

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-1



Legend

San Mateo Plain Subbasin

San Mateo Plain Groundwater Flow Model Boundary

County Boundary

Physiographic Zones

1	Merced Uplands (MU)
2	Merced (ME)
3	Westside Aprons (WA)
4	Westside Aprons south (WAs)
5	San Jose Plain (SP)
6	Eastside Aprons south (EAs)
7	Niles Cone (NC)
8	Eastside Aprons (EA)
9	Bay Plain-Niles Cone (BP-NC)
10	Bay Plain-Eastside Aprons (BP-EA)
11	Bay Plain-San Jose Plain (BP-SP)
12	Bay Plain-Westside Aprons (BP-WA)
13	Bay Plain-Merced (BP-ME)
14	Ocean (OC)
15	Niles Cone-Upper Fan (NC-UP)
16	Westside Aprons-Layer 1 only (WA-1)
17	Westside Aprons-Layers 1&2 only (WA-12)

Notes

1. All locations are approximate.
2. Contours for the shallow aquifer are from model layer 1.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 12 January 2018.

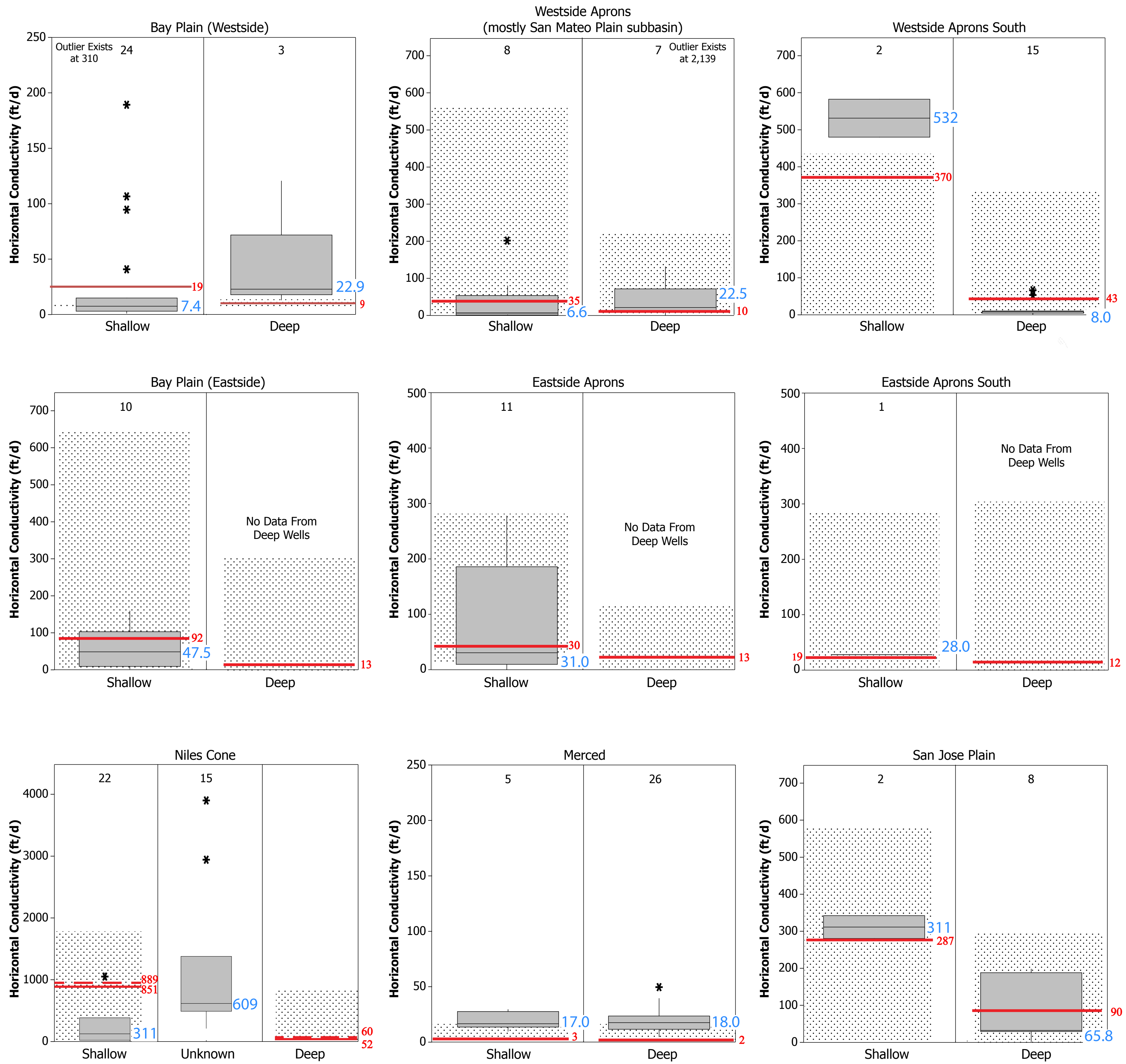
Physiographic Zones of the San Mateo Plain Groundwater Flow Model

San Mateo County, California

June 2018

EKI B60024.00

Figure 8-2



Legend

15 number of samples

* outlier

maximum

75th percentile

median 8.0

25th percentile

minimum

10 Average SMPGWM value

For Niles Cone:

upper fan

mid and lower fan

Range of horizontal conductivity values inferred from the WSBM, SCVM, and NEBIGSM models*

"Shallow" signifies wells with depths of 150 feet or less.

"Deep" signifies wells with depths of greater than 150 feet.

* Subareas located in Santa Clara Valley also included modeled conductivity values reported in "Hydrogeologic analysis of Santa Clara groundwater basin," MS Thesis, Stanford University, 1991.

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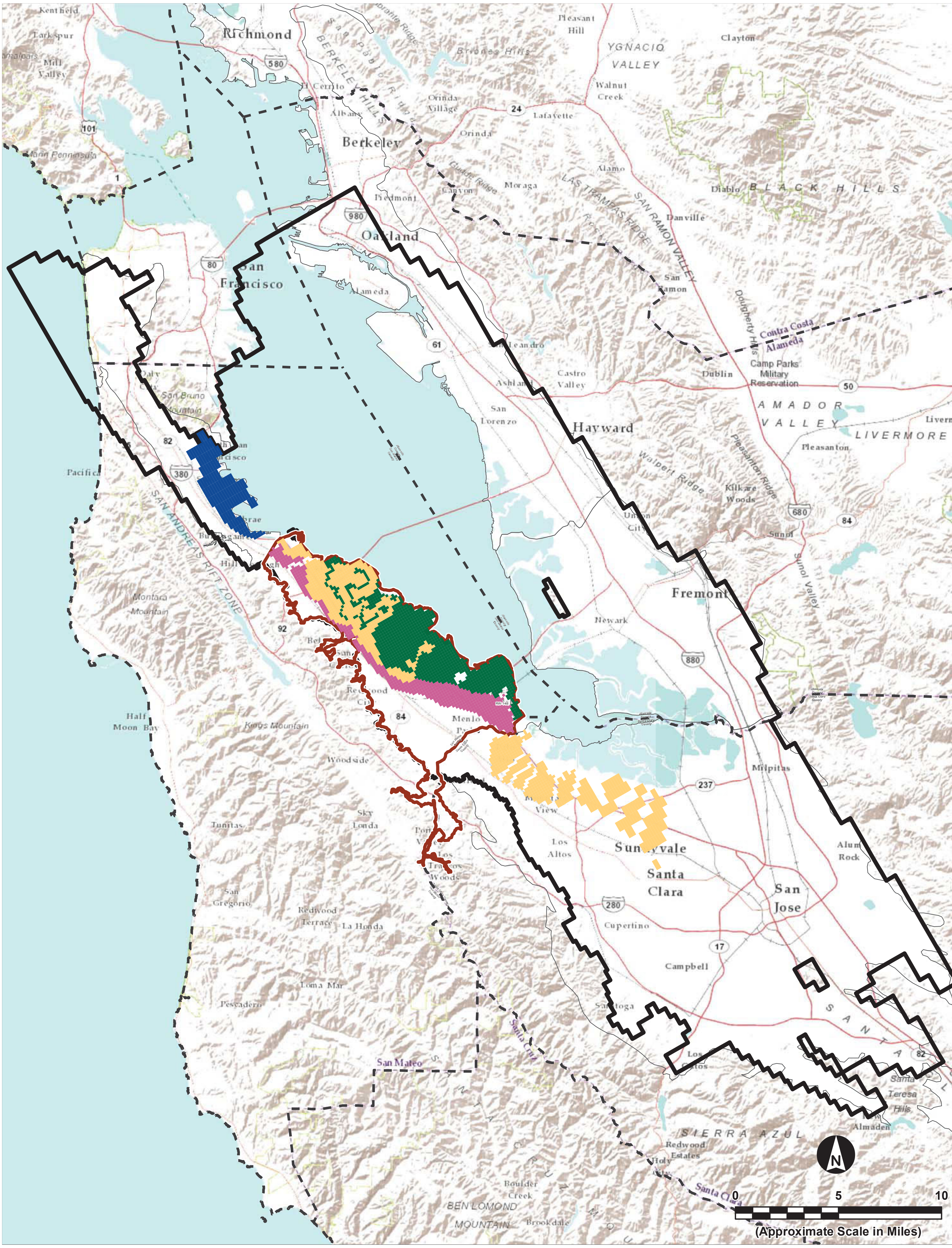
Boxplots of Aquifer Test results, Local Model Hydraulic Conductivity, and San Mateo Plain Groundwater Flow Model Calibrated Hydraulic Conductivity by Physiographic Zone

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-3



Path: P:\Projects\5075-2_San Mateo Plain GW\GIS\Maps\Report Figures\Fig6-6_drains.mxd

Legend

- San Mateo Plain Subbasin
- SMPGWM Boundary
- County Boundary

Drain Cells

- Marsh - Westside Basin
- Sewer - San Mateo Plan Subbasin and Santa Clara Subbasin
- Marsh - San Mateo Plain Subbasin
- Dewatering - San Mateo Plain Subbasin

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 18 January 2018.

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Drain Cells

San Mateo Plain Goundwater Subbasin

San Mateo County, California

June 2018

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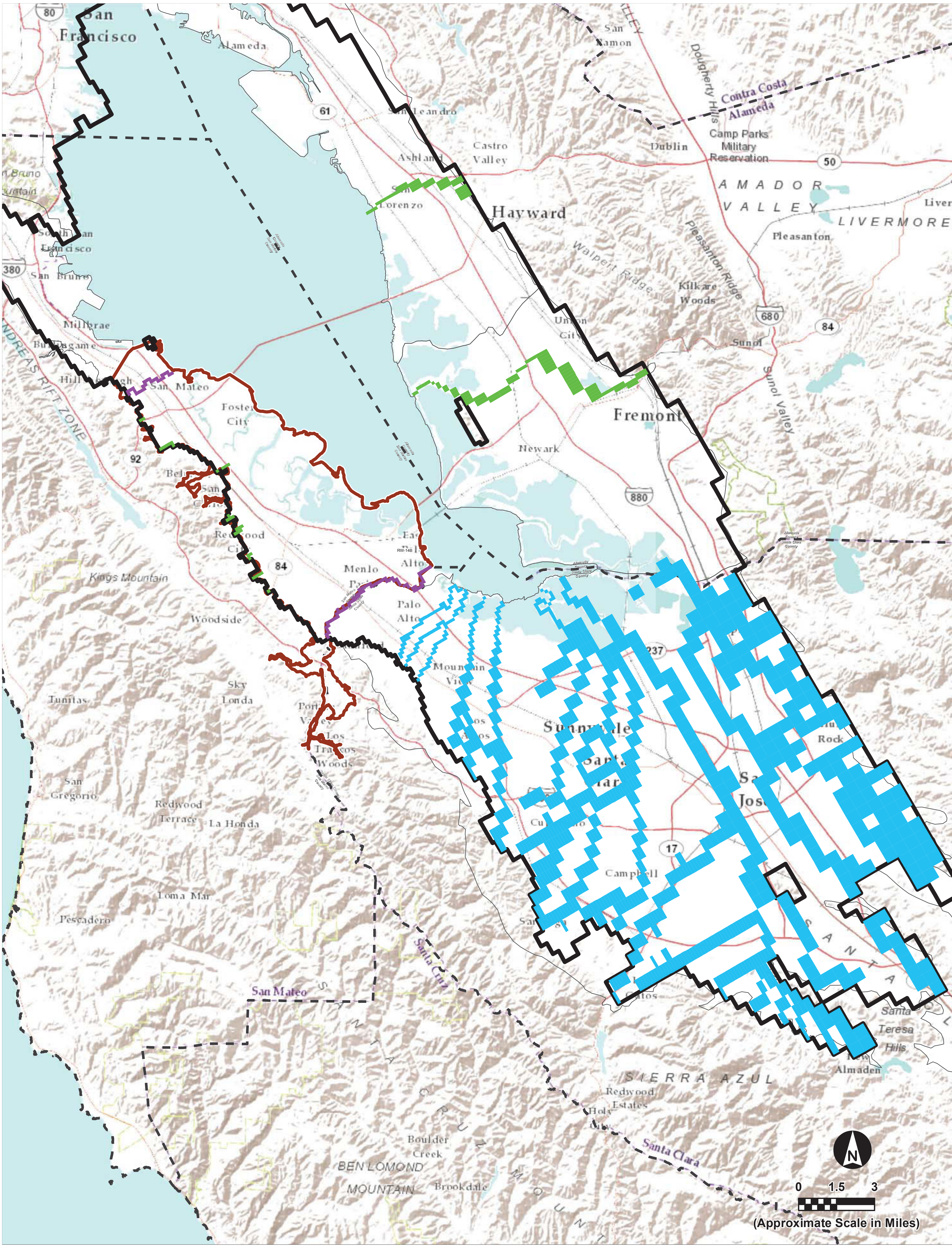
Figure 8-4



Path: P:\Projects\5075-2_San Mateo Plain GW\GIS\Maps\Report Figures\Fig6-7_streams.mxd

Legend

- San Mateo Plain Subbasin
- SMPGWM Boundary
- County Boundary

Stream Cells

- STR Package
- RIV Package
- Recharge Package

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 12 January 2018.

Stream Cells

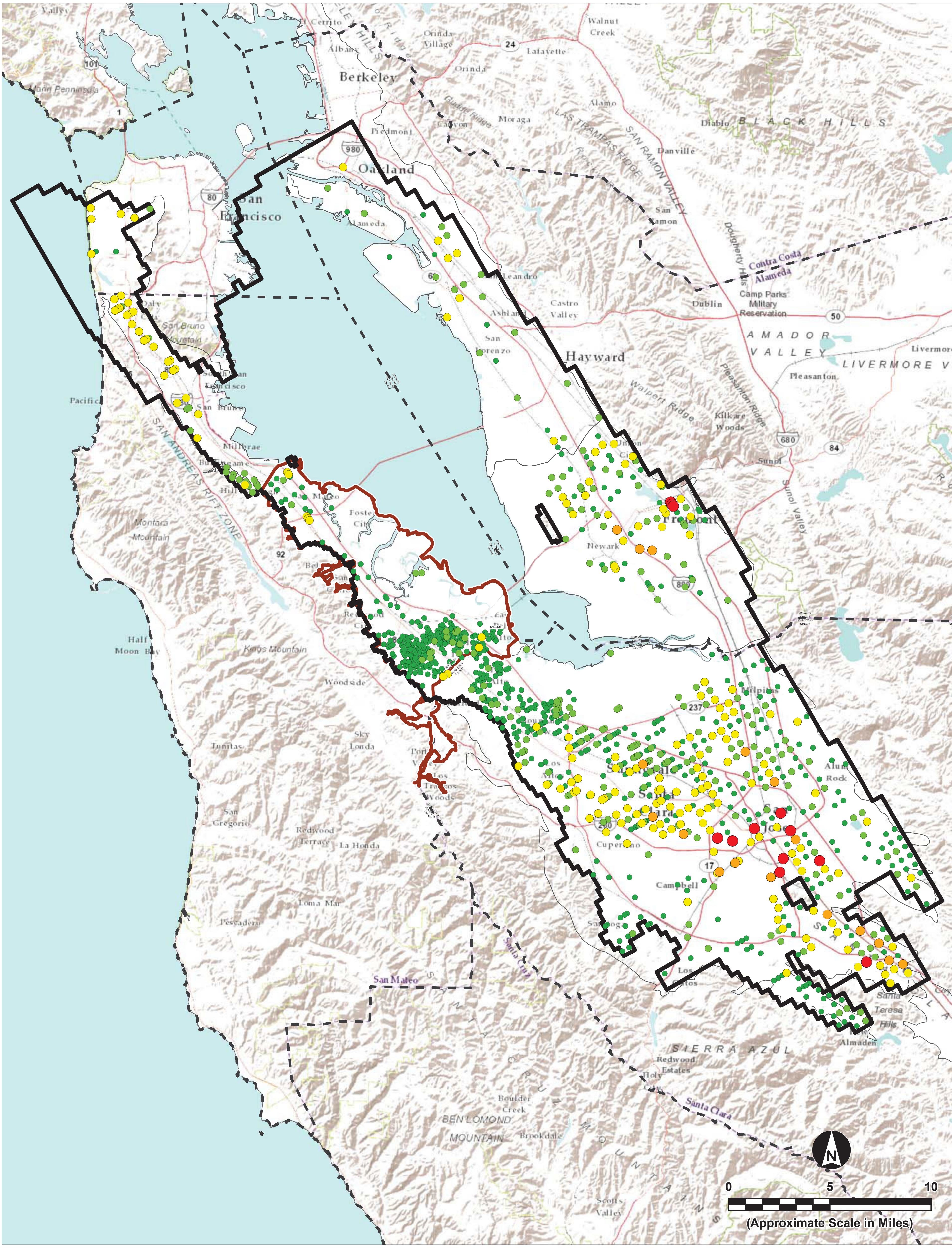
San Mateo Plain Groundwater Subbasin

San Mateo County, California

June 2018

EKI B60024.00

Figure 8-5



Path: P:\Projects\5075-2_San Mateo Plain GW\GIS\Maps\Report Figures\Fig6-8_Pumpage 1 panel.mxd

Legend

- San Mateo Plain Subbasin
- SMPGWM Boundary
- County Boundary

SMPGWM Groundwater Pumping (AFY)

- < 10
- 10 to 100
- 100 to 1,000
- 1,000 to 2,500
- > 2,500

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 11 January 2018.

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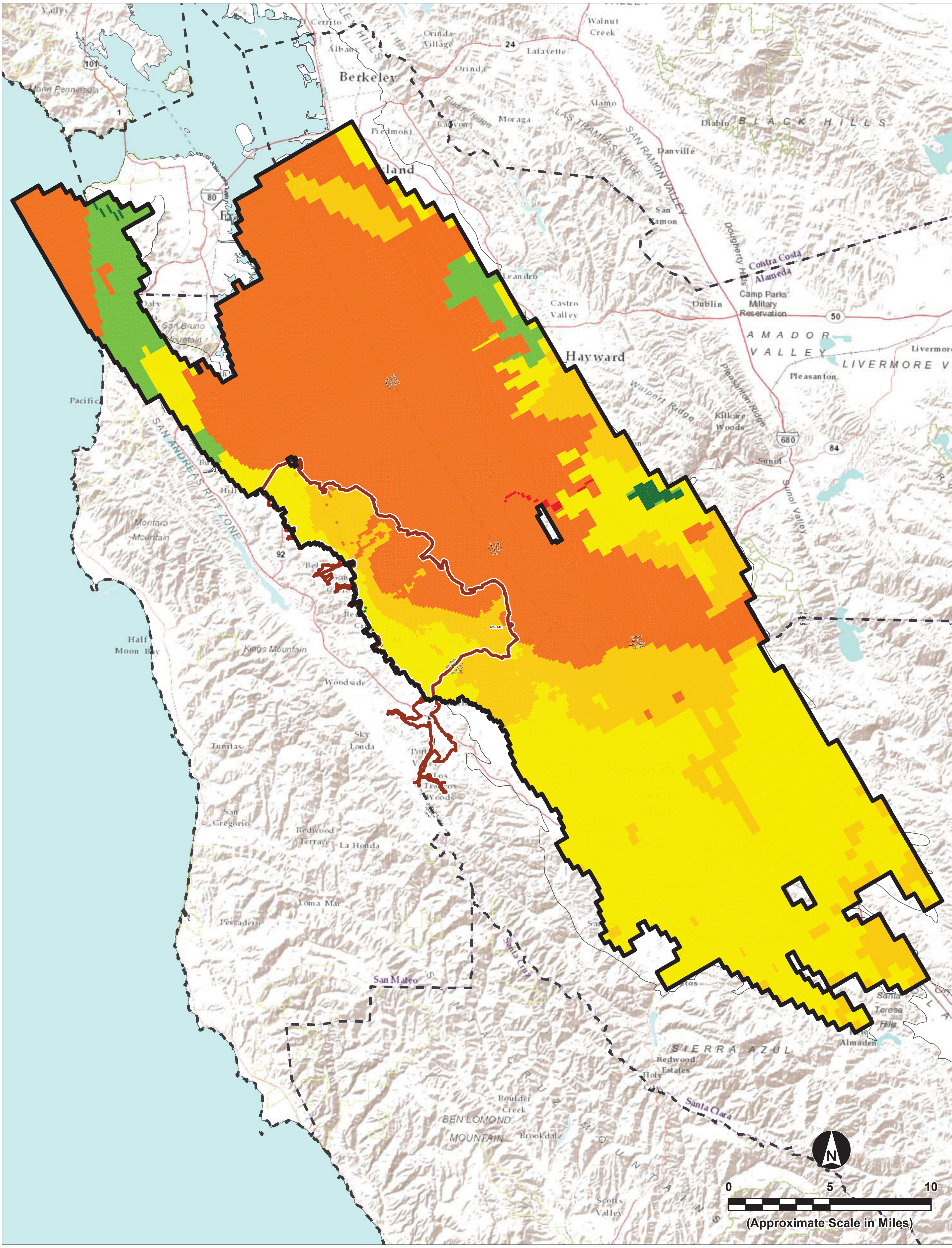
Distribution of Average Annual Groundwater Pumping

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-6



Path: P:\Projects\5075-2_San Mateo Plain GW\GIS\Maps\Report Figures\Fig6-9_Recharge 1 panel.mxd

Legend

- San Mateo Plain Subbasin
- SMPGWM Boundary
- County Boundary

SMPGWM Recharge (inches/yr)

- < 0.0
- 0.0
- 0.004 - 2.5
- 2.5 - 6
- 6 - 12
- > 12

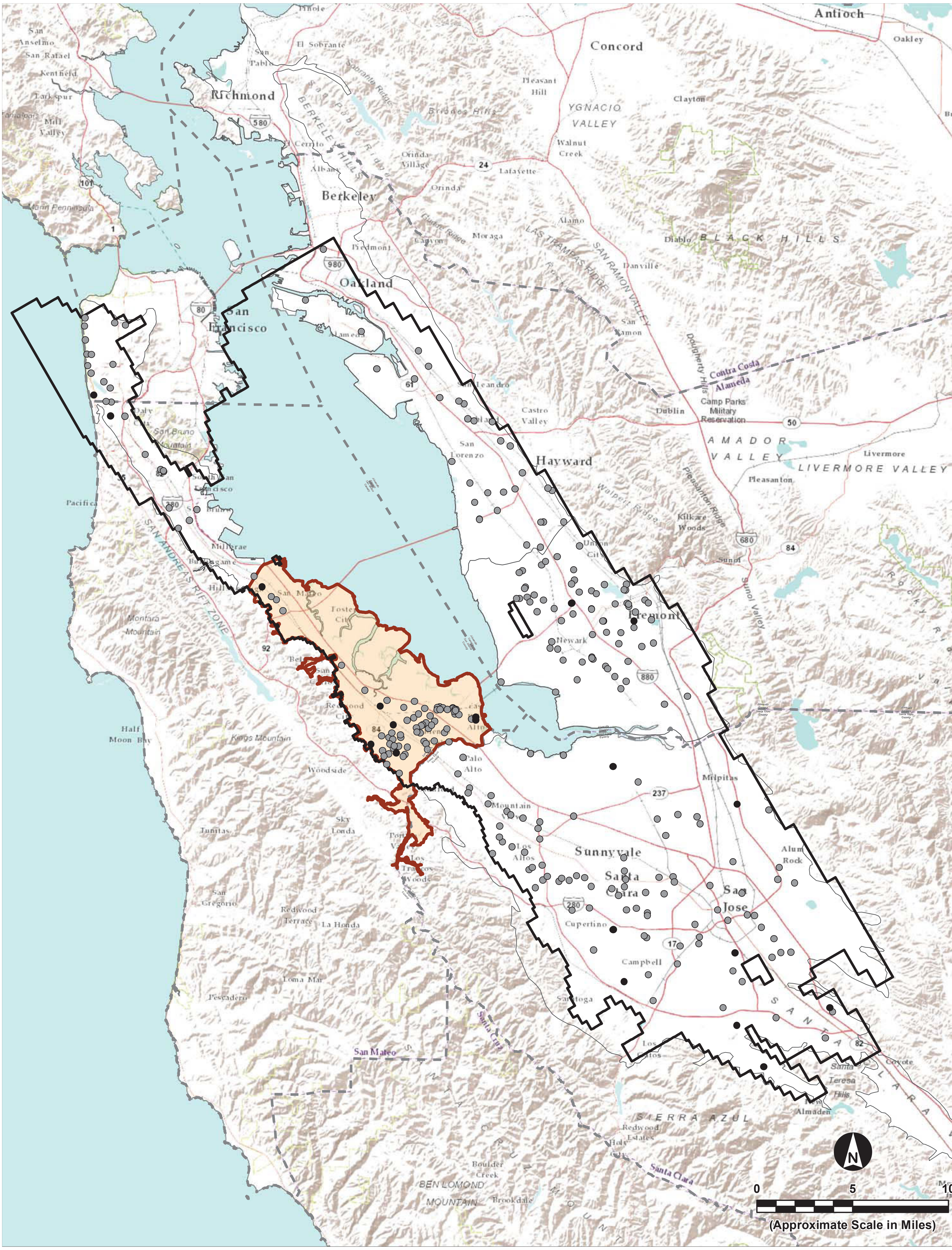
Notes
1. All locations are approximate.

Sources
1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 12 January 2018.

Distribution of Average Annual Recharge

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-7



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Phase 1 Steady State Well
- Phase 2 Added Steady State Well
- County Boundary

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 12 January 2018.

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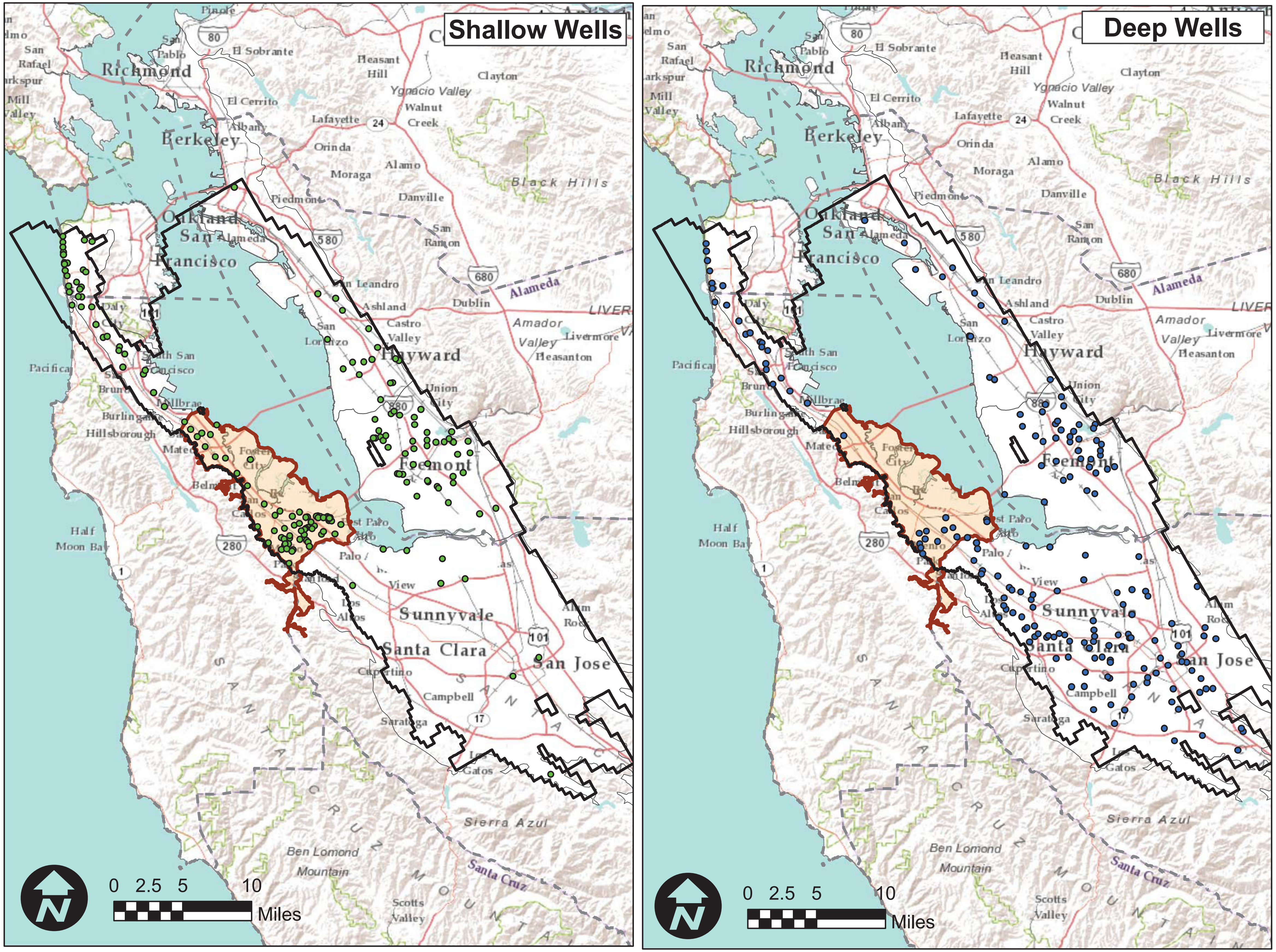
Steady-State Calibration Wells

San Mateo County, California
June 2018
EKI B60024.00

Figure 8-8



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- County Boundary
- Shallow Well
- Deep Well

Notes

1. All locations are approximate.
2. Shallow wells are from model layers 1 and 2.
3. Deep wells are from model layers 3, 4 and 5.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 12 January 2018.

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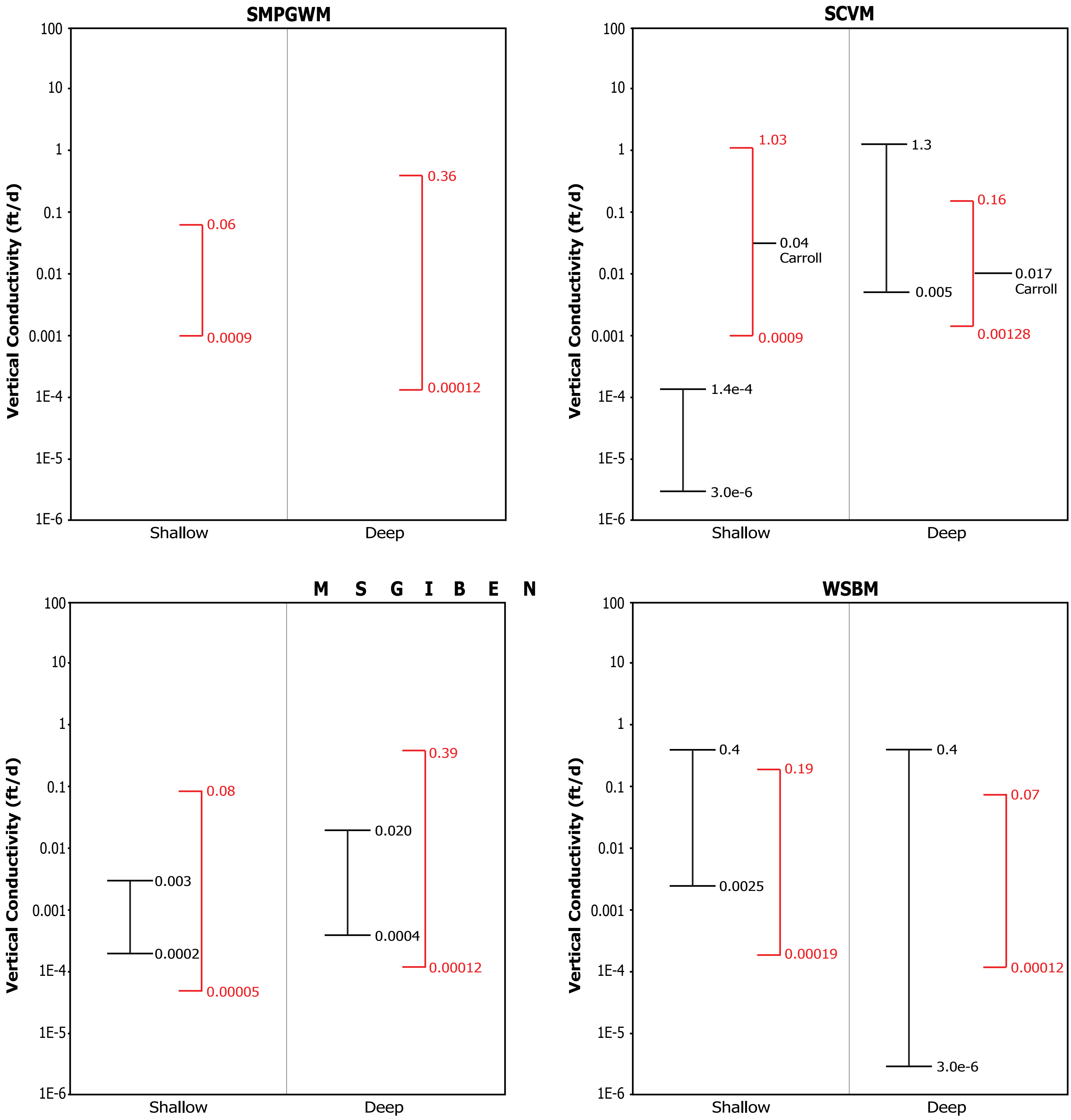
Shallow and Deep Transient Calibration Wells

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-9



Legend

0.06 / 0.0009 — Range of vertical K values (SMPGWM)

1.3 / 0.005 — Range of vertical K values (local models)

SMPGWM - San Mateo Plain Groundwater Flow Model
SCVM - USGS Santa Clara Valley Model
Carroll - "Hydrogeologic analysis of the Santa Clara groundwater basin," MS Thesis, Stanford University, 1991.
NEBIGSM - Niles Cone and South East Bay Plain Model
WSB - Westside Basin Model

Notes
1. Shallow signifies wells with depths of 150 ft. or less.
Deep signifies wells with depths of greater than150 ft.

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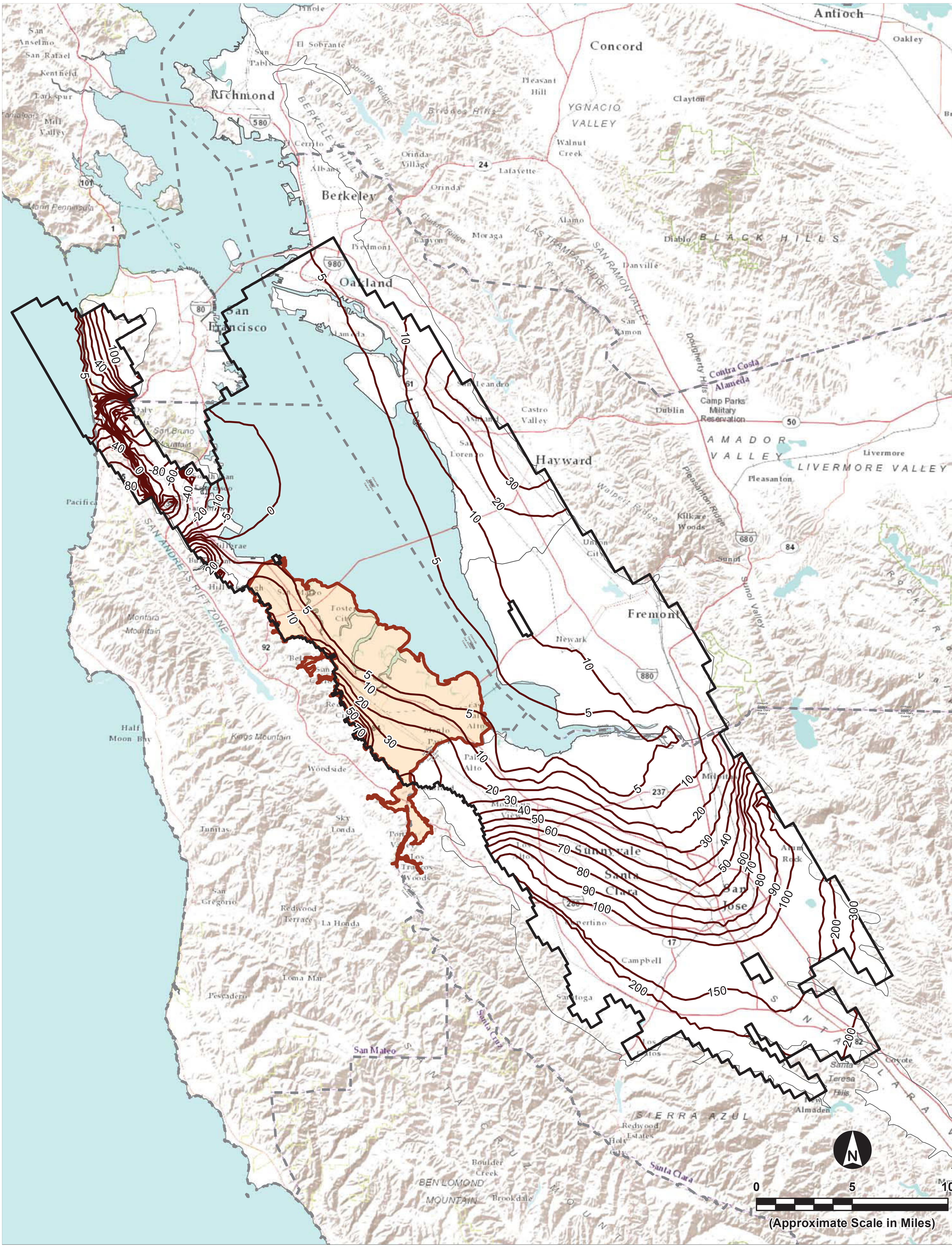
Modeled Vertical Hydraulic Conductivity Utilized in Local Models and Calibrated Vertical Conductivity in the San Mateo Plain Groundwater Flow Model
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-10



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Model-Calculated Groundwater Elevation Contours (ft; NAVD 88)
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the shallow aquifer are from model layer 1.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 12 January 2018.

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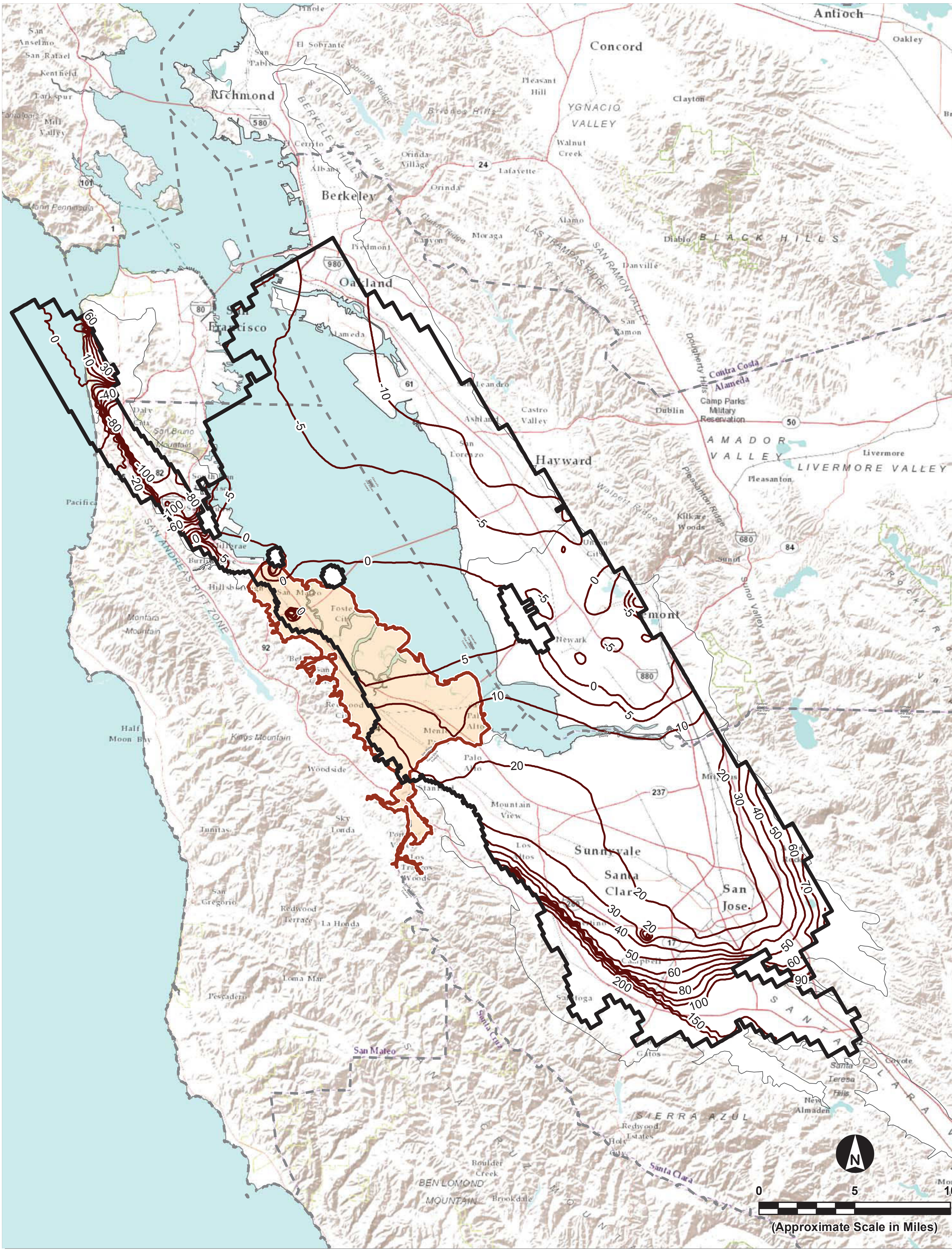
Steady-State Model-Calculated Groundwater Levels for the Shallow Aquifer

San Mateo County, California
June 2018
EKI B60024.00

Figure 8-11a



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Layer 3 Boundary
- 10 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88)
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the deep aquifer are a weighted average of model layers 3, 4, and 5 based on model layer thickness.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 17 January 2018.

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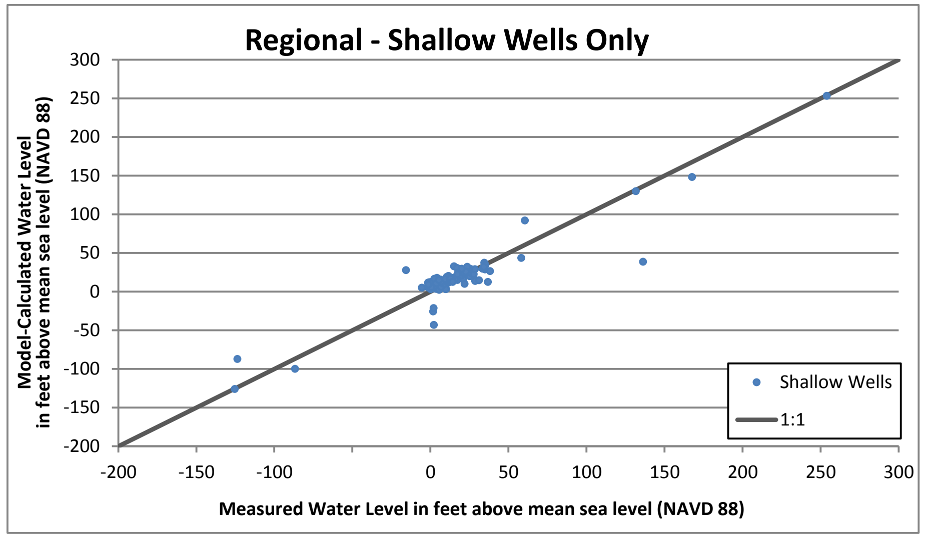
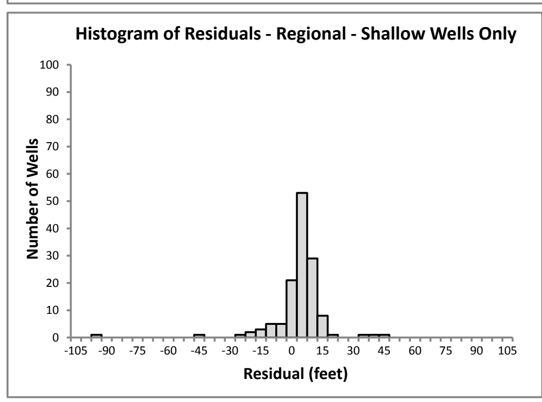
Steady-State Model-Calculated Groundwater Levels for the Deep Aquifer

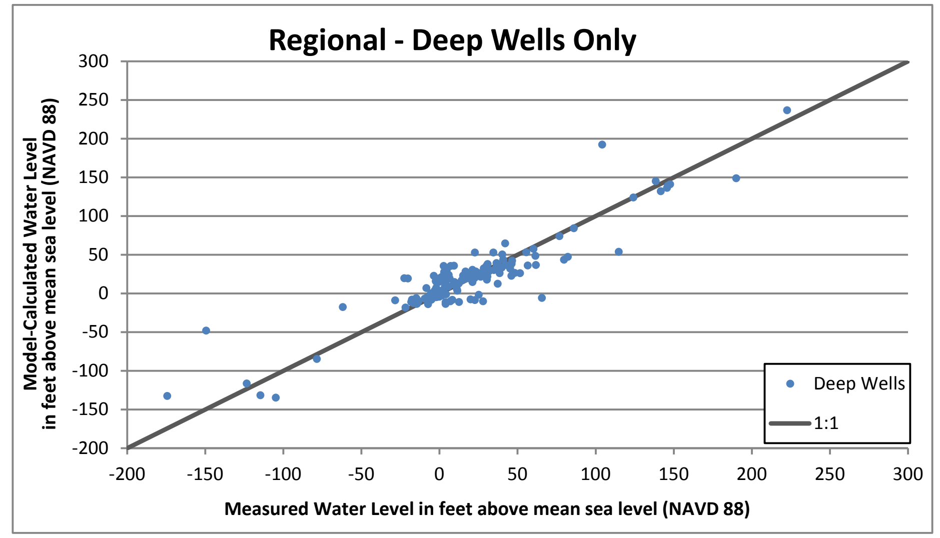
San Mateo County, California
June 2018
EKI B60024.00
Figure 8-11b

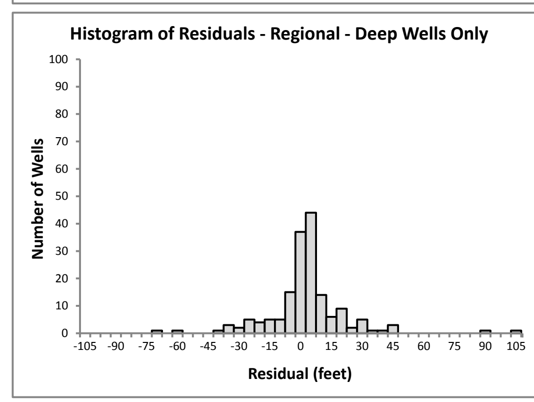




Error Statistics (in feet)

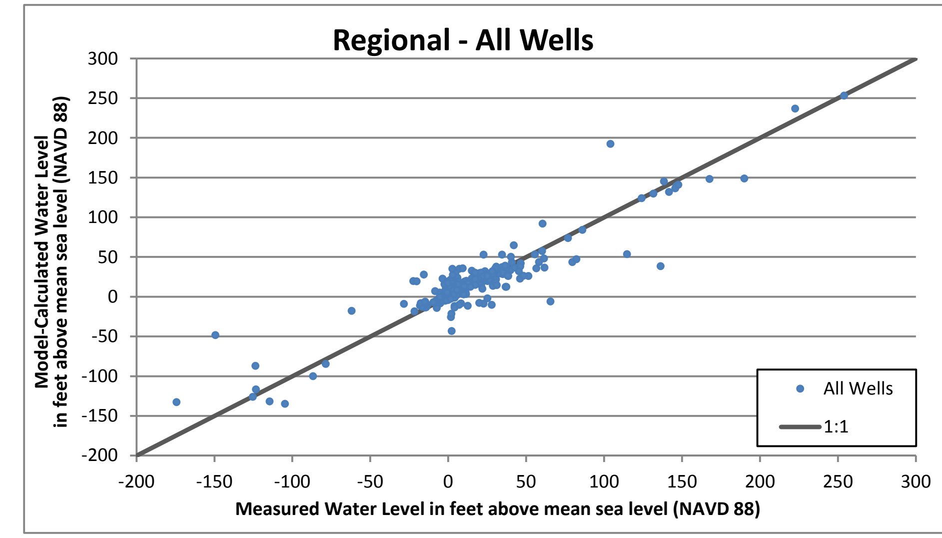
RMSE: 13.3
Min residual: -98.2
Max residual: 43.0
Mean residual: 1.2
Median residual: 2.9

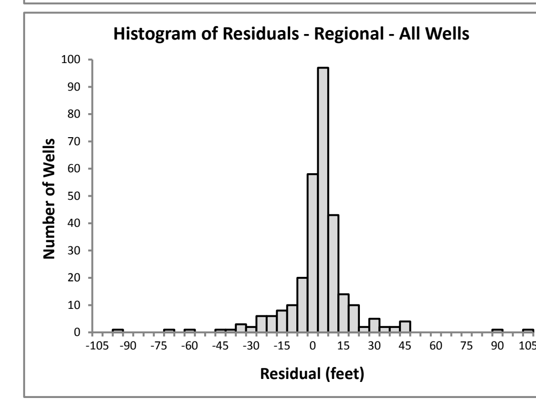




Error Statistics (in feet)

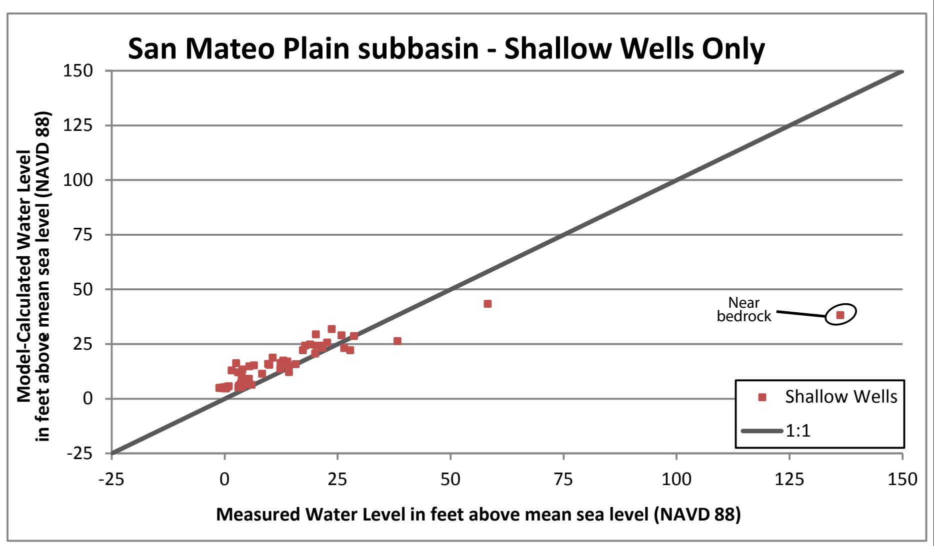
RMSE: 19.2
Min residual: -71.9
Max residual: 101
Mean residual: 0.5
Median residual: 0.6

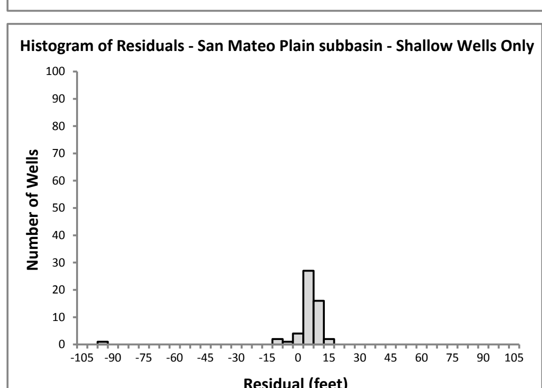




Error Statistics (in feet)

RMSE: 16.8
Min residual: -98.2
Max residual: 101
Mean residual: 0.8
Median residual: 1.5

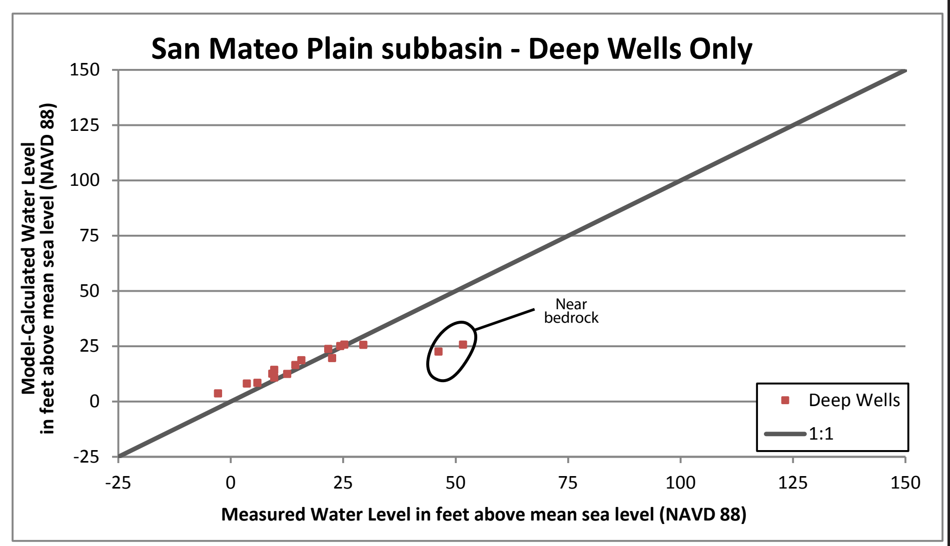


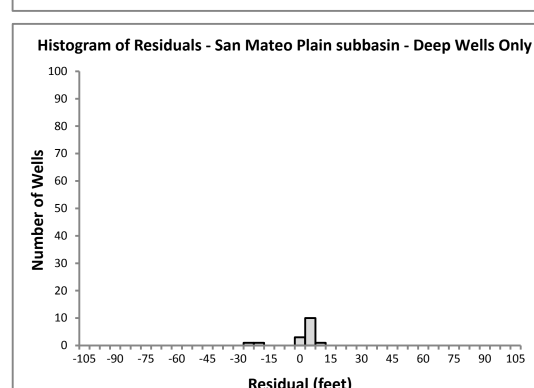


Error Statistics (in feet)

RMSE: 6.0
Min residual: -15.0
Max residual: 13.5
Mean residual: 3.4
Median residual: 3.7

Statistics exclude outlier near bedrock





Error Statistics (in feet)

RMSE: 3.2
Min residual: -4.0
Max residual: 6.4
Mean residual: 1.6
Median residual: 2.0

Statistics exclude outliers near bedrock

Note: Residual is the difference between model-calculated and measured water level. A positive residual indicates the model-calculated water level is greater than the measured water level. A negative resiudual indicates the model-calculated water level is less than the measured water level.

