PUBLIC REVIEW DRAFT | SEPTEMBER 17, 2021

EAST BAY PLAIN SUBBASIN GROUNDWATER SUSTAINABILITY PLAN CHAPTER 2—PLAN AREA AND BASIN SETTING

PREPARED FOR

EAST BAY MUNICIPAL UTILITY DISTRICT GSA AND
CITY OF HAYWARD GSA

PREPARED BY

LUHDORFF & SCALMANINI CONSULTING ENGINEERS
GEOSYNTEC CONSULTANTS
BROWN AND CALDWELL
ENVIRONMENTAL SCIENCE ASSOCIATES
DR. JEAN MORAN
FARALLON GEOGRAPHICS

LSCE TEAM

TABLE OF CONTENTS

2. PLAN AREA AND BASIN SETTING 1

2.1. Description of the Plan Area (California Code of Regulations [CCR] Title 23, Section 354.8) 1

2.1.1. Summary of Jurisdictional Areas and Other Features (23 CCR Section 354.8[b]) 1

2.1.2. Water Resources Monitoring and Management Programs (23 CCR Sections 354.8[c], 354.8[d], and 354.8[e]) 2

2.1.2.1. Water Planning Documents 3

2.1.2.2. Surface Water Monitoring and Management Programs 6

2.1.2.3. Groundwater Monitoring and Management Programs 8

2.1.2.4. Conjunctive Use Programs 9

2.1.3. Land Use Elements or Topic Categories of Applicable General Plans (23 CCR Section 354.8[f]) 9

2.1.3.1. General Plans in the East Bay Plain Subbasin 9

2.1.3.2. Permitting Process for Wells in the East Bay Plain Subbasin 10

2.1.3.3. Effects of Land Use Plans Outside the Subbasin 12

2.1.4. Additional GSP Elements (23 CCR Section 354.8[g]) 12

2.1.4.1. Control of Saline Water Intrusion 12

2.1.4.2. Wellhead Protection 12

2.1.4.3. Migration of Contaminated Groundwater 13

2.1.4.4. Well Abandonment and Well Destruction Program 13

2.1.4.5. Replenishment of Groundwater Extractions 14

2.1.4.6. Conjunctive Use and Underground Storage 14

2.1.4.7. Well Construction Policies 14

2.1.4.8. Groundwater Contamination Cleanup, Recharge, Diversions to Storage, Conservation, Water Recycling, and Extraction Projects 14

2.1.4.9. Efficient Water Management Practices 14

2.1.4.10. Relationships with Federal and State Agencies 15

2.1.4.11. Land Use Plans and Efforts to Address Potential Risks to Groundwater Quality and Quantity 16

2.1.4.12. Impacts on Groundwater Dependent Ecosystems 16

2.1.5. Notice and Communication (23 CCR Section 354.10) 16

2.1.5.1. Overview 16

2.1.5.2. Description of Beneficial Uses and Users in the Basin 16

2.1.5.3. Communications 17

2.1.5.4. Informing the Public about GSP Development Progress 21

2.2. Basin Setting 21

2.2.1. Hydrogeologic Conceptual Model (23 CCR Section 354.14) 22

2.2.1.1. Regional Geologic and Structural Setting 22
2.2.1.2. Lateral and Vertical Subbasin Boundaries 23
2.2.1.3. Major Aquifers/Aquitards 24
2.2.1.4. Aquifer Parameters 24
2.2.1.5. Recharge and Discharge Areas 25
2.2.1.6. Surface Water Bodies and Source/Delivery Points for Local and Imported Water Supplies 26
2.2.2. Current and Historical Groundwater Conditions (23 CCR Section 354.16) 27
2.2.2.1. Groundwater Levels 27
2.2.2.2. Groundwater Storage 29
2.2.2.3. Groundwater Quality 30
2.2.2.4. Seawater Intrusion 34
2.2.2.5. Land Subsidence 35
2.2.2.6. Surface Water/Groundwater Interaction 36
2.2.2.7. Groundwater Dependent Ecosystems 37
2.2.3. Water Budget Information (23 CCR Section 354.18) 38
2.2.3.1. Water Budget Analysis Approach 38
2.2.3.2. Water Budget Analysis Period 39
2.2.3.3. Initial Quantification of Recharge and Discharge Components 39
2.2.3.4. Final Quantification of Recharge and Discharge Components 41
2.2.4. Management Areas (23 CCR Section 354.20) 47
2.3. References 49

LIST OF TABLES

Table 2-1. Surface Water Monitoring Stations within EBP Subbasin
Table 2-2. Members of Key GSA Decision-Making Groups
Table 2-3. Potential Groundwater Dependent Ecosystems
Table 2-4. Initial Quantification of Recharge Components for the Historical Water Balance
Table 2-5. Initial Quantification of Discharge Components for the Historical Water Balance
Table 2-6. Initial and Final Quantification of Recharge Components for the Historical Water Balance
Table 2-7. Initial and Final Quantification of Discharge Components for the Historical Water Balance

LIST OF FIGURES

(All Figures except Figure 2-7 and 2-8 can be found at the end of the document)

Figure 2-1. East Bay Plain Subbasin Land Use Map
Figure 2-2. Map of Well Information by Section: Number of Domestic Wells (from WCR data)
Figure 2-3. Map of Well Information by Section: Number of Irrigation Wells (from WCR data)
Figure 2-4. Map of Well Information by Section: Number of Industrial Wells (from WCR data)
Figure 2-5. Map of Well Information by Section: Number of Public Supply Wells (from WCR data)
Figure 2-6. Map of Stream Gauge Locations
Figure 2-7. GSA Decision-Making Process
Figure 2-8a. GSA Public Live Event Held on February 27, 2018
Figure 2-8b. General Stakeholder Meeting Virtual Event Held of June 22, 2021
Figure 2-9. EBP Subbasin Location Map and Cross-Section Locations
Figure 2-10a. Surface Geologic Map
Figure 2-10b. Surface Geologic Map Legend
Figure 2-11. Structural Geology of San Francisco Bay Area
Figure 2-12. Map of Depositional Centers and Deep Aquifer Extent
Figure 2-13. Topography of East Bay Plain Subbasin and Surrounding Watershed
Figure 2-14. Map of Pre- and Post-2016 DWR Basin Boundary
Figure 2-15. Map of Bedrock Elevation in the East Bay Plain Subbasin
Figure 2-16. Geologic Cross Section A-A’ of Southern East Bay Plain
Figure 2-17. Geologic Cross Section B-B’ of Northern East Bay Plain
Figure 2-18. Geologic Cross Section C-C’ of the Northern and Southern East Bay Plain
Figure 2-19. Distribution of Transmissivity Values in Deep Aquifer
Figure 2-20. Mapping of the Distribution of Hydrologic Soils Groups
Figure 2-21. Map of Surface Water Bodies
Figure 2-22. Water Table Aquifer Groundwater Elevation Contour Map—Spring 2018
Figure 2-23. Deep Aquifer Groundwater Elevation Contour Map—Spring 2002
Figure 2-24. Deep Aquifer Groundwater Elevation Contour Map—Spring 2018
Figure 2-25. Selected Groundwater Hydrographs for Shallow, Intermediate, and Deep Zones in Southern EBP Subbasin
Figure 2-26. Composite Groundwater Hydrograph for Shallow Intermediate, and Deep Zones in Southern EBP Subbasin
Figure 2-27. Selected Groundwater Hydrographs for Shallow Zone in Southern EBP Subbasin
Figure 2-28. Composite Groundwater Hydrograph for Shallow Zone in EBP Subbasin

Figure 2-29. Average Total Dissolved Solids (TDS) Measurement for Wells Deeper than 50 Feet
Figure 2-30. Average Chloride (Cl) Measurement for Wells Deeper than 50 Feet
Figure 2-31. Average Nitrate (NO3N) Measurement for Wells Deeper than 50 Feet
Figure 2-32. Average Arsenic (As) Measurement for Wells Deeper than 50 Feet
Figure 2-33. Average Manganese (Mn) Measurement for Wells Deeper than 50 Feet
Figure 2-34. Map of Environmental Site Locations
Figure 2-35. Example Conceptual Cross Section of Saltwater Intrusion in Coastal Margin Aquifers
Figure 2-36. Compaction Diagram
Figure 2-37. Map of Depth to Water Table—Spring 2015
Figure 2-38. Map of Potential GDE Locations

APPENDICES

APPENDIX 2. PLAN AREA AND BASIN SETTING
2.A. Technical Memoranda and Data
2.A.a. Subtask 4.1 TM Data Compilation and Data Gaps Analysis
2.A.b. Subtask 4.2 TM Hydrogeologic Conceptual Model
2.A.c. ACPWA Streamflow Data and EBMUD Reservoir Releases
2.A.d. Existing Groundwater Monitoring Network Information
2.A.e. Summary of General Plans
2.A.f. Surface Water System Water Budget
2.B. Notice and Communication
2.B.a. East Bay Plain Subbasin Stakeholders Communication and Engagement Plan
2.B.b. East Bay Plain Subbasin Interested Parties List
2.B.c. East Bay Plain Subbasin Engagement Chart
2.B.d. East Bay Plain Subbasin Stakeholder Input Matrix
APPENDIX 6. REFERENCES AND TECHNICAL STUDIES
6.A. Interbasin and Coordination Agreements (as applicable) (Reg. Section 357)
6.B. Contact Information for Plan Manager and GSA Mailing Address (Reg. Section 354.6)
6.C. List of Public Meetings (Reg. Section 354.10)
6.D. Technical Appendices
6.E. Groundwater Model Documentation
6.F. Comments and Responses (Reg. Section 354.10)

LIST OF ACRONYMS AND ABBREVIATIONS

μg/L	micrograms per liter
ACFCWD	Alameda County Flood Control and Water Conservation District
ACPWA	Alameda County Public Works Agency
ACWD	Alameda County Water District
AF	acre-feet
AFY	acre-feet per year
ASR	aquifer storage and recovery
B	benzene
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CASGEM	California State Groundwater Elevation Monitoring Program
CCR	California Code of Regulations
CWC	California Water Code
DDW	California Division of Drinking Water
DTSC	California Department of Toxic Substances Control
DWR	California Department of Water Resources
DWSAP	Drinking Water Source Assessment and Protection
EBMUD	East Bay Municipal Utility District
EBP	East Bay Plain
ft	foot, feet
GAMA	Groundwater Ambient Monitoring and Assessment
GCM	Global Climate Models
GDE	groundwater dependent ecosystem
GMP	groundwater management plan
GP	general plan
gpd	gallons per day
gpd/ft	gallons per day per foot
GSA	groundwater sustainability agency
GSP	groundwater sustainability plan
Hayward	City of Hayward
HCM	hydrogeologic conceptual model
LBNL	Lawrence Berkeley National Laboratory
LSCE	Luhdorff & Scalmanini Consulting Engineers
LSCE Team	GSP consultant team: LSCE, Geosyntec, ESA, BC, Dr. Moran, and Farallon Geographics
LUST	Leaking Underground Storage Tank
MCL	maximum contaminant level
mg/L	milligrams per liter
MGD	million gallons per day
msl	mean sea level
MTBE	methyl tert-butyl ether
PCE	perchloroethene
RWQCB	Regional Water Quality Control Board
SFPUC	San Francisco Public Utilities Commission
SGMA	Sustainable Groundwater Management Act of 2014
SMCL	secondary MCL
TAC	Technical Advisory Committee
TCE	trichloroethene
TDS	total dissolved solids
TM	Technical Memorandum
TNC	The Nature Conservancy
TPH	total petroleum hydrocarbons
USGS	United States Geological Survey
WCR	well completion report

2. PLAN AREA AND BASIN SETTING

2.1. Description of the Plan Area

(California Code of Regulations [CCR] Title 23, Section 354.8)

The Plan Area for the East Bay Plain (EBP) Groundwater Sustainability Plan (GSP) is defined as the EBP Subbasin (2-09.04[1]), which is part of the Santa Clara Valley Groundwater Basin as described in California Department of Water Resources (DWR) Bulletin 118 (DWR, 2016), with boundary updates approved in 2016. The lateral extent of the EBP Subbasin is defined by the subbasin boundaries provided in Bulletin 118 (DWR, 2016). The EBP Subbasin is bounded in the north and west by San Francisco Bay, in the east by the East Bay Hills, and in the south by the Niles Cone Subbasin (**Figure 1-1**). As documented in **Appendices 2.A.a and 2.A.b**, the hydrogeologic conceptual model (HCM) describes detailed hydrogeologic and hydrologic features of the Subbasin. The plan area spans across Contra Costa and Alameda counties including City of Alameda, City of Albany, City of Berkeley, City of El Cerrito, City of Emeryville, City of Hayward, City of Oakland, City of Richmond, City of San Leandro, City of San Pablo. The vertical boundaries of the Subbasin are the land surface (upper boundary) and the definable bottom of the basin (lower boundary). The Subbasin's definable bottom was established as part of the development of the hydrogeologic conceptual model (HCM) using depth to bedrock and delineations of major aquifers/aquitards, see GSP Section 2.2.1.2 for more detail. Appendices 2.A.a and 2.A.b contain the technical memorandums (TMs) that document the development of the HCM.

2.1.1. Summary of Jurisdictional Areas and Other Features

(23 CCR Section 354.8[b])

As identified in Section 1.3, two exclusive groundwater sustainability agencies (GSAs) cover the EBP Subbasin: the East Bay Municipal Utility District (EBMUD) GSA and the City of Hayward (Hayward) GSA. These two GSAs are cooperating to develop a single GSP for the EBP Subbasin. **Table 1-2** and **Figure 1-1** delineate the areas managed exclusively by each GSA. No area in the Subbasin is covered by an Alternative (to a GSP), and the Subbasin is not adjudicated. The federal government recognizes the Lytton Band of Pomo Native Americans, which owns a casino in San Pablo located immediately west of San Pablo Avenue at its intersection with San Pablo Dam Road (U.S. Department of the Interior, Bureau of Indian Affairs, Office of Trust Services, 2016). The Lytton Casino property southern border aligns with Wildcat Creek (Google Maps, 2021).

The land use diagram in the City of Alameda General Plan shows three areas of Federal Facility Overlay, which is described as lands currently owned by the Federal Government for military use. Each area has an underlying land use designation that would apply if the land were conveyed out of federal ownership in the future. The three area are a portion of the former Alameda Naval Air Station in northwest Alameda (planned for wildlife habitat), Coast Guard Island in Oakland Estuary (planned for mixed use), and a small parcel on the southeast coast of Alameda Island adjacent to Oakland Estuary (planned for mixed use).

[1] Subbasin 2-09.04 is the formal California groundwater subbasin number assigned by DWR for the EBP Subbasin.

The EBP Subbasin lies within the jurisdictional boundaries of Alameda and Contra Costa Counties. Unincorporated areas are covered by the respective county general plans (GPs), and major portions of the Subbasin within the boundaries of the two GSAs are covered by various city GPs.

Figure 2-1 depicts land use in the EBP Subbasin, which is classified primarily as urban (94%), with the remaining area classified as native vegetation, barren land, and water surface. Urban land uses include commercial, industrial, and residential. The vast majority of the Subbasin's land area is classified as medium- to high-intensity urban development.

Figure 2-2 and **Figure 2-3,** respectively, show the densities of domestic and irrigation wells per section[2] within the EBP Subbasin determined from a well completion report (WCR) database provided by DWR. The densities on Figures 2-2 and 2-3 may not reflect the total number of existing or active wells in the Subbasin because not all wells may have been reported to DWR and may also reflect wells in DWR's database that are no longer active. In addition, it appears that residential irrigation wells have been categorized as either domestic or irrigation as described in the WCRs. Therefore, the DWR database was screened to distinguish between domestic irrigation wells (subsequently classified as domestic wells in **Figure 2-2**) and irrigation wells for larger parcels (included in **Figure 2-3**) based on well diameter.

The highest concentrations of both domestic and irrigation wells are located in the southern EBP Subbasin between San Leandro and Hayward. Higher concentrations of domestic wells are identified in San Leandro, San Lorenzo and Hayward area. Notably, the Hayward area has a large number of domestic wells. Some domestic wells are also present on Alameda Island and in Oakland and Richmond, with a notable concentration of domestic wells in portions of Alameda Island (**Figure 2-2**). Larger diameter (greater than 6 inches) irrigation wells are most prevalent from San Leandro to Hayward, with additional irrigation wells reported on Alameda Island, in north Oakland/Berkeley, and in Richmond/San Pablo (**Figure 2-3**).

The map of industrial well locations shows a widespread distribution from southern Richmond to Hayward (**Figure 2-4**). Concentrations of industrial wells are greater between Oakland and Hayward than farther north. The sections indicating well locations shown on the public water supply map (**Figure 2-5**) correspond to the EBMUD and Hayward well locations.

2.1.2. Water Resources Monitoring and Management Programs
(23 CCR Sections 354.8[c], 354.8[d], and 354.8[e])

Water planning documents, along with existing surface water and groundwater monitoring and management programs within the EBP Subbasin are identified below.

[2] The term "section" here refers to the Public Land Survey System's use of townships, ranges, and sections to designate locations in California, and is commonly used to specify specific well locations.

2.1.2.1. Water Planning Documents

As stewards of water resources within their jurisdictions, the EBP Subbasin GSAs and corresponding local agencies have prepared and adopted the water planning documents presented in **Table 2-1**. Information in these plans regarding GSA surface water and groundwater supplies, distribution infrastructure, and monitoring programs has contributed to the development of this GSP. Additional explanation is provided for the BAIRWMP and the SEBP GMP.

Table 2-1. Water Planning Documents

Category	Document
Regional Water Plans	• Bay Area Integrated Regional Water Management Plan (approved in 2006, updated in 2019) • Bay Area Regional Reliability Drought Contingency Plan (2018)
Local Management Plans	• EBMUD Water Supply Management Program 2040 Plan (2012)
Urban Water Management Plans	• EBMUD Urban Water Management Plan 2020 (2021) • City of Hayward 2020 Urban Water Management Plan (2021)
Groundwater Management Plans	• South East Bay Plain Basin Groundwater Management Plan (2013)
General Plans	• Alameda County (1956–2015; 2010) • Contra Costa County (2005) • City of San Pablo (2011) • City of Richmond (2010) • City of El Cerrito (1999) • City of Albany (2016) • City of Berkeley (2001) • City of Emeryville (2009) • City of Oakland (1996–1998) • City of Alameda (2021) • City of San Leandro (2016) • City of Hayward (2014)
Other Plans	• EBMUD Strategic Plan (July 2020) • EBMUD 2050 Demand Study (2020) • East Bay Watershed Master Plan (2018) • City of Berkeley 2011 Watershed Management Plan (2011)

Bay Area Integrated Regional Water Management Plan

This plan is a collaborative effort to improve regional coordination for water resources management among various agencies in the nine San Francisco Bay Area counties that have formed the Regional Water Management Group, as well as other interested parties. These agencies include two currently organized as GSAs in the EBP Subbasin (EBMUD and Hayward). The plan establishes regional water management goals and serves as a basis for pursuing funding to accomplish these goals.

South East Bay Plain Basin Groundwater Management Plan (2013)

This plan provides a framework for regional groundwater management that covers the southern portion of the EBP Subbasin from approximately 29th Avenue in the Fruitvale neighborhood of southern Oakland to the EBP Subbasin's pre-2016 southern boundary with the Niles Cone Subbasin in Hayward. The objectives of the plan are to preserve basin storage by maintaining groundwater elevations to ensure sustainable groundwater use; to maintain or improve groundwater quality to maintain basin sustainability; and to manage potential inelastic subsidence due to groundwater pumping. These objectives align with four of the six sustainability indicators under the Sustainable Groundwater Management Act of 2014 (SGMA). The major groundwater management plan (GMP) components to achieve the objectives are stakeholder/public involvement, a monitoring program, data management and analysis, groundwater resource protection, and groundwater sustainability. The GMP includes the seven mandatory and 12 voluntary components of GMPs listed in California Water Code (CWC) Section 10750, which include monitoring and management of changes in surface water flows caused by pumping and control of saline water intrusion (the two remaining sustainability indicators under SGMA). Thus, before SGMA was enacted, the GMP provided for evaluation and consideration of the six sustainability indicators for a portion of the EBP Subbasin.

EBMUD 2020 Urban Water Management Plan

The California Water Code requires urban water suppliers within the state to prepare and adopt Urban Water Management Plans (UWMPs) for submission to the California Department of Water Resources (DWR). The UWMPs, which are required to be filed every five years, must satisfy the requirements of the Urban Water Management Planning Act (UWMP Act) of 1983, including amendments that have been made to the Act and other applicable regulations. The EBMUD Board of Directors adopted the UWMP 2020 and Water Shortage Contingency Plan (WSCP) - Attachment 1 to the UWMP on June 22, 2021, which was subsequently submitted to the California Department of Water Resources.

The primary purpose of the UWMP is to promote efficient use of available water supplies and it is a long-term resource planning document in which urban water suppliers evaluate their supplies and demands to ensure that adequate water supplies are available to meet existing and future water needs. The associated Water Shortage Contingency Plan (WSCP) provides a framework to help address water shortages that may occur, such as droughts, earthquakes that damage infrastructure, floods in the Delta that impact aqueducts, power outages, fires, and other emergencies.

EBMUD's primary source of water supply is from the Mokelumne River for which EBMUD has water right permits and licenses, subject to the availability of runoff and other conditions that could restrict the ability to receive its full entitlement (i.e., use by senior water right holders, curtailments by SWRCB, downstream obligations to protect public trust resources). EBMUD holds a water service contract with the United

States Bureau of Reclamation to receive water from the Central Valley Project (CVP) through the Freeport Regional Water Facility in dry years only.

Supply and demand assessment from EBMUD's WSCP shows that during prolonged severe droughts, the Mokelumne River supply cannot meet EBMUD's projected customer demands. The CVP supply helps offset some of the water need; however, it's unreliable and is not sufficient in the long-term. Consequently, EBMUD's long-term water supply goals include improving its water supply reliability and continuing to diversify its water supply portfolio. EBMUD will continue to review and evaluate using local groundwater from the EBP Subbasin is as part of diversifying its water supply portfolio.

Hayward 2020 Urban Water Management Plan

Hayward recently completed their Final 2020 UWMP. Hayward currently receives 100 percent of its potable water supply from purchases of imported surface water from San Francisco Public Utilities Commission (SFPUC). SFPUC water supply sources include: Tuolumne River/Hetch Hetchy watershed (via Hetch Hetchy Reservoir, Lake Lloyd, and Lake Eleanor), with Don Pedro Reservoir acting as a water bank integrated into system operations, and local runoff in Alameda County into San Antonio and Calaveras Reservoirs with San Antoinio Reservoir also receiving water from the Hetch Hetchy system.

Hayward had a total of 36,300 connections in Fiscal Year 2020 and supplied a water volume of 5,259 million gallons in 2002; comprised of 5,082 MG from SFPUC and 177 MG of recycled water. Hayward water demands have declined from a high of nearly 20 MGD in the early 2000s to less than 15 MGD since 2015. Total water use is approximately 55% single-family and multi-family residential, with the remainder comprised of commercial, industrial, irrigation, institutional, and other uses. The future water demand forecast through 2040 indicates increasing water demands to 6,862 MG in 2030 and 7,671 MG in 2040. The analysis of available water supplies compared to future water demands indicates there will be sufficient water for normal years through 2045, but shortages can be expected in single dry and multiple dry years in the future.

The Hayward WSCP is a strategic planning document to prepare for and respond to water shortages. The Hayward WSCP describes Hayward's actions to implement and enforce regulations/restrictions in a water shortage emergency, which are consistent with are consistent with the plans/actions of its water wholesaler (SFPUC). Hayward dry year potable water supplies are from its SFPUC Regional Water System (RWS) allotment. Recycled water provides a small component of overall water supplies in terms of non-potable water. Hayward's emergency groundwater supply wells are currently intended for use only in emergencies involving interrupting of imported surface water supply infrastructure. Hayward relies on SFPUC's portfolio of water supply programs that include water transfers, storage and exchange agreements to provide supply augmentation.

Hayward will conduct an annual water supply and demand assessment by July 1 of each year and submit an annual water shortage assessment stating anticipate shortage and required shortage response actions. Hayward has designed six standard water shortage levels (0 through 6) that reflected water shortages (relative to normal demand) of 0% for Shortage Level 0 to greater than 50% for Shortage Level 6 with shortage increments of 10% between Shortage Levels of 0 and 6. The WSCP outlines a number of demand reduction actions at various shortage levels; for example, a Shortage Level of 3 (21 to 30% water shortage) requires that irrigation be limited to two days per week for turn when using potable water, among other actions.

2.1.2.2. Surface Water Monitoring and Management Programs

Available data and spatial information from the monitoring programs summarized in **Table 2-2** and described below were incorporated into this GSP to develop water budget and groundwater modeling, in compliance with 23 CCR Section 354.18.

Federal, State, and Regional Monitoring Programs

In support of GSP development, surface water data were collected from the following agencies and programs:

- California Data Exchange Center
- U.S. Geological Survey (USGS)
  - National Water Information System

Table 2-2 identifies key surface water monitoring stations and the agencies collecting the data for streamflow stations within the EBP Subbasin. Additional streamflow data for stations within the watershed east of the EBP Subbasin are not included in **Table 2-2**, but data for both USGS and California Data Exchange Center stations are provided in **Appendices 2.A.a and 2.A.b**. In the EBP Subbasin, limited streamflow data were available from USGS. These included monitoring data of two creeks in the Richmond area (Rheem and Wildcat Creeks), Peralta Creek in the Oakland area, San Lorenzo Creek, and Ward Creek in the Hayward area.

Local Monitoring Programs

Water data were also collected from the following local monitoring programs:

- Alameda County Public Works Agency (ACPWA) Flood Control Monitoring Program
- EBMUD reservoir releases from Briones/San Pablo Reservoirs to San Pablo Creek
- EBMUD reservoir releases from Upper San Leandro/Chabot Reservoirs to San Leandro Creek

The streamflow data obtained from ACPWA primarily recorded higher flows related to large rainfall events. **Figure 2-6** shows the surface water monitoring stations listed in **Table 2-2**. Streamflow data that were not incorporated into **Appendix 2.A.a** are included in **Appendix 2.A.c**.

Table 2-2. Surface Water Monitoring Stations within EBP Subbasin

Stream	Source	Site ID	Site Name	Available Data Period
Rheem Creek	USGS	11182030	Rheem Creek at San Pablo, CA	1960–1990
Wildcat Creek	USGS	11182030	Wildcat Creek at Richmond, CA	1964–1975
Wildcat Creek	USGS	11181390	Wildcat Creek at Vale Road at Richmond, CA	1975–1996
Peralta Creek	USGS	11181300	Peralta Creek at Oakland, CA	1972–1973
San Lorenzo Creek	USGS	11181040	San Lorenzo Creek at San Lorenzo, CA	1967–1978; 1987–2019
Ward Creek	USGS	373728122041401	Ward Creek at Folsom Avenue at Hayward, CA	1998–2002
San Pablo Creek	EBMUD	San Pablo Reservoir	Releases from San Pablo Reservoir	1992–Present
San Leandro Creek	EBMUD	Chabot Reservoir	Releases from Lake Chabot	1992–Present
Rockridge Branch—tributary to Glen Echo Creek	ACPWA	CCC01	Claremont Country Club Old Quarry Site	2013–2016
Temescal Creek	ACPWA	FA02	Lake Temescal Outlet	2013–2017
Temescal Creek	ACPWA	FA03	Lower Temescal Creek at Temescal Creek Park	2014–2017
Glen Echo Creek—tributary to Lake Merritt	ACPWA	FB01	Upstream of 27th Street near Valdez Street	2013–2015
Pleasant Valley Creek—tributary to Lake Merritt	ACPWA	FC01	Grand Avenue at Weldon Avenue	2013–2017
Sausal Creek	ACPWA	FE01/02	Logan at Culvert Outfall, Downstream of Logan Street	2013–2017
Chimes Creek—tributary to Lion Creek	ACPWA	FJ01	Altamont Avenue at Sunnymere Avenue	2013–2017
Lion Creek	ACPWA	FJ02	66th Avenue at Acts Christian Academy parking lot crossing of Line J, downstream of Eastlawn Street	2013–2017
Arroyo Viejo	ACPWA	FK01	Hegenberger Road at Rudsdale Street	2013–2017
Unknown	ACPWA	FM02	Line M at San Leandro Street	2013–2016
San Leandro Creek	ACPWA	FP01	San Leandro Creek Upstream of 98th Avenue	2013–2017
Estudillo Canal	ACPWA	M02A0001	Estudillo Canal at Manor Boulevard	2017–2019
San Lorenzo Creek	ACPWA	M02B0002	San Lorenzo Creek at Don Castro Reservoir (dam crest)	2017–2019
Chabot Creek	ACPWA	M02G0002	Chabot Creek at Norbridge Avenue	2017–2019
Ward Creek	ACPWA	M03B0001	Ward Creek at Folsom Avenue and Thackeray Avenue	2018–2019

Monitoring and Management Program Limitations on Operational Flexibility in the Basin

Continued operation of these water monitoring programs will support tracking the progress of GSP implementation by providing data on water availability and inflows and outflows from the Subbasin. However, currently operating surface water monitoring stations are generally limited to local programs, which focus on watershed releases from reservoirs outside of the Subbasin and flood flow monitoring within the Subbasin. With the exception of one station on San Lorenzo Creek, there are no ongoing surface water monitoring stations within the EBP Subbasin that monitor both low flows (base flows) and flows from storm events. Thus, the understanding of stream infiltration and stream inflows from shallow groundwater is currently very limited. This is a key data gap that needs to be addressed during GSP implementation.

2.1.2.3. Groundwater Monitoring and Management Programs

Various federal, state, and local monitoring programs related to groundwater levels, groundwater quality, and land subsidence were historically and are currently conducted in the EBP Subbasin. The sections below describe each monitoring category in more detail.

Groundwater Level Monitoring

Monitoring of groundwater levels (or periodic groundwater level measurements) in the Subbasin has been conducted historically by EBMUD, Hayward, Alameda County, DWR, USGS, and the GeoTracker Groundwater Ambient Monitoring and Assessment Program (GAMA). The majority of the data collected before 2000 for the southern EBP Subbasin was derived from a monitoring program implemented by Alameda County Flood Control and Water Conservation District (ACFCWCD), a program that started during a time of considerably greater groundwater pumping in the Subbasin. The California State Groundwater Elevation Monitoring Program (CASGEM) was initiated in 2011 in the southern EBP Subbasin, and in 2015 in the northern EBP Subbasin with EBMUD as the local monitoring entity. Groundwater levels are collected and submitted each fall and spring as part of the CASGEM program. **Appendix 2.A.d** presents maps that show the CASGEM well locations and recent monitoring dates for historical groundwater level monitoring in the EBP Subbasin.

Groundwater Quality Monitoring

Monitoring of groundwater quality in the Subbasin has been conducted historically by EBMUD, Hayward, ACFCWCD, Port of Oakland (for a channel deepening study), regulated facility operators and other entities (for contaminant site monitoring for the San Francisco Bay Regional Water Quality Control Board (RWQCB), USGS, GAMA, and DWR. **Appendices 2.A.a and 2.A.b** present maps that show the well locations, monitoring programs, and monitoring dates for historical groundwater quality monitoring conducted in the EBP Subbasin.

Land Subsidence Monitoring

Land subsidence monitoring has been conducted primarily by USGS, as described in **Appendices 2.A.a** and **2.A.b**. In cooperation with USGS, EBMUD installed two deep extensometers to continually measure aquifer system compaction (elastic and inelastic subsidence) and expansion (uplift) in the southern portion of the EBP Subbasin area in 2008. The USGS extensometer monitoring is a key ongoing program that collects subsidence data on a continuous basis. **Appendix 2.A.b** presents additional information on the extensometer monitoring site and recent data from historical land subsidence monitoring conducted in the EBP Subbasin and vicinity.

2.1.2.4. Conjunctive Use Programs

EBMUD has developed the Bayside Project as part of its supplemental water supply portfolio. The project currently includes one aquifer storage and recovery (ASR) well. The ASR well can inject potable water when surplus water is available from San Leandro Creek watershed. The ASR well can extract groundwater during droughts as necessary.

2.1.3. Land Use Elements or Topic Categories of Applicable General Plans (23 CCR Section 354.8[f])

This section includes discussion of applicable GPs and well permitting agencies in the EBP Subbasin. GPs have been prepared for two counties and several cities, and there are three different well permitting agencies (Contra Costa County, Alameda County and City of Berkeley) covering portions of the EBP Subbasin.

2.1.3.1. General Plans in the East Bay Plain Subbasin

The EBP Subbasin lies within portions of Alameda and Contra Costa Counties. Thus, both the Alameda County and Contra Costa County GPs have jurisdiction over unincorporated areas of the Subbasin located within respective counties. Incorporated areas of the Subbasin are covered by GPs completed by several cities. More than 95% of the total water supply for the EBP Subbasin is provided by imported surface water sources that originate from reservoirs in the Sierra Nevada primarily and from local reservoirs in the East Bay Hills (about 10% of total surface water provided by EBMUD).

Appendix 2.A.e describes several GPs for counties and cities in the EBP Subbasin. The GPs are summarized below, with a focus on factors potentially related to groundwater recharge, groundwater use, creek restoration, surface water/groundwater interaction, and GSP implementation.

Review of county and GPs indicated several common characteristics and themes in these documents:

- Most areas are considered essentially built out, with effective buildout having occurred several years before publication of the GP document. In some cities, the population has been greater in the past than at the present (i.e., the time of GP adoption).
- For many jurisdictions, vacant land typically composes less than 5% of the total land area, with potentially developable vacant land on the order of 2% of total land area. In many cases, even infill potential on vacant parcels have been previously built upon or have compacted soils, limiting recharge potential for the Subbasin.
- Although the State of California requires cities and counties to plan for a certain amount of future population growth with increased housing units, most of these additional housing developments are planned to be multifamily and mixed-use redevelopment projects in certain focused areas (e.g., transportation corridors, downtown).

- Most future changes and development will occur as redevelopment of parcels with existing structures and paving, supplemented by a small amount of infill development.
- Green infrastructure is emphasized for future development and redevelopment projects to reduce urban runoff, improve runoff and creek water quality, and increase infiltration of runoff and groundwater recharge. This would be accomplished using pervious pavement and development of stormwater retention/percolation basins and related best management practices.
- Many GPs emphasize creek protection and restoration, including daylighting of creeks currently carried underground in culverts.
- The GPs note that water supply is derived from surface water sources provided by EBMUD and Hayward. Few GPs mention the use of groundwater as a supply, even where groundwater pumping for irrigation and industrial uses is known to occur.
- GPs that do mention groundwater related to water supply (e.g., City of San Leandro GP) describe historical uses of groundwater (e.g., residential irrigation). These plans then emphasize cooperating with EBMUD regarding the use of groundwater as a potential supplemental drought supply, and potentially using groundwater (from Hayward) as an emergency supply (e.g., in case an earthquake interrupts surface water supplies).

