Local Hazard Mitigation Plan 2018

East Bay Municipal Utility District

Executive Summary

Hazard Mitigation is commonly defined as "sustained action taken to reduce or eliminate long-term risk to human life and property from hazards." A hazard mitigation plan identifies the hazards a community or region faces, assesses their vulnerability to the hazards, and identifies mitigation actions that can be taken to reduce the risk. A hazard mitigation plan is most effective when it is developed before a disaster occurs and formulated through a systematic process centered on the participation of citizens, businesses, public officials, and other community stakeholders.

The East Bay Municipal Utility District's (EBMUD) 2018 Local Hazard Mitigation Plan (2018 LHMP) is an update to its 2011 Local Hazard Mitigation Plan (2011 LHMP) and reflects EBMUD's most current system upgrades, improvements, and mitigation measures to reduce the community's exposure to hazards and to improve the reliability of its services to the public.

The 2018 LHMP is organized as follows:

Chapter 2 – Local Hazard Mitigation Plan Overview – details the process EBMUD used to assess and analyze the hazards to which EBMUD is most vulnerable, including its participation in regional and local meetings and forums for mitigation planning and information sharing. This section identifies how the public and other stakeholders were involved and includes a detailed summary of the key meetings held with associated outcomes.

Chapter 3 – EBMUD Goals and Objectives – provides a brief profile of EBMUD, including its service area, mission, goals, and priorities.

Chapter 4 – EBMUD Facilities – provides an overview of EBMUD's Water Supply and Wastewater Facilities, including its dams, reservoir tanks, pumping plants, transmission/distribution pipelines, water and wastewater treatment facilities, regulators, and rate control stations, Mokelumne Aqueduct, and Pardee and Camanche Reservoirs.

Chapter 5 – The Identified Hazards – builds on available historical data and establishes detailed profiles for each of the primary hazards impacting EBMUD's service area – five related to earthquakes (faulting, shaking, earthquake induced landslides, liquefaction, and tsunami), and four related to weather (flooding, landslides, wildfires, and drought). The 2018 LHMP updates the 2011 LHMP by adding climate change, terrorism, and fires.

Chapter 6 – Vulnerability Assessment – summarizes the risks to each facility type listed in Chapter 4. In particular, it assesses the exposure and vulnerability of the identified hazards and summarizes the impact and estimated loss by facility type. These risk assessments collectively contribute to the development, adoption, and implementation of a meaningful and functional mitigation strategy based on accurate background information.

Chapter 7 – Mitigation Goals, Objectives, and Actions – describes the specific mitigation actions, capital improvements, and other measures EBMUD has undertaken and/or will undertake to address the identified risks for each facility type.

Chapter 8 – 2018 LHMP Maintenance – includes the measures that EBMUD will take to monitor, evaluate, and update the 2018 LHMP to ensure continuous long-term implementation and to regularly evaluate and update the 2018 LHMP to remain a current and meaningful planning document.

Chapter 9 – Mitigation Plan Point of Contact – provides EBMUD staff contact information for the 2018 LHMP.

A draft copy of this plan was published on the EBMUD webpage for public comments in advance of the October 11, 2016 EBMUD Board of Directors Planning Committee meeting. Following FEMA approval, the final 2018 LHMP will be approved by the EBMUD Board of Directors.

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1. Introduction

The Federal Emergency Management Agency (FEMA) defines "hazard" as "any event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural losses, damage to the environment, interruption of business, or other types of harm or loss." Additionally, FEMA defines "hazard mitigation" as "sustained action taken to reduce or eliminate long term risk to human life and property from hazards."

Hazard mitigation is most effective when a long-term plan is developed before a disaster occurs. A hazard mitigation plan identifies the hazards a community or region faces, assesses their vulnerability to the hazards, and identifies mitigation actions that can be taken to reduce the risk.

On October 25, 2011, the East Bay Municipal Utility District (EBMUD) Board of Directors adopted the 2011 LHMP with a vision to reduce the community's exposure to natural hazards and improve the reliability of our services to the public. The 2011 LHMP focused primarily on EBMUD's water distribution facilities, located in the East Bay, and was submitted as an annex to the Association of Bay Area Governments (ABAG) multi-jurisdictional Local Hazard Mitigation Plan and was approved by FEMA on November 16, 2011. FEMA's approval of the 2011 LHMP was for a period of five years. EBMUD revised its LHMP in 2016.

The EBMUD 2018 LHMP is a replacement of the 2011 Annex described above. In addition to local water distribution facilities, the scope of the 2018 LHMP is expanded to include other types of facilities such as water supply and wastewater facilities, and is intended to meet the requirement of the Federal Disaster Mitigation Act (DMA) of 2000 (Public Law 106-390). EBMUD's 2018 LHMP is organized according to FEMA's Local Hazard Mitigation Plan Handbook (March 2013), and was revised to reflect the system upgrades, improvements and mitigations EBMUD completed since 2011.

This updated plan was first submitted on November 8, 2016 for Cal OES review, prior to going to FEMA for approval. EBMUD received comments from Cal OES on August 23, 2017, and revised the LHMP accordingly. Cal OES approved the revised LHMP and sent the plan to FEMA on November 20, 2017 for approval.

FEMA completed the review of the 2017 LHMP and returned the plan to EBMUD on December 20, 2017 with comments and requested edits. EMBUD revised the LHMP accordingly, and this final version of the plan, the 2018 LHMP, and Review Tool was resubmitted to FEMA on January 24, 2018.

2. Local Hazard Mitigation Plan Overview

2.1. Purpose of the 2018 LHMP

The purpose of the 2018 LHMP is to significantly reduce deaths, injuries, property loss, and water service disruption caused by natural hazards that might impact EBMUD property or facilities. These impacts could occur within or near any of the EBMUD assets in Alameda, Amador, Contra Costa, Calaveras, San Joaquin, and Sacramento Counties. The 2018 LHMP provides a process for assessing and analyzing those hazards to which EBMUD is most vulnerable. EBMUD's resilience can be improved by performing a hazard risk assessment, using available tools to complete a capabilities assessment, and then identifying mitigation actions for these hazards.

The 2018 LHMP analyzes the risk posed to people and property by earthquakes, landslides, floods, wildfires, drought and other hazards such as climate change and security events, and considers mitigation actions that EBMUD could implement prior to such events. The goal is to reduce the risk to life safety and property damage caused by these natural hazards.

Mitigation projects and programs identified in the 2018 LHMP may be given priority for funding and technical assistance by the State and/or Federal government. The projects most likely to receive funding are those that mitigate more than one hazard and address risks of concern to more than one agency.

This 2018 LHMP establishes prioritized mitigation goals and adopts a five-year implementation timeline with which EBMUD will seek to implement, subject to funding and resource limitations.

2.2. Plan Overview

The 2018 LHMP seeks to identify where EBMUD can take reasonable actions to minimize the adverse effects and dangers posed by disaster events before they occur. Despite EBMUD's actions to reduce the potential for damage and harm while increasing readiness to respond to such events, the potential for significant harm and damage arising from natural disasters remains.

The 2018 LHMP represents EBMUD's commitment to pre-disaster mitigation, prevention, and preparation. It helps fulfill EBMUD's regulatory obligations as established by law and serves as a guide for decision makers as they commit resources to reduce the impacts of such hazards in the future.

The 2018 LHMP provides a variety of new features and improves upon the 2011 LHMP. This 2018 LHMP follows the guidelines set in FEMA's Local Hazard Mitigation Plan Handbook (March 2013) and includes substantial new material, including a chapter on climate change mitigation.

2.3. Integration of Local and State/County Mitigation Efforts

EBMUD staff works very closely with the cities in its service area and with the Operational Areas Councils in each county where EBMUD owns and operates critical infrastructure. Upon completion of the original draft of this LHMP, the draft was posted online in October 2016. Steve Frew, Manager of Security and Emergency Preparedness, sent a link to the plan and requested a review and comments from the following people and their respective organizations:

Theresa Langdon, Secretary for the Alameda County Emergency Manager's Association;
Paul Hess, Emergency Manager, Alameda County OES;
Marcelle Indelicato, Emergency Planner, Contra Costa County OES;
Rick Kovar, Emergency Manager, Contra Costa County OES;
Michael Cockrell, Director, San Joaquin County OES;
John Silva, Amador County Sheriff's Office OES;
W. Whitney, Calaveras County Sheriff's Office OES;
Cathey Eide, Emergency Manager City of Oakland OES, Oakland Fire Department.

EBMUD regularly participates in regional meetings and collaborates on a variety of forums on mitigation planning and information sharing. The following are examples of this outreach.

<u>The Bay Area Center for Regional Disaster Resilience/California Earthquake Clearing House</u>
EBMUD has hosted meetings put on by these two consulting groups in its main administration building. The meetings have been attended by EBMUD's Emergency Operations Team section chiefs and support staff (Operations, Planning, Logistics, Finance, and Public Information sections).

During these meetings, EBMUD met and worked with planning partners from other water agencies, gas/electric utilities, telecommunications utilities, and other public agencies. These public agencies include BART, city and county governments, health care and special needs/dependencies representatives, and volunteer groups. The focus of the meetings was on drinking water following a regional emergency such as earthquake, fire, flood or other regional disasters. The meetings were held to specifically ensure that those attending would have reasonable expectations of EBMUD and other water agencies following such events, when water and wastewater services are disrupted or otherwise not available.

<u>Alameda County and Contra Costa County Operational Areas</u>
Each county has an Operational Area Council (OAC). The members of each council are generally representatives of the agencies within each county who are proactive in hazard identification and mitigation planning.

EBMUD's Manager of Security and Emergency Preparedness or his delegate attends these meetings as EBMUD's representative. EBMUD is part of the voting block that discusses and approves the allocation of Urban Area Security Initiative (UASI) grant funding. The projects that are funded are generally those that, like Local Hazard Mitigation Plans, will benefit more than one agency, will mitigate hazards and/or improve response capability, and improve resilience to natural disasters.

Each county also has an Emergency Management Association (EMA). Representatives from the EMA participate in their county's planning process, with the goal of enhancing the Operational Area Office of Emergency Services' ability to work with and support of each city and special district within the county.

These EMA and OAC meetings are usually held on a quarterly basis. The meetings provide an opportunity to run training courses and emergency exercises with the goal of improving awareness, daily and emergency communication amongst agencies, and an understanding of critical interdependencies. The meetings also allow for networking between agencies.

EBMUD works with representatives and emergency managers of the cities within each county, emergency managers of hospitals and health care organizations, and the Department of Public Health. The focus of these meetings is also on what to expect when water and wastewater services are disrupted or otherwise not available following local or regional disasters, and to keep those expectations reasonable.

Over the weekend of September 11, 2016, both Alameda and Contra Costa County Operational Areas participated in the Operation Urban Shield Yellow Command Exercise. The Yellow Command exercise focus was, and still is, in the development of Commodity Points of Distribution (C-PODs) for drinking water when water utilities are unable to provide water following an emergency. The Offices of Emergency Services must request that bottled water be brought in for distribution to the public.

EBMUD is actively working with all of the cities in its service area on the development of C-PODs, as well as on the establishment of locations where manifolds that can be attached to fire hydrants. Each city manages these drive-up points of distribution for water, allowing the community to fill their own containers to take to their homes and businesses.

<u>California Utilities Emergency Association (CUEA)</u>
The CUEA is located inside the State Operations Center (SOC) in Mather, California. Membership is comprised of public and private utilities and agencies from across the state. These utilities are typically energy utilities (gas/electric), water and wastewater agencies, pipeline agencies, and telecommunications agencies (wired and wireless). EBMUD is one of the seven at-large Board of Directors members and is represented by the Manager of Security and Emergency Preparedness. The Manager of Regulatory Compliance is the alternate Board representative.

In keeping with the Memorandum of Understanding (MOU) between the CUEA and the State of California (State), the CUEA assists the State in mission-tasking utility assistance that state agencies are not able to fill. During emergencies in which the SOC is activated, the Utility Operations Center (UOC) is also activated. The CUEA manages the UOC (a break-out room inside the SOC), and seats are staffed to represent each of the utility sectors described above. The CUEA is the one-stop-shop for the SOC to communicate with all utilities in the state as to their situation status, outages areas in each county, and repair status as damage repairs are made.

Through the CUEA, the Operational Area Emergency Operations Centers, and the Coastal Region Emergency Operations Center, EBMUD has the ability to communicate up to and back down from the SOC as needed on a daily basis, during an emergency response, under emergency conditions, and in recovery from an emergency in the state.

<u>Bay Area Regional Reliability (BARR) Partnership</u>
Together with seven other Bay Area water agencies – Alameda County Water District, the Bay Area Water Supply and Conservation District, Contra Costa Water District, Zone 7 Water Agency, Marin Municipal Water District, the San Francisco Public Utilities Commission, and the Santa Clara Valley Water District – EBMUD formed the BARR partnership to improve integrated regional water management and drought resilience. The agencies adopted principles in 2014 to guide the partnership, and then executed a formal Memorandum of Agreement in 2015.

The BARR partners received a $200,000 grant from the U.S. Bureau of Reclamation to prepare a Drought Contingency Plan (DCP) that would take an integrated, regional approach to water supply reliability. The draft DCP was completed in June 2017 and submitted to the U.S. Bureau of Reclamation for review and comment. The DCP reviewed the water supplies and demands for the eight agencies and assessed the vulnerability of the region's water supplies. It described drought response actions to help manage limited supplies and also identified 15 drought mitigation measures that could be implemented before a drought occurs to increase regional reliability and resilience. Drought mitigation measures are programs, and strategies implemented before a drought occurs to increase regional water supply reliability and improve long-term resilience. These efforts require detailed and often lengthy planning and implementation, and they may involve reconfiguring or expanding existing assets or constructing new facilities. A Drought Task Force composed of 25 stakeholder groups representing environmental, public policy, business, and other interests participated in the development of the DCP.

2.4. Integration with EBMUD Master Plans

EBMUD has 37 master plans covering its water and wastewater system infrastructure. In addition, tools were developed, including the Coordinated Infrastructure Master Planning Guidance Manual, to better organize the master plans to ensure they are comprehensive and coordinated.