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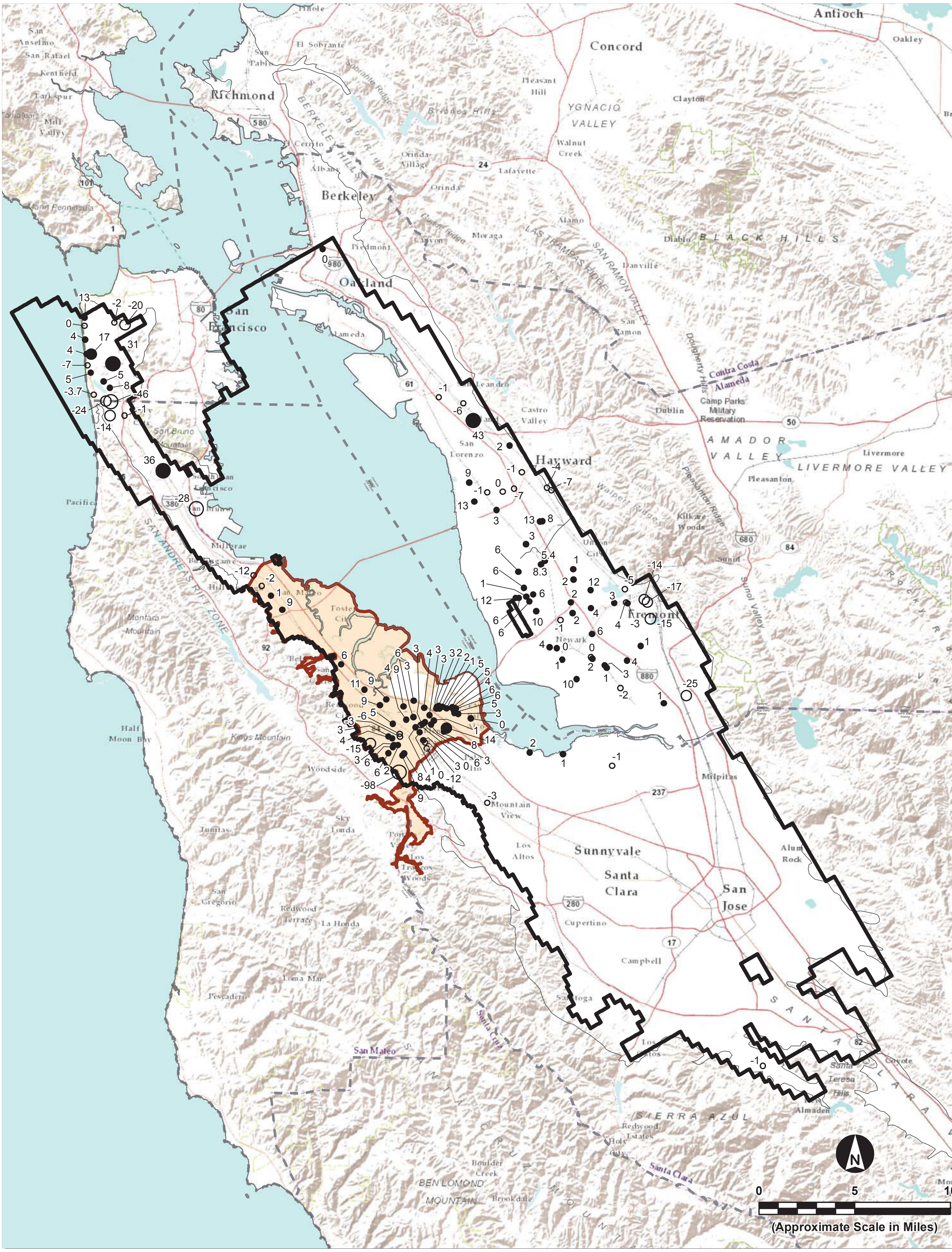
Comparison between Steady-State Model-Calculated and Measured Water Levels

San Mateo Plain Groundwater Subbasin
San Mateo County, California

June 2018
EKI B60024.00

Figure 8-12



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- County Boundary

Residual = Model Calculated - Measured

Model Calculated < Measured

- <-26.4 ft (-41)
- -26.4 to -13.2 ft (-16)
- -13.2 to 0 ft (-11)

number is calculated residual, in feet

Model Calculated > Measured

- 0 to 13.2 ft (3)
- 13.2 to 26.4 ft (17)
- >26.4 ft (40)

number is calculated residual, in feet

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 12 January 2018.

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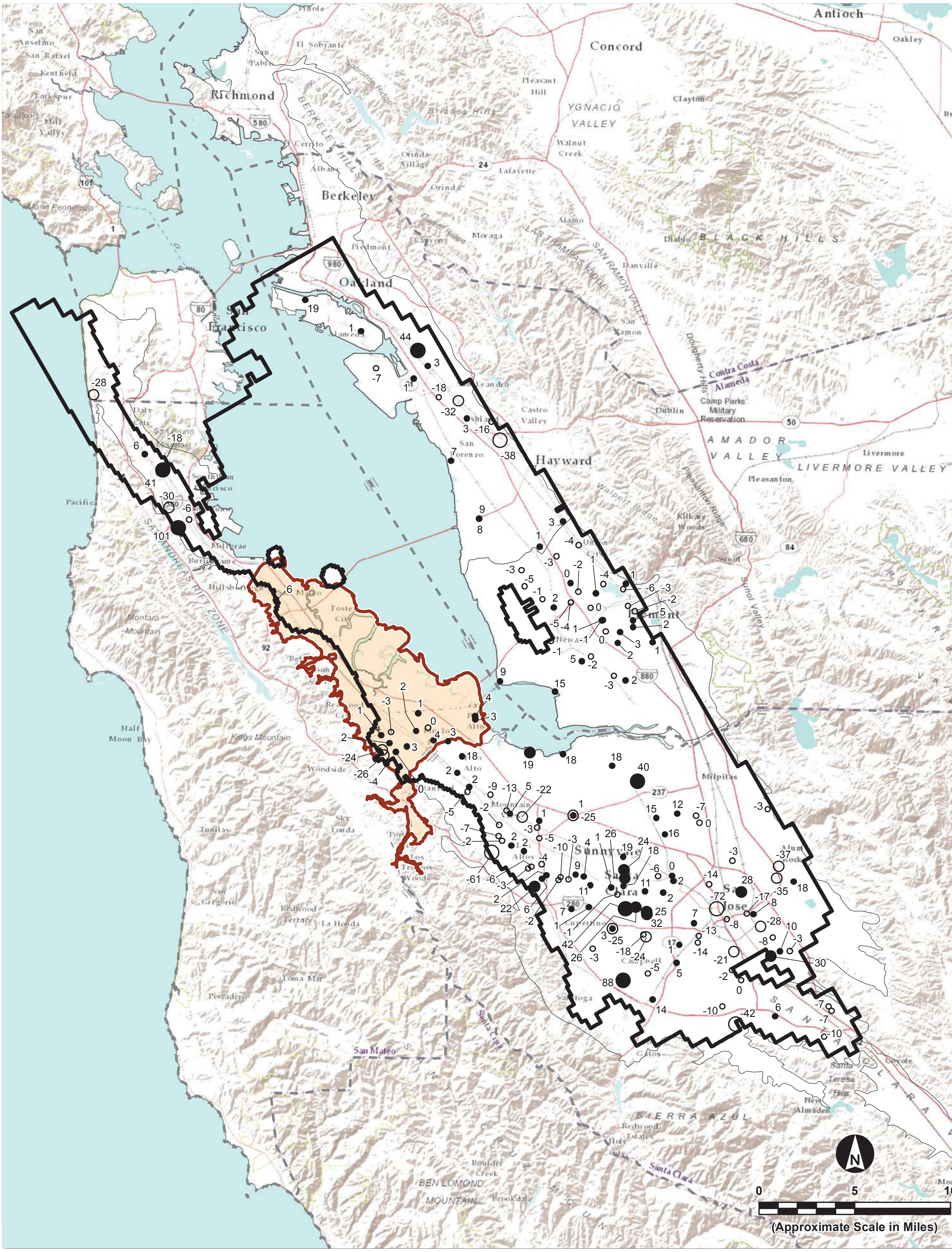
Spatial Distribution of Steady-State Residuals in the Shallow Aquifer

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-13a



Legend

San Mateo Plain Subbasin

San Mateo Plain Groundwater Flow Model Layer 3 Boundary

County Boundary

Residual = Model Calculated - Measured

Model Calculated < Measured

<-38.4 ft (-42)

-38.4 to -19.2 ft (-22)

-19.2 to 0 ft (-1)

number is calculated residual, in feet

Model Calculated > Measured

0 to 19.2 ft (3)

19.2 to 38.4 ft (18)

>38.4 ft (39)

number is calculated residual, in feet

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 12 January 2018.

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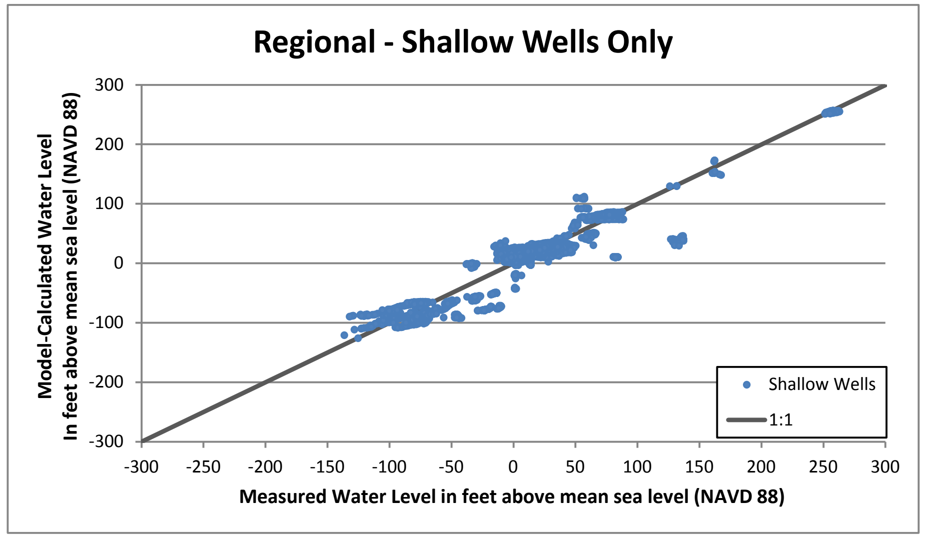
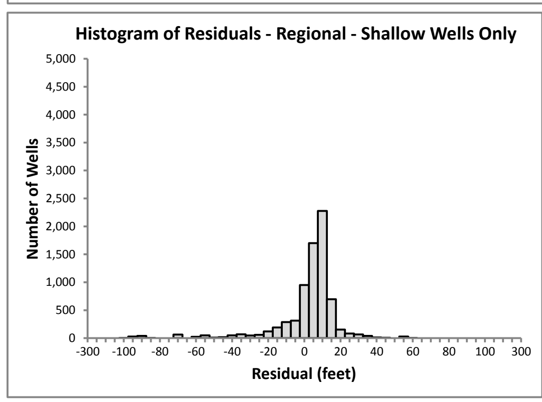
Spatial Distribution of Steady-State Residuals in the Deep Aquifer

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

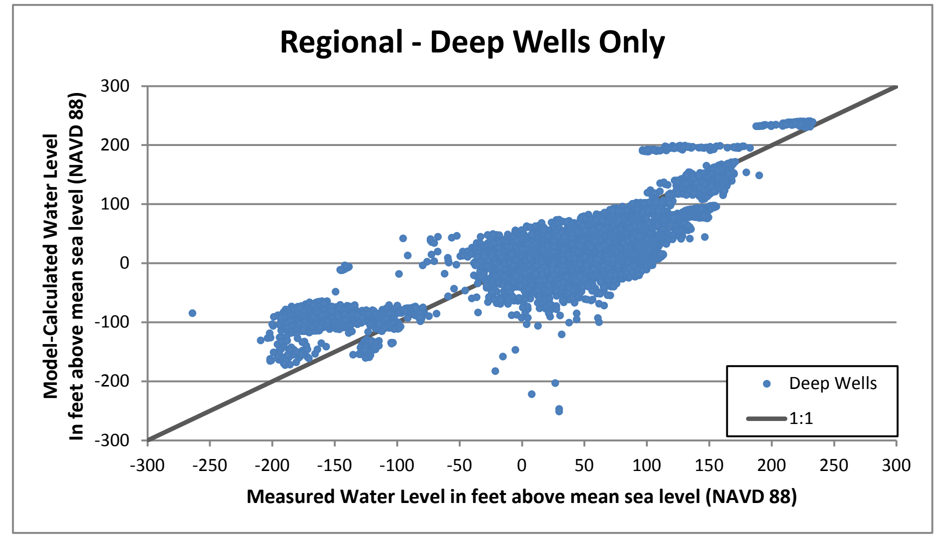
Figure 8-13b

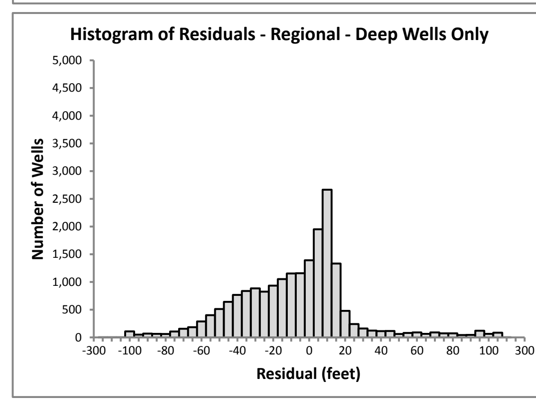




Error Statistics (in feet)

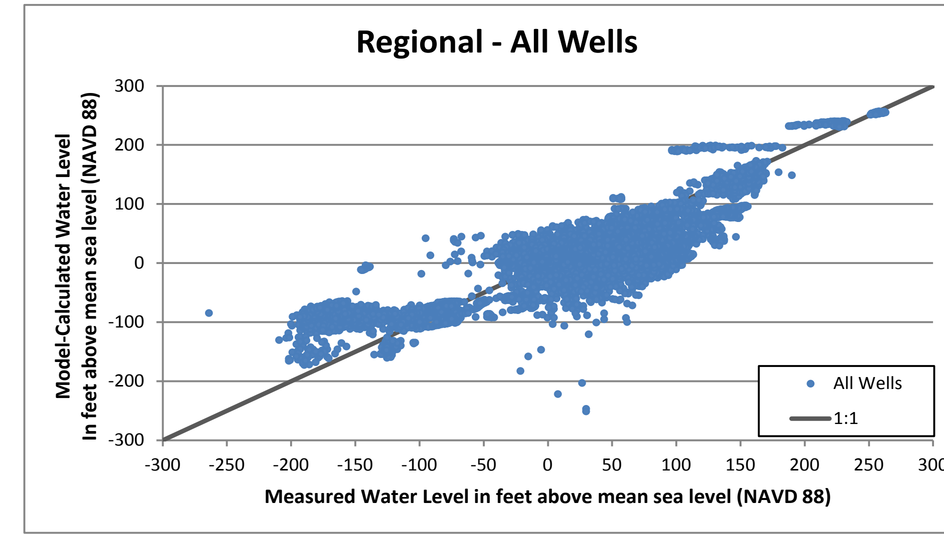
RMSE: 17.9
Min residual: -105
Max residual: 59.0
Mean residual: -0.1
Median residual: 3.7

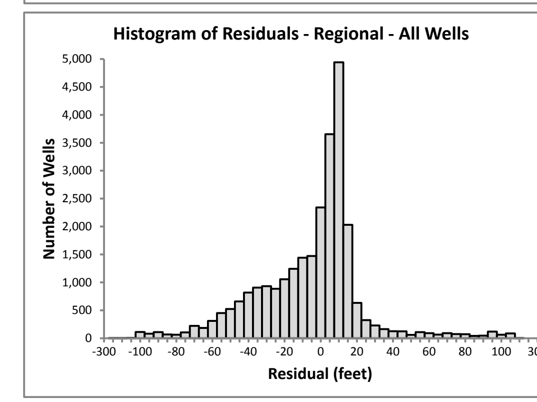




Error Statistics (in feet)

RMSE: 34.3
Min residual: -282
Max residual: 179
Mean residual: -10.5
Median residual: -6.4

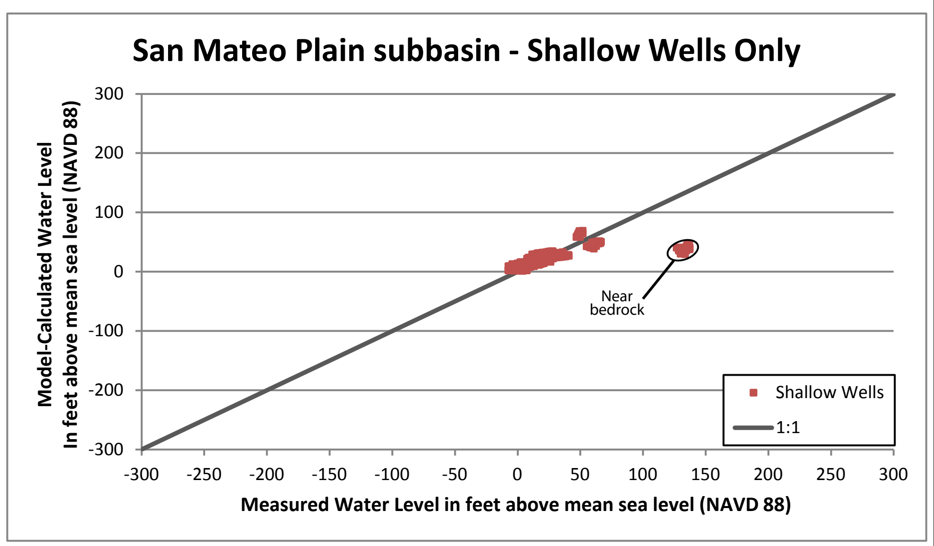


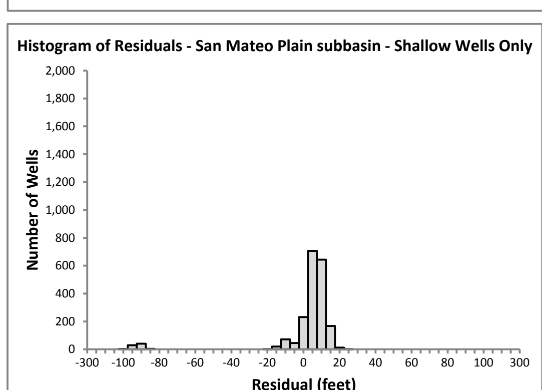


Error Statistics (in feet)

RMSE: 30.7
Min residual: -282
Max residual: 179
Mean residual: -7.6
Median residual: -0.7

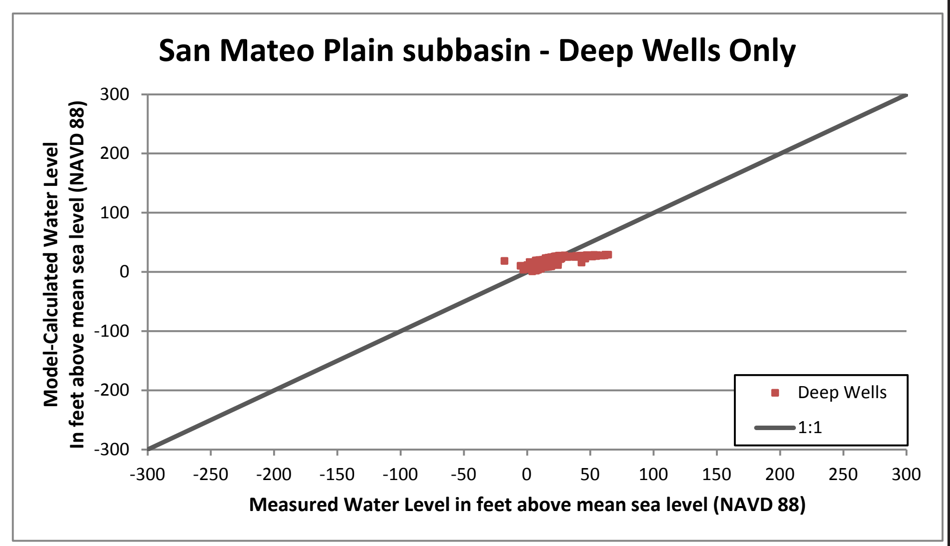
Note: Residual is the difference between model-calculated and measured water level. A positive residual indicates the model-calculated water level is greater than the measured water level. A negative resiudual indicates the model-calculated water level is less than the measured water level.

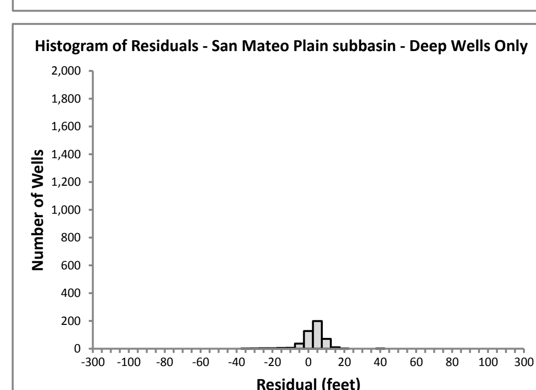




Error Statistics (in feet)

RMSE: 6.6
Min residual: -22.4
Max residual: 18.7
Mean residual: 2.9
Median residual: 7.8
Statistics exclude outlier near bedrock





Error Statistics (in feet)

RMSE: 7.0
Min residual: -35.5
Max residual: 36.0
Mean residual: 0.1
Median residual: 1.2

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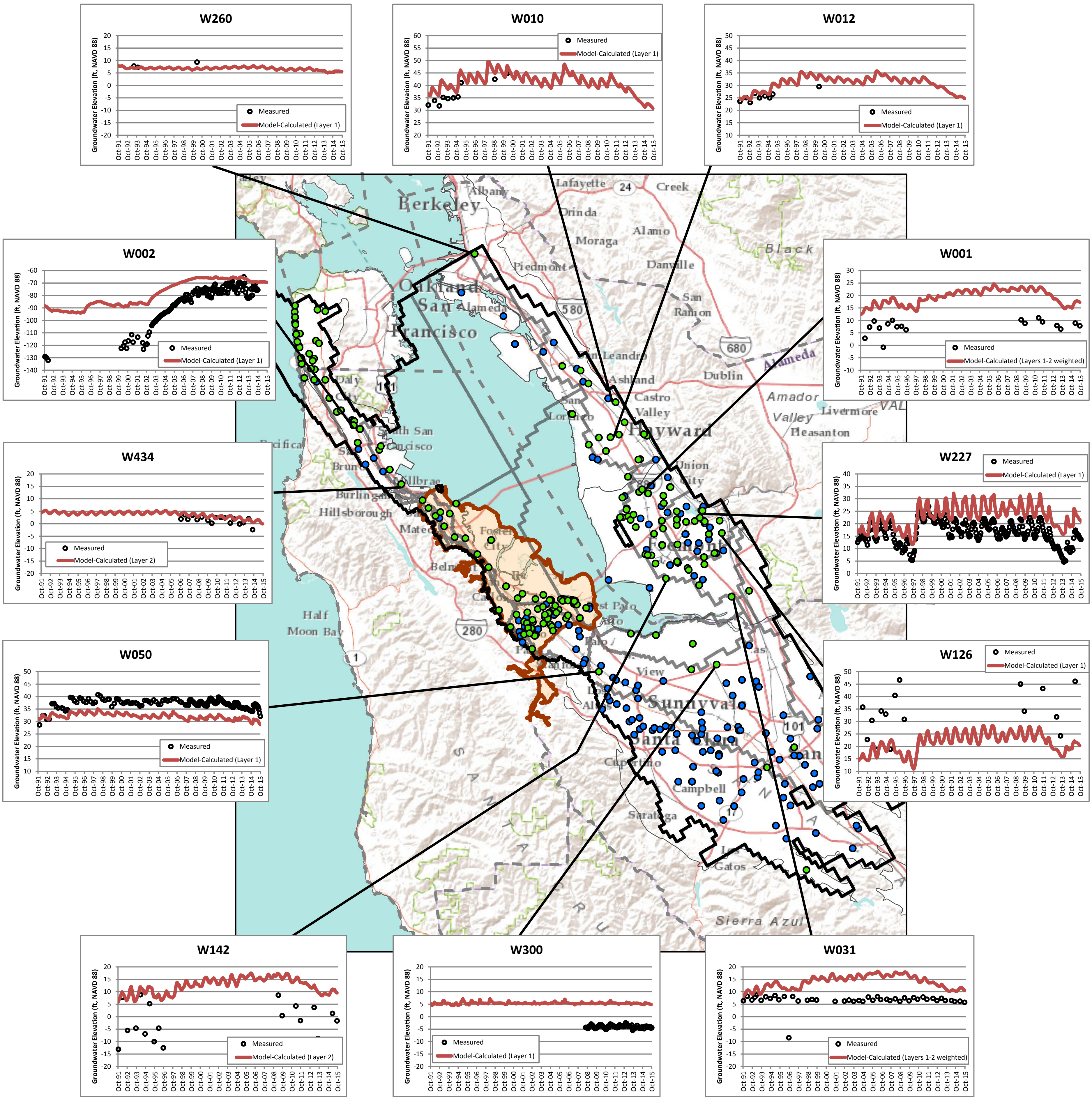
Comparison between Transient Model-Calculated and Measured Water Levels

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-14



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Physiographic Zone
- County Boundary
- Shallow Well
- Deep Well

0 2.5 5 Miles

Notes
1. All locations are approximate.
2. Shallow wells have more than 50% of their screen in model layers 1 and 2.
3. Deep wells have more than 50% of their screen in model layers 3, 4, 5, and 6.

Sources
1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 17 January 2018.

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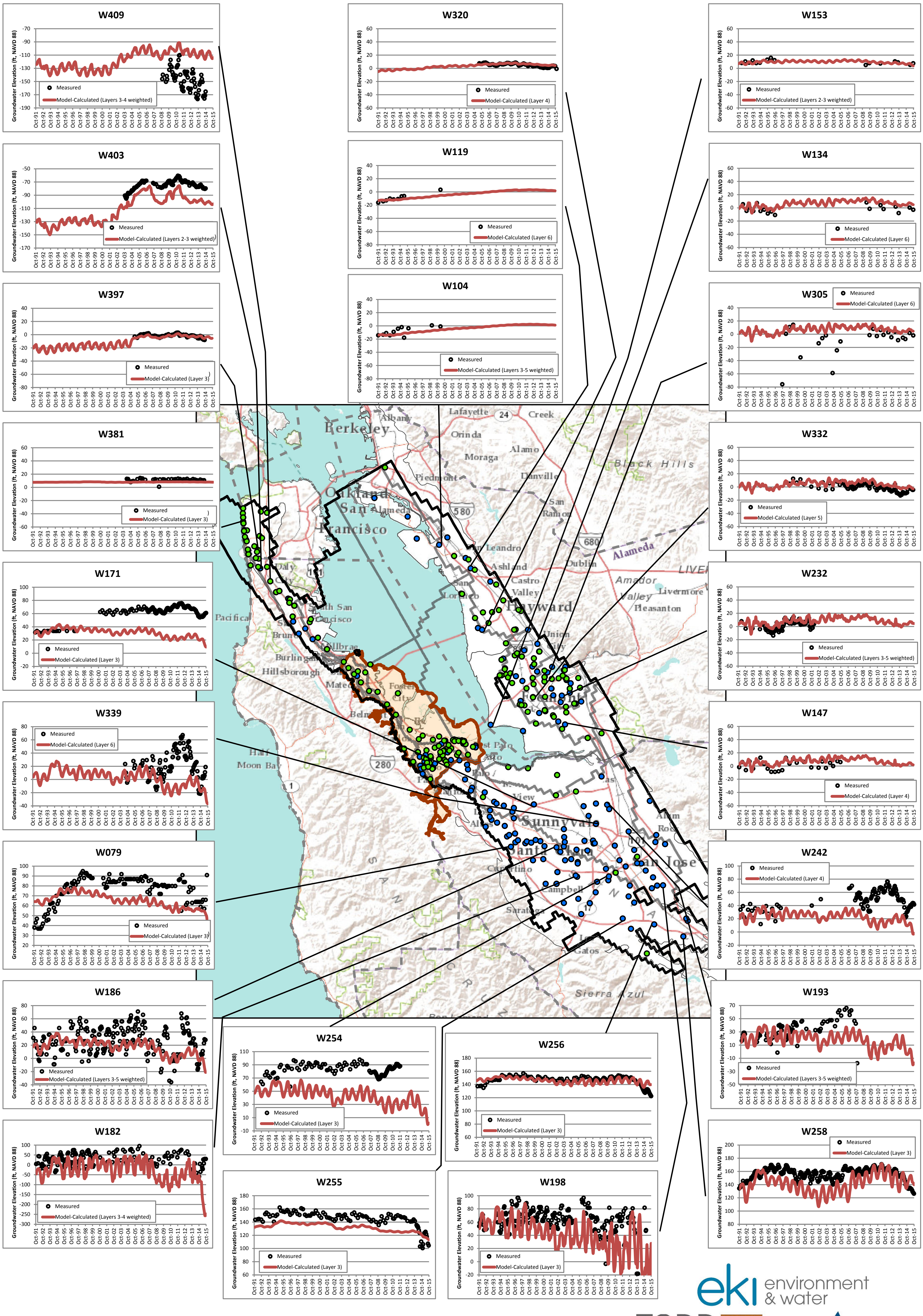
San Mateo Plain Groundwater Flow Model
Shallow Regional Representative Hydrographs

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 8-15a



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Physiographic Zone
- County Boundary
- Shallow Well
- Deep Well

0 2.5 5 Miles

Notes
1. All locations are approximate.
2. Shallow wells have more than 50% of their screen in model layers 1 and 2.
3. Deep wells have more than 50% of their screen in model layers 3, 4, 5, and 6.

Sources
1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 17 January 2018.

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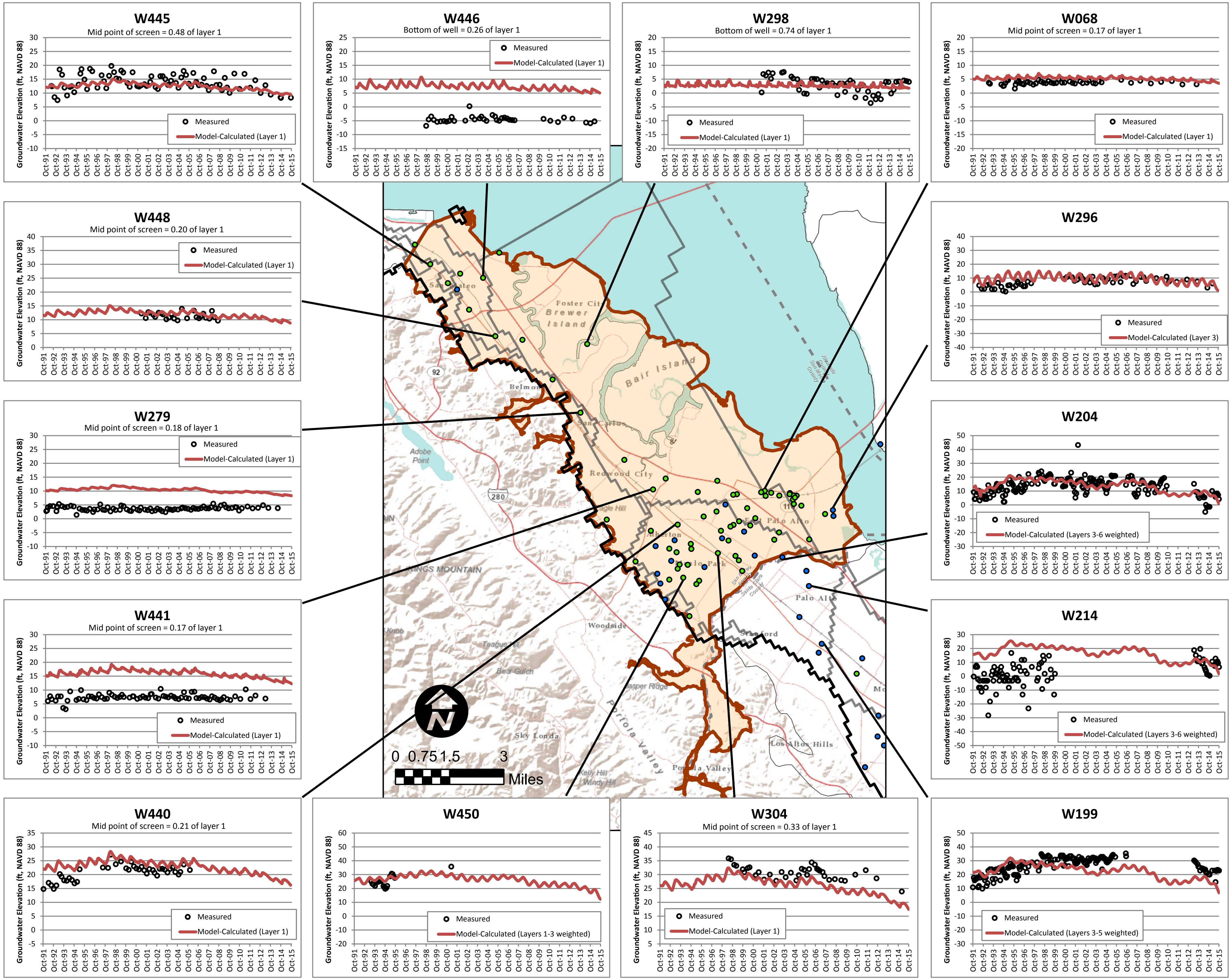
San Mateo Plain Groundwater Flow Model
Deep Regional Representative Hydrographs

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-15b



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Physiographic Zone
- County Boundary
- Shallow Well
- Deep Well

Notes

1. All locations are approximate.
2. Shallow wells have more than 50% of their screen in model layers 1 and 2.
3. Deep wells have more than 50% of their screen in model layers 3, 4, 5, and 6.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 22 December 2017.

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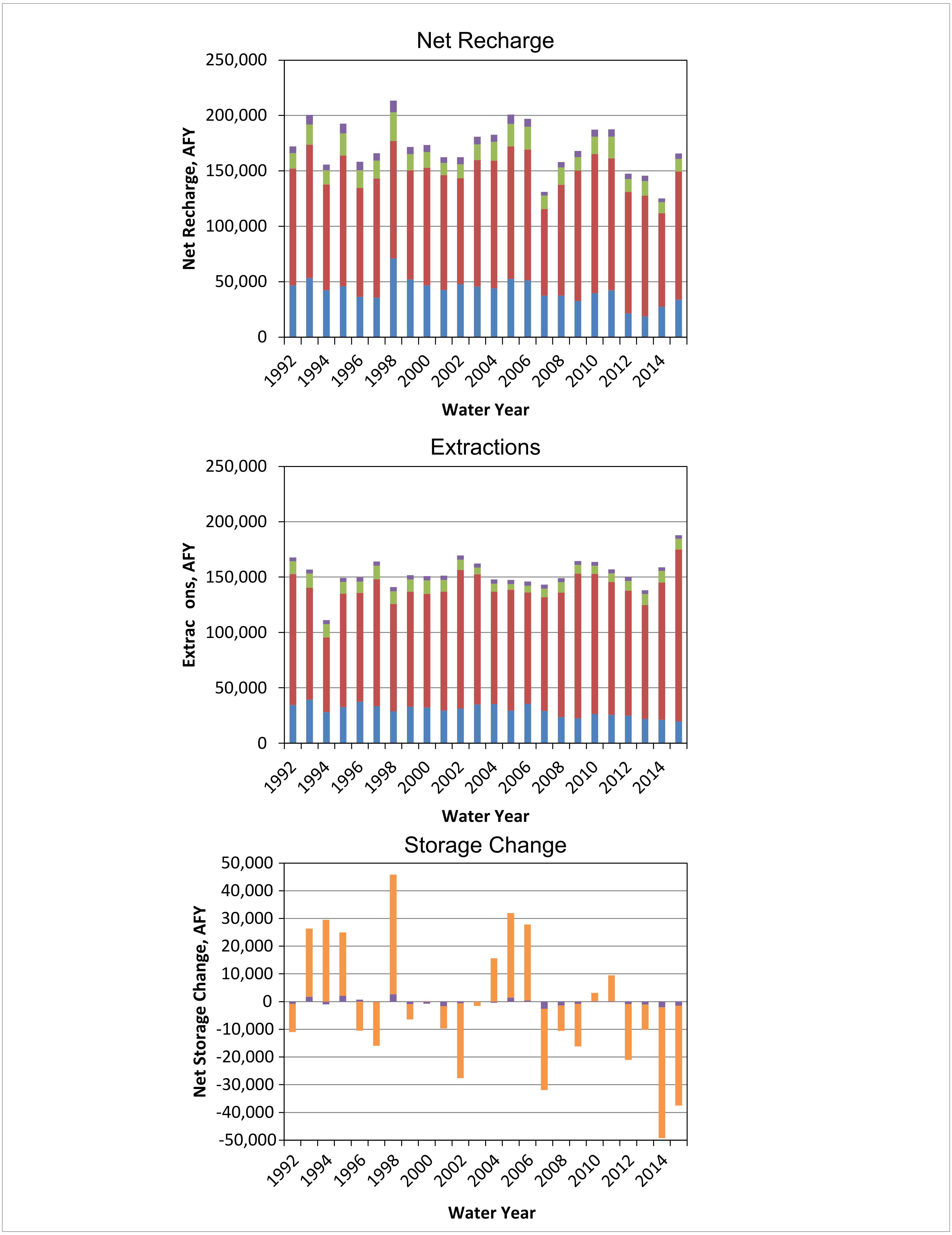
San Mateo Plain Subbasin Representative Hydrographs

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-15c



Legend

- Basin - San Mateo Plain Subbasin
- WSB - Westside Basin Model Area
- IMOD - Santa Clara Valley Model Area
- NEBIGSM - Niles Cone and South East Bay Plain Model Area
- SMPGWM (excluding SMP) - San Mateo Plain Groundwater Flow Model

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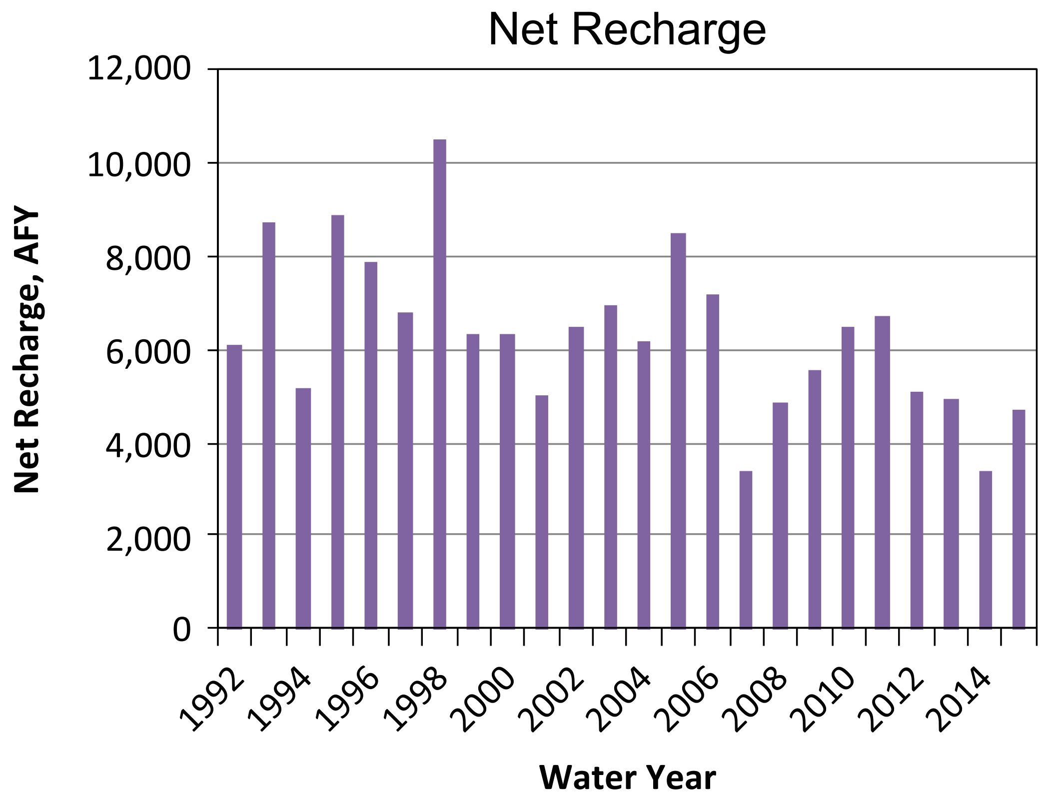
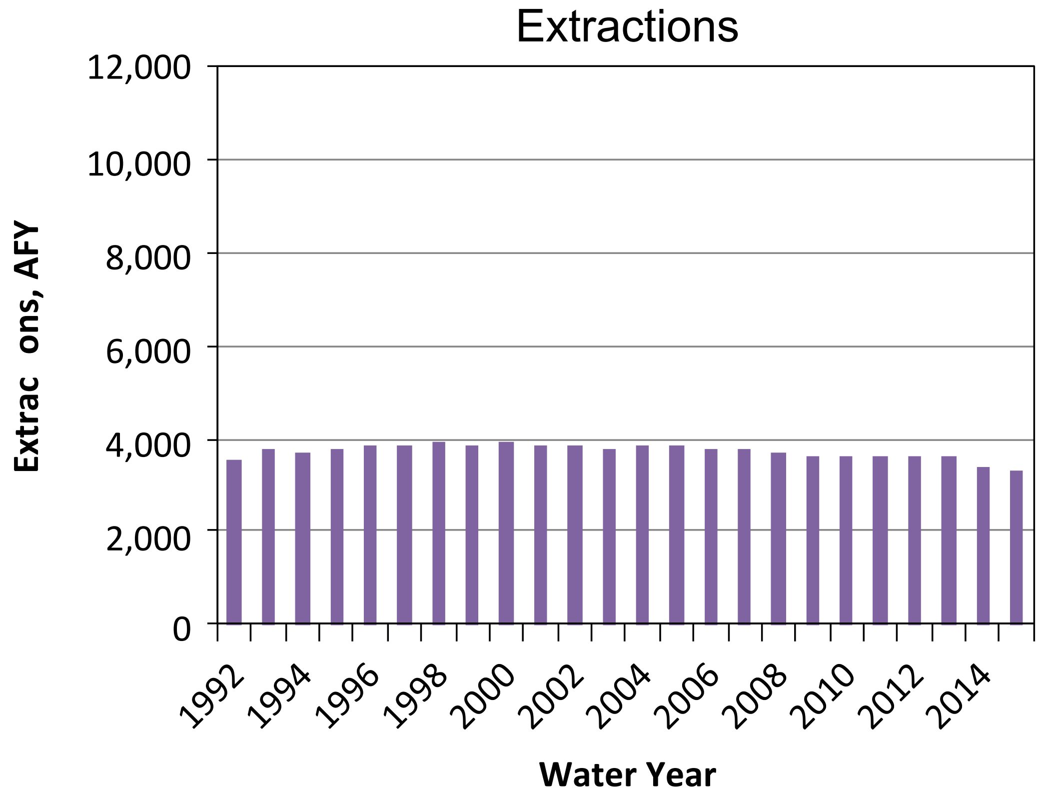
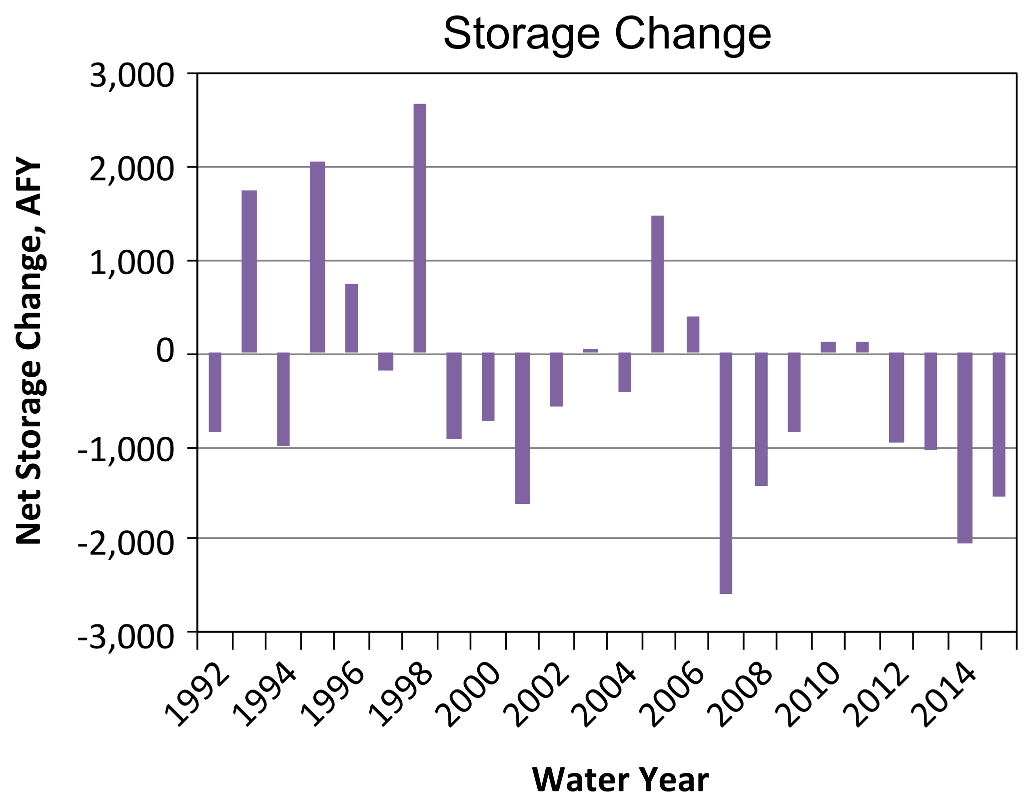
Transient Model-Calculated Water Budget, San Mateo Plain Groundwater Flow Model Regional Net Recharge, Extractions, and Storage Change
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-16a







Legend

■ Basin - San Mateo Plain Subbasin

Transient Model-Calculated Water Budget,
San Mateo Plain Groundwater Flow Model
San Mateo Plain Subbasin Net Recharge, Extractions, and Storage Change
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 8-16b

9.0 EVALUATION OF RISK OF POTENTIAL UNDESIRABLE RESULTS

Several municipalities and the general public have expressed interest in the Basin's groundwater resources for groundwater supply and other beneficial uses. This interest stems from a wide recognition among water agencies that multiple sources of water represent enhanced supply reliability and that local groundwater is a resource with both supply and storage benefits. As part of this interest in the local resource, there is also broad recognition that groundwater is a shared resource that requires understanding and, in some cases, action to address potential undesirable results.[41] Accordingly, this section presents a qualitative discussion of potential risks to the maintenance of local groundwater quantity and quality in the Basin, largely based on an understanding of historical conditions.[42] A quantitative analysis of some specific potential future scenarios was conducted using the SMPGWM, as discussed further in Section 11.0.

9.1 Potential Changes to Current Basin Water Balance

9.1.1 Future Reductions / Enhancements to Groundwater Recharge

Potential reductions in groundwater recharge have been a concern in many groundwater basins as urban development has replaced permeable open space with impervious buildings and paving. If stormwater flows are not managed as land uses are changed, runoff to streams and storm drains can be accelerated, reducing the opportunity for groundwater recharge. Further, impacts of climate change could reduce future precipitation and associated recharge.

Within the Basin, considerable outflow occurs to local streams, sewers, and into and beneath San Francisco Bay. Protection of groundwater recharge generally is beneficial and promotion of recharge may be an important management action for the future, and one that is actively being evaluated within the Basin.[43] At this time, with regard only to the water balance of the Basin, additional recharge would likely result in additional groundwater discharge. Specific benefits of enhanced recharge activities would need to be defined (e.g., in support of planned future groundwater extraction). In addition, the occurrence of dewatering activities throughout the Basin suggests that potential adverse impacts (such as shallow groundwater drainage problems) also would need to be considered.

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[41] Section 10721(x) of the Sustainable Groundwater Management Act of 2014 defines "undesirable results" as significant and unreasonable effects associated with the following conditions: chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, land subsidence, and depletions of interconnected surface water.

[42] As discussed in Section 11.5.2, above, significant undesirable affects are not anticipated within the parameterizations of the hypothetical scenarios modeled, but are appropriately evaluated on a project-by-project basis for future changes in groundwater use.

[43] San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) – of the City and County Association of Governments (C/CAG), a partnership between the County and each incorporated city and town within the County – is evaluating opportunities to infiltrate stormwater to the benefit of the groundwater systems.

9.1.2 Future Increases in Groundwater Pumping

Groundwater production within the Basin for potable and non-potable supply has been relatively limited for the last several decades, as the primary water supply source has been Hetch Hetchy water purchased from the SFPUC and accessed via the Regional Water System (RWS). The only municipal water suppliers within the Basin that currently utilize groundwater as a potable supply source are two mutual water companies that are located in the southern portion of the Basin: the PAPMWC and the O'Connor Tract CWC. Some institutions and private landowners within the Basin also use groundwater for domestic or landscape irrigation purposes, particularly in the southern portion of the Basin. The water balance presented in Section 7.0 estimates that total groundwater production within the Basin is currently about 2,300 AFY.

However, in recent years, several water agencies in the Basin have initiated investigation of local groundwater resources to supplement their existing SFPUC RWS supplies.

- The City of East Palo Alto is currently working to re-activate its Gloria Way Well to provide up to 450 AFY of potable water to City customers, with construction of a new wellhead treatment system for iron and manganese anticipated to be completed in 2018. The City is also pursuing additional potable groundwater supplies through the construction of the new Pad D Well, which is expected to produce up to 750 AFY. In total, and depending on final decisions about well operations and use, the City of East Palo Alto is projecting to potentially utilize up to 1,200 AFY of groundwater as early as 2020 (EKI, 2016a).

- The California Water Service Company (Cal Water) Bear Gulch District is currently investigating options to develop local groundwater resources with the installation of one or more potable groundwater production wells (Cal Water, 2016a).

- The Menlo Park Municipal Water District is pursuing groundwater as an emergency water supply source. The MPMWD's Emergency Water Supply Wells Project[44] includes the construction of three to four wells, with a combined capacity of up to 3,000 gpm (EKI, 2016b). The first well, the Corp Yard Well, was installed and tested in February through April 2017, and construction of the above-grade well head facilities is anticipated to take place in 2018. As these wells will be operated only in the event of a water supply emergency, they are not likely to represent an on-going demand on the Basin, aside from routine well exercising and maintenance.

- The BAWSCA, in partnership with Cal Water and the City of San Mateo, conducted an initial planning-level study of the feasibility of desalination of brackish groundwater as a potential supplemental dry-year water supply, an effort that included development of the

[44] Information regarding the Emergency Water Supply Wells Project can be found on the City's website: www.menlopark.org/emergencysupplywells.

Strategy Groundwater Model. Efforts to conduct further feasibility evaluation including field testing have been put on hold pending procurement of additional grant funding.

- BAWSCA, SVCW, SFPUC, and Cal Water are currently working together to evaluate the feasibility of using advanced recycled water produced by SCVW for potable reuse. This study, the Potable Reuse Exploratory Plan (PREP), will evaluate options of using undisinfected secondary treated and disinfected tertiary treated water for both groundwater replenishment via injection wells and as surface water augmentation to existing reservoirs (e.g., Crystal Springs and Bear Gulch) (BAWSCA, 2017a).

Other water suppliers in the Basin have historically explored the feasibility of groundwater production in the Basin, but do not have formal plans to pursue groundwater supplies at this time. For example, the City of Redwood City estimated that it could potentially extract between 500 AFY and 1,000 AFY from a network of properly sited and designed wells (EKI, 2016c; Todd, 2005). The Cal Water Mid-Peninsula District also investigated the possibility of constructing a groundwater well but determined that the well would not be economically feasible given the low anticipated yield (Cal Water, 2016b).

9.2 Potential Undesirable Results

9.2.1 Decline in Groundwater Levels and Storage

Of the potential undesirable results of groundwater development, a decline in groundwater levels and storage is central. Other undesirable results, such as land subsidence, seawater intrusion, and adverse impacts on streams, can occur only as an effect of groundwater level decline. Nonetheless, a decline in groundwater levels can directly cause undesirable results such as adversely affecting existing wells. This would involve falling groundwater levels in the affected well, with potential decreases in yield, exposure of screens (potentially damaging the well), declining groundwater quality, and even drying up the well, particularly in summer or drought. This would be most significant for domestic wells that are not particularly deep and are the sole source of domestic supply to a residence.

This potential impact is likely lessened in the Basin for several reasons. While numerous domestic wells have been drilled historically in the Basin, most were drilled prior to the availability of Hetch Hetchy supply, which is readily available to municipal customers and very high quality. Accordingly, many original domestic wells likely have been abandoned or are unused. If such domestic wells exist and continue to operate, it is not unreasonable to think that they have been switched to irrigation purposes. Groundwater level declines would also affect irrigation wells. When a new production well is planned for either domestic, irrigation, or municipal water supply, impacts to existing wells are addressed through California Environmental Quality Act (CEQA) review and community outreach to identify active wells and assess potential impacts.

With regard to groundwater storage, an overall lowering of groundwater levels from present levels to some future lower level also can represent a diminution of groundwater storage that could be used to provide water in a drought or emergency. This is a complex process (given that lowered groundwater levels can induce additional recharge), but can be addressed with monitoring, modeling, and management.

9.2.2 Land Subsidence

As described in Section 6.2.8, land subsidence of more than two feet was measured in East Palo Alto and Palo Alto between 1934 and 1967, when historical groundwater pumping lowered groundwater elevations below sea level (up to 140 feet below msl at the Hale Well in Palo Alto), thereby inducing compression of the overlying clay materials and land subsidence. It is estimated that total annual pumping from the San Francisquito Cone amounted to approximately 7,500 AFY prior to 1962, most of which occurred in vicinity of Palo Alto.