Currently, necessary data are not available to accurately quantify the net effects of small increases in development of currently vacant/undeveloped parcels, which would tend to increase impervious area and decrease groundwater recharge to some degree. However, given the effects of green infrastructure requirements for new developments, which would tend to maintain or increase groundwater recharge, a minimal net change is likely with future development/redevelopment. There could possibly even be a net increase in groundwater recharge. For example, future redevelopment of an existing parcel with impervious surfaces already in place (e.g., parking lot) with green infrastructure (e.g., pervious pavement, retention/infiltration basins) may improve rainfall infiltration (and reduce runoff).

Generally, implementation of GP policies aligns with GSP planning efforts and supports the sustainability of the EBP Subbasin. Additional discussion of potential increases in impervious surfaces is provided in Section 2.2.3.5.

2.1.3.2. Permitting Process for Wells in the East Bay Plain Subbasin

<u>Permitting Process for Wells in Alameda County</u>

ACPWA is responsible for all permitting and enforcement for the construction, reconstruction, and destruction of wells in the portion of the EBP Subbasin underlying Alameda County (except for the City of Berkeley). Wells overseen by ACPWA include monitoring, remediation, vapor monitoring, piezometer/seismic, cathode, water supply (domestic, municipal, industrial, and irrigation), and geothermal wells. ACPWA permitting also covers boreholes related to contamination, environmental, and geotechnical studies. The jurisdictions covered by Alameda County include the cities of Alameda, Albany, Castro Valley, Emeryville, Hayward, Oakland, Piedmont, San Leandro, and San Lorenzo. The City of Berkeley does its own well permitting, as described below.

The application process for water well permits can be completed by mail or handled online through the Alameda County Permits Online website: https://www.acpwa.org/drilling-and-wells-permit. Annular seal inspection appointments are scheduled by contacting ACPWA–Water Resources by phone. ACPWA restricts work on all water wells to be performed only by those possessing an active C-57 water well contractor's license. The website listed above includes additional information on Alameda County Water Well Ordinance No. O-2015-20, a DWR information sheet for water well owners, an Alameda County information sheet on testing of drinking water wells, and other permitting information.

Permitting Process for Wells in Contra Costa County

The Contra Costa Health Services Environmental Health Division (Contra Costa HS&EH Division) manages the permitting process for all well construction and destruction in the portion of the EBP Subbasin underlying Contra Costa County, , including the cities of El Cerrito, Richmond, and San Pablo. To protect groundwater, Contra Costa County reviews plans of well designs, issues permits for well construction and destruction and for soil borings, and conducts inspections during drilling to ensure that wells/borings are constructed properly and destroyed in a manner to prevent groundwater contamination. Wells under county oversight include water wells, dewatering wells, monitoring wells, cathodic protection wells, geothermal wells, piezometers, inclinometers, soil vapor probes, cone penetrometer tests, and soil borings (including geotechnical borings). The application process for well permits is detailed on the Contra Costa County website: https://www.cchealth.org/eh/land-use/#Wells. The Contra Costa Environmental Health Division restricts work on all water wells to be performed only by those possessing an active C-57 water well contractor's license. The website listed above includes additional information on the well permitting process; guidelines for well destruction and dewatering wells; requirements for annual seals and well destruction materials; county and state standards, ordinances, and regulations; and other information related to well permitting.

Permitting Process for Wells in the City of Berkeley

The City of Berkeley Toxics Management Division manages the permitting process for construction and destruction of monitoring wells in the portion of the EBP Subbasin underlying the City of Berkeley. A subsurface drilling permit application is available online[3]. The permit covers construction of groundwater monitoring and soil vapor wells, destruction of groundwater monitoring and soil vapor wells, well modification, and soil borings. The City of Berkeley inspects grout seals for wells, probes, and boreholes. The well permit includes conditions of approval, which include a note that the permit does not apply for domestic, municipal, agricultural, or irrigation water supply wells. It is not clear if a well permit for a water supply well is required in the City of Berkeley or if a water supply well is even allowed in the City of Berkeley (ACPWA has stated it does not cover the City of Berkeley, and the City of Berkeley has stated it does not permit water supply wells).

[3]https://www.cityofberkeley.info/uploadedFiles/Planning_and_Development/Level_3_-_Toxics/SubsurfacePermitApp.pdf.

2.1.3.3. Effects of Land Use Plans Outside the Subbasin

Outside the EBP Subbasin, other land use plans have been developed as part of the GPs for the cities in the Castro Valley Basin to the east and the Niles Cone Subbasin to the south. These GPs are similar in scope, goals, and objectives to the county and city GPs described above. In addition, portions of the GPs described above (e.g., City of Oakland, City of San Pablo, City of Hayward) cover areas located within the watershed but outside the EBP Subbasin.

The Castro Valley Basin is a small, low-priority groundwater basin with minimal groundwater development that does not require development of a GSP but does contribute a small amount of lateral subsurface inflow to the EBP Subbasin. The Niles Cone Subbasin is covered by an alternative (to a GSP) that has been prepared by Alameda County Water District (ACWD) to sustainably manage it in compliance with SGMA. Thus, future land use changes within the Castro Valley Basin and Niles Cone Subbasin will also be managed to maintain sustainability in the immediately adjacent EBP Subbasin. Provided that these subbasins are managed to maintain sustainability, these land use plans are not expected to affect the ability of the EBP Subbasin's GSAs to maintain sustainable groundwater management.

2.1.4. Additional GSP Elements (23 CCR Section 354.8[g])

2.1.4.1. Control of Saline Water Intrusion

Before 1930, areas near San Francisco Bay where groundwater was developed from the Shallow Aquifer Zone reportedly experienced some seawater intrusion issues (e.g., San Pablo Wellfield in Richmond, Alameda Island). After 1930, seawater intrusion was not a major issue for groundwater supply development. Extensive water supply development and groundwater pumping from the Intermediate and Deep Aquifer Zones occurred in the southern EBP Subbasin during the 1950s and 1960s, resulting in Intermediate/Deep Zone groundwater levels that ranged from 10s of feet (ft) to well over 100 ft below sea level. However, no seawater intrusion problems were reported during this time.

Additional information on the potential for seawater intrusion is provided in Section 2.2.2.4 and **Appendix 2.A.b**.

2.1.4.2. Wellhead Protection

Wellhead protection refers to both the immediate location of the well in terms of well and pump station design features (e.g., well pad, annual seal) and the broader area surrounding the well. In general, a wellhead protection area is the area surrounding a public water supply well through which contaminants are reasonably able to move toward the well (i.e., the recharge area that provides water to the well).

The ACPWA, Contra Costa HS&EH Division, and City of Berkeley well ordinances and well permitting processes do not specifically address wellhead protection, but do include requirements related to placement of annular seals. The EBMUD GMP's section on wellhead protection notes that EBMUD and Hayward groundwater wells used for drought supply and/or emergency purposes are subject to California Division of Drinking Water (DDW) permitting requirements related to wellhead projection areas, which includes implementation of the Drinking Water Source Assessment and Protection (DWSAP) program.

EBMUD completed a DWSAP assessment in 2012. The EBMUD GMP lists recommended actions as: (1) obtain updated coverage of potentially contaminating activities and provide that information to stakeholders; and (2) share current wellhead protection measures and provide a summary of actions taken by others as a tool in managing their individual wellhead protection programs. Hayward's emergency supply wells are currently permitted as standby sources pursuant to California Code of Regulations (CCR) Title 22 Section 64414. As such they are limited to five consecutive days of use and 15 total days per year of use. Additional requirements for longer term use of these wells, including potential preparation of DWSAPs, will be addressed as needed in the future.

2.1.4.3. Migration of Contaminated Groundwater

In general, groundwater contamination in the EBP Subbasin is limited to the upper portion of the Shallow Aquifer Zone, while most pumping for groundwater supply occurs in wells screened in the underlying Intermediate and Deep Aquifer Zones. The Intermediate and Deep Aquifer Zones are protected from contamination and potential seawater intrusion due to the prevalence of fine-grained deposits between the upper 120 ft or so (where most contamination occurs) and the deeper coarse-grained deposits (which are tapped for groundwater supply).

However, contaminated groundwater can migrate through improperly constructed groundwater wells and improperly abandoned wells screened in multiple aquifer units, which can become conduits for vertical flow of poor-quality water between aquifers. Inadequate surface sanitary seals can allow contaminants to migrate downward from the ground surface into the well structure, and ultimately into the aquifers screened by the well. Abandoned and improperly destroyed wells are also potential conduits for migration of contaminants in the subsurface. Also, numerous types of facilities and land uses can be potential sources of chemical constituents that migrate down through the vadose zone and into aquifers, with subsequent migration to pumping wells.

Section 2.1.4.2, *Wellhead Protection*, notes requirements for well permitting related to annular seals that are meant to help mitigate the potential for vertical migration of contaminants. Section 2.1.4.4, below, describes requirements related to well destruction and abandonment. Additional information on contaminated sites is provided in Section 2.2.2.3 and in **Appendix 2.A.b**.

2.1.4.4. Well Abandonment and Well Destruction Program

Existing ACPWA, Contra Costa HS&EH Division, , and City of Berkeley well ordinances/standards and state law require proper well destruction. Alameda and Contra Costa Counties and the City of Berkeley are responsible for administration and enforcement of the well ordinances and regulations and oversee proper well destruction in the EBP Subbasin. Wells are required to be destroyed in accordance with State standards as delineated in the Water Well Standards[4] (DWR, 1981).

[4] As of 2021, a comprehensive update to the DWR Water Well Standards is in progress.

2.1.4.5. Replenishment of Groundwater Extractions

The various forms of recharge that replenish extracted groundwater, including the types and amounts of historical and current recharge are described in detail in Section 2.2.3, *Water Budget Information*, while future estimates of recharge are detailed in Section 2.2.3 and **Appendix 6.E** - *Groundwater Model Documentation*. Chapter 4 presents a detailed description of future replenishment for groundwater extractions that will occur with the implementation of projects and management actions for this GSP.

2.1.4.6. Conjunctive Use and Underground Storage

Historical and current conjunctive use operations in the EBP Subbasin have been conducted primarily by EBMUD. Conjunctive use activities by EBMUD and other entities are described in more detail in Section 2.1.2.4, *Conjunctive Use Programs*. Potential future conjunctive use and underground storage operations are described in detail in Chapter 4 and simulated by the groundwater model as described in the **Appendix 6.E**.

2.1.4.7. Well Construction Policies

Well construction policies are described in Section 2.1.3.2. As part of GSP implementation, ACPWA, Contra Costa HS&EH Division, and the City of Berkeley will continue to process and approve new well construction permits. The GSAs will request well permitting agencies to consult with GSAs prior to issuing permits to ensure the groundwater basin's sustainability.

2.1.4.8. Groundwater Contamination Cleanup, Recharge, Diversions to Storage, Conservation, Water Recycling, and Extraction Projects

Monitoring and remediation of areas of preexisting and historical groundwater contamination are being addressed primarily by various regulatory programs under the San Francisco Bay RWQCB and DTSC.

Various types of projects (e.g., recharge, diversions, extraction, water recycling) are described in Section 2.2.1.6, *Surface Water Bodies and Source/Delivery Points for Local and Imported Water Supplies*, and Section 2.2.3, *Water Budget Information*, and in the Chapter 4 discussion of projects and management actions.

Water conservation projects are described in Section 2.1.3, *Land Use Elements or Topic Categories in Applicable General Plans,* and in Section 2.1.4.9.

There are several historical, current, and planned water recycling projects in the GSP area that are described in more detail in **Appendix 2.A.b**.

2.1.4.9. Efficient Water Management Practices

Water conservation and efficient water management practices are described in Section 2.1.3, *Land Use Elements or Topic Categories in Applicable General Plans*, and the associated **Appendix 2.A.e**. In addition, EBMUD prepare a Water Conservation Master Plan (EBMUD, 2011) that provided an overview of EBMUD water conservation efforts, anticipated water savings, and drought response plans to help ensure a reliable water supply by meeting water demand reduction targets consistent with other local and statewide policies. EBMUD adopted its first WCMP in 1994 and its customers have since saved an estimated 26 MGD through various conservation practices. As of 2010, total water demand remained at or below 1970s levels despite a population increase of 20 percent (more than 225,000 people). EBMUD promotes demand-side water conservation by leak detection and ongoing repairs/improvements in the water distribution system. EBMUD's overall conservation goal as of 2010 was to achieve an additional 36 MGD of water conservation savings by 2040. Water conservation measures used by EBMUD include:

- Water Management Services – providing information to customers regarding leak detection, consumption, and water savings cost-benefit calculators;
- Education and Outreach – marketing, community outreach, and sponsorships, professional training, community partner and stakeholder group participation;
- Conservation Incentives – promote customer use of new water saving technologies, including climate-appropriate landscaping, water efficient fixtures/appliances/irrigation systems;
- Regulations and Legislation – target new property development and some existing demand by establishing 'green" product standards, building and plumbing codes, and landscape ordinances;
- Supply-Side Conservation – expand use of new technology, instrumentation, and data collection for distribution system optimization, leak detection, and water loss reduction;
- Research and Development – use of new technologies and support demand and supply-side conservation.

The conservation measures outlined in the plan were to be implemented in two five-year phases based on several factors, including current and projected water supply, metered demand, code-driven water savings and regulatory targets.

The City of Hayward has a webpage devoted to water conservation practices (https://www.hayward-ca.gov/your-environment/green-your-life/conserve-water). The website offers free water efficient devices, rebates for homeowners, no-cost consulting for energy and water savings for multifamily properties, green house calls for Hayward residents, landscape classes and other landscaping information/outreach, education on monitoring water usage, and other water saving tips and resources.

2.1.4.10. Relationships with Federal and State Agencies

The GSAs in the EBP Subbasin have relationships with a number of federal and state agencies related to surface water supply, water quality, and water management. EBMUD obtains most of its surface water supply from Pardee and Camanche Reservoirs via the Mokelumne Aqueduct system; EBMUD also collects local runoff from the East Bay Hills in its reservoirs located in the East Bay. The Pardee and Camanche Reservoir dams are owned and operated by EBMUD and under the jurisdiction of the Federal Energy Regulatory Commission because they produce hydropower. DWR Division of Safety of Dams also has jurisdiction of both the Sierra Nevada and East Bay Hills dams related to meeting the State's established safety criteria. These same federal and state agencies regulate Hetch Hetchy Dam and Reservoir, which provides Hayward's water supply via SFPUC. The EBMUD Bayside Phase 1 project operates under a waste discharge permit issued by the RWQCB.

The GSAs also apply for and occasionally receive grants from various federal and state agencies for water-related projects. For example, EBMUD and Hayward are currently installing 12 new monitoring wells in the

EBP Subbasin that is being funded through a Proposition 68 grant awarded to EBMUD. The new wells will provide better definition of the Subbasin's geology, water levels, and water quality (along with aquifer testing and the collection and evaluation of isotope samples) and for ultimate incorporation into the GSP monitoring network.

2.1.4.11. Land Use Plans and Efforts to Address Potential Risks to Groundwater Quality and Quantity

Land use plans are described in Section 2.1.3, *Land Use Elements or Topic Categories in Applicable General Plans* and in **Appendix 2.A.e**. To the extent that a given land use plan mentions groundwater issues, **Appendix 2.A.e** includes discussion of how that land use plan addresses groundwater quality and quantity.

2.1.4.12. Impacts on Groundwater Dependent Ecosystems

Potential impacts on groundwater dependent ecosystems (GDEs) are described in detail in Section 2.2.2.7, *Groundwater Dependent Ecosystems* and in **Appendix 2.A.b**.

2.1.5. Notice and Communication
(23 CCR Section 354.10)

2.1.5.1. Overview

The intent of SGMA is to ensure successful, sustainable management of groundwater resources at the local level. Success will require cooperation by all beneficial users (defined below). Cooperation is far more likely if beneficial users have consistent messaging of valid information and are provided with opportunities to help shape the path forward. Hence, SGMA requires broad and diverse stakeholder involvement in GSA activities and the development and implementation of GSPs for groundwater basins around the state, including the EBP Subbasin.

To facilitate stakeholder involvement in the GSA process, the GSAs in the EBP Subbasin created a Communication and Engagement Plan (**Appendix 2.B.a**) for the following purposes:

- Explain the GSA's decision-making process.
- Identify opportunities for public engagement and discuss how public input and response will be used.
- Describe how the GSAs encourage the active involvement of diverse social, cultural, and economic elements of the population within the Subbasin.
- Outline othe methods the GSAs will follow to inform the public about progress implementing the GSP, including the status of projects and management actions.

2.1.5.2. Description of Beneficial Uses and Users in the Basin

Under SGMA, all beneficial uses and users of groundwater must be considered during the development of a GSP. GSAs must encourage the active involvement of diverse social, cultural, and economic elements of the population. Thus, beneficial users are any stakeholders in the EBP Subbasin community who have an interest in groundwater use and management. Their interest may be related to GSA activities, development, and implementation of a GSP, and/or water access and management in general. Beneficial uses and users also include the environmental uses including GDEs.

To assist in identifying the categories of beneficial uses and users in the EBP Subbasin, the Communications and Engagement Plan includes a stakeholder engagement chart (**Appendix 2.B.c**).

2.1.5.3. Communications

Decision-Making Processes

As noted above, the EBP Subbasin is divided among two GSAs for GSP development. The two GSAs have jointly developed this single GSP. GSAs' governing bodies (i.e., EBMUD's Board of Directors and Hayward's City Council) are the final decision-makers for the EBP Subbasin.

To assist in developing the GSP, the GSAs convened a EBP Subbasin GSP Technical Advisory Committee (TAC) in 2019. The committee brought together local agencies and related parties vested with the authority and/or ability to support SGMA implementation in the EBP Subbasin. Representatives from the Cities of Richmond, Berkeley, San Pablo, and Alameda, and from Lawrence Berkeley National Laboratory (LBNL), Alameda County Department of Public Works, the San Francisco Bay RWQCB, Contra Costa College, Sierra Club, and Grolutions Horticultural Landscaping regularly attended TAC meetings. **Figure 2-7** illustrates the GSA decision-making process, which includes the GSA governing bodies, Steering Committee, Technical Team, Consultants, TAC, Interbasin Working Group, and stakeholders (including the public).

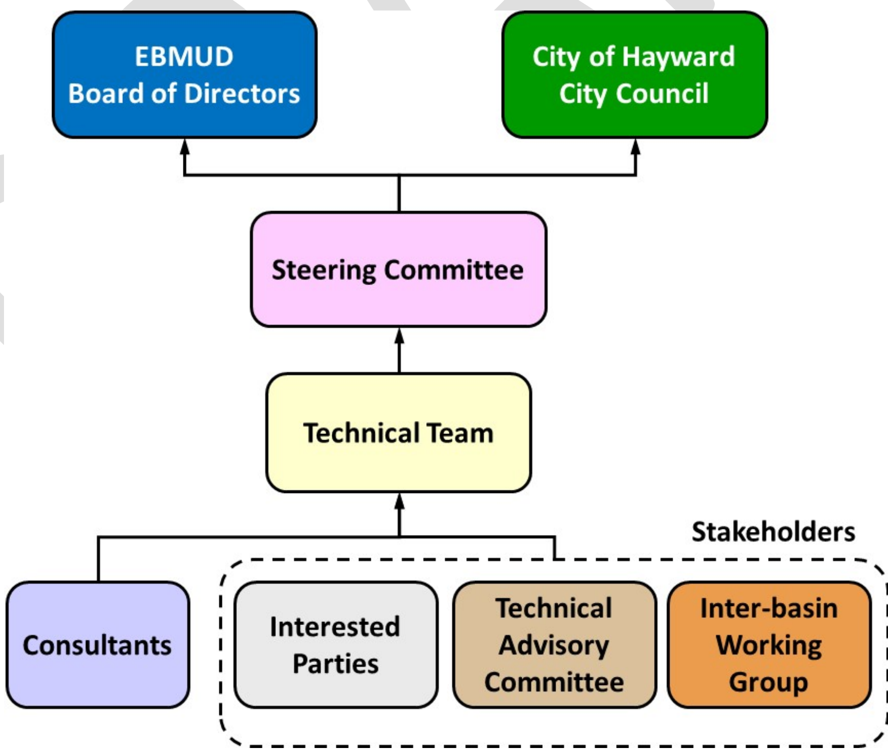


Figure 2-7. GSA Decision-Making Process

The Steering Committee included senior GSA staff members who oversaw and guided the Technical Team during development of the GSP. The Technical Team consisted of GSA staff members who developed and managed the GSP and associated projects, oversaw the consultants, and engaged with stakeholders. The Technical Team kept the Steering Committee updated during GSP development and provided recommendations at key decision points. The Consultants conducted technical studies and groundwater modeling and prepared draft GSP documents. **Table 2-3** lists the members of the Steering Committee and Technical Team and the Consultants for the GSP.

Generally, the representatives composing the TAC are technical experts and/or representatives associated with the various Subbasin stakeholders. The TAC reviewed and commented on the Consultant's deliverables and provided input for GSP development. The GSAs and Consultants considered the comments and input and incorporated them into the GSP as appropriate.

Table 2-3. Members of Key GSA Decision-Making Groups

Group	EBMUD Members	Hayward Members
Steering Committee	Mike Tognolini Linda Hu	Alex Ameri Cheryl Muñoz
Technical Team	Brad Ledesma Grace Su	Cheryl Muñoz
Consultants	Luhdorff and Scalmanini Consulting Engineers, Geosyntec, Brown and Caldwell, Environmental Science Associates, Dr. Jean Moran, Farallon Geographics	

Public Engagement Opportunities

Several meetings offered opportunities for public engagement while the GSP was being developed:

- **GSA Board meetings**: Both GSAs in the EBP Subbasin held regular public meetings, generally on a monthly schedule and generally in conjunction with standing Board and City Council meetings.
- **General stakeholder meetings**: Meetings were held throughout GSP development to enable Subbasin stakeholders and the public to learn about the SGMA process and Plan components, receive updates about planning activities, and provide input on GSP development. These meetings often included presentations by the Consultants about technical aspects of GSP preparation and topics such as the Subbasin setting, water budgets, and undesirable results.
- **SGMA webpage**: Each GSA developed and maintained interactive webpages providing SGMA compliance and GSP development information and updates. Interested parties can subscribe to a mailing list to be notified of updates and meeting information.
- **Email/Telephone**: GSAs' SGMA staff are available to reach via email and telephone on demand.

In addition to the regular GSA Board meetings, the GSP was discussed at the public meetings listed in **Appendix 2.B.c**. **Figure 2-8a** illustrates a typical GSP public live event held before the onset of the COVID-19 pandemic; subsequent GSP meetings and events were held virtually using Microsoft Teams or Zoom (**Figure 2-8b**).

Figure 2-8a. GSA Public Live Event Held on February 27, 2018

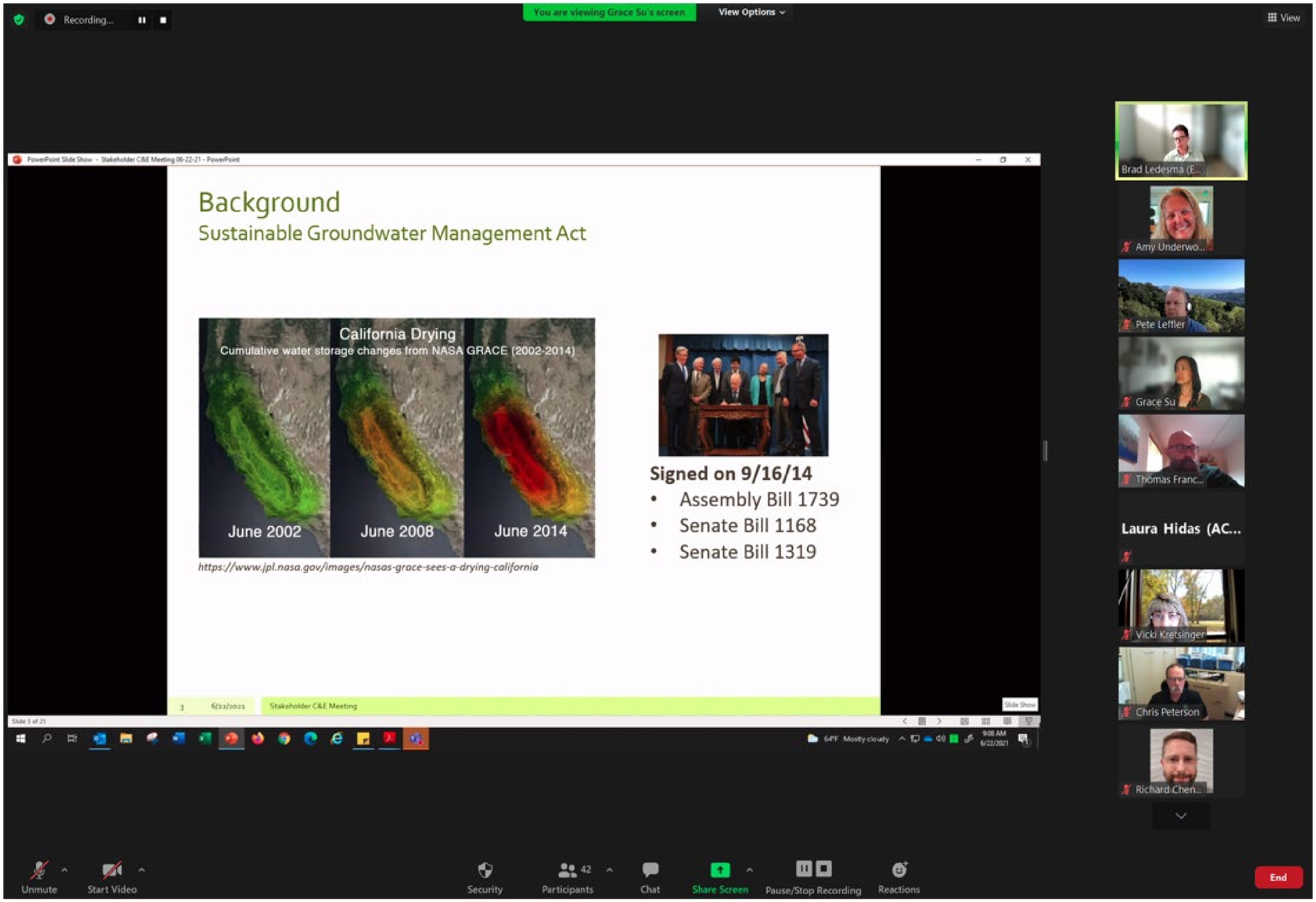


Figure 2-8b. General Stakeholder Meeting Virtual Event Held on June 22, 2021

2.1.5.4. Informing the Public about GSP Development Progress

List of Interested Parties

In accordance with CWC Section 10723.4, the GSAs established and maintained a list of persons interested in receiving notices regarding GSP preparation, meeting announcements, and availability of the draft GSP, maps, and other relevant documents. An email distribution list of Subbasin-wide stakeholders and beneficial users was developed for outreach throughout the GSP planning process. The GSAs maintained and updated the list, which is included in **Appendix 2.Bb**. Any person may send a written request to be placed on the list of interested persons.

Distribution of Materials

Typically, before a public meeting associated with the development of the GSP for the EBP Subbasin, the GSAs created and distributed an agenda containing key information about the topics to be covered. The agenda was emailed to the list of interested parties. Presentation materials were posted to EBMUD and Hayward GSP websites after the meetings. Technical memoranda were also posted to the GSA websites after being reviewed by the TAC and finalized by the Consultants. The Draft GSP was made available for a 90-day public review in September 2021. Comments received during public review of the Draft GSP were reviewed and appropriately addressed by the GSAs, the Technical Team, and Consultants. Appropriate modifications were made for the final GSP that was submitted to DWR that included responses to comments.

Press Outreach

The GSAs for the EBP Subbasin issued press releases before publishing the draft GSP for public review and conducting GSP adoption hearings.

Centralized EBP Subbasin Website

Throughout the planning process (and beyond), the GSAs have maintained Subbasin GSA/GSP websites with information about EBP Subbasin-wide planning efforts related to SGMA: https://www.ebmud.com/water/about-your-water/water-supply/groundwater-sustainability-agencies; and https://www.hayward-ca.gov/content/sustainable-groundwater-management.

The EBP Subbasin websites contain the following information:

- Calendar of public meetings and other events
- Information about past public meetings, including relevant meeting materials
- Links to external sites (e.g., DWR's SGMA portal) and other resources such as white papers
- Information about the GSAs and EBP Subbasin technical meetings
- GSP documents
- Subbasin maps

As the GSP is implemented, the GSAs will continue to maintain GSP websites to keep the public informed about progress made in implementing the GSP, including the status of projects and management actions.

Materials to be posted on the website will include GSP Annual Reports and other information documenting progress made in implementing the GSP and maintaining basin sustainability through and beyond 2042. In addition, the links to GSAs' data management system will be listed on the webpage for public and interested parties to view SGMA compliance information and query the GSP database.

Engagement Matrix

The Engagement Matrix in **Appendix 2.B.c** provides details about the meetings outlined above. The matrix lists the date, topic, and location of each public GSP-related meeting and identifies how each meeting was publicized, to whom it was targeted, what opportunities for feedback were provided, and who participated.

Stakeholder Input and Responses

The engagement opportunities described above provided various avenues for stakeholders to provide input on GSP development. The matrix in **Appendix 2.B.d** summarizes the public comments received and outlines how this input influenced decision-making during GSP development. A list of frequently asked questions (FAQ) has been compiled from stakeholder input and is included on the EBMUD webpage for the EBP Subbasin GSP.

2.2. Basin Setting

2.2.1. Hydrogeologic Conceptual Model
(23 CCR Section 354.14)

A detailed HCM was developed for the EBP Subbasin (DWR Subbasin No. 2-9.04) and the Technical Memorandum documenting HCM was published in February 2021 (**Appendix 2.A.b**). Various aspects of the detailed HCM are summarized and documented in this GSP. For more detailed information, refer to the TMs in **Appendix 2.A**.

2.2.1.1. Regional Geologic and Structural Setting

The topography of the EBP Subbasin is generally relatively flat and sloping gently upward to the east, although elevations begin to rise more rapidly near the East Bay Hills; bedrock knobs occur in the northern portion of the Subbasin. For the purposes of the HCM described in **Appendices 2.A.a and 2.A.b**, the northern EBP Subbasin is generally defined as lying north of Interstate 580/State Route 24 in Oakland and the southern EBP Subbasin is to the south of these highways (**Figure 2-9**).

A general surface geologic map for the study area (**Figures 2-10a and 2-10b**) delineates surficial sediments in the EBP Subbasin as Quaternary alluvium and marine deposits. The regional structural trend (encompassing the greater San Francisco Bay Area) is northwest-southeast, with the Hayward Fault forming the eastern boundary and the San Andreas Fault along the San Francisco Peninsula forming the western boundary (**Figure 2-11**). San Francisco Bay is situated along the Franciscan synform, which exerted a strong influence over early patterns of sediment deposition. Basement rocks in the study area include graywacke, shale, sandstone, greenstone, mélange, and ultramafic rocks. A regional structural analysis indicated local uplift west of the Hayward Fault in the Oakland-Berkeley area (Norfleet Consultants, 1998).

The unconsolidated fill within the San Francisco Basin is 800 ft to about 1,000 ft thick in much of the area, but it is asymmetrical, with the deepest portion occurring along the San Francisco Bay shoreline between San Leandro and Hayward. From this deepest portion, the basement surface rises gradually to the west and steeply to the east. The lower 300–500 ft of sediments consists of continental alluvial fan/plain deposits of the Merced and Santa Clara Formations and equivalent time units, whereas the overlying sediments are a series of alternating estuarine and alluvial deposits. The unconsolidated fill in the Richmond portion of the San Pablo Basin consists primarily of continental units, but it also has marine and freshwater clay layers in the upper portion of the stratigraphic section.

The EBP Subbasin has a major regional fault (Hayward Fault) along its eastern margin, and it lies within a geologic depression that resulted in deposition of unconsolidated sediments and formation of San Francisco Bay along the western margin of the Subbasin. The depositional history of the EBP Subbasin over the past 800,000 years involves the development of major depositional centers and alluvial cones that shifted over geologic time. This depositional history differentiates the likely different sources for Deep Aquifer Zone sediments in the EBP Subbasin (**Figure 2-12**). It also helps substantiate structural differences (confined vs. unconfined) and stratigraphic relationships in the transition zone between the EBP and Niles Cone Subbasins (**Appendix 2.A.b**). The transition zone is a hydrogeologic boundary between the two subbasins related to stratigraphic offsets of coarse-grained Deep Aquifer units that causes an impedance to groundwater flow in the Deep Aquifer between the two subbasins.

2.2.1.2. Lateral and Vertical Subbasin Boundaries

DWR defines the Subbasin's lateral boundaries as follows (DWR, 2003):

> *…a northwest trending alluvial plain bounded on the north by San Pablo Bay, on the east by the contact with Franciscan Basement rock, on the south by the Niles Cone Groundwater Basin. The East Bay Plain Basin extends beneath San Francisco Bay to the west.*

Figure 2-13 presents a map of the topography of the EBP Subbasin and surrounding watershed, with an outline of the Subbasin's boundaries. A surface geology map of the EBP Subbasin was also reviewed in comparison to EBP Subbasin boundaries defined by DWR, as displayed in **Figure 2-10**.

The actual western hydrogeologic boundaries of the EBP Subbasin aquifers beneath San Francisco Bay are not well defined. It is likely that the Deep Aquifer Zone extends a significant distance to the west beneath San Francisco Bay in the southern portion of the EBP Subbasin, while shallower aquifers likely do not extend as far to the west beneath the bay. To the east, the Hayward Fault generally separates older consolidated/fractured bedrock from more recent unconsolidated alluvium and forms the distinct eastern boundary of the Subbasin. The Subbasin's southern hydrogeologic boundary occurs within a "transition zone" defined originally by LSCE (2003) and refined more recently as part of GSP efforts (**Appendix 2.A.b**). However, a recent (2016) modification of the Subbasin boundary on jurisdictional grounds moved the basin boundary farther north along the western portion of the southern boundary (**Figure 2-14**).