There are three levels of master plans at EBMUD. Primary Master Plans are the highest level of master plans and provide the key strategic foundation and direction for EBMUD in achieving a strategic plan goal on a system wide basis for a major function. The planning horizon for these plans is 20 to 50 years and they are updated every 5 to 30 years. EBMUD currently has seven primary master plans. Examples of Primary Master Plans include the Urban Water Management Plan, Water Supply Management Plan 2040, Water Treatment and Transmission Master Plan, Distribution System Master Plan, Wastewater Treatment System Master Plan and Wastewater Collection System Master Plan.

Sub-element Master Plans are the second tier of master plans that either provides input to a primary master plan or conducts more focused study for a major sub-portion of a primary plan. Sub-element Master Plans identify projects for new facilities or significant changes to existing facilities. The planning horizon for these plans is 10 to 30 years and the plans are updated on a 5 to 15 year basis. EBMUD currently has 21 sub-element master plans. Examples of Sub-element Master Plans include the Seismic Evaluation Program, Pressure Zone Improvement Program Master Plan, Raw Water Master Plan, Wastewater Seismic Master Plan, and Wastewater Control Systems Master Plan.

Infrastructure Rehabilitation Plans (IRP) are the third tier of master plans that establish facility rehabilitation programs and/or operational processes. Infrastructure Rehabilitation Plans are the primary planning documents for EBMUD's ongoing rehabilitation related to maintaining the existing infrastructure at the appropriate level of operational readiness. The planning horizon for these plans is coordinated with EBMUD's ten year Capital Improvement Program with updates generally planned on a two to five year repeating basis. EBMUD currently has nine Infrastructure Rehabilitation Plans. Examples of Infrastructure Rehabilitation Plans include the Infrastructure Rehabilitation Plans for water treatment plants, reservoirs, pumping plants, rate control stations, and regulators, as well as the Large Diameter Pipeline Master Plan and the Distribution System Pipeline Master Plan.

Prioritization of mitigation actions and projects occurs continuously, but the process is formalized when the IRPs are created or updated biennially in support of EBMUD's biennial budget process for its Capital Improvement Program. The IRPs are also reevaluated when EBMUD is responding to an active emergency in our region. EBMUD must balance several considerations when prioritizing projects identified in its IRPs and allocating financial and personnel resources to any project. EBMUD's infrastructure rehabilitation projects are prioritized based on a combination of factors and screening criteria that vary by facility type and criticality.

For pipeline replacement projects, priorities are determined based on overall risk, considering both the likelihood of failure and the consequence of failure, and includes a cost benefit analysis comparing cost of continued maintenance (i.e., leak repairs) versus replacement. For other types of rehabilitation projects, such as treatment plants and pumping plants, priorities are driven by a different set of criteria including facility criticality, based on a vulnerability assessment, as well as a range of other screening criteria including operations and maintenance priority, health and safety, capacity needs, redundancy, and cost.

For its large diameter pipeline replacements and facility rehabilitation projects, EBMUD completes an alternatives analysis to determine the type of mitigation actions required to improve the overall reliability and maintenance of its facilities. This alternatives analysis process typically includes a comparison of advantages and disadvantages as well as cost benefit or life cycle cost analysis to select a mitigation option. Higher priority is given to projects and actions that address multiple hazards at once, mitigate hazards with a high probability of occurrence, can benefit other critical lifelines with complementary mitigation goals, or can significantly reduce the scale of impact of a hazard event. Priority is also given to mitigation measures that can be incorporated into ongoing projects as part of day-to-day capital improvement programs. The District's ongoing Pipeline Infrastructure Replacement Program is an example of this type of prioritization. The anticipated benefit of each project is weighed against the cost of implementation.

EBMUD has used, and will continue to use, a variety of project-specific mechanisms to ensure that the projects and mitigation strategies identified as existing or having relatively high priorities in this 2018 LHMP are implemented. EBMUD has completed three master plan documents to evaluate and help mitigate for earthquake hazards at its facilities. Other hazards are evaluated within the EBMUD master plans under the reliability component of the alternatives evaluation. As the individual master plans are updated, the recommendations from this 2018 LHMP will be incorporated into master plans, including the identified goals, objectives, and strategies.

2.5. Planning Process

2.5.1. The Regional Planning Process

Over the last few years, EBMUD has participated in various ABAG workshops and meetings. key participants in the ABAG workshops and meetings include: Pacific Gas and Electric Company (PG&E), the City of San Francisco's Lifelines Council, the California Earthquake Authority (CEA), United States Geological Survey (USGS), the California Geological Survey (CGS), the Structural Engineers Association of California (SEAOC), the Structural Engineers Association of Northern California (SEONC), the Pacific Earthquake Engineering Research Center (PEER), the Earthquake Engineering Research Institute (EERI), the California Seismic Safety Commission, the Bay Area Center for Regional Disaster Resilience, and the California Earthquake Clearinghouse.

The main goal of EBMUD’s participation in workshops and meetings with other agencies is to improve EBMUD’s earthquake preparedness, response, and initial recovery of the water distribution system after a major earthquake.

Since the adoption of the 2011 LHMP, the following notable events have occurred:

- EBMUD participated in the Loma Prieta 25 Symposium (LP25 Symposium) on October 16, 2014 as part of a panel of experts. The San Francisco Lifelines Council, PEER, PG&E, and the California Seismic Safety Commission assembled to discuss an infrastructure resilience policy as it relates to the interconnectedness of utility systems and social ecosystems.

  The symposium was organized by ABAG, in partnership with the CEA, USGS, CGS, SEAOC, SEAONC, PEER, EERI, and the California Seismic Safety Commission.

- Following the LP25 Symposium, EBMUD collaborated with ABAG and other organizations in the creation of a new Regional Lifelines Council Working Group.

  The Regional Lifelines Council Working Group began meeting in 2014 on a regular basis to improve regional coordination. The focus of the meetings is on assessing regional power, water, and transportation disruption resilience. In 2015, EBMUD focused on comparing its damage predictive modeling capabilities with PG&E's as a first step to completing regional risk assessment approach looking at major hazards impacting interdependent lifelines.

The ultimate goal of this working group is to develop an effective coordination strategy among regional stakeholders, agencies, and service providers by involving other regional partners, such as city representatives, in these discussions. The main objective of the group is to develop a guide for local governments on the operation of lifelines, how to manage disruptions, and how to effectively tap regional planning and restoration efforts by providing guidelines for energy assurance and water system contingency planning.

- EBMUD participated in a workshop on February 20, 2015 titled "Interdependent Lifelines Risk and Regional Resilience, South Napa Earthquake Lessons Learned, and Priority Actions for the 'Big One'". The workshop included a discussion on the work that EBMUD and PG&E are doing to accelerate and expand efforts to assess potential major earthquake damage to critical assets.

  This workshop was attended by representatives from the local government, private sector, and non-profit organizations from across the Bay Area. Workshop participants met with state and federal partners to examine lifelines response and initial recovery efforts after the Mw 6.0 South Napa earthquake on August 14, 2014.

  A key goal of the workshop was to determine how to better assess risk and assure the resilience of Bay Area interdependent lifelines (water and wastewater, energy, communications, and transportation) in a major earthquake or other regional event. The workshop resulted in a large number of findings on what did and did not work for restoring lifelines in the days after an earthquake. In addition, workshop attendees developed nine potential actions to improve Bay Area resilience for the next big earthquake.
- EBMUD attended a Hazard and Risk Workshop in Fairfield on June 19, 2015. The workshop was organized as part of ABAG's Resilience Program, and provided an overview of the new assessment process with specifics to be followed by agencies and cities when updating their LHMPs.
- EBMUD hosted a roundtable meeting titled "Sharing Earthquake Data for Improved Resiliency of Bay Area Lifelines and Critical Infrastructures." Representatives of Bay Area Lifelines, other essential service providers, and government agencies met on August 26, 2015 to discuss sharing earthquake-related impact information to enhance Bay Area resilience.

  Organizers of the roundtable included the California Earthquake Clearinghouse and the Bay Area Center for Regional Disaster Resilience (BACRDR), which served as roundtable facilitators.

- EBMUD participated in an ABAG meeting on October 14, 2015 with the Department of Homeland Security/Office of Infrastructure Protection (IP) to discuss coordination among Bay Area utilities, agencies, and local governments.

  This effort was aligned with a number of regional resilience planning and implementation initiatives underway. Some of these initiatives include the 100 Resilient Cities (100RC) program, the City of San Francisco's Lifelines Council, the Loma Prieta 25 Policy agenda, and the ABAG/FEMA Regional Resilience Partnership. The goal of the meeting was to improve planning on infrastructure reliability and resilience in order to better support communities in the event of a significant earthquake.

- EBMUD hosted a workshop on November 9, 2015 for the Lifelines and Critical Infrastructure Data Sharing Workgroup. This new workgroup was established at the recommendation of participants in the August 26, 2015 roundtable on "Sharing Earthquake Geotechnical and Related Damage Data for Improved Resiliency of Bay Area Lifelines and Critical Infrastructure."

  The workshop was organized by the Bay Area Center for Regional Disaster Resilience and the California Earthquake Clearinghouse to improve earthquake preparedness, response, and initial recovery.

- EBMUD participated in a joint workshop on December 16, 2015 with ABAG, the California Governor's Office of Emergency Services (Cal OES), the Department of Water Resources (DWR), and local cities. The focus of the workshop was on improving preparations for El Nino.

- EBMUD participated in the 13th Annual Northern California Earthquake Hazards workshop on January 26-27, 2016.

- On January 28, 2016, Dr. Charles Scawthorn and Dr. Keith Porter, Research Professors from the Department of Civil Environmental and Architectural Engineering at the University of Colorado Boulder, presented their preliminary findings on the HayWired project.

  This study utilizes an earthquake scenario model to help scientists, engineers and planners study the impacts a Mw 7.05 earthquake on the Hayward fault would have on the San Francisco Bay Area. Results demonstrated the vulnerabilities of modern urban infrastructure resulting from multiple layers of interdependencies between lifelines, and a major reliance on the Internet.

  EBMUD, along with the San Jose Water Company, participated in this study by providing data and assumptions that were used as part of Dr. Porter's modeling efforts to estimate the damage to the Bay Area's water supply and time required to restore service after such an event. The results of Dr. Porter's study are scheduled to be published as part of a larger USGS study to be released in April 2017.

- EBMUD participated in a 2-day HayWired Scenario Aftershock Workshop at USGS in Menlo Park on February 24-25, 2016.

- EBMUD participated in a Water Systems Panel Discussion and Table-Top Exercise on June 1, 2016 at the Alameda County Office of Emergency Services in Dublin.

  The goal of this training, workshop, and table-top exercise was to facilitate the building of regional capabilities to plan for, operate, and secure Points of Distribution (PODs) for potable water throughout the local area after a major disaster.

- EBMUD organized a series of workshops to evaluate regional water supply reliability and develop regional mitigation measures as part of the Bay Area Regional Reliability (BARR) Drought Contingency Plan (DCP). The BARR partnership includes eight Bay Area water agencies working together to improve regional water supply reliability and drought resilience. As part of the DCP development process, EBMUD also convened a "Drought Task Force" including 25 stakeholder groups representing environmental, planning, business, and other interests.

  EBMUD held a kickoff meeting for the DCP on April 15, 2016, which included the BARR agencies and the Drought Task Force members. The group met again on September 16, 2016 to discuss the initial vulnerability assessment and to review proposed mitigation measures. The group met a third time on March 29, 2017, to further refine the mitigation measures and discuss next steps.

2.5.2. The Local Planning Process

To create the 2018 LHMP, key EBMUD staff first met on July 26, 2016 to discuss how to update the 2011 LHMP and the goals for the revised LHMP. Planning meetings were held weekly, and also before and after major LHMP development milestones, until the LHMP was completed in September 2016.

The planning meetings accomplished several critical LHMP requirements, including defining general priorities, compiling and prioritizing hazard mitigation strategies, and determining the appropriate departments for implementing mitigation strategies. The meetings also involved reviewing preliminary budgets and establishing potential funding sources for improvement projects and strategies related to EBMUD owned and operated facilities.

The 2018 LHMP updates the 2011 LHMP with the incorporation of new information and the inclusion of hazard mitigation efforts not mentioned in the 2011 LHMP. These hazard mitigation efforts include EBMUD's Seismic Improvement Program (SIP), hazard and risk information developed in 2011, significant work that EBMUD has completed or currently has in progress from 2011 to the present, and planned hazard mitigation work for the next five years.

The first version of this plan, the 2016 LHMP, was sent to Cal OES for review on November 8, 2016. EBMUD followed-up with Cal OES to confirm the receipt of the 2016 LHMP in July 2017, and resubmitted the 2016 LHMP on July 3, 2017 for review. The 2016 LHMP was assigned for review on August 18, 2017, and returned to EBMUD with comments and requested edits on August 23, 2017.

The EBMUD team met and assigned tasks to address comments and incorporate requested edits. The second version of this plan, the 2017 LHMP, and the Review Tool was resubmitted to Cal OES on October 4, 2017. Cal OES returned the 2017 LHMP with another request for additional detail on October 23, 2017. The updated 2017 LHMP incorporated this request and was resubmitted to Cal OES for review on November 13, 2017. On November 20, 2017, Cal OES notified EBMUD that the review of the 2017 LHMP was complete, and the plan had been sent to FEMA for their assessment and approval.

FEMA completed the review of the 2017 LHMP and returned the plan to EBMUD on December 20, 2017 with comments and requested edits. The EBMUD team met and assigned tasks to staff members to address comments and incorporate requested edits. This final version of the plan, the 2018 LHMP, and Review Tool was resubmitted to FEMA on January 24, 2018.