The estimated total annual pumping in the Basin under current and future conditions is described in Section 7.3, **Table 7-1**, and amounts to around 3,500 AFY (inclusive of pumping for supply, remediation, and dewatering purposes). Accounting for the proposed future pumping by East Palo Alto (of up to 1,200 AFY by 2020 [EKI, 2016a]), and current pumping by other users, total future annual pumping in the Basin is estimated to be 4,700 AFY.

While future groundwater pumping in the Basin may approach 4,700 AFY, the level of overdraft that occurred in the aquifer between 1934 and 1967 when pumping was as high as 7,500 AFY is not expected because the region now has access to Hetch Hetchy supplies, and because former agricultural lands in the region have been converted to urban land uses (which use less water). As long as future water levels remain above these historical low levels, only elastic subsidence and rebound will occur, because the clay units in the aquifer have already experienced the inelastic subsidence component.

Land subsidence monitoring could be a part of any future Basin monitoring and management program. The existing NOAA NGS, SCVWD, and municipal survey benchmarks could be monitored for changes in land surface elevations. Additional land subsidence monitoring could be conducted in conjunction with the USGS (under their Local Agency Partnership program) who may be able to design and implement a monitoring program across the Basin potentially using GPS or InSAR.

9.2.3 Seawater Intrusion

Seawater intrusion has occurred in several groundwater basins around the southern San Francisco Bay (e.g., Niles Cone, Santa Clara Subbasin, and southern portion of the Basin) and thereby constitutes a significant issue.

The SCVWD monitors groundwater quality in a network of wells near the San Francisco Bay in Santa Clara County to assess saline water intrusion from the Bay.[45] Recent monitoring in Palo Alto does not indicate increasing saline water intrusion in the shallow or deep aquifer; on the contrary, data suggest downward trends in chloride levels over time (SCVWD, March 2010). Chloride concentrations in the Hale Well peaked at 215 mg/L in 1958 during the period when this well was actively pumped prior to 1962. Similarly, the Rinconada Well (located in Palo Alto) had a chloride concentration as high as 250 mg/L in 1972.

The GWMP for East Palo Alto (Todd, 2015b) expressed specific concern regarding saline water intrusion via the so-called Ravenswood abandoned wells located near the San Francisco Bay. As documented in GWMP, approximately 45 wells were drilled by the Spring Valley Water Company between 1904 and 1905 along the East Palo Alto bay front. These wells were not properly abandoned and could create a conduit for flow of saline water from the Bay into the aquifer. In response to these conditions, some of the wells were reportedly filled and sealed by the SCVWD in 1989, and the remaining wells likely have collapsed. However, the condition of the wells is not known. Subsequent work in the Cooley Landing Salt Pond identified at least one artesian flowing well in 2000/2001 (Papadopulos, 2001). As long as bayward and upward hydraulic gradients are maintained, the probability of saline water intrusion occurring via conduits is low. However, if water levels in the deep aquifer fall below sea level and downward and landward hydraulic gradients are reversed, these conditions could result in saline water intrusion via the conduits.

Recognizing the overall threat of seawater intrusion (among other issues), East Palo Alto has initiated a groundwater monitoring program that involves regular groundwater quality sampling to establish the current distribution and to track future water quality trends of selected chemicals of concern, including indicators of saline water intrusion from the Bay (GWMP, Appendix C; Todd, 2015b).

North of East Palo Alto, along the Menlo Park and Redwood City shores, the threat of seawater intrusion is compounded by the occurrence of existing salt ponds. While San Francisco Bay water has a representative chloride value of about 14,000 mg/L (see **Table 5-1**), measured chloride values in shallow monitoring wells at the salt ponds can contain chloride concentrations as high as 100,000 mg/L. The concentration of a contaminant source is only one factor in assessing such a threat (the density of brine is another) and maintenance of a positive bayward gradient in this region is essential. Nonetheless, the existing and planned development of groundwater in the Basin warrants establishment around its entire shoreline perimeter of a monitoring program with sentry wells for seawater intrusion. Monitoring would include measurement of groundwater levels and sampling for geochemical indicators of seawater intrusion.

The major cations sodium and chloride are good indicators for seawater intrusion because these constitute approximately 85 percent of seawater's composition (Hem, 1989). Analysis of all major

[45] No comparable monitoring program exists yet in San Mateo County.

ions allows application of other techniques (e.g., Piper diagrams and specific ion ratios). In addition, trace ions such as bromide, boron, and iodide should be considered (for example, see Metzger, 2002).

9.2.4 Impacts to Interconnected Surface Water

Increased use of groundwater in the Basin could potentially affect baseflow and steelhead fish habitat in San Francisquito and San Mateo Creeks. Fish habitat and groundwater interactions are very limited along the other creeks because baseflow is small and the channels are now rectangular cement channels.

Groundwater and surface water are hydraulically coupled only where the water table next to the creek is at or above the elevation of the creek bed. At lower water table elevations, stream percolation occurs at a rate that is independent of the groundwater level. Where the groundwater and creek are hydraulically connected, the rate of stream flow depletion caused by a well depends on its screen depth and proximity to the creek. For a shallow well close to a creek, nearly all of the pumped water is supplied by induced percolation from the creek. In alluvial basins with numerous or thick fine-grained layers, a deep well at the same location induces downward leakage from shallower aquifer units over a broad area, and much of the pumped water typically derives from other sources of recharge, such as rainfall, irrigation, and pipe leaks.

San Francisquito Creek supports riparian vegetation and fauna, including threatened species such as the red-legged frog and western pond turtle. It is the only free-flowing urban creek on the south Peninsula (USGS, 2015) and the most viable remaining native steelhead population in South San Francisco Bay. Citing concern for steelhead, the creek has been included in the 303(d) listing by the RWQCB as impaired for sediment (California Coastal Commission, 2006). A habitat assessment in the upland watershed (Jones & Stokes, 2006) concluded that a lack of suitable habitat (e.g., deep pools) is the key factor limiting smolt production and juvenile rearing, while steelhead outmigration is limited by seasonal drying of the channel (a natural phenomenon) and exacerbated by passage impediments. Given its environmental significance, San Francisquito Creek has been the subject of numerous studies (e.g., Jones & Stokes, 2006; USGS 2015), restoration plans focused on bank stabilization and re-vegetation, and active restoration, education and outreach efforts (Acterra, 2015).

A detailed study of groundwater-surface water interaction along San Francisquito Creek was undertaken by the USGS in 1996-1997 (Metzger, 2002). Flows measured at 13 locations along the creek on multiple dates were used to delineate gaining and losing reaches. The creek consistently lost water to percolation from the Basin boundary to Middlefield Road (half of the total distance to San Francisco Bay). However, groundwater levels at the time of the study were more than 20 feet below the creek bed, and percolation consequently interpreted to be independent of groundwater level. Increased groundwater pumping in that area would not have increased percolation losses. If groundwater levels rise in the future and create a hydraulic connection along part of that reach, then pumping could affect percolation losses.

Downstream of Middlefield Road, the study found alternating gaining and losing reaches, suggesting that the creek and water table had similar elevations and were hydraulically coupled. Pumping from shallow wells within 1,000 feet of the creek along that reach could potentially induce additional stream percolation. An evaluation of aquifer permeability and storativity at the production well would allow a more precise estimate of potential impacts. The impact of increased pumping from deep wells along the lower half of the creek is more difficult to determine because of the uncertain effects of clay layers in the depth interval between the creek bed and the well screen. In general, clay layers become thicker and more abundant toward the Bay, which tends to decrease the impact of pumping on stream flow. Measured groundwater elevations at a monitoring well cluster at Eleanor Pardee Park in Palo Alto (2,500 feet from San Francisquito Creek midway between Middlefield Road and the Bay) show upward head gradients and water levels above the ground surface in the three deepest wells (540-850 feet bgs) during 2010-2012. Water levels gradually declined to below ground surface by the end of 2014. The shallowest screen (180-200 feet below ground surface) had the lowest water levels: 5-to 10 feet bgs in 2010-2012 (approximately equal to the creek elevation), declining to as much as 30 feet below ground surface in fall 2014. The water-level declines during 2012-2014 resulted from a combination of decreased rainfall and stream percolation recharge during the exceptionally dry years of 2013 and 2014 and increased groundwater pumping—and lowered groundwater levels—farther south in the Santa Clara Subbasin Basin. The high water levels and smooth hydrographs in the deep Eleanor wells indicate a lack of nearby groundwater pumping; the deeper aquifers currently supply water to the shallower ones. If deep pumping were increased, inflow to the shallow aquifer would decrease. Shallow groundwater levels would likely decline, which could increase percolation losses along the lower half of San Francisquito Creek.

San Mateo Creek also has a natural channel along most of its length and has received increased releases from Crystal Springs Dam to increase available habitat for steelhead trout. A small decrease in flow between the Basin boundary and the Bay was measured in early May 2016 (0.3 cfs). Although groundwater elevations and gaining/losing reaches are less well studied than along San Francisquito Creek, it is likely that groundwater-surface water relationships are analogous. That is, the creek bed might be above the water table where it first enters the Basin, and percolation losses in that area would be independent of groundwater levels. Closer to the Bay, the creek is probably hydraulically coupled to groundwater, and pumping from shallow wells, and to some extent deep wells, near the creek would tend to induce percolation and decrease baseflow.

9.3 Other Potential Undesirable Effects on Basin Water Quality

9.3.1 Salt and Nutrient Loading

Deep municipal supply wells located in the southern portion of the Basin provide water supply that meets drinking water standards for salt and nutrient indicators (e.g., TDS, chloride, and nitrate). However, other local wells in the Atherton area have shown elevated nitrate. These occurrences indicate the existence of a nutrient source, presumably landscape fertilization, and the existence of flow pathways from the ground surface down to productive aquifer zones. Thus, undesirable impacts of current land uses on groundwater quality are already present. Nitrogen in fertilizer only reaches groundwater if the amount and timing of fertilizer application is such that plants cannot absorb all of the nitrogen. This nutrient load to the Basin can be controlled through management of fertilizer use.

The largest source of salt loading to the Basin is likely irrigation. When water is applied for irrigation, plants transpire only the water itself, leaving the minerals behind in the soil. Deep percolation of rainfall and some of the applied irrigation water flush the salts out of the root zone and down to the water table. This evaporative concentration of irrigation water is the largest salt load in many agricultural and urban basins. It can take decades for salts arriving at the water table to move downward to deeper aquifers tapped by water supply wells, so the effects of the impact and of corrective measures are not immediately apparent.

In basins where groundwater is the source of irrigation supply, salt concentrations in groundwater continue to increase each time water is pumped and applied for irrigation. In the Basin almost all irrigation water is imported Hetch Hetchy water. This water originates in the Sierra Nevada Mountains and has a much lower mineral content than native groundwater (e.g., TDS less than 100 mg/L versus 350-600 mg/L). Consequently, evaporatively concentrated irrigation water in the Basin has roughly the same salinity as native groundwater and is probably not increasing ambient groundwater salinity.

For similar reasons, sewer pipe leaks probably do not increase ambient groundwater salinity. Municipal wastewater commonly has a mineral content 250-300 mg/L greater than the water supply. Larger increases occur in areas where self-regenerating water softeners are in widespread use, but they are probably rare in this Basin. Adding 200-300 mg/L of TDS to imported water results in a wastewater TDS that is similar to or lower than ambient groundwater. Thus, because of the fortuitously low TDS of municipal supply water, leaking sewer pipes add a salt load to the Basin but do not increase salt concentrations in groundwater.

Recent planning by multiple agencies for water recycling may provide a comprehensive response to salt and nutrient loading in the Basin. Water recycling provides benefits of a locally-managed supply and reliability during drought. It also allows replacement of high quality, imported water with non-potable water for landscaping and other non-potable uses. However, use of recycled water in lieu of surface water or local groundwater source entails salt and nutrient loading.

Recognizing this, the SWRCB developed its Recycled Water Policy, which supports water recycling in the context of local management of groundwater resources with regard to salts, nutrients, and other significant chemical compounds. To implement water recycling, the Recycled Water Policy requires development of a salt and nutrient management plan (SNMP). An SNMP would include description of a conceptual hydrogeologic model, identification of all salt and nutrient sources, assessment of salt and nutrient loading, analysis of fate and transport, and evaluation of the assimilative capacity of local groundwater for key parameters such as total dissolved solids and nitrate. The SNMP also would identify implementation measures to monitor and manage salt and nutrient loading. See Section 10.2.1.3 for more detail regarding SNMP requirements and the SWRCB's Recycled Water Policy.

9.3.2 Point-Source Contamination

As discussed above in Section 5.0, point source contamination sites pose a potential risk to underlying groundwater. The degree of risk depends on the toxicity and concentrations of the contaminants and the potential for complete exposure pathways to sensitive receptors, including humans and biota. Exposure pathways include ingestion if the groundwater is a source of drinking water supply, inhalation of contaminants in indoor air as a result of vapor intrusion of volatile contaminants from contaminated soil and/or groundwater, and contact with contaminated media during construction or non-construction activities. The regulatory framework for point source contamination sites that have been identified and are under active oversight aims to provide protection of sensitive receptors through enforcement actions that may include engineering and/or administrative controls.

Both natural and anthropogenic factors affect the fate of contaminants released to the subsurface. Natural factors include: recharge rates, horizontal and vertical permeability of the sediments, horizontal and vertical hydraulic gradients (both magnitude and direction), presence of fine-grained layers that may impede advection but may also result in back-diffusion of contaminants to "cleaned-up" permeable zones, and biogeochemical conditions which can influence contamination degradation processes. Anthropogenic factors include: groundwater pumping and other changes to the natural fluxes and gradients, the presence of artificial subsurface conduits (e.g., horizontal pipelines and the backfill surrounding them, and vertical wells with perforations spanning multiple depth zones), and intentional remediation efforts to remove, degrade, or limit the spread of contaminant mass.

Public water systems using groundwater sources are required to prepare Drinking Water Source Assessments for those sources prior to bringing them online. These assessments, which are reviewed by the SWRCB (and formerly by the California Department of Public Health [CDPH]), provide a systematic method to identify and rank potentially contaminating activities within the groundwater source's zone of capture, and ultimately inform the decision whether to grant a drinking water permit for the source, and if so, what monitoring requirements might be imposed on the water system.

9.3.3 Cross-Contamination between Shallow and Deep Aquifers

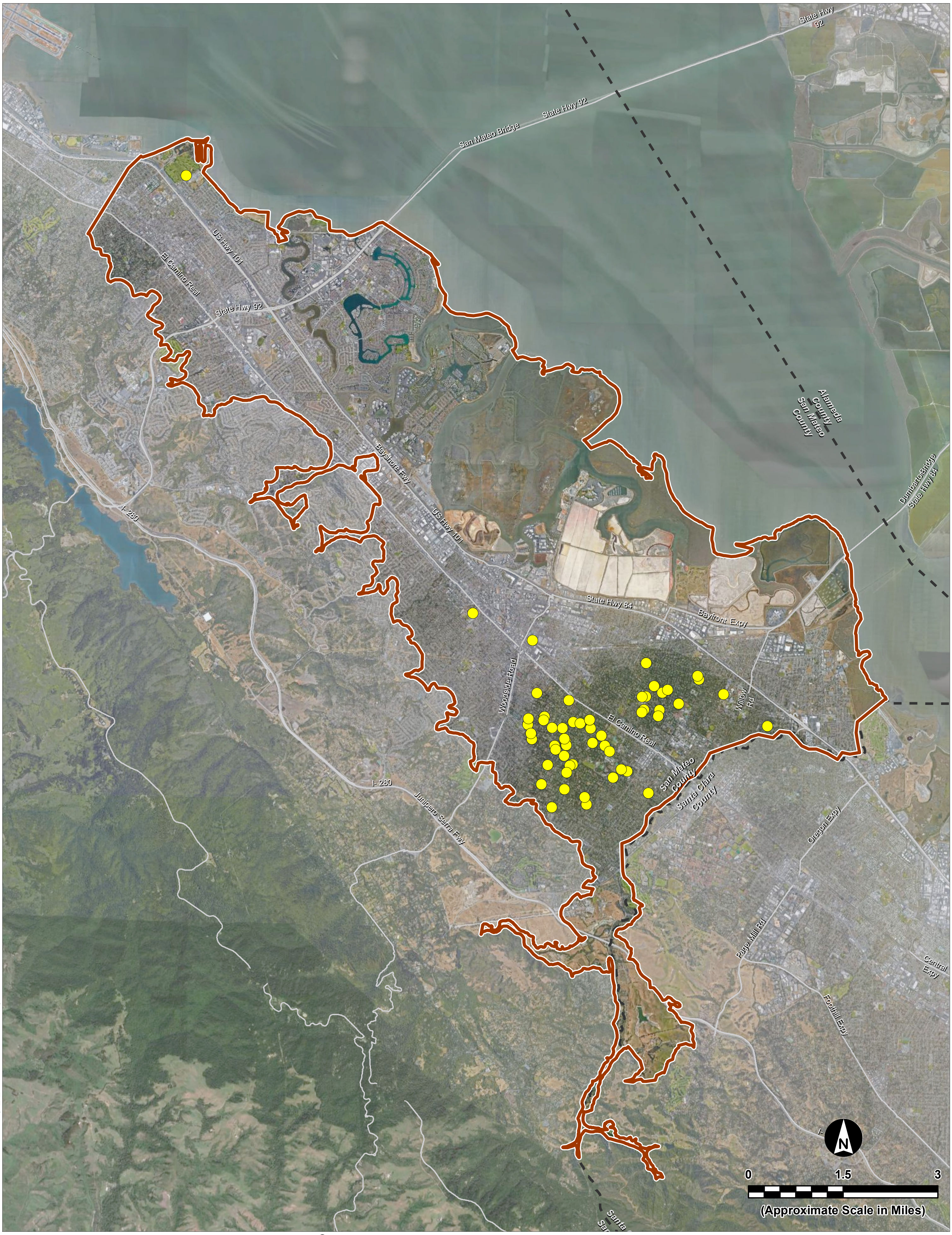
In the Basin, alluvial fan and intra-fan depositional processes have resulted in a highly anisotropic geologic setting, with sub-horizontal interbeds of coarse and fine layers that generally make vertical migration of groundwater and COCs much harder than horizontal migration. For this reason, most occurrences of point source contamination are limited vertically to the upper 50 feet or so of the Basin. Given that most groundwater production for drinking water supply occurs in the deeper aquifer zones separated from the shallow zone by numerous fine-grained layers (see **Figures 6-12a** through **6-19**), these drinking water supplies are generally less susceptible to contamination from point source sites.

Exceptions to this generality include instances where cross-connecting wells allow movement from shallow to deeper zones, locations where sediments are dominated by coarser material (e.g., closer to the foothills where depositional environments are more energetic), and locations where groundwater is pumped from relatively shallow production wells. **Figure 9-1** shows the locations of wells with screened intervals that span from less than 100 feet bgs to greater than 200 feet bgs, which therefore have the potential to connect the relatively shallow zone where point source contamination impacts occur to the deeper zones where groundwater production typically occurs. As shown on **Figure 9-1**, the majority of wells that pose a potential cross-connection threat are located in the southwestern portion of the Basin near Menlo Park and Atherton. Most of these wells are located southwest of El Camino Real, and are therefore upgradient of known contamination sites, mitigating the potential risk. However, several wells meeting these criteria are located to the northwest of El Camino Real, which is downgradient of several active remediation sites. These areas in particular may bode special consideration as Menlo Park considers the location for installation of its new emergency supply wells.

9.3.4 Sea Level Rise

Sea level rise resulting from thermal expansion of sea water and net addition of water from terrestrial sources (i.e., melting glaciers) has the potential to impact groundwater resources within the Basin. Estimates of sea level rise for the northern California coast south of Cape Mendocino range from 2 to 12 inches by 2030, from 5 to 24 inches by 2050, and from 17 to 66 inches by 2100 (NRC, 2012). The actual amount of sea level rise experienced at a given location depends on the shape of the seafloor and shoreline as well as regional tectonic trends. Sea level rise can have a multitude of impacts on the natural and manmade environment, including increased coastal erosion, increased inundation during storm events, increased volume and frequency of seawater infiltration into shallow pipelines. The reader is directed to Heberger et al. (2012) for a detailed discussion of these impacts.

In regard to impacts on groundwater resources, sea level rise can cause increased seawater intrusion into coastal aquifer systems. Because horizontal groundwater gradients are typically very small (i.e., less than 1 percent), small increases in sea level can result in large horizontal shifts in the position of the freshwater/seawater interface. The threat of seawater intrusion can be exacerbated by reduced aquifer recharge or increased groundwater pumping and remains an issue that will have to be monitored closely as additional groundwater development occurs in the Basin over time.



Legend

San Mateo Plain Subbasin

County Boundary

Major Road

Wells Screened from <100 ft bgs to >200 ft bgs

Abbreviations

"ft bgs" = feet below ground surface

Notes

1. All locations are approximate.
2. Wells with screen intervals spanning a range greater than 100 to 200 ft bgs are shown. Wells shown are limited to those for which screen intervals have been coded in the Project database.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Aerial imagery: Google Earth Pro, accessed 19 April 2016.

eki environment & water

TODD GROUNDWATER

HYDROFOCUS INC. Solutions for Land and Water Resources

Locations of Wells Potentially Cross-Connecting Shallow and Deep Aquifers

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 9-1

10.0 INITIAL EVALUATION OF BASIN MANAGEMENT OPTIONS

The occurrence of undesirable results can be prevented and/or mitigated through active groundwater basin management. Given the recent drought, the local interest in groundwater development, and the passage of SGMA in 2014, one of the objectives of this Project was to better understand what groundwater management options were available and if any were being employed in other similarly sized and used basins throughout California, and what relevance, if any, such approaches had for the Basin.

Groundwater basin management is generally composed of two components: (1) institutional management and (2) physical management. *Institutional* management refers to the governance structures, laws, and policies that define how groundwater is managed within a basin (Kemper, 2007). *Physical* management refers to the projects and programs that are implemented within a basin to achieve certain management objectives (e.g., operation of injection/extraction wells to create a hydraulic barrier against seawater intrusion).

10.1 Current Basin Management

10.1.1 Current Groundwater Oversight and Management Within the Basin

The Basin is not currently managed pursuant to any groundwater management plan, although, as described below, various entities do have a formal role and/or have expressed a formal interest in maintaining Basin health and sustainability (i.e., avoidance of undesirable results).

San Mateo County: The County manages well permitting and construction within the Basin and provides oversight of the investigation and remediation of groundwater contamination. Specifically, the County's Environmental Health Services Division (EHS) enforces a County well ordinance[46] that imposes standards (beyond the state-wide standards) on domestic water supply well construction and destruction. The EHS also administers the Groundwater Protection Program, which, among other things, provides oversight of cleanup efforts at groundwater contamination sites in conjunction with the RWQCB, DTSC, and USEPA. The County also acts on behalf of the State Public Health Officer in regard to water quality and quantity issues affecting the community.

Resolutions in Support of Sustainable Groundwater Management in the San Francisquito Creek Area: In recent years, there has been an increased focus on groundwater management in the southern portion of the Basin. In 2014, seven entities in the southern portion of the Basin and northern portion of the adjacent Santa Clara Subbasin – the governing bodies of the cities of East Palo Alto, Menlo Park, and Palo Alto, the towns of Atherton and Portola Valley, SCVWD, and the

[46] Chapter 4.68 of the San Mateo County Ordinance Code, as amended by Ordinance No. 4023 in January 2001.

County – passed resolutions in support of cooperative, sustainable management of the San Francisquito Cone (an alluvial area spanning both basins; see Section 5.0). These resolutions express shared concerns about the cost of SFPUC RWS water, growing water demands, potential supply shortages, seawater intrusion, and land subsidence. To address these concerns, the resolutions recognize the role that groundwater management strategies such as water conservation, recycled water use, storm water infiltration, and groundwater recharge can play in mitigating these potential issues. The adopted resolutions also recognize the need to further characterize the hydrology and geology of the San Francisquito Cone.

Groundwater Management Plans: SCVWD adopted a Groundwater Management Plan (GWMP) in 2012 that covers the portion of the Basin within Santa Clara County (SCVWD, 2012). SCVWD updated this GWMP in 2016 (SCVWD, 2016c) and submitted it to DWR as an Alternative to a Groundwater Sustainability Plan (GSP) in advance of the January 2017 deadline.

In November 2015, the City of East Palo Alto adopted a GWMP to cover its portion of the Basin (Todd, 2015b). The *2015 East Palo Alto GWMP* addresses groundwater conditions within the jurisdictional boundary of the City of East Palo Alto, which is located in the southern portion of the Basin. The *2015 East Palo Alto GWMP* was prepared in accordance with Assembly Bill (AB) 3030 and the amendments to AB 3030 provided by Senate Bill (SB) 1938 and AB 359. On-going efforts associated with implementation of the East Palo Alto GWMP include groundwater monitoring and reporting.

Groundwater Reliability Partnership: In October 2015, BAWSCA initiated work with the County and its member agencies to form the Groundwater Reliability Partnership (GRP).[47] The stated purpose of the GRP is to provide a forum for groundwater users and stakeholders to address the following goals: (1) increasing knowledge of the Basin's geology and hydrology; (2) facilitating information sharing through a series of public forums; and (3) supporting the continued sustainable management of the Basin's groundwater. In its current form, the GRP meets regularly to share information, but has taken no formal action (i.e., adoption of resolutions by participating agencies) with respect to policy or otherwise. The most recent meeting of the GRP was on 22 March 2017.

To date, no projects have been implemented with the direct purposes of enhancing or managing local groundwater resources within the Basin. However, as a part of the SMCWPPP of C/CAG, a partnership between the County and each incorporated city and town within the County, opportunities to infiltrate stormwater to the benefit of the groundwater systems were evaluated, as documented in the *Stormwater Resource Plan for San Mateo County* (Paradigm Environmental and Larry Walker Associates, Inc., 2017), adopted by the C/CAG Board of Directors on 9 February 2017.[48]

[47] http://bawsca.org/water/reliability/groundwater
[48] http://ccag.ca.gov/plansreportslibrary/san-mateo-county-stormwater-resource-plan/

10.1.2 Current and Pending Basin Priority Ranking per the Sustainable Groundwater Management Act

The first comprehensive groundwater legislation in California history, SGMA, was enacted on 16 September 2014 as part of a three-bill package and subsequent amendments.[49] The legislation provides a framework for the sustainable management of groundwater basins by local agencies, with an emphasis on the preservation of local control. Basins are subject to the requirements of SGMA if they are designated by DWR as a Medium or High priority basin.

The initial basin priorities were based upon the California Statewide Groundwater Elevation Monitoring (CASGEM) Basin Prioritization Process, which was completed in June 2014. As part of this process, DWR assigned a priority ranking of Very Low, Low, Medium, or High to each of the 517 groundwater basins in California based upon an evaluation of the following eight data components (DWR, 2014):

1. *Population* – The population overlying the basin;
2. *Population Growth* – The rate of current and projected growth of the population overlying the basin;
3. *Public Supply Wells* – The number of public supply wells that draw from the basin;
4. *Total Wells* – The total number of wells that draw from the basin;
5. *Irrigated Acreage* – The irrigated acreage overlying the basin;
6. *Groundwater Reliance* – The degree to which persons overlying the basin rely on groundwater as their primary source of water (a combination of the volume of groundwater use and its percentage of the total water supply for the basin or subbasin);
7. *Impacts* – Any documented impacts on the groundwater within the basin, including overdraft, subsidence, saline intrusion, and other water quality degradation; and
8. *Other Information* – Any other information determined to be relevant by the department.

In each basin, a ranking value between 0 and 5 was assigned to each data component, and these values were included as inputs to the formula used to calculate the resultant Basin Ranking Score (BRS)[50] and prioritization.[51] Based on the June 2014 Final CASGEM Groundwater Basin Prioritization Results, the Basin's BRS would have been 16.75 (i.e., a Medium priority basin) if it had not received the "groundwater reliance exemption" described below.

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[49] Including AB 1739 (Dickinson), SB 1169 (Pavley), and SB 1319 (Pavley), as amended by SB 13 (Pavley), AB 939 (Salas), SB 226 (Pavley), and AB 617 (Perea).
[50] Basin Ranking Score = Population + Population Growth + Public Supply Wells + (Total Wells x .75) + Irrigated Acreage + (Groundwater Use + Groundwater % of Total Supply)/2 + Impacts + Other Information
[51] The range of Basin Ranking Scores for each priority ranking were as follows: Very Low priority (<5.75), Low priority (5.75-13.42), Medium priority (13.43-21.08) or High priority (>21.08).

To facilitate the basin ranking process, DWR conducted an initial screening of the basins based upon *Component #6 – Groundwater Reliance* wherein they screened all basins with groundwater use of less than 2,000 AFY for potential exclusion from the ranking process (i.e., the "groundwater reliance exemption"). If no impacts or issues were documented within one of these basins, the BRS was overridden with a zero and the Basin was automatically ranked as a Very Low Priority basin. In 2014, DWR determined that groundwater use within the Basin was lower than the 2,000 AFY threshold and ranked it as a Very Low priority basin, exempting it from mandatory SGMA compliance.

Per SGMA, DWR is required to reassess basin prioritization every time the Bulletin 118 groundwater basin boundaries are updated (CWC §10722.4(b)). The next full Bulletin 118 report will be issued in 2020, but new revisions to basin boundaries were included in *Bulletin 118 – Interim Update*, in Fall 2016. Further, in May 2018, DWR issued an addendum to the Interim Update, which included draft updated basin priority rankings. In addition to the criteria used in the initial (2014) basin prioritization, the updated basin prioritization considered adverse impacts on local habitat and local streamflows (CWC §10933).

In its addendum to the *Interim Update*, DWR proposed changing the Basin's priority ranking from Very Low to Medium. Based on the currently available schedule, these priority rankings are expected to be finalized by the California Water Commission in October 2018, following a 60-day public comment period. If the Basin's draft priority ranking as Medium is finalized, such a reprioritization would mean that the Basin would now be subject to the requirements of SGMA, which will include, among other things, the establishment of one or more Groundwater Sustainability Agencies (GSAs) by October 2020 and the development of a basin-wide GSP by October 2023 (see Section 10.2.1.2).

10.2 Overview of Various Groundwater Basin Management Frameworks

While groundwater management of the Basin is not currently required, as discussed previously, the likely re-prioritization of the Basin could trigger mandatory SGMA compliance. Further, as evidenced by the strong interest in groundwater resource development and protection demonstrated by Basin stakeholders (see Section 3.0 and Appendix A), many entities are considering what options might be available for long-term sustainable coordination and/or management of the Basin irrespective of its current priority ranking. For example, a main focus of the BAWSCA GRP to date has been to provide information regarding SGMA and other locally-relevant groundwater management efforts to the BAWSCA member agencies and other interested parties. As a compliment to that information sharing, additional detail regarding applicable regulatory guidelines and codified frameworks, local examples, and potential benefits (e.g., in terms of funding eligibility) of various basin management options are presented below.

10.2.1 Existing Statewide Frameworks

10.2.1.1 California Statewide Groundwater Elevation Monitoring Program

The CASGEM Program is a groundwater elevation monitoring program that was developed by DWR per the requirements of SBx7-6. The objective of CASGEM is to establish a permanent, locally-managed program of regular groundwater monitoring to track seasonal and long-term trends in groundwater elevations. Monitoring responsibility for a basin or portion of a basin is delegated to "Monitoring Entities." Local agencies can volunteer to serve the role of a Monitoring Entity for all or a portion of a basin.

While no agencies are *required* to become Monitoring Entities, if DWR assumes that role by default the local agencies become ineligible for certain state funding. To date, enforcement of this eligibility criteria has been focused primarily on higher priority basins. For example, the Integrated Regional Water Management (IRWM) Grant Program requires that entities in Medium and High priority basins be compliant with CASGEM in order to receive a portion of the $510 million of Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1) funding allocated to the IRWM program (DWR, 2016). The same is true for the Proposition 1 Groundwater Grant Program funds.

The Basin does not currently have a Monitoring Entity that monitors groundwater levels, and is not participating in CASGEM. Because of this, if the Basin is re-prioritized as a Medium priority basin, many local agencies may lose eligibility for certain state funding. In order to fulfill the requirements of CASGEM, one or multiple Monitoring Entities would need to be established for the Basin. The following entities are eligible to be a Monitoring Entity (CWC §10927), the last three of which have potential applicability within the Basin:

- Watermasters or court appointed water management engineers;
- Groundwater management agencies with statutory authority who were monitoring groundwater elevations prior to 1 January 2010;
- Water replenishment districts;
- Local agencies that manage all or part of the groundwater basin and were monitoring groundwater elevations prior to 1 January 2010;
- Local agencies implementing an IRWM Plan that includes a groundwater management component;
- Counties; and
- Voluntary groundwater associations formed pursuant to CWC §10935.[52]

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[52] Voluntary cooperative groundwater monitoring associations may be formed by contract, joint powers agreement, memorandum of agreement or other form of agreement deemed acceptable to DWR.

Monitoring Entities do not need to collect all groundwater measurements, but can instead compile measurements from other entities for reporting to DWR. Therefore, it is possible to establish an umbrella Monitoring Entity that coordinates data submission from several agencies within a basin.

Under CASGEM, water level data must be submitted electronically to DWR twice a year, reflecting data from fall measurements and spring measurements. In addition to water level measurements, detailed information must be submitted for each well in the monitoring program, including well coordinates, well use, and depth of screened intervals. While data standards have been established by DWR, the monitoring methodologies are determined by the Monitoring Entities. Each Monitoring Entity must coordinate with DWR to develop a Monitoring Plan that addresses monitoring sites and timing, field methods, and data reporting. Although DWR may recommend improvements to a Monitoring Plan, it cannot require additional monitoring wells unless funds are provided for that purpose.

Compliance with CASGEM is potentially an important consideration for the Basin in the future and could be an important first step in setting the Basin up for long-term sustainable management and funding. Among other things, one or more agencies would have to assume responsibility as a Monitoring Entity and establish a data collection, storing and sharing framework that would satisfy DWR requirements.

Recognizing the importance and benefits of CASGEM compliance, the County hosted a meeting on 12 January 2018 to discuss the matter with representatives of stakeholder agencies within the Basin and in the surrounding basins. During the meeting, the County presented an overview of the CASGEM program and compliance requirements and solicited feedback from attendees on their level of interest in potentially working towards CASGEM compliance through collaborative efforts (e.g., identification of candidate wells, design of a monitoring networks, potential approaches to designation of a CASGEM Monitoring Entity). Based on the initial feedback from meeting attendees and follow-up discussions with the remaining entities, there is interest in some form of collaboration within the Basin towards achieving CASGEM compliance.

10.2.1.2 Sustainable Groundwater Management Act

As discussed in Section 10.1.2, all Medium and High priority basins must comply with the requirements of SGMA, and all other basins are encouraged to comply with the management framework outlined in the CWC. Specifically, under SGMA, basins must be managed by one or more GSAs pursuant to a GSP (or equivalent) and must maintain or achieve sustainability within 20 years of GSP adoption.[53] The SWRCB and DWR are responsible for SGMA implementation, and intervention by the SWRCB is triggered at specific intervals if a basin does not meet the applicable

[53] Sustainable groundwater management is defined under SGMA as "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results" (CWC §10721(v)).

SGMA requirements. In its initial ranking as a Very Low priority basin, the Basin was not required to comply with SGMA, but the legislation and accompanying regulations provided a helpful perspective as to how the state (and many local agencies) are thinking about sustainable groundwater management.

Form GSA	• By 30 June 2017 for Medium and High priority basins • Within two years for reprioritized basins following reprioritization
Prepare GSP and begin implementation	• By January 2022 for Medium and High priority basins (January 2020 if critically overdrafted) • Five years for reprioritized basins following reprioritization
Achieve sustainability	• By 2042 for Medium and High priority basins (2020 if critically overdrafted) • 20 years following adoption of GSP for reprioritized basins

Then, in May 2018, DWR issued draft basin re-prioritizations, which if finalized, would change the Basin to Medium priority and require entities in the Basin to comply with SGMA.

Formation of Groundwater Sustainability Agencies

The first major SGMA milestone is the requirement to form a GSA. If a basin is re-prioritized such that it becomes subject to the requirements of SGMA, the GSA formation deadline will be established as two years from the date of re-prioritization.[54,55] If an entire basin is not covered by one or multiple GSAs by this date, the SWRCB may designate the basin as "probationary" and intervene in the management of the Basin. Overlapping GSA boundaries are not permitted, and any overlap issues must be resolved between the agencies prior to the approval of a GSA by DWR. Any local public agency that has water supply, water management, or land use responsibilities within a groundwater basin is eligible to become a GSA for the portion of the basin that lies within their service area (CWC §10723(a)). Mutual water companies and water companies regulated by the California Public Utilities Commission (CPUC) may participate in a GSA through a memorandum of understanding (MOU) or other legal agreement.

Based on the above criteria, multiple entities within the Basin would be eligible to form and/or participate in a GSA (see **Table 10-1**). The entities within the Basin eligible to form a GSA include overlying cities (shown on **Figure 2-1**), San Mateo County, water districts and water suppliers (shown on **Figure 2-2**), and wastewater agencies (shown on **Figure 2-3**).[56] The entities eligible to

[54] The GSA formation deadline for basins currently ranked as Medium or High priority was 30 June 2017.
[55] If the current draft re-prioritization of the Basin is finalized in October 2018, the GSA formation deadline will be October 2020.
[56] It is anticipated that wastewater agencies will be eligible to form and participate in a GSA (personal correspondence, Jessica Bean, SWRCB, 30 June 2016).

participate in, but not independently form, a GSA include O'Connor Tract CWC and PAPMWC (mutual water companies) and Cal Water (CPUC-regulated utility).

If an area within a High or Medium priority basin is not included in the management areas of any GSAs, then the overlying county is presumed to be the GSA for that area (CWC §10724(a)). The county may decline to serve as a GSA for such an area. If the county does not serve as the GSA, then groundwater extractions within the applicable area must be reported to the SWRCB by the extractors, if greater than 2 AFY. Therefore, counties have an explicit role under SGMA in the management of the parts of a basin where other GSAs have not claimed jurisdiction (termed "white areas" in SGMA documentation).

Under SGMA, numerous authorities are granted to GSAs to empower them to implement GSPs and achieve sustainable groundwater management. Among other things, a GSA may exercise the following general powers:[57,58]

- Perform any act "necessary or proper" to carry out the purposes of SGMA;
- Adopt rules, regulations, ordinances, and resolutions;
- Acquire property, including surface water and groundwater rights;
- Regulate groundwater use, including imposing spacing requirements on new wells, limiting groundwater extraction, regulating the construction of new wells,[59] requiring metering of all wells, and requiring annual reporting of extraction totals;
- Manage surface water and groundwater by importing water, providing surface water in lieu of groundwater, and managing wastewater and stormwater; and
- Conduct investigations, sue to collect groundwater fees, and impose civil penalties for violations.

In all basins, significant stakeholder coordination is required to identify an appropriate GSA and the associated governance, financial and regulatory authorities, and structure of that GSA. That being said, pursuant to SGMA, formation of GSAs is a necessary precursor to GSP development, and the governing structure of GSAs within a basin determines how the GSP will be prepared and implemented.

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[57] GSAs are not authorized to issue permits for the construction, modification, or abandonment of groundwater wells, unless authorized by the county with authority to do so.
[58] Retail water supplies may not be delivered within the service area of a public water system without the consent of that system or authority under the GSA's existing authorities.
[59] GSAs are not authorized to issue permits for the construction, modification, or abandonment of groundwater wells, unless authorized by the county with authority to do so.

Development and Implementation of Groundwater Sustainability Plans

The GSP is the fundamental tool for managing groundwater under SGMA. If a basin is re-prioritized such that it must comply with the requirements of SGMA, the deadline for GSP adoption will be five years from the date of re-prioritization.[60,61] Failure to adopt a GSP by these deadlines will result in SWRCB intervention. All basins that are subject to SGMA must achieve sustainability within 20 years following adoption of the GSP.

In May 2016, the California Water Commission adopted the *Groundwater Sustainability Plan Emergency Regulations* (GSP Regulations) developed by DWR, and the GSP Regulations were submitted to the Office of Administrative Law in August 2016.[62] These regulations substantially revise and supersede the requirements for groundwater management plans articulated in AB 3030 and SB 1938. The GSP Regulations provide the framework for what will be required in a GSP, how the GSP must be implemented, and the process/criteria by which GSPs will be reviewed by DWR. Among other things, a GSP must provide a description of the existing land uses and groundwater management within the Basin, and the current and historical groundwater conditions. Public outreach and input is a key component of a GSP, and the processes by which the public is engaged must be documented thoroughly in the plan. Significant scientific and technical work is required to prepare a GSP, including the development of a hydrogeologic conceptual model and quantitative water budget. While a numerical groundwater and surface water model is not strictly required, if one is not used then a GSP must demonstrate that an "equally effective" tool is being utilized to inform the technical analysis. A monitoring program must be established in support of the GSP, and the GSP Regulations provide the technical and reporting standards for such a program, including for a centralized data management system. Although multiple, non-overlapping GSPs may be adopted within the same basin, there are substantial coordination requirements, not to mention cost implications, associated with this approach.

A GSP must adopt a sustainability goal for the basin and specifically define criteria that will ensure that undesirable results do not occur for each of the following "sustainability indicators": chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, land subsidence, and depletions of interconnected surface water. "Minimum thresholds" must be established for each sustainability indicator, which will define the point at which basin conditions become significant and unreasonable. "Measurable objectives" must then be established for each sustainability indicator; these are specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted GSP to achieve the sustainability goal for the basin. "Interim milestones" (IMs) must also

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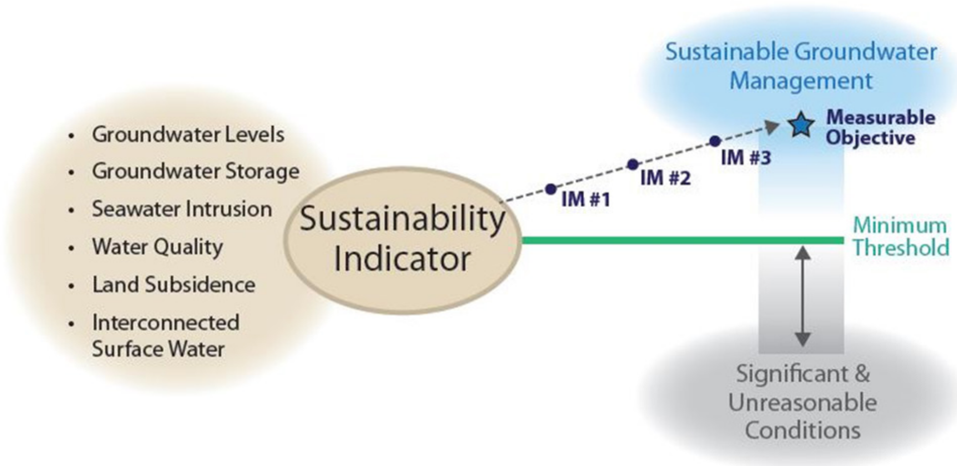
[60] The deadline for GSP adoption for basins currently ranked as Medium and High priority is 30 June 2020 if the basin is designated as "critically-overdrafted" and 30 June 2022 for all others.

[61] If the current draft re-prioritization of the Basin is finalized in October 2018, the GSP adoption deadline will be October 2023.

[62] http://www.water.ca.gov/groundwater/sgm/pdfs/GSP_Emergency_Regulations.pdf, accessed September 2016.

be established for each sustainability indicator in five-year increments, providing a pathway towards meeting sustainability goal. The graphic shown below has been developed by DWR to illustrate these concepts.



10.2.1.3 Recycled Water Policy

As discussed in Section 9.3.1, the Recycled Water Policy adopted by the SWRCB states that local stakeholders, including municipalities, water and wastewater agencies, and others, will develop SNMPs consistent with CWC §10750 et seq. for every groundwater basin in California (SWRCB, 2013).[63,64] Development of SNMPs is consistent with the Recycled Water Policy goals to increase the use of recycled water from municipal wastewater sources and streamline permitting of recycled water projects by the RWQCB, while maintaining the quality of groundwater supplies.

Per the Recycled Water Policy, an SNMP shall include, among other things, the following components:

- A basin-wide monitoring plan that includes an appropriate network of monitoring locations;
- A provision for annual monitoring of Emerging Constituents/ Constituents of Emerging Concern;
- Water recycling and stormwater recharge/use goals and objectives;
- Salt and nutrient source identification, basin assimilative capacity and loading estimates, together with fate and transport of salts and nutrients;

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[63] http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/recycledwaterpolicy_approved.pdf, accessed 27 September 2016.
[64] http://www.swrcb.ca.gov/rwqcb9/publications_forms/publications/docs/2014_Annual_WateReuse_Conference_SNMP_Paper-Final.pdf, accessed 27 September 2016.

- Implementation measures to manage salt and nutrient loading in the basin on a sustainable basis; and
- An antidegradation analysis demonstrating that the projects included within the plan will, collectively, satisfy the requirements of the SWRCB's Antidegradation Policy.[65]

No SNMP has been developed to date in the Basin, but other basins in the region have developed SNMPs, including the Santa Clara Subbasin. The San Francisco Bay RWQCB gave SNMP implementation a "Medium" rank as a project in their 2015 Triennial Review of the Basin Plan (SFRWQCB, 2015b).

10.2.1.4 Basin Adjudications

Adjudication of a groundwater basin is one method of regulating groundwater extraction and allocating costs of replenishment. When multiple parties withdraw water from the same aquifer, groundwater pumpers can ask the court to "adjudicate,"[66] or define the rights that various entities have to use groundwater resources. Through adjudication, the courts can assign specific water rights to water users and can compel the cooperation of those who might otherwise refuse to limit their pumping of groundwater. This court-directed process can be lengthy and costly, although some of these cases have been resolved with a court-approved negotiated settlement, called a stipulated judgment. Watermasters are typically appointed by the court to ensure that pumping conforms to the limits defined by the adjudication. Through this process, the courts have adjudicated over 20 basins in California, mostly in Southern California.

10.2.1.5 Special Act Districts

In California, a water special district can be created (1) by forming under a general water district act or (2) through a special act of the Legislature.[67] Most water districts have formed under a general act, with less than one-in-ten districts authorized by a special act. The governing bodies of special districts are either dependent or independent. A dependent governing body is one in which the governing body is directly controlled by either a city or county. For dependent districts, a city council or county board of supervisors acts as the district's ruling body, or they appoint individuals for that responsibility who serve at the pleasure of the city or county. Independent special districts have their governing body either directly elected by the voters or appointed for a fixed term of service (often by a board of supervisors). As described below, in several adjacent basins, groundwater management is exclusively done by special act districts.

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[65] *SWRCB Resolution No. 68-16*
[66] http://www.watereducation.org/aquapedia/groundwater-adjudication, accessed 19 December 2016.
[67] http://www.lao.ca.gov/2002/water_districts/special_water_districts.html, accessed 19 December 2016.

10.2.2 Existing Frameworks in Adjacent Basins

As shown on **Figure 10-1** and described in Section 6.2.6, the Basin shares boundaries on the north with the Westside Basin and on the south with the Santa Clara Subbasin. The Niles Cone and East Bay Plain Subbasins are located across the San Francisco Bay to the east. As has been presented at previous BAWSCA GRP meetings, and as summarized in the following sections, groundwater is actively managed in each of these adjacent basins, although the management framework differs from basin to basin.

10.2.2.1 Westside Basin

Although the Westside Basin was designated as a Very Low priority basin in 2014, several entities within the basin planned to voluntarily comply with SGMA through the formation of GSAs and development of GSPs. DWR has now proposed re-prioritizing the basin to Medium. If this change is adopted when final re-prioritizations are issued in October 2018, SGMA compliance will be required rather than voluntary.

Active management has long been occurring in the Westside Basin, with the basin informally split into two management areas, covering generally the northern and southern portions of the basin, and coincident with the boundary between San Mateo County and San Francisco County.

The North Westside Basin is managed by the SFPUC, which serves as the designated CASGEM Monitoring Entity and established itself as the GSA for that portion of the basin in March 2015 (SFPUC, 2015a). The SFPUC is currently preparing a GSP for that portion of the basin that will supersede the *2005 North Westside Basin GWMP*. To ensure consistent implementation of GSPs within the Westside Basin, the SFPUC has resolved to enter into coordination agreements with each of the agencies in the South Westside Basin (SFPUC, 2015b).

Large portions of the South Westside Basin are jointly managed by a majority of the overlying water suppliers (San Bruno, Daly City and Cal Water South San Francisco) and the SFPUC (collectively, the “Westside Basin Partners”) in accordance with the *2012 South Westside Basin GWMP* (Westside Basin Partners, 2012) and the *2014 Westside Basin Groundwater Storage and Recovery Agreement* (GSR Agreement). The GSR Agreement, among other things, established a self-imposed pumping limitation of 6.9 MGD for the South Westside Basin (calculated over a five-year averaging period) in order to maintain groundwater extractions within the basin sustainable yield. This annual pumping volume was then allocated among the participants as follows: 3.43 MGD for Daly City, 2.10 MGD for San Bruno, and 1.37 MGD for Cal Water (SFPUC, 2013).

As part of basin management, groundwater levels and water quality samples are routinely collected and compared to established triggers related to water levels[68] and groundwater quality[69] to assess if the Basin Management Objectives (BMOs) are being met (Westside Basin Partners, 2012). If the thresholds defined by these triggers are exceeded, the GWMP establishes specific mitigation measures that will be implemented. The Westside Basin Partners formed the "South Westside Basin" CASGEM Monitoring Entity and report the results of their monitoring program to DWR as part of their responsibilities as the CASGEM Monitoring Entity for the corresponding portion of the Westside Basin.

In January 2016, Daly City, San Bruno, and Cal Water entered into a joint funding agreement to develop a GSP for the South Westside Basin (City of San Bruno, 2016).[70] The *2012 South Westside Basin GWMP* will be transitioned into a SGMA-compliant GSP through modifications and additions. The South Westside Basin GSP will be coordinated with the North Westside Basin GSP to ensure that both GSPs are using the same data and methodologies, as required by the GSP Regulations. The Westside Basin Partners are also currently exploring options for GSA formation, but no GSA has been formed for the South Westside Basin as of 6 February 2018.

10.2.2.2 Santa Clara Subbasin

The SCVWD is a Special Act District that is the designated groundwater management agency for the Santa Clara Subbasin as well as all other basins within Santa Clara County, as established by the *Santa Clara Valley Water District Act* (District Act) in 1929. The SCVWD actively manages groundwater through the implementation of its GWMP (SCVWD, 2016c), which was first published in 2001 and was most recently updated in 2016.

In addition to its groundwater management responsibilities, the SCVWD is also the primary water wholesaler, flood manager, and watershed steward for Santa Clara County. As such, the SCVWD is able to maximize conjunctive use within the Santa Clara Subbasin through managed recharge and "in-lieu" recharge, where groundwater pumping is reduced through the provision of imported water, water conservation, or water recycling. The SCVWD has broad authorities under the District Act that allow for centralized management of groundwater within the Santa Clara Subbasin. For example, the SCVWD levies groundwater production charges and uses the revenue to offset the costs of importing water and to fund the construction, operation, and maintenance of district facilities (SCVWD, 2012). The charges are set annually and are established for

[68] The first water level trigger is groundwater elevations below the historical minimum elevation, as defined specifically for individual wells. The second water level trigger is groundwater elevations that are ten feet below the historical minimum elevation.

[69] Water quality triggers are defined as specific values for chloride and as percentages above the historical maximum concentration for other indicator parameters.

[70] Since SFPUC is not a "continuous purveyor of groundwater" in the South Westside Basin, the SFPUC is not funding GSP development in the basin (City of San Bruno, 2016).

agricultural and non-agricultural groundwater production for two separate zones within the SCVWD service area.[71] The SCVWD also enforces an ordinance for the construction and destruction of wells.

The Santa Clara Subbasin is a Medium priority basin and is therefore subject to the requirements of SGMA. DWR has now proposed re-prioritizing the basin to High, which would not change its obligations under SGMA. Under SGMA, the SCVWD is specifically called out as the exclusive local agency for the Santa Clara Subbasin and is the sole GSA for the basin.[72] In May 2016, SCVWD filed a formal notification with DWR to form a GSA (SCVWD, 2016b). The SCVWD also serves as the designated CASGEM Monitoring Entity for the Santa Clara Subbasin.

As directed by SGMA, the GSP Regulations establish the procedures for submitting "Alternative Plans" to DWR, which will serve in place of a GSP. The key provisions in the GSP Regulations are that an Alternative Plan must cover the entire basin and be "functionally equivalent" to a GSP. The SCVWD submitted its 2016 GWMP to DWR as an Alternative Plan in December 2016, after which DWR accepted public comments on the Alternative Plan through 1 April 2017. A total of five sets of comments on the Alternative Plan were received. The SCVWD Alternative Plan does not discuss potential impacts on the Basin, but does note that public outreach related to SGMA compliance included San Mateo County. The SCVWD's Alternative Plan is currently under review by DWR.

10.2.2.3 Niles Cone Subbasin

The Niles Cone Subbasin is managed by a single entity, the ACWD. The ACWD was formed in 1914 pursuant to the County Water District Act of 1913 and manages the basin pursuant to its *Groundwater Management Policy*, as amended in 2001. The *Replenishment Act of the Alameda County Water District*, as amended in 1974, grants ACWD the authority to charge operators of groundwater production facilities an assessment based on the quantity of groundwater produced (see Section 10.4.4.1). The *2009 Alameda County Water District Groundwater Protection Act* also granted the ACWD with the authority to implement and enforce a well ordinance within the cities of Fremont, Newark, and Union City.

The Niles Cone Subbasin is a Medium priority basin and, like the SCVWD, ACWD is specifically designated under SGMA as the exclusive local agency (i.e., presumed GSA) for the basin. The ACWD is also the designated CASGEM Monitoring Entity for the Niles Cone Subbasin.

In November 2016 ACWD formed a GSA and in December 2016 ACWD submitted an Alternative Plan which was open for public comments until 1 April 2017. A total of four sets of comments were received on the Alternative Plan. The ACWD Alternative Plan discusses potential impacts

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[71] The current SCVWD charges for the Santa Clara Subbasin (i.e., Zone W-2) are available at: http://valleywater.org/Services/WaterCharges.aspx., accessed 26 September 2016.
[72] CWC §10723(c)(1)(M)

on neighboring groundwater basins and states that artificial recharge operations in the Niles Cone Subbasin will preclude the potential for operations in the Niles Cone Subbasin to cause undesired results in neighboring, hydraulically connected groundwater basins. The ACWD's Alternative Plan is currently under review by DWR.

10.2.2.4 East Bay Plain Subbasin

The East Bay Plain Subbasin was designated as a Medium priority basin in 2014, but under the draft re-prioritizations may be re-ranked as Very Low. It is unknown how this will impact future management in the subbasin with respect to SGMA.