DWR states, "The East Bay Plain subbasin aquifer system consists of unconsolidated sediments of Quaternary age…The cumulative thickness of the unconsolidated sediments is about 1,000 ft…" (DWR, 2003). The vertical extent of the Subbasin was further evaluated in terms of the depth to bedrock and relative to delineation of major aquifers/aquitards. **Figure 2-15** shows contours for the top of bedrock elevation beneath the Subbasin. The map of bedrock elevation contours generally shows that the deepest portion of the Subbasin is located along the San Francisco Bay shoreline between Bay Farm Island and Hayward, with depths reaching to slightly greater than 1,000 ft below ground surface (bgs). The area of greatest depths to bedrock are south of Oakland and extend beneath San Francisco Bay to the west. Between Bay Farm Island and Hayward, depths to bedrock gradually decrease toward the east to about 600 ft bgs, and then decrease rapidly from that point to the Hayward Fault, which forms the eastern boundary of the Subbasin. North of Oakland, EBP Subbasin areas are generally less than 400 ft deep and, in much of the northern Subbasin, are less than 200 ft to bedrock. The Subbasin is shallowest in Albany and El Cerrito (close to zero feet thickness in some areas), and then deepens somewhat in the Richmond area, where depths of about 600 ft to bedrock are present in some areas.

In the portion of the EBP Subbasin south of Alameda Island, the Deep Aquifer (i.e., primary coarse-grained sediments within the Deep Aquifer Zone) is considered to be the deepest aquifer in the Subbasin. Depths to the base of the Deep Aquifer range up to 650 ft bgs. At several locations where deeper boreholes were drilled, sediments below the Deep Aquifer were generally described (and/or indicated on geophysical logs) as fine-grained, although some logs indicate some thin discontinuous beds of coarse-grained units.

2.2.1.3. Major Aquifers/Aquitards

The major aquifers and aquitards of the EBP Subbasin have been subdivided into a Shallow Aquifer Zone (0–200 ft bgs), Intermediate Aquifer Zone (200–400 ft bgs), and Deep Aquifer Zone (greater than 400 ft bgs). In general, all three zones are present in the southern EBP Subbasin; however, only the Shallow Zone or the Shallow and Intermediate Zones are present over most of the northern EBP Subbasin.

Each designated zone has combinations of fine- and coarse-grained units. The coarse-grained units are generally discontinuous and make up a much smaller portion of total sediment thickness. The major exception to these conditions occurs in the upper portion of the Deep Aquifer Zone in the southern EBP Subbasin. In this location, coarse-grained units (i.e., the Deep Aquifer) tend to be relatively thick and continuous, as shown in geologic cross section A-A’ (**Figure 2-16**).

Geologic cross sections illustrate the occurrence of much shallower depth to bedrock and less frequent occurrence of coarse-grained units in the northern EBP Subbasin: geologic cross section B-B’ (**Figure 2-17**), for the Richmond area; and the northern portion of geologic cross section C-C’ (**Figures 2-18a, 2-18b, and 2-18c**), which covers the area between Berkeley and San Leandro (in the northern and southern portions of the EBP Subbasin, respectively). These cross sections also illustrate the occurrence of only the Shallow or Shallow/Intermediate Zones in the northern EBP Subbasin, as compared to the presence of all three depth zones over most of the southern EBP Subbasin. This designation of Shallow, Intermediate, and Deep Aquifer Zones is applied throughout the Subbasin to classify groundwater level and quality data. Additional information on major aquifers and aquitards is provided in **Appendix 2.A.b**.

2.2.1.4. Aquifer Parameters

Appendix 2.A.b provides a detailed summary of aquifer parameter data derived from existing reports. Data for the Shallow and Intermediate Aquifer Zones in the northern portion of the Subbasin are limited to specific capacity data (only available for five wells total). Transmissivities range widely, from about 10 to 40,000 gallons per day (gpd) per foot (gpd/ft), with a geometric mean of about 1,200 gpd/ft.

Aquifer parameter data for the Shallow and Intermediate Aquifer Zones in the southern portion of the Subbasin are also generally limited to specific capacity data (about 30 wells). Transmissivities are typically in the range of 5,000–10,000 gpd/ft for the Shallow Aquifer Zone and 10,000–20,000 gpd/ft for the Intermediate Aquifer Zone.

Local and regional aquifer testing combined with extensive and detailed work on geologic cross sections validate that the EBP Deep Aquifer is continuous from south of Davis Street in San Leandro to Hayward and from near the Hayward Fault to beneath San Francisco Bay. In this area, transmissivity values are high, ranging from 50,000 gpd/ft to more than 100,000 gpd/ft over much of the Deep Aquifer extent (although lower transmissivity values, 10,000 gpd/ft, occur along the eastern edges of the Deep Aquifer near the Hayward Fault).

Figure 2-19 provides transmissivity values for the continuous portion of the Deep Aquifer in the EBP Subbasin. The map generally shows relatively high transmissivity values on the order of 100,000 gpd/ft through the depositional center of the Deep Aquifer along the western EBP Subbasin from south of San Leandro to Hayward. The transmissivity of the Deep Aquifer declines to the east toward the Hayward Fault as the aquifer thins and pinches out.

The primary source of information about specific yield values, which are generally applicable to shallow unconfined aquifers, is the study conducted by DWR (1994) to evaluate groundwater storage in the portion of EBP Subbasin from Berkeley on the north to Hayward on the south (using DWR's pre-2016 southern basin boundary). DWR evaluated 357 well logs based on 50-ft depth intervals by assigning specific yield values to lithologic descriptions on well logs (e.g., clay = 3%, silt = 5%, medium to coarse sand = 20%, gravel = 25%). The results indicated a range of specific yield from 4% to 9% for most 50-ft depth intervals, with an overall average of 6%. These relatively low specific yield values are consistent with the predominantly fine-grained sediments observed in the EBP Subbasin.

Storage coefficient values, which are generally applicable to confined aquifers, are available from aquifer tests involving observation wells. Aquifer test data are only available for the Deep Aquifer in the southern EBP Subbasin, where storage coefficient values locally ranged from 0.00002 (EBMUD Farmhouse Well) to 0.002 (EBMUD Bayside Well). A long-term regional test covering the area from San Lorenzo to Hayward yielded an overall average storage coefficient value for the Deep Aquifer of 0.00015 (**Appendix 2.A.b**).

2.2.1.5. Recharge and Discharge Areas

Groundwater recharge has the potential to occur throughout the EBP Subbasin. Areas of groundwater recharge were evaluated based on recharge mechanisms, soil types, and surface geologic data. The primary sources of vertical recharge include precipitation and excess irrigation recharge, streamflow infiltration, and leaking pipes. The area with potential for recharge from rainfall/irrigation water and leaking pipes essentially covers the entire Subbasin, whereas streamflow infiltration potential is limited to areas where stream channels are present. However, some areas may provide greater potential for existing recharge and future managed recharge that may occur during GSP implementation.

Mapping of soils by hydrologic groups A, B, C, and D provides a good indication of recharge potential. Hydrologic group A soils have high infiltration rates, group B soils have moderate infiltration rates, group C soils have slow infiltration rates, and group D soils have very slow infiltration rates. If a soil is placed in group D because of a high water table, it may have a dual designation such as B/D (with the first letter representing the soil's infiltration rate if the soil is drained).

The hydrologic group soils mapping in **Figure 2-20** shows three relatively large areas of group B soils, which appear to be associated with San Leandro and San Lorenzo Creek alluvial fans and an area south of San Lorenzo Creek. These group B soils are generally in the middle to eastern portion of the Subbasin in these areas. Large areas of group A soils are present on Alameda Island and in the western Oakland and northwestern San Leandro areas, corresponding primarily with the locations of Merritt Sand deposits indicated on geologic maps. Hydrologic group C soils cover most of the remaining central and eastern areas of the southern Subbasin, and hydrologic group D soils cover most of the remaining western portions of the southern Subbasin. The northern EBP Subbasin consists primarily of hydrologic group C and D soils, with a greater proportion of hydrologic group C soils occurring in the Richmond area.

Overall, significant recharge can generally be expected to occur in areas with hydrologic group A, B, and C soils, with the highest infiltration rate in group A and the lowest rate in group C (all other factors being equal). Specifically, the best recharge areas are in the central to eastern portions of the southern EBP Subbasin between Oakland and Hayward, and in areas with group A and B soils and a sufficiently deep water table. The Richmond area, in the northernmost portion of the EBP Subbasin, is the next best recharge area, while the western portion of the entire Subbasin and the area between Oakland and Richmond have the lowest potential for recharge.

2.2.1.6. Surface Water Bodies and Source/Delivery Points for Local and Imported Water Supplies

The primary surface water bodies within the boundaries of the EBP Subbasin are various creeks and Lake Merritt. The creeks with the largest contributing watersheds in the East Bay Hills are San Pablo Creek and Wildcat Creek in the northern portion of the EBP Subbasin, and San Leandro Creek and San Lorenzo Creek in the southern portion of the Subbasin (**Figure 2-21**). Several creeks with smaller watersheds are also present. Lake Merritt was created in 1869 by building a dam across tidal marshes of the former San Antonio Slough. Lake Merritt currently serves many recreational functions, is a wintering location on the Pacific Flyway, and is a receiving water body for a highly developed 4,600-acre urban watershed. The major reservoirs within the watersheds east of the EBP Subbasin include San Pablo Reservoir, along San Pablo Creek, and Upper San Leandro Reservoir and Lake Chabot, along San Leandro Creek. **Figure 2-21** shows these surface water features.

EBMUD and Hayward provide nearly the entire water supply for the EBP Subbasin, which is primarily surface water. EBMUD diverts surface water from its Mokelumne River watershed reservoirs in addition to managing water supply from local reservoirs in the East Bay Hills. EBMUD also has a contract with the U.S. Bureau of Reclamation to divert from the Central Valley Project which it diverts from the Sacramento River in dry years through Freeport Intake Facility that is available to meet water demands during droughts, and has developed the Bayside Groundwater Project to also meet water demands during droughts. Hayward obtains surface water from the SFPUC Tuolumne River system and has developed a system of emergency groundwater supply wells for potential use in the event the surface water supply is disrupted.

EBMUD and Hayward have extensive wastewater collection and treatment systems that cover the majority of the EBP Subbasin. Additional wastewater collection and treatment facilities are operated by the City of Richmond, Stege Sanitary District, City of San Leandro, and Oro Loma Sanitary District. Most treated wastewater is discharged to the San Francisco Bay. The remaining treated wastewater is part of the EBMUD and Hayward recycled water systems (some of the other smaller wastewater treatment facilities also provide some recycled water). Uses of recycled water includes large-scale irrigation projects (e.g., parks, golf courses) and industrial facilities (e.g., energy facility and refinery cooling). Local and imported water supplies are described in detail in **Appendix 2.A.b**.

2.2.2. Current and Historical Groundwater Conditions
(23 CCR Section 354.16)

Groundwater conditions include groundwater levels, groundwater storage, groundwater quality seawater intrusion, land subsidence, surface water/groundwater interaction, and GDEs. The following sections describe each element of groundwater conditions in detail.

2.2.2.1. Groundwater Levels

Groundwater elevations can vary with depth, so the aquifer system is divided into four depth intervals for characterization of groundwater levels and flow:

- **Upper Shallow Aquifer:** 0–50 ft bgs (Water Table Aquifer Zone, or upper portion of Shallow Aquifer Zone where stream/aquifer interaction occurs),
- **Lower Shallow Aquifer:** 50–200 ft bgs (middle to lower portion of Shallow Aquifer Zone)
- **Intermediate Aquifer:** 200–400 ft bgs (Intermediate Aquifer Zone)
- **Deep Aquifer:** Greater than 400 ft bgs (Deep Aquifer Zone)

Most groundwater supply wells are screened at depth intervals somewhere between the lower portion of the Shallow Aquifer Zone and the bottom of the Deep Aquifer Zone. Aquifer productivity generally increases with depth.

The spatial (geographic) and temporal (over time) distributions of historical groundwater level data are limited for all aquifer/depth zones. In general, the majority of wells with historical groundwater level data from the late 1950s to 1990s are groundwater supply wells in the southern EBP Subbasin. Most water level data collected since 2000 have come from monitoring wells throughout the entire Subbasin that are screened in the Shallow Aquifer Zone. However, during this time period, some data have also been collected for the Intermediate and Deep Aquifer Zones from EBMUD and Hayward monitoring and production wells in the southern EBP Subbasin. In general, overall groundwater flow is from the East Bay Hills toward San Francisco Bay, with local influences from pumping depressions.

Shallow Aquifer Zone

Available data for the Upper Shallow Aquifer (0-50 feet bgs) show the overall pattern of groundwater flow is from northeast to southwest following topography, although localized influences (e.g., utility trenches, streams, dewatering operations) tend to affect localized flow directions **(Figure 2-22)**. Groundwater elevation contour maps for other years, such as Spring/Fall 2002, 2008, and 2012, show similar elevations and groundwater flow patterns as maps for 2018 (**Appendix 2.A.b**).

Available data for the Lower Shallow Aquifer Zone (50–200 ft bgs) for various years in the area south of San Leandro Creek indicate that groundwater flows from the East Bay Hills toward San Francisco Bay and toward the southern boundary of the EBP Subbasin. Groundwater elevations typically range from about 40 ft above mean sea level (msl) near the East Bay Hills to about 0 ft above msl at the San Francisco Bay margin. Groundwater contour elevation maps for several years such as 1993, 2002, and 2018 (along with some years before 1990) are provided in **Appendix 2.A.b**.

Intermediate Aquifer Zone

Groundwater elevation contours for the Intermediate Aquifer Zone (200-400 ft bgs) for several representative years were prepared and are provided in **Appendix 2.A.b**. In general, before the 1990s, groundwater elevations were below sea level, with elevations highest near the East Bay Hills and lowest closest to the bay shoreline. The gradual recovery in Intermediate Aquifer Zone groundwater elevations continued into the early 1990s for most of the EBP Subbasin between Berkeley and Hayward; in spring 1993, the lowest groundwater elevations were in the range of -20 ft to -30 ft msl.

After the 1990s, Alameda County discontinued its groundwater monitoring program, and groundwater level data for the Intermediate Aquifer Zone became sparser than in previous years. To the extent that water level data are available after 2000, groundwater elevations in the Intermediate Aquifer Zone are indicated to generally be above sea level. Recent groundwater elevations (from spring 2018) indicate a range from about 10 ft msl near the East Bay Hills to about 0 ft msl near the San Francisco Bay margin in the southern EBP Subbasin.

Deep Aquifer Zone

Groundwater level data are sparse for wells with depths greater than 400 ft; for many years, only one or two data points are available. Thus, maps prepared for **Appendix 2.A.b** have available data plotted to provide some indication of groundwater levels, but contours of groundwater elevations were not drawn. In general, the available data were limited to the southern portion of the Subbasin. A greater number of data points were available for the Deep Aquifer Zone starting in 2000, although available data remained limited to the southern one-third of the Subbasin.

Data for Spring 2002 indicated that Deep Aquifer Zone groundwater elevations ranged from about 30 ft above msl to about -10 ft below msl (**Figure 2-23**). The Spring 2002 map has limited data points, but the data generally show higher elevations near San Leandro Creek, with decreasing elevations (and groundwater flow) toward the south in the Hayward and Union City areas. The Fall 2002 map is generally similar to the Spring 2002 map, but more available data in the southern EBP Subbasin indicate a component of flow toward San Francisco Bay and toward the south within the EBP Subbasin. Groundwater elevations in the Deep Aquifer Zone for Spring 2018 show a relatively narrow range of groundwater elevations, from about -5 ft msl to 10 ft above msl for most wells. The hydraulic gradient has a relatively gentle slope from east to west (**Figure 2-24**). Deep Aquifer Zone groundwater elevations for the Fall 2018 generally ranged from -20 ft below msl to 0 ft above msl, with most data clustered between -4 below msl and 1 ft above msl.

Groundwater Hydrographs for Various Aquifer Zones

Groundwater hydrographs for selected individual wells in various depth zones are provided in **Appendix 2.A.b**. A map with an inset hydrograph of groundwater levels and a composite hydrograph illustrates how groundwater levels in the EBP Subbasin have fluctuated over time (**Figures 2-24 and 2-25**). Heavy groundwater pumping in the 1950s and early 1960s caused groundwater elevations in the Intermediate and Deep Aquifer Zones to fall well below sea level in the southern portion of the Subbasin. Beginning in the mid-1960s, groundwater pumping (by Hayward and for other industrial/irrigation uses) was reduced substantially, which resulted in a long-term recovery in groundwater levels in the Intermediate and Deep Aquifer Zones from the mid-1960s to the 1990s (**Figures 2-25 and 2-26**).

Also, although groundwater elevations in the Intermediate and Deep Aquifer Zones were substantially below sea level from the 1950s through 1970s, when considerably more groundwater pumping took place than occurs today, groundwater elevations in the Shallow Aquifer Zone were substantially higher and were generally maintained above sea level, a condition that has continued to the present day. Groundwater elevations in all aquifers have been relatively stable (at or above mean sea level) over the past 10–20 years. The composite hydrograph (**Figure 2-26**) provides a further indication of the hydraulic isolation of the Intermediate and Deep Aquifer Zones from the Shallow Aquifer Zone that is illustrated in the geologic cross sections described in Section 2.2.1.3.

Figures 2-27 and 2-28 show maps with inset groundwater level hydrographs and a composite hydrograph for water levels in the Shallow Aquifer Zone throughout the EBP Subbasin over the past 20 years. These hydrograph figures demonstrate that shallow groundwater levels in both the northern and southern portions of the EBP Subbasin have been maintained above sea level in the recent years for which data are available.

2.2.2.2. Groundwater Storage

DWR (1994) provided estimates of total groundwater storage capacity (from the ground surface to the base of alluvium), total groundwater in storage (from the water table to the base of alluvium), and total usable groundwater storage capacity (the volume of groundwater in storage above sea level). Total groundwater storage capacity was estimated to be 2,670,000 acre-feet (AF), which is based on an average equivalent specific yield of about 6%. Total groundwater volume in storage was estimated to be 2,560,000 AF, which is based on an average depth to water of 25 ft (range of 5–40 ft) and an average specific yield of 6%. Total usable storage capacity was estimated to be 80,000 AF, which represents the volume of groundwater in storage in the Shallow Aquifer Zone above msl.

As described in **Appendix 2.A.b**, the area covered by DWR's calculations differs significantly from the EBP Subbasin as defined in this GSP. The general approach used by DWR (1994) to calculate changes in groundwater storage was applied to the area within the current EBP Subbasin boundaries. The calculated total groundwater storage capacity for the entire EBP Subbasin is 2,280,000 AF, and total groundwater in storage beneath the water table was calculated to be 2,173,000 AF. Overall, the DWR study area for the groundwater storage calculations was approximately 5% larger than the current area of the EBP Subbasin.

The total usable storage capacity as calculated by DWR (80,000 AF) is likely underestimated, given that groundwater levels in the Intermediate and Deep Aquifer Zones have historically been drawn down more than 100 ft below sea level for an extended period of years without causing seawater intrusion (see discussion in Section 2.2.2.4). Additional evaluation of groundwater storage was conducted using the calibrated groundwater model documented in **Appendix 6.E.** Evaluation of groundwater storage using the groundwater model indicated a total of 1,926,000 AF in the entire EBP Subbasin, with 233,000 AF in the northern EBP Subbasin and 1,693,000 AF in the southern EBP Subbasin. Within the southern EBP Subbasin, there is a total of 511,000 AF in the Shallow Aquifer Zone, and a total of 1,182,000 AF in storage in the Intermediate and Deep Aquifer Zones.

2.2.2.3. Groundwater Quality

SGMA defines significant and unreasonable degradation of water quality, including the migration of contaminant plumes that impair water supplies, as one of six sustainability indicators. The GSP and GSAs are not responsible for remediation of existing and historical poor groundwater quality in the EBP Subbasin; regulated sites are addressed by other ongoing programs and are under the jurisdiction of regulatory agencies such as the San Francisco Bay RWQCB and DTSC. However, the GSP is intended to document baseline conditions and identify projects or management actions that avoid significant and unreasonable degradation of groundwater quality caused by groundwater extraction and/or other projects planned for ongoing groundwater sustainability (e.g., injection, environmental uses of groundwater).

Maps of available groundwater quality data for key groundwater quality constituents (TDS, chloride, nitrate, arsenic, and manganese) were prepared to characterize groundwater quality in the EBP Subbasin. **Table 2-4** lists each of the constituents and why the constituent was chosen to highlight groundwater quality.

Table 2-4. Key Groundwater Quality Constituents Selected for Characterizing the EBP Subbasin

Constituent	Reason Selected
Total Dissolved Solids (TDS)	Provides an indication of the overall quality of the groundwater and suitability for municipal, domestic, industrial, irrigation, and other water supply purposes.
Chloride	Provides a useful indicator for seawater intrusion.
Nitrate	Provides a useful indicator of the potential impact of wastewater treatment and disposal system (e.g., septic tanks, percolation ponds), fertilizer application, and livestock operations.
Arsenic	A naturally occurring constituent that was included to provide an indication of suitability for municipal, domestic, industrial, irrigation, and other water supply purposes
Manganese	A naturally occurring constituent that was included to provide an indication of suitability for municipal, domestic, industrial, irrigation, and other water supply purposes

Wells with groundwater quality data were classified into four different depth categories in the same manner as for groundwater level data: less than 50 ft bgs (Water Table Aquifer Zone or Upper Shallow Zone), 50–200 ft bgs (Lower Shallow Aquifer Zone), 200–400 ft bgs (Intermediate Aquifer Zone), and deeper than 400 ft (Deep Aquifer Zone). Separate maps were prepared for each of the four different aquifer depth zones, and a single map was prepared showing all wells deeper than 50 ft bgs. The map for wells deeper than 50 ft bgs includes wells with unknown construction and composite wells.

The five primary inorganic constituents described above were evaluated in detail, with maps showing the distribution of each constituent in the EBP Subbasin by aquifer. Maps were prepared to show average and maximum concentrations for each of the five constituents for the Shallow, Intermediate, and Deep Aquifer Zones. Additional water quality maps are provided in **Appendix 2.A.b**.

The key constituents listed in Table 2-3 are described below followed by a discussion of existing and historical contaminants.

<u>TDS, Chloride, and Nitrate</u>

The maps of average TDS and chloride concentrations for all wells deeper than 50 ft (including wells with unknown depths) are similar. The maps indicate that areas of elevated concentrations[5] occur just south of the transition zone, in the northwest portion of Niles Cone Subbasin north of San Mateo Bridge adjacent to the EBP Subbasin, along the shoreline in western EBP Subbasin between Alameda Island and Bay Farm Island, in the middle to western portion of central Oakland, and in the Richmond area (**Figures 2-29 and 2-30**). The majority of wells with elevated TDS and chloride concentrations reflect conditions in the Shallow Aquifer Zone, although there also appear to be elevated TDS concentrations in deeper zones near Bay Farm Island.

Nitrate (as N) concentrations are generally greatest in the Shallow Aquifer Zone and lowest in the Deep Aquifer Zone. The map of average nitrate as nitrogen concentrations for all wells deeper than 50 ft (including wells with unknown depths) indicates that several wells exceed the primary MCL[6] (10 mg/L nitrate as N) throughout the Subbasin; however, a greater number of wells have nitrate concentrations below the MCL (**Figure 2-31**). A review of figures showing nitrate concentrations by depth zone, provided in **Appendix 2.A.b**, indicated that multiple wells have average and/or maximum concentrations of nitrate exceeding the MCL in the Shallow Aquifer Zone, but no wells classified as Deep Aquifer Zone have nitrate concentrations greater than 10 mg/L.

Several additional maps of TDS, chloride, and nitrate concentrations in different depth zones are provided in **Appendix 2.A.b**.

[5] For the purposes of this discussion, "elevated concentrations" generally refers to the occurrence of concentrations near or above the Secondary Maximum Contaminant Level (SMCL...). SMCLs serve as guidelines to assist public water systems in managing drinking water for aesthetic qualities such as taste, color, and odor. Recommended and maximum SMCLs are 500 milligrams per liter (mg/L) and 1,000 mg/L, respectively, for TDS and 250 mg/L and 500 mg/L for chloride.

[6] Primary MCLs are enforceable standards designed to protect the public from health risks. They represent the maximum allowable contaminant concentration in drinking water delivered to the consumer.

Arsenic and Manganese

The map of average arsenic concentrations for all wells deeper than 50 ft (including wells with unknown depths) indicate that multiple wells arsenic concentrations exceeding the primary MCL[5] occur in the South EBP Subbasin, and in a portion of Richmond near San Francisco Bay in the northern EBP Subbasin. (**Figure 2-32**). Elevated arsenic concentrations have been reported in at least one well in all three aquifer zones (**Appendix 2.A.b**).

Manganese concentrations are elevated throughout the EBP Subbasin (**Figure 2-33**) and in all three aquifer zones (**Appendix 2.A.b**). Manganese is a naturally occurring constituent that is prevalent in EBP Subbasin sediments, and often requires treatment for drinking water supplies.

Several additional maps of arsenic and manganese concentrations in different depth zones are provided in **Appendix 2.A.b**.

Existing and Historical Contaminants

A long history of commercial and industrial activities in the EBP Subbasin has resulted in the release of contaminants into the soil and groundwater system. To characterize the extent of contamination, a review of publicly available data from State of California databases was conducted. The GeoTracker database is the State Water Resources Control Board's (SWRCB) data management system for sites that affect, or have the potential to affect, water quality in California, with an emphasis on groundwater.

GeoTracker was used to plot the location of open contamination sites by site type in the Subbasin (**Figure 2-34**). Although contamination sites are distributed throughout the Subbasin, there is a denser concentration of sites in Emeryville, Oakland, Alameda, and northern San Leandro than in the rest of the Subbasin. Most contamination sites are classified as Cleanup Program Sites and Leaking Underground Storage Tank (LUST) Cleanup Sites; however, there are also several military-related sites in Alameda and western Oakland.

GeoTracker was also used to query groundwater quality data for the contamination sites of greatest concern within the EBP Subbasin, including for the following contaminants:

- Perchloroethene (PCE)
- Trichloroethene (TCE)
- Total petroleum hydrocarbons (TPH)
- Benzene, toluene, ethylbenzene, and xylenes (BTEX)
- Methyl tert-butyl ether (MTBE)
- Hexavalent chromium

The contaminants and dates selected for the query were based on the need to establish current baseline conditions for the most common and potentially impactful contaminants. The largest number of groundwater contamination sites in the EBP Subbasin (by number of sites) has resulted from the release of fuel-related contaminants (gasoline, BTEX, and MTBE) from leaking underground storage tanks. These fuel-related contaminants are typically found in the shallow groundwater system, as their density is lighter than water and they tend to "float" on the water table. As such, they pose less of a concern to groundwater resources than chlorinated solvents, which tend to sink, as their density is greater than that of water. **Appendix 2.A.b** provides maps and tabulated data for the TPH, BTEX, and MTBE groundwater contamination in the SBP Subbasin as of 2018–2019.

TCE and PCE are present at multiple locations in the EBP Subbasin. **Appendix 2.A.b** provides a summary of the sites with current TCE and PCE concentrations above the MCL of 5 µg/L. Current PCE and TCE groundwater contaminant concentrations in the Subbasin range from 0 µg/L to 8,800 µg/L and occur at depths between approximately 3 ft and 121 ft bgs (i.e., isolated to the Shallow Aquifer Zone). The highest concentrations occur at the Chevron Chemical site in the city of Richmond.

Additional data and maps for a variety of other groundwater quality constituents are presented in **Appendix 2.A.b**. Many of these maps highlight distinct areas of local groundwater contamination that should be considered when evaluating potential groundwater quality impacts from implementation of projects and management actions to achieve sustainability.

The environmental site information compiled in Appendix 2.A.b indicates that contaminant plumes in the EBP Subbasin are currently limited in size relative to the scale of the EBP Subbasin and limited to the upper portion of the Shallow Aquifer Zone. Groundwater pumping occurs primarily from the Intermediate and Deep Aquifer Zones, and is not expected to impact shallow contaminant plumes. The potential occurrence of new contaminant plumes that may develop in proximity to future GSA projects will be evaluated for potential influences from GSA activities as necessary.

Emerging Issue: PFOS/PFAS

The occurrence and distribution of per- and polyfluoroalkyl substances (PFAS) have become an emerging contaminant issue. According to the U.S. Centers for Disease Control and Prevention, PFAS have potential health effects related to cancer, liver damage, decreased fertility, asthma, and thyroid disease. No regulatory thresholds currently exist but some PFAS compounds have interim final environmental screening levels (ESLs) as non-regulatory guidance used to identify conditions for potential further investigation. A brief summary of currently available site information for the EBP Subbasin is provided below; additional updates on PFAS sites will be provided in future GSP update reports.

A review of available information on PFAS contaminants in the EBP Subbasin as of August 2021 revealed three reported sites located adjacent to San Francisco Bay in the EBP Subbasin: West Contra Costa Landfill (Richmond area), Oakland Airport, and West Winton Landfill (Hayward area). The West Contra Costa Landfill is located adjacent to biosolids drying lagoons for a wastewater treatment plant, and had perfluorooctanoic acid (PFOA) detected in shallow brackish groundwater from six wells (up to 47 feet deep) and perfluorooctane sulfonate (PFOS) detected in four of six wells (up to 21 feet deep) at concentrations consistent with the range expected in municipal solid waste leachate. No additional sampling was recommended as of July 2020 (Geosyntec, 2020). The Oakland Airport site report indicated detection of PFAS compounds in soil and groundwater (in monitoring wells up to nine feet deep) in four different areas of the site. Additional investigation was ongoing at the time of the latest available report (CH2M Hill, December 2020). The West Winton Landfill site has been evaluated under a SWRCB order for PFAS sampling of landfill leachate and groundwater. Relatively low concentrations of PFAS compounds were detected in shallow brackish groundwater from monitoring wells up to 27 feet deep (Wood, April 2020).

The SWRCB is actively pursuing efforts to evaluate and reduce human exposure to PFAS, including:

On February 16, 2021, DDW issued General Order DW-2021-0001-DDW for public water systems to sample and report PFAS within and adjacent to Department of Defense facilities in California.

On March 5, 2021, DDW issued a drinking water notification level and response level of 0.5 parts per billion (ppb) and 5 ppb, respectively for perfluorobutane sulfonic acid (PFBS).

On March 12, 2021, the State Water Board issued Investigative Orders to Refineries and Bulk Fuel Terminals (161) for a one-time sampling effort to determine whether soil, groundwater, surface water, and influent and effluent wastewater at their locations were impacted by PFAS. These Orders included the required sampling for 31 PFAS compounds.

On July 1, 2021, The Department of Toxic Substances Control (DTSC) designated carpets and rugs containing per- or polyfluoroalkyl substances (PFASs) that are manufactured in or imported to California as a Priority Product. This designation requires domestic and foreign carpet and rug manufacturers that use PFAS and related chemicals in their products to submit a Priority Product Notification (PPN) for the affected products by August 30, 2021, with the goal of reducing human exposure to PFAS.

On July 22, 2021, The Office of Environmental Health Hazard Assessment (OEHHA) announced the release of a draft document for public review describing Public Health Goals (PHGs) for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) in drinking water. A PHG is a non-regulatory level of a contaminant in drinking water that does not pose a significant health risk. The public comment period for the draft document begins July 30, 2021, and ends September 28, 2021.

The EBP Subbasin GSAs will continue to monitor new developments related to PFAS and coordinate with the RWQCB in evaluating potential impacts on the EBP Subbasin.

2.2.2.4. Seawater Intrusion

Generally, aquifers interfacing with seawater have the potential to experience seawater intrusion when groundwater levels decline below msl. However, geologic conditions and the connection between aquifers and the seabed are equally important in determining the potential occurrence of seawater intrusion. Thus, an evaluation of seawater intrusion potential requires a detailed understanding of both groundwater level conditions and geologic conditions relating to the nature and occurrence of aquifers and aquitards.

Figure 2-35 depicts conceptual seawater intrusion scenarios for aquifers in a coastal basin. Typically, an unconfined aquifer in a coastal groundwater basin can be subject to seawater intrusion when groundwater levels fall below sea level. In this case, there is no hydraulic barrier of fine-grained units to slow or prevent inland migration of saline water to pumping wells.

In a multilayered aquifer/aquitard system, similar to the EBP Subbasin, where an unconfined aquifer is underlain by confined aquifers, the potential for seawater intrusion is a function of both groundwater elevations (or pressure head in a confined aquifer) and stratigraphic relationships. If the confined aquifer outcrops or intersects the seabed, significant potential for seawater intrusion remains when the confined aquifer's pressure heads are maintained below sea level.

A confined aquifer is also susceptible to seawater intrusion when the confining layer(s) have thin spots or "holes," or when improperly abandoned wells form conduits between an upper unconfined aquifer that may be intruded and the confined aquifer. However, if a confined aquifer does not intersect the seabed and has adequate confining layer(s), it may be able to withstand long-term pressure heads below sea level without experiencing seawater intrusion.

The shallow and intermediate zones in the EBP Subbasin are primarily fine-grained without well-defined aquifers. As a result, saline bay water that may flow into the EBP Subbasin encounters shallow, disconnected coarse-grained zones that limit lateral inland flow and encounters substantial impedance to vertical flow from the presence of thick layers of fine-grained sediments such as clay.

Although seawater intrusion has occurred in locally small areas of the Shallow Aquifer Zone near the bay margin in the EBP Subbasin (as indicated in TDS maps provided in **Appendix 2.A.b**), seawater was generally unable to migrate downward into the Intermediate and Deep Aquifer Zones because of the presence of relatively thick and continuous clay layers. From at least the 1950s through the 1970s, groundwater elevations in the EBP Subbasin were substantially below sea level in the Intermediate and Deep Aquifer Zones; however, this extended period of low groundwater elevations in the Subbasin did not result in seawater intrusion into the Intermediate and Deep Aquifer Zones.

2.2.2.5. Land Subsidence

Land subsidence is a decline in ground surface elevation, which can occur from natural or human-induced causes. Natural causes of land subsidence include natural consolidation of sediment and tectonics (seismic activity); human-induced causes are numerous and include oil and gas extraction, geothermal energy development, and groundwater pumping (LSCE et al., 2014). Groundwater pumping induces subsidence when the pumping reduces fluid pressure, which causes fine-grained materials (clay/silt particles) to be rearranged (flatten), thereby resulting in the compaction (reduction in thickness) of a fine-grained layer (**Figure 2-36**).

The groundwater pumping–induced compaction that causes land subsidence can be either elastic or inelastic. *Elastic* compaction or deformation is reversible when fluid pressures increase again; by contrast, *inelastic* deformation from compaction at lower fluid pressures is permanent and will not be reversed with future increases in fluid pressure. Small amounts of seasonal elastic deformation are quite common and typically do not cause problems with infrastructure (e.g., production wells, canals, and building foundations). Permanent land subsidence can result if current groundwater pumping lowers groundwater levels below the lowest historical groundwater elevation (i.e., historic low).

Similar to seawater intrusion, land subsidence is an undesirable result that can occur with certain groundwater level and geologic conditions. Although the groundwater level conditions that can lead to seawater intrusion are similar to those that can lead to land subsidence (i.e., significant declines in groundwater elevation), the geologic conditions conducive to land subsidence are different. In general, thick and continuous clay layers can serve as important aquitards to help prevent seawater intrusion; however, these same thick, continuous clay layers may provide geologic conditions susceptible to land subsidence.