The main contributors to the development of the EBMUD Local Hazard Mitigation Plan includes:

Serge Terentieff, Manager of Design
Paul Franceschi, Senior Civil Engineer, Design
Andrea Chen, Associate Civil Engineer, Design
Lilian Leung, Assistant Civil Engineer, Design
Suzanne Corralejo, Senior Administrative Clerk, Design
Steve Frew, Manager of Security and Emergency Preparedness
Michael Ambrose, Manager of Regulatory Compliance
Elizabeth Bialek, Manager of Engineering Services
Atta Yiadom, Senior Civil Engineer, Engineering Services
Yogesh Prashar, Associate Civil Engineer, Engineering Services
Lena Tam, Manager of Water Resources Planning
Ben Bray, Senior Civil Engineer, Water Resources Planning
Priyanka Jain, Senior Civil Engineer, Water Resources Planning
Ginger Chen, Associate Civil Engineer, Water Resources Planning
Carlton Chan, Manager of Pipeline Infrastructure
Roberts McMullin, Senior Civil Engineer, Pipeline Infrastructure
Alice Towey, Sr. Civil Engineer, Water Supply Improvements
Alicia Chakrabarti, Senior Civil Engineer, Wastewater Engineering
Jennifer Ku, Associate Civil Engineer, Wastewater Engineering
Kent Lambert, Manager of Mokelumne Watershed and Recreation
Scott Hill, Manager of East Bay Watershed and Recreation
John Hurlburt, Manager of Water Supply
Michael Tognolini, Manager of Water Supply Improvements

2.6. Public Involvement

A draft copy of the 2016 LHMP was made available to the public for comment, and the public was given two opportunities to comment on the draft 2016 LHMP.

1. The draft 2016 LHMP was published on the EBMUD website (www.ebmud.com) for public viewing for a period of two weeks, starting on October 5, 2016. Changes were made, based on public review comments received, and incorporated into the 2016 LHMP.

2. In addition to the two-week public review comment period, EBMUD also provided an opportunity for public comments on the draft 2016 LHMP at a public meeting of the EBMUD Board of Directors Planning Committee on October 11, 2016 at 8:00 a.m. at 375 11th Street in Oakland, California. The meeting and agenda item were advertised on the EBMUD website (www.ebmud.com) and through the public noticing of the meeting. Public comments received at this meeting were incorporated into the 2016 LHMP.

   EBMUD Board meetings are open and accessible to the public. Meeting notices and agendas are posted at least 72 hours in advance at the EBMUD office and on EBMUD's website (www.ebmud.com).

2.7. Formal Adoption of LHMP

EBMUD operates under the oversight and guidance of a Board of Directors elected by wards by the voters within each of the wards. As part of the process of creating and implementing the LHMP, a preliminary version of this plan was presented to the Board of Directors for their approval on October 11, 2016. Following the approval of the Board, the LHMP was then submitted to Cal OES and ultimately FEMA for review and acceptance.

Within approximately four weeks of FEMA's approval of the 2018 LHMP, the final plan will be presented to the Board of Directors during a regularly scheduled meeting for formal adoption.

3. EBMUD Goals and Objectives

3.1. Background

EBMUD is a publicly owned utility formed under the Municipal Utility District Act (MUD Act) passed by the California state legislature in 1921. The MUD Act permits the formation of multi-purpose government agencies to provide needed services on a regional basis. In 1923, voters in the East San Francisco Bay Area created EBMUD to provide water service. The MUD Act was amended in 1941 to enable the formation of special districts. In 1944, voters in six East Bay cities elected to form the EBMUD Special District No. 1 to treat wastewater before being released into San Francisco Bay. Wastewater treatment began in 1951.

EBMUD is a California Special District and is governed by a seven-member Board of Directors elected from wards within its service area. The Board is committed to developing policy through an open, public process, guided by the EBMUD's Mission Statement. Policies are then implemented under the direction of the General Manager. The General Manager and General Counsel are appointed by and report directly to the Board of Directors. The senior management team is responsible for managing the operations of EBMUD, and its approximately 1,800 employees.

3.2. EBMUD Profile

EBMUD is a water and wastewater utility district serving water to approximately 1.4 million customers in a 332-square-mile area extending from Crockett on the north towards southward to San Lorenzo (encompassing the major cities of Oakland and Berkeley), and eastward from Oakland to Walnut Creek, and southward through the San Ramon Valley. EBMUD's wastewater system serves approximately 680,000 customers in an 88-square-mile area of Alameda and Contra Costa counties along the bay's east shore, extending from Richmond on the north, to San Leandro on the south. In addition to providing wastewater treatment, laboratory service operates 365 days a year to constantly monitor water quality for drinking water and wastewater systems. See Exhibits A and B at the end of this 2018 LHMP.

EBMUD currently has an average annual growth rate of 0.8 percent and is projected to serve almost 1.6 million people by 2030. EBMUD's administrative offices are located in Oakland, California, from which EBMUD maintains two water storage reservoirs on the Mokelumne River in Calaveras and Amador counties, five terminal reservoirs, 91 miles of water transmission aqueducts, 4,200 miles of water mains, six water treatment plants, 37 miles of wastewater interceptor sewer lines and a regional wastewater treatment facility.

3.3. Vision and Mission

EBMUD is committed to providing reliable, high-quality drinking water and wastewater service through sustainable activities that avoid, minimize, or mitigate adverse effects to the environment and the public.

3.4. Goals and Objectives

EBMUD provides high-quality drinking water for 1.4 million customers in Alameda and Contra Costa counties. EBMUD's wastewater treatment serves 680,000 customers while protecting the San Francisco Bay.

EBMUD's mission is as follows:
To manage the natural resources with which EBMUD is entrusted; to provide reliable, high quality water and wastewater services at fair and reasonable rates for the customers of the East Bay; and to preserve and protect the environment for future generations.

The principles used in accomplishing this mission are:

- Exercise responsible financial management
- Ensure fair and reasonable rates and charges
- Provide responsive quality customer service
- Promote ethical behavior in the conduct of EBMUD business
- Ensure fair and open processes involving the public

- Provide a healthy work environment
- Promote diversity and equality in personnel matters and contracting
- Promote environmental, economic, and social sustainability

Our goals define what EBMUD wants to achieve; they explain "what" not "how," and tell where we are going rather than how we will get there. EBMUD's goals:

- **Long term Water Supply:** Ensure a reliable high quality water supply for the future.
- **Water Quality & Environmental Protection:** Meet or surpass environmental and public health standards and protect public trust values.
- **Long term Infrastructure Investment:** Maintain and improve EBMUD's infrastructure in a cost effective manner to ensure sustainable delivery of reliable, high quality service now and in the future, and addressing economic, environmental, and social concerns.
- **Long term Finical Stability:** Manage EBMUD's finances to meet funding needs and maintain fair and reasonable water and wastewater rates.
- **Customer and Community Services:** Maintain and enhance service excellence through continuous improvement.
- **Workforce Planning & Development:** Create an environment that attracts, retains, and engages a high performing diverse workforce in support of EBMUD's mission and core values.

EBMUD's goals for the Sewer System Management Plan (SSMP) are as follows:

- Properly manage, operate, and maintain all parts of the wastewater collection system.
- Provide adequate capacity to convey flows consistent with secondary treatment capacities.
- Minimize frequency of sanitary sewer overflows (SSOs) on EBMUD's collection system.
- Mitigate impact of SSOs on EBMUD's collection system.

3.5. EBMUD Capital Improvement Program

EBMUD's Water System Capital Improvement Program (CIP) cash flow for Fiscal Year (FY) 2016 was $231 million (M), while the Wastewater System CIP cash flow for FY 2016 was $45M. The total CIP budget for FY 2016-2020 includes estimated cash flow spending of $1.5 billion on water system capital projects and $191M on wastewater system capital projects.

The largest water system capital projects funded as part of EBMUD's FY16-20 CIP include:

- Pipeline Renewals and Large Diameter Pipelines, $258M
- Mokelumne Aqueduct Relining, $96M
- North Richmond Recycled Water, $70M
- Pumping Plant Rehabilitation Program, $63M
- West of Hills Transmission Improvements, $61M

- Reservoir Rehabilitation and Maintenance, $59M

The largest wastewater system capital projects funded as part of EBMUD's FY16-20 CIP include:

- 3rd Street Sewer Interceptor, $32M
- Wastewater Treatment Plant Infrastructure Improvements, $19M
- Odor Control Improvements, $19M
- Concrete Rehabilitation, $15M
- Resource Recovery, $14M
- Wood Street Sewer Interceptor, $12M

3.6. EBMUD Priorities

Because of the probability and severity of multiple risks, EBMUD is forced to address the multiple hazards, vulnerability, and risks described in Chapter 5 and 6 as part of its ongoing CIP. Differences in diversity, geography, and levels of risks and vulnerability make it difficult to assign priority to one type of hazard over another one. EBMUD's disaster history indicates that the primary hazards of earthquakes, floods, and wildfires require priority attention because they account for the largest losses.

4. EBMUD Facilities

4.1. Water Supply and Distribution Facilities

Based on historical average, about 90 percent of the raw water entering EBMUD's system originates from about a 600 square mile watershed of the Mokelumne River on the western slope of the Sierra Nevada. The Mokelumne watershed collects snowmelt from Alpine, Amador, and Calaveras counties. The snowmelt flows into Pardee Reservoir near the town of Valley Springs. When water demand is high or during times of operational need, EBMUD also draws water from protected local watersheds. Three large aqueducts carry water more than 90 miles from Pardee Reservoir to the East Bay area and protect it from pesticides, agricultural and urban runoff, municipal sewage, and industrial discharges.

Raw water is treated at one of EBMUD's six water treatment plants, which include three in-line plants (Orinda, Lafayette, and Walnut Creek) and three conventional plants including the Upper San Leandro in Oakland, San Pablo in Kensington, and Sobrante in El Sobrante. A majority of the water treated at the Orinda plant passes through the Claremont Tunnel, which emerges on the western side of the range between Berkeley and Oakland. Water not immediately put into the municipal system is stored in reservoirs for use in times of low delivery or drought.

Local runoff is also stored in reservoirs for treatment, delivery to customers, and for local emergency storage. In a year of normal precipitation, EBMUD uses an average of 21 MGD of water from local watershed runoff. EBMUD can store up to 151,670 acre-feet of water in the East Bay reservoirs. Typically, EBMUD stores a six-month emergency supply in its local reservoirs.

EBMUD's water system is shown in Exhibit A of the Appendix.

4.1.1. EBMUD Facilities within the Bay Area

4.1.1.1. Dams

EBMUD relies on dams to store much of the water it supplies to customers. EBMUD currently manages 26 dams. In the East Bay, there are 5 local water supply reservoirs and 19 open-cut reservoirs that hold treated water. The dams range in height from 10 feet to about 360 feet and were built from the late 1800s to the late 1960s.

EBMUD has a comprehensive Dam Safety Program. Engineers and other staff monitor dams using instruments, monthly visual inspections, surveys and periodic dam safety reviews to prevent loss of life, personal injury, and property damage from the failure of dams. The safety of each dam is reevaluated with advances in geotechnical, structural and earthquake engineering and also if there is evidence of seepage, ongoing ground movement or any other concern. Most of the local dams are under the jurisdiction of the California Division of Safety of Dams (DSOD). DSOD staff performs independent annual dam safety inspections of the dams under their jurisdiction.

The large water supply dams incorporate outlet towers that send reservoir water through conduits such as aqueducts and tunnels to water treatment plants. These outlet towers are inspected as part of the dam safety program and their structural and operational safeties are periodically evaluated. EBMUD currently has plans to retrofit four of the outlet towers.

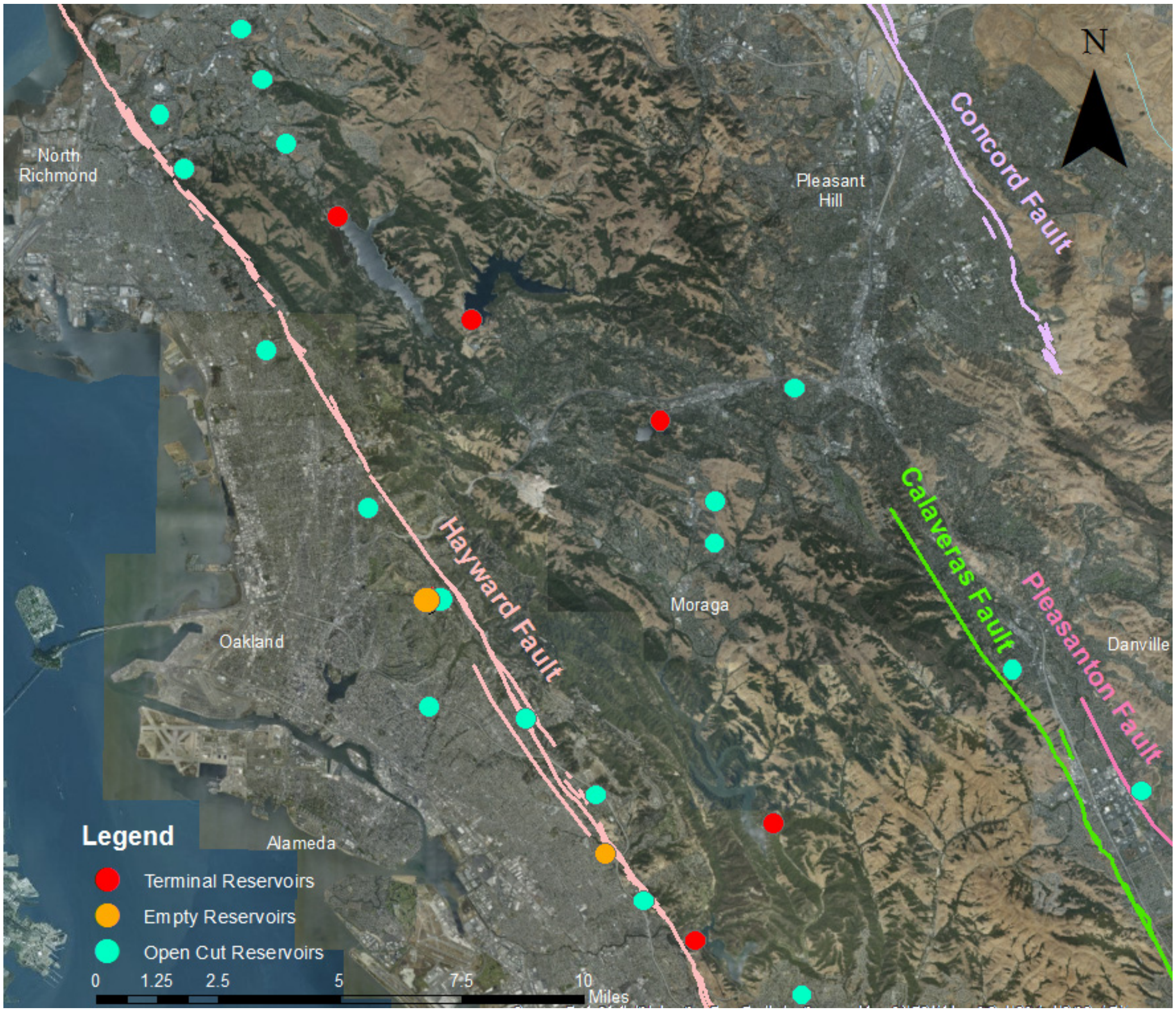

Figure 4.1. EBMUD Reservoirs and Fault Map

4.1.1.2. Reservoir Tanks

EBMUD's water system includes 147 water reservoir tanks, consisting of 86 steel tanks, 58 concrete tanks, and 4 wood tanks. The reservoirs, having a total water capacity of 830 million gallons, are used to store treated drinking water.