The EBMUD service area covers the majority of the East Bay Plain Subbasin, with the exception of the southern portion of the basin that underlies the City of Hayward.[73] The *2013 South East Bay Plain Basin GWMP* provides a management framework for the southern portion of the East Bay Plain Subbasin (EBMUD, 2013) and EBMUD is the designated CASGEM Monitoring Entity for the entire subbasin.

The EBMUD is a public utility that was formed in 1923 under the *Municipal Utility District Act*. The district was created by a vote of residents in the East Bay Area in order to provide retail water service. The EBMUD began serving water from the Mokelumne River in 1929 and expanded its services to include wastewater treatment in 1944.

The EBMUD hosted three GSA formation meetings with cities, counties, and water agencies overlying the East Bay Plain Subbasin, as well as several one-on-one meetings with select stakeholders. Through this outreach process, key stakeholders, including the counties (i.e., Alameda and Contra Costa) and cities overlying the basin within the EBMUD service area, have supported EBMUD's formation of a GSA for the basin (EBMUD, 2016a). These entities have indicated a willingness to develop a Memorandum of Agreement that describes ongoing roles and responsibilities, such as well permitting and inspection.

On 9 August 2016, EBMUD passed a resolution to form a GSA for the portion of its service area that overlies the East Bay Plain Subbasin (EBMUD, 2016b). As of November 2016, EBMUD is the exclusive GSA for its portion of the East Bay Plan Subbasin.

The City of Hayward passed a resolution to form a GSA for the portion of the East Bay Plain Subbasin that underlies the city on 7 February 2017 and on 6 June 2017 was declared the exclusive GSA for its portion of the subbasin. Prior to adopting the resolution, the City of Hayward held a public hearing, notice of which was published pursuant to Government Code Section 6066, as well as provided to interested parties.

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[73] The ACWD requested a basin boundary adjustment from DWR to shift the shared boundary of the Niles Cone and East Bay Plain Subbasins northward to match the ACWD service area boundary. The request was approved and the boundary modification took effect with the publication of *Bulletin 118 – Interim Update*, in Fall 2016.

EBMUD and the City of Hayward formally notified the DWR of their intention to work together to develop a single GSP for the East Bay Plain Subbasin, and that GSP development will be coordinated closely with ACWD's GSP development in the Niles Cone Subbasin (EBMUD, 2016a).

EBMUD held stakeholder meetings on 10 August 2017 and 27 February 2018 to provide updates on SGMA compliance and share plans for continued SGMA compliance activities (EBMUD, 2018). Attendees at one or both of these meetings included representatives from ACWD, BAWSCA, the City of Berkeley, the Berkeley Community Environmental Advisory Commission, the City of Hayward, the City of Richmond, the City of San Pablo, Contra Costa County, San Mateo County, the Port of Oakland, San Francisco Bay RWQCB, DWR, UC Berkeley, and Lawrence Berkeley National Laboratory, among others.

10.2.3 Existing Frameworks in Other Similarly Sized and Similarly Used Basins

The Basin is distinguished from other basins ranked as Low and Very Low priority in 2014 by its large population and relatively small land area (see **Figure 10-2**). Specifically, there are only three other Low and Very Low priority basins that are similar to San Mateo Plain in both size and population:[74]

- The Downtown San Francisco Basin (DWR 2-004) is a Very Low priority basin that experiences little to no groundwater production and is managed exclusively by SFPUC.
- The Hollywood Subbasin of the Coastal Plain of Los Angeles Basin (DWR 4-011.02) is a Very Low priority basin in Los Angeles with one major groundwater pumper.
- The Westside Basin is described in detail in Section 10.2.2.1.

Groundwater management in similarly-used basins is summarized in **Table 10-2** and **Figure 10-3**. These basins were selected based upon their ranking values for the data components utilized in the 2014 CASGEM Basin Prioritization Process (see Section 10.1.2).[75] Basins were determined to be "similarly-used" if they ranked within one ranking value of the Basin's ranking value for the following criteria: 'Irrigated Acreage', 'Groundwater Reliance', sum of 'Population' and 'Population Growth', and sum of 'Public Supply Wells' and 'Total Wells'. This evaluation resulted in nine similarly-used basins. Five of these basins are less applicable to the Basin because they are adjudicated or are managed by a single entity (including exclusive agencies under SGMA). The following four basins are similar to the Basin in that they are either (a) Very Low priority

[74] These basins were selected using data from the 2014 CASGEM basin prioritization process (see Section 10.1.2) based on the following criteria: population greater than 150,000 and basin area less than 50,000 acres. According to this 2014 data, the Basin has a population of 291,899 and a basin area of 37,708 acres.
[75] Statewide CASGEM prioritization data is available at http://www.water.ca.gov/groundwatercasgem/basin_prioritization.cfm, accessed 23 November 2016.

basins that are not subject to SGMA, or (b) are managed by multiple entities with an interest in groundwater:

- The East Bay Plain Subbasin, described in detail in Section 10.2.2.4, is a Medium priority basin that is managed by multiple entities (EBMUD and City of Hayward). However, the recent draft re-ranking by DWR dropped its priority to Very Low.
- The Martis Valley Basin (DWR 6-067) is a Medium priority basin underlying the Town of Truckee, north of Lake Tahoe. A GWMP was prepared for the basin in 2013 by Placer County Water Agency, Northstar Community Services District, and Truckee Donner Public Utilities District. In response to SGMA, the GWMP agencies have collaborated with the overlying counties (Placer and Nevada) and the town of Truckee to pursue an Alternative Plan.
- The Pittsburg Plain Basin (DWR 2-004) is a Very Low priority basin that, similar to the Basin, would have ranked as a Medium priority basin if it had exceeded the 2,000 AFY groundwater use threshold. A GWMP was prepared in 2012 by the predominant groundwater user in the basin, the City of Pittsburg. Although the basin is not required to comply with SGMA, a recent grand jury report prepared by Contra Costa County recommended that the county should encourage water districts in Low and Very Low priority basins to form GSAs (Contra Costa County, 2016). The report specifically discusses GSA formation in the Pittsburg Plain Basin, suggesting that the City of Pittsburg should consider forming a GSA for the basin in order to "establish its practical sustainable yield and maximum storage capacity."
- Ygnacio Valley Basin (DWR 2-006) is a Very Low priority basin that is located in northern Contra Costa County along the south shore of Suisun Bay and shares many similarities with the adjacent Pittsburg Plain Basin.

Table 10-2. Groundwater Management in Similarly-Used Basins

Basin	Subbasin	CASGEM Priority Ranking	GSA Formation	GSP Preparation
Very Low Priority Basins (SGMA not Required)				
Ygnacio Valley	--	Very Low	Not required	Not required
Pittsburg Plain	--	Very Low	Not required	Not required
Multiple Entities with Groundwater Interest				
Santa Clara Valley	East Bay Plain	Medium**	Exclusive/ Multiple Entities	GSP
Martis Valley	--	Medium	Multiple Entities	Alternative
Exclusive Agency, Single Entity, Adjudicated				
Livermore Valley	--	Medium	Exclusive/Single Entity	Alternative
Coastal Plain of Los Angeles	Santa Monica	Medium	Multiple Entities	GSP*
Redding Area	Bowman	Medium**	Exclusive	GSP*
Upper Santa Ana	Temescal	Medium	Multiple	GSP*
Warren Valley	--	Medium**	Adjudicated	Adjudicated

Notes:
1) GSP preparations indicated with an asterisk (*) were tentative and not yet finalized as of April 2018.
2) Indicated CASGEM priority ranking is from the June 2014 basin prioritization process and may be subject to revision (**).

10.3 Potential Supply Sources that Could Be Used to Augment Groundwater Recharge and Storage

As identified by Basin stakeholders, there are several sources of water that have been or could be used directly or indirectly to augment groundwater recharge and storage within the Basin.

10.3.1 Hetch Hetchy Water

The SFPUC is the water wholesaler to all municipal water suppliers in the Basin, with the exception of the two mutual water companies in the cities of East Palo Alto and Menlo Park, which rely solely on groundwater. The SFPUC RWS water supply consists predominantly of Tuolumne River water originating in Hetch Hetchy Reservoir in Yosemite National Park, and is a high-quality water source. As discussed in Section 7.0, the importation of Hetch Hetchy water to the region is largely responsible for the recovery of groundwater levels in the Basin as reliance on groundwater decreased and irrigation return flows increased.

Deliveries of SFPUC RWS water to retail water suppliers in the Basin are governed by the 2009 Water Supply Agreement. Pursuant to this agreement, each wholesale customer has an Individual Supply Guarantee (ISG), which represents that agency's perpetual allocation of water from the SFPUC RWS. Some water suppliers in the Basin use only a portion of their ISG each year with some not using the amount they have to pay for at a minimum, whereas others, such as the

City of East Palo Alto, typically use close to their full ISG. As such, access to "surplus" SFPUC RWS water as a source of supply for direct or indirect groundwater recharge projects varies greatly between water suppliers in the Basin.

10.3.2 Recycled Water

Several water suppliers in the Basin are actively considering or pursuing the use of recycled water for landscape irrigation and other non-potable uses within their service areas.[76] Highly treated recycled water is available or may soon be available within the Basin from the three wastewater treatment facilities serving customers within the Basin: San Mateo WWTP, SVCW WWTP, and the Palo Alto Regional Water Quality Control Plant (Palo Alto RWQCP) (see **Figure 2-3)**. Significant demand for recycled water for landscape irrigation has been identified within the Basin, although in many cases the demands are geographically distributed and the infrastructure does not exist to deliver the recycled water to these locations (EKI, 2016b; EKI, 2016c; Cal Water, 2016a; Cal Water, 2016b; RMC, 2013, HydroScience, 2015). A summary of current and potential recycled water projects in or proximate to the Basin is provided below.

- The San Mateo WWTP[77] treats wastewater from the northern portion of the Basin, including the cities of San Mateo and Foster City. These cities are in the process of completing improvements to the WWTP that will generate between 1 MGD and 3 MGD of highly-treated wastewater that could be a source for recycled water supply to the region by 2022. If additional treatment is added at the WWTP, the San Mateo WWTP may be able to provide sufficiently treated water such that it could supply IPR/DPR projects by 2025 (BAWSCA, 2016).

- The SVCW[78] treats wastewater for the middle portion of the Basin, serving the cities of Belmont, San Carlos, Menlo Park, and Redwood City. Phase 2A of the Redwood City distribution system project was completed in September 2016. Recycled water treated at the SVCW WWTP supplied the city of Redwood City with approximately 700 AFY of recycled water in 2015, and that volume is expected to increase to approximately 1,600 AFY by 2040 (EKI, 2016c). Subject to regional cooperation, and planned plant and treatment system improvements, it is estimated that between 8 MGD and 10 MGD of recycled water will be available for recycled water and potentially IPR/DPR projects from SVCW (BAWSCA, 2016).

- The Palo Alto RWQCP serves the southern portion of the Basin, including the city of East Palo Alto. The treatment facility has average flows of 20 MGD, of which approximately 3 MGD is currently utilized for recycled water supply in the Santa Clara Subbasin

[76] The SWRCB issued a report on 29 December 2016 concluding that it is feasible to develop and adopt regulations for use of recycled water for drinking water, provided that certain research and key knowledge gaps are addressed.
[77] http://www.cleanwaterprogramsanmateo.org/, accessed 24 September 2016.
[78] http://www.svcw.org/SitePages/Home.aspx, accessed 24 September 2016.

(BAWSCA, 2016). The City of Palo Alto is investigating the possibility to reuse more recycled water from the Palo Alto RWQCP (City of Palo Alto, 2016). Specifically, one objective of the Northwest County Indirect Potable Reuse Feasibility Study is to evaluate whether increased groundwater utilization by the City is viable, and if so, to evaluate the feasibility of IPR/DPR with recycled water.

- The West Bay Sanitary District (WBSD) collects wastewater in the southern portion of the Basin and currently conveys the wastewater to the SVCW WWTP for treatment. The WBSD is partnering with the Sharon Heights Golf and Country Club (SHGCC) in the City of Menlo Park to construct and operate a wastewater treatment plant and recycled water treatment facility near the SHGCC. It is estimated that such a project could result in approximately 300 AFY of recycled water use by the SHGCC, SLAC National Accelerator Laboratory, and at nearby business parks and homeowners' associations (EKI, 2016b; RMC, 2015).

While recycled water projects in the region have historically been implemented by individual cities or water suppliers, there is the potential to develop regional projects that provide economies of scale to the participants. Several entities are exploring joint projects to upgrade treatment facilities, to construct recycled water distribution systems, and/or to evaluate IPR and DPR options. In addition to these options, this highly-treated recycled water could potentially be a source of groundwater recharge (directly or indirectly) to the Basin, or could be injected into the groundwater system to create a barrier to sea water intrusion. Expanded use of wastewater for beneficial use within the Basin should be informed by the SWRCB's Recycled Water Policy(see Section 10.2.1.3) and may be regulated under the San Francisco Bay RWQCB Water Reclamation Requirements (WRR) Order 96-011.[79] As there is currently no SNMP in place, no actions related to recycled water can currently be taken.

10.3.3 Stormwater

Stormwater within the Basin is generated primarily from runoff from impervious surfaces during precipitation events. A substantial portion of this stormwater is conveyed directly to San Francisco Bay through concrete-lined drainage channels or underground pipes, and thus does not recharge the Basin. Stormwater represents a potential source to augment recharge, because it can be captured and diverted before it reaches stormwater conveyance infrastructure, or the existing infrastructure can be modified to enhance recharge (e.g., "un-lining" concrete channels), emphasizing low impact development (LID), or engineering small, distributed systems that would collect and recharge stormwater. As discussed previously, opportunities to infiltrate stormwater to the benefit of the groundwater systems are being evaluated by C/CAG as a part of the SMCWPPP. The San Mateo County Stormwater Resource Plan (SRP) was approved by the C/CAG Board of Directors on 9 February 2017, approved by the Bay Area IRWMP Coordination

[79]http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/recycledwaterpolicy_approved.pdf, accessed 27 September 2016.

Committee on 27 February 2017, and submitted to the SWRCB in March 2017. On 21 June 2017, a workshop was held on stormwater controls for green development projects, including green infrastructure requirements.

10.3.4 Water Conservation

Groundwater storage in the Basin can also be managed indirectly by reducing water demands. "Passive conservation" refers to water savings resulting from actions and activities that do not depend on direct financial assistance or educational programs implemented by water suppliers. These savings result primarily from: (1) the on-going replacement of existing plumbing fixtures with water-efficient models required under current plumbing code standards,[80] and (2) the installation of water-efficient fixtures and equipment in new buildings and retrofits as required under CALGreen Building Code Standards. "Active conservation" refers to water savings resulting from a city or water supplier's implementation of water conservation programs, education programs, and the offering of financial incentives (e.g., rebates). In 2014, BAWSCA projected that passive conservation alone could provide up to 4.5 MGD of water conservation savings to suppliers in the Basin by 2040, whereas a combination of passive and active conservation could provide up to 19.4 MGD of savings (BAWSCA, 2014).[81] To the extent that water conservation reduces water demands in the future, seasonally or in total, the pressure to expand groundwater production may be reduced and there may be more opportunities to implement conjunctive management of the surface and groundwater resources.

10.4 Inventory of Potential Physical and Institutional Groundwater Management Options

As discussed in prior sections, historical rates of groundwater extraction in the Basin resulted in documented undesirable results such as declining water levels, sea water intrusion, and subsidence. These conditions have since been reversed and the Basin is currently in a stable and relatively "full" condition. However, as plans for increased groundwater extraction are developed, stakeholders have indicated that maintaining the integrity of the resource is an important consideration.

In the previous section, potential water supply sources were identified that could be used to enhance groundwater storage within the Basin. The following sections present some of the physical and institutional management strategies or projects that have been deployed in adjacent basins to proactively or reactively address similar "threats" to groundwater sustainability in those basins. The potential interest or feasibility of implementing such projects within the Basin is something that can be further explored through coordinated discussion with interested

[80] Including the California Energy Commission Title 20 appliance standards for toilets, urinals, faucets, and showerheads. The appliance standards determine what can be sold in California and therefore will impact both new construction and replacement fixtures in existing homes.

[81] Includes projected savings for East Palo Alto, Foster City, Menlo Park, Redwood City, Cal Water Mid-Peninsula District, and Cal Water Bear Gulch District, but excludes savings for Burlingame and Hillsborough.

stakeholders. There are many potential project partners within the Basin and beyond that may be interested in collaborating to undertake one of the management options discussed herein; an illustrative list of such potential partners is provided in **Table 10-1**. It should be noted that all of the projects discussed in the following sections are illustrative and conceptual in nature. Further technical work (including groundwater modeling, cost estimation and local hydrogeologic investigation) would need to be done to further assess project costs, benefits, and technical feasibility.

10.4.1 Conjunctive Use and In-Lieu Recharge

Conjunctive use is defined as the coordinated use of surface water and groundwater. One of the most common methods of conjunctive use is in-lieu recharge, wherein groundwater pumping from an aquifer is decreased as surface water supplies are utilized "in-lieu" of groundwater production. This typically occurs during wet years or wet seasons, when excess surface water supplies are available for use.

In the South Westside Basin, SFPUC and the Westside Basin Partners (see Section 10.2.2.1) are pursuing an in-lieu recharge project in the form of the Groundwater Storage and Recovery (GSR) project.[82] As part of this project, the SFPUC supplies the Westside Basin Partners with supplemental SFPUC RWS water during normal and wet years and, in return, the Westside Basin Partners reduce their groundwater production by a comparable amount (SFPUC, 2013). As a result, relative to conditions without the GSR project, groundwater storage in the South Westside Basin increases in normal and wet years, providing a supply of "stored" groundwater that can then be pumped by both the Westside Basin Partners and SFPUC in dry years to supplement other supplies. Construction is underway with scheduled completion in 2019.

In-lieu recharge programs are conducted elsewhere in the region by other agencies, including by SCVWD in the Santa Clara Subbasin, ACWD in the Niles Cone Subbasin, and the Alameda County Flood Control and Water Conservation District, Zone 7 (Zone 7) in the Livermore Valley Groundwater Basin (DWR 2-010). The GSR project in the South Westside Basin provides the most relevant example of a local in-lieu recharge program; however, because in that case entities within the basin with an interest in groundwater management proactively established the program in the absence of a centralized, basin-wide groundwater management agency.

As described in Section 5.0, the Basin is currently relatively "full" and therefore the opportunity to increase groundwater storage is likely limited. However, to the extent that groundwater pumping increases in the future and geologic conditions are favorable, there is the potential that a small-scale conjunctive use program could be developed within the Basin by interested parties, similar to what has occurred in the South Westside Basin.

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[82] More information regarding the GSR is accessible at: http://sfwater.org/index.aspx?page=982., accessed 24 September 2016.

10.4.2 Managed Recharge

Two of the primary sources of recharge in the Basin are percolation in stream channels and percolation of stormwater. The following sections discuss physical management strategies that could potentially be employed to protect and enhance recharge from these sources.

10.4.2.1 In-Stream Recharge

Under certain conditions, water can seep through stream beds to recharge the water table below. This process can be enhanced through management of stream flows, surface water releases from reservoirs, or other methods that act to augment groundwater recharge. The SCVWD is able to enhance in-stream recharge in the Santa Clara Subbasin through the storage and release of local and imported surface water into local streams at certain times of year from a system of dams and reservoirs[83]. In the Niles Cone Subbasin, ACWD also facilitates in-stream recharge on Alameda Creek through use of rubber dams and controlled releases from its storage reservoirs.

In the Basin, some potential likely exists to augment and enhance in-stream groundwater recharge by "un-lining" sections of channelized streams[84] or otherwise enhancing recharge along creeks. However, while there has been significant interest expressed about stream recharge options by stakeholders, this option may be limited due to flooding concerns, lack of locally-controlled surface water storage, and unfavorable geology (i.e., the presence of relatively impermeable Bay Mud), particularly within the eastern portions of the Basin. To the extent practicable, opportunities to pursue such in-stream recharge projects may be further explored through coordinated discussion with interested stakeholders, especially for the larger creeks such as San Mateo Creek and San Francisquito Creek.

10.4.2.2 Stormwater Recharge

Impervious area can contribute to stormwater runoff in different ways. If an impervious area is "connected" to a storm drainage system, then groundwater recharge is reduced because the potential recharge source is conveyed directly to the Bay. If an impervious area is "disconnected," then run off is able to flow to adjacent pervious soils, allowing the water to infiltrate and recharge the Basin. To the extent that connected areas can be converted to disconnected areas, through the construction of bioswales for example, the recharge to the Basin can be increased. In some cases, these opportunities are constrained by regulatory issues, water quality concerns, construction costs, and more. In addition, the options and potential benefits of various stormwater recharge projects should be coordinated with the SMCWPPP program being

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[83] This in-stream recharge program has been the subject of scrutiny in regards to its environmental impacts, particularly concerning habitat for steelhead trout and Chinook salmon. The SCVWD has worked with the SWRCB, National Marine Fisheries Service, California Department of Fish and Game, and other stakeholders to develop a Settlement Agreement to manage future dam releases by SCVWD.

[84] As summarized in **Table 6-1**, there are approximately 12.7 miles of engineered ("lined") stream channels in the Basin.

developed by C/CAG. Several projects in the SRP were approved for funding, including an infiltration gallery beneath a sports field in Atherton.

10.4.2.3 Percolation Ponds

In the Santa Clara Subbasin, the SCVWD actively recharges the aquifer through the delivery of local and imported surface water to a series of recharge ponds, which range in size from less than 1 acre to more than 20 acres. The total recharge capacity of these recharge ponds is greater than 53,000 AFY, but the amount of water that is delivered to the ponds in a given year varies based on the availability of surface water supplies. For example, as the recent drought intensified, only 16,000 AF of recharge occurred through these ponds in 2015 (SCVWD, 2016).

In the Niles Cone Subbasin, ACWD also manages recharge ponds. During wet periods, local runoff is diverted into these ponds, using inflatable rubber dams to capture and divert Alameda Creek flow (ACWD, 2016). The ACWD also uses the ponds to percolate imported water supplies.

In the Basin, groundwater recharge using spreading ponds or other methods of surface application could theoretically be done with SFPUC RWS, local runoff, or recycled water. However, implementing managed recharge through surface application is practically limited by the high cost of land within the Basin, the lack of infrastructure, the relatively tight soils which limit the percolation of stored water (see Section 7.0), and the current high groundwater elevations which limit the available storage in the aquifer. The development of smaller, distributed recharge ponds may be able to avoid some of the constraints listed above by targeting specific areas of the Basin that have favorable geologic conditions and limited competition for development. However, this option is likely to have limited viability in the Basin.

10.4.2.4 Subsurface Injection

Some of the limiting constraints of recharging an aquifer through surface application can be addressed by using wells to inject water directly into the subsurface. These injection projects typically have limited land use requirements (i.e., the footprint of a well site) and overcome geological constraints by injecting directly into specific aquifer zones.

An aquifer storage and recovery (ASR) project typically involves the injection of potable water into an aquifer when surplus supplies are available, creating a “bubble” of stored water in the aquifer. This supply is then extracted from the aquifer using the same well to meet peak demands or to supplement surface water supplies during dry years. Additional treatment of the water may be required upon extraction. Alternatively, an IPR/DPR project entails injecting recycled water into the aquifer. After a specified minimum residence time, this stored recycled water is then extracted from wells located a distance from the injection site and treated to potable water standards prior to use.

Both ASR and IPR/DPR projects have been implemented across the state and are being considered in adjacent basins. For example, in the northern portion of the Santa Clara Subbasin, the City of Palo Alto is investigating the possibility to reuse recycled water from the Palo Alto RWQCP (City of Palo Alto, 2016). Specifically, one objective of the *Northwest County Indirect Potable Reuse Feasibility Study* is to evaluate whether increased groundwater utilization by the City is viable, and if so, to evaluate the feasibility of IPR/DPR with recycled water. Analysis performed as a part of the feasibility study have estimated a yield of 2,500 AFY available with no managed recharge through IPR (Todd, 2017b). SCVWD is also developing the Expedited Purified Water Program (Program)[85] as part of the District's strategy to respond to the recent drought, consistent with the SCVWD Board's direction to expand the County's water supply. As currently conceived, the Program could provide up to 45,000 AFY of purified wastewater for IPR/DPR to supplement groundwater recharge in the Santa Clara Subbasin using percolation ponds and injection wells. The SFPUC is also researching the potential to conduct IPR and DPR and is working with water and wastewater agencies toward a potential partnership to explore IPR and DPR projects to serve customers in the future (SFPUC, 2015c).

Within the Basin, an ASR project would most likely utilize SFPUC RWS water, whereas an IPR/DPR project would utilize highly-treated recycled water generated at one of the local wastewater facilities (see Section 10.3). However, any subsurface injection project would need to factor in, among other things, physical constraints such as potential geochemical interaction between the injected water and the native groundwater and the potential for injection to increase mobilization or dissolution of contaminants in the aquifer. There are also significant regulatory constraints related to the implementation of both ASR and IPR/DPR projects. The SWRCB has adopted a revised Recycled Water Policy (dated January 2013) and provided a report to the State Legislature on the feasibility of developing uniform water recycling criteria (i.e., regulations) for DPR in December 2016. AB 574 was signed into law on 6 October 2017, which requires the SWRCB to adopt uniform water recycling criteria for DPR by 31 December 2023. A workshop tentatively titled *Bay Area Regional Partnerships Towards Sustainable Water Supplies through Potable Reuse* convened by Silicon Valley Clean Water and supported by many local organizations including but not limited to ReNUWIt, Association of California Water Agencies (ACWA), BAWSCA, American Water Works Association (AWWA), WateReuse California, WE&RF, CASA, and CWEA, occurred 9 March 2018.

10.4.3 Protection of Natural Recharge Areas

The Basin receives significant recharge from rainfall percolation in non-irrigated areas. As the Basin experiences further pressure to develop, this recharge is at risk of being reduced by the construction of impervious land uses. Identifying important recharge areas and protecting them from such development will help to preserve this important source of recharge to the Basin.[86]

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[85] http://www.valleywater.org/Design-Build.aspx, accessed 24 September 2016.

[86] Currently-available soil and hydrogeologic data do not support delineating some parts of the basin as "recharge areas" relative to other parts. While recharge occurs everywhere, it may be possible to delineate a relative ranking based on: 1) shallow subsurface texture compiled from the SWRCB's GeoTracker database and foundation boring

An example of a program implemented to protect natural recharge areas is given by the South Westside Basin. One of the actions recommended in the *2012 South Westside Basin GWMP* is to identify key groundwater recharge areas and offer financial incentives to landowners in exchange for limiting the development of their property (Westside Basin Partners, 2012). These incentives are intended to promote protection of natural recharge without imposing undue hardship on the property owners.

A program to protect areas of natural recharge could be implemented by cities and counties at the planning level (e.g., zoning polices) or through an incentive program similar to that in the South Westside Basin. The stakeholder engagement process provides an opportunity to understand what policies are currently being implemented within the Basin, and to coordinate with the C/CAG's SMCWPPP program.

10.4.4 Groundwater Production Regulation

One way to maintain groundwater storage is to provide disincentives to pump groundwater at rates that create long-term, sustained depletions of storage. As described below, examples of this type of groundwater regulation exist in the region and are implemented by either (a) a single groundwater management agency with authority to regulate groundwater, or (b) a group of agencies that voluntarily decide to impose groundwater production restrictions.

10.4.4.1 Production Charges

One way to incentivize efficient use of groundwater is to establish a price for use of the resource through the imposition of a groundwater production charge or "pump tax." In the Santa Clara Subbasin, groundwater users are required to pay for the groundwater that they pump. Pursuant to §26 of the District Act, SCVWD has the authority to levy and collect a fee for the production of groundwater from all water-producing facilities, whether public or private. Different charges are established based on location[87] and type of use (i.e., agricultural and non-agricultural). The purpose of these groundwater charges is to fund SCVWD activities that protect and augment the groundwater supplies (SCVWD, 2016c). Each year, SCVWD conducts a charge-setting process where input from the public is solicited. The applicable FY 2017-2018 groundwater charges for the Santa Clara Subbasin are $25.09 per AF for agricultural groundwater production and $1,175 per AF for non-agricultural production.[88]

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logs, 2) wells in the Project geodatabase that indicate high percentage of coarse material in the top 50 feet, and 3) interpolation and extrapolation from soil survey maps. The SRP notes that regional data on groundwater depth are limited, but that feasibility assessment of groundwater recharge projects should include geotechnical evaluation and analysis of soil borings to understand groundwater depth, soil characteristics, and other factors that effect infiltration (Paradigm Environmental and Larry Walker Associates, Inc., 2017).

[87] The SCVWD service area is split into a North Zone (W-2) and a South Zone (W-5). The Santa Clara Subbasin is included in the North Zone.

[88] http://www.valleywater.org/Services/WaterCharges.aspx

The ACWD also imposes groundwater production charges known as Replenishment Assessment rates. These rates are established annually and separate rates are set for (1) agricultural, municipal, and recreational uses, and (2) all other uses.[89] The rates apply to water wells, dewatering wells, and remedial extraction wells. Revenue from the Replenishment Assessment rates is used to offset the costs of recharging and managing groundwater within the Niles Cone Subbasin.

10.4.4.2 Production Restrictions

Groundwater production regulation can also be conducted through a wide variety of other production restrictions. Perhaps the most direct way of managing pumping is to "self-adjudicate" a basin by establishing quotas for each user that dictate how much groundwater an entity can use over a given time period (e.g., annually, monthly, seasonally). As discussed in Section 10.2.2.1, self-imposed groundwater production quotas have been established in the South Westside Basin by and for the primary groundwater users in the basin, the Westside Basin Partners (SFPUC, 2013).

Another example of negotiated groundwater production quotas is provided by the Livermore Valley Basin, where Zone 7 is the designated groundwater management agency and has broad powers as specified in Act 205 of the California Uncodified Water Code. In addition to managing the groundwater basin, Zone 7 is the wholesale water supplier for the major retail water suppliers in the basin: Dublin-San Ramon Services District, City of Livermore, and Cal Water Pleasanton District. Through conditions included in the retail water suppliers' service contracts, Zone 7 has established Groundwater Pumping Quotas that limit the amount of groundwater each water supplier is allowed to pump in a given year (Zone 7, 2016).

In addition to direct quotas, there are several other potential methods of restricting groundwater production. For example, groundwater "buy-back" programs have been implemented elsewhere in the U.S.,[90] where a government or private party pays a pumper of groundwater to temporarily or permanently reduce groundwater pumping. These programs are generally used to increase stream flow in environmentally-sensitive, inter-connected surface waters.

10.4.5 Maintenance of Groundwater Quality

10.4.5.1 Well Monitoring Program

In each of the adjacent basins, the respective groundwater management agencies have established and currently implement groundwater monitoring programs. The core components

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[89] The current Replenishment Assessment rates are available at: http://www.acwd.org/index.aspx?NID=228.

[90] Including programs in New Mexico to augment streamflow within the Pecos River Basin; in Idaho to benefit spring-fed trout hatcheries on the Snake River; and in Nebraska, Wyoming, and Colorado to restore Platte River flows to benefit endangered fish and migratory birds (Nelson and Casey, 2013).

of these monitoring programs include comprehensive groundwater elevation monitoring throughout each basin, targeted water quality sampling, and the establishment of triggers and thresholds that, if exceeded, require action on the part of the management agency. These programs have benefitted these agencies and basins by generating better scientific understanding of basin conditions and functions, bringing the basins into compliance with CASGEM (see Section 10.2.1.1), and setting the basins up for SGMA compliance (see Section 10.2.1.2). As several stakeholders have stated, a basin-wide monitoring program (e.g., CASGEM) could provide similar benefits within the Basin. As mentioned above, water and land use agencies in the Basin are considering forming a CASGEM Monitoring Entity and are exploring mechanisms (e.g., Memoranda of Agreement) by which other entities could be included in the CASGEM Monitoring Entity.

10.4.5.2 Well Ordinance Revision

The County currently administers a well ordinance that covers the Basin and a majority of the South Westside Basin and addresses issues related to well permitting, construction, and abandonment. The current ordinance imposes stricter level of scrutiny for well permits issued in the South Westside Basin than for permits in the Basin (§4.68.225). This ordinance empowers the County Health Officer to deny or impose special conditions on a permit for a well producing greater than 50 gpm that either (a) is in an area subject to a localized groundwater problem, or (b) presents a potential of overdraft to the aquifer.[91]

Similar well ordinances are enforced by the groundwater management agencies in the adjacent basins. The SCVWD enforces a well ordinance (*Ordinance No. 90-1*) that regulates construction and destruction of wells and other deep excavations. The ACWD enforces a well ordinance (*Ordinance No. 2010-01*) regulating wells, exploratory holes, and other excavations within the cities of Fremont, Newark, and Union City. The East Bay Plain Subbasin is subject to the standards established in the Alameda County well ordinance.[92] In March 2015, Alameda County revised its well ordinance to (1) bring the ordinance into compliance with current codes, (2) enhance enforcement provisions, (3) allow for the creation of "special requirement areas" to protect areas of concern, and (4) include a mechanism that allows the County to delegate administration of the ordinance to other public entities (Alameda County, 2015).

A County well ordinance revision could be considered in order to more comprehensively address current or potential future issues including but not limited to impacting interactions between surface water and groundwater, increased potential for seawater intrusion, and the potential for cross-contamination between shallow and deep aquifers in the Basin, which was identified in Section 9.0 as a potential threat to groundwater quality.

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[91] Excludes residential wells, temporary construction wells, cathodic protection wells, geophysical exploration/monitoring wells, and wells required in an emergency situation for drinking water purposes.
[92] *General Ordinance Code Title VI, Chapter 6.88*

10.4.5.3 Seawater Intrusion Prevention

The Basin has experienced groundwater quality degradation in the past due to seawater intrusion (see Section 9.2.3). As groundwater production increases within the Basin, particularly in areas proximate to the Bay such as East Palo Alto, it will be critical to monitor for and potentially mitigate seawater intrusion. The City of East Palo Alto has defined its water quality BMO to include the identification or installation of monitoring wells along the Bay to serve as sentry wells for seawater intrusion (Todd, 2015b).

In each of the adjacent basins, historical seawater intrusion was also an issue and now the groundwater basins are actively monitored for seawater intrusion. For example, the South Westside Basin, which has experienced groundwater elevations below sea level, has a robust seawater intrusion monitoring program. Dedicated monitoring wells have been installed to monitor seawater intrusion (Todd, 2015b). Individual chloride thresholds have also been established as approximately 10 percent above the historical maximum concentration over the past twenty years of sampling (Westside Basin Partners, 2012). If concentrations in the monitoring wells exceed these thresholds, actions may be taken to address the issue, including increased monitoring, studies of the source of the chloride, decreased production, and use of alternate supplies.

The Niles Cone Subbasin experienced seawater intrusion in the early 1900s. Among other aquifer reclamation measures (e.g., managed aquifer recharge), the ACWD operates a brackish water desalination facility, the Newark Desalination Facility, which treats brackish groundwater and produces up to 10 MGD of potable water (ACWD, 2016). This desalination facility was constructed as part of the Aquifer Reclamation Program, which was developed to stop the spread of seawater into the groundwater basin and to reclaim the aquifers of the basin for future potable use.

Another method of mitigating for seawater intrusion is to inject water into the freshwater portion of an aquifer to raise water levels and prevent salt water from migrating inland. This method has been utilized successfully by the Orange County Water District since the 1960s (OCWD, 2015).

At this point, seawater intrusion is not thought to be impacting groundwater quality in the Basin. However, the City of East Palo Alto has identified seawater intrusion as a risk to groundwater quality in its GWMP (Todd, 2015b) and has identified the need to establish a monitoring well network to monitor the threat. Two City of East Palo Alto wells (Well RW-16D and Rhone Poulenc Well W-101) are located along the Bay margin and show variability in TDS concentrations that may be influenced by saline water (Todd, 2017a). The potential for establishment of a more regional monitoring program in the Basin, as well as mitigation measures that could be taken if seawater intrusion were to occur, could be discussed with interested stakeholders.

10.4.5.4 Wellhead Protection Program

Wellheads represent a threat to a groundwater basin because wells can act as conduit for contamination to reach the underlying aquifer. In response to this threat, groundwater management agencies in adjacent basins have established wellhead protection programs. In the Niles Cone Subbasin, ACWD administers a wellhead protection program to (1) identify sensitive recharge and groundwater areas, (2) maintain an inventory of potential threats within these areas, (3) assess the vulnerability of source water, and (4) develop management strategies to minimize the potential for groundwater quality impacts (ACWD, 2016). In their respective basins, SCVWD and EBMUD assist water suppliers in their compliance with the SWRCB Division of Drinking Water Drinking Water Source Assessment and Protection (DWSAP) Program by maintaining updated information regarding potentially contaminating activities. The SCVWD has also developed a GIS-based tool that can be used to delineate protection areas in accordance with state guidelines.

No such wellhead protection program is formally administered in the Basin. However, as part of the DWSAP Program, the SWRCB requires a drinking water source assessment to assess the risk of contamination at new public water supply wells. The SWRCB also requires certain wellhead standards and sanitary seals to ensure the integrity of the well and the aquifer.

10.4.6 Institutional Frameworks

Implementation of the physical groundwater management options discussed above is strongly dependent on what form future groundwater management takes within the Basin, if any. Some of the groundwater recharge augmentation and resource protection projects discussed above can be effectively implemented at a small scale by individual cities or water suppliers. Many of the projects, however, would achieve significant economies of scale from a more regional approach. Furthermore, state funding is often more accessible to larger projects that represent a coordinated approach between multiple stakeholders. As such, potential options for the future Basin coordination and management options are discussed in the following sections, and will also be discussed as part of future stakeholder meetings.

10.4.6.1 Advisory Committee

Establishing a technical advisory committee within the Basin may help to facilitate the implementation of regional or Basin-wide studies or projects. Advisory committees have been utilized in basins across the state to inform decisions through stakeholder input, technical expertise, and local knowledge.

In the South Westside Basin, the Westside Basin Partners established an advisory committee to solicit input and direct the development of the *2012 South Westside Basin GWMP*. This committee consisted of other groundwater users (cemeteries and the Town of Colma), other municipalities (the cities of Brisbane, Burlingame, and South San Francisco), regulatory agencies (DWR, RWQCB), BAWSCA, SFPUC, and interested citizens. After the development of the GWMP, this advisory committee was transitioned into a decision-making entity, the Groundwater Task Force, which guides the implementation of the GWMP and consists of representatives from the advisory committee entities and more.

An advisory committee in the Basin would provide a means through which implementation of regional projects, such as those discussed above, could be funded and implemented. The potential to form an advisory committee consisting of representatives of all of the interested stakeholders in the Basin could be explored with interested stakeholders.

10.4.6.2 Governance Options

As the Basin is currently not required to comply with SGMA, one option is simply to continue with the status quo. As discussed in Section 10.1.1, this involves a limited role by the County overseeing well permitting and groundwater remediation and local implementation by East Palo Alto of its GWMP. As has been done historically, the review of potential threats to groundwater quality and quantity would be conducted on an "as-needed" basis through the environmental review process for specific projects.

Alternatively, another approach to groundwater management in the Basin could be pursued by a collection of agencies that commit to work together as part of a committee (see above). Under this option, those agencies with an interest in groundwater use and management could initiate the process and work together to develop groundwater management projects and programs and potentially develop a more regional GWMP. An example of such a "Coordinated Agencies" approach is provided by the South Westside Basin, wherein the agencies that had an interest in groundwater management came together to form the Westside Basin Partners. An outcome of this could be the formation of a Monitoring Entity under CASGEM that would make the Basin more competitive for state funding.

Yet another approach to groundwater management, and one that may be required if the Basin is formally upgraded to Medium priority in 2018, is for multiple agencies to establish a new SGMA-compliant groundwater management entity (i.e., a GSA), through a legal agreement such as an MOU or JPA. As discussed in Section 10.2.1.2, many entities in the Basin are eligible to be, or become part of, a GSA.

Table 10-1
GSA-Eligible Entities and Potential Project Partners in the San Mateo Plain Subbasin

Agency	Land or Water Responsibilities within Basin	GSA Elibility within Basin (a)(b)		Potential Project Partner	Description or Enabling Legislation
		Formation	Participation		
Entities Eligible to Form or Partipate in a GSA					
Cities or Towns					
Atherton, Town of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Belmont, City of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Burlingame, City of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
East Palo Alto, City of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Foster City, City of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Hillsborough, Town of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Menlo Park, City of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Palo Alto, City of (c)	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Portola Valley, Town of (c)	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Redwood City, City of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
San Carlos, City of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
San Mateo, City of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Woodside, Town of	Land, Water	☑	☑	☑	Incorporated city that overlies the Basin
Water Districts, Agencies, and Suppliers					
Bay Area Water Supply and Conservation Agency	Water	☑	☑	☑	CWC §81300 et seq.
Estero Municipal Improvement District	Water	☑	☑	☑	Statutes of 1960, First Extra Session, Chapter 82, Page 459
Los Trancos County Water District (c)	Water	☑	☑	☑	CWC §30000 et seq.
Menlo Park Municipal Water District	Water	☑	☑	☑	CWC §71000 et seq.
Mid-Peninsula Water District (d)	Water	☑	☑	☑	CWC §34000 et seq.
Purissima Hills Water District (c)	Water	☑	☑	☑	CWC §34000 et seq.
San Francisco Public Utilities Commission	Water	☑	☑	☑	§2701 et seq. of the CA Public Utilities Code
Santa Clara Valley Water District (c)	Water	☑	☑	☑	Santa Clara Valley Water District Act (CWC Appendix Chapter 60)
Stanford University (c)(e)	Water	☑	☑	☑	Private university and water supplier
Mutual Water Companies and Utilities Regulated by CPUC (b)					
California Water Service - Bear Gulch	Water	☐	☑	☑	Investor-owned public utility regulated by CPUC
California Water Service - Mid-Peninsula	Water	☐	☑	☑	Investor-owned public utility regulated by CPUC
O'Connor Tract Co-Operative Water Company	Water	☐	☑	☑	Nonprofit mutual benefit corporation
Palo Alto Park Mutual Water Company	Water	☐	☑	☑	Nonprofit mutual benefit corporation
Counties					
San Mateo, County of	Land, Water	☑	☑	☑	County in California
Santa Clara, County of (c)	Land, Water	☑	☑	☑	County in California

Table 10-1
GSA-Eligible Entities and Potential Project Partners in the San Mateo Plain Subbasin

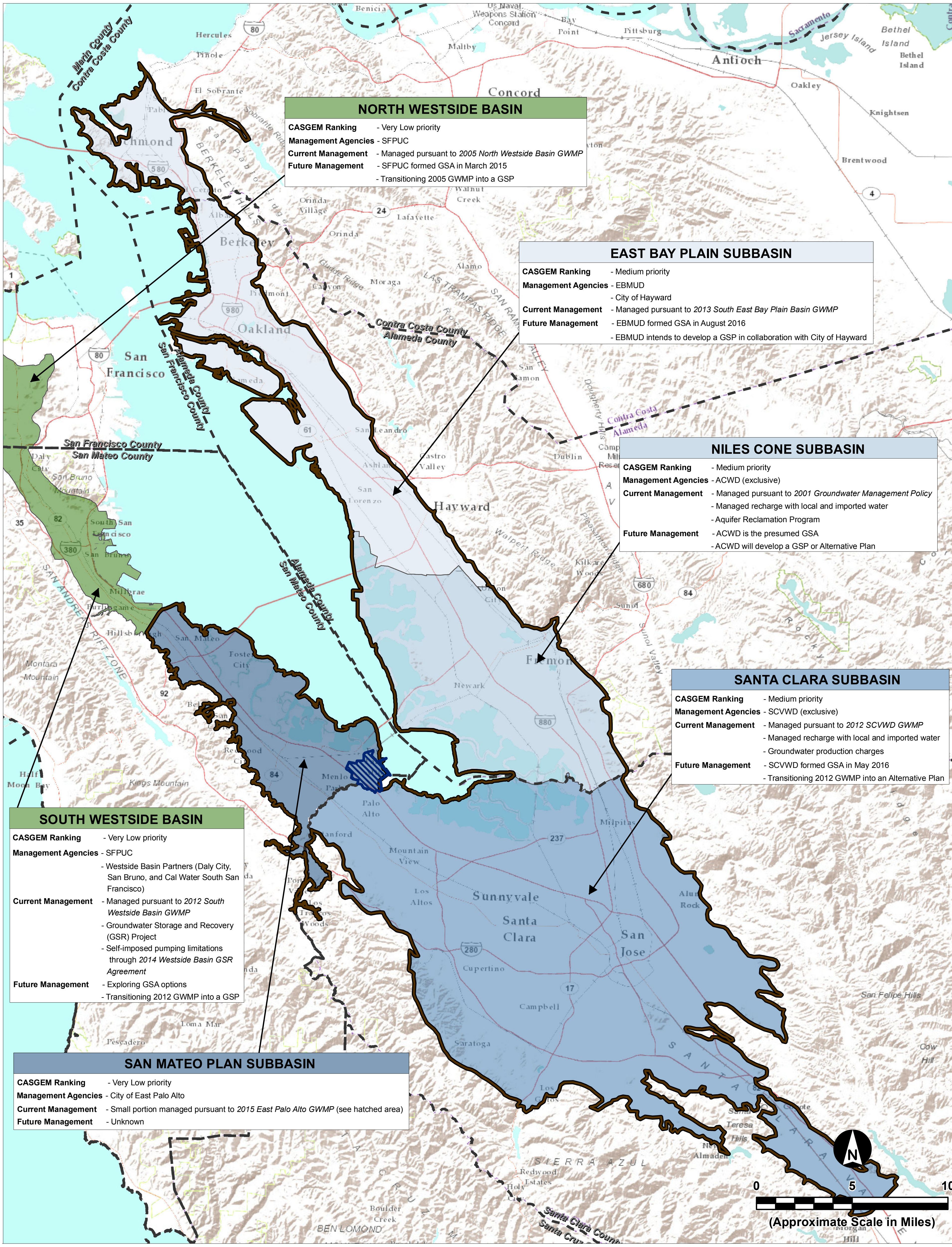
Agency	Land or Water Responsibilities within Basin	GSA Elibility within Basin (a)(b)		Potential Project Partner	Description or Enabling Legislation
		Formation	Participation		
Entities Eligible to Form or Partipate in a GSA (Continued)					
Wastewater Agencies (f)					
Crystal Springs County Sanitation District	Wastewater	☑	☑	☑	§4700 et seq. of the CA Health and Safety Code
Devonshire County Sanitation District	Wastewater	☑	☑	☑	§4700 et seq. of the CA Health and Safety Code
East Palo Alto Sanitary District	Wastewater	☑	☑	☑	§6400 et seq. of the CA Health and Safety Code
Edgewood Sewer Maintenance District	Wastewater	☑	☑	☑	§5820 et seq. of the CA Streets and Highways Code
Emerald Lake Heights Sewer Maintenance District	Wastewater	☑	☑	☑	§4860 et seq. of the CA Health and Safety Code
Fair Oaks Sewer Maintenance District	Wastewater	☑	☑	☑	§4860 et seq. of the CA Health and Safety Code
Harbor Industrial Sewer Maintenance District	Wastewater	☑	☑	☑	§4860 et seq. of the CA Health and Safety Code
Kensington Square Sewer Maintenance District	Wastewater	☑	☑	☑	§4860 et seq. of the CA Health and Safety Code
Oak Knoll Sewer Maintenance District	Wastewater	☑	☑	☑	§4860 et seq. of the CA Health and Safety Code
Scenic Heights County Sanitation District	Wastewater	☑	☑	☑	§4700 et seq. of the CA Health and Safety Code
Silcon Valley Clean Water (g)	Wastewater	☑	☑	☑	Joint powers authority of cities and a wastewater agency
West Bay Sanitary District	Wastewater	☑	☑	☑	§6400 et seq. of the CA Health and Safety Code
Other Entities					
Midpeninsula Regional Open Space District	Land	☑	☑	☑	§5500 et seq. of the CA Public Resources Code
San Mateo County Flood Control District	Water	☑	☑	☑	Statutes of 1959, Chapter 2037, Page 4703
San Mateo County Resource Conservation District	Land	☑	☑	☑	§9000 et seq. of the CA Public Resources Code
Potential Project Partners					
Regulatory Agencies					
California Department of Water Resources, North Central Region	--	☐	☐	☑	State regulatory agency
San Francisco Regional Water Quality Board	--	☐	☐	☑	State regulatory agency
Water Districts, Agencies, and Suppliers in Adjacent Basins					
Alameda County Water District	--	☐	☐	☑	Water district responsible for groundwater management of Niles Cone Subbasin
East Bay Municipal Utilities District	--	☐	☐	☑	Water district responsible for groundwater management of East Bay Plain Subbasin
Westside Basin Partners (h)	--	☐	☐	☑	Partnership between cities and water agencies to manage the Westside Basin
Regional Organizations					
Bay Area Flood Protection Agencies Association	--	☐	☐	☑	Association of flood protection agencies
Bay-Delta Region of California Association of Resource Conservation Districts	--	☐	☐	☑	Association of resource conservation districts
Bay Area Water Agencies Coalition	--	☐	☐	☑	Association of water agencies
Bay Area Clean Water Agencies	--	☐	☐	☑	Joint powers authority of wastewater agencies
Bay Area Regional Collaborative	--	☐	☐	☑	Regional collaboration to address climate adaptation
San Francsiquito Creek Joint Powers Authority (i)	--	☐	☐	☑	Regional government agency
Association of Bay Area Governments	--	☐	☐	☑	Regional land planning organization
City/County Association of Governments of San Mateo County	--	☐	☐	☑	Regional land planning organization
San Francisco Bay Area IRWMP	--	☐	☐	☑	Regional water management effort
San Mateo County Local Agency Formation Commision	--	☐	☐	☑	Independent commission to regulate boundaries of cities and special districts

Table 10-1
GSA-Eligible Entities and Potential Project Partners in the San Mateo Plain Subbasin

Agency	Land or Water Responsibilities within Basin	GSA Elibility within Basin (a)(b)		Potential Project Partner	Description or Enabling Legislation
		Formation	Participation		
Potential Project Partners (Continued)					
Stakeholders					
Acterra Watershed Project (j)	--	☐	☐	☑	Environmental non-governmental organization
Bay Area Watershed Network	--	☐	☐	☑	Environmental non-governmental organization
Bay Institute of San Francsico	--	☐	☐	☑	Environmental non-governmental organization
Bay Nature Institute	--	☐	☐	☑	Environmental non-governmental organization
Baykeeper	--	☐	☐	☑	Environmental non-governmental organization
Environmental Defense Fund	--	☐	☐	☑	Environmental non-governmental organization
Friends of the River	--	☐	☐	☑	Environmental non-governmental organization
Low Impact Development Leadership Group	--	☐	☐	☑	Local agency staff and researchers/research institutions
San Francisco Estuary Institute	--	☐	☐	☑	Environmental non-governmental organization
San Francsico Bay Joint Venture	--	☐	☐	☑	Environmental non-governmental organization
Santa Clara Basin Watershed Management Initiative	--	☐	☐	☑	Environmental non-governmental organization
San Francisco Bay Area Planning and Urban Research Association	--	☐	☐	☑	Research, education and advocacy non-governmental organization
Save the Bay	--	☐	☐	☑	Environmental non-governmental organization
Sierra Club	--	☐	☐	☑	Environmental non-governmental organization
SLAC National Accelerator Laboratory	--	☐	☐	☑	Research laboratory operated by Stanford University on behalf of the DOE
Sustainable San Mateo County	--	☐	☐	☑	Environmental non-governmental organization
Trust for Public Land	--	☐	☐	☑	Environmental non-governmental organization
Tuloumne River Trust	--	☐	☐	☑	Environmental non-governmental organization
Urban Creeks Council	--	☐	☐	☑	Environmental non-governmental organization
Water Reuse Association	--	☐	☐	☑	Environmental non-governmental organization

Abbreviations:
"CPUC" = California Public Utilities Commission
"CWC" = California Water Code
"DOE" = Department of Energy
"GSA" = Groundwater Sustainability Agency
"IRWM" = Integrated Regional Water Management Plan
"SGMA" = Sustainable Groundwater Management Act
"SWRCB" = State Water Resources Control Board

Notes:
(a) Per SGMA, a GSA may be formed by a local public agency that has water supply, water management, or land use responsibilities within a groundwater basin (CWC §10723(a); CWC §10721(n)).
(b) A water corporation regulated by the CPUC or a mutual water company may participate in a GSA through a memorandum of agreement or other legal authority (CWC §10723.6(a)(2)(b)).
(c) This entity overlies a small portion of the southern portion of the Basin.
(d) Formerly Belmont County Water District.
(e) Stanford University is not eligible to be a GSA because it is a private entity, but it is anticipated that it may participate in a GSA through a memorandum of agreement or other legal authority (personal coresspondence, Jessica Bean, SWRCB, 30 June 2016).
(f) It is anticipated that wastewater agencies will be eligible to form and participate in a GSA (personal correspondence, Jessica Bean, SWRCB, 30 June 2016).
(g) Partnership between the cities of Belmont, Redwood City, and San Carlos and the West Bay Sanitary District.
(h) The Westside Basin is jointly managed by City of Daly City, City of San Bruno, City of Burlingame, Town of Colma, City of South Francisco, City of Millbrae, California Water Services Company, and San Francisco Public Utilities Commission.
(i) Partnership between the cities of Palo Alto, Menlo Park, and East Palo Alto, San Mateo County, and the Santa Clara Valley Water District.
(j) Formerly San Francisquito Watershed Council.



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Legend

County Boundary

East Palo Alto GWMP

Groundwater Basins and Subbasins

2-35: Westside Basin

2-9: Santa Clara Valley Basin

Subbasins of the Santa Clara Valley Basin

2-9.01: Niles Cone Subbasin

2-9.02: Santa Clara Subbasin

2-9.03: San Mateo Plain Subbasin

2-9.04: East Bay Plain Subbasin

Notes

1. All locations are approximate.

Abbreviations

ACWD = Alameda County Water District
CASGEM = California Statewide Groundwater Elevation Monitoring Program
DWR = California Department of Water Resources
EBMUD = East Bay Municipal Utility District
GSA = Groundwater Sustainability Agency
GSP = Groundwater Sustainability Plan
GWMP = Groundwater Management Plan
SCVWD = Santa Clara Valley Water District
SFPUC = San Francisco Public Utilities Commission

Sources

1. Groundwater basins from DWR's Final 2016 Bulletin 118 Groundwater Basin Boundaries, downloaded 24 October 2016. Basin boundaries reflect the final revisions approved as part of the 2016 basin boundary modification process.
2. CASGEM priority ranking from June 2014 Basin Prioritization Process.
3. Basemap: Esri's World Reference and World Terrain Base, accessed 6 June 2018.