It is important to recognize that some clay layers are much more susceptible to compaction (and thus to land subsidence) than others. Some groundwater basins have 200 ft or more of decline in groundwater elevations yet have not experienced significant subsidence. Thus, it is very important to understand the properties of clay layers when evaluating land subsidence. Although land subsidence has not been documented historically or reported as being a problem in the EBP Subbasin, the potential for future increased pumping of the Subbasin's Deep Aquifer system requires further evaluation and management of the potential for land subsidence.

The future potential for land subsidence in the EBP Subbasin as a result of groundwater withdrawal would exist only in areas where future groundwater levels are drawn down below historic lows. Information available to evaluate the potential for subsidence in the EBP Subbasin includes conditions when groundwater levels were at their historical lows, extensometer data collected during an eight-week regional pumping test completed in 2010, well logs and geologic cross sections, and clay properties documented by USGS (2015). These data and other information on subsidence are discussed in more detail in **Appendix 2.A.b**.

Available data indicate that the EBP Subbasin is not particularly susceptible to land subsidence. Nonetheless, land subsidence has at least the potential to occur should pumping cause groundwater levels to fall below historical lows.

2.2.2.6. Surface Water/Groundwater Interaction

The characterization of surface water/groundwater interactions is dependent on the availability of streamflow data, shallow groundwater level data, and an understanding of stratigraphic relationships within the EBP Subbasin. Available data relative to these three key data components are described in **Appendices 2.A.a and 2.A.b**. This section provides an overview of surface water/groundwater interactions, which is a key sustainability indicator and is important for assessment of GDEs.

The general occurrence and distribution of the major aquifers and aquitards in the EBP Subbasin are described in Section 2.2.1.3. The Upper Shallow Aquifer (i.e., the upper 50 ft of sediments or Water Table Aquifer Zone), where the streams interact most directly with and recharge/discharge to shallow groundwater, can generally be characterized as having a greater proportion of fine-grained sediments (clay and silt) with interbedded and discontinuous lenses of coarse-grained deposits (sand and gravel). A review of lithologic logs for shallow boreholes that emphasize characterization of the shallow zone lithology (e.g., environmental sites) indicates that the shallow zone's stratigraphy is quite variable among different streams and at different locations along the same stream.

As described in Section 2.2.2.1, available groundwater level data have been evaluated for four different depth zones: 0–50 ft, 50–200 ft, 200–400 ft, and greater than 400 ft. A review of hydrogeologic conditions in the EBP Subbasin in terms of geology and groundwater levels indicates that groundwater levels within the Upper Shallow Aquifer Zone are generally shallow **(Figure 2-37)**. In general, depths to groundwater in the Upper Shallow Aquifer Zone are less than 20 ft bgs in most of the EBP Subbasin, although there are some areas with groundwater levels between 20 ft and 30 ft bgs or more. Overall, depth to groundwater generally decreases from northeast (near the East Bay Hills) to southwest (San Francisco Bay) across the Subbasin, albeit with significant local variations. Thus, it can be expected that the potential for surface water/groundwater connection increases from east to west. In addition, where a surface water/groundwater connection is present, it can be expected that losing conditions are more likely in the eastern portion of the Subbasin and gaining conditions have more potential to occur in the western portion of the Subbasin. It should also be noted that portions of creek lengths are lined within the EBP Subbasin; particularly, for San Lorenzo Creek where a majority of the creek bed is lined until about one mile inland from the Bay Margin.

2.2.2.7. Groundwater Dependent Ecosystems

SGMA requires GSAs to identify GDEs in their GSPs and to consider impacts on GDEs when managing groundwater. GDEs are defined under SGMA as "ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (23 CCR Section 351[m]). GDE types include seeps and springs; wetlands and lakes; terrestrial vegetation connected to shallow groundwater; and rivers, streams, and estuaries.

A detailed analysis of potential GDEs was conducted in accordance with guidance from The Nature Conservancy (TNC) and is described in detail in **Appendix 2.A.b**. The analysis resulted in identification of potential GDEs covering a total of 147 acres (**Table 2-5** and **Figure 2-38**). Potential GDEs were concentrated around four waterways: San Pablo Creek, San Leandro Creek, Wildcat Creek, and Arroyo Viejo; and to a lesser extent, in wetlands located in Richmond. San Pablo Creek made up the majority of potential GDE area, totaling 127 acres.

Table 2-5. Potential Groundwater Dependent Ecosystems

Waterway/Tributary	Habitat Classification Based on Imagery Analysis	Area (acres)
San Leandro Creek	Riparian Mixed Shrub/Hardwood	7.1
San Pablo Creek	Riparian Mixed Hardwood	32.2
Unnamed wetland	Riparian Mixed Hardwood	1.4
Wildcat Creek	Riparian Mixed Hardwood	1.3
San Pablo Creek	Riparian Mixed Hardwood	5.7
San Pablo Creek	Riparian Mixed Hardwood	19.9
San Pablo Creek	Riparian Mixed Hardwood	60.5
San Pablo Creek	Riparian Oak Woodland	8.9
Arroyo Viejo	Riparian Mixed Hardwood	6.9
Arroyo Viejo	Riparian Mixed Hardwood	2.8
	Total	**147**

Available data indicate that historical groundwater pumping from the Intermediate and Deep Aquifer Zones in the southern EBP Subbasin may have had minimal effects on the shallow zone's groundwater levels; however, there are no historical data on groundwater pumping and shallow groundwater levels for a similar assessment in the northern EBP Subbasin. Subsequent chapters of this GSP provide additional evaluation of potential impacts on GDEs.

2.2.3. Water Budget Information

(23 CCR Section 354.18)

A water budget is a tabulation of all the components of inflow (recharge) and outflow (discharge) from the groundwater basin. Data collected during water budget calculations were summarized in **Appendices 2.A.a and 2.A.b**. This section describes the approach to the water budget analysis, identifies the water budget analysis period, and quantifies recharge and discharge (i.e., inflow and outflow) components for both historical, current, and projected future conditions. While the water balance presented in this section focuses on the groundwater system water budget, the surface water (imported surface water and local streamflow) contributions to groundwater recharge are included in the water budgets described below. However, a separate accounting of the surface water system budget that provided input to the groundwater system budget described below is provided in **Appendix 2.A.f.**

2.2.3.1. Water Budget Analysis Approach

The water budget evaluation for this GSP is based on results of previous studies and additional analyses to verify and/or update previous calculations. Water budget components that were derived before and independent of the groundwater model are described in detail in **Appendix 2.A.b** and summarized in this section of the GSP. These components were used as initial input to the groundwater model and were subsequently modified to some extent during the model calibration process. Because certain components of a water budget require output from a model (e.g., lateral subsurface inflow/outflow), the initial, pre-model water budget did not include these components. The final water budget for the GSP was derived from the calibrated model, which is described in detail in **Appendix 6.E**. The results of the modeled water budget are also summarized in this section, along with a comparison of the pre- and post-modeled water budgets.

The primary components of groundwater recharge in the EBP Subbasin are:

- Rainfall infiltration,
- Streamflow infiltration (i.e., losing streams),
- Leaking pipes from water and sewer systems,
- Irrigation return flows, and
- Inflow from fractured bedrock (not accounted-for in previous studies).

The primary components of groundwater discharge in the EBP Subbasin include:

- Groundwater pumping,
- Subsurface outflow towards San Francisco Bay,
- Net inflow/outflow across the southern EBP Subbasin's boundary with the Niles Cone (new, not accounted-for in previous studies),
- Streamflow discharge (i.e., gaining streams), and

- Sewer pipe outflow (i.e., groundwater entering non-pressurized systems).

As noted above, inflow from bedrock and net inflow/outflow across the southern EBP Subbasin's boundary with the Niles Cone were either discounted or not included in previous studies. Based on the LSCE Team's experience with studies in other basins and a review of DWR well logs for the East Bay Hills, groundwater present in fractured bedrock should be included as a component of inflow to the groundwater basin. Net inflow/outflow between the EBP Subbasin and Niles Cone is important and can be best estimated using a groundwater model; hence, the new groundwater model was used as a tool to quantify components of the water budget.

2.2.3.2. Water Budget Analysis Period

Precipitation records for three stations with relatively long periods of record were reviewed for average annual precipitation and the occurrence of wet, normal, and dry years. Cumulative departure from mean curves were prepared to evaluate the occurrence of different water year types and to select a representative hydrologic period (**Appendix 2.A.b**). A review of precipitation data since 1950 for three stations (Richmond, Berkeley, and San Leandro) in the EBP Subbasin generally shows an average rainfall period from 1951 to 1958, followed by sequences of overall dry and wet years. Dry-year sequences occurred in 1959–1966, 1974–1977, 1984–1994, and 2007–2015. Wet-year sequences occurred in 1967–1973, 1978–1983, 1995–2006, and 2016–2019.

Based on review of the departure from mean curves, the 26-year period from 1990 to 2015 was selected for the historical water budget analysis period for the following reasons:

- It begins and ends with dry years, when the amount of water in transit within the vadose (unsaturated) zone is minimal;
- Rainfall during this period is close to long-term average conditions, which provides a time period representative of long-term average hydrologic conditions;
- This period includes a range of hydrologic conditions (dry, wet, average), which helps for the model calibration and evaluation of hypothetical scenarios.

2.2.3.3. Initial Quantification of Recharge and Discharge Components

The primary components of recharge in the EBP Subbasin that require quantification are rainfall infiltration, excess infiltration of applied irrigation water, streamflow infiltration, pipe leakage, bedrock inflow, and lateral subsurface inflows. The primary discharge components in the Subbasin that require quantification are groundwater pumping, lateral subsurface outflows, discharge to streams, and sewer pipe outflow.

Most of these recharge and discharge components were quantified initially to provide input to the groundwater model. Each water balance component was evaluated further during development and calibration of the groundwater model. **Table 2-6** and **Table 2-7**, respectively, summarize initial quantification of the recharge and discharge components of the water balance. More detailed information about the derivation of each water balance component is provided in **Appendix 2.A.b**.

Table 2-6. Initial Quantification of Recharge Components for the Historical Water Balance

Inflows	Average Annual (AFY[1])	Potential Range	Comments
Rainfall Infiltration	4,800	3,000–8,000	Builds on Muir (1994) analysis, with refinements to the San Lorenzo/San Leandro areas and inclusion of the Richmond area.
Irrigation Return Flows—Large Parcels	750	500–1,000	Based only on area of relatively large, irrigated parcels (e.g., parks, golf courses, cemeteries), 2.5 ft of applied irrigation water, and 15% return flows.
Irrigation Return Flows—Residential Parcels	1,600	1,000–2,000	Based only on area of residential properties, after removal of building/road area, assumes one-third of remaining area irrigated, 2.0 ft of applied irrigation water, and 10% return flows.
Leaking Pipes - Water	4,350	2,000–7,500	Based on Muir analysis for 1990s and water audit data for 2017, assumes 50% of annual leakage is lost to evapotranspiration by trees, utility trench inflow, runoff to storm drains, etc.
Leaking Pipes - Sewer	3,000	1,500–5,000	Based on Muir analysis for 1990s, wastewater treatment plant data for 2015, and a sewer pipe leak rate estimated to be 5%. The estimate was reduced by one-third to account for losses via evapotranspiration, utility trench inflow, etc.
Stream Infiltration	2,350	1,000–5,000	Based on review of previous studies and data, estimated infiltration rates of 0.5 to 0.8 cfs[2]/mile for unlined stream channels.
Fractured Bedrock	2,600	1,000–4,000	Darcy's Law calculation based on bedrock WCR specific capacity data. For comparison, 2,600 AFY of bedrock inflow equates to 0.9 inches per year of recharge over 34,000 acres of hills bordering the subbasin (3% to 4% of average annual rainfall) in adjacent bedrock areas.
Recharge Totals	**19,450**	**10,000–32,500**	--

1 AFY = acre-feet per year.
2 cfs = cubic feet per second.

Table 2-7. Initial Quantification of Discharge Components for the Historical Water Balance			
Outflows	Average Annual (AFY)	Potential Range	Outflows
Groundwater Pumping	3,150	2,000–4,000	Based on analyses conducted by Muir (1996), EBMUD (2018), and WRIME (2005).
Subsurface Outflow towards San Francisco Bay	13,500	8,000–17,000	Based on estimate by Muir (1996); refined value was determined during model development/ calibration; value can vary widely (and possibly outside listed range) depending on amount of groundwater pumping.
Stream Outflow and Sewer Pipe Outflow	2,800	500–4,000	Calculated as residual of water balance; will be determined during model development and calibration; value can vary widely (and possibly outside the listed range) depending on amount of groundwater pumping.
Discharge Totals	**19,450**	**10,500–25,000**	

The EBP Subbasin has not undergone significant changes that would change the water balance since 1990, in terms of either land use or other factors. The Subbasin's urban, commercial, and industrial uses were largely developed by 1990, and subsequent changes have been relatively minor (see Section 2.1.3). As of 1990, sources of water supply for the Subbasin were dominated by surface water imported by EBMUD and from Hetch Hetchy (for Hayward), a condition that continues today. Groundwater pumping for industrial, agricultural/irrigation, and domestic uses has remained relatively steady from the 1990s to present. Therefore, the current water budget is essentially the same as the historical water budget.

Total recharge (and discharge) in the EBP Subbasin was initially estimated to be approximately 19,450 AFY under historical (1990 to 2015) and current conditions. Various components of the water balance were modified as part of the model calibration phase. The final water balance derived from the calibrated groundwater flow model is described below and in **Appendix 6**.

2.2.3.4. Final Quantification of Recharge and Discharge Components

The initial estimates for the historical budget summarized in **Tables 2-6 and 2-7** provided the basis for initial inputs to the groundwater model that is described in **Appendix 6**. Some additional work was conducted as part of model development to develop the annual variation in rainfall recharge based on fluctuations in rainfall over the historical model calibration base period. In addition, stream recharge and discharge were not direct inputs to the model, but rather were simulated in the model to quantify these components (as a function of differences between shallow groundwater levels and stream stage). Stream recharge and discharge are more of an output from the modeling calibration effort than an input during model development. This is also the case for the amount of subsurface outflow to San Francisco Bay. During calibration of the groundwater model, aquifer parameters (e.g., hydraulic conductivity, storage coefficient) and water balance components were adjusted to optimize the match between model-simulated and observed (field-measured) groundwater levels. As a result of groundwater model calibration, some modest adjustments were made to initial water budget model inputs to achieve a final water budget for the historical calibrated model. The final modeled historical water balance is described in detail in **Appendix 6.E** and summarized in **Tables 2-8 and 2-9**.

Table 2-8. Initial and Final Quantification of Recharge Components for the Historical Water Balance

<table>
<tr><th>Inflows</th><th>Initial Average[1] Annual (AFY)</th><th>Final Transient Average[2] Annual (AFY)</th><th>Difference of Initial and Final (AFY)</th><th>Comments</th></tr>
<tr><td>Precipitation Recharge</td><td>4,800</td><td rowspan="5">14,400</td><td rowspan="5">-100</td><td rowspan="5"></td></tr>
<tr><td>Excess Irrigation Recharge—Large Parcels</td><td>750</td></tr>
<tr><td>Excess Irrigation Recharge—Residential Parcels</td><td>1,600</td></tr>
<tr><td>Water Pipe Leaks</td><td>4,350</td></tr>
<tr><td>Sewer Pipe Leaks</td><td>3,000</td></tr>
<tr><td>Stream Infiltration</td><td>2,350</td><td>2,500</td><td>+150</td><td></td></tr>
<tr><td>Bedrock Inflow</td><td>2,600</td><td>1,850</td><td>-750</td><td></td></tr>
<tr><td>Inflow from Niles Cone</td><td>NE[3]</td><td>950</td><td>NA[4]</td><td>When combined with outflow (Table 2-9), there is a net outflow from EBP to Niles Cone of 1,450 AFY.</td></tr>
<tr><td>Total</td><td>19,450</td><td>18,750</td><td>-700</td><td>Totals do not include inflow from Niles Cone</td></tr>
</table>

[1] Derived from analyses presented in **Appendix 2.A.b**; represents initial estimate of historical (1991-2015) water budget

[2] Derived from calibrated groundwater model presented in **Appendix 6.E**; based on transient (1991-2015) groundwater model run; represents final estimate of historical (1991-2015) water budget

[3] Not Estimated

[4] Not Applicable

Table 2-9. Initial and Final Quantification of Discharge Components for the Historical Water Balance

Discharges	Initial Average[1] Annual (AFY)	Final Transient Average[2] Annual (AFY)	Average Annual Difference (AFY)	Comments
Groundwater Pumping	3,150	3,850	+700	
Subsurface Outflow toward San Francisco Bay	13,500	8,450	-5,050	This difference is related, in part, to the increase in groundwater storage from 1991 to 2015.
Stream Discharge and Sewer Pipe Outflow	2,800	2,950	+150	
Outflow to Niles Cone	NE[3]	2,350	+2,350	This difference should be combined with difference in Subsurface Outflow toward SF Bay
Total	**19,450**	**17,600**	**-1,850**	

[1] Derived from analyses presented in **Appendix 2.A.b**; represents initial estimate of historical (1990-2015) budget.

[2] Derived from calibrated groundwater model presented in **Appendix 6.E**; based on transient (1991-2015) groundwater model run; represents final estimate of historical (1991-2015) water budget.

[3] Not Estimated (NE): this component is effectively incorporated into the estimate of Subsurface Outflow toward San Francisco Bay.

2.2.3.5. Future Projected Water Budget

The future projected water budget includes the anticipated influences of climate change, land use changes, and changes related to implementation of GSA projects and management actions. The analysis of each of these components is described briefly in this section, and additional details are provided in other sections and appendices of this GSP.

2.2.3.5.1. *Climate Change*

Several documents describing climate change in California, the San Francisco Bay region, and the East Bay Plain Subbasin were reviewed as described in **Appendix 6.D**. The anticipated effects of future climate change were considered both in terms of expected sea level rise and expected changes in hydrology (i.e., precipitation, evapotranspiration or ET, and streamflow). Projections of sea level rise expected by 2070 include significant uncertainty, with estimates ranging from 1.5 to 3.5 feet by 2070. The DWR climate change guidance document was given greater weight and provides an estimated sea level rise of 1.5 feet by 2070. However, this GSP uses a slightly greater assumed sea level rise of 2.0 feet by 2070, which is conservative and includes consideration of other studies indicating somewhat higher estimates of sea level rise.

Several climate changes studies were also reviewed with respect to anticipated changes in various components of hydrology, including precipitation, ET, and streamflow; the results are documented in **Appendix 6.D**. Overall, these studies indicate a tendency towards greater precipitation and streamflow along with higher ET. The DWR climate change guidance included specific change factors for the EBP Subbasin with regard to all three hydrologic components (**Appendix 6.D**). The change factors indicate a higher percentage of increase for precipitation than for ET, especially in the key months of December to March when most groundwater recharge occurs. In addition, future streamflow is expected to be greater than historically. However, there is significant uncertainty is associated with these change factors, and to be more conservative in the implications of future hydrology for groundwater conditions, groundwater recharge and streamflow in the future were assumed to remain the same as historical levels (i.e., less recharge and streamflow than forecasted) for analysis in this GSP.

2.2.3.5.2. *Land Use Changes*

A detailed review of several land use planning documents and General Plans covering the EBP Subbasin is provided in Appendix 2.A.e and a brief summary is provided in Section 2.1.3. As described in these other sections, vacant land typically comprises less than 5% of the total land area, with potentially developable vacant land on the order of 2% of total land area. The majority of future population growth is expected to occur via redevelopment. Furthermore, green infrastructure is emphasized in all land use and general plans, including retention/detention and percolation of storm runoff and use of pervious pavement that likely will locally increase groundwater recharge. Overall, the net effect of anticipated land use changes and the emphasis on green infrastructure is most likely to increase overall groundwater recharge across the EBP Subbasin as a whole. Even if a net increase in impervious area of 2% is assumed, the net decline in groundwater recharge would only be on the order of 100 AFY (based on a 2% reduction in the total area subject to precipitation recharge; 44,864 ac x 0.02 = 900 ac x .107 AFY/ac = 96 AFY reduction). This small change in total groundwater recharge is due, in part, to the fact that precipitation recharge only accounts for approximately 25% of total recharge to the EBP Subbasin and is the primary recharge component that would be reduced by an increase in impervious area.

2.2.3.5.3. *Projected Future Water Budget*

Projected future water budgets were derived from the groundwater model after accounting for anticipated climate change and land use changes as described above. In addition, future water budgets were estimated both without GSA groundwater development projects (i.e., baseline) and with GSA projects (i.e., future scenario with projects). **Table 2-10** shows recharge components for the projected future model runs compared to the historical and current model water budgets. The historical water budget period is 1991 to 2015, the current water budget period is 2016 to 2021, and the projected future water budgets cover the period from 2022 to 2071. Differences in recharge components among these various water budgets are relatively small and illustrate the relatively stable groundwater conditions in the EBP Subbasin.

<table>
<tr><th colspan="5">Table 2-10. Recharge Components for Historical, Current, and Projected Water Balances</th></tr>
<tr><th>Inflows</th><th>Final Historical Transient Average[1] Annual (AFY)</th><th>Final Current Transient Average[2] Annual (AFY)</th><th>Projected Future Baseline[3](AFY)</th><th>Project Future Scenario with Projects[4] (AFY)</th></tr>
<tr><td>Precipitation Recharge</td><td rowspan="5">14,400</td><td rowspan="5">14,300</td><td rowspan="5">14,400</td><td rowspan="5">14,400</td></tr>
<tr><td>Excess Irrigation Recharge—Large Parcels</td></tr>
<tr><td>Excess Irrigation Recharge—Residential Parcels</td></tr>
<tr><td>Water Pipe Leaks</td></tr>
<tr><td>Sewer Pipe Leaks</td></tr>
<tr><td>Stream Infiltration</td><td>2,500</td><td>2,550</td><td>2,400</td><td>2,400</td></tr>
<tr><td>Bedrock Inflow</td><td>1,850</td><td>1,850</td><td>1,850</td><td>1,850</td></tr>
<tr><td>Injection</td><td>0</td><td>0</td><td>0</td><td>50</td></tr>
<tr><td>Inflow from Niles Cone</td><td>950</td><td>775</td><td>650</td><td>750</td></tr>
<tr><td>Total</td><td>19,700</td><td>19,475</td><td>19,300</td><td>19,450</td></tr>
</table>

[1] Derived from calibrated groundwater model presented in **Appendix 6.E**; based on transient (1991-2015) groundwater model run; represents final estimate of historical (1991-2015) water budget.

[2] Derived from calibrated groundwater model presented in **Appendix 6.E**; based on the transient (2016-2021 conditions) groundwater model run; represents final estimate of current water budget.

[3] Derived from calibrated groundwater model presented in **Appendix 6.E**; base on the transient (2022-2071) groundwater model run; represents projected future water budget baseline without GSA projects.

[4] Derived from calibrated groundwater model presented in Appendix 6.E; base on the transient (2022-2071) groundwater model run; represents projected future water budget baseline with GSA projects.

Table 2-11 shows water budget discharge components for the simulations of future conditions compared to the historical and current conditions. The primary differences are an increase in groundwater discharge to San Francisco Bay from historical conditions to current and projected future conditions (primarily due to ongoing recovery of groundwater levels in the 1990s and early 2000s from previous lows), and a slight increase in stream discharge and sewer pipe outflow under projected future conditions due to rising sea level. In addition, the model simulations show no difference between groundwater discharge to streams for the baseline future simulation and the groundwater resources development scenario: both of the 50-year transient simulations show an average total stream discharge of 3,625 AFY**.** Total recharge and total discharge to/from the EBP Subbasin show minimal changes (250 AFY or less out of about 19,500 AFY) between current and projected future water balance conditions**.**

Table 2-11. Discharge Components for Historical, Current, and Projected Future Water Balances

Discharges	Final Historical Transient Average[1] Annual (AFY)	Final Current Transient Average[2] Annual (AFY)	Projected Future Baseline[3] (AFY)	Project Future Scenario with Projects[4] (AFY)
Groundwater Pumping	3,825	3,625	3,625	3,900
Subsurface Outflow toward San Francisco Bay	8,425	10,050	9,750	9,700
Stream Discharge and Sewer Pipe Outflow	2,975	3,100	3,625	3,625
Outflow to Niles Cone	2,325	2,225	2,025	2,025
Total	**17,550**	**19,000**	**19,025**	**19,250**

[1] Derived from calibrated groundwater model presented in **Appendix 6.E**; based on transient (1991-2015) groundwater model run; represents final estimate of historical (1991-2015) water budget.

[2] Derived from calibrated groundwater model presented in **Appendix 6.E**; based on the transient (2016-2021 conditions) groundwater model run; represents final estimate of current water budget.

[3] Derived from calibrated groundwater model presented in **Appendix 6.E**; base on the transient (2022-2071) groundwater model run; represents projected future water budget baseline without GSA projects.

[4] Derived from calibrated groundwater model presented in **Appendix 6.E**; base on the transient (2022-2071) groundwater model run; represents projected future water budget baseline with GSA projects.

2.2.3.6. Sustainable Yield

The estimate of sustainable yield is based on

- previous studies (Muir, 1996; Norfleet, 1998),
- the water balance analysis provided in the GSP HCM (**Appendix 2.A.b**), and
- the groundwater model developed for this GSP.

Muir conducted studies in the 1990s on the Alameda County portion of the EBP Subbasin from Berkeley in the north to Hayward in the south. Muir prepared three studies on recharge (1994), discharge (1996), and groundwater yield (1996), which are all summarized in **Appendix 2.A.b**. Muir defined the "yield of the groundwater reservoir" in the East Bay Plain to be based on the amount of groundwater that could be pumped "…year after year without decreasing groundwater in storage to the point where the intrusion of seawater from San Francisco Bay would occur." Muir (1996) concluded that the groundwater yield of the East Bay Plain was approximately 10,000 AFY. The area covered by Muir's study is the pre-2016 southern EBP Subbasin boundary in the south to the Alameda County line in the north and did not include the portion of the EBP Subbasin north of Berkeley.

Norfleet (1998) documented historical groundwater use in the East Bay Plain, including in the Richmond area at the northern end of the EBP Subbasin in an area that was not included in Muir's study. Records of total groundwater pumping in the Richmond area prior to 1930 indicated total groundwater pumping as high as 3 to 4 MGD (equivalent to 2,100 to 2,800 gpm, or 3,400 to 4,500 AFY). However, it was determined that this pumping rate was not sustainable, and that the "safe yield" for the Richmond area was approximately 2 MGD (1,400 gpm or 2,200 AFY). The areas covered by the Muir (1996) and Norfleet (1998) reports did not include the area between Berkeley and Richmond (i.e., El Cerrito and Albany).

The water balance analysis conducted for this GSP (and documented in **Appendix 2.A.b**) included various components of recharge (infiltration from precipitation, infiltration from applied irrigation water, stream infiltration, pipe leaks, and bedrock inflow) and discharge (groundwater pumping, discharge towards the Bay, discharge to streams, sewer inflow/infiltration). The initial estimate of total recharge comprising the five major recharge components was 19,450 AFY. The estimated total discharge was also 19,450 AFY with groundwater pumping accounting for 3,150 AFY, subsurface outflow towards the Bay accounting for 13,500 AFY, and the remaining amount of 2,800 AFY is associated with stream discharge and sewer pipe outflow. Allowing for a relatively large and conservative subsurface outflow of 4,000 to 5,000 AFY towards the Bay and 3,000 AFY for stream discharge/sewer outflow indicates sustainable yield may be on the order of 12,000 to 13,000 AFY.

The EBP Subbasin groundwater model developed for this GSP used a steady-state groundwater model run to evaluate sustainable yield for the EBP Subbasin. Hypothetical wells were distributed fairly evenly over the extent of the Subbasin, and pumping rates were assigned in proportion to transmissivity of the major aquifers at each well location. The assigned pumping rates were adjusted in three areas (northern EBP Subbasin, and the northern and southern areas of the southern EBP Subbasin) to satisfy three criteria to estimate the sustainable yield:

1. Maintain simulated groundwater elevations in the Shallow Aquifer Zone along the Bay margin above the elevation of San Francisco Bay;
2. Maintain net neutral to positive groundwater flow towards the Bay in each of the three areas; and
3. No intrusion of saline water into the EBP Subbasin**.**

This analysis with the groundwater model resulted in an estimated sustainable yield of approximately 12,500 AFY for the entire EBP Subbasin. Based on best available data at this time, this estimated sustainable yield represents a maximum amount that assumes approximately evenly spaced pumping throughout the Subbasin that is unlikely to actually occur. This initial estimate of sustainable yield will be refined in the future with collection of additional field data, refinement of the water balance, development of a better understanding of surface water depletion, updates to the groundwater model, and additional model simulations of transient model runs with specific proposed projects and management actions.

2.2.4. Management Areas (23 CCR Section 354.20)

No management areas are proposed for the EBP Subbasin because there is hydraulic connection between the northern and southern EBP Subbasin (groundwater pumping in the southern EBP Subbasin can affect the northern EBP Subbasin and vice versa) and there are data gaps in the northern EBP Subbasin that would make developing separate management areas very difficult. Management areas may be considered in the future if new data indicates it is necessary.

2.3. References

California Department of Water Resources (DWR). 1981. Bulletin 74-81: *Water Well Standards: State of California*.

DWR. 1994. *Ground Water Storage Capacity of a Portion of the East Bay Plain, Alameda County, California*.

DWR. 2003. Bulletin 118: *California's Groundwater. Update 2003*.

DWR. 2016. Bulletin 118: *California's Groundwater, Interim Update 2016*.

CH2M Hill. December 2020. Preliminary Per- and Polyfluoroalkyl Substance Investigation Completion Report, Oakland, California. Prepared for Port of Oakland.

City of Berkeley. 2011. *City of Berkeley 2011 Watershed Management Plan*.

City of Hayward. 2016. *City of Hayward 2015 Urban Water Management Plan*.

City of Hayward. 2021. The City of Hayward 2020 Urban Water Management Plan. . Prepared by Maddaus Water Management and EKI for City of Hayward.

City of Hayward. 2021. Hayward 2020 Water Shortage Contingency Plan. Prepared by Maddaus Water Management for City of Hayward.

East Bay Municipal Utility District (EBMUD). 2012. *Water Conservation Master Plan 2011*.

EBMUD. 2012. *Water Supply Management Program 2040*.

EBMUD. 2013. *South East Bay Plain Basin, Groundwater Management Plan*.

EBMUD. 2016. *East Bay Municipal Utility District Urban Water Management Plan 2015*.

EBMUD. 2018. *East Bay Watershed Master Plan*.

EBMUD. 2020. *Strategic Plan 2020*.

EBMUD. 2021. *Urban Water Management Plan 2020*.

EBMUD. 2021. *Water Shortage Contingency Plan 2020*.

Geosyntec Consultants. July 2020. *PFAS Groundwater and Leachate Investigation Report Transmittal, West Contra Costa Sanitary Landfill, Richmond, California*. Prepared for West Contra Costa Sanitary Landfill, Inc.

Hazen. 2020. *East Bay Municipal Utility District, 2050 Demand Study*. Prepared for EBMUD.

Luhdorff & Scalmanini Consulting Engineers (LSCE), 2003. *East Bay Plain, Aquifer Test Project, South East Bay Plain and Niles Cone Ground-Water Basins*. Prepared for Alameda County Water District, City of Hayward, and East Bay Municipal Utility District.

LSCE, Borchers, J., and M. Carpenter, 2014. *Land Subsidence for Groundwater Use in California*. Prepared for California Water Foundation.

Muir, K. 1994. *Groundwater Recharge in the East Bay Plain Area, Alameda County, California*. Prepared for ACFCWCD.

Muir, K. 1996. *Groundwater Discharge in the East Bay Plain Area, Alameda County, California*. Prepared for ACFCWCD.

Norfleet Consultants. 1998. *Groundwater Study and Water Supply History of the East Bay Plain, Alameda and Contra Costa Counties, California*. Prepared for The Friends of the San Francisco Estuary.

San Francisco Bay Area Integrated Regional Water Management (IRWM) Coordinating Committee. 2019. *San Francisco Bay Area Integrated Regional Water Management Plan*.

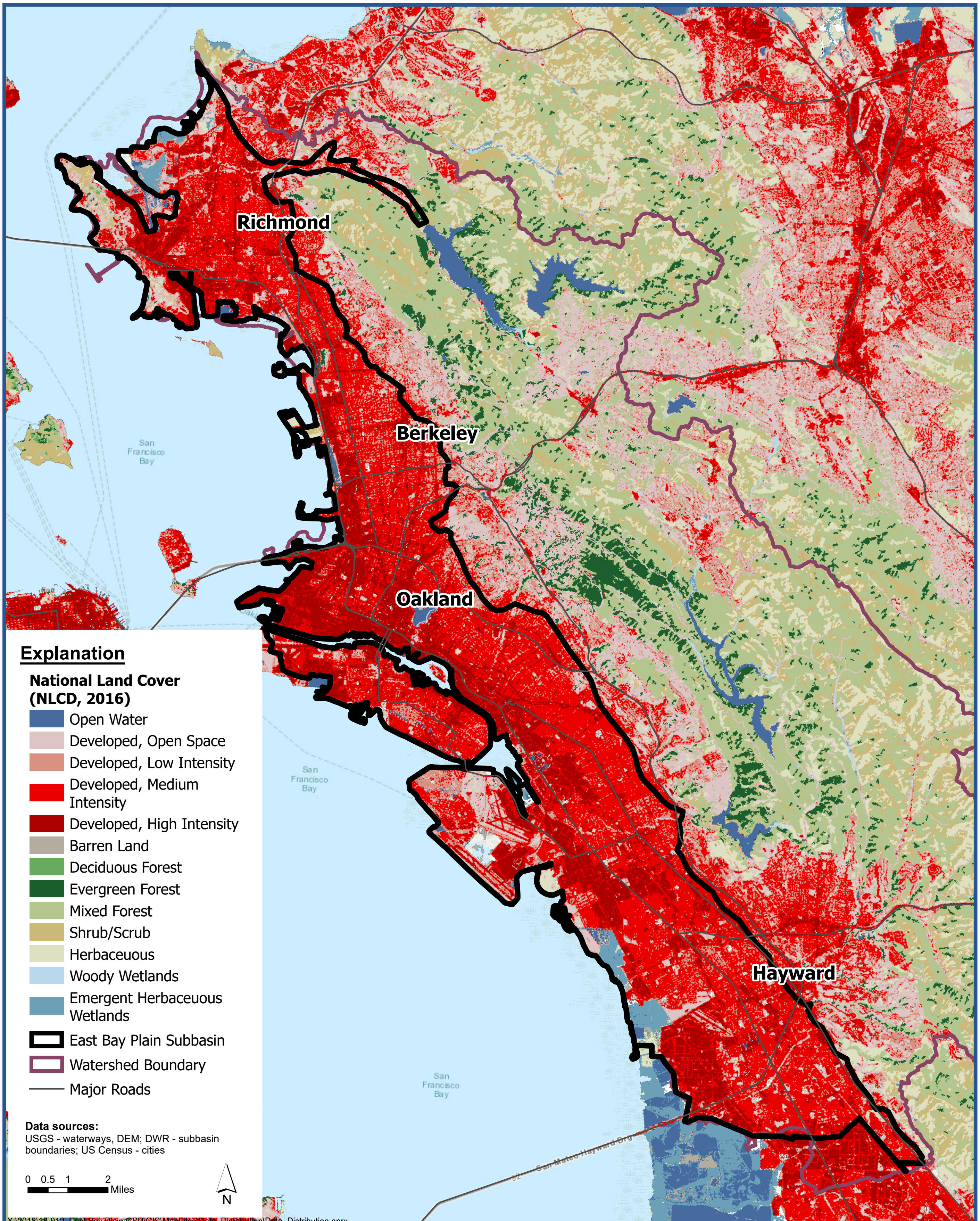
Sneed, M., Orlando, P., Borchers, J., Everett, R., Solt, M. McGann, Lowers, H., and S. Mahan. 2015. *Lithostratigraphic, Bore-Geophysical, Hydrogeologic, and Hydrochemical Data from the East Bay Plain, Alameda County, California*. United States Geological Survey (USGS) Data Series 890.