EBMUD's staff continually monitors the water quality and tests water samples throughout the reservoir tank system. The modern reservoirs are sized to provide more than a day's quantity of water on the hottest day and to maintain at all times a specified quantity of water for fire flow. Tanks may be pumped full once a day, which enables EBMUD to save a significant amount of money in energy costs by taking advantage of lower PG&E energy rates at night.

EBMUD constructed most of the reservoir tanks. Some reservoirs were acquired when smaller independent water systems where consolidated into EBMUD. Some smaller reservoirs have been disassembled and relocated. More than half were originally constructed during 1940s, 1950s and

1960s, and some of the oldest and largest reservoirs even predate the formation of EBMUD in 1923. The reservoirs vary widely in size, age, and composition.

Reservoir storage capacities range in size from as small as 3,000 gallons to over 153 million gallons. The construction type and material used for EBMUD's reservoirs have changed over time. From the turn of the century through the 1960's, EBMUD primarily relied upon open-cut reservoirs for its system storage. These are large basins excavated into the earth, and lined and covered to store drinking water.

4.1.1.3. Pumping Plants

Pumping plants in the water distribution system serve two primary functions. One function is to pump water directly into the system. The second function is to distribute water to where pressure needs to be increased due to an insufficient difference in water levels in the gravity flow portion of the distribution systems. The pumping plants are positioned throughout the length of the pipeline system and can adjust the water pressure, pump water along the line, monitor flow, and collect critical information about the water.

EBMUD maintains and operates more than 150 pumping plants ranging in capacity from 20 gallons per minute (gpm) to 70 million gallons per day (MGD), with pumps ranging in size from 5 HP to 3600 HP. EBMUD's system comprises of 13 supply pumping plants, 4 wash water pumping plants, and more than 130 distribution pumping plants.

4.1.1.4. Transmission/Distribution Pipelines

EBMUD's water system consists of approximately 4,200 miles of potable water pipelines within a 332 square mile service area. Approximately 340 miles of the water system are comprised of transmission pipelines greater than or equal to 20 inches in diameter. The transmission system contains welded steel, reinforced concrete cylinder, cast-iron, and pre-tensioned concrete cylinder pipe. The distribution system contributes to 92% percent of the total potable pipelines, or approximately 3,900 miles. Distribution pipelines include cast iron, asbestos cement, steel, PVC, and HDPE pipe materials.

4.1.1.5. Water Treatment Facilities

All potable water delivered to customers is treated at one of EBMUD's six water treatment plants. The water treatment plants are Upper San Leandro in Oakland, San Pablo in Kensington, Sobrante in El Sobrante, and plants located in and named for Orinda, Lafayette, and Walnut Creek.

The Orinda Water Treatment Plant has the largest output, with a maximum capacity of 200 MGD. This plant serves all or parts of Alameda, Albany, Berkeley, El Cerrito, Emeryville, Moraga, Oakland, Orinda, Piedmont, Richmond, and San Leandro. The other water treatment plants supply water in varying amounts to the remainder of EBMUD's service area.

Orinda, Lafayette, and Walnut Creek Water Treatment Plants normally obtain water directly from the Mokelumne Aqueducts, although they may also obtain raw water from Briones Reservoir. Lafayette Reservoir is a standby terminal storage reservoir. Water from the Mokelumne Aqueducts requires limited treatment, so these plants usually provide only coagulation, filtration, disinfection, pH control, and fluoridation. The other three plants normally obtain raw water from terminal reservoirs, which require additional treatment. These plants also provide aeration, coagulation, flocculation, sedimentation, and ozonation, in addition to, filtration, disinfection, pH control, and fluoridation.

4.1.1.6. Regulators and Rate Control Stations

There are approximately 35 Rate Control Stations (RCSs) located throughout the distribution system ranging in size from 6 to 48 inches. RCSs are remotely controlled valve facilities that set flow rates within large transmission pipelines, usually between pressure zones. RCSs are extremely critical to the operation of the distribution system. The failure of a RCS can cause over pressurizing in the pipeline system resulting in main breaks and ultimately damaging property and disrupting service.

There are approximately 73 Regulators located throughout the distribution system ranging in size from 4 to 12 inches. Regulators supply water from an upper pressure zone (source zone) to a lower pressure zone (service zone) by reducing the operating water pressure to an appropriate level. Often these regulators are the sole supply source to the pressure zone for both potable and fire flow, which makes continuous operation of these regulators critical for residential and fire flow water supply. In addition, failure of these regulator stations could lead to excessive pressures in the service area that could cause pipe failures and over-pressurizing of services to EBMUD customers.

4.1.2. EBMUD Facilities Outside the Bay Area

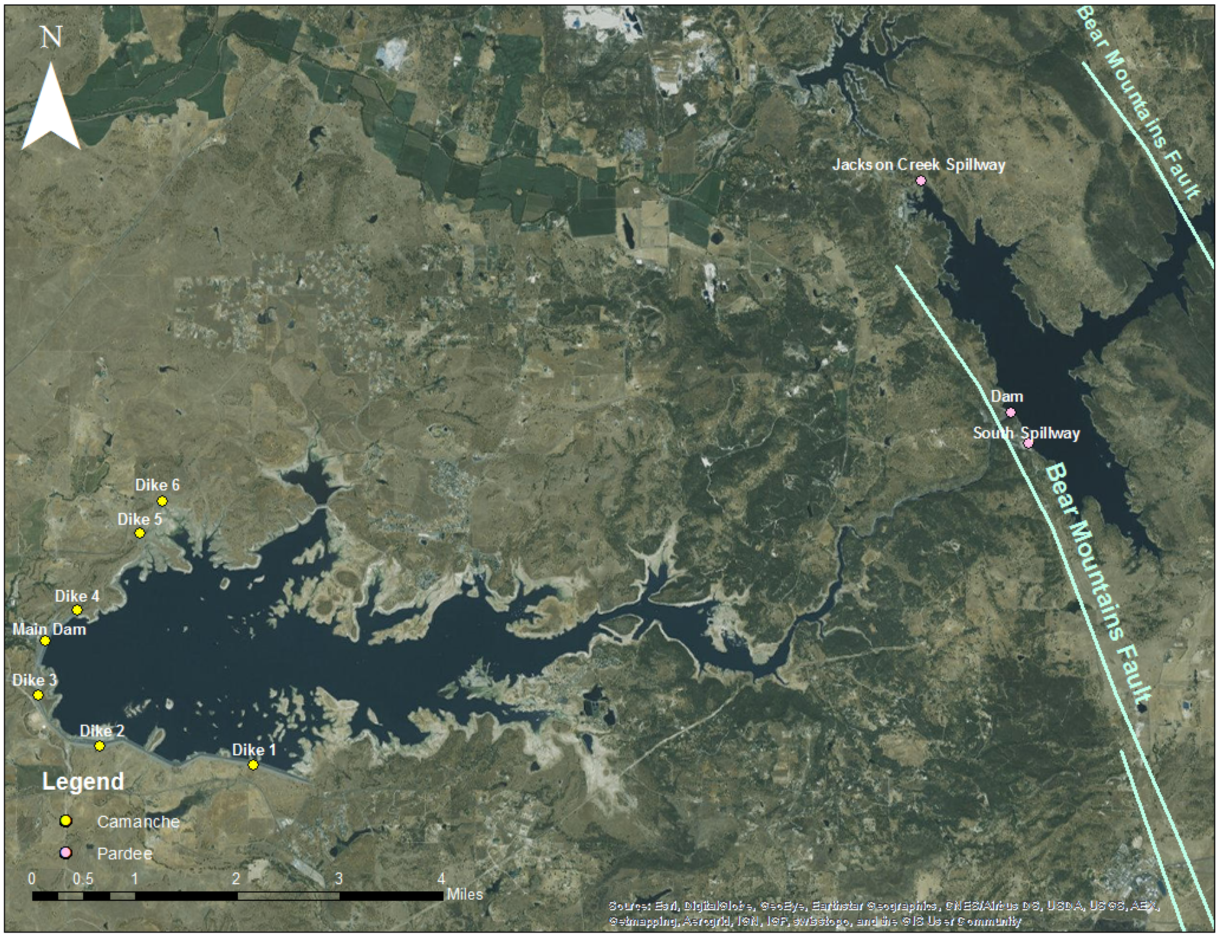

Figure 4.2. EBMUD Facilities Outside of the Bay Area

4.1.2.1. Mokelumne Aqueducts

EBMUD's main source of water is the Mokelumne River watershed in the Sierra foothills, located about 90 miles northeast of the San Francisco East Bay Area. The aqueduct system that transports water to the service area consists of three large diameter steel pipelines of 65-inches, 67-inches, and 87-inches, built in 1929, 1949 and 1963, respectively. These pipelines, collectively referred to as the Mokelumne Aqueducts, are a critical component of EBMUD's water system and the State of California's (State) overall water infrastructure.

The Mokelumne Aqueducts provide about 90 percent of the water used by EBMUD. The aqueduct system starts at Pardee Reservoir, which is formed by Pardee Dam on the Mokelumne River, and traverse through the western foothills of the Sierra Nevada. he aqueducts then head west across the Central Valley along the Calaveras River before crossing the Sacramento–San Joaquin River Delta (Delta). Approximately 15 miles of the aqueduct runs across the Delta area through 5 islands that are approximately 5 to 15 feet below mean sea level. This Delta crossing consists of approximately 4.5 miles of buried pipeline, 10 miles of elevated pipeline, and 3 major river crossings with about 0.5 miles of submerged pipeline.

Near the community of Clements, the Mokelumne Aqueducts are joined by the Freeport Regional Water Authority/Folsom South Canal Connection (FRWA/FSCC) system, a system of pumping plants and pipelines that delivers water from the Sacramento River to the Mokelumne Aqueducts, which supplements the Mokelumne River supply during drought periods.

Once the Mokelumne Aqueducts water reaches the EBMUD service area in Walnut Creek, it is delivered directly to water treatment plants or transferred into one of five terminal storage reservoirs located in the EBMUD service area.

Figure 4.3. Mokelumne Aqueduct

4.1.2.2. Pardee Reservoir

Pardee Reservoir, approximately 30 miles northeast of Stockton, is created by three structures – Pardee Dam, Pardee South Spillway, and the Jackson Creek Spillway. Pardee Dam is a curved concrete gravity structure 345 feet in height and marks the boundary between Amador and Calaveras Counties. The Pardee South Spillway is a separate concrete gravity overflow spillway located south of the main dam. The Jackson Creek Spillway is a concrete and earth structure located at the north end of the reservoir.

Water from Pardee Reservoir is transported across the Central Valley via the Mokelumne Aqueducts to several water treatment plants and storage reservoirs located in the East Bay region. Releases into the Mokelumne Aqueducts are made through an independent outlet tower.

A three-unit, 23.6 megawatt hydroelectric power plant at the base of Pardee Dam generates approximately 110 million kilowatt-hours of electric energy annually.

Pardee Reservoir storage capacity is 203,795 acre-feet at elevation 567.65 feet (local datum) the spillway crest elevation. At this elevation, the reservoir has a surface area of about 2,200 acres (3.4 square miles) and 37 miles of shoreline. The total drainage area above Pardee Dam is approximately 577 square miles.

The dam is classified as “High Hazard Potential” under the Federal Energy Regulatory Commission (FERC) Guidelines.