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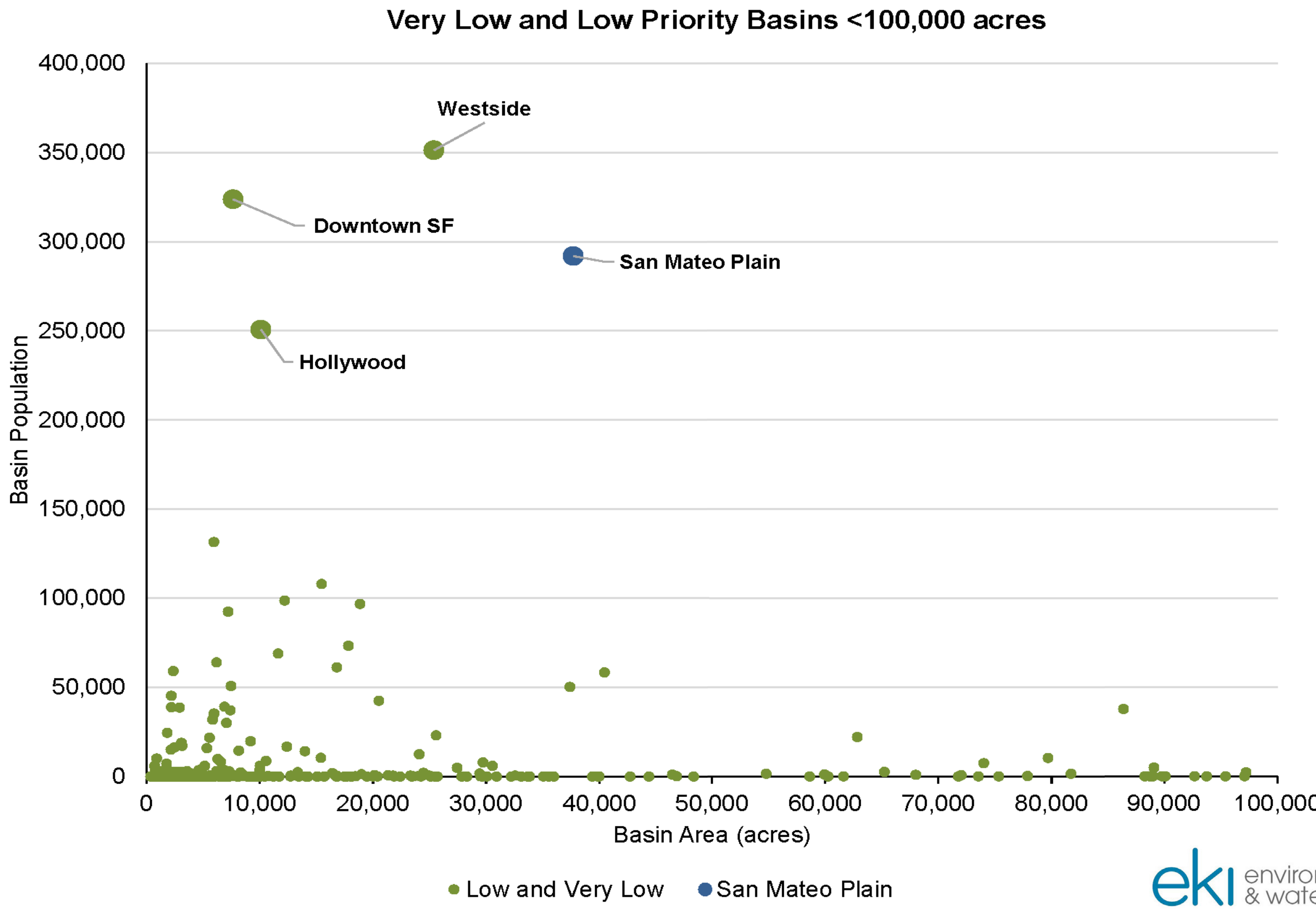
TODD GROUNDWATER
HYDROFOCUS INC. Solutions for Land and Water Resources

Summary of Local and Regional Groundwater Management

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 10-1

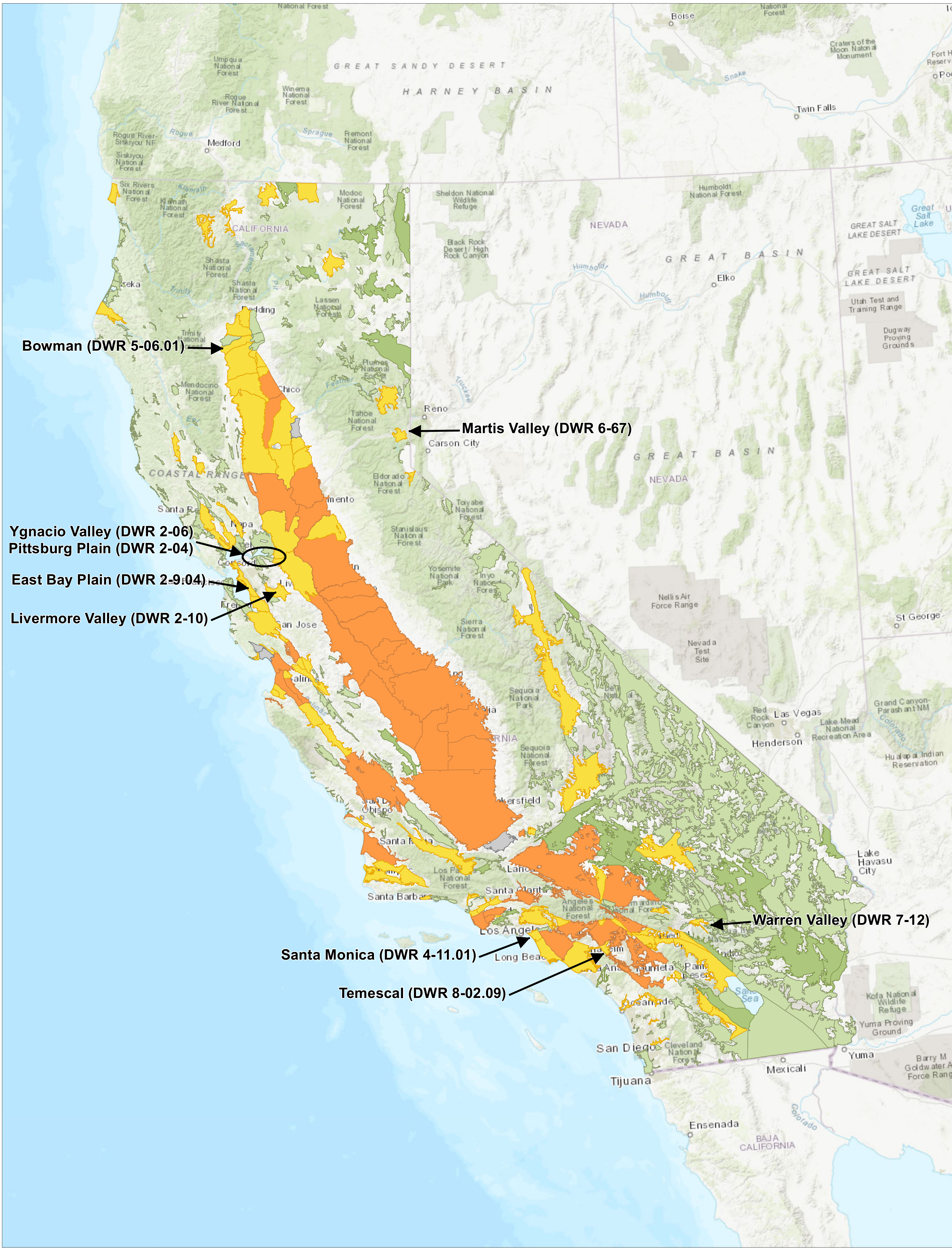


Source:
Based on June 2014 CASGEM basin prioritization.

Comparison of Basin Size and Population

San Mateo Plain Groundwater Basin
San Mateo County, California
June 2018
EKI B60024.00

Figure 10-2



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Legend

Current Basin Priority Ranking

- High
- Medium
- Low
- Very Low
- Pending

Abbreviations

DWR = Department of Water Resources

Notes

1. All locations are approximate.

Sources

1. Topoographic basemap provided by ESRI's ArcGIS Online, obtained 6 June 2018.
2. Groundwater basins obtained from DWR SGM Online System - Public Portal, accessed 24 October, 2016.
3. CASGEM priority ranking from June 2014 Basin Prioritization Process.

0 70 140

(Approximate Scale in Miles)

N

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Locations of Other Similarly Sized and Used Groundwater Basins

San Mateo Plain Groundwater Subbasin

San Mateo County, California

June 2018

EKI B60024.00

Figure 10-3

11.0 SCENARIO EVALUATIONS USING THE SAN MATEO PLAIN GROUNDWATER FLOW MODEL

The SMPGWM was developed as a tool to understand hydrologic conditions in the Basin and to evaluate the effects of various changes on groundwater conditions. Based on the qualitative discussion of potential risks in Section 9.0, there is the possibility for undesirable results to occur in the Basin with some level of increased groundwater pumping. Based on the summary of potential physical and institutional management options presented in Section 10.0, there are also potential programs and actions that can be employed to address and/or mitigate potential undesirable results.

In order to better understand and quantify these risks of undesirable results and/or the benefit of certain management options, the SMPGWM was used to model four scenarios of future groundwater conditions and use. This scenario evaluation approach was necessarily limited within the scope of this Project, but it should be noted that the SMPGWM can be further utilized to evaluate the effects on the Basin of additional use and Basin management scenarios within the Basin and in the adjacent groundwater basins. It is the intent of the County to make the SMPGWM available for future analyses by interested parties.

11.1 Objectives of Scenario Modeling

The objectives of the Phase 3 scenario modeling effort were to evaluate hypothetical scenarios of future groundwater conditions/management, and to assess the effects of these scenarios in terms of changes to groundwater levels, groundwater flow directions and gradients, and the Basin water budget. The results are interpreted in the context of groundwater sustainability (e.g., the Sustainable Groundwater Management Act, or SGMA). While efforts were made to incorporate realistic assumptions about potential future basin management alternatives and groundwater development, this modeling effort is not an attempt to model/represent specific projects.[93] Furthermore, this effort only considered potential changes from baseline conditions within the Basin, not outside of the Basin.

11.2 Model Scenario Development

11.2.1 Model Scenario Identification

During Stakeholder Workshop #6 (Section 3.1), the Project Team solicited stakeholder input regarding topics of importance to consider in the scenario modeling effort. At that Workshop, attendees were divided into small groups and asked to discuss and report back to the whole group regarding the following two topics:

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[93] The SMPGWM will be available to the public at the conclusion of the Project for other uses.

1. Identify and prioritize potential scenarios to model and identify the basis for prioritization
2. Identify assumptions for the top-ranked modeling scenarios

Results from these breakout sessions were compiled and summarized and presented back to the public at Stakeholder Workshop #7 on 9 November 2017, and are provided in Appendix A.[94] The top three ranked scenarios included increased groundwater pumping, stormwater recharge projects, and climate change. Stakeholders prioritized these scenarios because of their potential implications for Basin sustainability and because of the timeframe for implementation of currently planned projects and policy changes. Regarding the assumptions for these scenarios, stakeholders generally identified the locations for stormwater recharge along the western portion of the Basin, and the location for groundwater pumping in the southern and eastern portions of the Basin. These locations were further refined by the Project Team based on the constraints analysis discussed below. Stakeholders also indicated that the time period of interest for future scenario modeling was generally over the next 20 years (i.e., to about 2040).

11.2.2 Model Scenario Refinement and Technical Development

The Project Team utilized the feedback from stakeholders and consideration of the overall Project objectives to develop a set of four scenarios to model. The scenarios represent a stepwise approach that allows for evaluation of incremental effects relative to the "baseline" condition. The four scenarios are:

1. Baseline
2. Baseline + Climate Change
3. Baseline + Climate Change + Urban Demand Pumping Increase
4. Baseline + Climate Change + Urban Demand Pumping Increase + Implementation of Recharge Projects

11.2.2.1 Scenario 1 – Baseline

As mentioned above, Scenario 1 (Baseline) is intended to be representative of "current" land/water use conditions/demands,[95] which are extended into the future through the entire simulation period. Results from this scenario would be indicative of how the Basin would respond to a period with historical hydrology and a continuation of current pumping and recharge patterns.

11.2.2.2 Scenario 2 – Baseline + Climate Change

Scenario 2 builds upon the Baseline scenario by incorporating the anticipated effects of two main aspects of climate change – namely changes to hydrology (precipitation, evapotranspiration, and

[94] http://www.smcsustainability.org/smplain
[95] Average groundwater production rates from 2011-2015 were used to represent "current" conditions under Scenario 1.

streamflow) and increases in sea level. Changes to hydrology affect the *a priori* calculation of dispersed recharge and the streamflow rates used in the model, and changes in sea level affect the boundary condition specified for San Francisco Bay and adjacent low-lying areas.

11.2.2.3 Scenario 3 – Baseline + Climate Change + Urban Demand Pumping Increase

Scenario 3 adds on to the conditions of Scenario 2 the effect of potential increases in groundwater production to meet increased urban demand within the Basin. The amount of increased groundwater production under Scenario 3 reflects consideration of anticipated increased urban water demand within the Basin and an approximate sum of known or anticipated groundwater development projects but, as mentioned previously, is not intended to explicitly represent specific projects. Scenario 3 therefore represents a conservative view of potential pumping increases. Locations of increased pumping were modeled based on input from stakeholders at Workshop #6 and the constraints analysis described below.

11.2.2.4 Scenario 4 – Baseline + Climate Change + Urban Demand Pumping Increase + Implementation of Recharge Projects

Scenario 4 evaluates the effect of implementation of projects that would enhance recharge to the Basin, as an evaluation of the effectiveness of recharge as a potential management strategy. For the purposes of this modeling effort, these projects include (1) increased stormwater recharge resulting from low impact development (LID) practices that tend to cause infiltration of precipitation rather than runoff, and (2) direct recharge (injection) projects, also known as groundwater replenishment and reuse projects or indirect potable reuse (IPR) when the source of the recharge water is tertiary-treated recycled water. As with Scenario 3, the locations and rates of modeled recharge enhancements under Scenario 4 were informed by stakeholder input as well as the constraints analysis.

11.2.3 Constraints Analysis for Increased Groundwater Production and Enhanced Recharge

Once the general scenario framework was identified through stakeholder input and subsequent discussion by the Project Team, a constraints analysis was performed to help refine the locations within the Basin that would be modeled as having increased groundwater production (under Scenarios 3 and 4) and increased recharge (Scenario 4). The constraints analysis considered geographic, hydrogeologic, and regulatory factors, that would affect the ability to conduct either greater pumping or recharge. The analysis was performed using Geographic Information System (GIS) software and the SMPGWM layer and texture information.

11.2.3.1 Potential Areas for Increased Groundwater Production

For Scenario 3, the constraints analysis assumed that increases in groundwater production to supply urban demand could occur in the following areas:

- Combined thickness of model layers 3 – 5 (i.e., the pumped confined aquifer zone) of at least 100 feet;
- Fraction of coarse-grained material at least 40 percent in at least one of those layers;
- Minimum of 500 feet away from any "open" contamination/cleanup site; and
- Minimum of one mile away from the existing or projected Bay shore.

The locations within the Basin that meet all of the above criteria are shown on **Figure 11-1**. The areas that meet these criteria are located both in the northern and southern portions of the Basin. The prevalence of existing groundwater production wells in the southern area (i.e., in and around Atherton and Menlo Park), and the relatively high coarseness and permeability of the San Francisquito Creek Cone informed a decision to distribute a majority (70 percent) of increased pumping to the southern area and the remainder to the northern area.

11.2.3.2 Potential Areas for Increased Groundwater Recharge

For Scenario 4, separate constraints analyses were conducted for potential increases in stormwater recharge (LID) and potential locations for recharge via direct injection (IPR). The stormwater constraints analysis assumed that such recharge would be most effective in the following areas:

- Hydrologic soils groups not C or D (i.e., are known to have slow or very slow infiltration rates);
- Land surface slope less than 5 percent;
- Thin or non-existent shallow confining layer; and
- Minimum of 500 feet away from any "open" contamination/cleanup site.

The locations within the Basin that meet all of the above criteria are shown on **Figure 11-2**. As shown on **Figure 11-2**, these areas are generally along the western side of the Basin where the confining layer is thin or non-existent, but are also limited by the surface slope constraint.

The direct injection (IPR) constraints analysis assumed that such recharge would be most effective in the following areas:

- Combined thickness of model layers 3 – 5 (i.e., the confined aquifer zone) of at least 100 feet;
- Fraction of coarse-grained material at least 40 percent in at least one of those layers;
- Minimum of 1,000 feet away from public supply or large irrigation wells;
- Minimum of 500 feet away from any "open" contamination/cleanup site; and
- Minimum of one mile away from the existing or projected Bay shore.

The locations within the Basin that meet all of the above criteria are shown on **Figure 11-3**. It is noted that this set of constraints for IPR includes all of the same constraints as the increased groundwater production and also includes a minimum distance from public supply or large irrigation wells. This additional constraint limits the potential area for IPR largely to the northern half of the Basin.

11.3 Scenario Modeling Approach

This section describes the scenario modeling approach including specification of initial conditions and temporal set-up, boundary conditions, and the methodology used for comparison of scenarios.

11.3.1 Initial Conditions and Temporal Setup

Initial conditions (i.e., starting groundwater elevations in each model cell) for all four scenarios were based on the final simulated water levels (September 2015) from the historical transient model run (Section 8.4.3). Each scenario was run using a monthly time-step for a total of 300 months, representing a 25-year simulation time period (i.e., approximately Water Years 2016 – 2040).

11.3.2 Boundary Conditions Modifications

11.3.2.1 General Head and Drain Boundaries

A "General Head" boundary condition is used for Layer 1 cells underlying the San Francisco Bay. This type of boundary condition is a head-dependent flux, where the user specifies the hydraulic head value at each time step and the model calculates the flux into or out of the boundary based on the simulated head in the model cell. In the SMPGWM, the general head boundary condition is used to represent the exchange of water between the top model layer (Layer 1) and the San Francisco Bay. Therefore, under Scenario 1 (as with the historical simulation), the general head boundary condition in cells underlying San Francisco Bay was assigned a head of 0 feet msl. Under Scenarios 2, 3, and 4, the head assigned to these general head boundary cells was increased to account for sea level rise.

The amount of sea level rise applied to Scenarios 2, 3, and 4 was based on estimates from the National Research Council (NRC) (National Research Council, 2012), which are considered the most up to date and best available estimates of sea level rise for California (California Ocean Protection Council, 2013). Estimated sea level rise within the model projection period ranges from 6 ±2 inches in 2030 to 11 ±4 inches in 2050. Estimated sea level rise by 2040 is therefore assumed to be approximately 8.5 ±3 inches. For this modeling effort, the entire increase of sea level was assumed to occur immediately at the start of the simulation, rather than as a gradual increase over time; as such, the model is more conservative in its assessment of potential impacts of sea level rise.

A "Drain" boundary condition is used in the SMPGWM to simulate outflows from shallow groundwater (i.e., Layer 1) due to riparian ET, marshes, and sewers. Drain boundaries are another type of head-dependent flux boundary, although unlike the General Head boundary conditions, the Drain boundary condition only allows for outflow. In order to account for the encroachment of rising sea level into low-lying lands in Scenarios 2, 3, and 4, an area of model cells along the eastern edge of the Basin that were originally specified as Drain cells under Scenario 1 were converted to General Head boundary cells in Scenarios 2, 3, and 4. This area included all cells with a land surface elevation of 1 feet msl. The area of cells converted from Drain to General Head boundary cells is 4,890 acres and is shown on **Figure 11-4**.

11.3.2.2 Recharge

Recharge boundary conditions are used in the SMPGWM to specify dispersed recharge, including infiltration of precipitation, irrigation return flows, and leakage from municipal water system pipelines. To account for changes in hydrology associated with climate change in Scenarios 2, 3, and 4, the amount of dispersed recharge, calculated *a priori* using a rainfall/runoff/recharge model, was recalculated using revised information for precipitation and evapotranspiration.[96] In addition, in Scenario 4, the dispersed recharge was adjusted in the areas identified in the constraints analysis to account for additional stormwater (LID) recharge.

Climate change projections were obtained from the California Water Commission, Water Storage Investment Program (WSIP) (California Water Commission, 2016). The information includes projected changes in precipitation (rainfall), potential evapotranspiration, and runoff. Climate change effects were calculated as the differences between historical and 2030 projected values. Similarly, the differences in resulting runoff were utilized to modify monthly runoff into San Francisquito Creek and San Mateo Creek. For the two climate stations used to represent conditions in the Basin, average precipitation changes were estimated and used to adjust the 1991-2015 historical record. As a result, 2030 climate change projections indicate that average annual rainfall may increase almost 4 percent. Similarly, the 2030 climate change projections indicate that average annual potential evapotranspiration may increase about 3 percent. The net result of the monthly rainfall and evapotranspiration changes was a negligible decrease in annual average dispersed recharge (a projected decrease of less than 1 percent). **Figure 11-5** shows the historical/Baseline net recharge and the recharge projected to occur under climate change.

With respect to streamflow, projections indicate a negligible increase in small stream runoff, but runoff in San Francisquito Creek and San Mateo Creek was projected to increase approximately 10 percent and 5 percent respectively. **Figure 11-6** shows the model-calculated streamflows at a location along San Francisquito Creek under the baseline scenario (Scenario 1) and Scenario 2, which includes the effects of climate change. As shown on **Figure 11-6**, the effect of climate change is most significant during wetter years. Groundwater recharge due to the leakage of increased runoff in San Francisquito and San Mateo creeks are calculated by the SMPGWM.

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[96] The amount of bedrock recharge and small stream recharge was also revised to reflect climate change under Scenarios 2, 3, and 4, but the change was minimal.

Dispersed recharge from leakage from municipal water system pipelines was increased in proportion to the increase in water deliveries projected by 2040 under Scenarios 3 and 4 (discussed below). The amount of this increase in dispersed recharge was small – less than 100 AFY.

Dispersed recharge was also increased to reflect adoption of LID measures in certain portions of the Basin, as described in the constraints analysis section above. LID measures relevant to stormwater all tend to increase infiltration of runoff from impervious areas and include such measures as bioswales along streets and parking lots, downspout disconnection, dry wells, lot-scale and neighborhood-scale storm water infiltration ponding areas, and so forth. The parameter in the rainfall/runoff/recharge model that represents the fraction of impervious area from which runoff infiltrates into soil was increased to simulate LID effects. Within the Basin, we assumed an LID retrofitting program that results in infiltration of an additional 25 percent of the runoff from the impervious area. The total increase in dispersed recharge resulting from inclusion of LID measures in Scenario 4 is approximately 200 AFY.

11.3.2.3 Pumping

Increased groundwater pumping was included as part of Scenario 3 and 4 based on the constraints analysis described above. Modeled well extraction rates in the Basin were increased by 2,000 AFY (600 AFY from wells located north of the San Francisquito Creek Cone, and 1,400 AFY from wells constructed in the San Francisquito Creek Cone). The wells from which this increased extraction is pumped are not associated with specific real-world wells, but rather hypothetical production wells in the general areas identified in the constraints analysis. The assumed typical extraction rates for the deep wells range from 100 AFY in the north, to 200 AFY for wells located in the San Francisquito Creek Cone. The wells are all located in inferred high potential groundwater production areas. In addition to the increased pumping for Scenarios 3 and 4, minor modifications were made to account for relatively recent well conversions to inactive status and applied in all scenarios relative to the historical SMPGWM.

11.3.2.4 Injection

As part of Scenario 4, injection wells were incorporated into the model to simulate direct recharge by injection (IPR). As with the increased pumping under Scenario 3 and 4, the locations of modeled injection wells were set generally based on the constraints analysis. Because of clogging, injection rates are typically lower than extraction rates. In Scenario 4, the injection rates are assumed to be 50 percent of the typical well extraction rate (50 to 100 AFY depending on well location) (American Society of Civil Engineers, 2001). The feasible injection rate is also limited by the maximum permissible injection head, which is determined by the aquifer, groundwater conditions, and well construction. If this maximum head is exceeded, hydro-fracturing of fine-grained beds and the seals of existing deep wells could occur. As a result, the injected water could flow through fractures in the clay beds and damaged well seals, establishing hydraulic connections with adjacent aquifers and possibly land surface. To prevent hydro-fracturing from occurring, well locations were constrained to ensure that the injection head did not exceed the maximum permissible value calculated from well screen depth and the potentiometric surface at the well (Huisman and Olsthoorn, 1983). Lastly, each simulated injection well site is greater than 1,500 feet from the extraction wells implemented in Scenario 3 and greater than 1,500 feet from the nearest injection well.

11.3.2.5 Subsidence

The MODFLOW subsidence package (SUB) was added to the SMPGWM. The SUB package requires specification of pre-consolidation head, elastic storage coefficient, and inelastic storage coefficient. Pre-consolidation heads were calculated by adjusting the initial model heads (October 1990) downward to match the lowest measured groundwater elevations reported for database wells. The adjustments also considered 1965 groundwater elevation contour maps for shallow and deep zones (Fio and Leighton, 1995) and other published historical maps (USGS, 1988). Pre-consolidation head adjustments ensured negligible model-calculated subsidence during the historical simulation. Outside of the Basin, the pre-consolidation heads were set to a low value to exclude those areas from the inelastic subsidence calculations.

Elastic and inelastic skeletal storage coefficients were calculated as the product of the cell-by-cell aggregate thickness of the fine-grained sediment and skeletal elastic and inelastic specific storage values. The skeletal elastic and inelastic specific storage values were obtained from the USGS's Santa Clara Valley model (SCVM) (Hanson, Zhen, and Faunt, 2004). The cell-by-cell aggregate thickness of the fine-grained sediments was represented by the fraction of fine-grained sediment within each cell. This methodology is consistent with the USGS SCVM. Outside of the Basin, inelastic storage capacity was set to zero to effectively de-activate subsidence calculations (the model utilizes the specific storage to calculate groundwater storage changes in these external areas). Because the subsidence input is based on other studies and the lack of subsidence-related data in the Basin, model-calculated storage and land surface elevation changes due to subsidence are considered qualitative and should be interpreted with caution.

11.3.3 Scenario Comparison Methodology

This section describes the methods used to compare results from the modeled scenarios, including comparison of simulated hydrographs at four locations, comparison of simulated groundwater elevation contours for the shallow and deep aquifer zones, and comparison of the simulated water budgets.

11.3.3.1 Hydrograph Comparison

Hydrographs show groundwater elevations over time at a single location and are useful in understanding the temporal changes in groundwater conditions at specific locations. For this modeling analysis, hydrographs were generated at nearly 80 locations within the Basin (i.e., at each well for which observation data were available and used in model calibration in Phase 2). In order to distill the Basin behavior, a set of four locations throughout the Basin was selected that provide representative results for their respective areas. Locations were chosen to provide spatial as well as vertical coverage. The four hydrograph locations are shown on **Figure 11-7**, and details of the wells are provided in **Table 11-1** below.

Table 11-1. Simulated Water Level Observation Points

Well ID	Location in Basin	Screened Interval (ft bgs)	Aquifer Zone
W143	North	60 to 180	Deep
W279	Central	7 to 20	Shallow
W167	South, San Francisquito Cone	80 to 180	Deep
W296	South, near Bay shore	164 to 184	Deep

ft bgs = feet below ground surface

11.3.3.2 Groundwater Elevation Contour Comparison

Groundwater elevation contour maps provide a spatial view of groundwater conditions at a specific snapshot in time. As such, these maps allow for identification of where groundwater conditions are affected by various basin stresses (i.e., boundary conditions). For this analysis, groundwater elevation contour maps were prepared for the last time step of each simulation (i.e., at the end of the 25-year simulated period representing approximately the year 2040). In addition, groundwater level difference maps were prepared which show the difference in simulated groundwater elevation between the selected pairs of scenarios. While comparisons could be made between any pair of the four scenarios, in most cases the relevant comparisons involve scenario pairs that include the Baseline scenario (Scenario 1).

11.3.3.3 Water Budget Comparison

Water budgets are conceptually and mathematically simple yet powerful tools that, through tabulation of the component-level and total inflows and outflows, allow for a quantitative assessment of the overall groundwater sustainability of a given area. Numerical groundwater models are ideal tools for evaluation of water budgets. Long-term water budgets were developed from the SMPGWM for the Basin for the entire 25-year simulation period, and comparisons of the individual components between scenarios are discussed in the results below.

11.4 Scenario Modeling Results

11.4.1 Scenario 1 – Baseline

11.4.1.1 Groundwater Levels

Model-calculated water level hydrographs at each of the four selected observation points under Scenario 1 (Baseline) are shown on **Figure 11-8**. As shown on **Figure 11-8**, water levels tend to fluctuate seasonally in the three wells screened in the deep aquifer zone (i.e., approximately 5 feet in well W143, and 3 to 4 feet in wells W167 and W296), whereas seasonal fluctuations in the shallow zone well (well W279) are much more muted. Long-term water level trends in all wells show a slight rise over the first eight years, relatively steady levels for the next seven years, and then a gradual decline over the remaining 10 years. These long-term patterns are climatically driven based on variations in hydrology and dispersed recharge to the Basin over the simulation period. The magnitude of the trend is larger in the two wells in the southern portion of the Basin. For three out of four wells (i.e., all except well W296), the end of the simulation period is the point of lowest groundwater level.

Groundwater elevation contour maps for the shallow and deep zone are presented on **Figures 11-9a** and **11-9b**. As shown on **Figure 11-9a**, groundwater gradients in the shallow zone are pointed generally from southwest to northeast, flowing from the uplands along the western Basin boundary towards the Bay. Gradients in the shallow zone have a northward component along the northern and southern Basin boundaries. As shown on **Figure 11-9b**, groundwater levels in the deep zone are relatively flat with elevations between 0 and 5 feet msl over most of the Basin. Localized drawdown cones are evident in several areas due to pumping, including in the upper portion of the San Francisquito Creek cone and in the City of San Mateo area. It should be noted that these simulated local drawdown cones are not necessarily observed in measured water level data (which is sparse for the deep aquifer zone) and may be an artifact of estimated production well pumping rates. For example, the simulated pumping rates from wells located in the City of San Mateo area are uncertain and estimated based on irrigated turf area and estimated demand for water (Section 7.2). However, on a Basin or subarea scale, the simulated pumping rates are consistent with available information.

11.4.1.2 Water Budget

Table 11-2 presents the simulated water budgets for all four scenarios as well as the historical model run. As shown in **Table 11-2,** Scenario 1 (Baseline) had 800 AFY less subsurface inflow from the Santa Clara Subbasin to the south and correspondingly greater subsurface inflow from the east beneath San Francisco Bay. This is due to greater pumping and lower average simulated groundwater levels in the Santa Clara Subbasin in the Scenario 1 (Baseline) relative to the 1991-2015 historical average. All other inflow water budget components were unchanged (within the precision of 100 AFY shown in **Table 11-2** due to rounding). Outflows from the Basin are generally similar in the Scenario 1 (Baseline) as in the historical model run; pumping for water supply and dewatering are approximately 300 AFY lower and outflow to the Westside Basin to the north is slightly higher. These changes are due to removal of several inactive wells from the pumpage data set specified in the scenarios and reduced water levels in the areas represented by the dewatering drains.

11.4.2 Scenario 2 – Baseline + Climate Change

11.4.2.1 Groundwater Levels

Figure 11-10 shows the model-calculated water level hydrographs at each well under Scenario 2. Also shown on **Figure 11-10** are the hydrographs under Scenario 1 (Baseline). It is clear from

Figure 11-10 that the effects of climate change resulted in negligible differences in groundwater levels at these four well locations which is not surprising given that the simulated recharge changed (decreased) by less than 1 percent, as discussed previously.

Figures 11-11a and **11-11b** show the simulated groundwater elevation contour maps for the shallow zone and deep zone, respectively. Overall both of these maps closely resemble the results from the Scenario 1 (Baseline). **Figure 11-12a** shows the simulated groundwater level difference between Scenario 2 and Scenario 1 (Baseline) in the shallow zone. The difference in deep zone groundwater levels between Scenario 2 and Scenario 1 (Baseline) is negligible and not shown. The primary difference evident on **Figure 11-12a** is the increase in water levels of approximately 1 foot in the area around the inundated cells. **Figure 11-12b** shows the simulated groundwater level difference between Scenario 2 and Scenario 1 in the deep aquifer zone; however, using a contour level of 1 foot, no difference between the scenarios is apparent.

11.4.2.2 Water Budget

As shown in **Table 11-2**, comparing Scenario 2 to Scenario 1 (Baseline), the primary difference is a decrease in subsurface inflows to the Basin from the south and east of approximately 500 AFY total, and a net decrease in total groundwater seepage from 3,900 AFY in Scenario 1 to 3,300 AFY in Scenario 2. All of these effects stem from the increased sea level which reduces the eastward flow in both the shallow and deep zones. The negligible decrease in recharge due to changes in precipitation and evapotranspiration patterns is too small to register in the rounded values. Overall the water budget indicates a decrease in "throughput" (i.e., total water moving through the Basin) from approximately 7,500 AFY in Scenario 1 to 7,000 AFY in Scenario 2.

11.4.3 Scenario 3 – Baseline + Climate Change + Urban Demand Pumping Increase

11.4.3.1 Groundwater Levels

Figure 11-13 shows the model-calculated water level hydrographs at each well under Scenario 3, as well as Scenarios 1 and 2. **Figure 11-13** shows a large decrease in simulated water level in well W167 located in the San Francisquito Cone area. Within just a few years of the start of this simulation, water levels in this well are lowered relative to Scenario 2 by approximately 10 to 12 feet. A much smaller decrease of about 2 to 3 feet is seen in the hydrographs for wells W143 and W296. The cause of the decrease is increased pumping in the deep zone in the San Francisquito Cone area. The water level in well W167 drops below sea level during the low point of each of the last four years of the simulation, though the water level in well W296, closer to the Bay, only reaches sea level (0 feet msl) during the last year.

Figures 11-14a and **11-14b** show the simulated groundwater elevation contours at the end of the simulation period for the shallow and deep zone, respectively. As shown on **Figure 11-14a**, groundwater levels in the shallow zone still exhibit the same general pattern of gradients to the east but are somewhat steeper in the area further from the Bay shore and flatter in the area closer to the Bay shore. As shown on **Figure 11-14b,** groundwater levels in the deep zone, from which the additional extraction under Scenarios 3 and 4 is occurring, decrease to elevations below sea level over much of the Basin.

Figures 11-15a and **11-15b** show the difference in groundwater elevation between Scenario 1 (Baseline) and Scenario 3 for the shallow and deep aquifer zones, respectively. As shown on **Figure 11-15a**, groundwater levels in the shallow zone are lower by more than 5 feet under this Scenario in the southern portion of the Basin, and lower by approximately 1 foot in the northern portion. As shown on **Figure 11-15b**, in the deep zone, groundwater levels are over 15 feet lower in the southern portion of the Basin and over 10 feet lower in the northern portion. These differences reflect the distribution of increased groundwater pumping, 70 percent of which is specified to occur in the southern portion of the Basin.

11.4.3.2 Water Budget

As shown in **Table 11-2**, in comparison to Scenario 1 (Baseline) and Scenario 2, Scenario 3 shows increased subsurface inflow to the Basin from the south and from the east (i.e., a total of 1,700 AFY for Scenario 3 versus a total of 1,100 AFY for Scenario 1 and 600 AFY for Scenario 2). These increased subsurface inflows partially account for the specified increase in pumping outflows of 2,000 AFY. Outflow estimates also reflect a decreased outflow from groundwater seepage (i.e., down from a total of 3,900 AFY in Scenario 1 and 3,300 AFY in Scenario 2 to a total of 2,800 AFY in Scenario 3), slightly reduced dewatering pumping and subsurface outflow to the north (i.e., both reduced by 100 AFY), and a slightly more negative change in storage (i.e., -200 AFY in Scenario 3 versus -100 AFY in Scenario 1 and 0 AFY in Scenario 2). This indicates that when pumping demand is increased by 2,000 AFY, this water comes roughly 60 percent from increased subsurface inflows or reduced subsurface outflows; about 35 percent from reduced seepage to riparian ET, creeks and wetlands, sewers, dewatering pumping, and the Bay; and about 5 percent from reduction in storage. Overall, the Basin throughput is increased by about 1,200 AFY under Scenario 3 relative to Scenario 2.

11.4.4 Scenario 4 – Baseline + Climate Change + Urban Demand Pumping Increase + Implementation of Recharge Projects

11.4.4.1 Groundwater Levels

Figure 11-16 shows the model-calculated water level hydrographs at each well under all four scenarios. As shown on **Figure 11-16**, the Scenario 4 hydrographs in wells W143, W279, and W296 all show more or less complete recovery from the impact of increased pumping under Scenario 3, and even a slight increase in water levels relative to Scenario 1 (Baseline). The hydrograph for well W167, which is located in an area of increased pumping but not as much increased IPR recharge, shows a smaller recovery of roughly 3 feet by the end of the simulation period relative to Scenario 3.

Figures 11-17a and **11-17b** show the simulated groundwater elevation contours under Scenario 4 at the end of the simulation period for the shallow and deep aquifer zones, respectively. The shallow zone groundwater elevation contours are similar to the pattern under Scenario 3, indicating that the effect of increased LID recharge results in only small changes in shallow groundwater levels. The deep zone groundwater elevation contours show similar patterns to other scenarios (i.e., localized pumping drawdown cones in the northern and southern portions of the Basin), but the area of groundwater levels less than 0 feet msl is much smaller than under Scenario 3.

Figures 11-18a and **11-18b** show the difference in groundwater elevation contours between Scenario 1 and Scenario 4 at the end of the simulation period for the shallow and deep aquifer zones, respectively. For the shallow zone, the effect of increased urban pumping from the deep zone is still evident in the southern portion of the Basin but is mitigated by increased LID recharge in the central and northern portions of the Basin. For the deep zone, groundwater levels under Scenario 4 are still lower in the main pumping areas than they were in Scenario 1, but are increased by between 0 and five feet in areas where increased recharge by IPR is specified to occur.

11.4.4.2 Water Budget

As shown in **Table 11-2**, under Scenario 4 dispersed recharge is greater by 200 AFY and injection increases from zero to 1,800 AFY. As discussed above, these two recharge mechanisms increase the groundwater levels in both the shallow and the deep aquifer zones, which results in some counteracting effects including: decreased subsurface inflow from the south and east to levels similar to what they were under Scenario 2; increased shallow groundwater seepage to a total of 3,300 AFY (again, similar to Scenario 2), a slight increase in dewatering pumping, and a reduction in storage loss relative to Scenario 3. Under this Scenario, the Basin's throughput is increased to roughly 8,900 AFY.

11.4.5 Subsidence

As mentioned above, the ability to simulate land subsidence was added to the SMPGWM as part of Phase 3 modeling efforts. However, results indicate a negligible amount of subsidence for all scenarios. While parameterization of the subsidence package is challenging due to uncertainty in pre-consolidation heads and elastic and inelastic storage coefficients, these results should be considered qualitative, yet they do indicate that land subsidence is likely not a major concern under simulated conditions.

11.4.6 Cross-Boundary Subsurface Flow to Adjacent Basins

Figure 11-19 presents results from the four scenarios modeled in terms of cross-boundary subsurface flow to/from adjacent basins in each of the following depth zones: shallow aquifer zone (model layers 1 and 2), the "pumped" deep aquifer zone (model layers 3 – 5), and the unpumped deep aquifer (model layer 6). Inspection of **Figure 11-19** reveals the following:

- Most groundwater exchange with adjacent basins occurs within the shallow aquifer zone;

- The effects of climate change under Scenario 2 result in less inflow across the southern and eastern Basin boundaries;
- About half of the increased pumping under Scenario 3 is satisfied by inflow from adjacent basins; and
- About 70 percent of the increased recharge under Scenario 4 goes to outflow to adjacent basins.

11.5 Discussion

11.5.1 Model Uncertainty

In accordance with the objectives of the Project modeling effort, the scenarios evaluated herein are hypothetical and were developed in part based on generalizations regarding potential future groundwater development and/or management activities. Furthermore, and as discussed in Section 8.0, all numerical models represent simplifications to the real-world system they are meant to represent and as such are infused with a level of uncertainty. The uncertainty in model properties, boundary conditions, and stresses introduce uncertainty in the projected groundwater levels calculated by the model. While this does not mean that results from models are unreliable, it does mean that results should be interpreted with an understanding of the inherent simplifications, assumptions, and limitations of the model. It is also difficult to reliably predict future climate and water use conditions. The insights provided from models are therefore more reliable when based on relative comparisons between model runs (e.g., "scenarios") than each scenario in isolation. Additionally, the relationships between the uncertainty in model input and the discrepancies they introduce to the model output can be explored to quantify the likelihood of expected outcomes and management decisions made based on a level of risk that is considered acceptable. As such, the direct use of scenario results to draw conclusions regarding specific outcomes (e.g., specific levels of drawdown in specific locations) is probably not warranted. With that in mind, the next section presents high-level interpretations of modeling results in the context of Basin sustainability.

11.5.2 Basin Sustainability

This section presents a discussion of the Phase 3 modeling results in the context of sustainability and SGMA. Modeling results are discussed relative to each of the SGMA-defined "undesirable results."

11.5.2.1 Groundwater Levels

Model results indicate relatively stable groundwater level trends for the four modeled scenarios. Clearly, increased pumping demand under Scenario 3 represents a more stressed condition than the other scenarios, and results in the greatest decrease in groundwater levels, especially in the deep aquifer zone. However, as shown on **Figures 11-13**, **11-14a**, and **11-14b**, even locations within the area of focused increased pumping shows a decrease of only about 15 feet over 25 years. While every basin subject to SGMA (which the Basin currently is not) must determine its own sustainability criteria and levels of significance, a long-term change in water levels of at most less than 1 foot per year in and of itself likely would not be deemed "significant and unreasonable," which is the current SGMA standard.

11.5.2.2 Groundwater Storage

The model-calculated water budget results (**Table 11-2**) indicate an annual change in storage for the four modeled scenarios of between 0 and -200 AFY. This amount does not suggest a significant level of overdraft. Even under the most "stressed" condition (Scenario 3), where pumping for urban water supply is nearly doubled relative to current conditions, the Basin does not exhibit a substantial long-term decrease in storage that would indicate overdraft conditions because of recharge across Basin boundaries. To put the small simulated change in storage of -200 AFY under Scenario 3 in context, this represents only about 2.5 percent of the total annual water budget, and in a basin with a total storage volume on the order of 1 to 1.3 million AF, represents less than 0.02 percent of total storage.

11.5.2.3 Seawater Intrusion

Due to its location directly adjacent to San Francisco Bay, the potential for salt water/seawater intrusion is real and there is historical evidence that it has occurred in the Basin (Section 5.1.2). As mentioned above, the most stressed condition occurs under Scenario 3. **Figures 11-13, 11-14a**, and **11-14b** indicate that groundwater levels at the low point (end of) the simulation period include large areas with groundwater levels below sea level, which may create conditions conducive to migration of seawater into the Basin. It is, however, uncertain whether the water quality in the deep aquifer zone that enters the Basin from the east is saline or not, and the shallow zone retains a condition of net outflow to the east due to seepage (see **Figure 11-19**). It is therefore possible that the Basin could operate under conditions where groundwater levels dip below sea level, either temporarily or more continuously, without resulting in "significant and unreasonable" seawater intrusion.

We also note that spatial differences in water density due to variable salinity concentrations can influence groundwater flow near the interface between inland groundwater and baywater. The SMPGWM assumes the effect of this density contrast is negligible on the Basin-wide groundwater elevations and water budget. The assumption can be reasonable for regional models because groundwater-flow is influenced much more by the recharge and pumping stresses than the contrast in water density. Monitoring of groundwater quality in deep sentinel wells along the shoreline, as is being conducted as part of the City of East Palo Alto's Groundwater Management Plan implementation, will be vital to a better understanding, and potential early warning, of seawater intrusion.

11.5.2.4 Groundwater Quality

The modeling work performed here does not specifically address groundwater quality, other than the potential for seawater intrusion discussed above. It should be noted that groundwater quality issues in the shallow aquifer zone related to localized contamination caused by near-surface releases are (a) generally controlled through existing regulatory programs and (b) expected to be largely unaffected by potential groundwater development and/or management activities considered herein. Nevertheless, in the deep aquifer zone, the drawdown of groundwater levels due to increased pumping could potentially cause increases in vertical hydraulic gradients that could allow for downward migration of contaminants to the deep aquifer zone where the hydraulic connection exists. Such a potential would presumably be considered in any project-level analysis for the installation and operation of a production well.

11.5.2.5 Land Subsidence

As discussed above, this scenario evaluation did not indicate a significant risk of land subsidence based on the scenarios modeled. Section 6.2.8 describes historical inelastic subsidence caused by groundwater level drawdown, which in some locations exceeded 140 feet by 1962. Groundwater levels subsequently recovered to above sea level. Future potential drawdown of groundwater level within this historical range, such as the maximum of 15 feet suggested by Scenario 3 model results, would not be expected cause further inelastic subsidence. However, due to uncertainty in parameterization, these results should be interpreted with caution. As with seawater intrusion, the potential for land subsidence would best be addressed by the establishment of an appropriate land subsidence monitoring program (which could occur if a GSP is required to be developed for the Basin) and through project-specific analysis.

11.5.2.6 Interconnected-Surface Water

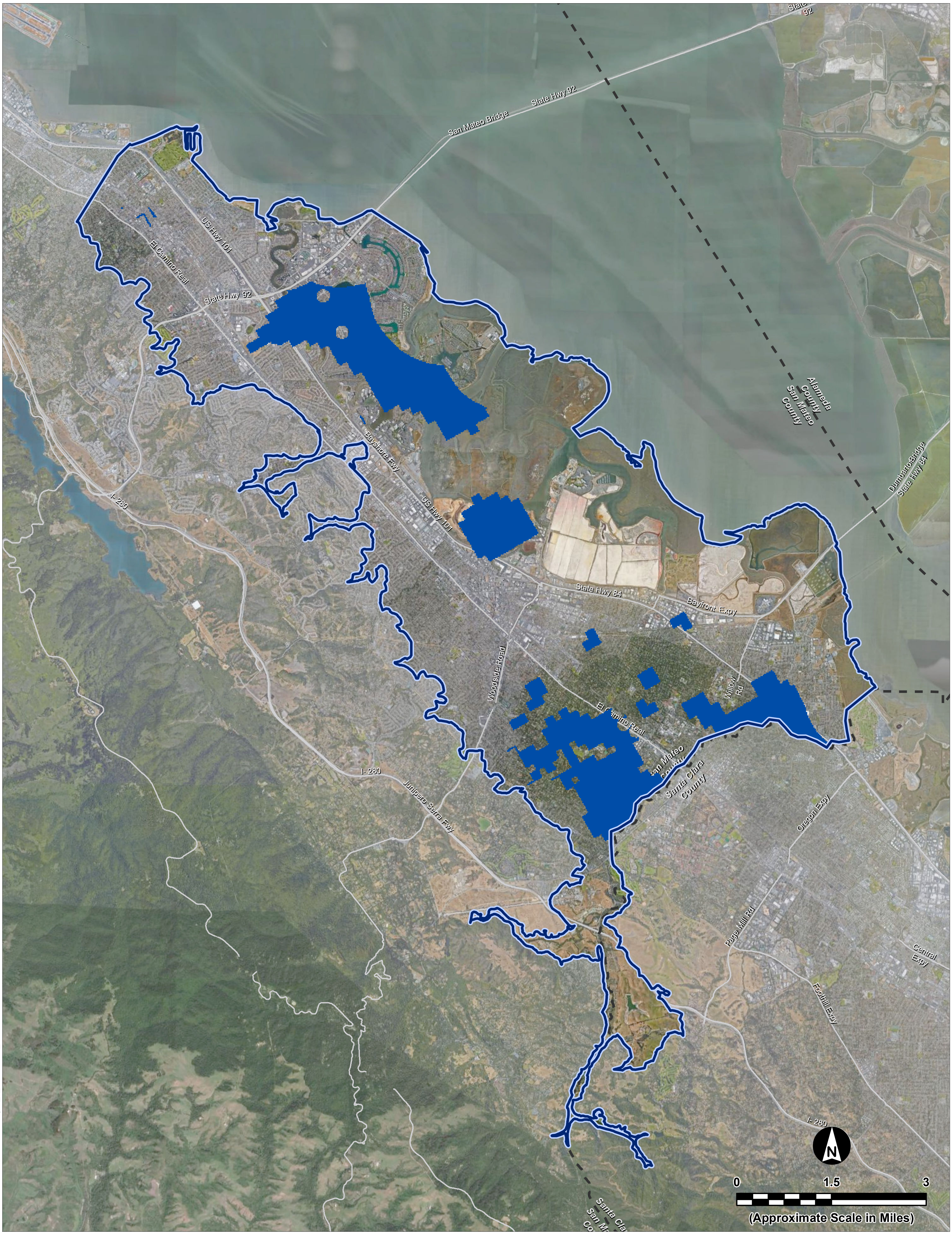
As shown in the water budget results presented in **Table 11-2**, none of the scenarios modeled indicated a significant change in the amount of inflow to the Basin from recharge from creeks, including San Francisquito Creek, San Mateo Creek, and the multiple smaller creeks. San Francisquito Creek is a primary source of recharge to the Basin, but most leakage from the creek to the aquifer occurs in the upper reaches of the creek. In these areas, the water table is below the bottom of the streambed and hydraulically disconnected from water flowing in the creek. As such, the leakage rate under these conditions is determined by the water level in the creek, the elevation of the bottom of the streambed, and the hydraulic conductivity of the streambed deposits beneath the creek and is not sensitive to changes in the water table. Therefore, these preliminary results suggest that impacts of groundwater management/ development activities, if sited and managed appropriately, are not likely to be significant. However, this study does not substitute for the more refined analysis of potential impacts that is necessary on a project-by-project basis as part of the environmental review process.

Table 11-2
Model-Calculated Water Budgets

	Historical Period (WY 1992-2015)	Projected Future Scenarios			
		Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Inflows (AFY) (1)					
Dispersed Recharge	4,700	4,700	4,700	4,700	4,900
Stream Percolation					
San Francisquito Creek	400	400	400	400	400
San Mateo Creek	200	200	200	200	200
Other creeks	500	500	500	500	500
Bedrock Inflow	600	600	600	600	600
Injection	0	0	0	0	1,800
Inflow from the South (from Santa Clara Subbasin)	1,100	300	100	700	100
Inflow from the East (beneath San Francisco Bay)	0	800	500	1,000	400
Total Inflows	*7,500*	*7,500*	*7,000*	*8,100*	*8,800*
Outflows (AFY) (1)					
Wells	2,700	2,500	2,500	4,500	4,500
Dewatering	1,000	900	1,000	900	1,000
Groundwater Seepage					
Riparian ET	2,500	2,600	1,300	1,100	1,300
Creeks and Tidal Wetlands					
Sewers	1,400	1,300	1,500	1,300	1,500
San Francisco Bay	0	0	500	400	500
Outflow to the East (beneath San Francisco Bay)	0	0	0	0	0
Outflow to the North (to Westside Basin)	100	200	200	100	200
Total Outflows	*7,700*	*7,500*	*7,000*	*8,400*	*9,000*
Change in Storage (AFY) (1)					
Storage Change (2)	-200	-100	0	-200	-100

Abbreviations:
"AFY" = acre-feet per year
"ET" = evapotranspiration
"WY" = water year

Notes:
(1) All values shown are rounded to the nearest 100 AFY. Therefore, totals shown may not match the sum of components in all cases.
(2) Storage change determined by balance of total inflow and outflow.



Path: X:\B60024\Maps\2018\06\Fig11_1_Constraints_PotIncGW.mxd

Legend

County Boundary

Major Road

San Mateo Plain Subbasin

Areas of Potential Increased Groundwater Production

Notes

1. All locations are approximate.
2. Basin areas with potential for increased groundwater production, were identifed based on the following criteria:
   - Aquifer is relatively permeable and thick to allow for storage (the combined thickness of Model Layers 3 through 5 is at least 100 feet and at least one of the layers has a coarse fraction of at least 40%);
   - Area is at least 1 mile from the northeastern subbasin boundary, to avoid losing stored water to the Bay; and
   - Area is not located near known, open contamination sites (area is not within 500 feet of an open contamination site identified on GeoTracker).

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Aerial imagery: Google Earth Pro, accessed 19 April 2016.

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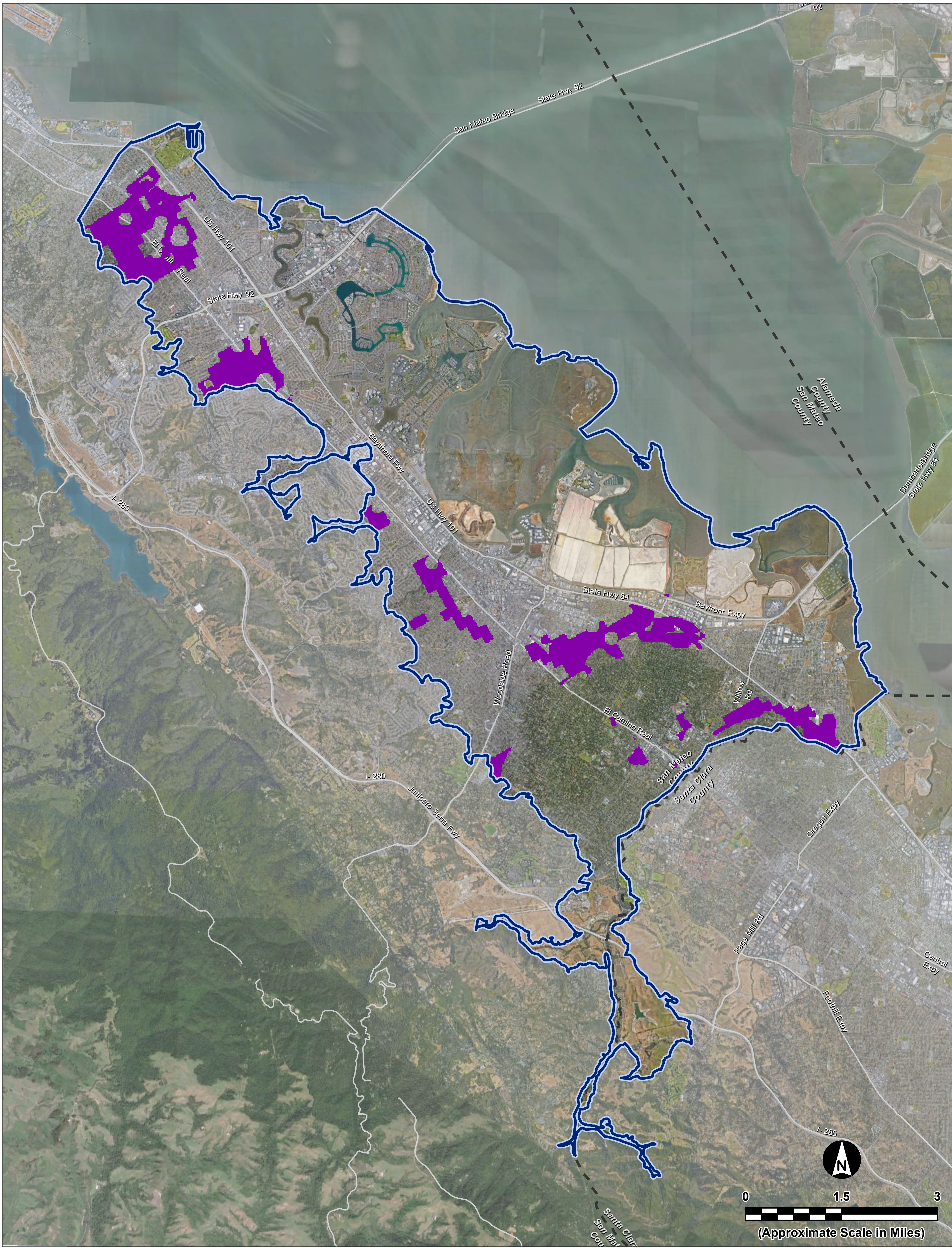
Constraints Analysis - Areas of Potential Increased Groundwater Production

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 11-1



Path: X:\B60024\Maps\2018\06\Fig11_2_Constraints_Stormwater.mxd

Legend

- County Boundary
- Major Road
- San Mateo Plain Subbasin
- Areas with Highest Potential for Stormwater Recharge

Abbreviations

DEM = digital elevation model
LID = low-impact design
NRCS = Natural Resources Conservation Service
USDA = United States Department of Agriculture
USGS = United States Geological Survey

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Aerial imagery: Google Earth Pro, accessed 19 April 2016.