Water Resources & Information Management Engineering, Inc. (WRIME). 2005. *Niles Cone and South East Bay Plain Integrated Groundwater and Surface Water Model (NEBIGSM)*. Prepared for ACWD, EBMUD, and City of Hayward.

Wood, Data Submittal for Compliance with 13267 Order WQ 2019-0006-DWQ. April 2020. *Waste management of Alameda County, Inc., West Winton Landfill, Hayward, Alameda County, California.* Prepare for Waste Management of Alameda County, Inc., San Leandro, California.

FIGURES

Figures 2-1 through 2-6 and 2-9 through 2-38

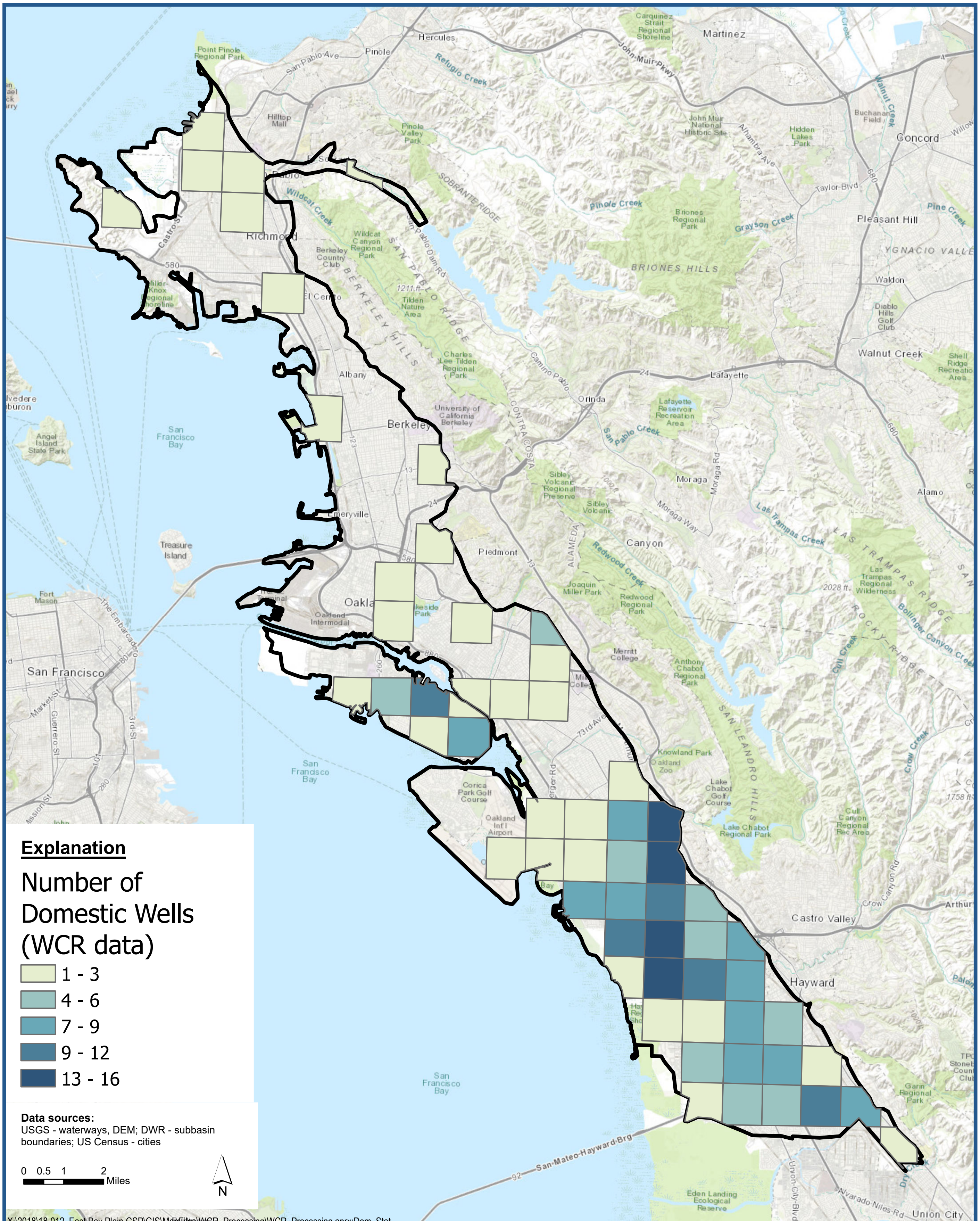


LSCE TEAM

East Bay Plain Subbasin Land Use Map

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-1

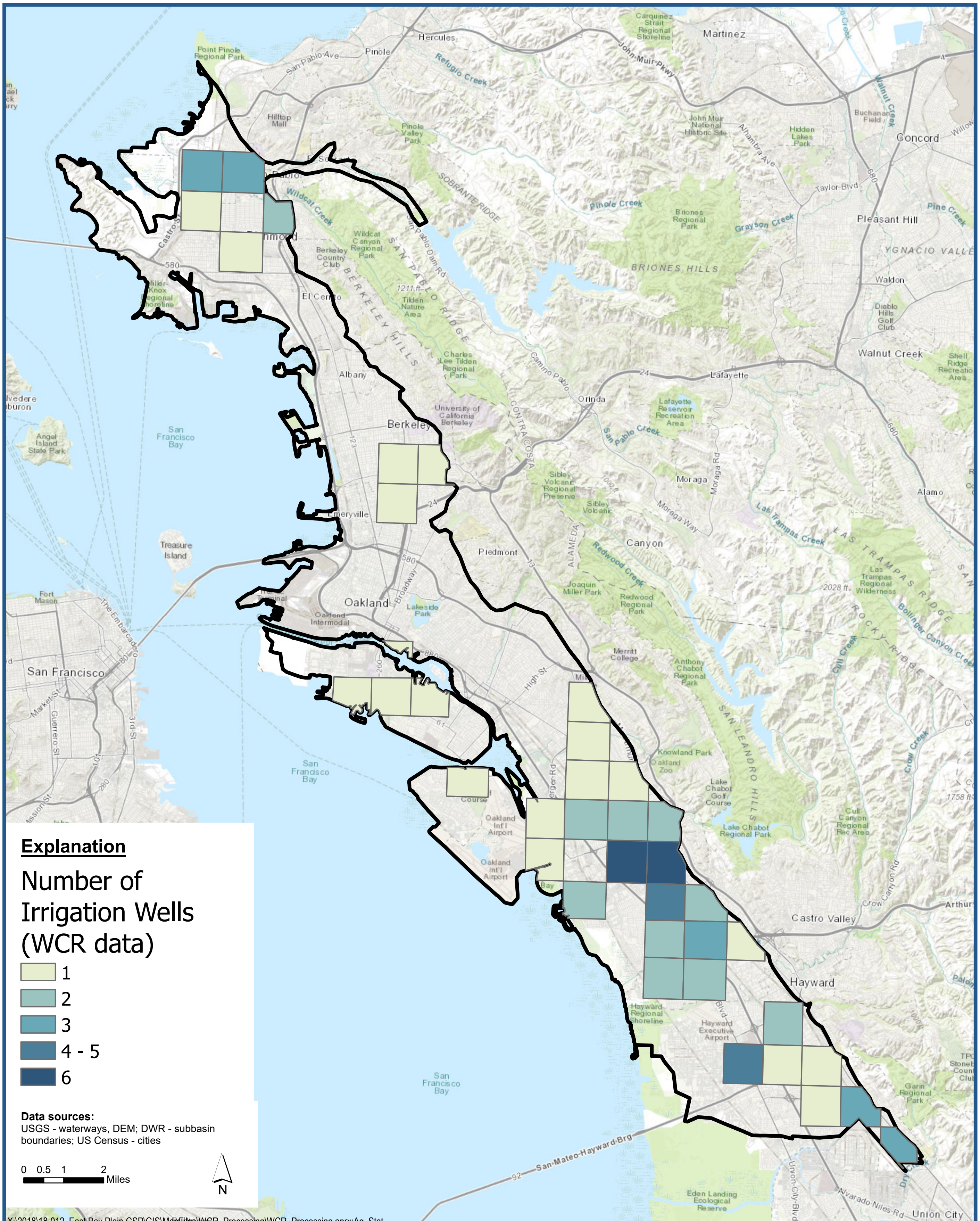


LSCE TEAM

Map of Well Information by Section: Number of Domestic Wells (from WCR data)

East Bay Plain Subbasin
Groundwater Sustainability Plan

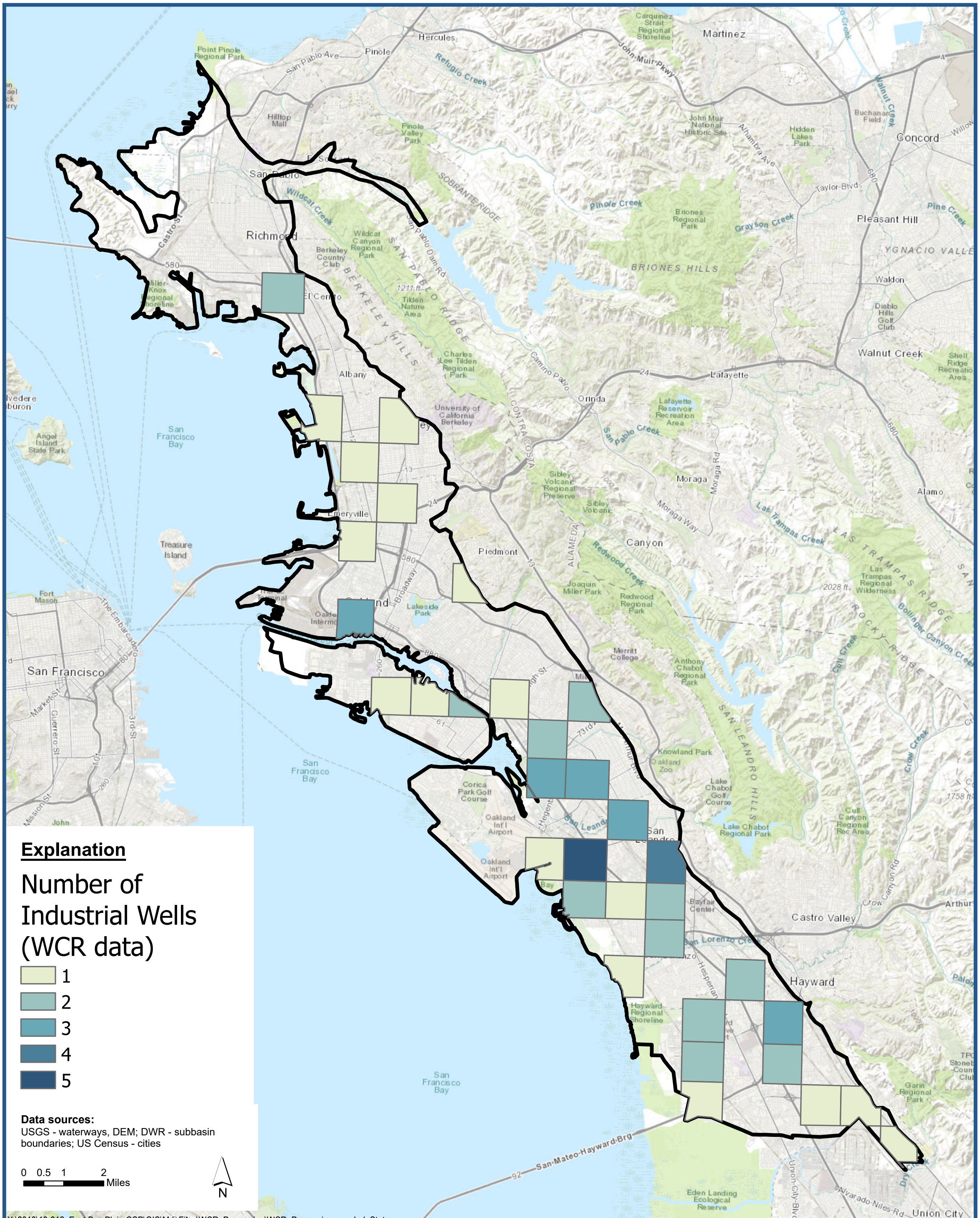
Figure 2-2



Map of Well Information by Section: Number of Irrigation Wells (from WCR data)

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-3



LSCE TEAM

Map of Well Information by Section: Number of Industrial Wells (from WCR data)

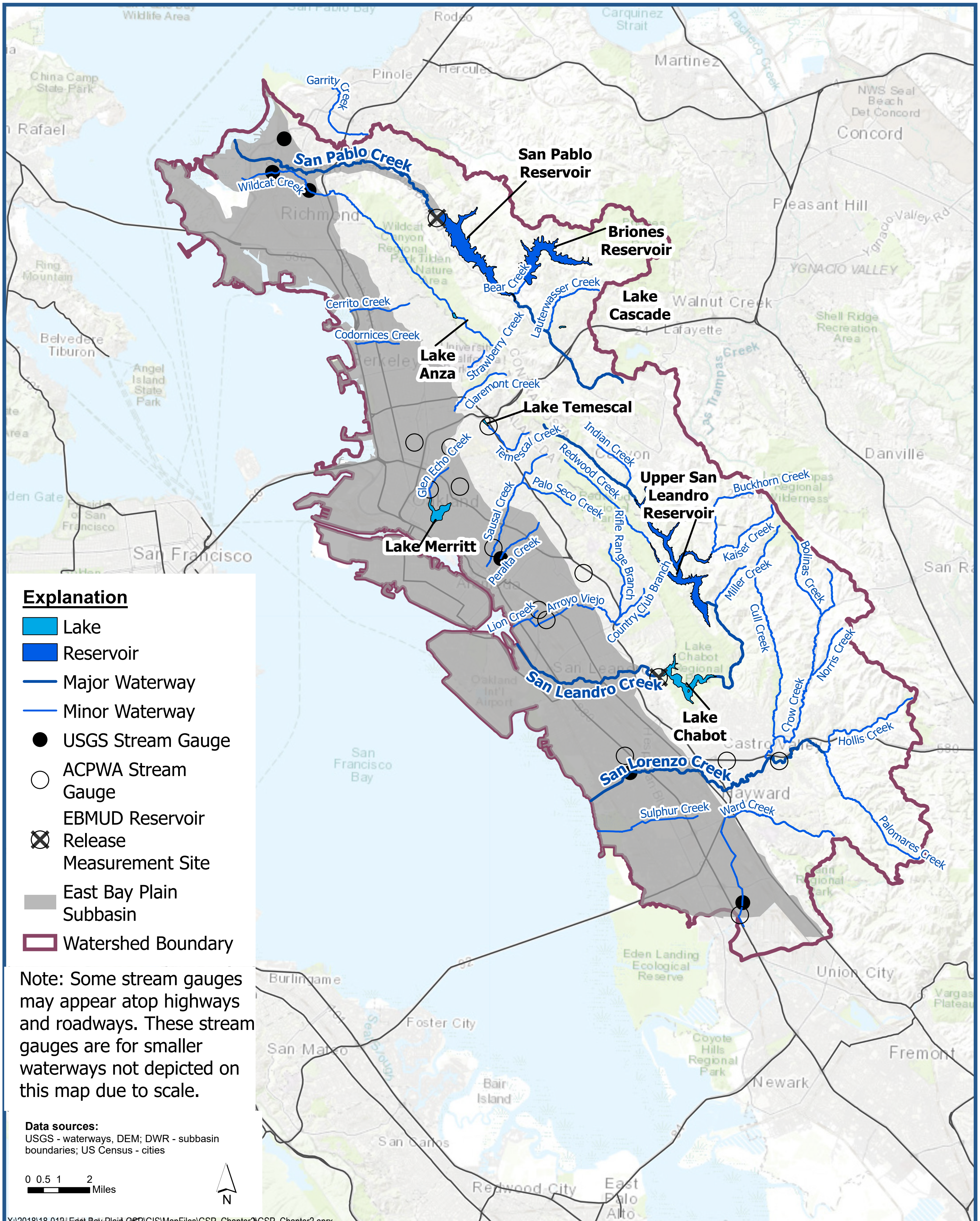
East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-4

Map of Well Information by Section: Number of Public Supply Wells (from WCR data)

Groundwater Sustainability Plan
East Bay Plain

Figure 2-5

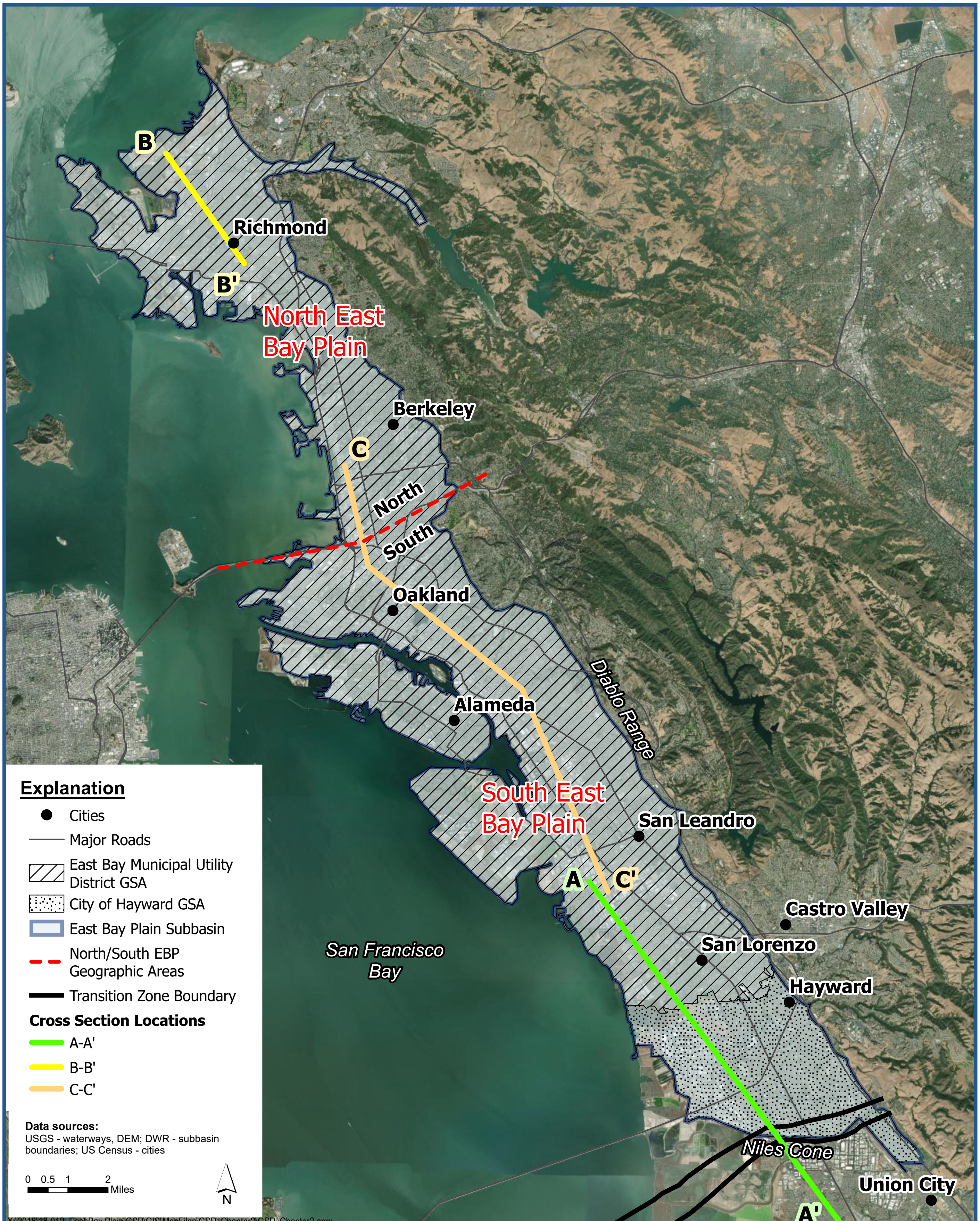


LSCE TEAM

Map of Stream Gauge Locations

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-6

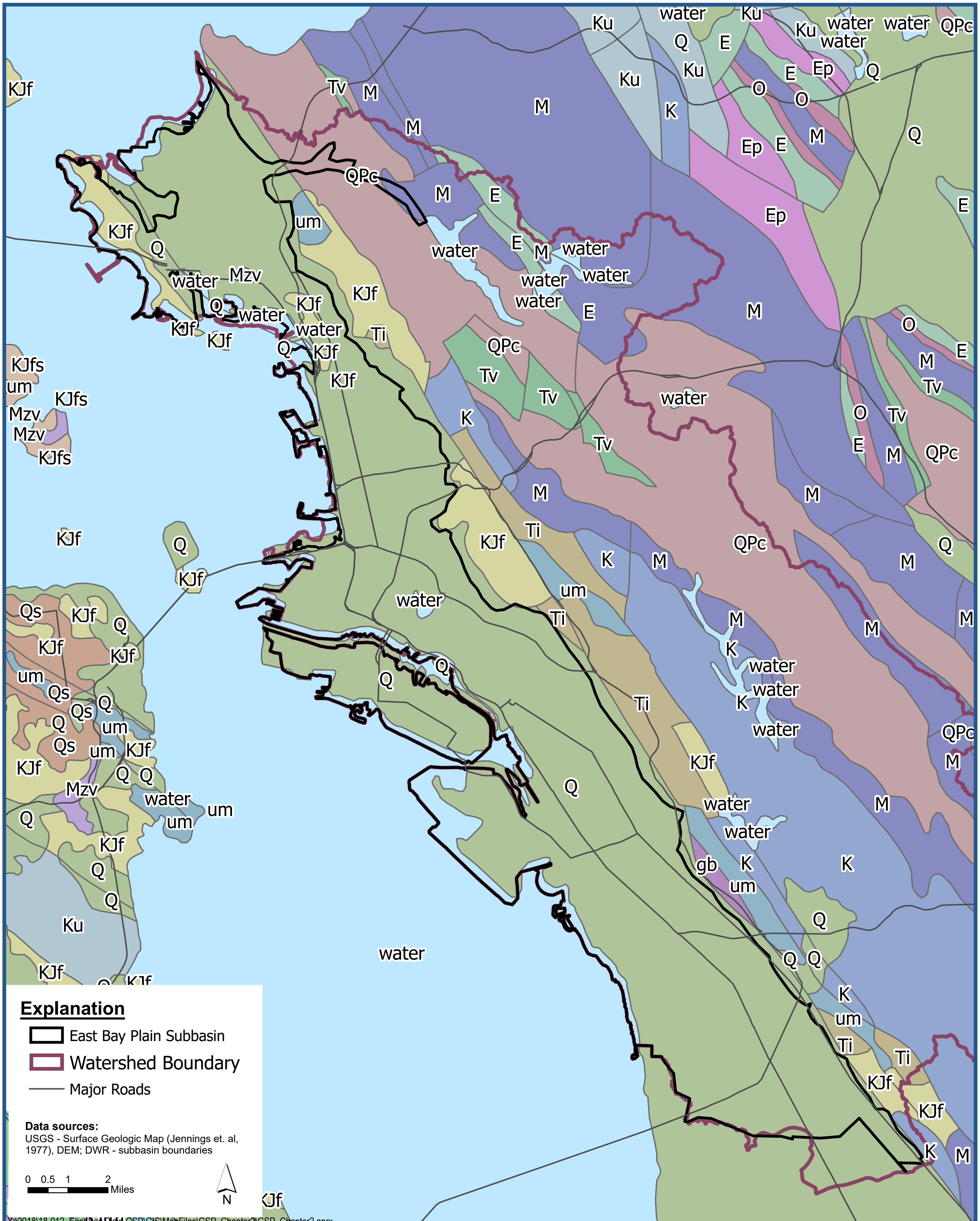


LSCE TEAM

East Bay Plain Subbasin Location Map and Cross-Section Locations

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-9



LSCE TEAM

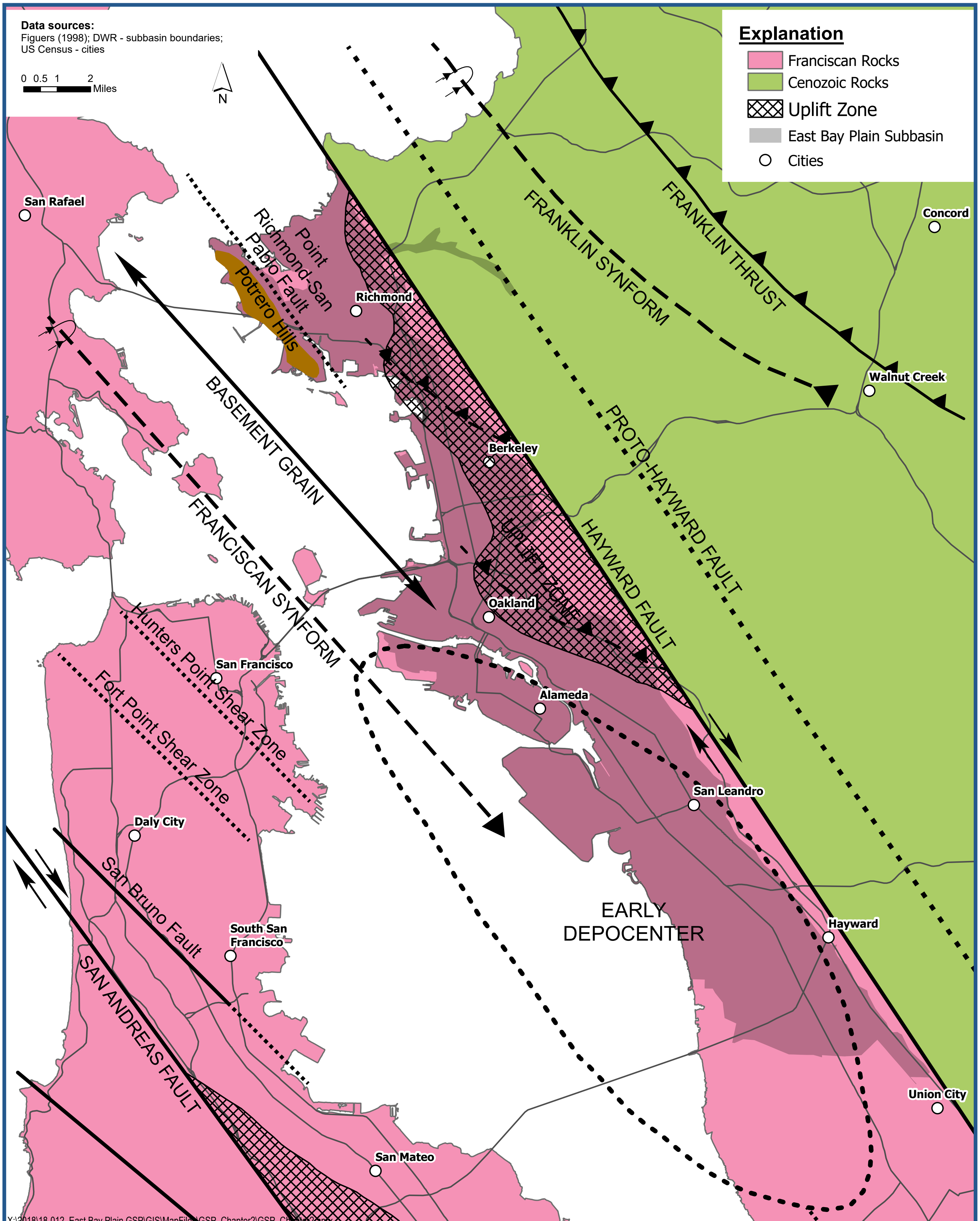
Surface Geologic Map

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-10a

Explanation

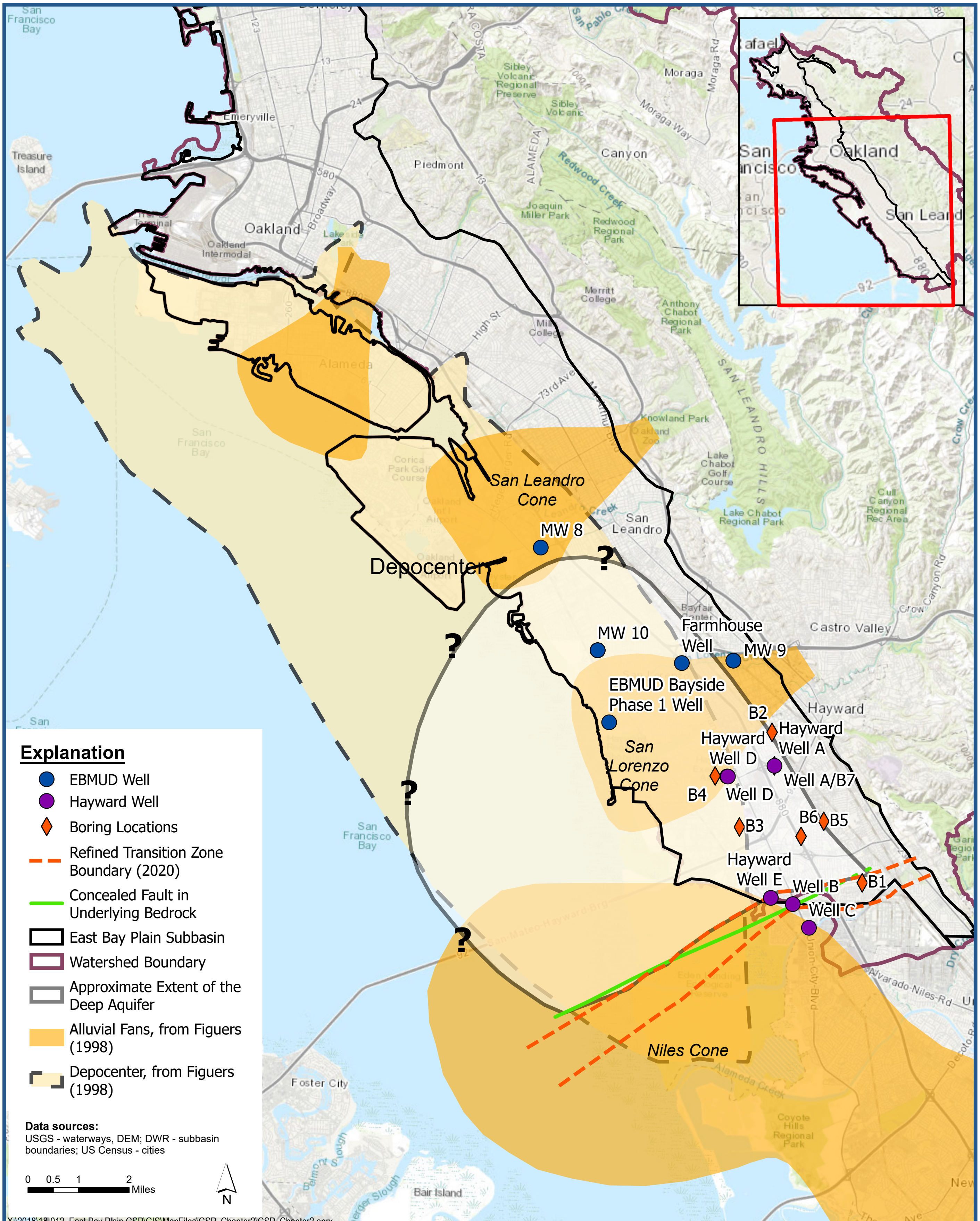
E	Eocene marine rocks
Ep	Paleocene marine rocks
J	Jurassic marine rocks
K	Cretaceous marine rocks (in part nonmarine)
KJf	Franciscan Complex
KJfm	Franciscan melange
KJfs	Franciscan schist
Kl	Lower Cretaceous marine rocks
Ku	Upper Cretaceous marine rocks
M	Miocene marine rocks
Mzv	Mesozoic volcanic rocks
O	Oligocene marine rocks
P	Pliocene marine rocks
Q	Quaternary alluvium and marine deposits
QPc	Plio-Pleistocene and Pliocene loosely consolidated deposits
Qs	Quaternary sand deposits
Ti	Tertiary intrusive rocks (hypabyssal)
Tv	Tertiary volcanic flow rocks
Tvp	Tertiary pyroclastic and volcanic mudflow deposits
gb	Mesozoic gabbroic rocks
grMz	Mesozoic granitic rocks
um	Ultramafic rocks, chiefly Mesozoic
Water	