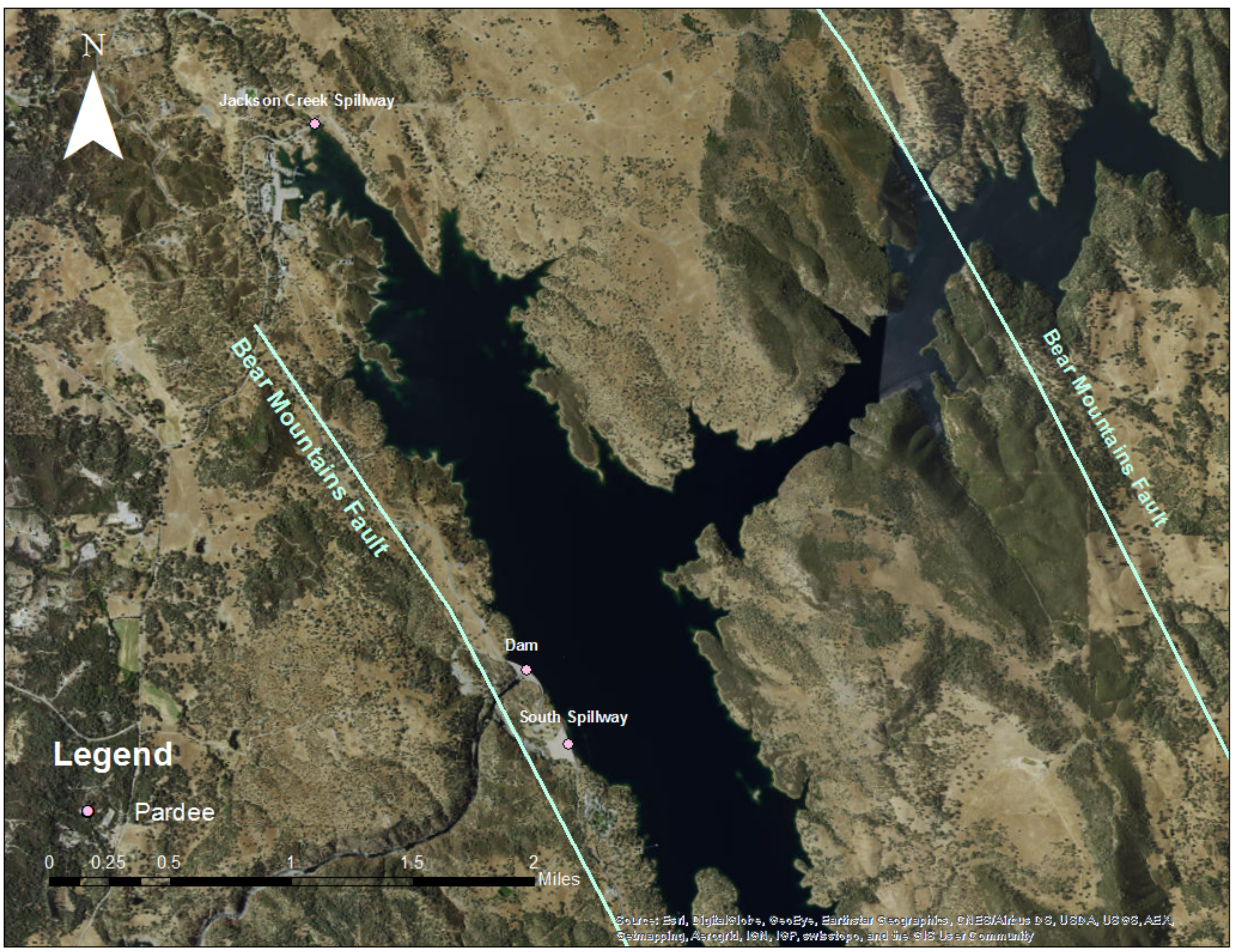

Figure 4.4. Pardee Reservoir and Dam

4.1.2.3. Camanche Reservoir

Camanche Reservoir, with a storage capacity of 417,124 acre-feet at spillway crest elevation of 235.5 feet, was completed in 1964 to provide for multiple beneficial uses. When at spill elevation, the reservoir has a surface area of about 7,400 acres. The drainage area above the reservoir is 620 square miles. The reservoir is located within Amador, Calaveras, and San Joaquin Counties, California, on the Mokelumne River approximately 14 miles east of the community of Lodi. The reservoir is created by a main dam and six earth dikes: three on the north side and three on the south side. An un-gated concrete overflow spillway is located south of the main dam. A three-unit 10.7 megawatt powerhouse is at the base of the main dam.

Figure 4.5. Camanche Reservoir

4.2. Wastewater Facilities

EBMUD's Special District No. 1 (SD-1), was established in 1944 as a subsidiary district within EBMUD, and is administered by the same EBMUD Board of Directors. EBMUD treats domestic, commercial, and industrial wastewater within the 88 square mile service area. The SD-1 service area consists of the cities of Alameda, Albany, Berkeley, Emeryville, Oakland, Piedmont, and the Stege Sanitary District. The Stege Sanitary District serves the city of El Cerrito, the community of Kensington, and a portion of the city of Richmond.

EBMUD's wastewater collection system includes 37 miles of pipelines, 15 pump stations, three wet weather facilities, and five overflow structures. The communities within the SD-1 service area own and operate their own wastewater collection systems that discharge to the EBMUD interceptor system. Wastewater is transported by the five interceptor sewer trunk lines to EBMUD's Main Wastewater Treatment Plant (MWWTP) in Oakland. The average annual daily flow is approximately 50 MGD.

4.2.1. Main Wastewater Treatment Plant

EBMUD's MWWTP serves approximately 680,000 customers along the eastern shore of San Francisco Bay. EBMUD's wastewater treatment plant is located near the foot of West Grand Avenue in Oakland, adjacent to the San Francisco-Oakland Bay Bridge approach.

At the MWWTP, primary treatment removes floating materials, oils and greases, sand and silt, and organic solids heavy enough to settle in water. Primary treatment can be provided for up to 320 MGD. Secondary treatment biologically removes most of the suspended and dissolved organic matter and chemical impurities. EBMUD provides secondary treatment for a maximum flow of 168 MGD. Wastewater solids removed during the wastewater treatment process are treated separately and beneficially used.

Storage basins provide short-term plant capacity of 415 MGD during peak wet weather events. The treated effluent is disinfected, dechlorinated, and discharged through a deep water outfall into San Francisco Bay. The dechlorination facility, which provides the final treatment step, is located at the foot of the San Francisco-Oakland Bay Bridge.

The solids digestion process produces a biogas that is used onsite to produce renewable electricity and heat for MWWTP. Excess electricity is exported. EBMUD accepts trucked-in high-strength organic waste, such as food scraps, for anaerobic digestion, which generates additional biogas. On an annual average, EBMUD produces more renewable electricity than is required to meet all onsite electricity demands.

4.2.2. Wet Weather Facilities

EBMUD operates three wet weather treatment facilities that are used to store and manage wastewater flows during wet weather events. During winter rainfall periods, significant quantities of rainwater enter the sanitary sewer systems in the form of infiltration/inflow (I/I). I/I cause dramatic increases in flow in the community sewer systems.

The Oakport, Point Isabel, and San Antonio Creek Wet Weather Facilities (WWF) provide additional wet weather capacity of 158 MGD, 100 MGD, and 51 MGD, respectively. The Oakport and San Antonio Creek WWFs are located in Oakland. The Point Isabel WWF is located in Richmond. Due to a consent decree with the Environmental Protection Agency (EPA) in 2014, EBMUD and its satellite agencies are working to minimize I/I and eventually eliminate discharges from the WWFs.

The flows to all WWFs undergo screening, chlorination, and dechlorination. Oakport and Point Isabel WWFs also provide sedimentation. The sedimentation basins at these two facilities can provide storage so the flow can be returned to the interceptor system for treatment at the MWWTP once peak flows have subsided.

4.2.3. Interceptor Pipelines

EBMUD's collection system includes approximately 37 miles of interceptor sewer pipelines. The communities within the SD-1 service area each own and operate local wastewater collection systems that convey wastewater to the EBMUD interceptor system. The interceptors range in size from 12 inches to 9 feet in diameter. The interceptor system consists of nearly 29 miles of gravity pipelines, over 8 miles of pressure pipeline, five emergency overflow structures, and storage facilities at one pump station and two of EBMUD's WWFs.

4.2.4. Pump Stations

EBMUD's collection system includes 15 pump stations. The pump stations range in capacity from 1.5 to 60 MGD. "Pump Station Q" is a designated wet weather pump station and is only used to divert flows from the North Interceptor towards the Point Isabel WWF when needed. Pump Station H is the largest pump station and is an in-line lift station on the South Interceptor. All other pump stations lift flows from surrounding satellite collection systems into the interceptor system.

5. Identified Hazards

5.1. Hazard Identification Background

The 2011 LHMP identified hazards that impact EBMUD's service area – five related to earthquakes (faulting, shaking, earthquake induced landsides, liquefaction, and tsunami) and four related to weather (flooding, landslides, wildfires, and drought).

The 2018 LHMP updates the 2011 LHMP by adding climate change, terrorism, and fires following earthquakes. All of these hazards impact EBMUD's planning region.
EBMUD conducted a number of studies identifying hazards and risks associated with its system. These studies include the following:

1. Seismic Evaluation Program Final Report, January 1994, Revised December 23, 1994, R10.5, Revision 1, G&E Engineering Systems, Inc.
2. Seismic Evaluation Program Final Report, Appendix A, April 1, 1994, R10.04.01 Revision 1, G&E Engineering Systems, Inc.
3. Buried Pipe Performance in Scenario Earthquakes, January 1994, R10.4, Revision 0, G&E Engineering Systems, Inc.

4. Restoration of Water Supply after Earthquakes, May 24, 1967, R30.03.01 Revision A, G&E Engineering Systems, Inc.
5. Emergency Response and Recovery, Final Technical Report, November 4, 1997, R19.06.04 Revision 0, G&E Engineering Systems, Inc.
6. Fault Crossing Evaluation and Conceptual Design, December 1994, R21.04.01, G&E Engineering Systems, Inc.
7. Strategic Transmission Plan Final Report, July 30, 1997, R19.06.02, G&E Engineering Systems, Inc.
8. Strategy for Protecting the Aqueducts in the Delta, Summary Report, October 5, 2007
9. Strategy for Protecting the Aqueducts in the Delta, Technical Memorandum No. 1 Alternative Identification, September 2007
10. Strategy for Protecting the Aqueducts in the Delta, Technical Memorandum No. 2 Preliminary Cost Estimates
11. Strategy for Protecting the Aqueducts in the Delta, Technical Memorandum No. 3 Risk Evaluation, August 2007
12. Strategy for Protecting the Aqueducts in the Delta, Technical Memorandum No. 4 Acceptable Risk Determination, September 2007
13. Indirect Loss Estimation: Fire Following Earthquake, March 1994, R10.04.02 Revision A, G&E Engineering Systems, Inc.
14. Economic Impacts of Scenario Earthquakes on the EBMUD Service Area Final Report, April 1, 1994, Goettel & Horner, Inc.
15. EBMUD Biennial Budget for FY 2012-2013, Volume 1 – Executive Summary, Strategic Plan Priorities and Operating Budget
16. EBMUD Biennial Budget for FY2012-2013, Volume 2 – Capital Improvement Program
17. Urban Water Management Plan 2010 (UWMP 2010), EBMUD, June 2011
18. Seismic Evaluation of Selected East Bay Municipal Utility District Wastewater Facilities, July 1991, EQE Engineering
19. Seismic Evaluation Program East Bay Municipal Utility District Wastewater Facilities, March 1994, EQE Engineering
20. Seismic Conceptual Retrofit of Selected East Bay

Additionally EBMUD Staff have actively participated and published technical papers on seismic resiliency. Selected publications are provided below:

- Prashar, Y., Yiadom, A., Bialek, E., “Developing Embankment Dam Fragilities for Emergency Modeling and Response for 29 East Bay Municipal Utility District Reservoirs,” New Orleans, LA, United States Society of Dams, April 23-26, 2012.
- Prashar, Y., McMullin, R., Chen A., and Irias, X. J Water System Seismic Fragility of Embankment Dams, Tank Reservoirs, and Large Diameter Pipelines,” presented at the AWWA, Oakland, California, September 2013
- Prashar, Y., McMullin, R., Chen A., and Irias, X. J., “Main Shock and After Shock Impact to Water System Seismic Fragility of Embankment Dams, Tank

Reservoirs, and Large Diameter Pipelines," presented at the AWWA, October 2017

- Prashar, Y., McMullin, R., Cain, W., and Irias, X. J., "Pilot Large Diameter Pipeline Seismic Fragility Assessment," presented at the 2012 ASCE Pipelines Conference, August 20-22, 2012.
- Irias, X. J., Cain, W., Prashar, Y., and McMullin, R., 2011. "Rapid Modeling of Seismic Damage to Water Infrastructure," presented at the 7th U.S. – Japan Workshop on Water System Seismic Practices in Niigata, Japan, October 2011.

EBMUD has reviewed the hazards identified and ranked the hazards based on past disasters and expected future impacts. **Error! Reference source not found.** below provides a summary of the probability of the identified hazards for the 2018 LHMP.

Table 5.1. Probability of Identified Hazards

	Probability Descriptor			
Identified Hazards	**Unlikely[1]**	**Possibly[2]**	**Likely[3]**	**Highly Likely[4]**
Earthquake				**X**
Flood				**X**
Landslide				**X**
Fire				**X**
Drought				**X**

Notes:
1. Extremely rare with no documented history of occurrence or events. Annual probability of less than 1 in 1,000 years.
2. Rare occurrences. Annual probability of between 1 in 100 years and 1 in 1,000 years.
3. Occasional occurrences. Annual probability of between 1 in 10 years and 1 in 100 years.
4. Frequent events with a well-documented history of occurrence. Annual probability of greater than 1 every year.

5.2. Earthquake Hazard

5.2.1. Earthquake Hazard Background

Earthquakes happen less frequently than other hazards. However, earthquakes have a high probability of future occurrence and have the greatest potential for loss of life and property. Every resident and structure in EBMUD's service area is exposed to high earthquake hazard. A major active fault runs directly beneath some of the most densely populated areas of the service boundary on the west and the east by earthquake faults.

The San Francisco Bay Area has more ground movement along tectonic plates than any urban area in the United States. Earthquakes can temporarily disrupt water and sewer service. Reliable water supplies are essential to both the routine of daily lives and the health of the regional economy. EBMUD continuously works to protect public health and safety from water service disruptions by strengthening facilities and strategies for quickly recovering water and wastewater services after a major earthquake.

There are several major earthquake faults that intersect or are located near EBMUD service area. The most signification seismic risk to the East Bay is the Hayward Fault, as it crosses major water distribution facilities. Additional seismic risks threaten EBMUD's water transmission lines in the Delta. There is also a smaller risk of damage to EBMUD water supply and flood control reservoirs located in the central Sierra.

EBMUD facilities located outside of the nine-county Bay Area are also subject to damage from earthquake. For example, Pardee Dam is located within three miles of the Bear Mountain Fault Zone. In addition, the Mokelumne Aqueducts were not designed to resist earthquake forces in the Delta. As a result, severe damage to the aqueducts may occur from an earthquake, resulting in a complete outage of the Mokelumne water supply for an extended period.