Notes

1. All locations are approximate.
2. Basin areas with the highest potential for stormwater infiltration and recharge of groundwater were identifed based on the following criteria:
   - Surface soils are not identified as hydrologic soil groups C or D based on the USDA NRCS soils classification;
   - The ground surface has a low slope (less than 5% slope based on USGS DEM file;
   - The major shallow confining layer is weak or not present (Layers 1 and 2 of the model both have a coarse fraction of greater than 20%; where Layer 2 is not active, Layer 1 has coarse fraction of greater than 20%); and
   - Area is not located near known, open contamination sites (area is not within 500 feet of an open contamination site identified on GeoTracker).

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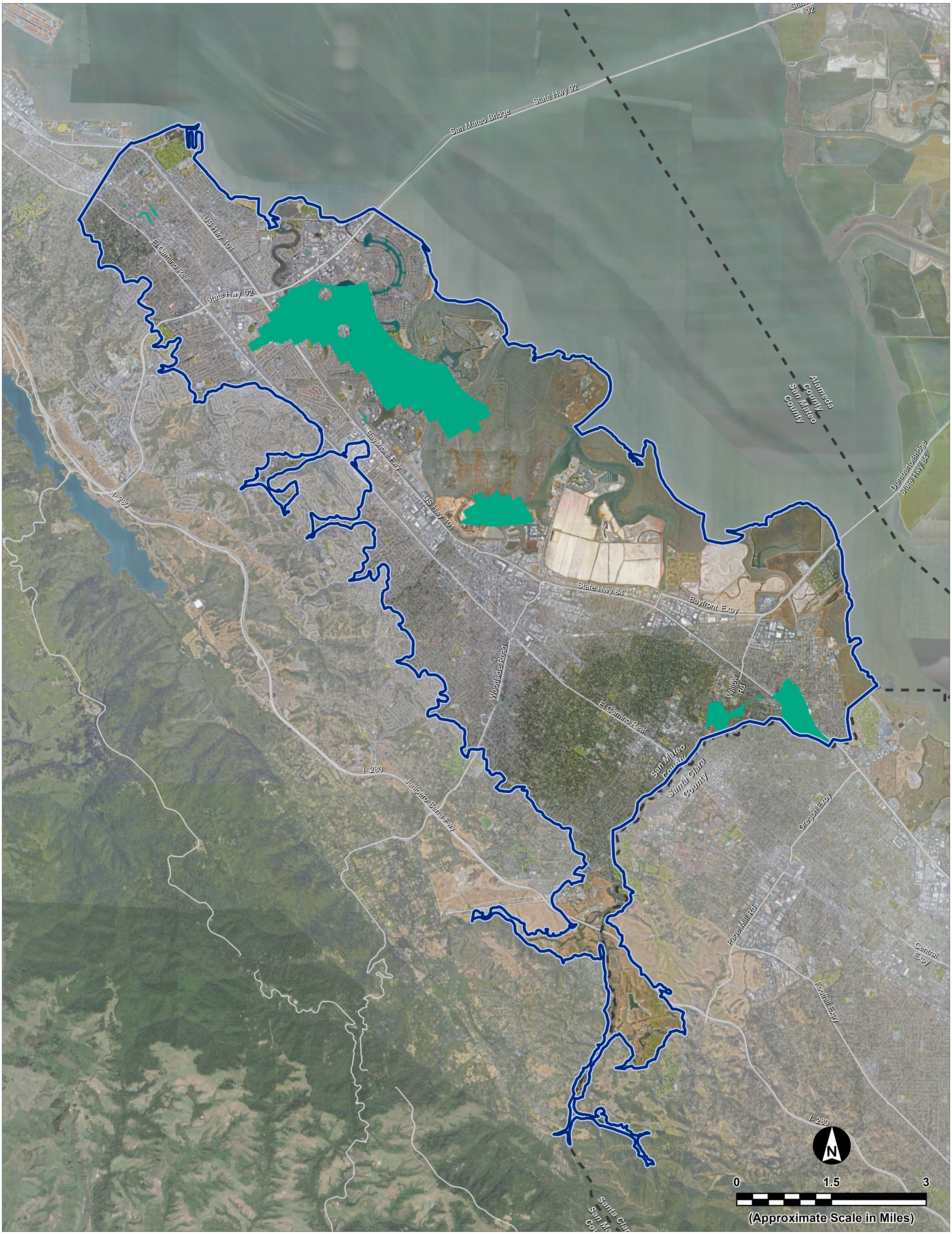
Constraints Analysis - Areas of Potential Increased Stormwater (LID) Recharge
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00
Figure 11-2



Path: X:\B60024\Maps\2018\06\Fig11_3_Constraints_IPR.mxd

Legend

- County Boundary
- Major Road
- San Mateo Plain Subbasin
- Areas with Highest Potential for IPR Projects

Abbreviations

IPR = Indirect Potable Reuse

Notes

1. All locations are approximate.
2. Basin areas with the highest potential for indirect potable reuse projects were identifed based on the following criteria:
   - Aquifer is relatively permeable and thick to allow for storage (the combined thickness of Model Layers 3 through 5 is at least 100 feet and at least one of the layers is has a coarse fraction of at least 40%);
   - Area is at least 1 mile from the existing bayshore, to avoid losing stored water to the Bay;
   - Area is within 3 miles from an existing wastewater treatment plant;
   - Area is at least 1,000 feet from an existing public water supply well, which represents an approximate travel time of six to twelve months from an injection area to a public supply well; and
   - Area is not located near known, open contamination sites (area is not within 500 feet of an open contamination site identified on GeoTracker).

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Aerial imagery: Google Earth Pro, accessed 19 April 2016.

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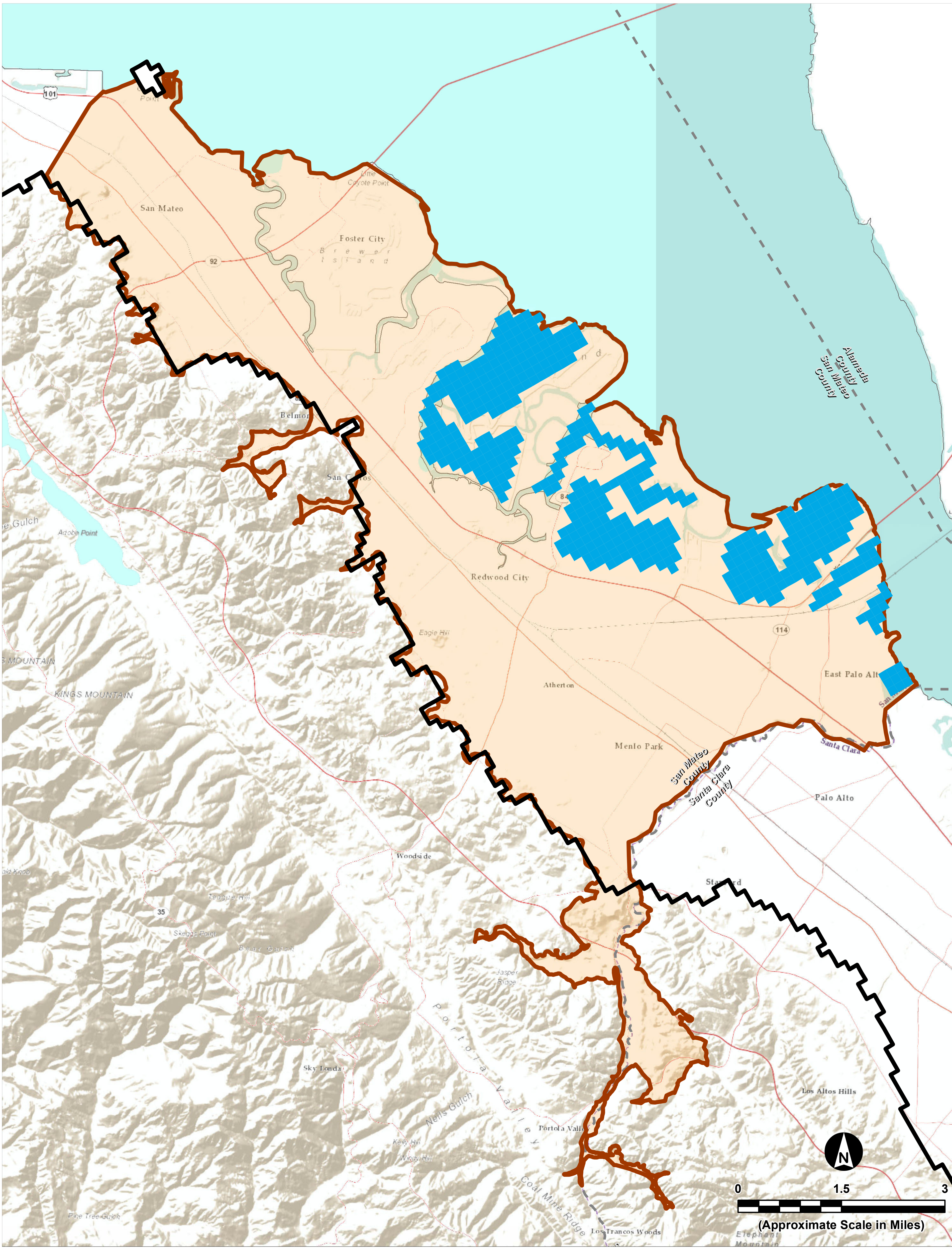
Constraints Analysis - Areas of Potential Direct (IPR) Recharge

San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 11-3



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Projected Inundated Model Cells due to Sea Level Rise
- County Boundary

Notes

1. All locations are approximate.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 13 April 2018.

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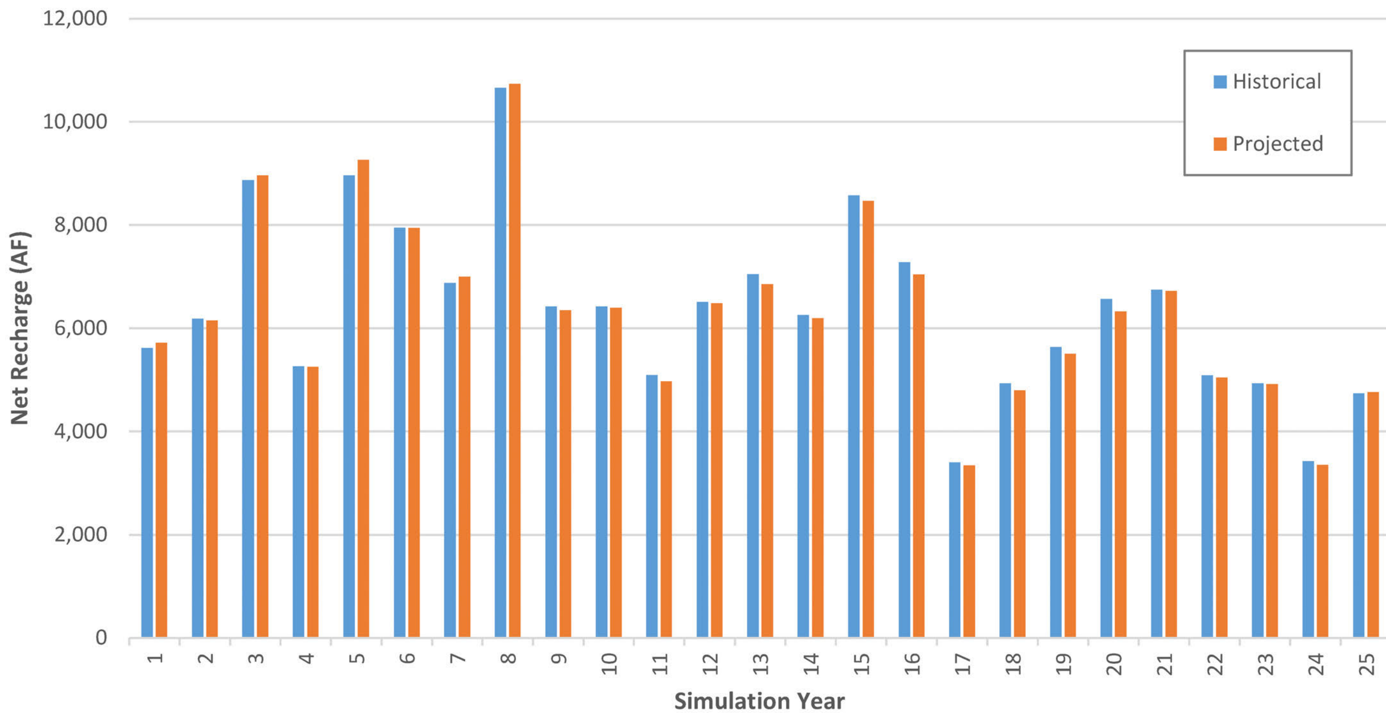
Location of Model Cells Inundated by Sea Level Rise

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

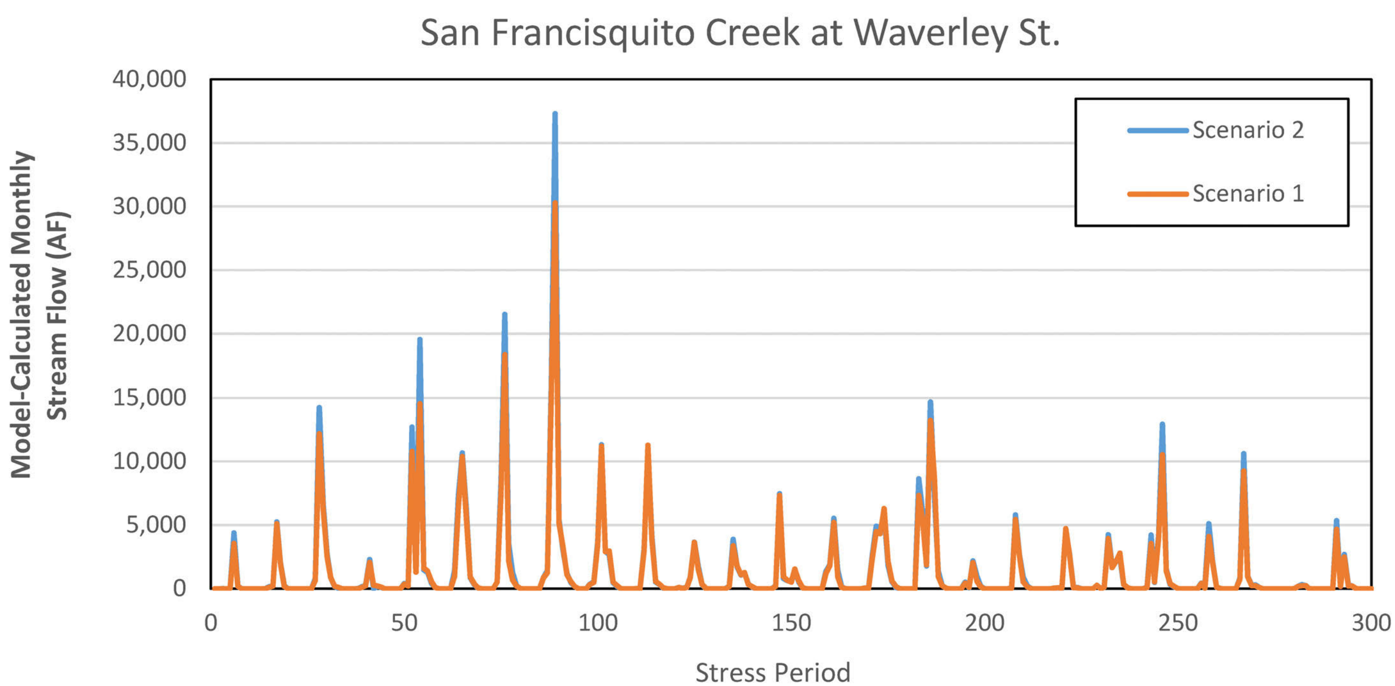
Figure 11-4



Abbreviations
AF = acre-feet

Net Recharge – Historical and Projected with Climate Change

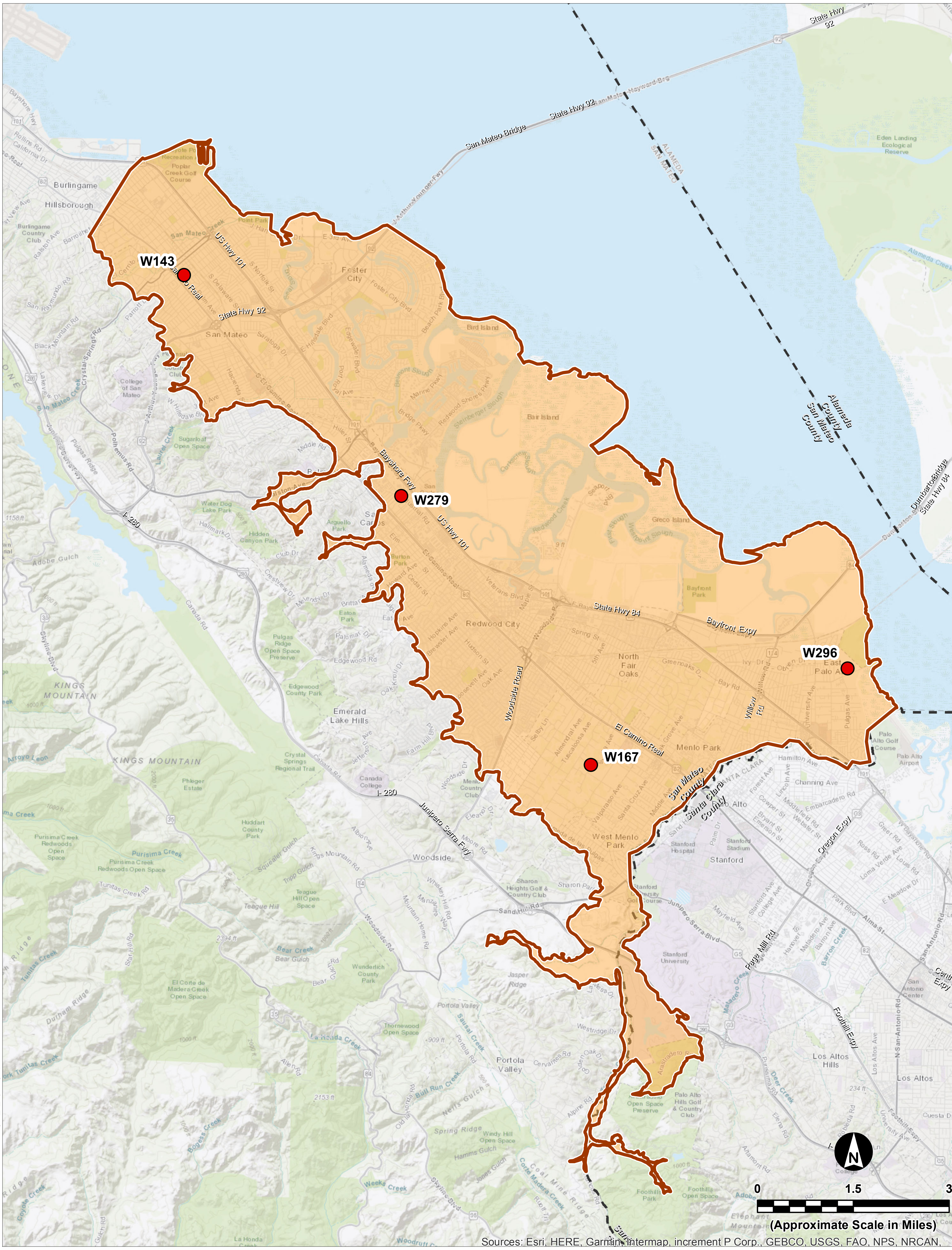
San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00
Figure 11-5



Abbreviations
AF = acre-feet

Model-Calculated Stream Flows under Baseline Condition and with Climate Change

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00
Figure 11-6



Path: X:\B60024\Maps\2018\06\Fig11_7_HydrographWells.mxd

Legend

- San Mateo Plain Subbasin
- County Boundary
- Major Road
- Simulated Water Level Observation Point

Notes
1. All locations are approximate.

Sources
1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.

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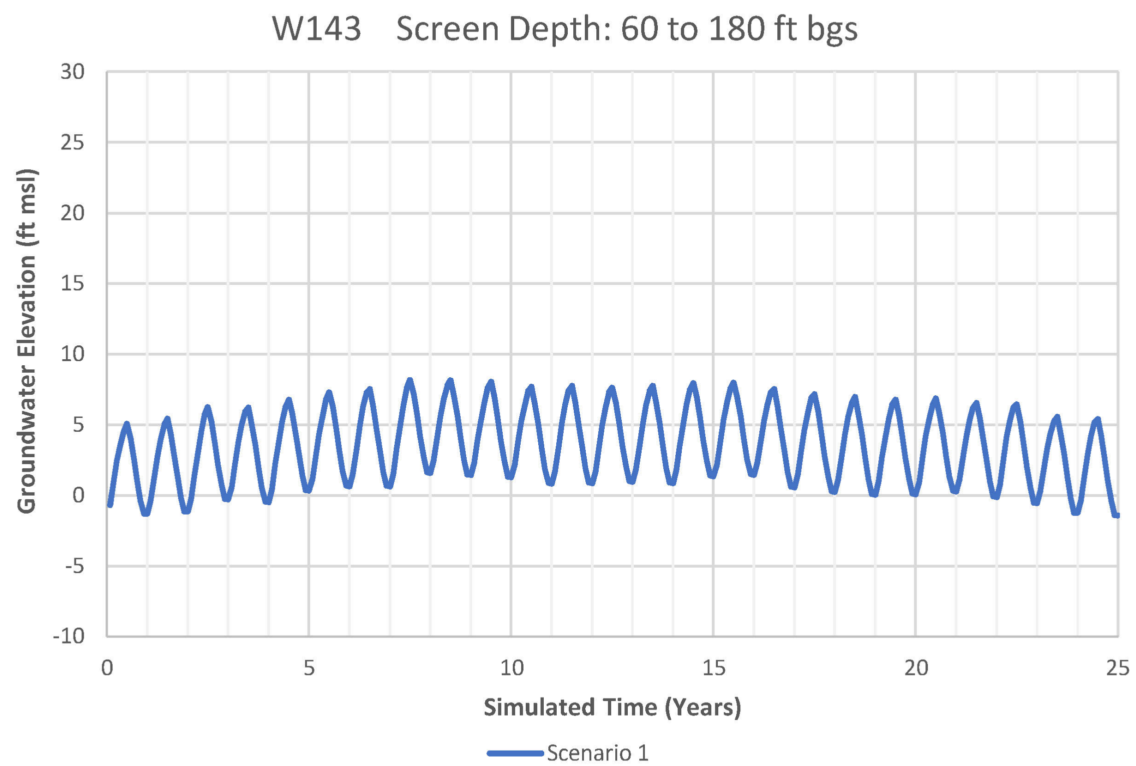
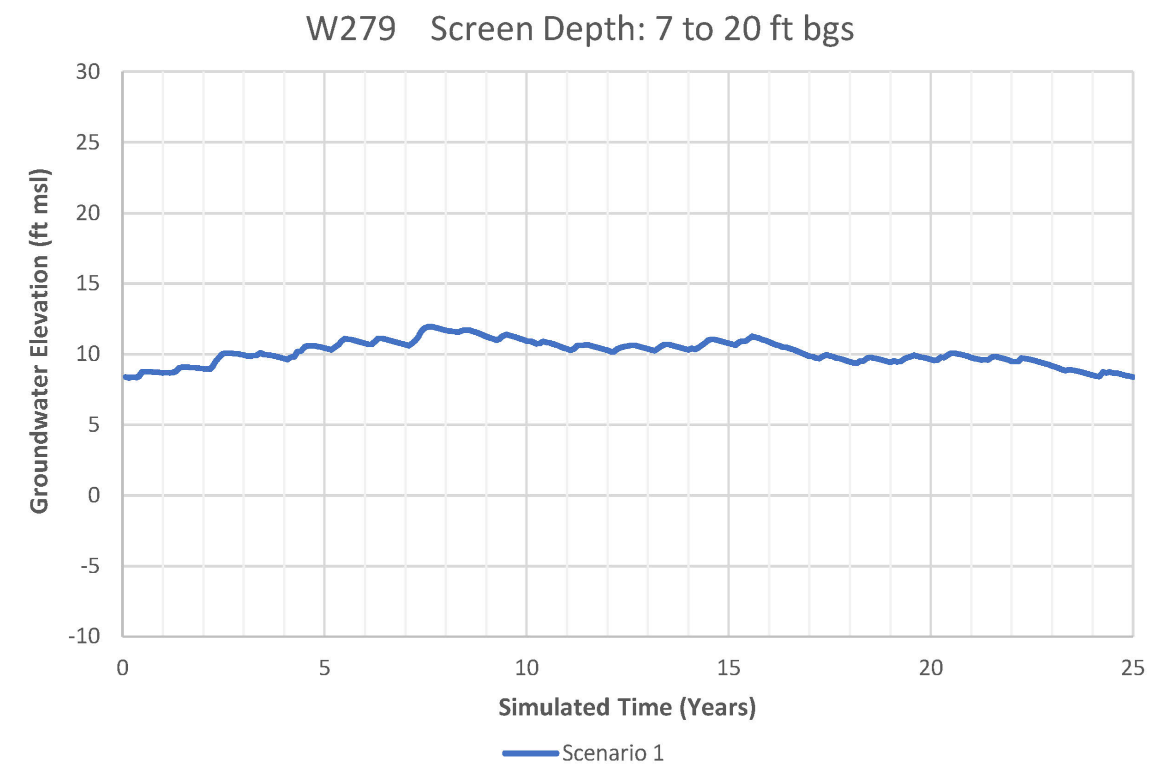
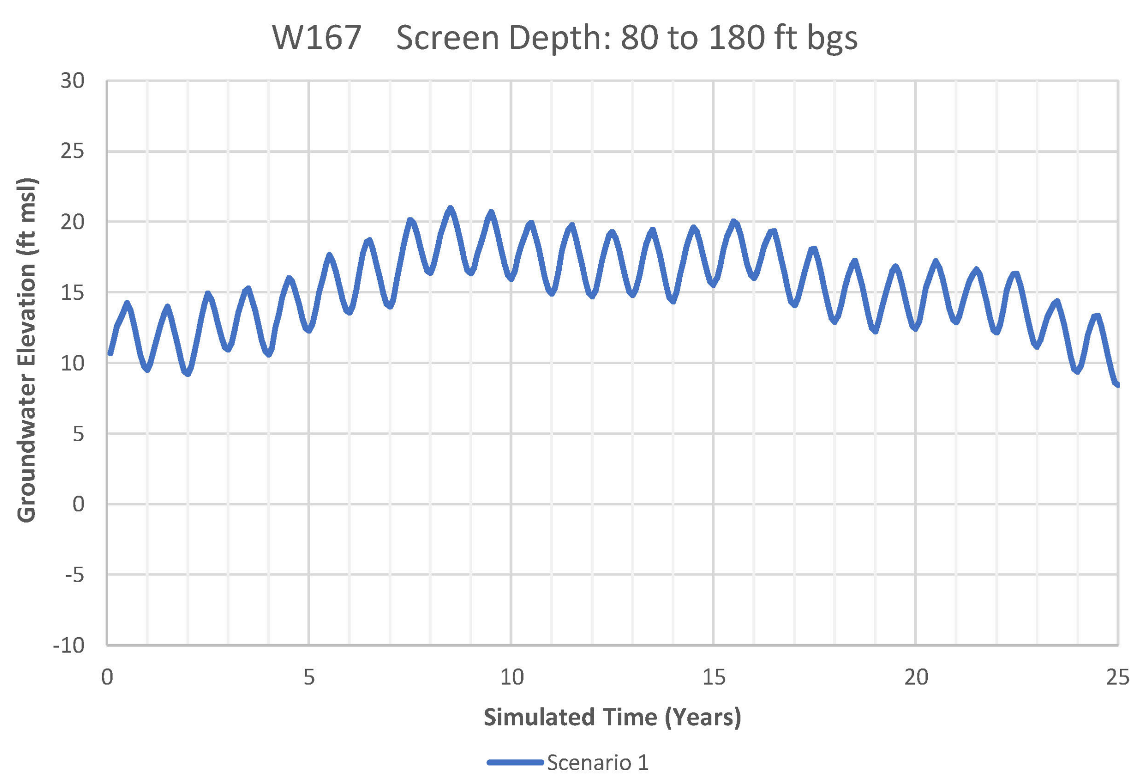
Locations of Simulated Water Level Observation Points

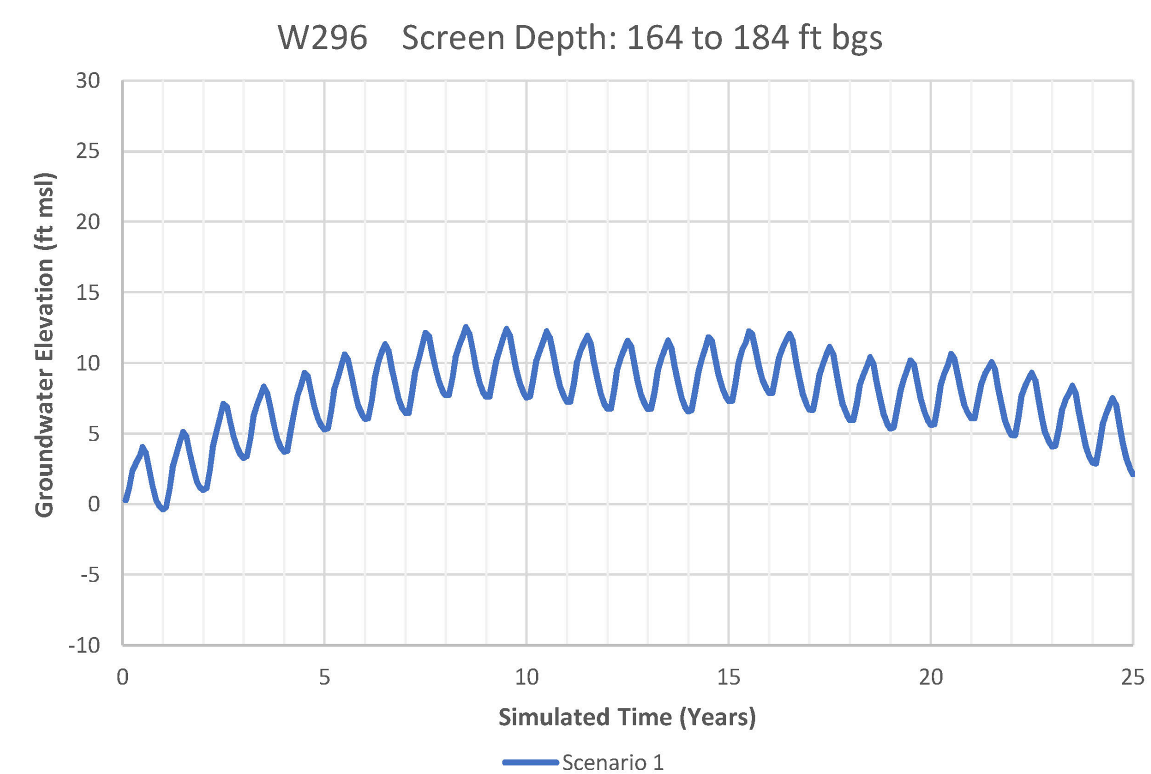
San Mateo Plain Groundwater Subbasin
San Mateo County, California
June 2018
EKI B60024.00

Figure 11-7







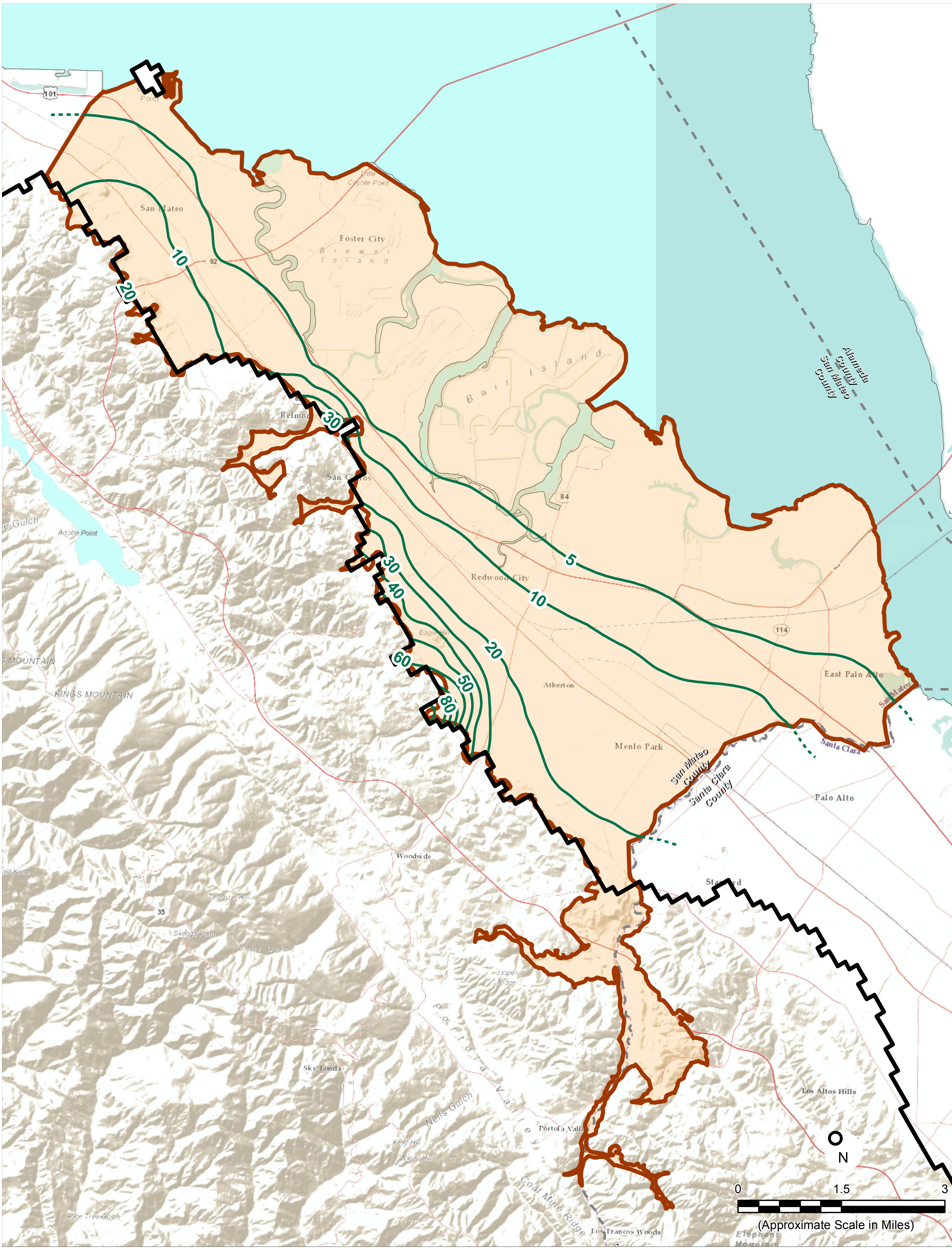


Abbreviation
ft bgs = feet below ground surface
ft msl = feel above mean sea level

Model-Calculated Groundwater Levels at Observation Points – Scenario 1

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-8



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- —5— Scenario 1 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88) dashed outside San Mateo Plain Subbasin
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the shallow aquifer are from model layer 1.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 29 March 2018.

Abbreviations

NAVD = North American Vertical Datum

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Simulated End-of-Period Groundwater Elevation Contours, Shallow Zone -- Scenario 1

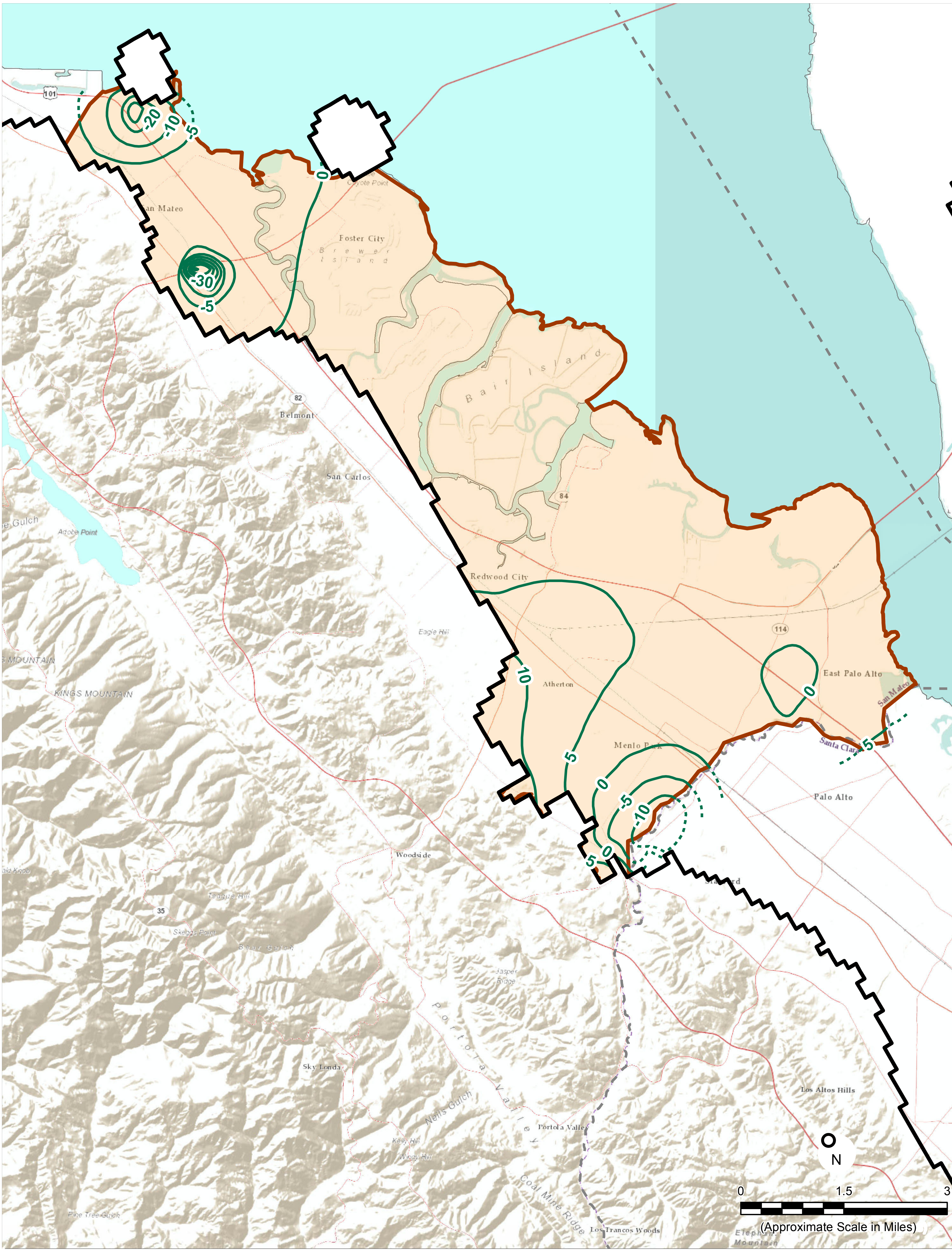
San Mateo County, California

San Mateo Plain Groundwater Subbasin

June 2018

EKI B60024.00

Figure 11-9a



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Layer 3 Boundary
- –5– Scenario 1 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88) dashed outside San Mateo Plain Subbasin
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the deep aquifer are a weighted average of model layers 3, 4, and 5 based on model layer thickness.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 29 March 2018.

Abbreviations

NAVD = North American Vertical Datum

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Simulated End-of-Period Groundwater Elevation Contours, Deep Zone -- Scenario 1

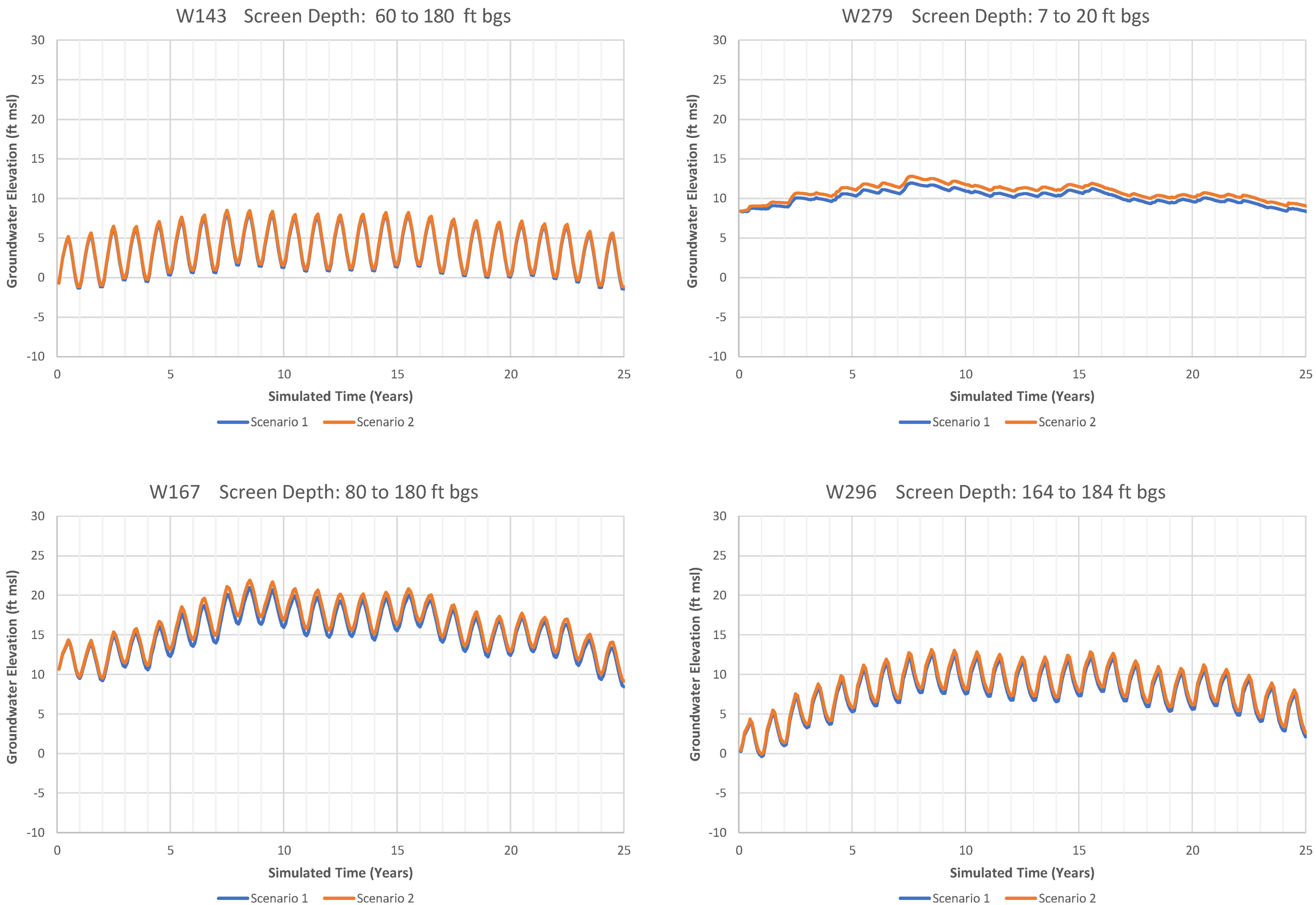
San Mateo County, California

San Mateo Plain Groundwater Subbasin

June 2018

EKI B60024.00

Figure 11-9b



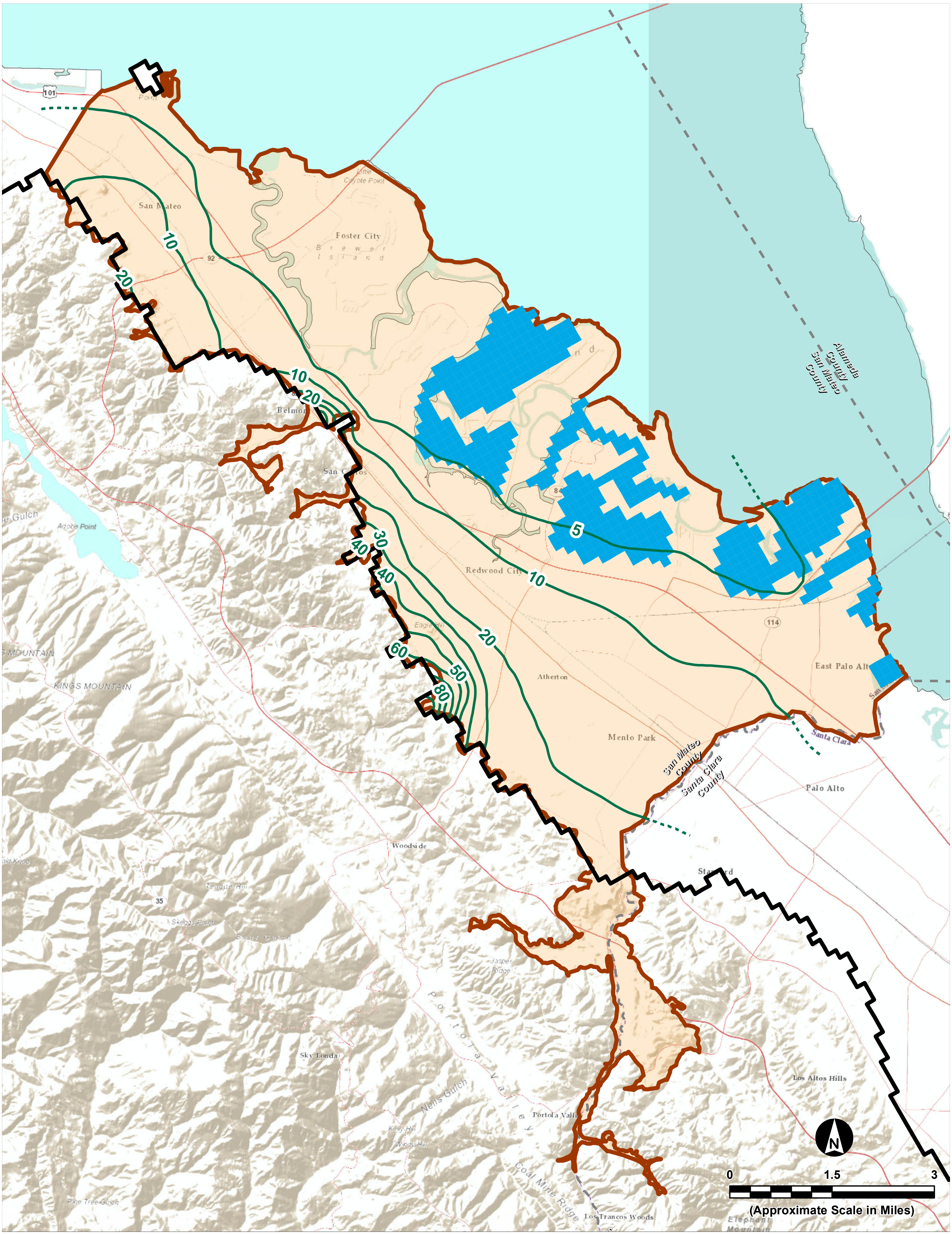
Abbreviation

ft bgs = feet below ground surface
ft msl = feet above mean sea level

Model-Calculated Groundwater Levels at Observation Points – Scenarios 1 and 2

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-10



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Scenario 2 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88), dashed outside San Mateo Plain Subbasin
- San Mateo Plain Subbasin Areas Inundated due to Sea Level Rise
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the shallow aquifer are from model layer 1.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 29 March 2018.

Abbreviations

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Simulated End-of-Period Groundwater Elevation Contours, Shallow Zone -- Scenario 2

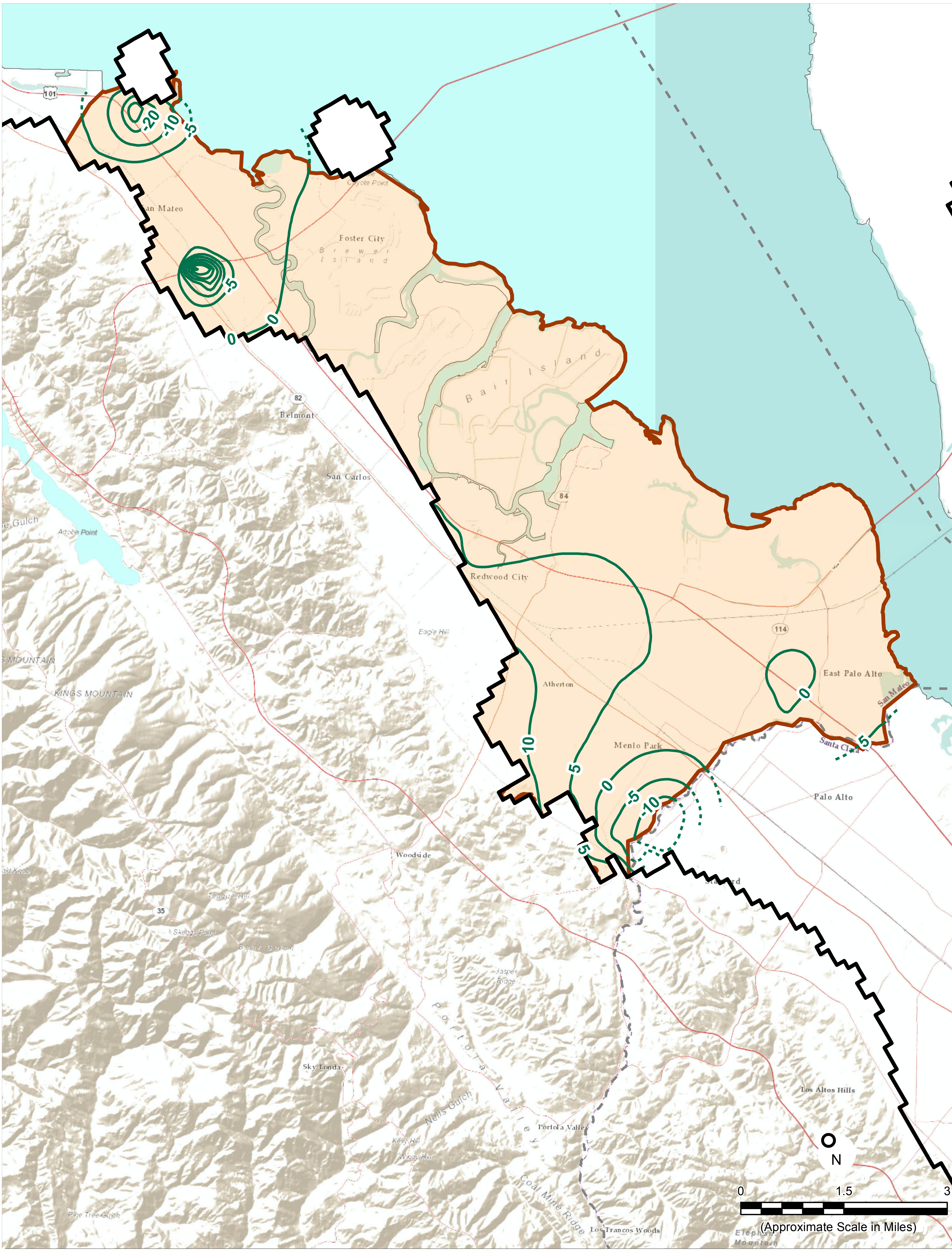
San Mateo County, California

San Mateo Plain Groundwater Subbasin

June 2018

EKI B60024.00

Figure 11-11a



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Layer 3 Boundary
- –5– Scenario 2 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88) dashed outside San Mateo Plain Subbasin
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the deep aquifer are a weighted average of model layers 3, 4, and 5 based on model layer thickness.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 29 March 2018.