Structural Geology of San Francisco Bay Area

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-11

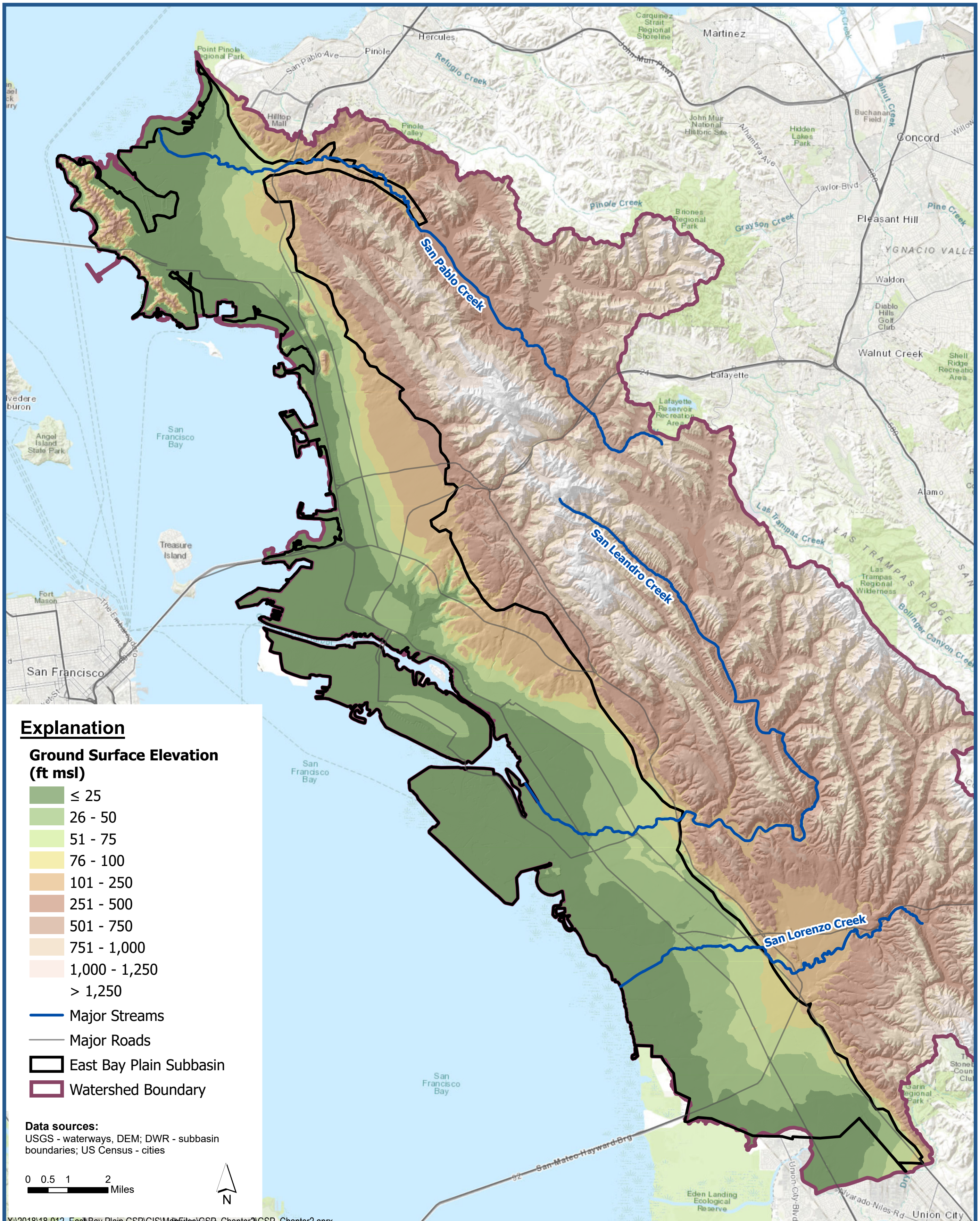


LSCE TEAM

Map of Depositional Centers and Deep Aquifer Extent

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-12

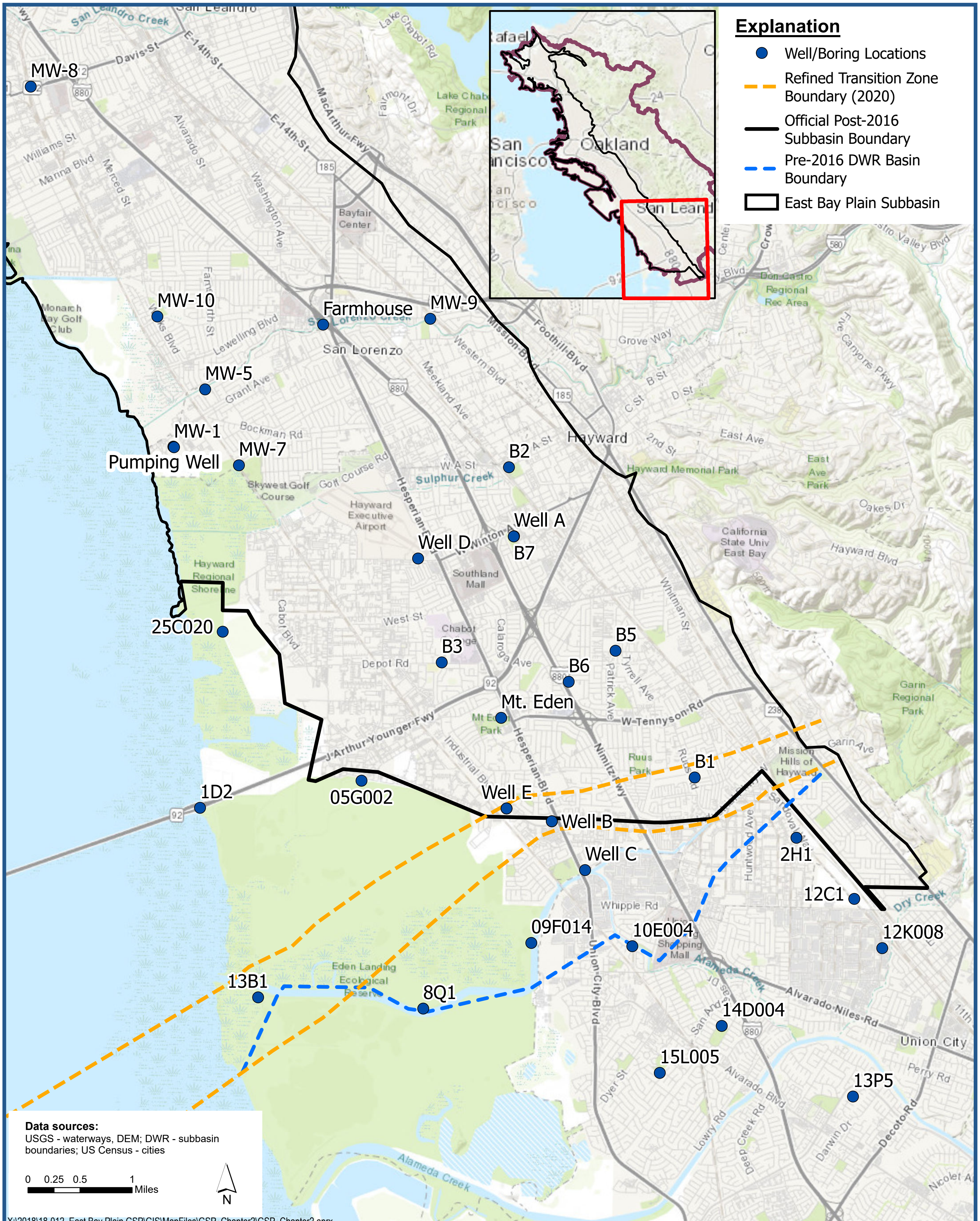


Topography of East Bay Plain Subbasin and Surrounding Watershed

LSCE TEAM

Figure 2-13

East Bay Plain Subbasin
Groundwater Sustainability Plan

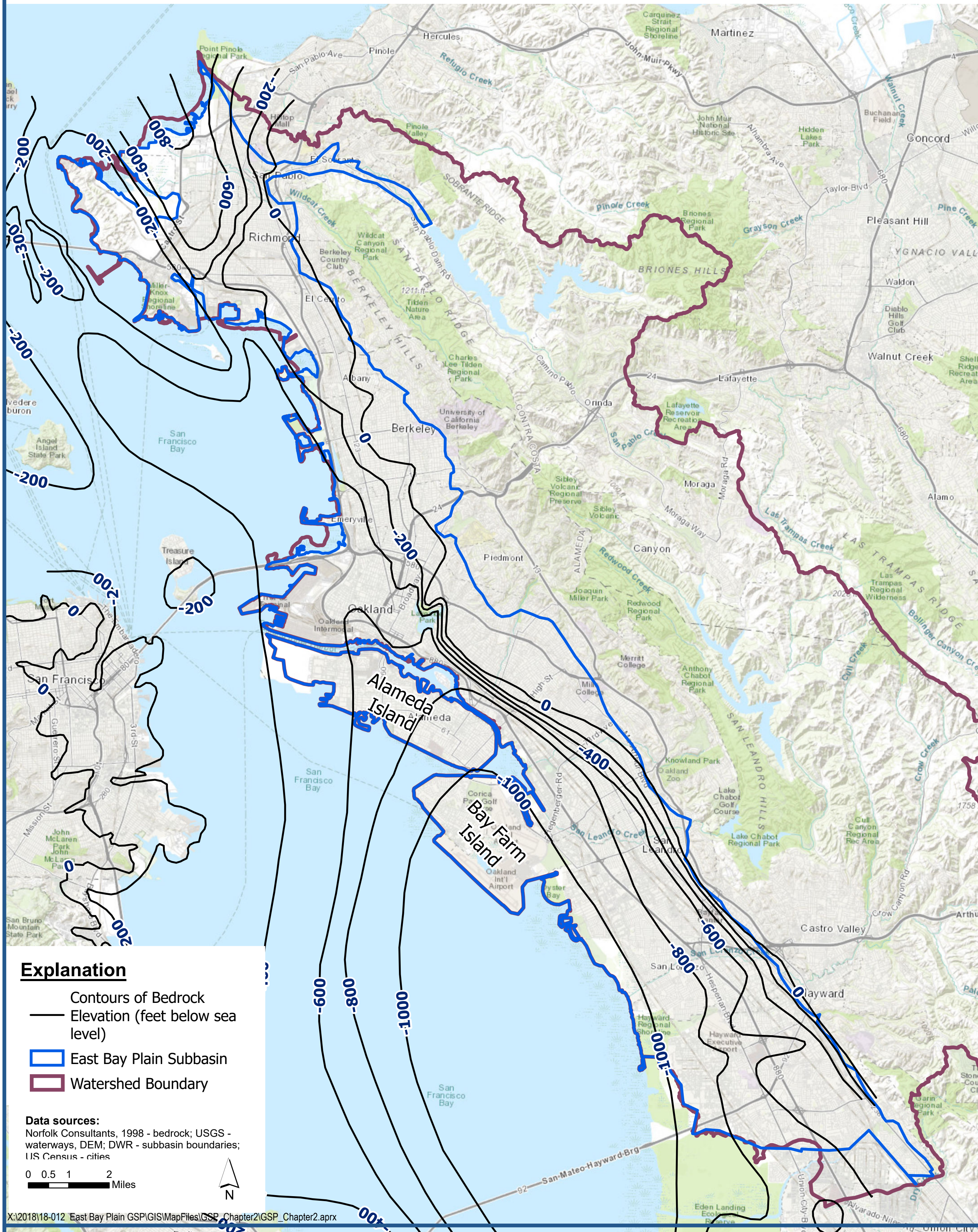


LSCE TEAM

Map of Pre- and Post-2016 DWR Basin Boundary

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-14

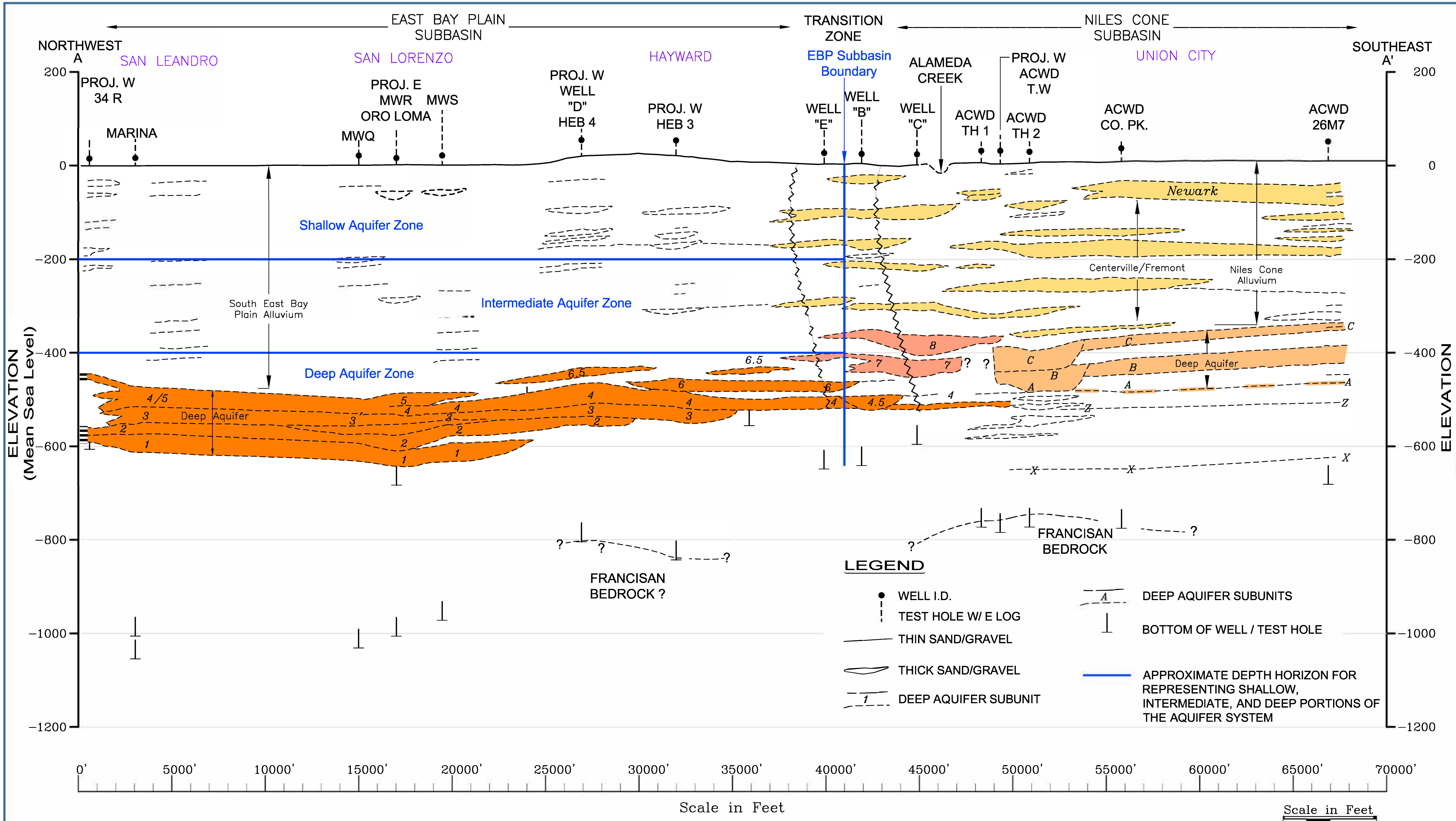


Map of Bedrock Elevation in East Bay Plain Subbasin

Figure 2-15

East Bay Plain Subbasin
Groundwater Sustainability Plan

LSCE TEAM



Note:
Figure modified from Figure 18; LSCE, 2003.

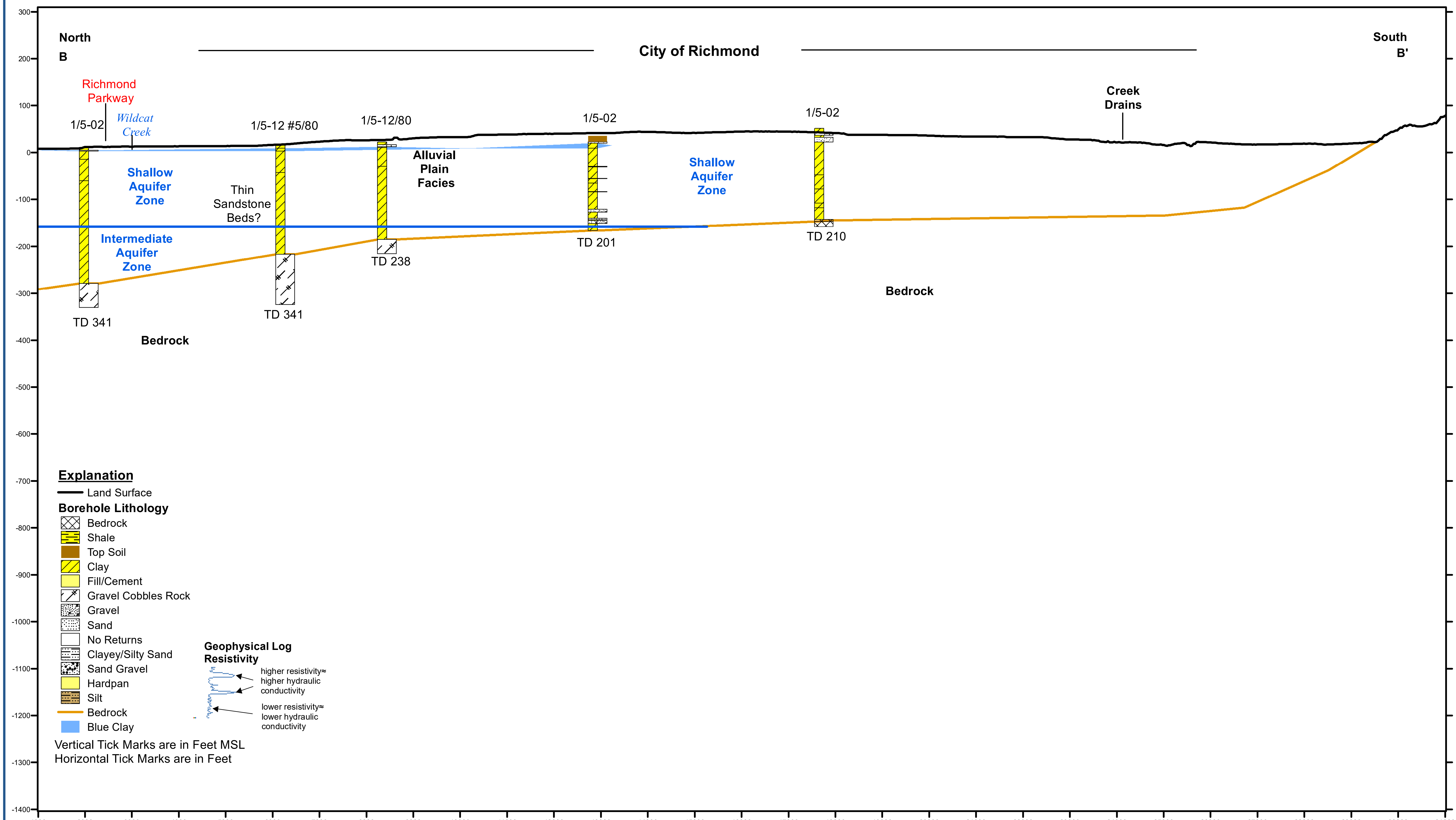
CAD FILE: D:\LS ACAD Dropbox\Projects\Alameda County Water District\18-1-012\ShallowAquiferZone.dwg DATE: 10/30/2020 4:34 PM