The adverse effects of earthquakes result from physical effects of surface fault rupture, ground shaking, liquefaction, and earthquake induced-landslides and/or secondary effects such as tsunamis. Each of these hazards is briefly discussed below. More information on these hazards can be found at http://resilience.abag.ca.gov/earthquakes.

5.2.1.1. Surface Fault Rupture Hazard

Surface fault ruptures can result from large magnitude earthquakes. A surface rupture is an offset of the ground surface when a fault rupture extends to the Earth's surface. Structures located within the fault rupture zone are subject to excessive ground deformations. Most structures are not designed to withstand such large deformations and experience major damage. Pipelines crossing the fault zones can also be damaged by stresses caused by ground deformation.

The 1972 Alquist-Priolo Earthquake Fault Zoning Act was passed to mitigate the hazard of surface faulting to structures for human occupancy. The state law was a direct result of the 1971 San Fernando Earthquake that had extensive surface breaks damaging many homes, commercial buildings, and other structures.

The Alquist-Priolo Earthquake Fault Zoning Act's main purpose is to prevent construction of human-occupied buildings on the surface trace of active faults. The act requires projects to conduct a geologic investigation to demonstrate that proposed buildings will not be constructed across active faults. A structure for human occupancy cannot be placed over the trace of the fault and must be set back from the fault (at least 50 feet).

EBMUD owns about 86 facilities that are in an Alquist-Priolo Fault Rupture Study Zone. Of these 86 facilities, 33 are associated with the Northern Hayward fault, 51 with the Southern

Hayward fault, and two with the Northern Calaveras fault. However, this initial mapping of EBMUD's assets does not necessarily mean that the facilities are located astride a fault.

EBMUD's service area is located in a highly active seismic area east of the San Francisco Bay. Figure 5.1 respectively show the location of the EBMUD service area and the active faults (red lines) within the large diameter pipeline (blue lines) service area. These faults include the Hayward, Mt. Diablo Thrust, Calaveras, and Concord Faults. Although outside the service area, the San Andreas Fault will also subject pipelines to significant ground motions.

The highly active Hayward Fault dominates the EBMUD risk profile. The Hayward Fault is capable of Mw 7.05 earthquake with a 140-year major event return cycle. The fault has a maximum earthquake of Mw 7.25 with several thousand year return period. With the last major earthquake occurring in 1868 (149 years ago), the next major quake is due at any time. The economic losses from a similar earthquake occurring today would likely exceed $165 billion in damages (Brocher, 2008) in the Bay Area.

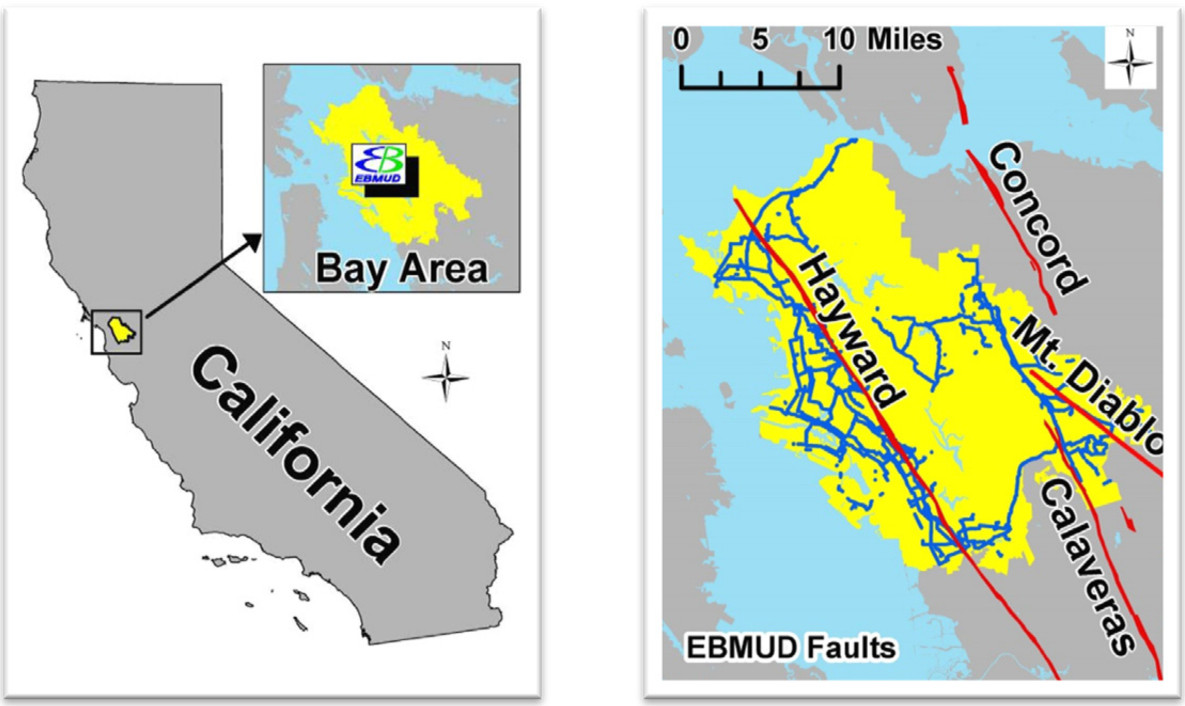

Figure 5.1. EBMUD Service Area and Faults

5.2.1.2. Strong Ground Shaking

The most significant physical characteristic of a major earthquake is ground shaking. According to the State of California Multi-Hazard Mitigation Plan, damage due to ground shaking produces over 98 percent of all building losses in a typical earthquake. During an earthquake, the ground can shake for a few seconds or over a minute.

Estimates of Peak Ground Acceleration (PGA) for the design earthquake for sites can be obtained from statewide maps developed by USGS and CGS as part of the National Seismic Hazard Mapping Project (NSHMP) (http://earthquake.usgs.gov/hazards/).

The strength and duration of ground shaking is affected by many factors, such as distance from the fault. However, geologic conditions, direction of the fault rupture, magnitude and depth are also critical factors. Shaking, particularly horizontal shaking causes the most earthquake damage, because structures often have inadequate resistance to this type of motion. The strongest shaking is typically close to the fault where the earthquake occurs. Weak soils, such as valley alluvium or soils along river and stream beds, also experience strong shaking in earthquakes, even from distant quakes.

For EBMUD water and wastewater system facilities, 87% (999 of 1,154 facilities) are exposed to extremely high ground shaking levels (peak accelerations greater than 60% g with a 10% chance of being exceeded in the next 50 years). An additional 19% (218 of 1154 facilities) are exposed to high ground shaking levels (peak accelerations greater than 50% g), while 1% (15 of 1,154 facilities) are exposed to peak accelerations greater than 40% g. Only 3% (33 of 1,154 facilities) are exposed to moderate shaking (peak accelerations of greater than 30% g). A Shaking Hazard Map is available on the ABAG Resilience Program website: http://resilience.abag.ca.gov/earthquakes/#FAULTS.

The map shows the shaking severity level for the majority of EBMUD's service area. A magnitude Mw 7.0 earthquake on the Hayward fault would result in shaking severity levels ranging from strong to very violent for most of the service area as shown in **Error! Reference source not found.** below.

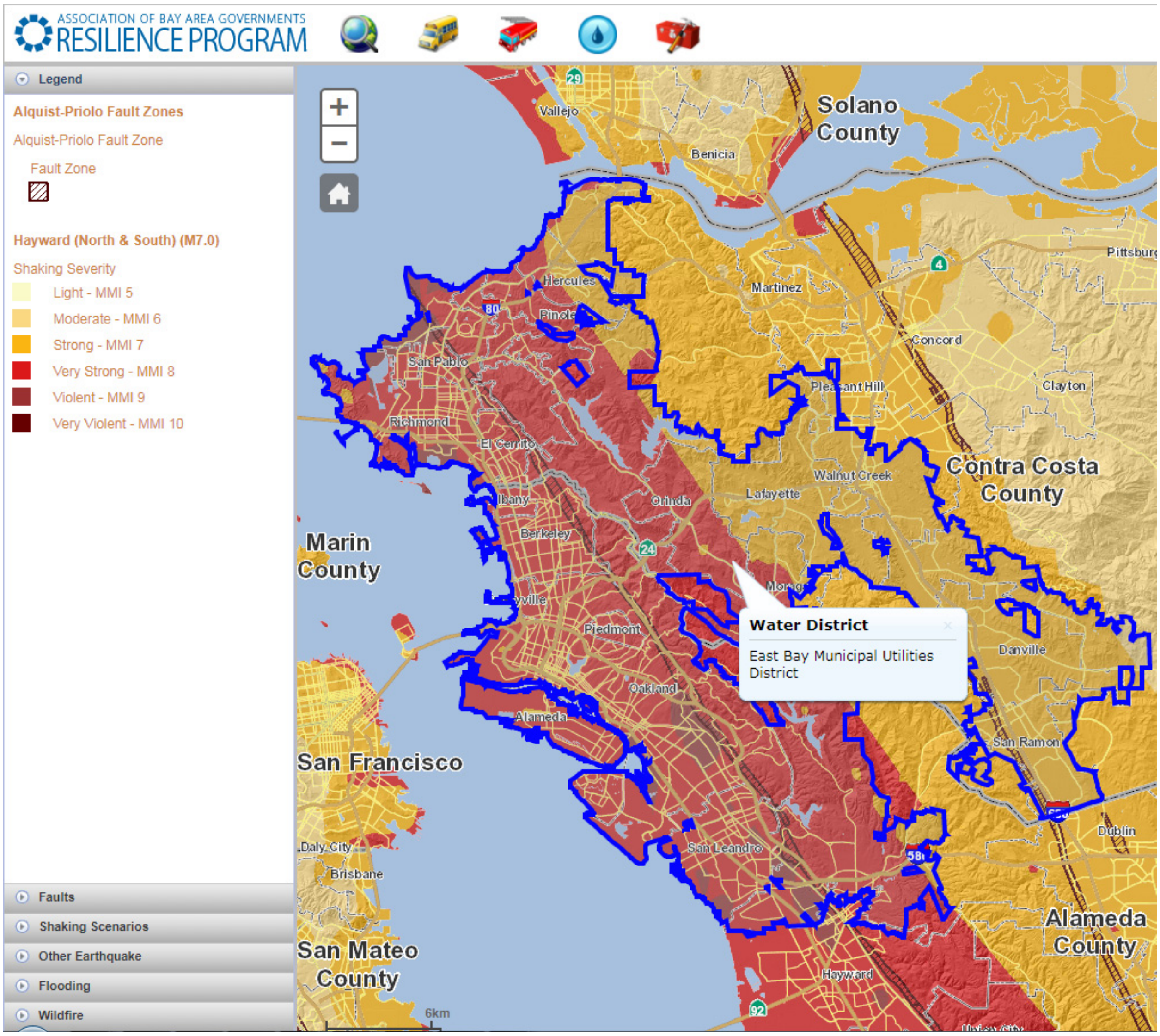

Figure 5.2. Hayward (North and South) – Mw 7.0 Shaking Earthquake Induced Liquefaction

A high water table, layers of loose sand, and moderate or greater earthquake shaking are required for liquefaction to occur. Liquefaction is a process where water-saturated sediment temporarily loses strength and acts as a fluid. This effect can be caused by earthquake shaking. The soil surface may sink or spread laterally. Structures located on liquefiable soils can sink, tip unevenly, or even collapse. Pipelines and paving can be damaged from this differential settlement and lateral spreading phenomenon.

While 165 of EBMUD's facilities are in areas mapped as study zones for earthquake-induced liquefaction and 359 facilities are outside of the liquefaction area, EBMUD's remaining facilities are in areas that have not been mapped by the California Geological Survey.

There is a significant correlation with the areas of moderate-to-very high liquefaction mapped by the USGS) and the California Geologic Survey. Based on the USGS mapping, 97 facilities are in areas mapped as having “Very High” susceptibility to liquefaction, 4 facilities are in areas mapped as having “High” susceptibility to liquefaction, and 223 facilities are in areas mapped as having “Moderate” susceptibility to liquefaction. Thus, roughly 25-30% of EBMUD’s facilities should be expected to be subject to liquefaction.

The majority of wastewater facilities, including the main wastewater treatment plant and wet weather facilities, are located in areas prone to liquefaction and liquefaction induced lateral spreading. The interactive liquefaction susceptibility map is available on ABAG’s website: http://gis.abag.ca.gov/website/Hazards/?hlyr=liqSusceptibility

5.2.1.3. Earthquake Induced Landslides

Seismicity is a major trigger for landslides. Most moderate and large earthquakes trigger landslides, which commonly account for a significant portion of total earthquake damage and injuries.

While 53 of EBMUD’s facilities are in areas mapped as study zones for earthquake-induced landslides by the California Geological Survey (CGS), 471 facilities are outside of these areas. EBMUD’s remaining facilities are in areas that have not been mapped yet. There is limited correlation with the areas of rainfall-induced landslide mapped by the U.S. Geological Survey. Thus, roughly 10-15% of EBMUD’s facilities should be expected to be subject to this hazard.

The CGS recently developed susceptibility to deep-seated landslide maps for the State of California. This map shows the relative likelihood of deep land sliding based on regional estimates of rock strength and steepness of slope. The map uses detailed information on the location of past landslides, the location and relative strength of rock units, and steepness of slope. The maps also provide landslide susceptibility classes from zero to ten, increasing in level of susceptibility.

The steps to develop this map include an inventory of existing landslides in the San Francisco East Bay Area. Rock strengths ranked to three strength classes (1, 2, and 3) in their respective mapped areas. The slope gradient was evaluated from a 2009 national elevation model and slope values were grouped into eight slope classes ranging from flat to very steep (greater than 40 degrees). Overall, landslide susceptibility is a function of the slope and rock strength classes.

The landslide probability map covers the EBMUD service areas and beyond. The slope failures are triggered by a hypothetical earthquake with a moment magnitude of Mw 7.0 on the Hayward Fault in the east bay part of California’s San Francisco Bay region. The landslide potential ranges from low to vary high. Estimated of anticipated slope displacements are also given in this study.