Abbreviations

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Simulated End-of-Period Groundwater Elevation Contours, Deep Zone -- Scenario 2

San Mateo County, California

San Mateo Plain Groundwater Subbasin

June 2018

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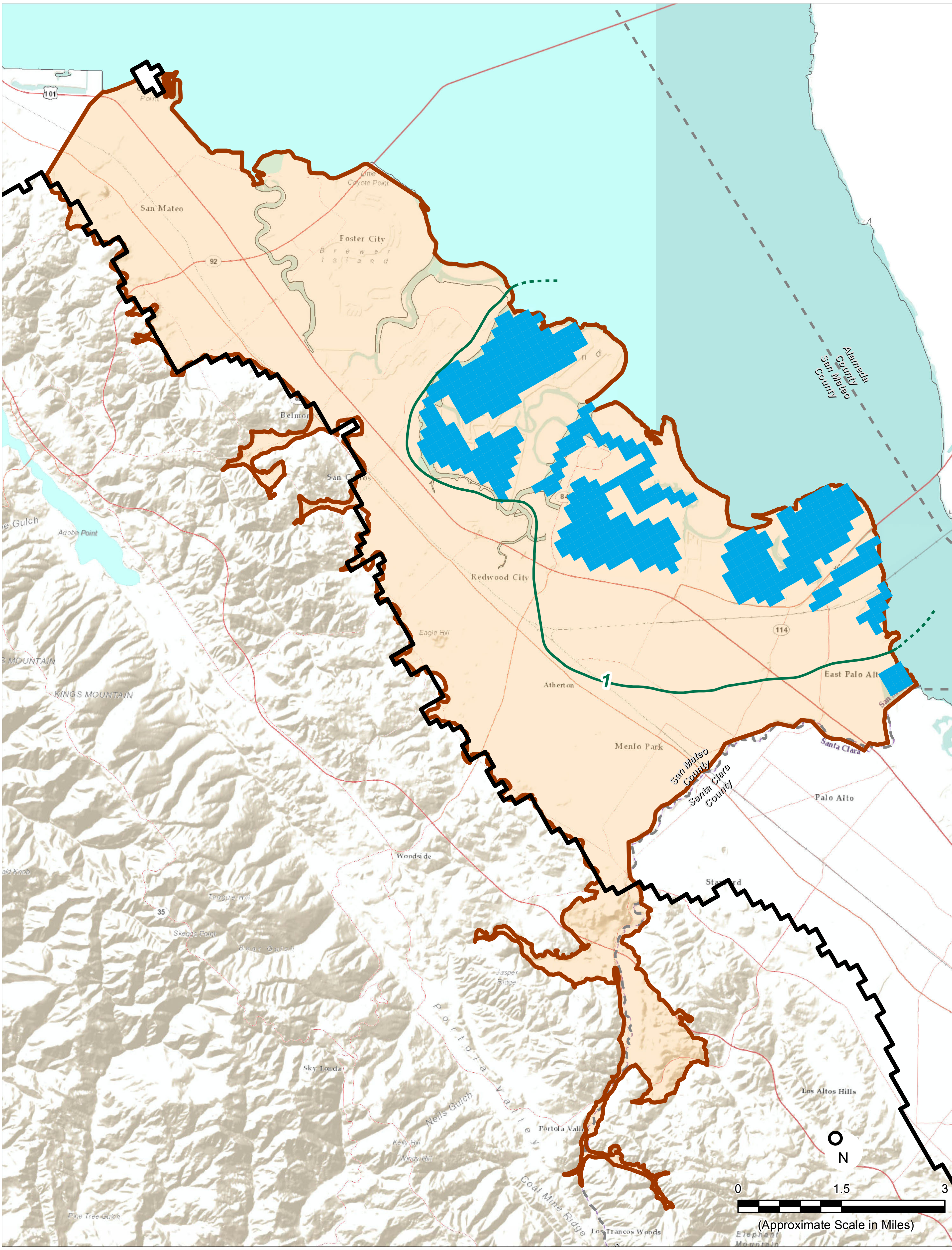
Figure 11-11b



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Difference in Model-Calculated Groundwater Elevation Contours (ft; NAVD 88) Scenario 2 - Scenario 1, dashed outside San Mateo Plain Subbasin
- Inundated San Mateo Plain Subbasin Areas due to Sea Level Rise
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the shallow aquifer are from model layer 1.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 2 March 2018.

Abbreviations

NAVD = North American Vertical Datum

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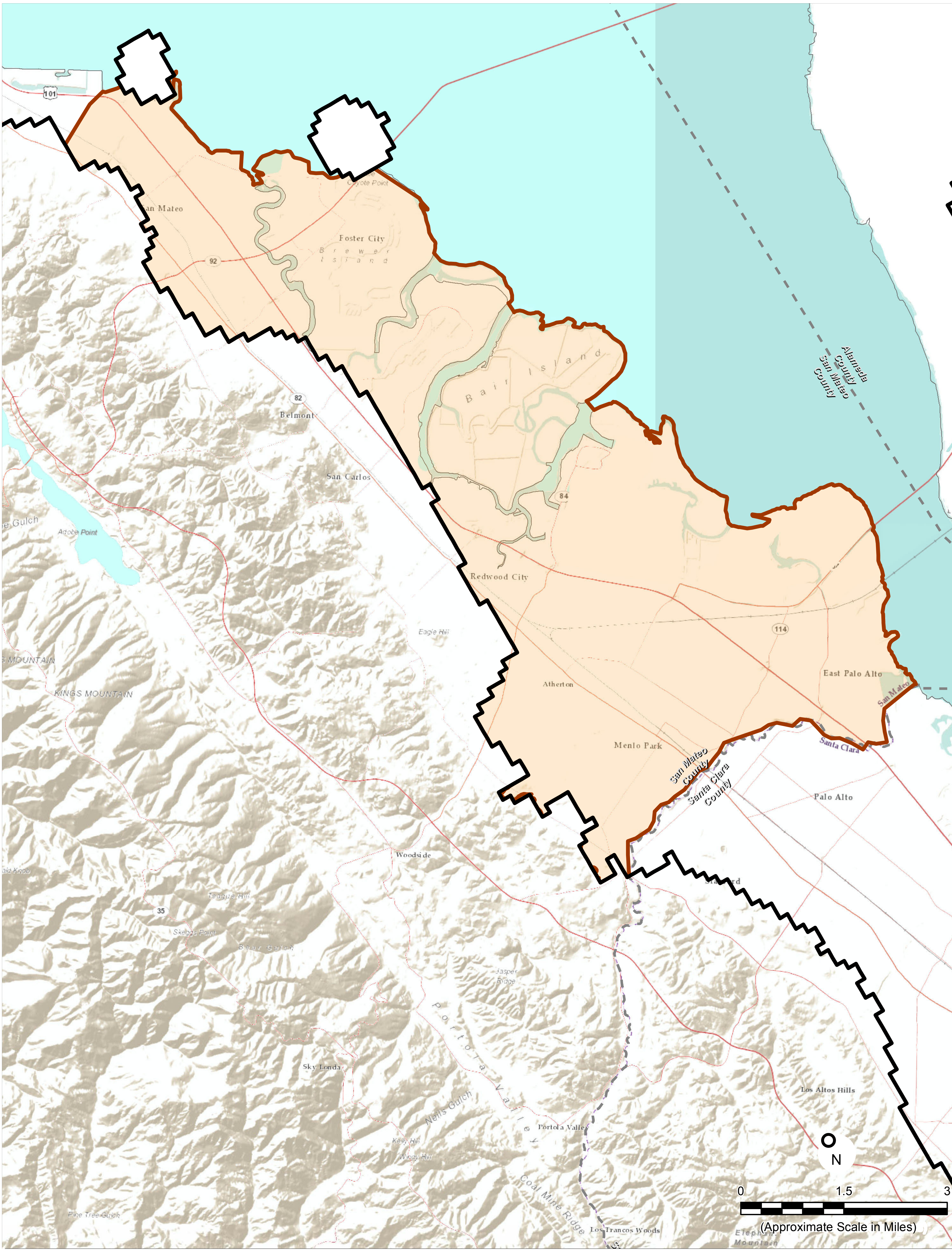
Simulated End-of-Period Groundwater Elevation Difference, Shallow Zone -- Scenario 2 Versus Scenario 1

San Mateo County, California

San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-12a



Legend

San Mateo Plain Subbasin

San Mateo Plain Groundwater Flow Model Layer 3 Boundary

County Boundary

Notes

1. All locations are approximate.
2. Contours for the deep aquifer are a weighted average of model layers 3, 4, and 5 based on model layer thickness.
3. The difference in model-calculated groundwater levels are less than 1 ft, and therefore contours are not shown.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 18 April 2018.

Abbreviations

NAVD = North American Vertical Datum

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Simulated End-of-Period Groundwater Elevation Difference, Deep Zone -- Scenario 2 Versus Scenario 1

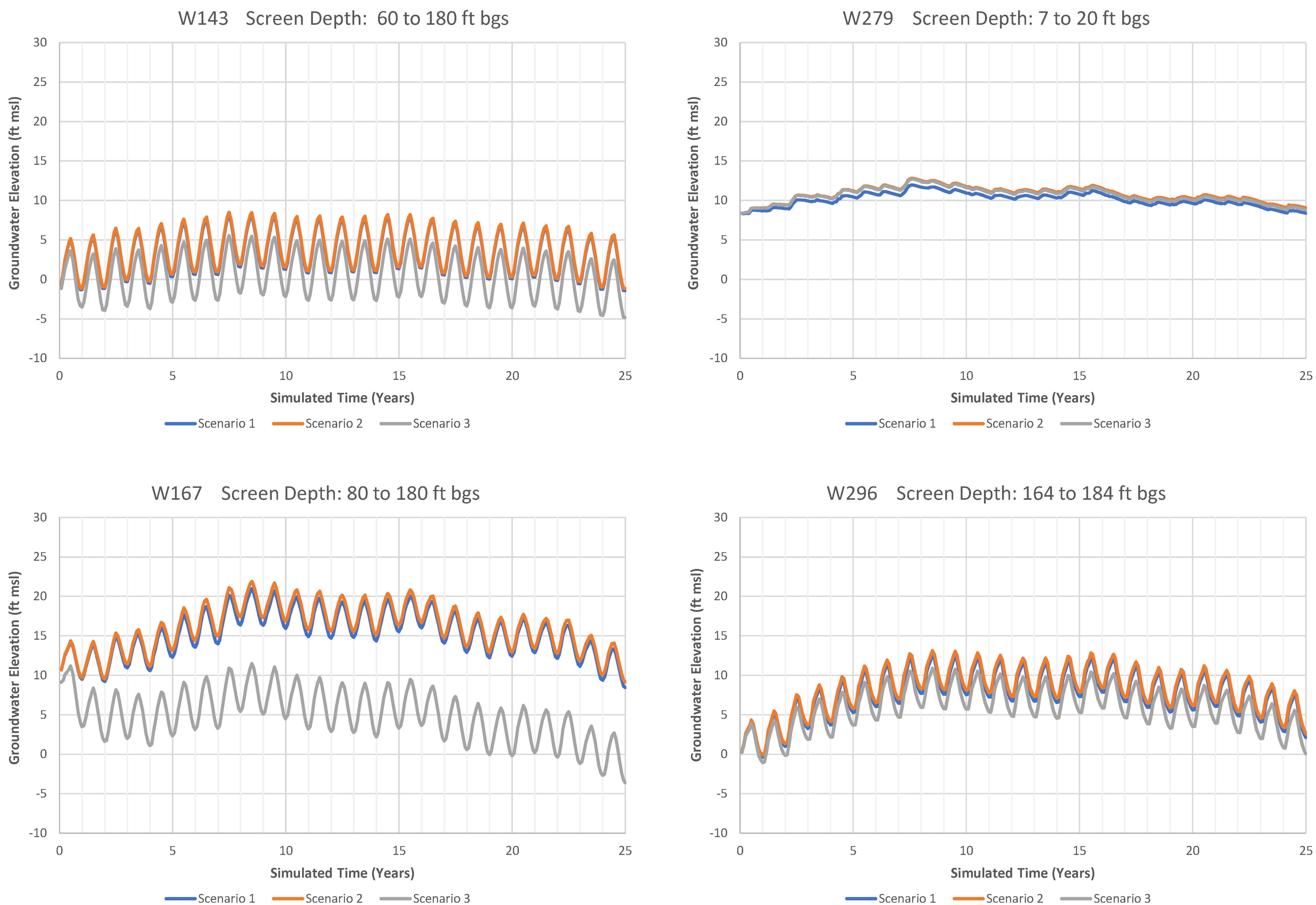
San Mateo County, California

San Mateo Plain Groundwater Subbasin

June 2018

EKI B60024.00

Figure 11-12b



Abbreviation

ft bgs = feet below ground surface

ft msl = feet above mean sea level

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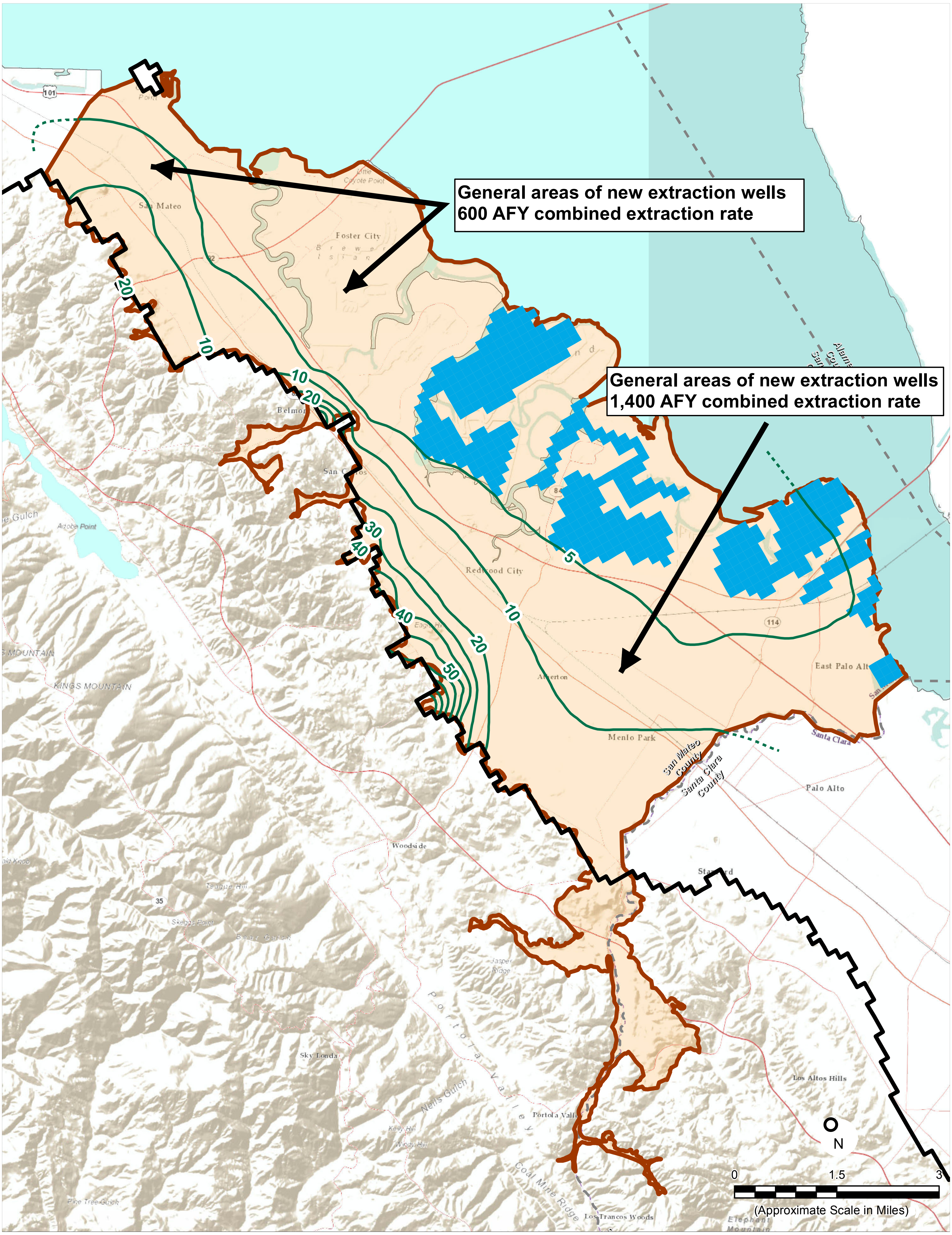
Model-Calculated Groundwater Levels at Observation Points – Scenarios 1, 2 and 3

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-13



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Scenario 3 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88), dashed outside San Mateo Plain Subbasin
- San Mateo Plain Subbasin Areas Inundated due to Sea Level Rise
- County Boundary

Notes
1. All locations are approximate.
2. Contours for the shallow aquifer are from model layer 1.

Sources
1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 29 March 2018.

Abbreviations
NAVD = North American Vertical Datum

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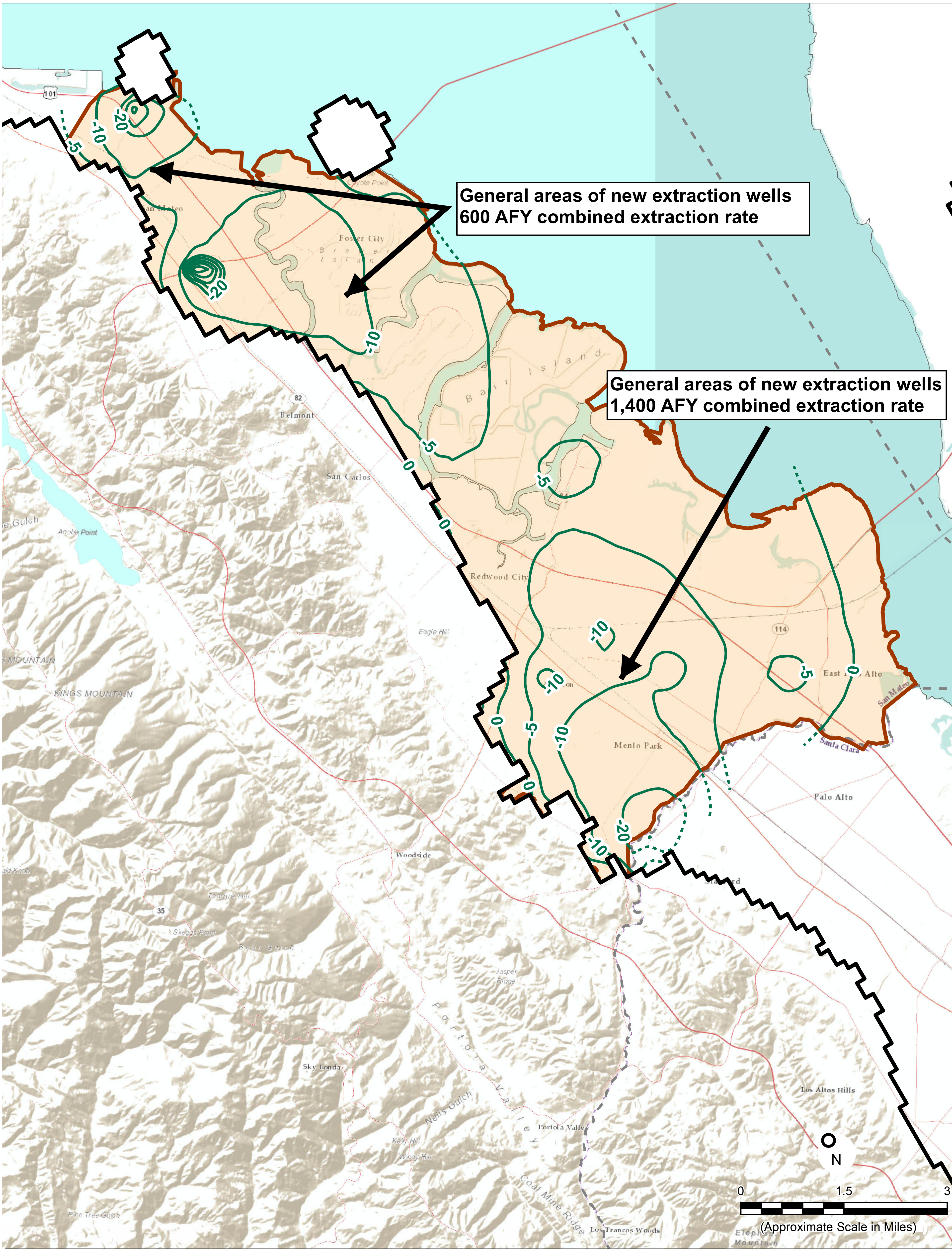
Simulated End-of-Period Groundwater Elevation Contours, Shallow Zone -- Scenario 3

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00
Figure 11-14a



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Layer 3 Boundary
- -5- Scenario 3 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88), dashed outside San Mateo Plain Subbasin
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the deep aquifer are a weighted average of model layers 3, 4, and 5 based on model layer thickness.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 29 March 2018.

Abbreviations

NAVD = North American Vertical Datum

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Simulated End-of-Period Groundwater Elevation Contours, Deep Zone -- Scenario 3

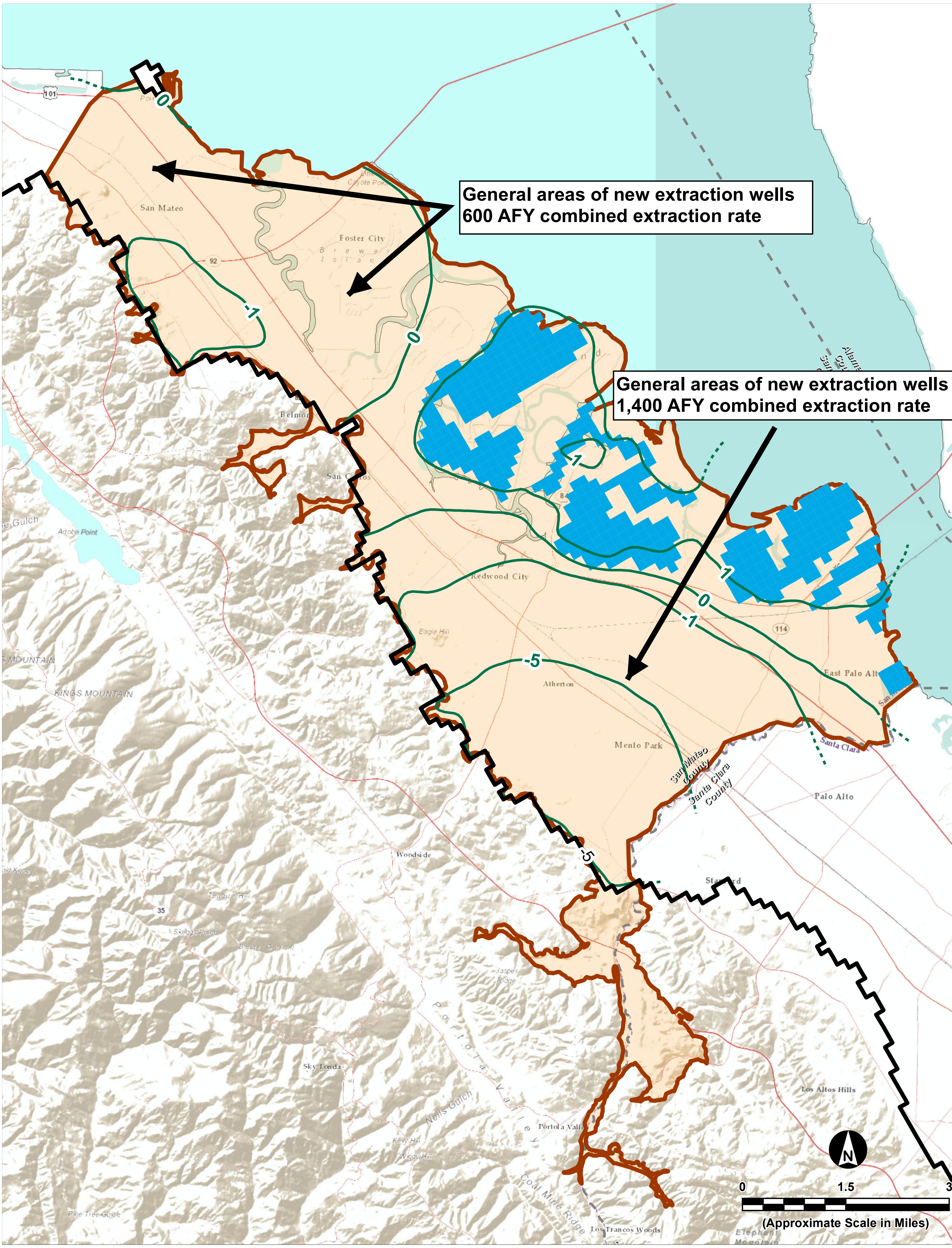
San Mateo County, California

San Mateo Plain Groundwater Subbasin

June 2018

EKI B60024.00

Figure 11-14b



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Scenario 3 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88) Scenario 3 - Scenario 1, dashed outside San Mateo Plain Subbasin
- San Mateo Plain Subbasin Areas Inundated due to Sea Level Rise
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the shallow aquifer are from model layer 1.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 March 2018.

Abbreviations

NAVD = North American Vertical Datum

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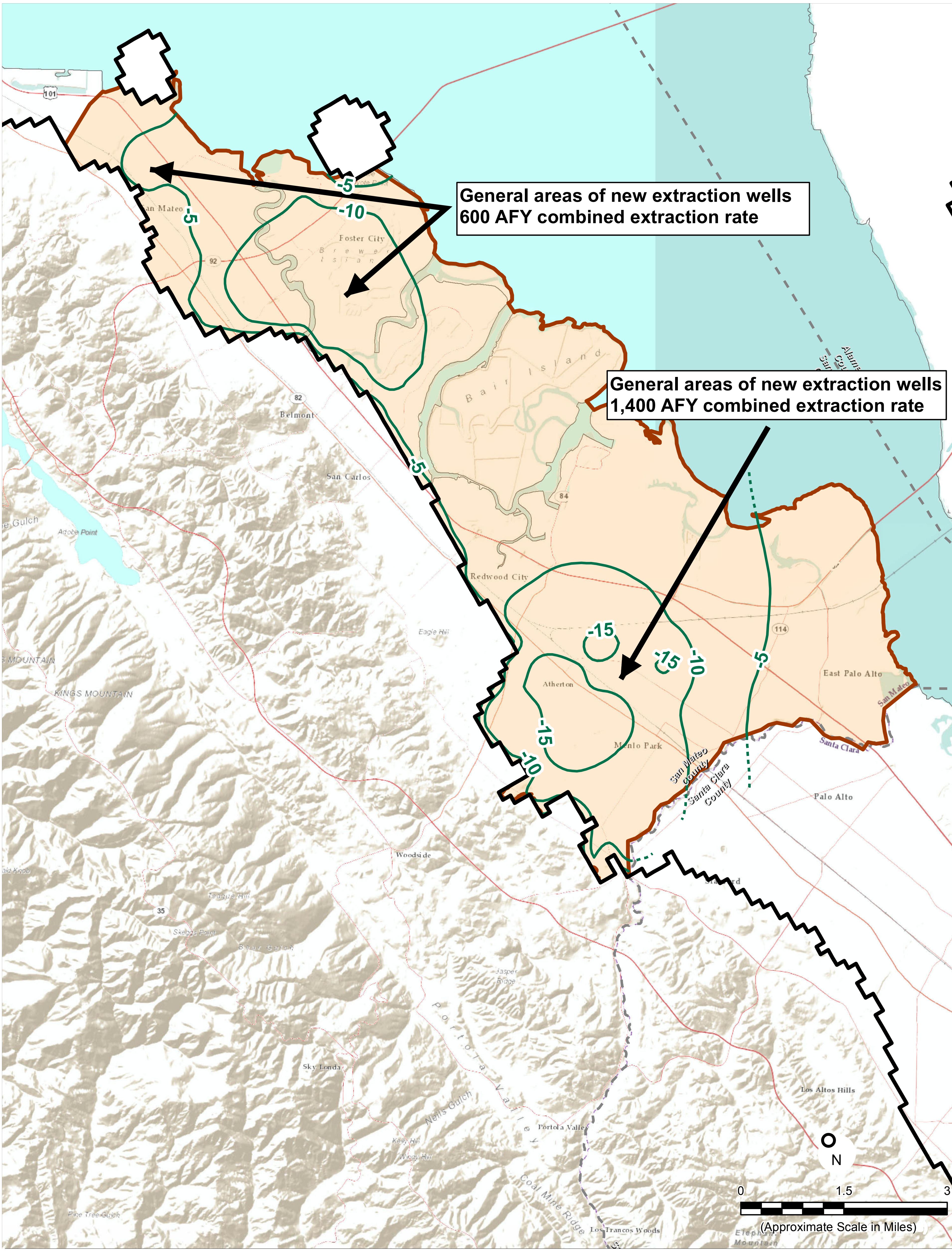
Simulated End-of-Period Groundwater Elevation Difference, Shallow Zone -- Scenario Versus Scenario 1

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-15a



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Layer 3 Boundary
- Difference in Model-Calculated Groundwater Elevation Contours (ft; NAVD 88) Scenario 3 - Scenario 1 dashed outside San Mateo Plain Subbasin
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the deep aquifer are a weighted average of model layers 3, 4, and 5 based on model layer thickness.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 March 2018.

Abbreviations

NAVD = North American Vertical Datum

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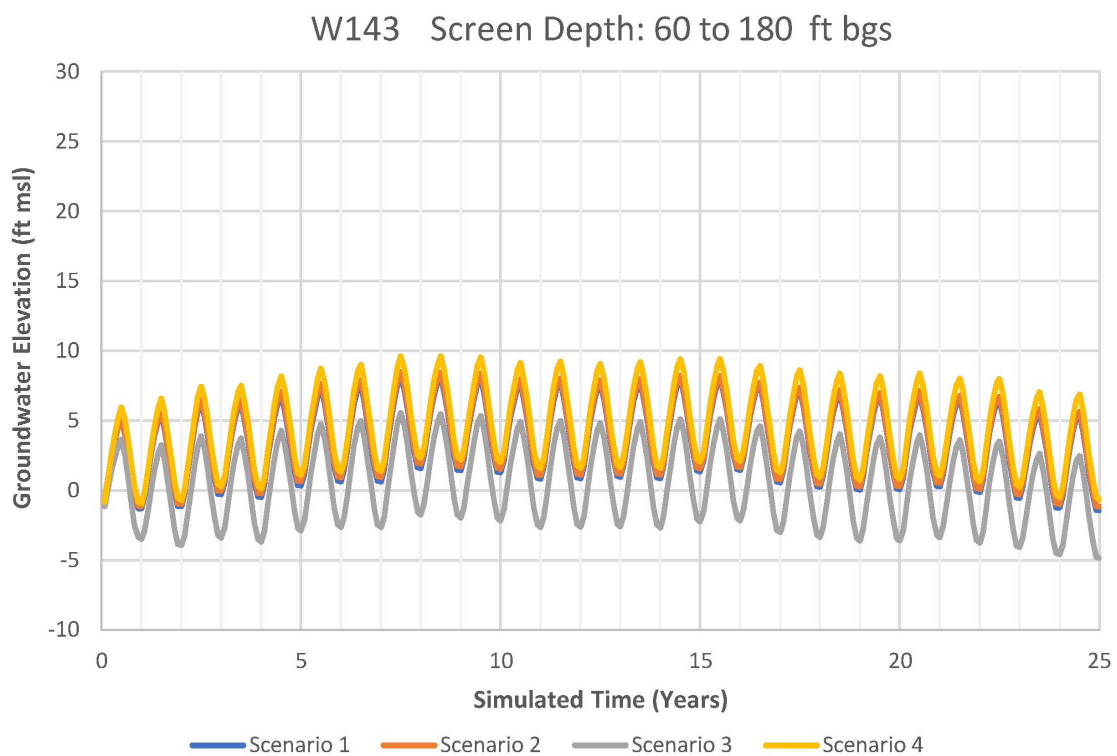
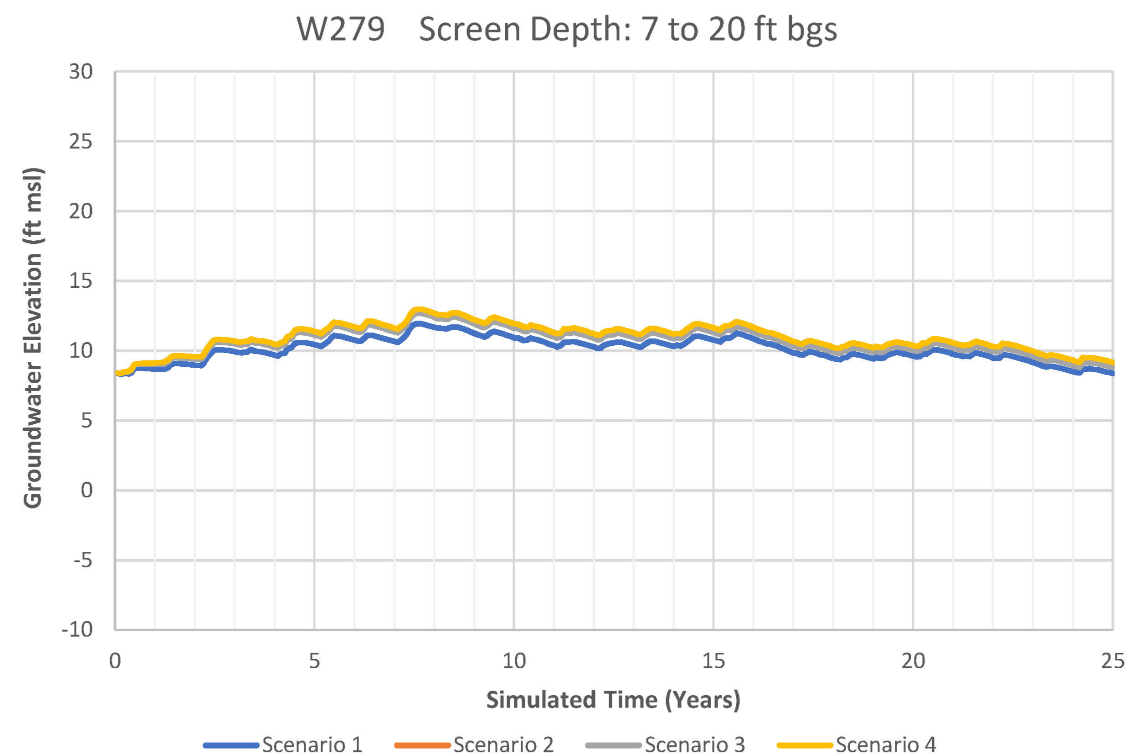
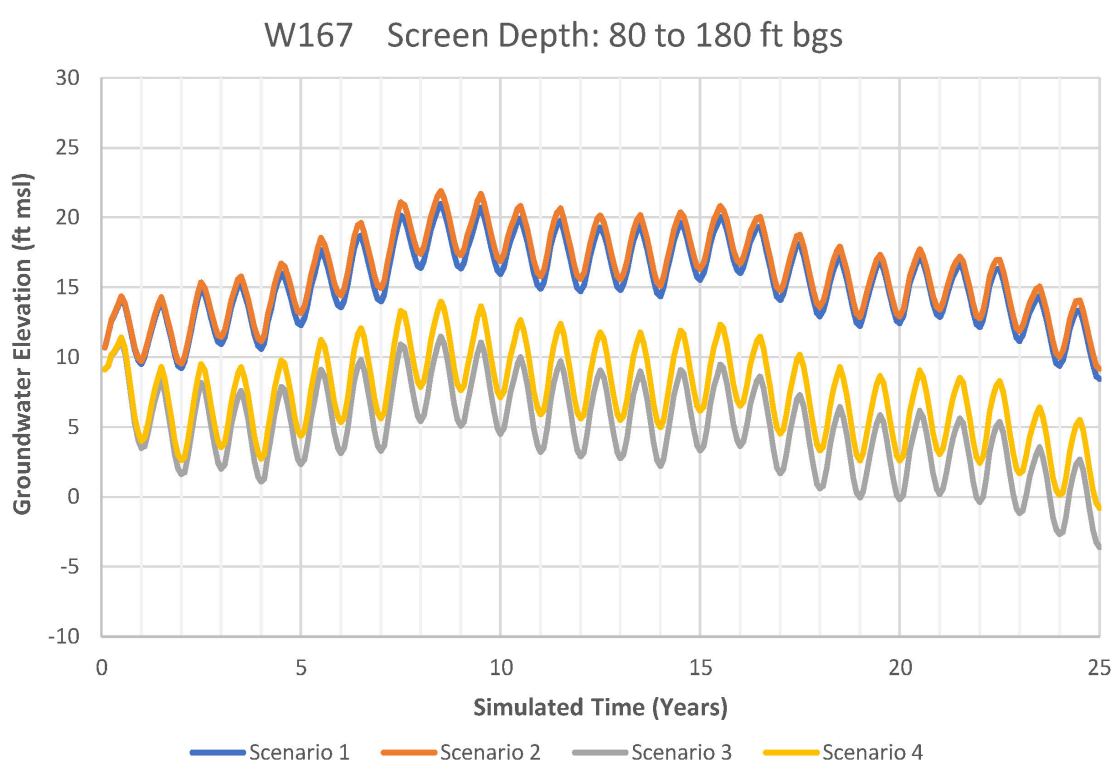
Simulated End-of-Period Groundwater Elevation Difference, Deep Zone -- Scenario 3 Versus Scenario 1

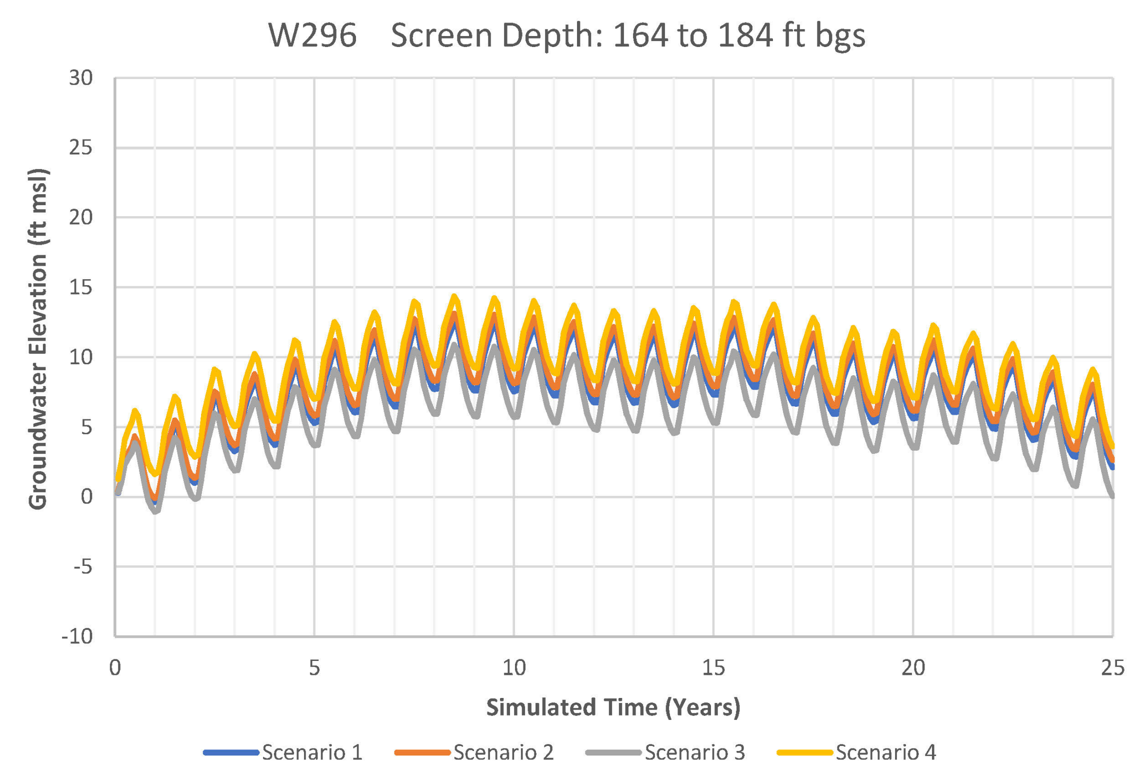
San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-15b









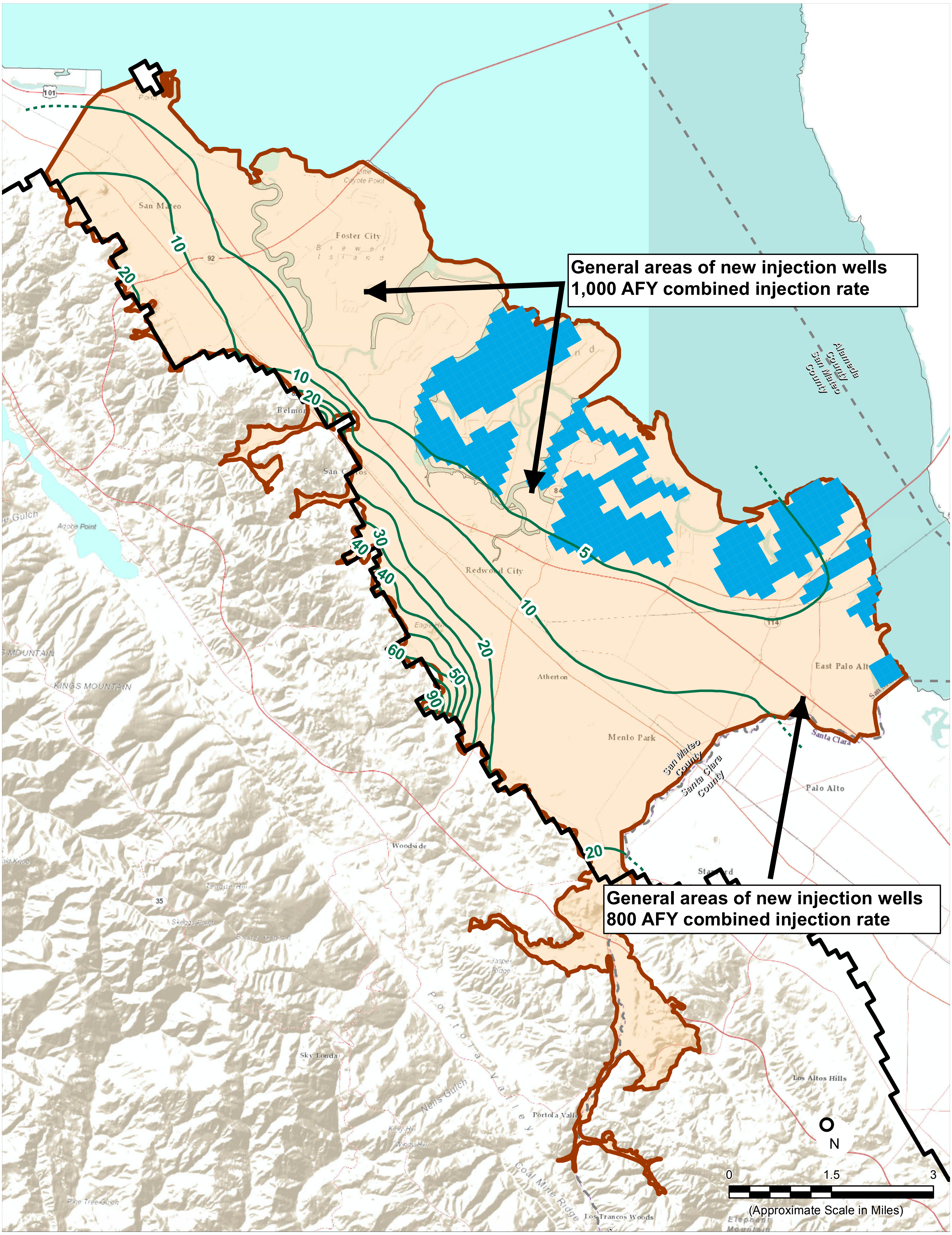
Abbreviation

ft bgs = feet below ground surface
ft msl = feet above mean sea level

Model-Calculated Groundwater Levels at Observation Points – Scenarios 1, 2, 3, and 4

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-16



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- –5– Scenario 4 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88), dashed outside San Mateo Plain Subbasin
- Inundated San Mateo Plain Subbasin Areas due to Sea Level Rise
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the shallow aquifer are from model layer 1.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 29 March 2018.

Abbreviations

NAVD = North American Vertical Datum

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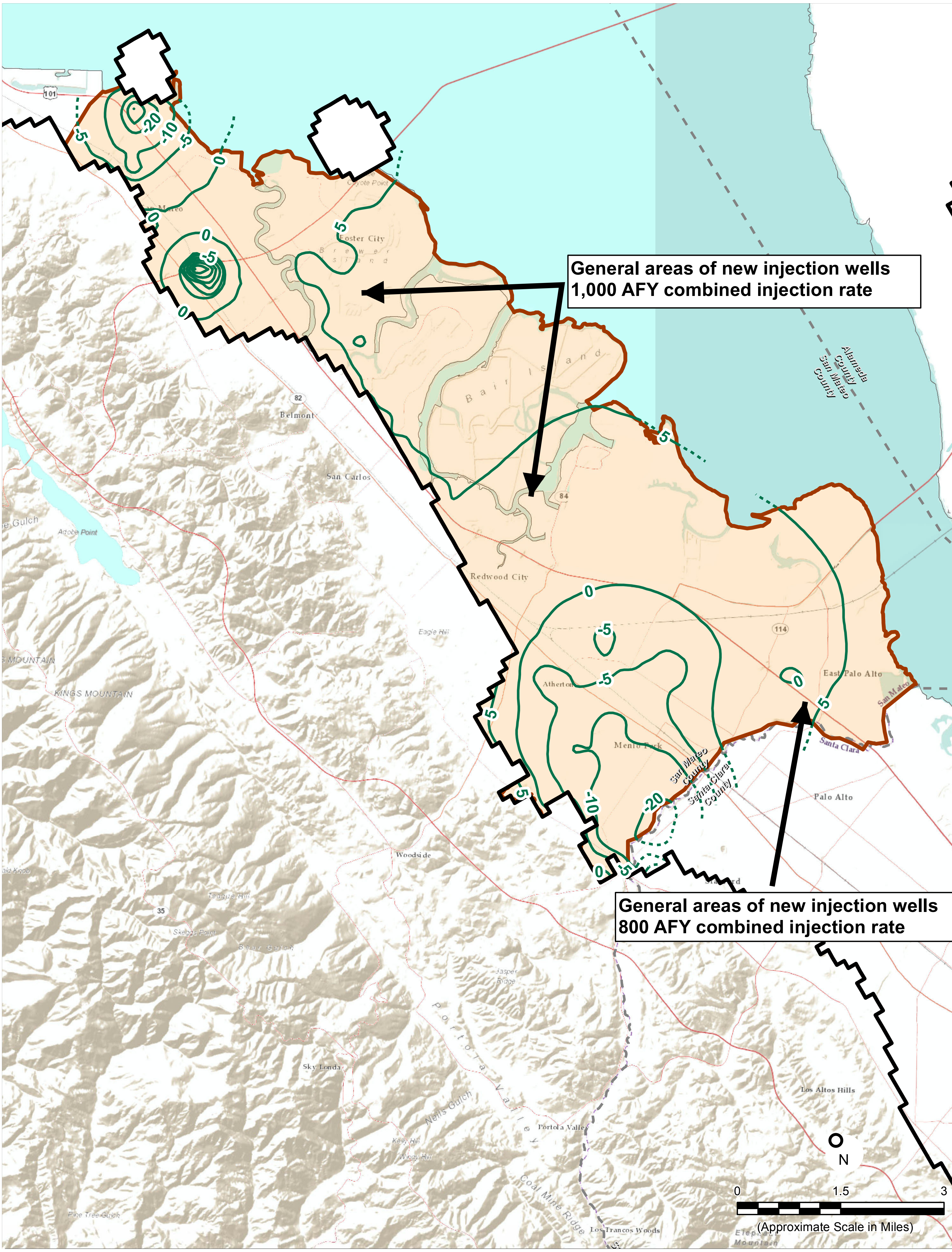
Simulated End-of-Period Groundwater Elevation Contours, Shallow Zone -- Scenario 4

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-17a



Legend

San Mateo Plain Subbasin

San Mateo Plain Groundwater Flow Model Layer 3 Boundary

-5- Scenario 4 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88), dashed outside San Mateo Plain Subbasin

County Boundary

Notes

1. All locations are approximate.
2. Contours for the deep aquifer are a weighted average of model layers 3, 4, and 5 based on model layer thickness.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 29 March 2018.

Abbreviations

NAVD = North American Vertical Datum

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HYDROFOCUS INC. Solutions for Land and Water Resources

Simulated End-of-Period Groundwater Elevation Contours, Deep Zone -- Scenario 4

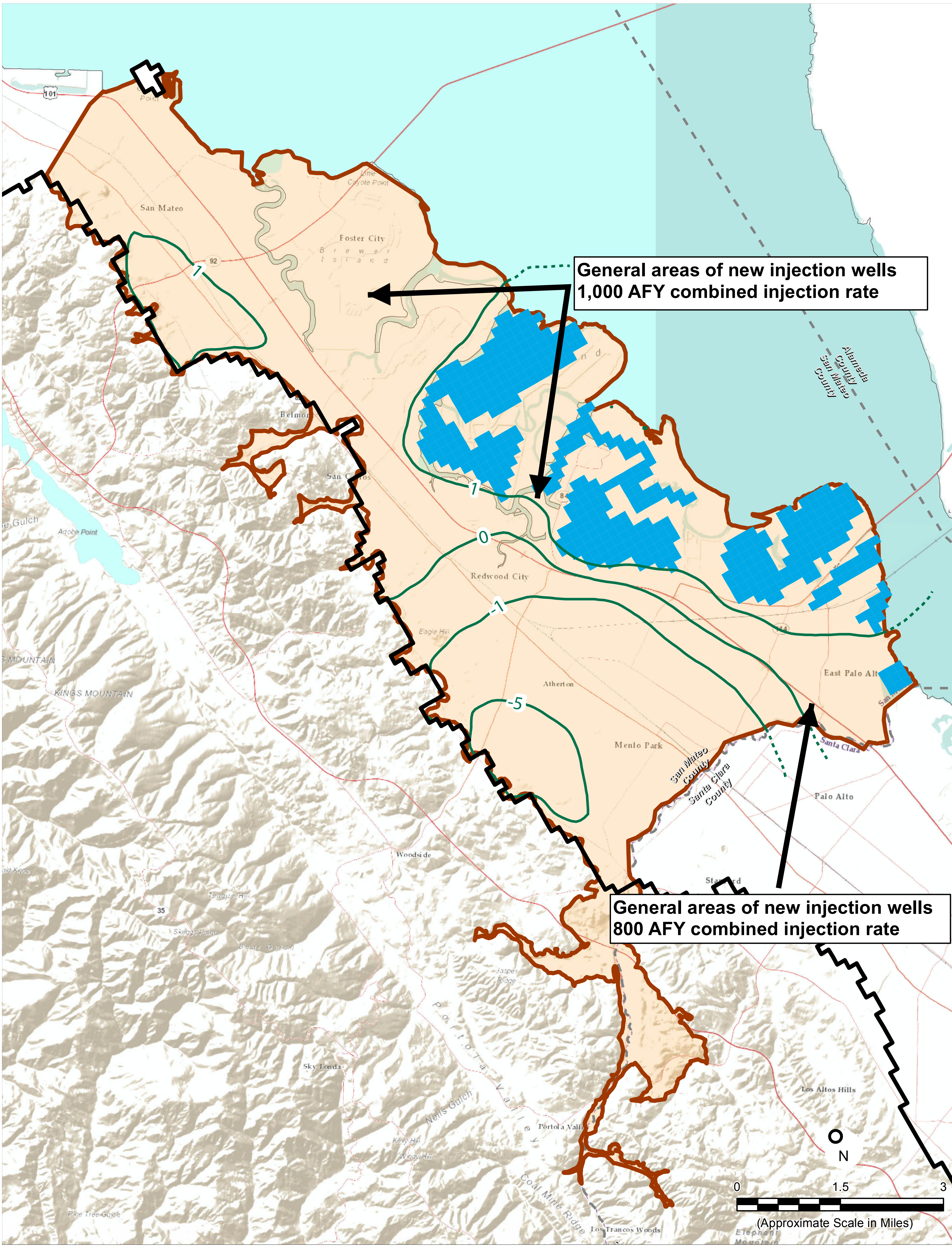
San Mateo County, California

San Mateo Plain Groundwater Subbasin

June 2018

EKI B60024.00

Figure 11-17b



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Boundary
- Scenario 3 Model-Calculated Groundwater Elevation Contours (ft; NAVD 88) Scenario 4 - Scenario 1, dashed outside San Mateo Plain Subbasin
- San Mateo Plain Subbasin Areas Inundated due to Sea Level Rise
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the shallow aquifer are from model layer 1.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 March 2018.

Abbreviations

NAVD = North American Vertical Datum

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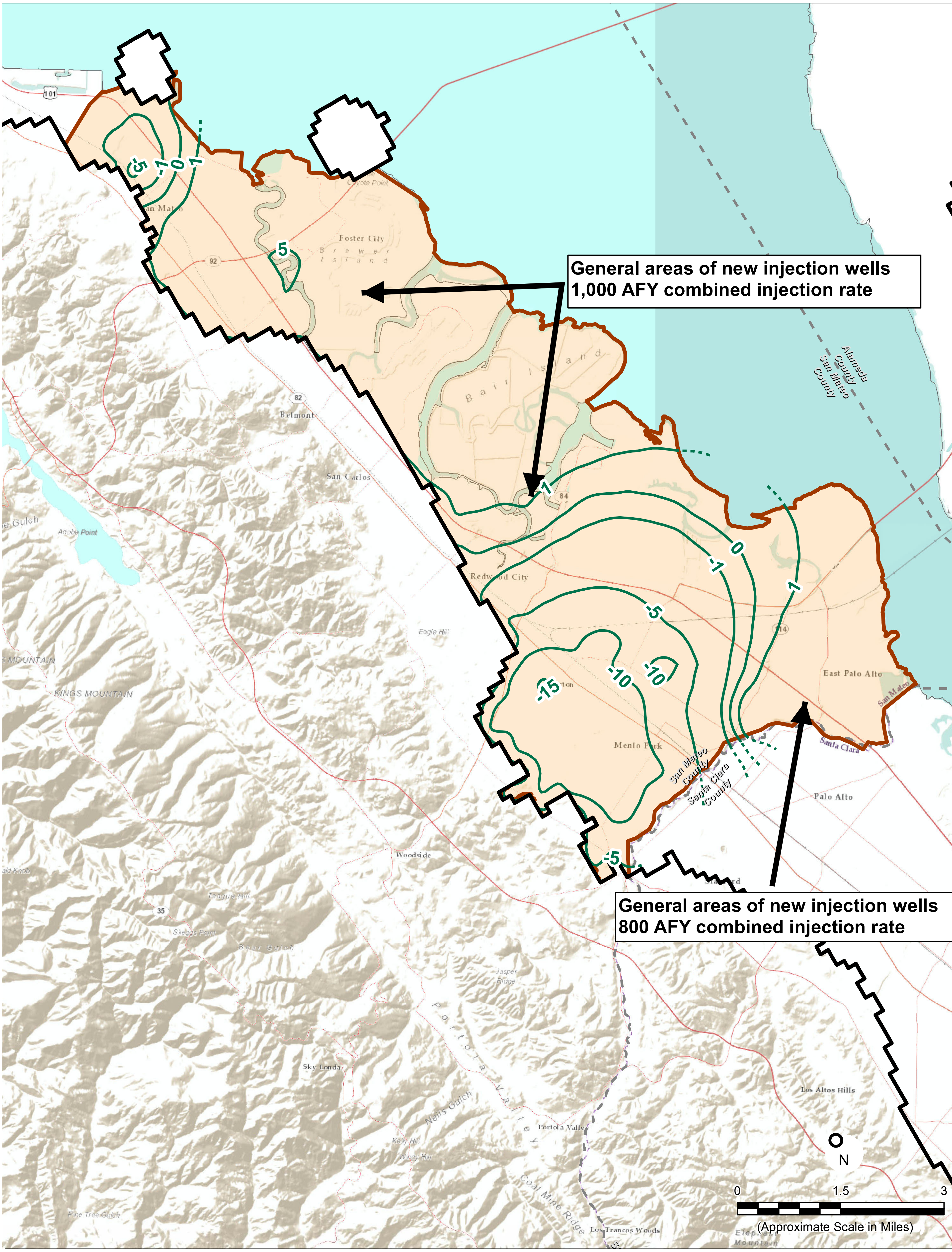
Simulated End-of-Period Groundwater Elevation Difference, Shallow Zone -- Scenario 4 Versus Scenario 1

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-18a



Legend

- San Mateo Plain Subbasin
- San Mateo Plain Groundwater Flow Model Layer 3 Boundary
- Difference in Model-Calculated Groundwater Elevation Contours (ft; NAVD 88) Scenario 4 - Scenario 1 dashed outside San Mateo Plain Subbasin
- County Boundary

Notes

1. All locations are approximate.
2. Contours for the deep aquifer are a weighted average of model layers 3, 4, and 5 based on model layer thickness.