LSCE TEAM

Geologic Cross Section A-A' of Southern East Bay Plain

East Bay Plain Subbasin Groundwater Sustainability Plan

Figure 2-16

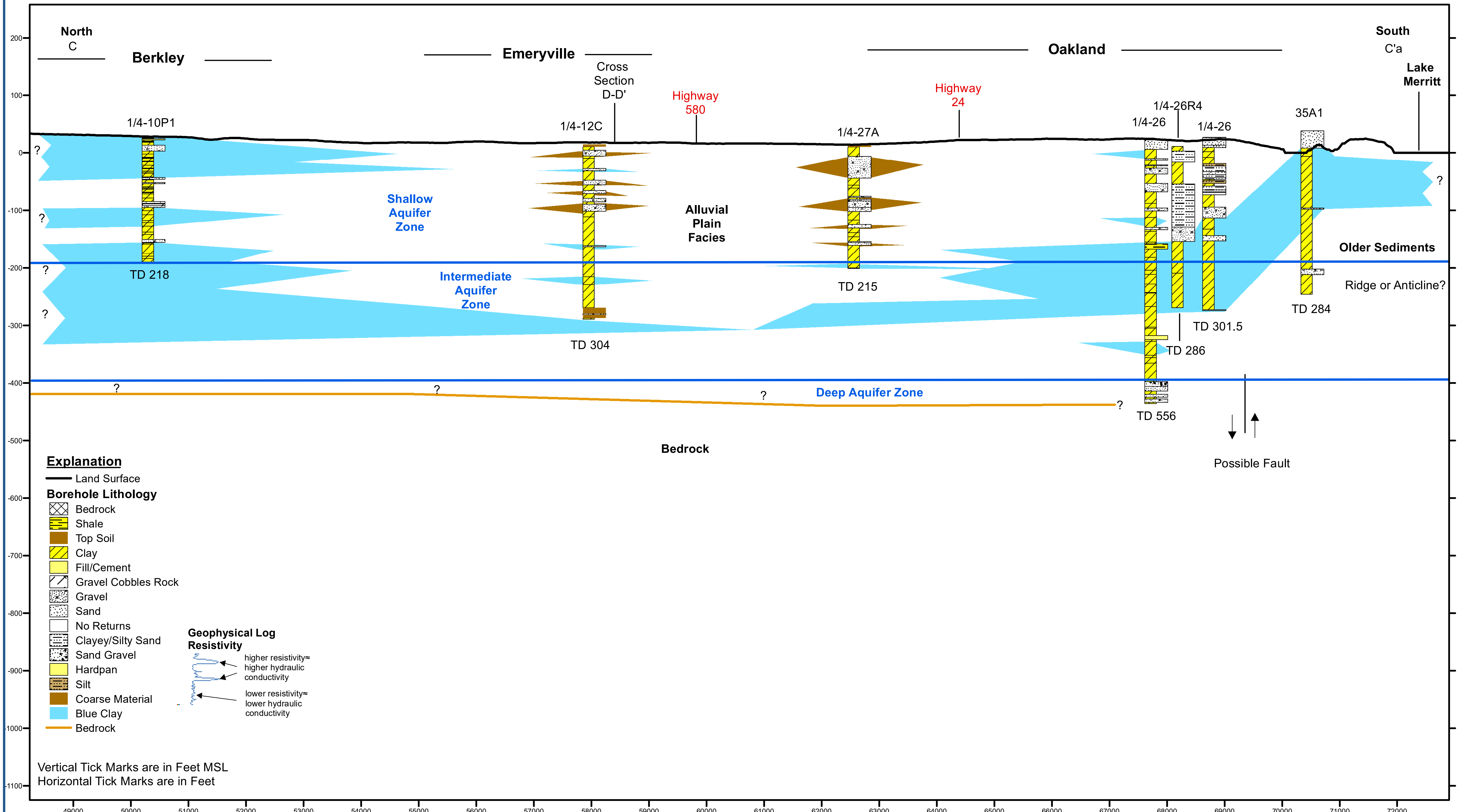


LSCE TEAM

Geologic Cross Section B-B' of Northern East Bay Plain

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-17

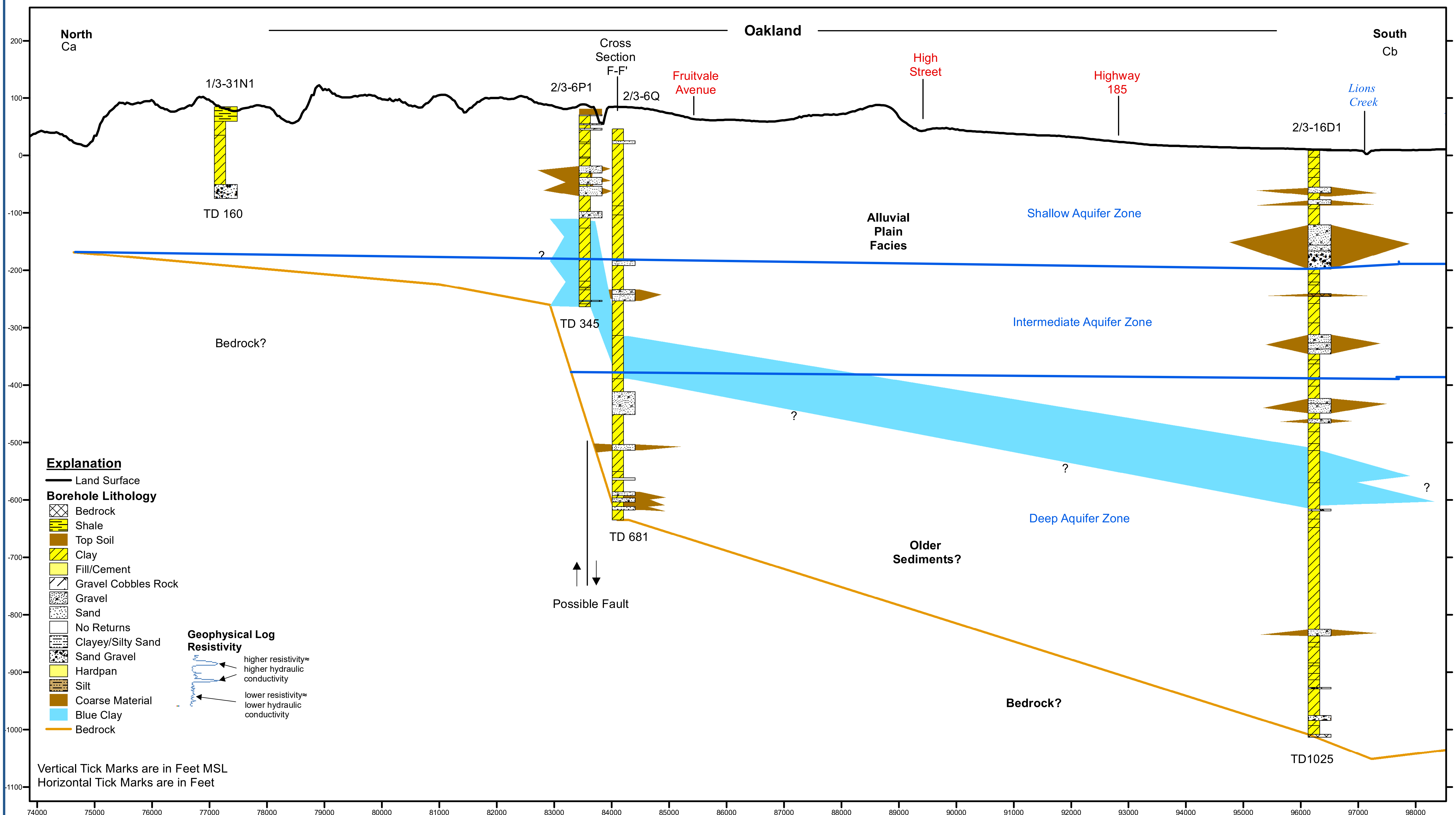


LSCE TEAM

Geologic Cross Section C-C' of the Northern and Southern East Bay Plain

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-18a

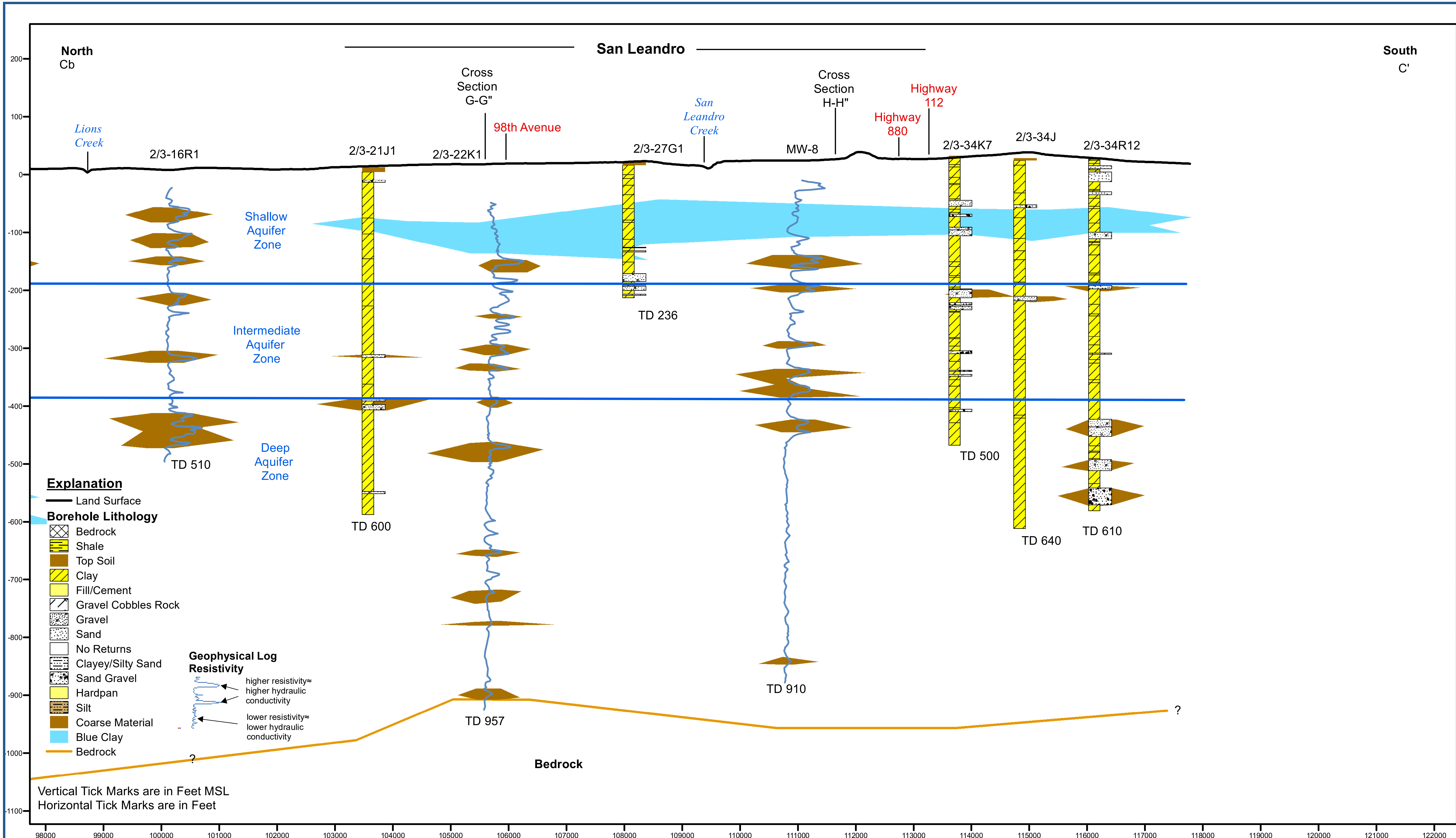


LSCE TEAM

Geologic Cross Section C-C' of the Northern and Southern East Bay Plain

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-18b

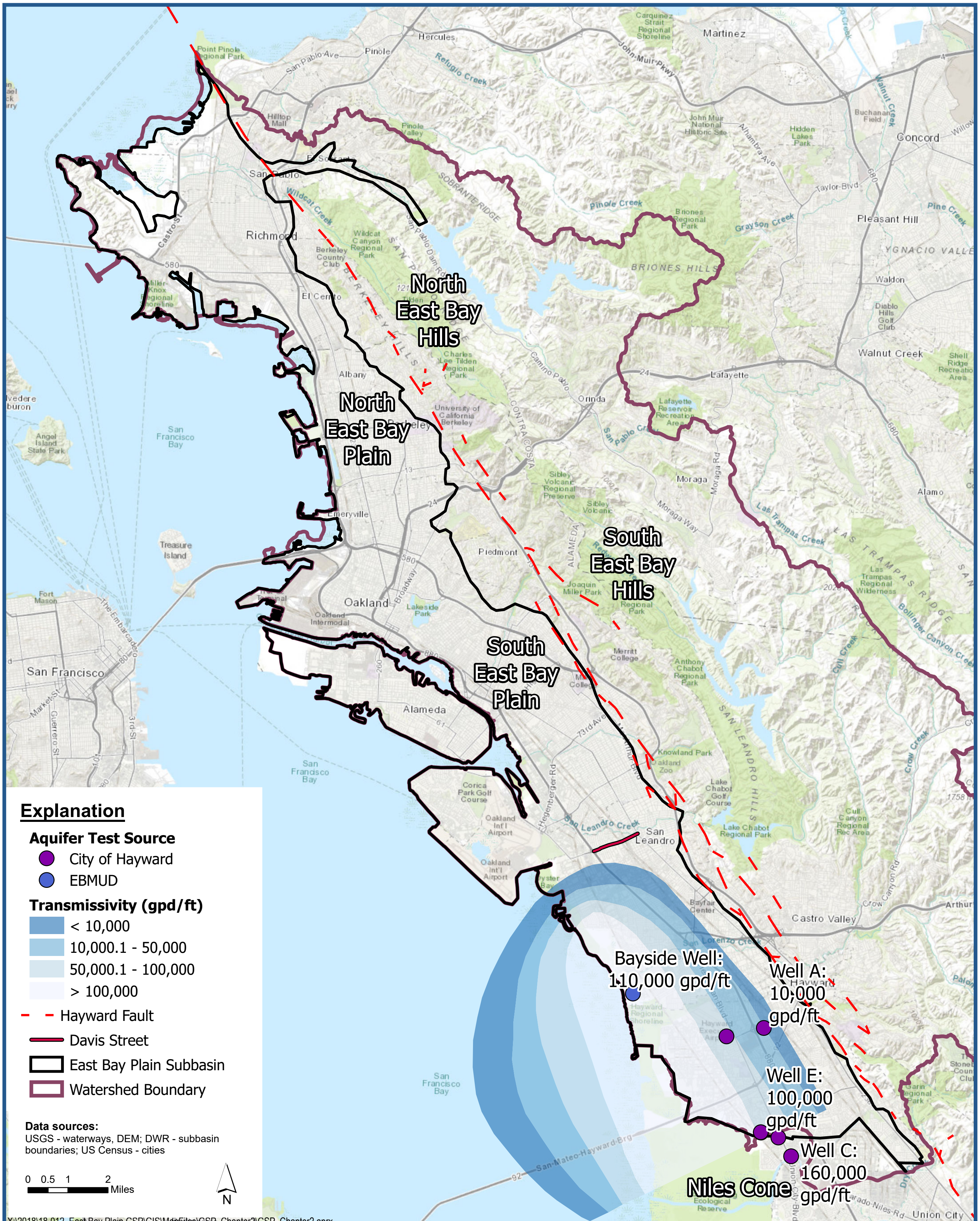


LSCE TEAM

Geologic Cross Section C-C' of the Northern and Southern East Bay Plain

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-18c

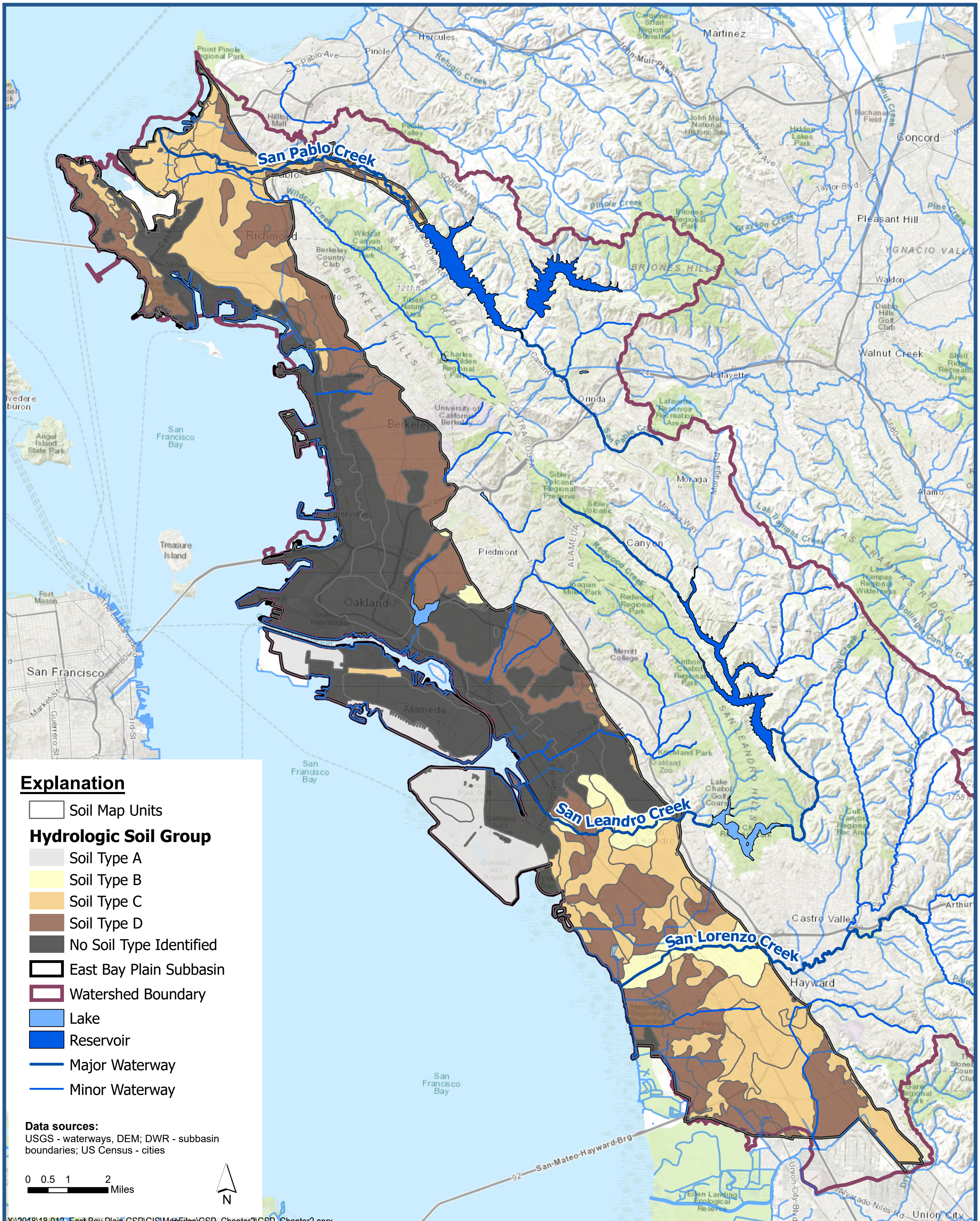


LSCE TEAM

Distribution of Transmissivity Values in Deep Aquifer

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-19



LSCE TEAM

Mapping of the Distribution of Hydrologic Soils Groups

East Bay Plain Subbasin
Groundwater Sustainability Plan

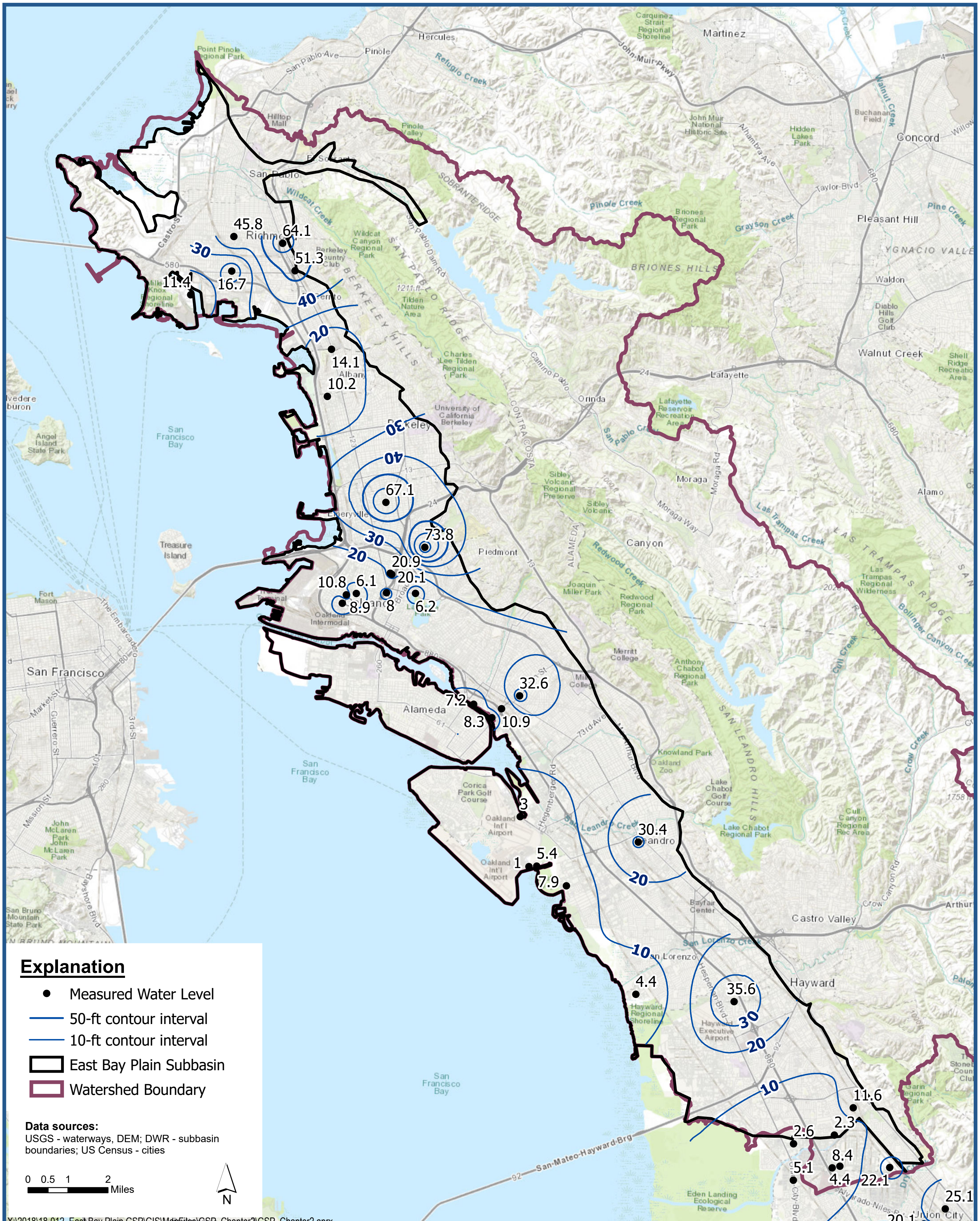
Figure 2-20

LSCE TEAM

Map of Surface Water Bodies

East Bay Plain Subbasin
Groundwater Sustainability Plan

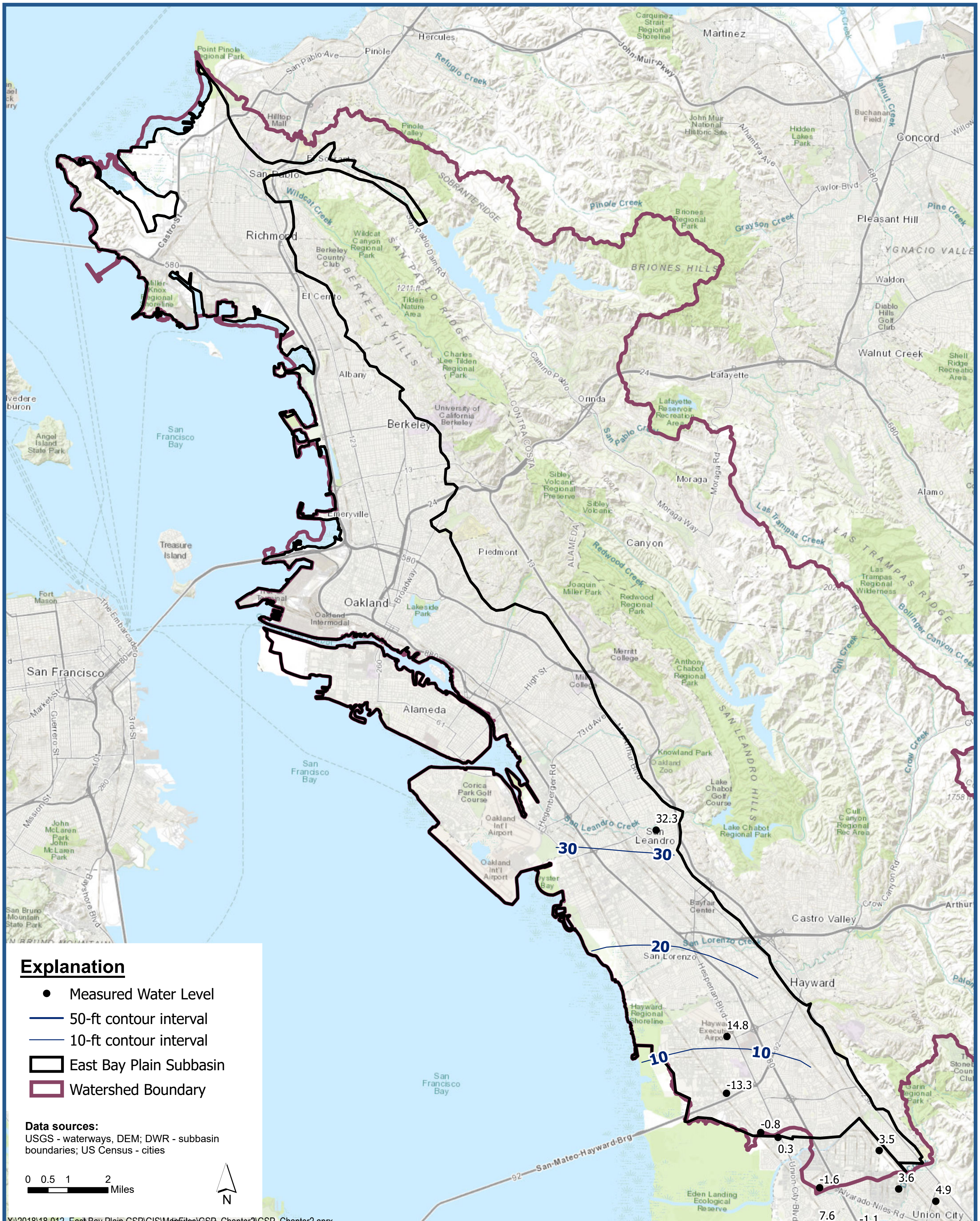
Figure 2-21



Water Table Aquifer Groundwater Elevation Contour Map – Spring 2018

East Bay Plain Subbasin
Groundwater Sustainability Plan

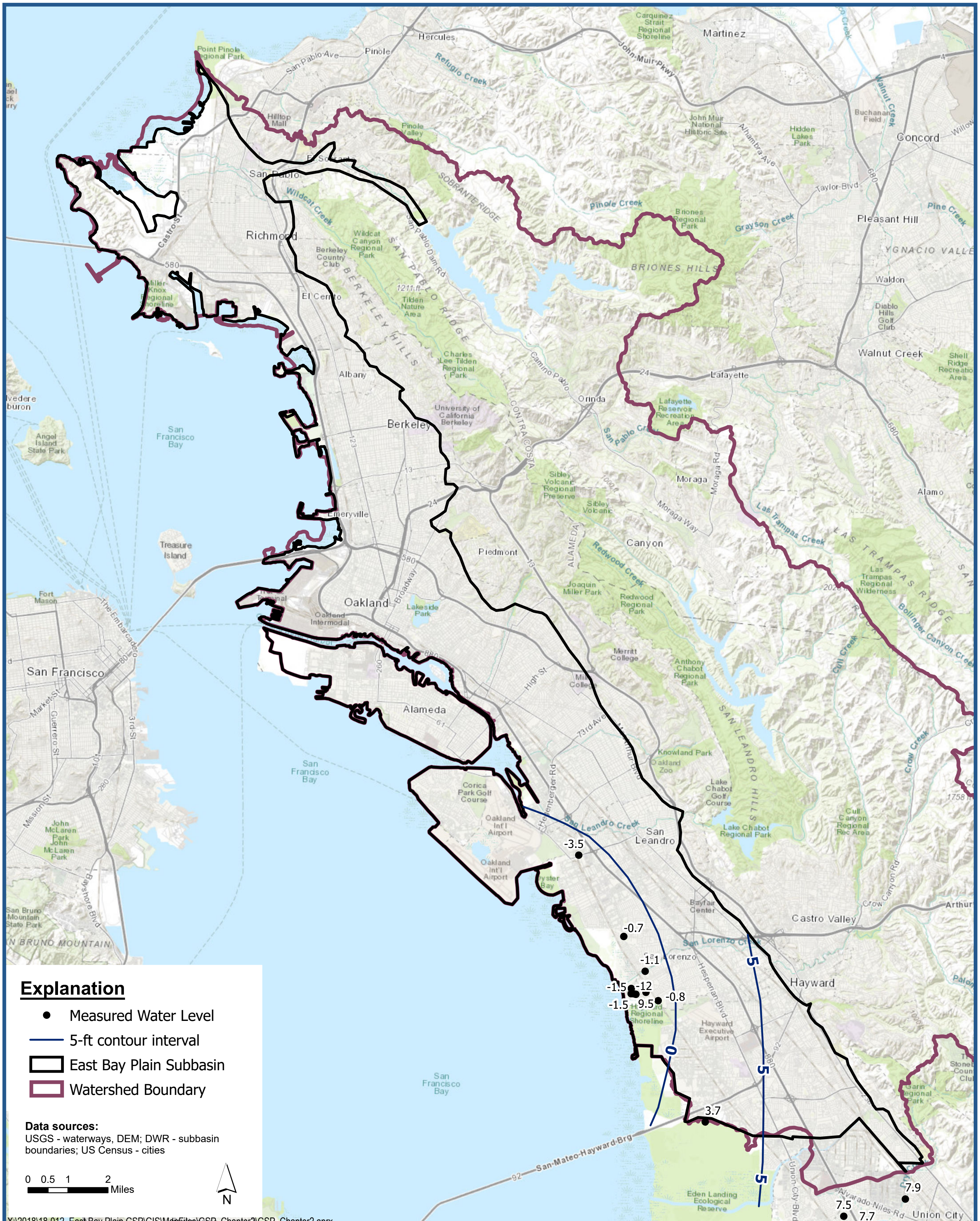
Figure 2-22



Deep Aquifer Groundwater Elevation Contour Map
Spring 2002

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-23

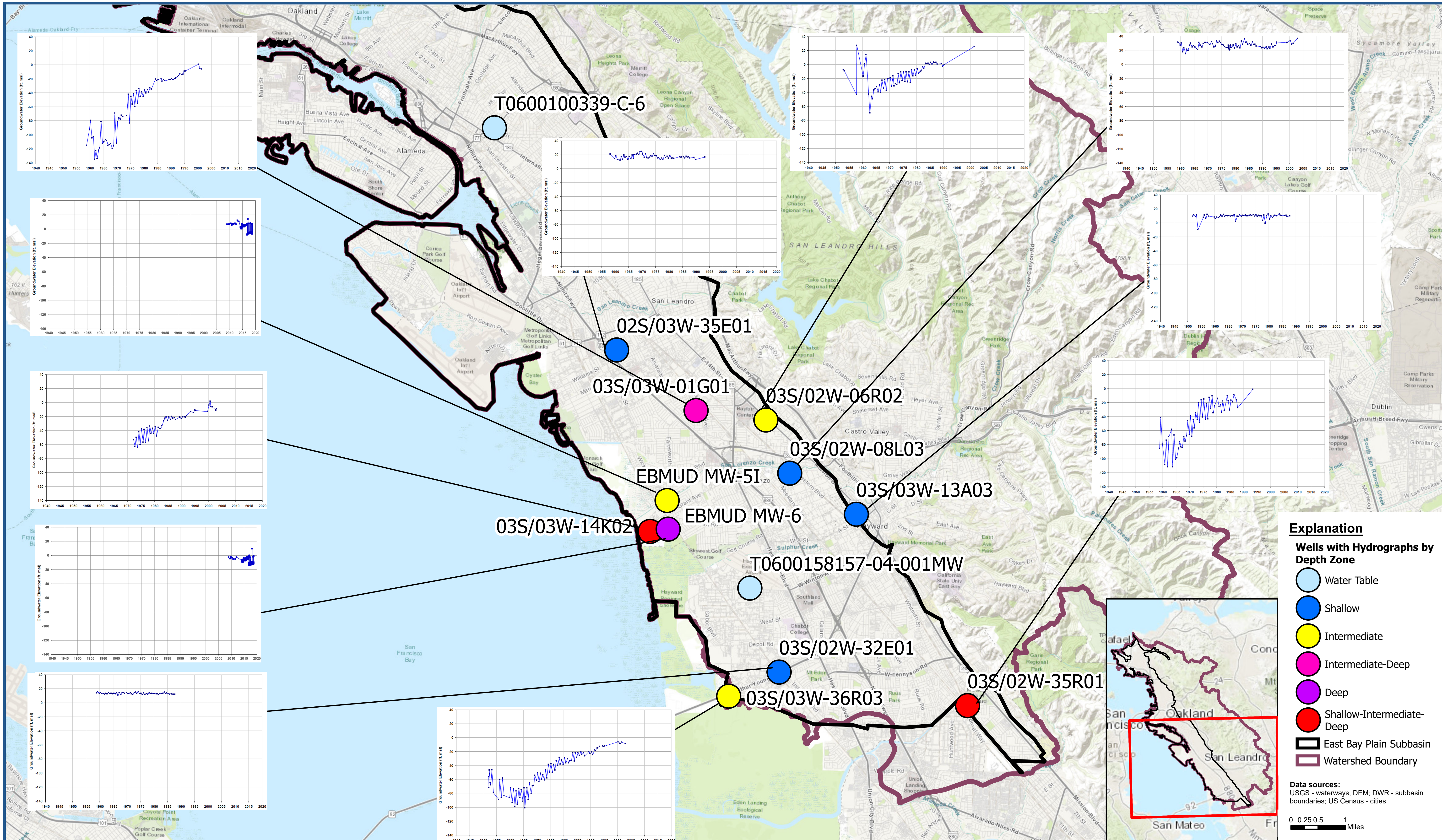


LSCE TEAM

Deep Aquifer Groundwater Elevation Contour Map Spring 2018

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-24



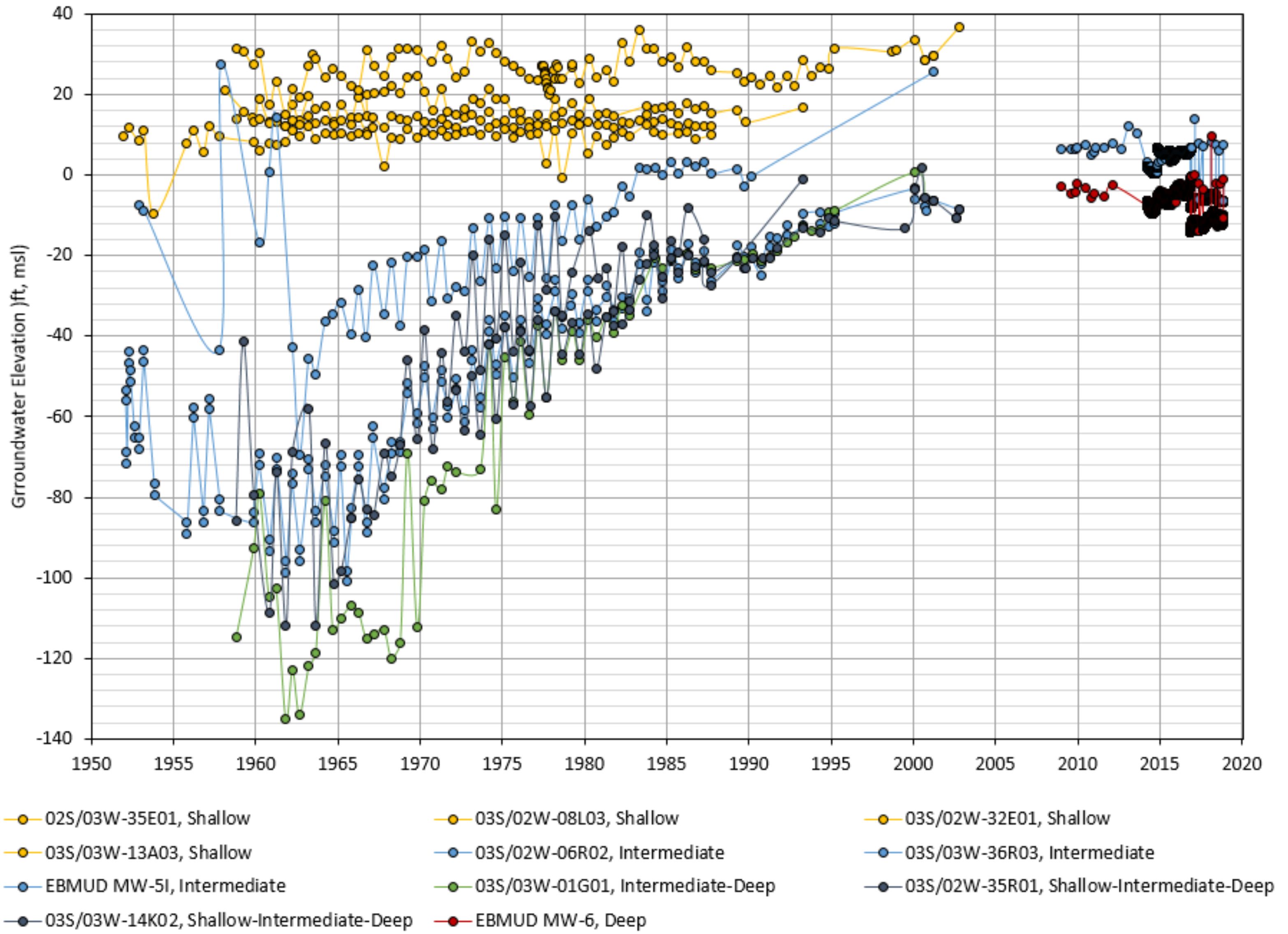
X:\2018\18-012 East Bay Plain GSP\GIS\MapFiles\GSP_Chapter2\GSP_Chapter2.aprx:Figure NEW Hydrographs 1

LSCE TEAM

Selected Groundwater Hydrographs for Shallow, Intermediate, and Deep Zones in Southern EBP Subbasin

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-25



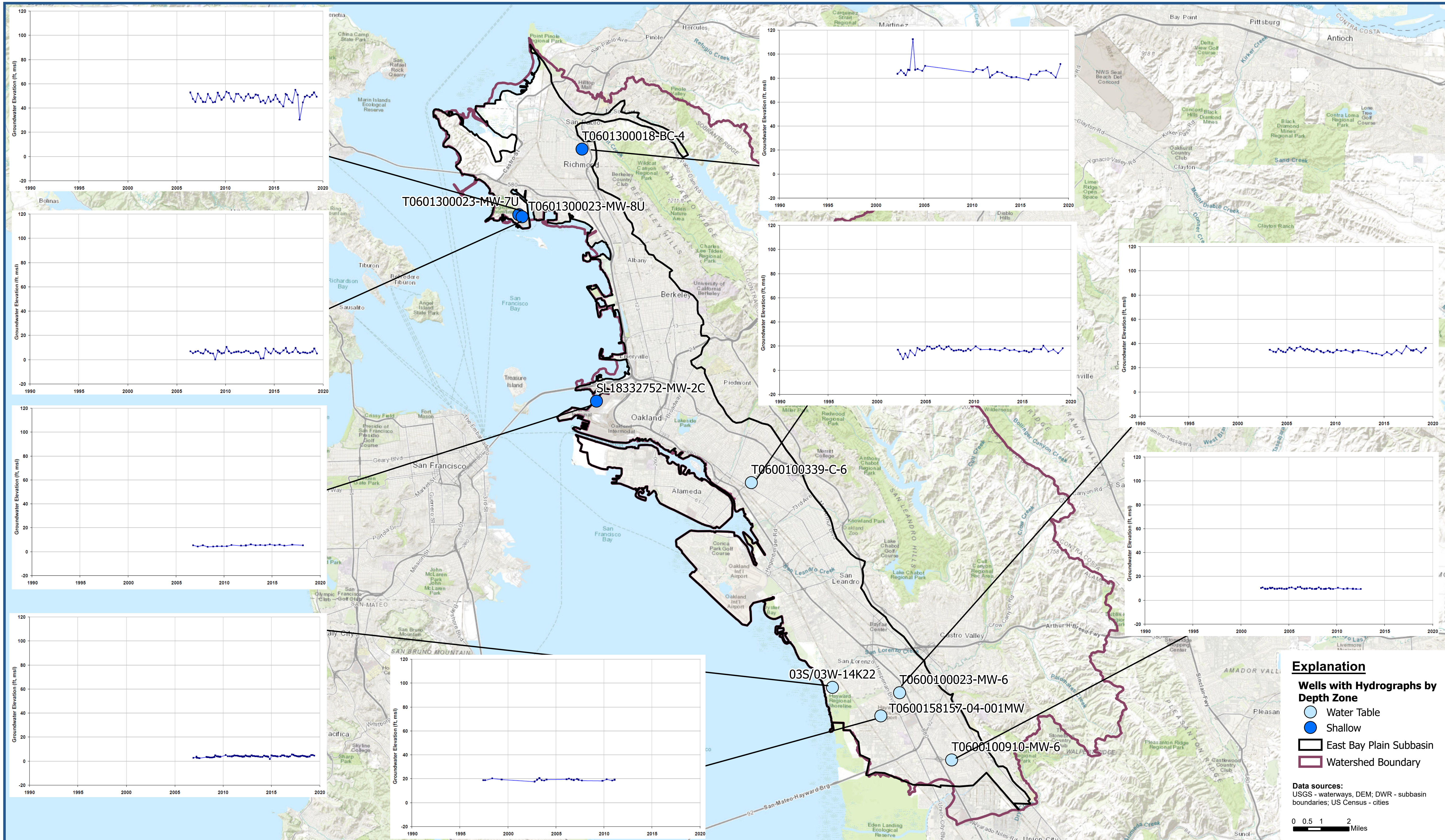
X:\2018\18-012_East Bay Plain GSP\GIS\MapFiles\GSP_Chapter2\GSP_Chapter2.aprx:[empty]

LSCE TEAM

Composite Groundwater Hydrograph for Shallow, Intermediate, and Deep Zones in Southern EBP Subbasin

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-26

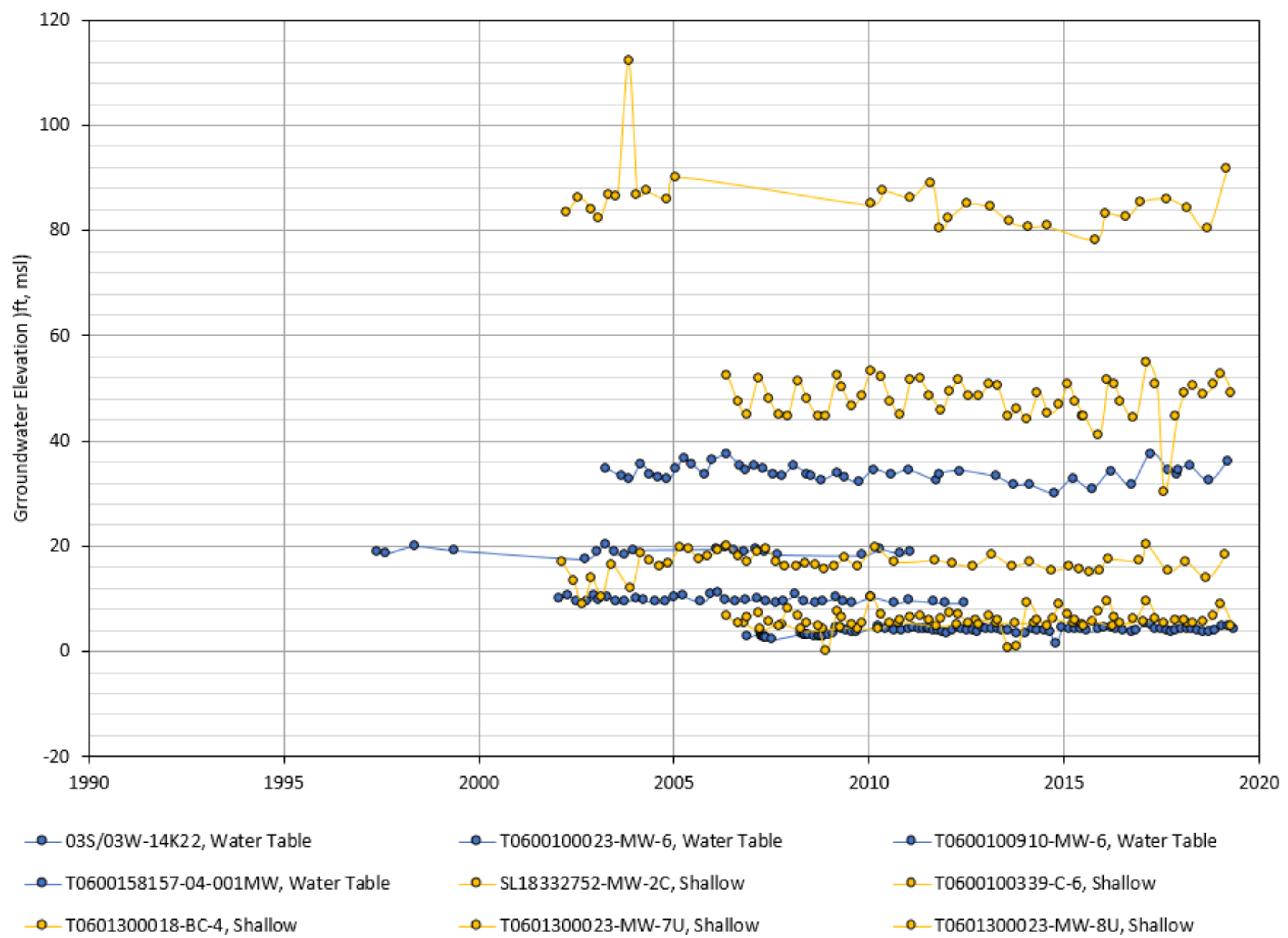


LSCE TEAM

Selected Groundwater Hydrographs for Shallow Zone in EBP Subbasin

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-27



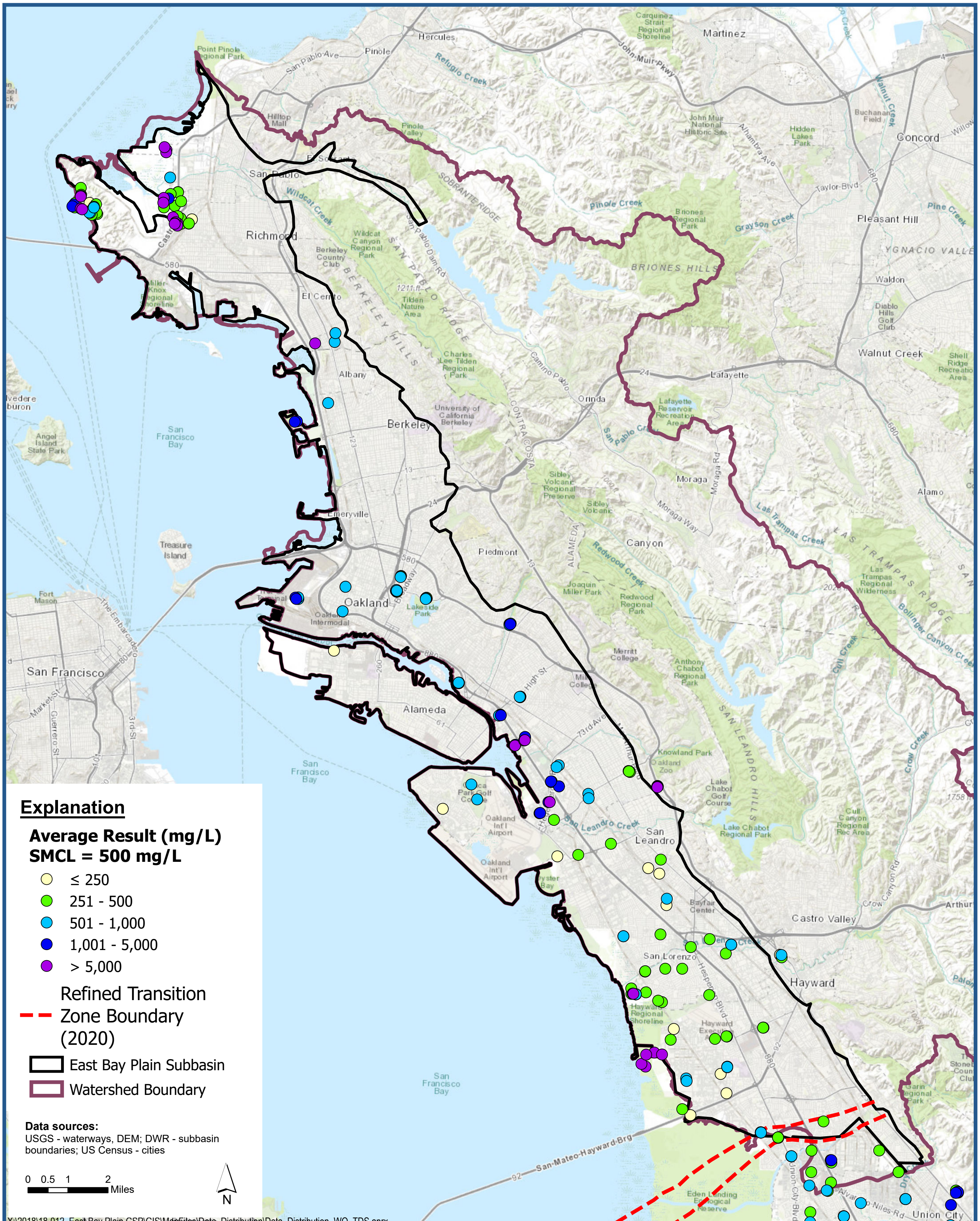
X:\2018\18-012_East Bay Plain GSP\GIS\MapFiles\GSP_Chapter2\GSP_Chapter2.aprx:[empty]