Figure 5.3 below and was obtained from recent USGS publication in May 2017 and is available from the following URL:
https://www.sciencebase.gov/catalog/item/58f8bb4be4b0b7ea54522604.

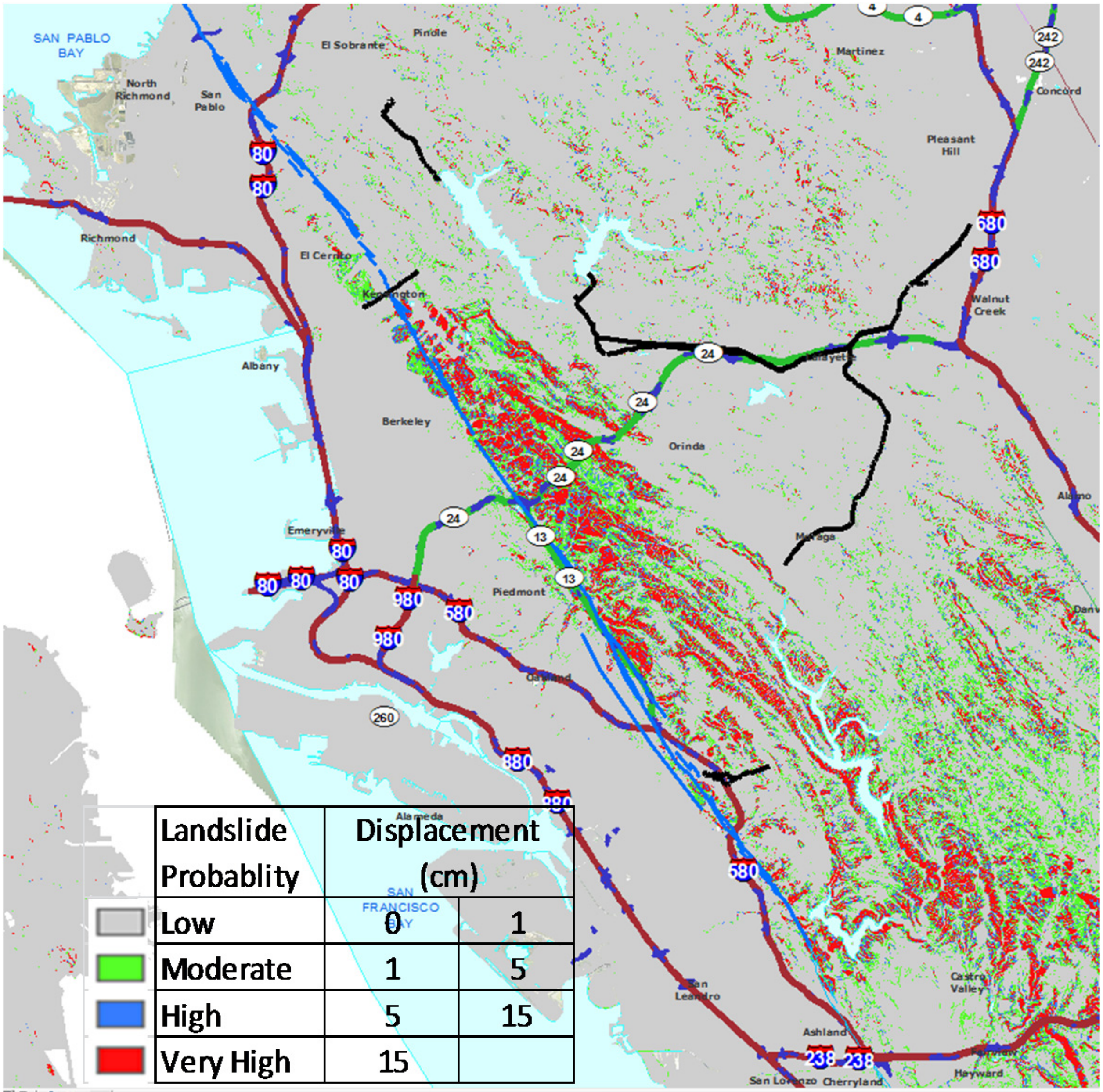

Figure 5.3. USGS Earthquake Induced Landslide Probability and Estimated Displacements for Scenario – Mw 7.05

5.2.1.4. Tsunami

Tsunami is considered an earthquake hazard. Technological hazards, such as dam, levee, or pipeline failure, are included in this 2018 LHMP only as potential secondary hazards that may be triggered by the five natural hazards of focus.

Damaging tsunami waves can be caused by large distant or near shore earthquakes. A tsunami is a series of traveling ocean waves generated by undersea earthquakes or landslides. Tsunamis' wave height at the shore can range from inches to over 50 feet.

Factors influencing the size and speed of a tsunami include the source and magnitude of the triggering event, and off-shore and on-shore topography. When the tsunami enters shallow coastal waters its speed decreases and the wave height increases, thus creating the large wave that becomes a threat to life and property. Following the arrival of the first wave, subsequent waves may increase in height and arrive minutes to hours later.

The National Oceanic and Atmospheric Administration (NOAA), the California Emergency Management Agency (Cal EMA), the CGS, and the University of Southern California has conducted systematic analyses of all historic and possible tsunami hazards along the coast of California as part of the National Tsunami Hazard Mitigation Program, for the purpose of mapping tsunami run-up zones for at risk communities from near shore events. An inundation map has been compiled for the East Bay coast area with the best currently available scientific information. The inundation line represents the maximum tsunami run-up from a number of extreme, yet realistic, tsunami scenarios. However, given the limits of available data, it remains possible that actual inundation could be greater in a major tsunami event.

The December 2009 version of the tsunami inundation map for emergency planning maps indicated that 74 of the EBMUD facilities are in the Tsunami Inundation area. While the maps are conservative because they are intended for emergency evacuations, they are a first step in a hazard evaluation. Most of the facilities in the mapped area are in Oakland, but a few are in Alameda, San Leandro, and in one case each, in Albany and Richmond. EBMUD is in the process of working with Cal EMA on developing appropriate evacuation planning that is specific to various impacted facilities, particularly the MWTP.

The MWWTP specifically evaluated two scenarios in 2014 – An Eastern Aleutians, Alaska Mw 9.2 earthquake and a Mw 7.0 rupture of the offshore Point Reyes Thrust Fault. The Alaskan earthquake scenario would provide approximately 5 hours to evacuate before the arrival of the wave. The Point Reyes earthquake would arrive in tens of minutes, giving little or no time to evacuate but water levels are not expected to be high enough to flood facilities. There is a Tsunami Response Plan in place for the MWWTP and all other low lying areas that are within the mapped Tsunami Hazard areas (see Figure 5.4).

http://maps.conservation.ca.gov/cgs/informationwarehouse/index.html?map=tsunami

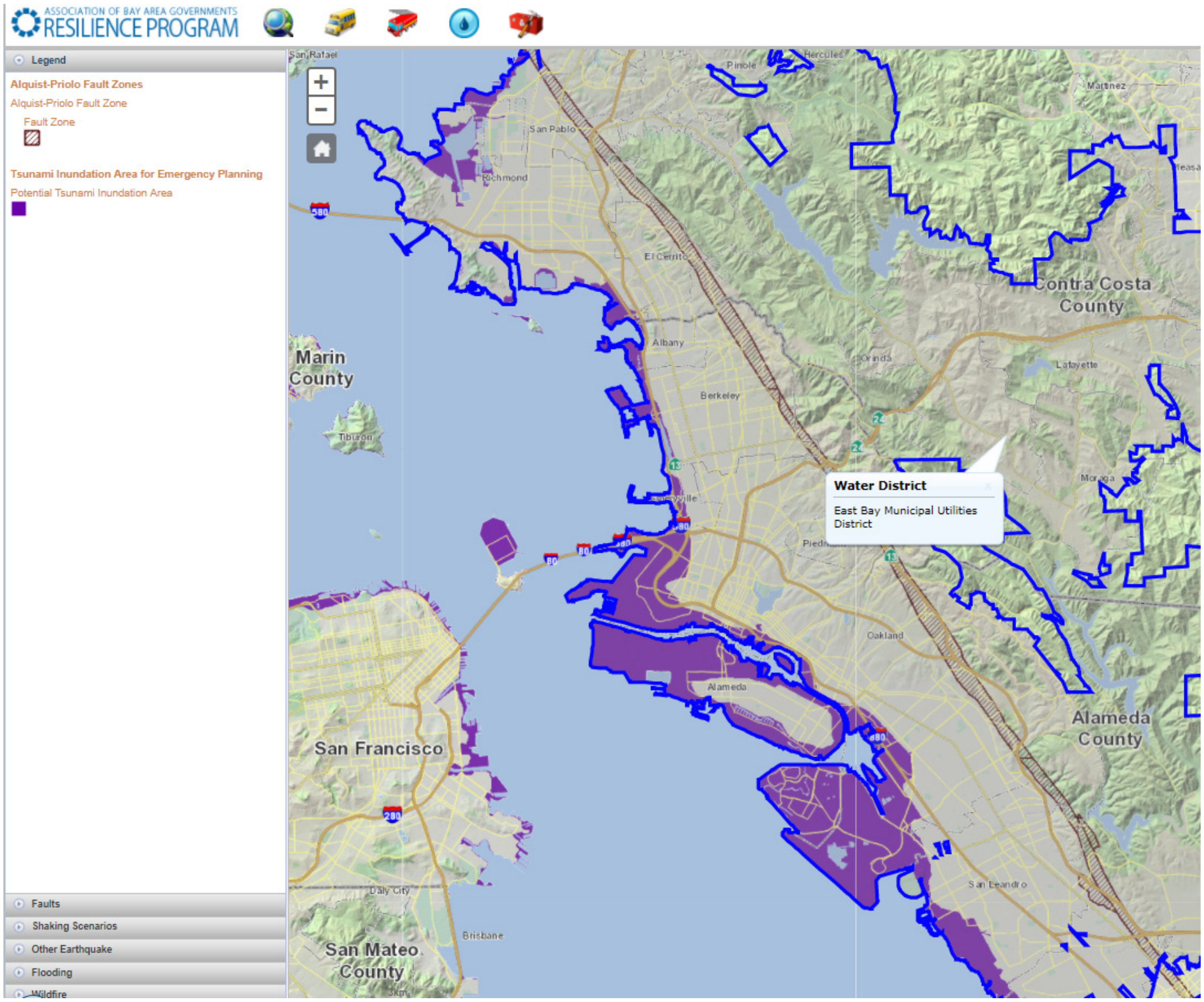

Figure 5.4. Tsunami Inundation for EBMUD Service Area

5.2.2. Earthquake Event History

EBMUD service area has experienced numerous earthquakes over the last 50 years. The 1989 Loma Prieta Earthquake is the most locally significant incident that has impacted EBMUD facilities.

The Loma Prieta Earthquake in October 1989 was a magnitude 6.9 earthquake. The earthquake killed 63 people and injured 3,757 others. With over 20,000 homes and businesses damaged, and over 1,100 destroyed throughout the Monterey and San Francisco Bay Areas, this quake caused approximately $6 billion in damages ($11.6 billion in current value). Reconstruction continues two decades later. The Loma Prieta Earthquake was the largest earthquake to occur on the San Andreas Fault since the great 1906 San Francisco earthquake.

The Loma Prieta Earthquake caused numerous main breaks attributed to ground shaking near EBMUD's service area. As a result of that earthquake, EBMUD repaired damage to 123 water mains. This number did not include service leaks and breakage on the customer side of the meter, for which the customer is responsible. One of the leaks repaired was on the large raw water line supplying the Sobrante Water Treatment Plant.

The magnitude 6.0 South Napa earthquake occurred in August 2014 and was the largest earthquake in the Bay Area since the 1989 Loma Prieta earthquake. This earthquake caused an estimated $400M in damage, power interruptions to 70,000 households, hundreds of injuries, and one death. EBMUD facilities were unaffected from this earthquake event.

5.2.3. Earthquake Event Future Potential

The San Francisco Bay Area is a region of high seismic activity with numerous active and potentially active faults. Major earthquakes have affected the region in the past and are expected to occur in the near future on one of the principal active faults in the San Andreas Fault System.

The USGS Working Group on California Earthquake Probabilities determined there is a 63 percent likelihood of one or more earthquakes of magnitude 6.7 or greater occurring in the San Francisco Bay Area region within the 30-year period from 2002 to 2032 (USGS, 2003). An earthquake of this size is capable of causing widespread damage.

More information about earthquake probabilities in the San Francisco Bay Area can be found on the USGS website: https://pubs.usgs.gov/fs/2016/3020/fs20163020.pdf.

The United States Geological Survey (USGS) provides computational tools in developing these estimates of ground motions. USGS has developed a revised set of specific scenario events for the rupture of the Hayward Fault, the main fault of concern in the EBMUD's service area.

A scenario represents one realization of a potential future earthquake by assuming a particular magnitude, location, and fault-rupture geometry and estimating shaking using a variety of strategies. In planning and coordinating emergency responses, utilities, local government, and other organizations are best served by conducting training exercises based on realistic earthquake situations—ones similar to those they are most likely to face.

ShakeMap scenario earthquakes can fill this role. A ShakeMap earthquake scenario is a seismic event with an assumed magnitude and location, and, optionally, specified fault geometry. Scenarios can be used to examine the exposure of structures, lifelines, utilities, and transportation corridors to specified potential earthquakes. In 2014-2015, USGS conducted the HayWired study, which modeled an earthquake scenario and its impacts on the San Francisco Bay Area from a Mw 7.05 earthquake on the Hayward Fault.

For this study, USGS developed a 2-year aftershock sequence scenario and ran thirteen different aftershock sequence models. A sequence with 175 aftershocks of Mw greater than 4.0, and 16 aftershocks of Mw greater than 5.0 was selected. The modeled aftershocks were placed on actual faults in the San Francisco Bay Region. More information about the HayWired scenario can be found at https://earthquake.usgs.gov/scenarios/eventpage/ushaywiredm7.05_se#executive.

EBMUD has completed several studies using scenario event files to test the resiliency of the water system facilities. The results of these studies help EBMUD make informed decisions on hazard mitigation, response, and recovery strategies.