Sources

1. Subbasin boundary: DWR CASGEM Online System – Public Portal, accessed 2 November 2015.
2. Basemap: Esri's World Reference and World Terrain Base, accessed 6 March 2018.

Abbreviations

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Simulated End-of-Period Groundwater Elevation Difference, Deep Zone -- Scenario 4 Versus Scenario 1

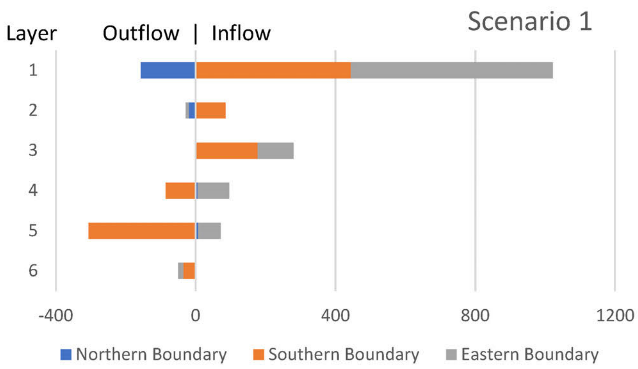
San Mateo County, California

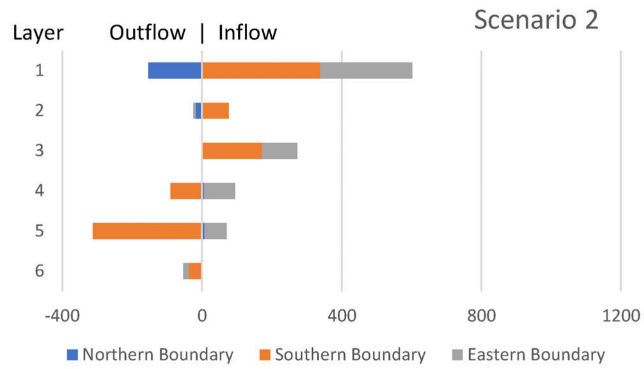
San Mateo Plain Groundwater Subbasin

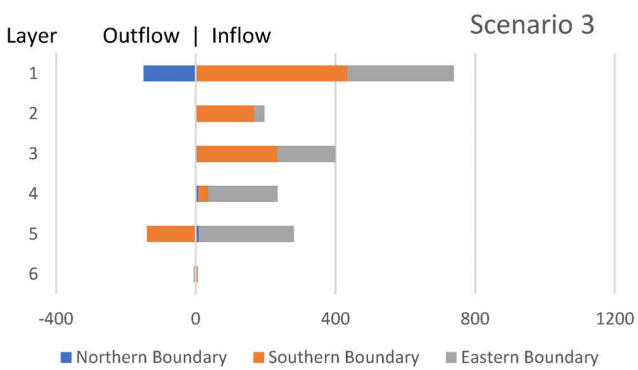
June 2018

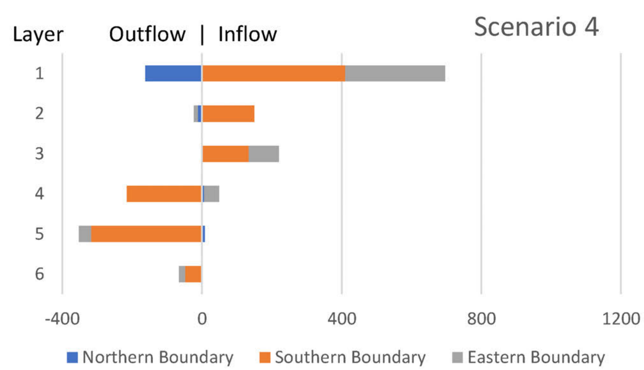
EKI B60024.00

Figure 11-18b









Notes

1. All flows are in acre-feet per year.
2. Layers 1 and 2 comprise the shallow aquifer zone; layers 3 – 5 comprise the pumped deep aquifer zone; layer 6 is the unpumped deep aquifer zone.

Long-Term Average Cross-Boundary Flow by Depth Zone

San Mateo County, California
San Mateo Plain Groundwater Subbasin
June 2018
EKI B60024.00

Figure 11-19

12.0 CONCLUSION

The primary objectives of the Project as they relate to the Basin were to:

1. Increase public knowledge,
2. Evaluate hydrogeologic and groundwater conditions,
3. Identify potential impacts of sea level rise and climate change,
4. Evaluate potential impacts to groundwater quality and quantity, and
5. Develop potential groundwater management strategies.

The Project has fulfilled these objectives and created a foundation and context for analysis of future hydrogeologic data and provided the basis for the development and evaluation of potential groundwater management strategies. Specifically, we now have a more complete understanding of the Basin hydrogeologic framework and groundwater flow and quality conditions. The most comprehensive regional groundwater model in existence for the Basin was developed as part of this Project and provides, among other things, a quantitative assessment of basin inflows, outflows, and interactions within the Basin and between adjacent basins. Basin vulnerabilities have also been highlighted and potential options to address these vulnerabilities, in terms of physical or institutional management, have been inventoried based on a state-wide evaluation of what others are doing in similar basins that are faced with similar issues. All of the above information has been shared with the public through workshops, one-on-one and small group meetings, and the County's website and data portal. The SMPGWM has been demonstrated to be a useful tool for evaluating Basin-scale impacts of various potential groundwater management options and will be made available through the County for use by interested parties.

This effort highlighted several gaps in available historical data, particularly the lack of spatial and temporal groundwater level and quality data within the Basin. Additional data were collected as part of this effort and the County has had discussions with stakeholders about the development of a CASGEM-compliant monitoring well network to collect new data that will further our understanding of the Basin.

This Project and the data shared through the County's web resources can serve as a foundation to support future efforts, including the evaluation of potential future groundwater use and management projects, the development of a GSP should the Basin become subject to SGMA in 2018, and the development of an SNMP for Basin.

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Appendix A
Input from Stakeholders During Public Workshops

STAKEHOLDER WORKSHOP #1
MAY 17, 2016

- Project Overview
- Breakout Sessions on Three Topics

Potential Issues and Opportunities within the Basin

Objectives for the San Mateo Plain Groundwater Assessment Project

Data Gap Filling

TOPIC #1: POTENTIAL ISSUES AND OPPORTUNITIES

Potential Opportunity	Ways to Foster
Recharge with recycled water	• Encourage wastewater agency participation
Recharge with stormwater	• Dual-purpose projects / incentivize infiltration • “Unline” creeks
Conjunctive use of surface water and stormwater	• ASR, IPR
Funding partnerships and opportunities	• Private-Public Partnerships • IRWM funding
Public education	• Regional planning / solutions
Rethinking water infrastructure	• Distributed infrastructure (IPR / recharge)

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TOPIC #1: POTENTIAL ISSUES AND OPPORTUNITIES

Potential Issue	Potential Mitigation
Lack of data / understanding	• Identify existing private wells and collect data
Climate change threats	• Leverage existing studies / data
Long-term sustainable management	• Establish sustainable yield • Different thresholds for different areas • Distinguish between short-term and long-term needs
Resource protection	• Multiple-benefit projects • Land use planning • Reuse / recycled water
Competition within and between basins	• Regional planning / solutions

TOPIC #2: RANKING PROJECT OBJECTIVES

1	Evaluate the hydrogeologic and groundwater conditions of the entire Basin
2	Develop Basin water balance
3	Assess groundwater recharge areas
4	Develop a Basin hydrogeologic conceptual model
5	Evaluate interactions with adjacent basins and subbasins
6	Evaluate threats to the Basin groundwater quality and quantity
7	Identify long-term strategies to sustainably manage groundwater resources
8	Evaluate surface water and groundwater interactions in the Basin
9	Assess threats to water quality
10	Identify and position the Basin for funding opportunities
11	Increase public knowledge through data sharing and collaboration
12	Evaluate potential impacts of sea level rise and climate change

Strong emphasis on establishing the scientific and technical foundation

Funding ranked lower because CASGEM ranking may limit competitiveness for funds

EKI Erler & Kalinowski, Inc. TODD GROUNDWATER HYDROFOCUS Solutions for Land and Water Resources

TOPIC #3: DATA GAP FILLING

- Established contacts for agencies and groups in the Basin and beyond
- Identified relevant studies
- General impressions:
  - Filling data gaps is high priority
  - Data should be shared across basin boundaries
- Prioritize coordination with entities with existing wells
  - Gather time-series water level / water quality data

THE NEIGHBORHOOD UNDERGROUND

EKI Erler & Kalinowski, Inc. TODD GROUNDWATER HYDROFOCUS

RESOURCE USE AND ECOSYSTEM PROTECTION

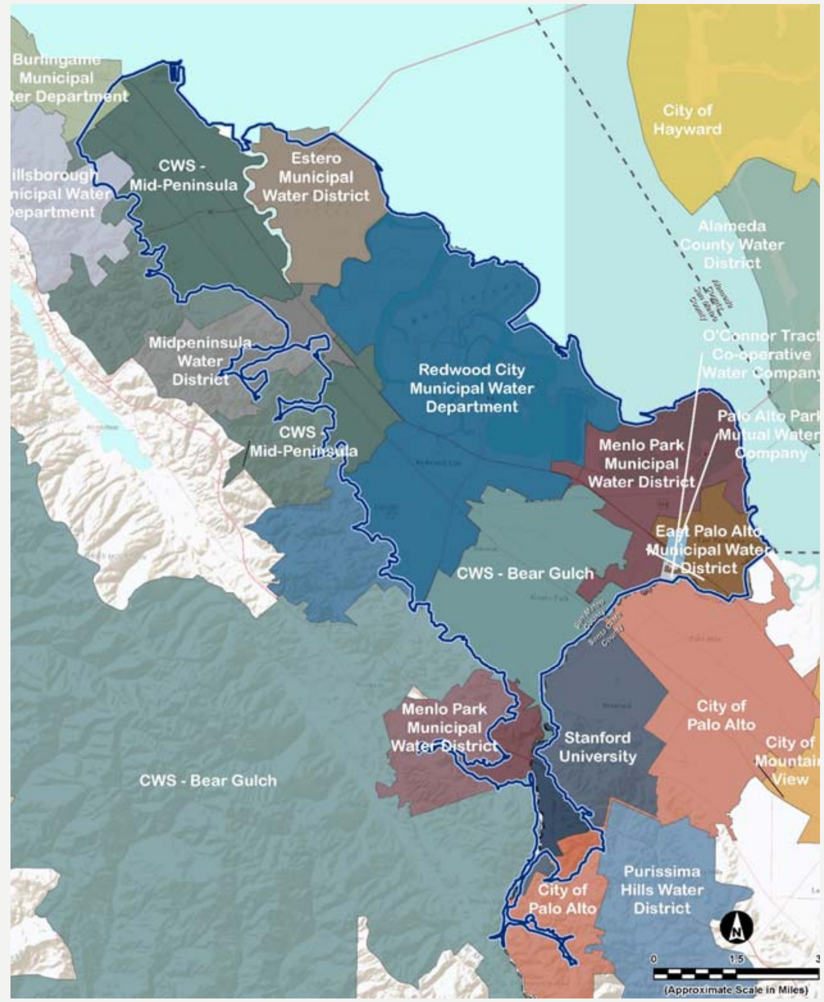
- “Project should emphasize the important role of groundwater in supporting ecosystems”

AND

- Local groundwater is critical to ensuring a reliable emergency and supplemental water supply

ON-GOING STAKEHOLDER OUTREACH

- Small group and one-on-one meetings
- Presentations to organizations and governing bodies
- Stakeholder workshops
- Website: http://green.smcgov.org/san-mateo-plain
- Open Data Portal



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San Mateo Plain Groundwater Basin Assessment Stakeholder Workshop #4

STAKEHOLDER DISCUSSION TOPIC 1:

What do you think are the most important issues to focus on when we think about "groundwater management options"?

Legend:
Management **Outreach** **Data** **Costs** **Other Issues of Importance**

Group 1:

- Who is going to manage? Who is going to fund management?
- Trust (e.g., equitable allocation; equitable cost-sharing)
- Public outreach that Hetch Hetchy is not an unlimited resource; other options for recharge should be explained to public
- Basin may not be able to serve needs of all entities (WW agencies, water agencies, stormwater agencies)
- Identify priorities of stakeholders
- Focus on collaboration among stakeholders
- Concern by small water companies that groundwater rights, supplies will be allocated elsewhere and/or their needs are not met.
- Technical accuracy; good data
- How will we coordinate with Land Use agencies on water management issues down the road?
- Outreach/communication to broader (public) audience that this study is happening
- Consistent message from this group, tailored to audience

Group 2:

- Avoid undesirable results
  - Surface water impacts, salt water intrusion, subsidence
- Climate change adaptation, resilience in water supplies
- Avoid adjudication – keep local control
- Pro-active rather than passive (management)
- Collaboration
- Voluntary management
- San Francisquito Cone area is of major importance
- Special status species
- Costs of programs, equity

Group 3:

- Efficient management structure
- Continual monitoring
- Clarify Subbasin boundaries – but also resource management of each subbasin boundary
- Coordination w/other Groundwater Management Agencies – better understand hydro-linkage

- Level of management regulation – not too onerous
- Balance priorities of (43) Groundwater Sustainability Agencies (GSAs)
- Broader Bay Area regionally coordination (Alameda, San Francisco, Santa Clara)

Group 4:
- Collecting data/filling gaps
- Are there 2 basins/subbasins? And if so, how to address each?
- Speed of implementation, even if Basin is not reprioritized by Sustainable Groundwater Management Act (SGMA)
    - quicker will allow for quicker action by entities
    - what pace for each entity?
- Expanding outreach to more stakeholders (e.g., environmental groups)
- How management/interactions work between basins
- Revisit demands for water w/in basin and if any more agencies may look to developing groundwater
- Options depend on future demands (e.g., use and recharge likelihood)
- Would management beget more groundwater use?
- Working group as opposed to formal governance

Group 5:
- Construction dewatering
- Existing irrigators (interference)
- Cross-boundary inflow/outflows
- Lack of historical data (temporal, spatial, vertical)
- Lack of drivers to bring people to table
- Getting everyone involved

STAKEHOLDER DISCUSSION TOPIC 2:

Do you envision groundwater management occurring within the Basin?

Legend:

1) **What potential actions or options seem feasible to you?**
2) **What actions or options should be prioritized?**
3) **What limitations do you believe exist?**

1) What potential actions or options seem feasible to you?

Group 1:

- Data collection and monitoring, repository and framework
  - Water level,
  - funding?
  - Administration?
  - Learn more about basin over time
- Better understand the priorities of the 43+/- GSA's
  - Willingness to fund
  - Study capacity of surface water resources – stormwater – reuse – (coordination with other efforts)

Group 2 (group did not designate by sub-question):

- Advisory group formation
  - Possible funding benefit
  - Data sharing
- Further basin characterization (i.e., data gap filling) before physical solutions are considered
- Information sharing, for all purposes not just mgmt.
- Identifying right level/intensity of management (if any)
- Identifying safe level of pumping (safe yield)
- Watershed protection/management – "One Water" concept

Group 3:

- Data gaps need to be fleshed out w/input from all stakeholders
  - Continued collaboration
  - More dedication of Measure A $$ for all additional data gathering
    - (determine yield; new wells; more long-term data collection; pumping info; private well use; better define recharge areas.)
  - Are there plans, desires by entities for future use?
  - Consolidate contamination and salt intrusion data and risks
  - Recycled and stormwater reuse expansion; brackish water (shallow zone/coastal?) (re)use

Group 4:

- Yes, if we want reliable/sustainable groundwater
- Start small, advisory group, get more data and funding to work toward MOU/formal entity/etc.
- Ask for DWR funding for outreach
- Regional messaging through water agencies

Group 5 (group did not designate by sub-question):

- Recycled water for irrigation
- Determining which of 43 GSA-eligible entities are interested in GW management
- Technical/Advisory committee
- Project-based management
- Might need an agency to take the lead
- Sharing costs (e.g., monitoring network)
- Survey to gauge interest (in management)
- Potential for consolidation of suppliers
- Pump tax for private irrigators

2) What actions or options should be prioritized?

Group 1:

- Better understand GSAs
- Work towards a formalized framework for management

Group 2 (group did not designate by sub-question):

- Advisory group formation
  - Possible funding benefit
  - Data sharing
- Further basin characterization (i.e., data gap filling) before physical solutions are considered
- Information sharing, for all purposes not just management.
- Identifying right level/intensity of management (if any)
- Identifying safe level of pumping (safe yield)

Group 3:

- Complete basin characterization (see #1); measure subsidence, sea water intrusion, contamination; surface/groundwater interaction accurately
- Discharging into creeks
- Advising new well permitting that groundwater oversight may be forthcoming
- Who is most impacted and when?

Group 4:

- Land use planning w/infrastructure and open space in mind
- Data, data, data!

Group 5 (group did not designate by sub-question):

- RW for irrigation

- Determining which of 43 GSA-eligible entities are interested in GW management
- Technical/Advisory committee
- Project-based management
- Might need an agency to take the lead
- Sharing costs (e.g. monitoring network)
- Survey to gauge interest
- Potential for consolidation of suppliers
- Pump tax for private irrigators

3) What limitations do you believe exist?

Group 1:

- Getting agreement on a management structure/governance and role
- Understanding limits of hydrogeology
- Funding
- Public vs. private land, and other complications

Group 2 (group did not designate by sub-question):

Group 3:

- Lots of unknowns
- The higher the management level, the more $$
- Time and urgency

Group 4:

- Limited lands owned/available for some physical options
- Geology vs. infiltration
- Limited/driver for groundwater use currently
- Limited data to understand impacts and interactions w/ neighboring Basins

Group 5 (group did not designate by sub-question):

- Aesthetic/taste concerns
- Data gaps – limitation
- Siting constraints/land value and availability
  - Open space? Multi-benefits
- Water rights for existing users
- How would sustainable yield get divided up? Who gets to put a straw in the ground?

STAKEHOLDER DISCUSSION TOPIC 1: Model Scenarios & Priority

Identify model scenarios for the future that you would like to see be modeled as part of the Phase 3 work. Think about the specifics of the scenarios and then rank the these in order of importance, with 1 being of the highest importance. Note the basis for ranking values.

Priority	Potential Model Scenarios	Basis for Priority Ranking
Group A		
1	Stormwater recharge - Subsurface detention basins - Green Street, LID	Timeframe – within 5 years to inform projects and policy
2	IDR and recycled water and how it changes yield	Slightly later timeframe than 1
1'	Increased pumping - Normal vs. dry year/emergency	Same as for stormwater recharge
3	Rainfall changes - Temporal and amount shifts	Can't change rainfall itself, can only react – less planning of specific projects
5	Sea level rise	Least certainty with respect to groundwater impacts (water balance of outflows)
Group B		
All	Drought effects	
Top 2	Increase groundwater pumping – shallow/deep, time patterns	Widespread and shallow; localized and deep
Top 2	Climate change - Rain intensity - Increase drought pumping - Annual rain and evapotranspiration	Sea level rise; two time periods
4	Pipe leak repairs - water - sewer	
All	Include Palo Alto	
All	Pumping depletion of streamflow	
3	Increase stormwater recharge	
Calibration	Simulate 1950s – 1960s recovery	

Priority	Potential Model Scenarios	Basis for Priority Ranking
Group C		
2a	Stormwater treatment percolation	Recharge and pumping (shallow)
1	Increased pumping - Variable depths - Variable spacing - Levels	How much and where (basin yield)
2b	Shallow recharge (RW) with shallow pumping (irrigation)	How much and where (basin yield)
3	Indirect potable use (deep agricultural recharge and pumping)	Recharge and pumping (deep)
2c	Reduced recharge from climate change (increased)	Recharge and pumping (deep)
Group D		
A''	Interactions between the subbasins due to changes in pumping	Sustainability determination
B'	Long-term loss of SFPUC (outages)	
B'	Sea level rise changing groundwater levels, saltwater intrusion potential	More public questions preemptively answered potential SGMA compliance
B'	Changes in balance between recharge and additional pumping	Sustainability determination
B'	Precipitation pattern changes; 50-year horizon	Bigger impact than sea level Potential SGMA compliance
C	Degradation in water quality due to increased groundwater use	
C	Impact of deep well water use increasing on the shallow aquifer	
B'	Changes to surface water/groundwater interactions	Potential SGMA compliance

Priority	Potential Model Scenarios	Basis for Priority Ranking
Group E		
1?	Stormwater recharge (managed) - focused and distributed	- Question of location - What about flood risk? - These are required/inevitable programs - Good model input data should be available
2?	Increased groundwater pumping - due to population growth - cumulative due to multiple "projects"	- Some very large projects on the horizon
	Hybrid scenarios; e.g.: - increased pumping and increased recharge - climate change and pumping, etc.	
3?	Climate change - change in rainfall recharge? - change in ET - change in imported water - sea level rise -	Include in baseline?
	Recycled water Better "assignment" of water type to use	

STAKEHOLDER DISCUSSION TOPIC 2: Defining Model Scenarios

For your group's highest ranked scenarios, detail what factors you think should be assumed for purposes of modeling the future scenario. Please be specific as possible.

Scenario: Stormwater Recharge

Key Factors that Would Deviate from Current Conditions & Basis for Selecting these Factors:
- Infrastructure – policy and projects; private and public
- Increased recharge to groundwater and potentially outflows to bay
- Decrease flows to WWTP, decrease flooding

How significantly might these factors deviate from Current Conditions:
- C/CAG will model this, develop scenarios
- have an acreage estimate of private development, approximately 1,600 acres

Time period the changes may occur:
- 2020 – 2040 policy in place by 2019

Location of changes in Basin (use map at right):
- Regional capture – western areas, residential/parks (Bayfront canal, South San Francisco at Orange Memorial Park, Belmont Creek)

Other Stakeholder notes:
- Question – is there a negative impact? or max benefit?

Scenario: Stormwater recharge (managed)

Key Factors that Would Deviate from Current Conditions & Basis for Selecting these Factors:

(blank)

How significantly might these factors deviate from Current Conditions:

(blank)

Time period the changes may occur:
- to 2040 – similar to land planning interval

Location of changes in Basin (use map at right):

(blank)

Scenario: Increased pumping

Key Factors that Would Deviate from Current Conditions & Basis for Selecting these Factors:
- Well depths, spacing, and volumes

How significantly might these factors deviate from Current Conditions:
- a lot – population, water supply, climate, policy, use

Time period the changes may occur:
- decades

Location of changes in Basin (use map at right):
- 101 Corridor (bay side)
- treatment plants
- storm drains

Scenario: Increased pumping

Key Factors that Would Deviate from Current Conditions & Basis for Selecting these Factors:
- Increase pumping and areas of pumping
- Difference in normal year/all time pumping vs dry years only

How significantly might these factors deviate from Current Conditions:
- very significant potential for increase

Time period the changes may occur:
- next year and beyond

Location of changes in Basin (use map at right):
- S. area
- Where is the best area to pump?

Scenario: Interactions between subbasins

Key Factors that Would Deviate from Current Conditions & Basis for Selecting these Factors:

- Decreased amount of water in San Francisquito Creek, decreasing recharge
- Take into account new info from adjacent basins
- Boundary condition modifications
- Change in pumping

How significantly might these factors deviate from Current Conditions:

- change in pumping most significant

Time period the changes may occur:

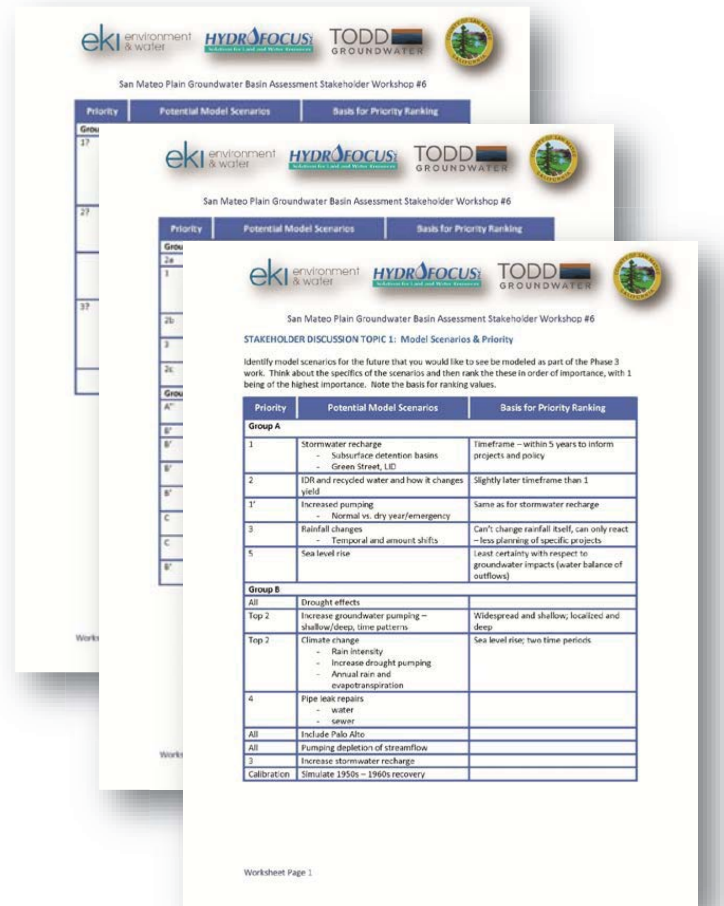
- 20 – 30, up to 50 years

Location of changes in Basin (use map at right):

- Southern Part

WORKSHOP #6 BREAKOUT SESSION RESULTS

- Topic 1 – Groups asked to identify and prioritize potential scenarios to model within the Basin and identify basis for prioritization
- Top 3 ranked Scenarios:
  - Increased groundwater pumping
  - Stormwater recharge projects
  - Climate change
- Basis for prioritization include:
  - Timeframe of implementation of currently planned projects and policy changes
  - Determine if factors will affect sustainability of the Basin


San Mateo Plain Groundwater Basin Assessment Stakeholder Workshop #6

STAKEHOLDER DISCUSSION TOPIC 1: Model Scenarios & Priority

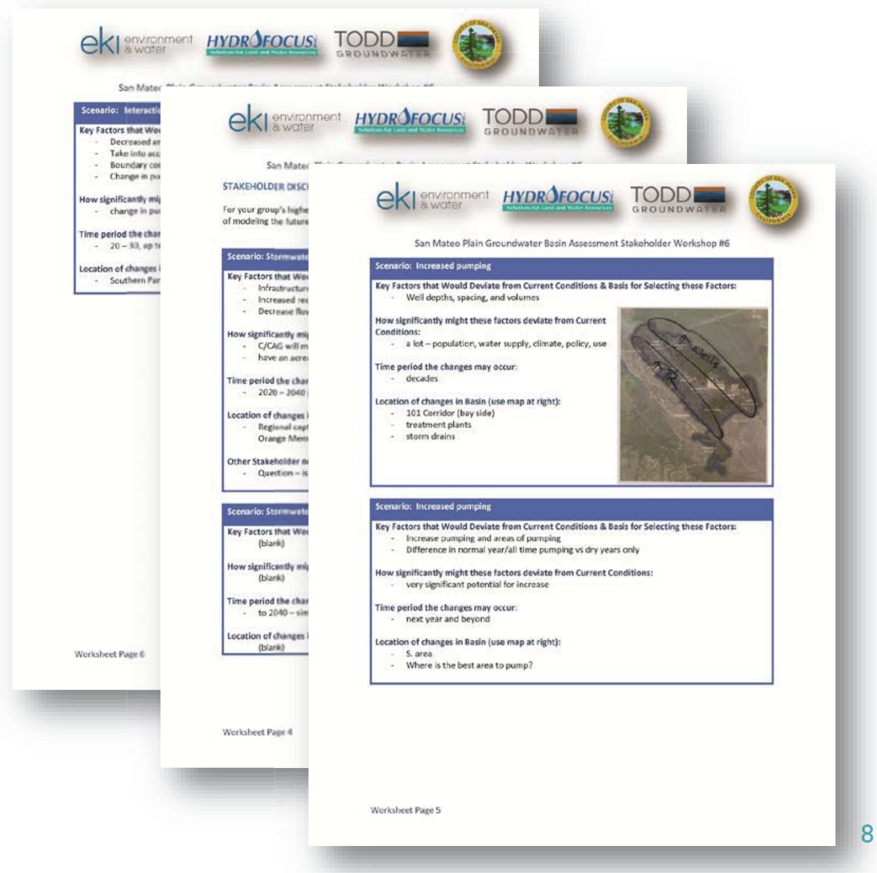
Identify model scenarios for the future that you would like to see be modeled as part of the Phase 3 work. Think about the specifics of the scenarios and then rank the these in order of importance, with 1 being of the highest importance. Note the basis for ranking values.

Priority	Potential Model Scenarios	Basis for Priority Ranking
Group A		
1	Stormwater recharge - Subsurface detention basins - Green Street, LID	Timeframe – within 5 years to inform projects and policy
2	IDR and recycled water and how it changes yield	Slightly later timeframe than 1
1'	Increased pumping - Normal vs. dry year/emergency	Same as for stormwater recharge
3	Rainfall changes - Temporal and amount shifts	Can't change rainfall itself, can only react – less planning of specific projects
5	Sea level rise	Least certainty with respect to groundwater impacts (water balance of outflows)
Group B		
All	Drought effects	
Top 2	Increase groundwater pumping – shallow/deep, time patterns	Widespread and shallow; localized and deep
Top 2	Climate change - Rain intensity - Increase drought pumping - Annual rain and evapotranspiration	Sea level rise; two time periods
4	Pipe leak repairs - water - sewer	
All	Include Palo Alto	
All	Pumping depletion of streamflow	
3	Increase stormwater recharge	
Calibration	Simulate 1950s – 1960s recovery	

Worksheet Page 1

WORKSHOP #6 BREAKOUT SESSION RESULTS

- Topic 2 – Groups asked to identify assumptions for their top ranked modeling scenarios
  - Locations – western portions of Basin for stormwater recharge, southern and eastern portions of Basin for groundwater pumping
  - Time period – generally over next ~20 years (2040)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Scenario: Increased pumping

Key Factors that Would Deviate from Current Conditions & Basis for Selecting these Factors:
- Well depths, spacing, and volumes

How significantly might these factors deviate from Current Conditions:
- a lot – population, water supply, climate, policy, use

Time period the changes may occur:
- decades

Location of changes in Basin (use map at right):
- 101 Corridor (bay side)
- treatment plants
- storm drains

Scenario: Increased pumping

Key Factors that Would Deviate from Current Conditions & Basis for Selecting these Factors:
- Increase pumping and areas of pumping
- Difference in normal year/all time pumping vs dry years only

How significantly might these factors deviate from Current Conditions:
- very significant potential for increase

Time period the changes may occur:
- next year and beyond

Location of changes in Basin (use map at right):
- S. area
- Where is the best area to pump?

Worksheet Page 5

FOUR SELECTED SCENARIOS

Baseline

Baseline + Climate Change

Baseline + Climate Change + Urban Demand Pumping Increase

Baseline + Climate Change + Urban Demand Pumping Increase + Implementation of Recharge Projects

- Stepwise approach allows for measurement of incremental effects
- Reflects progression of natural effects and potential local changes to address those effects

Appendix B
Basin Water Balance – Supporting Documentation

Appendix B.
Basin Water Balance – Supporting Documentation

A substantial amount of recharge in many California groundwater basins consists of percolation of infiltrated rainwater, irrigation return flow and pipe leaks distributed widely across the basin. These hydrologic processes involve nonlinear relationships among variables, which means that the resulting recharge cannot be accurately estimated on an annual or even monthly basis. The objective of the recharge simulation model is to simulate groundwater recharge for a mix of natural, agricultural and urban land uses using algorithms that represent important hydrologic processes at a level of conceptual, spatial and temporal detail appropriate for input to regional groundwater flow and transport models. The model simulates processes from the vegetation canopy down to the water table in one dimension. The one-dimensional results are applied to geographic recharge zones delineated by the user. They can be as coarse or fine as the user desires, but it is expected that zones generally will be the size of model cells or larger. That is, the model does not attempt to simulate water movement at the scale of pores or vegetation root depths at the scale of individual plants.

Temporally, the recharge model simulates hydrologic processes using daily time steps, because daily rainfall and reference evapotranspiration (ETo) data can be readily obtained or synthesized. The model subtotals simulated daily recharge amounts to the time intervals used as stress periods in the groundwater model, which can be variable and as short as one day. Hydrologic processes included in the recharge model are precipitation, interception, direct runoff (from pervious and impervious surfaces), infiltration, soil moisture storage in the root zone, evapotranspiration, irrigation, leaks from water and sewer pipes, and the attenuating effect of shallow groundwater storage on recharge to deeper aquifers.

Each recharge zone simulated by the model is assumed to consist of impervious, pervious (non-irrigated) and irrigated subareas that are not mapped explicitly but simulated as percentages of the zone area. A one-dimensional soil moisture and shallow groundwater water balance is calculated separately for the three component subareas, multiplied by their respective areas, then totaled to obtain volumetric daily recharge for the entire zone. Parameters used to characterize physical conditions in each zone are described in the following sections.

B-1 Rainfall and Interception

Daily rainfall for the period simulated by the groundwater model must be obtained or synthesized for at least one (and up to three) stations in the study area. Average annual rainfall at each recharge zone must be estimated, usually by means of a rainfall contour map. Daily rainfall at the zone is then calculated as daily rainfall at the station multiplied by the ratio of average annual rainfall at the zone to average annual rainfall at the station. With multiple stations, the user assigns a weight to each station, with weights summing to 1.0.

Interception refers to rainwater that adheres to the leaves of plants and does not reach the ground. The amount is small at any time, but interception occurs repeatedly throughout the rainy season and can substantially decrease the amount of soil infiltration on days with small amounts of rain. Typical interception values are 0.08 inch for evergreen trees and shrubs, 0.04 inch for crops and urban residential (where vegetation is a mix of turf, shrubs and trees), 0.02 inch for turf, and 0 inch for impervious surfaces.

These values are consistent with field studies of interception in other areas (Viessman et al., 1977). Interception is subtracted from rainfall on a daily basis, reflecting an assumption that daily evaporation equals or exceeds the interception amounts.

B-2 Runoff and Infiltration

Most rainfall reaching the ground surface (net rainfall) infiltrates into the soil, but direct runoff occurs when net rainfall exceeds a certain threshold. The threshold at which runoff commences and the percent of additional rainfall that runs off are significantly influenced by a number of variables, including soil texture, soil compaction, leaf litter, ground slope, and antecedent moisture. These factors can be highly variable within a recharge zone, and data are not normally available for them. Also, the intercept and slope of the rainfall-runoff relationship depends on the time increment of analysis. Most analytical equations for infiltration and runoff apply to spatial scales of a few square meters over periods of minutes to hours (Viessman et al., 1977). They are suitable for detailed analysis of individual storm events. The curve number approach to estimating runoff also applies to single, large storm events. It is not suitable for continuous simulation of runoff over the complete range of rainfall intensities (Van Mullen and others, 2002). The approach used in the recharge model is similar but less complex than the approach used in popular watershed models such as HSPF (Bicknell et al., 1997).

In the recharge model, daily infiltration is simulated as a three-segment linear function of net rainfall, and net rainfall that exceeds infiltration is assumed to become runoff. The general shape of the relationship of daily infiltration to daily net rainfall is shown in **Figure B-1** (upper graph). Below a specified runoff threshold, all daily net rainfall is assumed to infiltrate. Above that amount, a fixed percentage of rainfall is assumed to infiltrate, which is the slope of the second segment of the infiltration function. Finally, an upper limit is imposed that represents the maximum infiltration capacity of the soil. The runoff threshold, the percentage of excess net rainfall that infiltrates, and the maximum daily infiltration capacity vary by land use, soil type and slope, and initial estimates are usually adjusted during model calibration. In basins where the program was recently applied, the runoff threshold ranged from 0.2 inches per day (in/d) for unpaved areas in industrial and commercial zones to 0.8 in/d for turf and natural vegetation areas. The infiltration percentage for excess rainfall ranged from 55 percent in commercial and industrial areas to 87 percent in large turf areas and upland natural vegetation. In urban residential areas the runoff threshold was 0.35 in/d and the infiltration percentage was 80 percent. The maximum daily infiltration was set to 3 in/d for all land uses and soil types (Todd Groundwater, 2015 and 2016).

The above parameter values are for soils that are relatively dry. Infiltration rates decrease as soils become more saturated. This phenomenon led to the development of the Antecedent Runoff Condition adjustment factor for rainfall-runoff equations (Rawls et al., 1993). However, application of the concept has been focused on individual storm events. For the purpose of the recharge model, the adjustment provides a means of simulating empirical observations that a given amount of rainfall produces less runoff at the beginning of the rainy season when soils are relatively dry than at the end of the rainy season when soils are relatively wet. This effect is included in the recharge model as a multiplier that decreases the estimated infiltration as soil saturation increases. This multiplier is applied to the runoff threshold, the infiltration slope and the maximum infiltration rate. The multiplier decreases from 1.0 when the soil is dry to a user-selected value between 1.0 and 0.60 when the soil is fully saturated (lower graph in **Figure B-1**). A low value has the effect of decreasing infiltration (and potential groundwater recharge) toward the end of the rainy season or in very wet years, and also to increase simulated peak runoff during large storm events. In one recent application a multiplier value of 0.75 was used.

For impervious surfaces, the interception parameter can be used to simulate depression storage. Otherwise, impervious runoff is assumed to equal 100 percent of rainfall. Runoff that flows into a storm drain system (known as “connected impervious runoff”) contributes to stream flow but not groundwater recharge. However, runoff from some impervious surfaces flows onto adjacent areas of pervious soils (“disconnected impervious runoff”). The surface hydrology model treats this type of runoff as if it were an increment of additional rainfall where it flows over or ponds on the pervious soils. The excess water can quickly saturate the soil and initiate deep percolation. The model incorporates this process by means of a variable representing the fraction of impervious runoff that becomes deep percolation. Data and literature values are not available for this variable, so it is typically estimated by professional judgment regarding urban development patterns and also included among the recharge variables adjusted during calibration. In low-density development (for example, parks, golf courses and rural residential areas) most or all runoff from impervious areas can flow to adjacent pervious soils. In highly impervious commercial or industrial areas, only a small percentage of the impervious area drains to pervious soils. Gaged stormwater runoff data are available for some urban catchments in the San Jose area, and calibrated estimates of the percentage of impervious runoff that becomes deep percolation through adjacent pervious soils were seven percent in residential areas, three percent in commercial and industrial areas and one hundred percent in rural residential area (Todd Groundwater, 2016). Simulated groundwater recharge in urban areas is typically fairly sensitive to the percentage of disconnected impervious runoff.

B-3 Root Zone Depth and Moisture Content

The storage capacity of the root zone equals the product of the vegetation root depth and the available water capacity of the soil. The available water capacity for each recharge zone can be estimated as a depth-weighted average of soil horizons for the dominant soil type, as reported in published soil surveys. Root depth is a complex variable. Except for cropland, vegetation cover typically consists of a mix of species with different root depths. At a very local scale, roots are deepest directly beneath a plant and shallower between plants. Root density and water extraction also typically decrease with depth within the root zone. To complicate matters, root depth is somewhat facultative for many plants, which means that roots will tend to grow deeper in soils with low available water capacity, such as sands. Finally, root depth in many upland watershed areas is restricted by shallow bedrock. The root depth selected for each recharge zone represents an average of all these factors such that simulated deep percolation and stream flow are the same as the spatially variable values would be when averaged over the area of the zone. Separate root depths are specified for irrigated and non-irrigated vegetation in each recharge zone, because non-irrigated vegetation is typically shrubs and trees with deep roots whereas the dominant irrigated vegetation is relatively shallow-rooted turf. For consistency, the root depth for any given vegetation type (such as lawn or truck crops) is required to be the same in all recharge zones. Root depth has a large effect on simulated rainfall recharge in non-irrigated areas.

B-4 Evapotranspiration

Evapotranspiration is affected by meteorological conditions, plant type and growth stage, and soil moisture availability. All of these factors are included in the recharge model. The evaporative demand created by meteorological conditions is represented by reference evapotranspiration (ETo). Numerous equations have been developed over the years relating ETo to solar radiation, air temperature, relative humidity and wind speed. In California, it is generally easiest to extrapolate measured ETo from a California Irrigation Management Information System (CIMIS) microclimate station. Spatial extrapolation can be done on the basis of a statewide ETo zone map (Jones, 1999). Temporal extrapolation can be done by correlation with another CIMIS station or by regression relationships between ETo and air temperature. Air temperature data are more widely available, and often have long historical records. Fortunately, ETo usually varies by less than +/- 15 percent from year to year (much less than the variability of rainfall), so even rough estimates will not cause large errors in simulated groundwater recharge.

Evapotranspiration varies by vegetation type and growth stage. ETo is the amount of water evapotranspired from a broad expanse of turf mowed to a height of 4-6 inches with ample irrigation. ETo is multiplied by a monthly crop coefficient to obtain the actual evapotranspiration from a different crop or vegetation type at a particular stage in its growth and development. Although primarily used for agricultural crops, crop coefficients can also be applied to urban landscape plants and natural vegetation. Compilations of crop coefficients for many plant types based on field studies are available from numerous sources, in some cases specified by calendar month and in others by growth stage of the plant. The State of California's Model Water Efficient Landscape Ordinance uses "plant factors" that are equivalent to crop coefficients, and tables are available listing plant factors for hundreds of common landscape species.

B-5 Irrigation

Evapotranspiration gradually depletes soil moisture, and for irrigated areas the recharge model triggers an irrigation event whenever soil moisture falls below a specified threshold. The amount of applied irrigation water is equal to the volume required to refill soil moisture storage to field capacity, divided by the assumed irrigation efficiency. For example, an irrigation threshold equal to 50-80 percent of maximum soil moisture storage would probably be appropriate for urban landscaping and most crops. This variable primarily affects the frequency of irrigation; a higher threshold results in more frequent irrigation but approximately the same total amount of water applied annually.

The irrigation efficiency parameter in the recharge model is used to simulate applied irrigation water that percolates past the root zone. In agricultural settings, inefficiency results primarily from nonuniformity in soil texture and in applying irrigation water. It is assumed that the irrigator applies enough water over the entire field to ensure that soils in the driest part of the field are fully replenished. This means that other parts of the field receive slightly more than enough water than is needed to replenish the root zone (bring soil moisture up to field capacity). There are other components of irrigation inefficiency, such as tailwater runoff for furrow irrigation, evaporation of spray droplets for sprinkler irrigation, and overspray of sprinklers beyond the target area. In the recharge model, the parameter refers only to the deep percolation component. For example, if 10 percent of sprinkler water is lost to spray evaporation and 10 percent becomes deep percolation, an irrigation efficiency of 90 percent would be used. When the model is being used to estimate the amount of water used for irrigation, the efficiency value can be temporarily adjusted to reflect all components of inefficiency. Irrigation efficiency can vary substantially depending on site conditions, the grower and irrigation method. For furrow irrigation, reasonable initial estimates might be 70-75 percent, for sprinkler irrigation 80-85 percent and for drip irrigation 95 percent. Vineyards grown with regulated deficit irrigation have an efficiency of 100 percent.

Urban irrigation other than for large turf areas typically has much lower efficiencies because irrigation zones are typically small (large perimeter to area ratio), irregularly shaped and managed by landowners who have limited knowledge of plant water requirements or pay inadequate attention to irrigation activities. Large sources of inefficiency in urban areas include direct evaporation from spray droplets and sprinkler overspray onto driveways, sidewalks and other impervious surfaces (Baum et al., 2005; Xiao et al., 2007; Kumar et al., 2009). Application efficiencies of 50 percent are common for the San Francisco Bay Area (Sandoval-Solis et al., 2013).

Because irrigation is assumed to completely refill the soil moisture storage and is less than 100 percent efficient, simulated soil moisture storage exceeds capacity immediately following an irrigation event. The excess is assumed to become deep percolation beneath the root zone. This approach ignores unsaturated flow processes and is commonly referred to as a “bathtub model” approach.

In urban areas, the percent irrigated area for each urban land use category and the amount of applied water can be estimated by curve separation of seasonal variations in monthly water use. Using monthly delivery data from the local water purveyor, water use during the minimum-use month (typically December, January or February) is assumed to represent only indoor water use because irrigation is generally unnecessary in mid-winter. Indoor water use was assumed to be constant year-round, and excess water use in all other months was attributed to irrigation. This assumption is reasonable in northern California, where rainfall is relatively high and winter ETo is low. It is questionable for study areas in southern California. In any case, the annual volume of water used for irrigation is divided by the theoretical crop water demand and irrigation efficiency (obtained from the recharge model) to estimate the total irrigated area within the purveyor’s service area.

B-6 Deep Percolation from Root Zone to Shallow Groundwater

The recharge model updates soil moisture storage each day to reflect inflows and outflows. Rainfall infiltration and applied irrigation water are added to the ending storage of the previous day, and evapotranspiration is subtracted. If the resulting soil moisture storage exceeds the root zone storage capacity, all of the excess is assumed to percolate down from the root zone to shallow groundwater. These continuous water balances are calculated separately for the pervious, impervious and irrigated subareas of each recharge zone.

B-7 Pipe Leaks

Water, sewer, and storm drain pipes in urban areas leak to some extent, creating a source of recharge to the underlying groundwater system. Conversely, sewer and storm drain pipes can gain flow from infiltration of groundwater where the water table is high. Leaks are often small and difficult to detect. Of the three types of pipelines, municipal water distribution systems are typically the most studied and best maintained. Leak rates are relatively high because the pipes are pressurized, but leak detection is relatively aggressive because the leakage can be a significant economic loss and because leak detection is a best management practice for water conservation. One leak detection program compiled leak detection data from 17 California water utilities and found an average loss of 9 percent, with a range of 4-22 percent of the total annual flow (Water Systems Optimization, Inc., 2009). Another study monitored water use at numerous individual residences in 10 medium to large California water systems using data loggers, and it found an average leak rate of 18 percent of the delivered volume (Aquacraft, 2011). A U.S. Environmental

Protection Agency (USEPA) study found that "unaccounted for water" (which includes incidental unmetered uses in addition to leaks) in the range of 10-20 percent of total volume delivered is normal (Lahlou, 2001).

Unaccounted for water is estimated in urban water management plans prepared by local water purveyors. Those losses are typically estimated as a residual, that is, as the difference between metered production and the sum of metered deliveries. "Apparent losses" consisting of known unmetered uses (fire hydrants, main flushing, etc.) are then subtracted to obtain an estimate of "real losses" which are leaks from the distribution system. The water system leak rate is commonly expressed as a percentage of flow because of the water-balance approach used to estimate it. However, it is actually independent of flow because the network of pressurized pipes would leak even if all faucets and other outlets were turned off. Estimates typically vary widely from one purveyor to another. For nine water service areas in the eastern half of San Mateo County, for example, leak rates reported in the 2015 urban water management plans ranged from 0.5-6.4 percent.

Plant roots probably intercept a substantial amount of leaked water, consuming it as evapotranspiration and preventing it from becoming groundwater recharge. That interception presumably depends strongly on the sizes and locations of leaks and the proximity of nearby vegetation. No data are available to support quantitative estimates. A reasonable estimate might be that plants capture one-third of the leaked water, averaged over a year.

Sewer pipes also leak, but few studies are available in the literature and those indicate highly variable results. Because sewer pipes are mostly not pressurized, and leaks probably self-seal to some extent due to clogging by solids and biofilms, leak rates could be low. But the tendency for tree roots to invade sewer lines and the lower level of maintenance for sewer pipes compared to water pipes would suggest high leak rates. A placeholder assumption used in recent model applications has been that the sewer leak rate is half of the water pipe leak rate (as a percentage of annual flow). Sewer flow can be estimated in a two-step process. First indoor use is estimated by curve separation of monthly purveyor water production. This separation assumes that in the minimum-use month (usually February), all water is used indoors and none is used for irrigation. Furthermore, indoor use was assumed to remain constant year-round. Almost all water used indoors leaves the building as wastewater in drains; only about 2 percent is consumed (Mitchell et al., 2001). Interception of sewer leaks by plants is probably similar to interception of water pipe leaks, and the net amount of leaked water that becomes groundwater recharge can be estimated accordingly. The recharge model tabulates recharge from water and sewer pipe leaks as user-specified percentages of their annual flows, and the percentages can change over time to reflect historical conservation efforts.

B-8 Movement of Shallow Groundwater to Deep Recharge and Stream Base Flow

In some basins, deep percolation from the root zone does not appear to flow directly to regional water supply aquifers but rather to a shallow groundwater zone from which it slowly dissipates as lateral flow to streams or steady downward recharge to deeper aquifers. Lateral flow to streams is usually substantial only in upland watersheds, where groundwater sustains baseflow. Discharge of groundwater from regional aquifers within the basin to hydraulically-coupled streams and rivers is calculated by groundwater flow models (for which the recharge estimate is normally being prepared) and is not included in the recharge simulation model. In addition to shunting some recharge to stream baseflow, the shallow groundwater component of the recharge model attenuates seasonal pulses of rainfall recharge.

B-9 Flow of Information from GIS to Recharge Program to MODFLOW

The recharge simulation program is designed to interface with GIS for data input and to produce output files that are easy to input to MODFLOW, a program developed by the U.S. Geological Survey that is the most widely used groundwater modeling software in the United States. The data input file containing parameter values for recharge zones (39 columns of parameter values, one row per recharge zone) is the attribute table for a GIS shapefile of recharge zones. A file of MODFLOW stress period starting dates and durations is one of the inputs to the recharge program, so that daily values for all outputs can be subtotaled or averaged into time periods corresponding to MODFOW stress periods. The recharge program constructs the input file for the MODFLOW recharge package (*.rch) directly; no further processing is needed. It also produces files of simulated rainfall runoff and simulated irrigation pumping in formats convenient for incorporating into the MODFLOW stream and well package input files.

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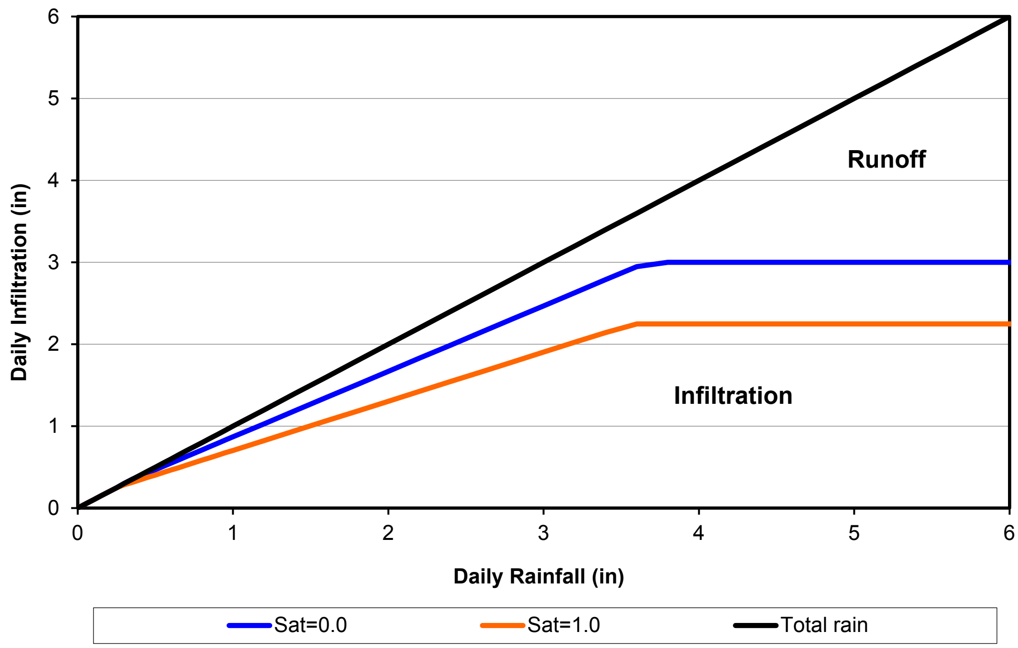
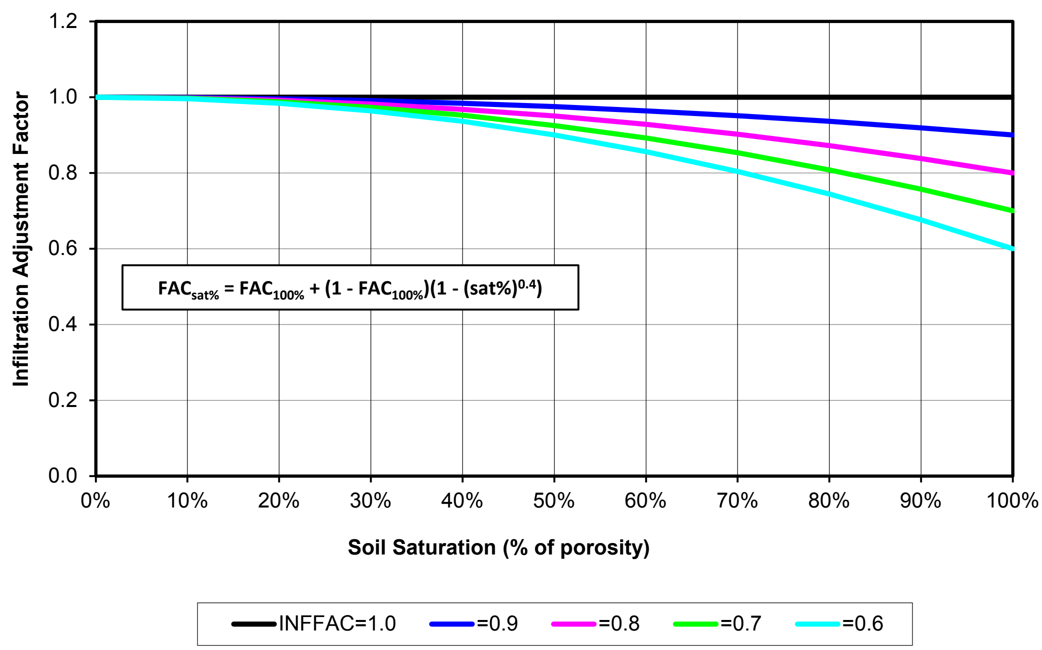
A. Relationship of Infiltration to Rainfall



B. Effect of Soil Saturation on Infiltration



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Generalized Relationship of Daily Infiltration to Rainfall

San Mateo Plain Groundwater Basin
San Mateo County, California
April 2018
EKI B60024.00

Figure B-1