LSCE TEAM

Composite Groundwater Hydrograph for Shallow Zone in EBP Subbasin

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-28

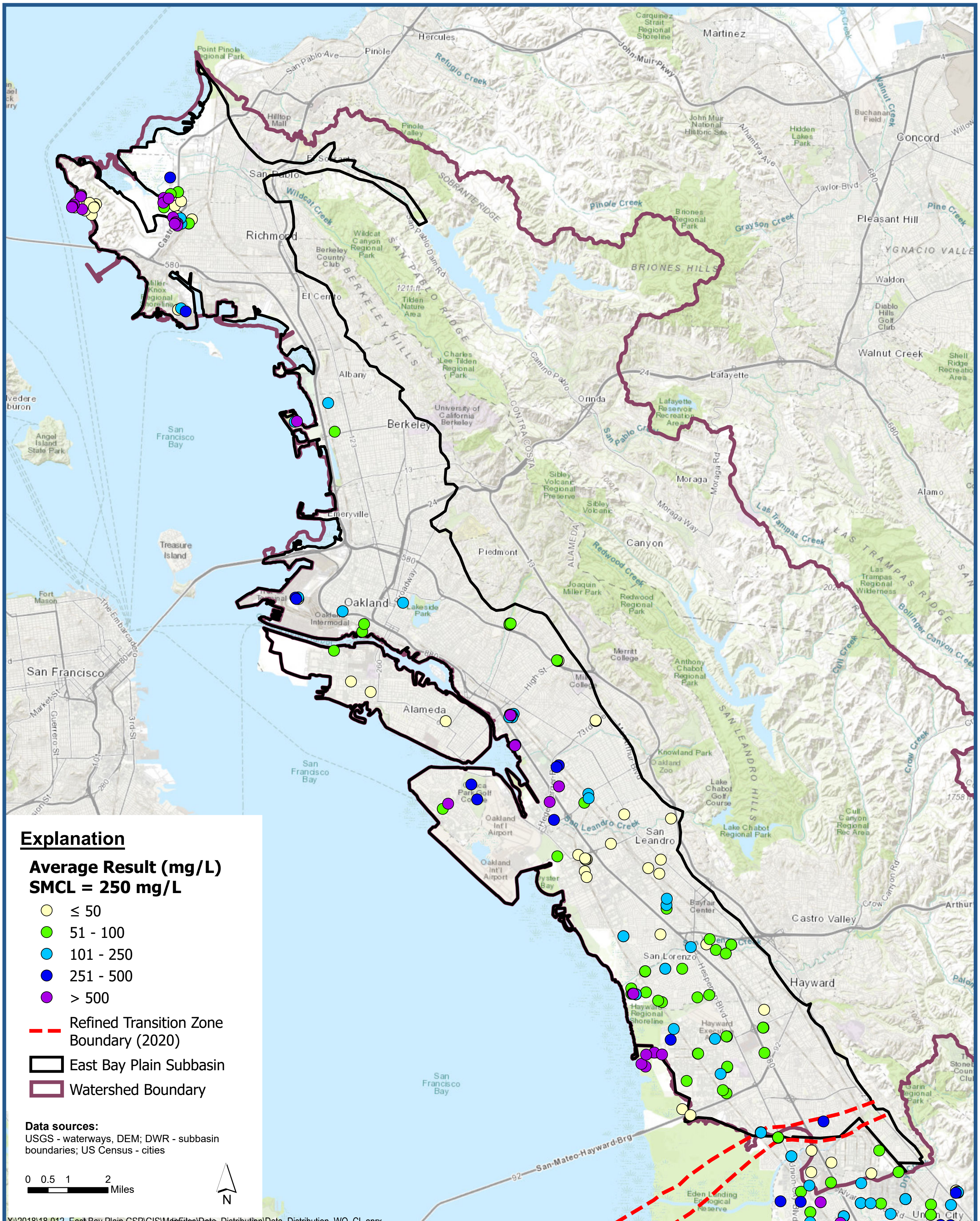


LSCE TEAM

Average Total Dissolved Solids (TDS) Measurement for Wells deeper than 50-feet

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-29

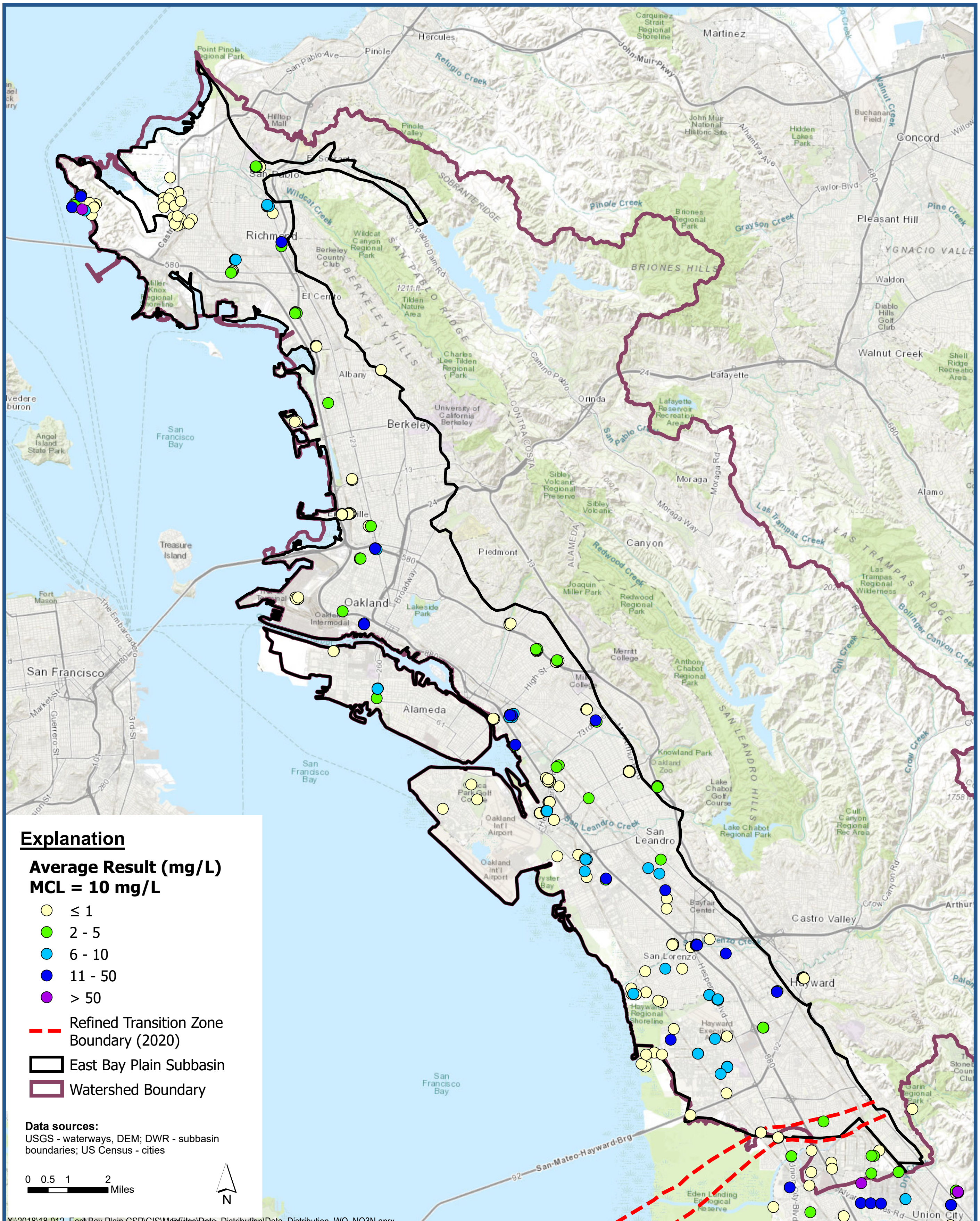


LSCE TEAM

Average Chloride (Cl) Measurement for Wells deeper than 50-feet

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-30

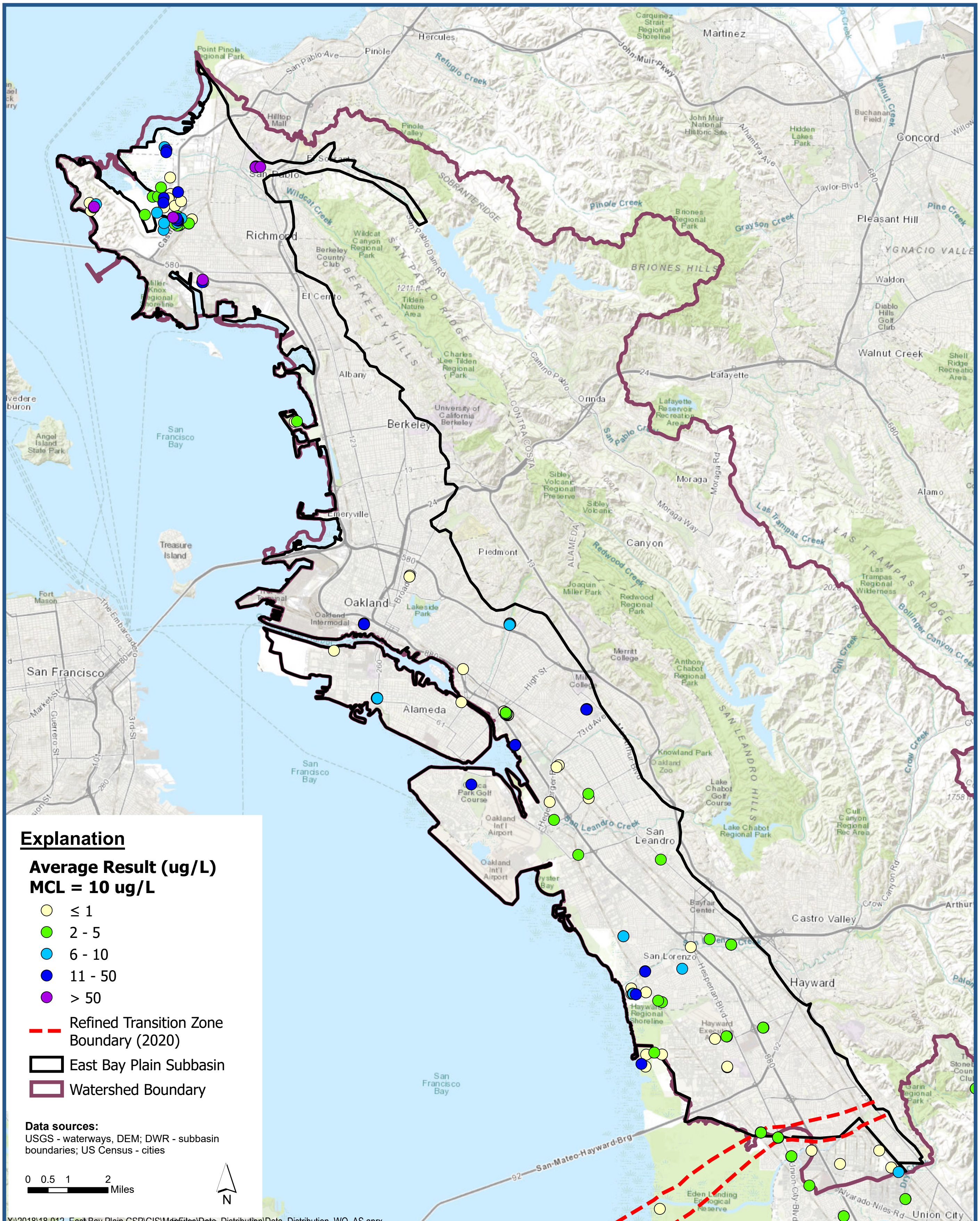


LSCE TEAM

Average Nitrate (NO_3N) Measurement for Wells deeper than 50-feet

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-31

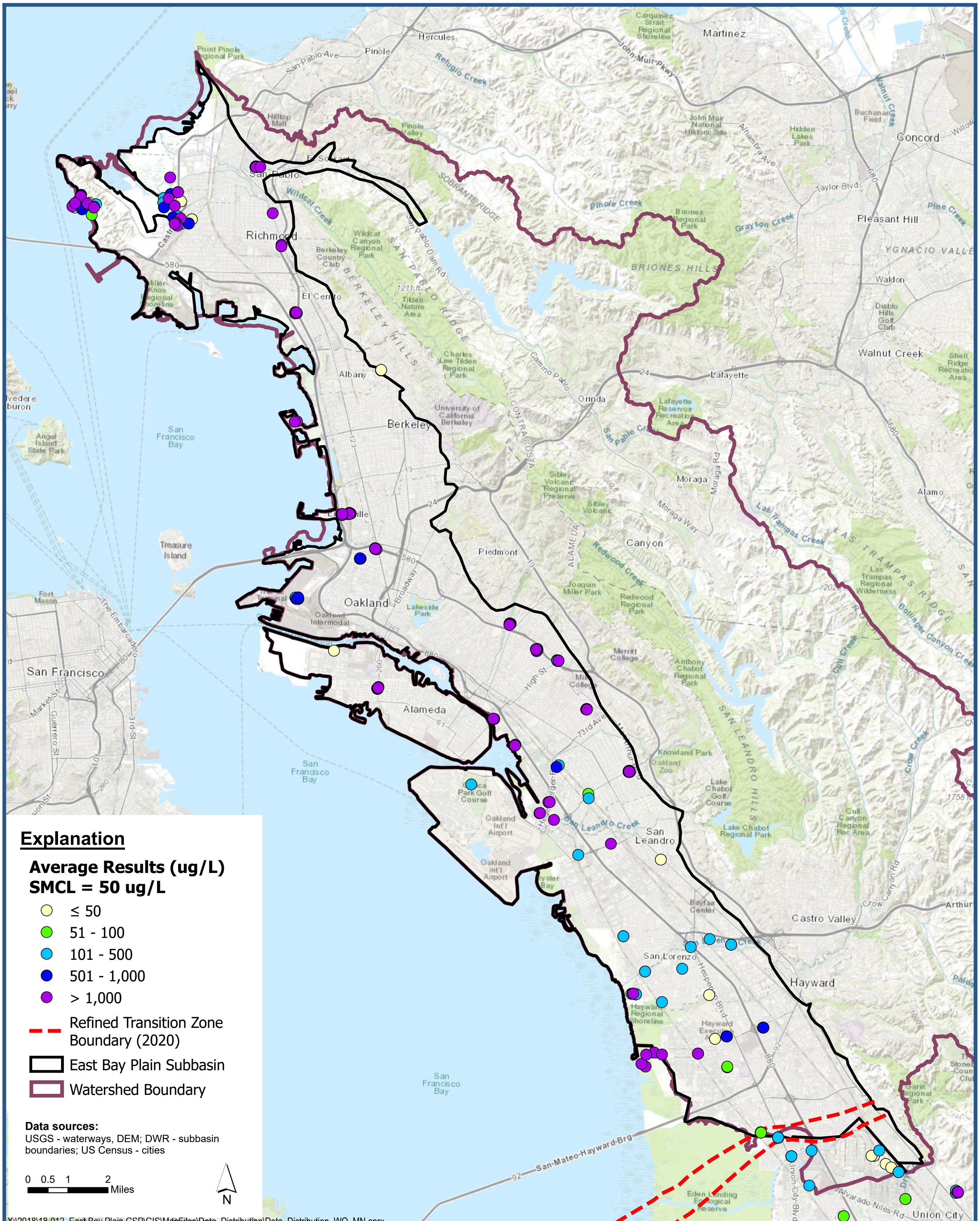


LSCE TEAM

Average Arsenic (As) Measurement for Wells deeper than 50-feet

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-32

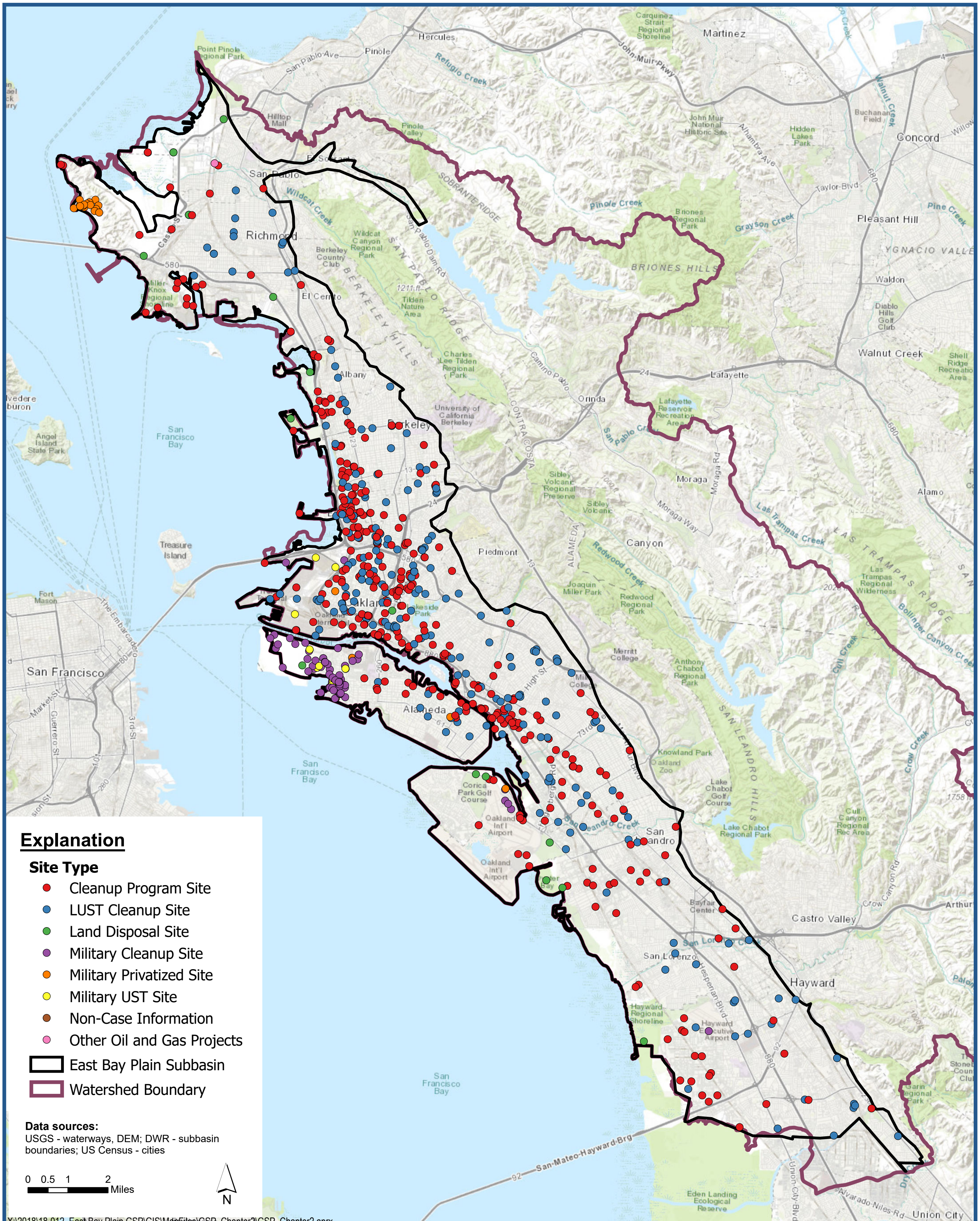


Average Manganese (Mn) Measurement for Wells deeper than 50-feet

East Bay Plain Subbasin
Groundwater Sustainability Plan

LSCE TEAM

Figure 2-33

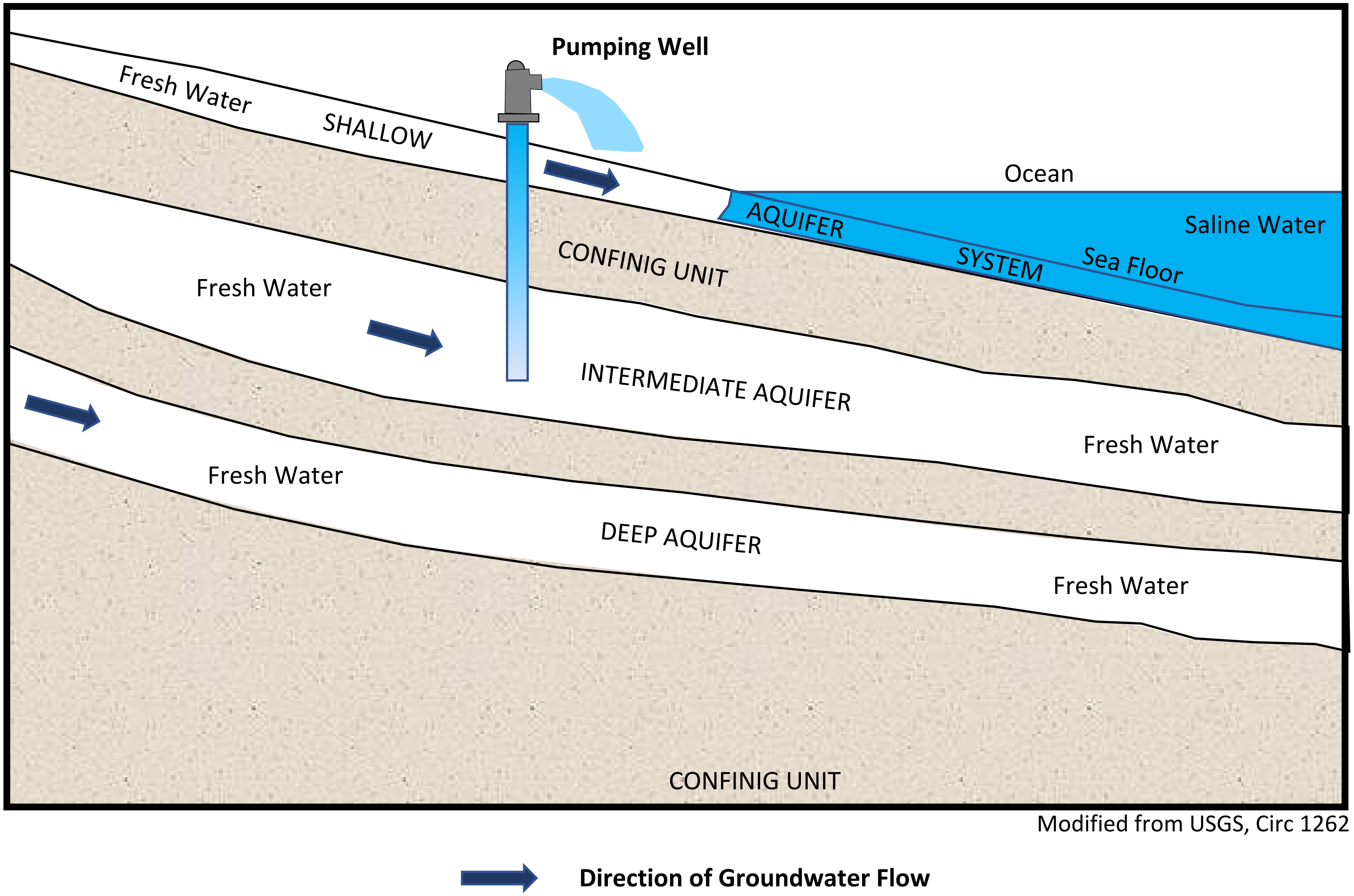


LSCE TEAM

Map of Environmental Site Locations

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-34



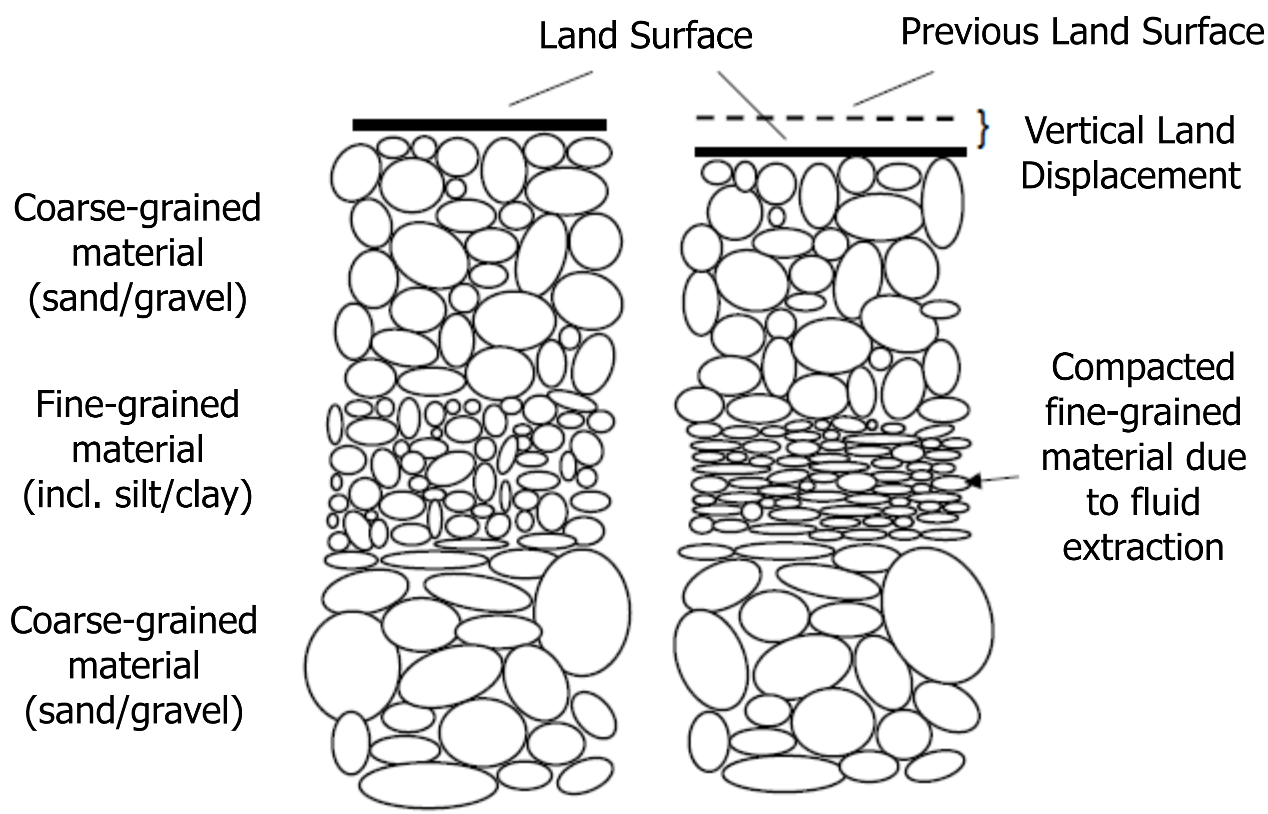
Modified from USGS, Circ 1262

LSCE TEAM

Example Conceptual Cross-Section of Salt Water Intrusion in Coastal Margin Aquifers

Figure 2-35

East Bay Plain Subbasin
Groundwater Sustainability Plan



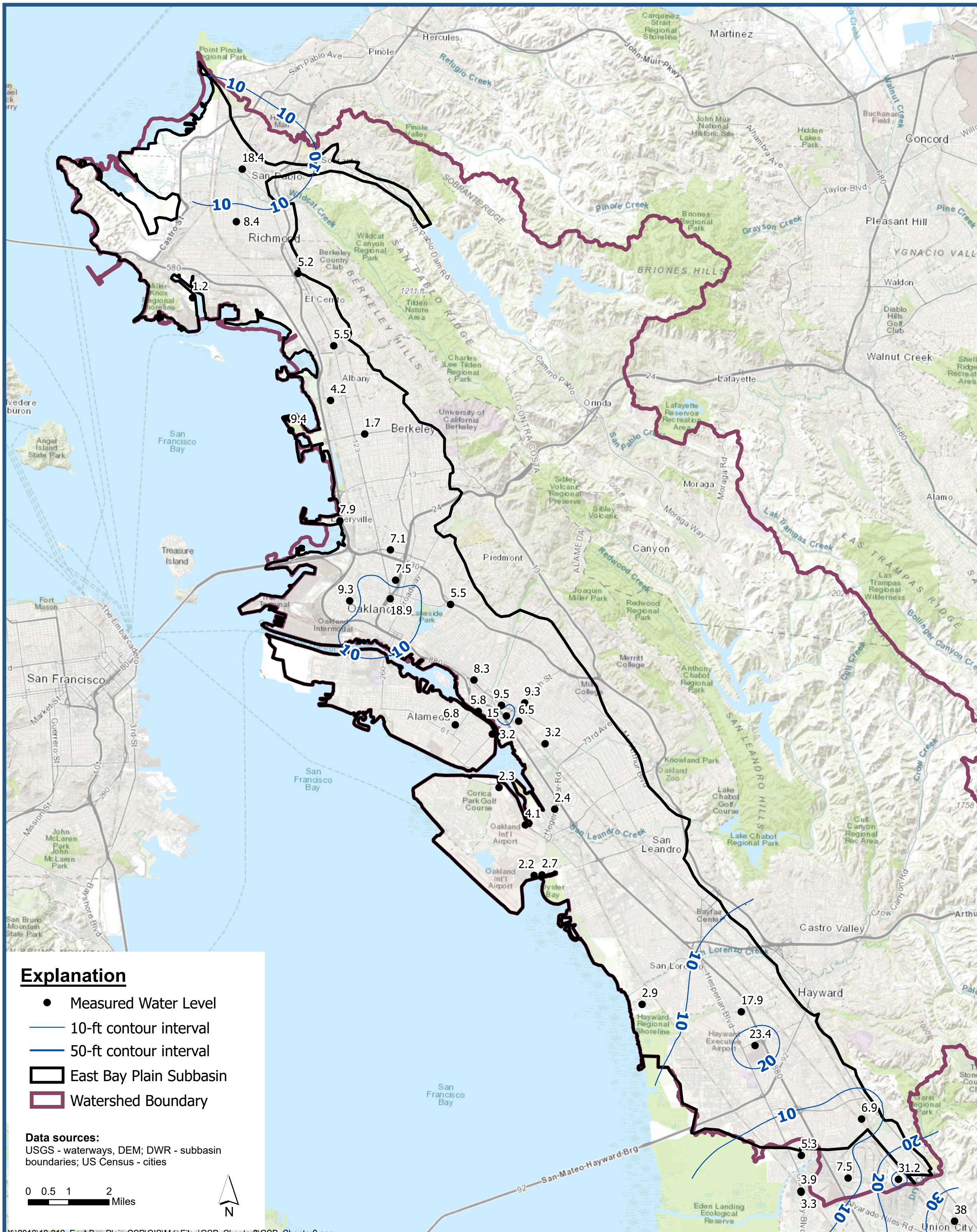
X:\2018\18-012_East Bay Plain GSP\GIS\MapFiles\GSP_Chapter2\GSP_Chapter2.aprx:[empty]

LSCE TEAM

Compaction Diagram

East Bay Plain Subbasin
Groundwater Sustainability Plan

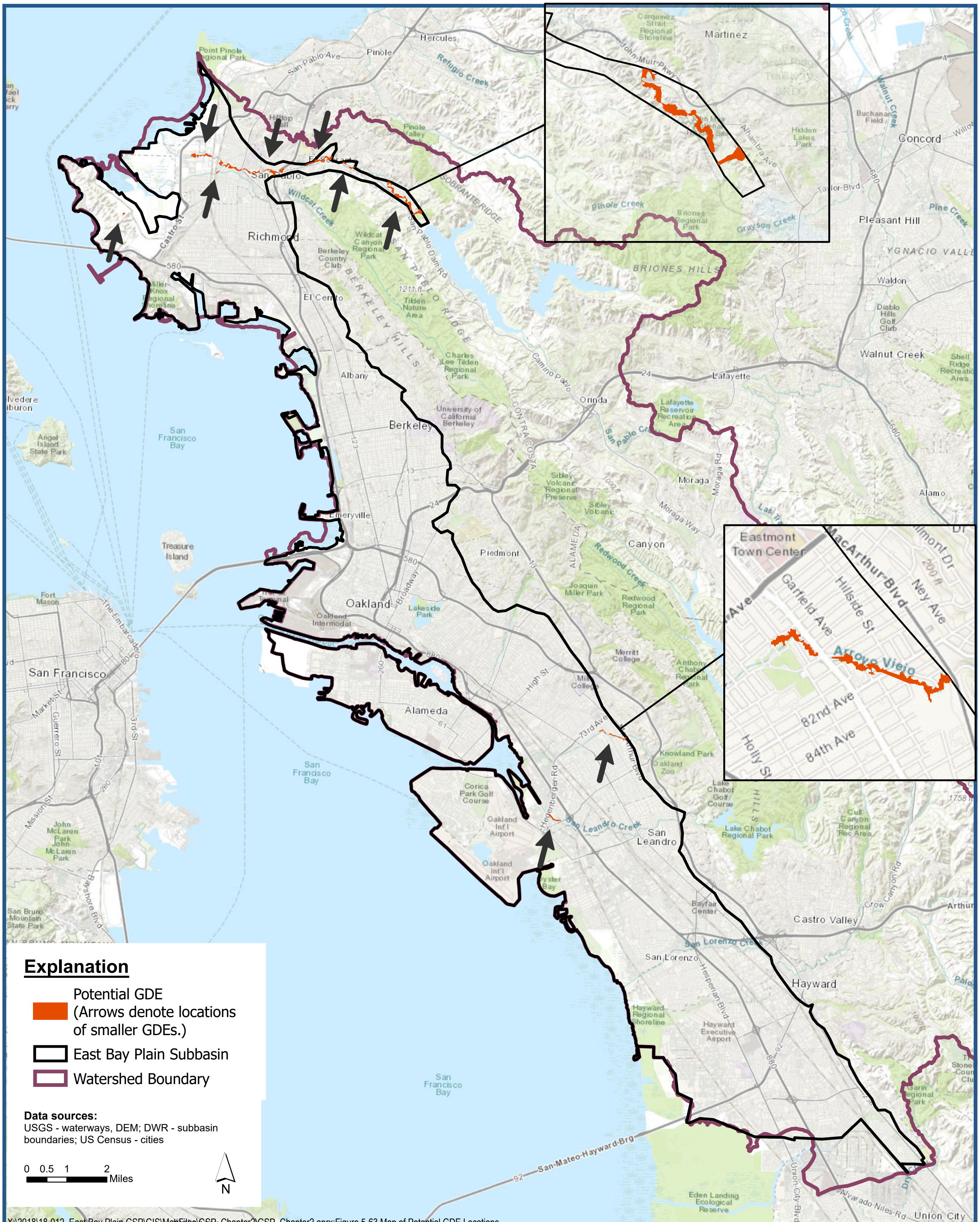
Figure 2-36



Map of Depth to Water Table – Spring 2015

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 2-37



Map of Potential Groundwater Dependent Ecosystem (GDE) Locations

Groundwater Sustainability Plan
EBMUD/East Bay Plain Subbasin

LSCE TEAM

Figure 2-38