Figure 5.5 below depicts the major faults in the Bay Area and their associated probability of occurrence of one or more Mw 6.7 or greater earthquake from 2014 to 2043. There is a 72% probability of experiencing such an event in the San Francisco Bay Region. The Hayward-Rodgers Creek fault system has the highest probability (33%) for a large rupture (Mw>6.7) on the major faults in the region.

More information about the probability of ruptures can be found at https://pubs.er.usgs.gov/publication/sir20175013v1

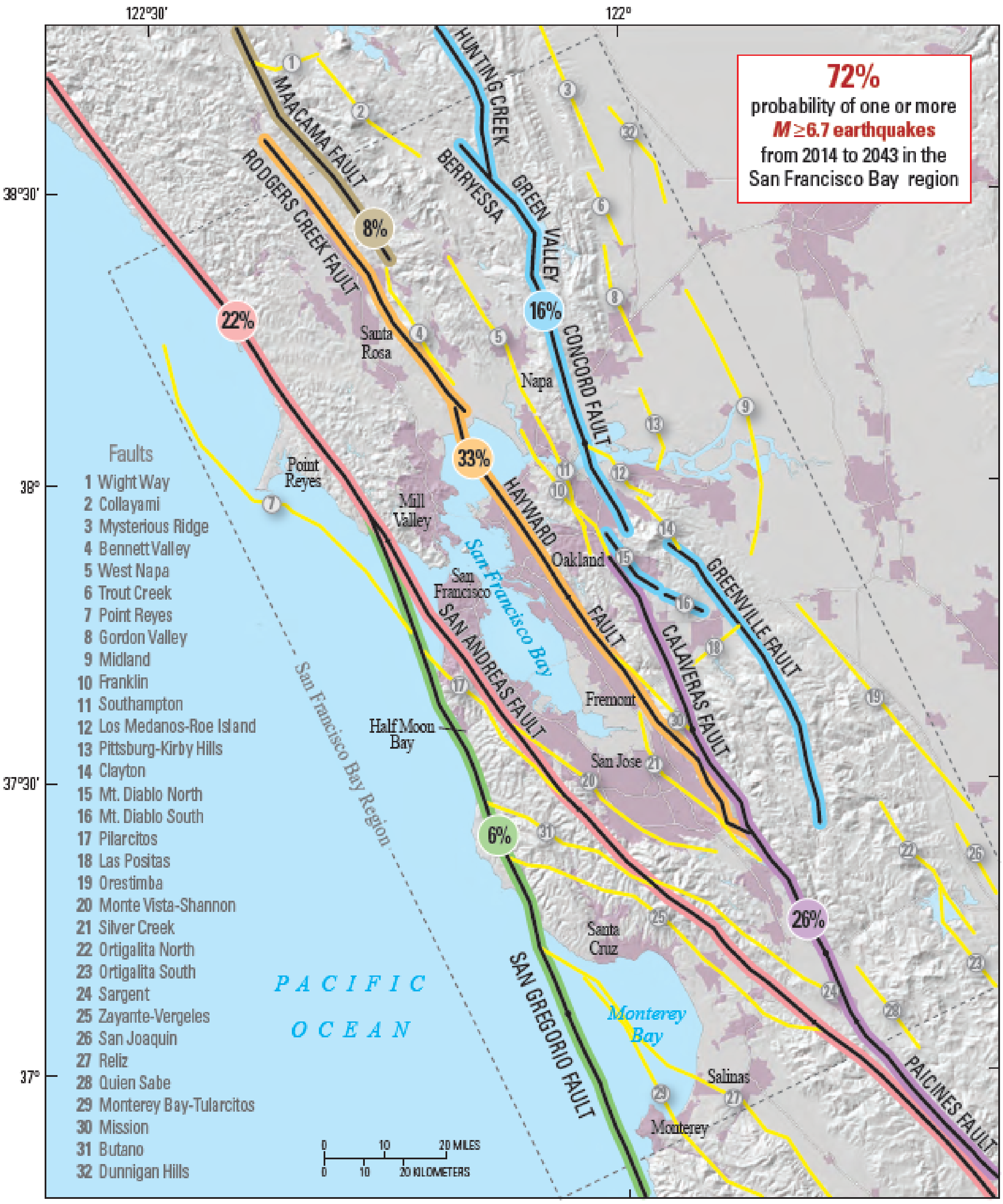

Figure 5.5. Regional Faults

5.3. Flood Hazard

5.3.1. Flood Hazard Background

Most communities in the United States are susceptible to some kind of flooding after spring rains, heavy thunderstorms, or winter snow melts thaws. The flood hazard includes coastal erosion, expansive soils, and land subsidence. Some flooding develops slowly, while others, such as flash floods, can develop in just a few minutes and without visible signs of rain.

In response to increasing losses from flood hazards nationwide, the National Flood Insurance Program (NFIP) was established. The 1968 Act provided for the availability of flood insurance within communities that were willing to adopt floodplain management programs to mitigate future flood losses. As a Special District, EBMUD is not eligible to participate in the NFIP.

There are 23 EBMUD facilities that are subject to a 100-year flood plain as mapped by FEMA, including one with a water velocity issue. An additional 33 are subject to a 500-year flood. The remaining 1,097 are not subject to flooding.

5.3.2. Flood Event History

Flooding associated with severe storms has been among the most common disasters in the Bay Area during the period of 1950 to 2010, occurring on average 1.3 times a year over the past 60 years. Often, heavy rainfall brings many areas of localized flooding, especially in low lying areas of the region. Many other locally significant floods have occurred during this time period. There is a history of floods causing damage to EBMUD's property and facilities.

On February 25, 2004, a flood caused significant damage to the Orinda Water Treatment Plant and nearly shut down the plant. On December 31, 2005 and January 1, 2006, there was another significant storm event resulting in residential property damage in the vicinity of North Lane and Camino Pablo Road in the City of Orinda. In both instances, the culvert along North Lane overflowed with mud and debris and cascaded over Camino Pablo Road and into the southern portion of the Orinda Water Treatment Plant.

In response to these events, EBMUD completed two mitigation projects to address the flooding hazard to Orinda Water Treatment Plant.

The first project to address the flooding hazard was the construction of a flood wall and concrete swales diversion system. This project was a stopgap measure to immediately address the flooding hazard until a more effective solution could be implemented. Construction was completed in 2007. The flood wall diverted storm water flowing towards and along Camino Pablo away from the Orinda Water Treatment Plant. If storm waters overtopped the flood wall, concrete swales controlled and directed the flow of water towards flood gates that opened into San Pablo Creek. Additional flood gates at the southern portion of the water treatment plant provided further protection to the filters by diverting water and debris away from the filters, towards the concrete swales, and ultimately into San Pablo Creek.

The second project to mitigate the flooding hazard to Orinda Water Treatment Plant was the North Lane Storm Drain project, which installed a new storm drain on North Lane to increase the storm water collection capacity of the area. EBMUD, in conjunction with the City of Orinda, designed, constructed, and funded this project.

The new storm drain was constructed under the southwest corner of Orinda Water Treatment Plant and flowed directly into San Pablo Creek. Installing this new storm drain decreased the amount of runoff onto the water treatment plant property and reduced the risk of flooding to the area.

The City of Orinda installed approximately 1,300 feet of 60-inch storm sewer pipe and created an outfall structure at San Pablo Creek. Approximately 900 feet of 60-inch reinforced concrete pipe (RCP) was installed under the length of North Lane. From the foot of North Lane, 320 linear feet of 60-inch RCP was jacked and bored under Camino Pablo. An additional 80 feet of 60-inch concrete jacking pipe connected to a new outfall structure upstream from the existing outfall on San Pablo Creek.

The new storm drain system also comprised of a debris rack, headwall, three inlet structures at the upstream end, and six manholes. The scope of the project included connection into existing lateral storm drain pipes, fence installation, and pavement repair. This new storm drain system was constructed in parallel to the existing corrugated metal pipe and ditch system on North Lane.

To address this flooding hazard, EBMUD obtained a grant that provided funding by the Federal Emergency Management Agency (FEMA) for 75% of the cost for both the design and construction of the bypass project. EBMUD and the City of Orinda had a cost sharing agreement for the balance of costs not covered by the grant.

On July 22, 2012, FEMA approved the bypass project cost of $1,687,427, with a total cost of $236,500 for the design phase. The project was finished in August, 2016, and has successful in handling the flow of storm water from subsequent rain storms thus far.

The Mokelumne Aqueducts are at risk of failure within the Sacramento-San Joaquin Delta due to flooding and seismic hazards. The three aqueducts are buried for most of the 90 mile alignment. However, due to the poor ground conditions, the aqueducts are elevated on pile supported bents for 10 miles across the Delta.

The Delta is comprised of a system of levees, rivers, sloughs, and low lying tracts of agricultural land. The Delta has approximately 1,100 miles of levees, up to 25 feet high. Beginning 150 years ago, the levees were built by individual farmers or reclamation groups to prevent flooding and reclaim the fertile farmland. They were constructed progressively of native soils and dredge spoils by manual construction methods, such as hand tools and clamshell dredging. Failures were expected and were simply rebuilt to the pre-failure condition, with only minor or no improvements. While the native soils are excellent for agriculture, they do not provide a strong foundation for levee barriers meant to continuously contain water. The soils underlying the levees and along the aqueduct alignment are composed of peat strata and soils that are susceptible to liquefaction and settlement during earthquakes.

During the last century, there have been 166 levee failures in the Delta region leading to island inundations. Under normal conditions, there is risk of damage to the aqueducts because of levee failure caused by unstable levee construction, seepage, and subsidence. These risks will be exacerbated in the event of a large earthquake or flood event.

- Seepage has been blamed for “sunny day” failures such as the failure of a levee at Jones Tract in 2004 that submerged the aqueducts. Seepage refers to water flowing under the levee in the underlying foundation materials resulting in boils. These boils can lead to progressive internal erosion, undermining and levee failure. Damage from burrowing animals exacerbates the problem of the high permeable materials.
- The elevation of Delta islands has gradually become lower, with some parcels now more than 20 feet below sea level. Subsidence is a direct result of farming activities that have accelerated microbial oxidation of the peat soils and increased compaction and soil loss due to wind erosion. For both buried and above ground sections of aqueducts the ground subsidence poses a significant hazard. Projected elevation decreases range from 1 to 5 feet by 2050. Subsidence of the islands directly impacts the stability of the levee system since it increases the height of the levees on the landside and hence increases the potential for seepage. Subsidence also reduces the stability of the levees.
- Overtopping failure occurs when the floodwater level rises above the crest of a levee and erodes the levee to the point of failure. Studies estimate that the sea level will rise by 0.6 to 1.9 feet over the next 100 years. Subsiding levees, bigger storms and sea-level rise due to climate change all serve to shrink the minimal available freeboard and increase the risk of overtopping.
- Scour profiles adjacent to historical levee breaches have been measured at up to 1,000 feet wide and over 1000 feet long, with up to 80 feet depths, below all three aqueduct’s pile tip elevations. With the proximity of the aqueducts to vulnerable levees, presenting a risk of aqueduct failure due to scour after a levee breach event.
- The aqueducts were not designed for submerged or semi-submerged service. If scour did not damage the aqueducts after a breach they would be vulnerable in the submerged condition due to wave action, floating debris, corrosion and buoyancy.

The Mokelumne Aqueducts are vulnerable to failure in the Delta due to flood and earthquake hazards. Following the 2004 Jones Tract levee failure, EBMUD’s report titled Strategy for Protecting the Aqueducts in the Delta (SPAD) recommended a Mokelumne Aqueduct Delta tunnel across the Delta as the long-term solution for risks to the aqueducts within the Delta. The recommended short-term mitigation was to construct the aqueduct interconnections that were completed in 2013. In 2014, a conceptual design for replacing the existing aqueducts through the Delta with a deep tunnel was developed as part of the Mokelumne Aqueducts Delta Tunnel Study. In 2016, EBMUD hired a tunnel engineering consultant to conduct a comprehensive geotechnical exploration program to study to augment historical geotechnical data, further characterize the ground conditions and reduce geologic uncertainties as basis of design for a Delta Tunnel and perform structural analysis of the existing pile supported aqueduct pipelines.

5.3.3. Flood Event Future Potential

With climate change, it is expected for the sea level to rise. Sea level rise mapping and shoreline analysis was completed for Alameda and Contra Costa counties by the Adapting to Rising Tides program in May 2015. These studies considered sea level rise scenarios from 6 to 60 inches and storm surge events from the 1-year extreme tide to the 500-year coastal storm surge event. Shoreline type and overtopping potential were also examined to determine where adaption strategies would be needed. Reports are available on the Adapting to Rising Tides website (http://www.adaptingtorisingtides.org/project/regional-sea-level-rise-mapping-and-shoreline-analysis/).

The Mokelumne Aqueducts are vulnerable to failure in the Delta due to flood and earthquake hazards. The aqueducts are located in a seismically active area. Bay Area faults, such as the San Andreas and Hayward, are capable of producing damaging ground shaking in the Southern Delta area, as well as the Midland Fault underlying the Delta. The seismic hazard risk is increasing by the ongoing deterioration of levees. The peat surface stratum offers little lateral resistance to aqueduct foundation piles during ground shaking increasing the risk of structural damage to the elevated aqueducts. Liquefaction during an earthquake can induce differential settlement of the aqueduct foundations resulting in pipeline failures. Additionally, the liquefaction hazard impacts the 50 miles of levees surrounding the aqueducts. The consequences of liquefaction of the deposits underlying the levees are excessive levee lateral deformations, settlement and loss of freeboard, leading to overtopping of the levee. Following a major earthquake, the duration of an island inundation is estimated to exceed 4 years due to various interests competing for the same resources to repair the numerous breaches throughout the Delta. There is also the risk that large scale levee failures may have prohibitively high repair costs and the islands could be left submerged indefinitely. For example, Frank’s Tract was never restored after a 1938 flood.

Localized flooding in EBMUD’s service boundary occurs during storm events due to runoff from heavy rain. Events cited were the flooding at the Orinda Water Treatment Plant and a residential property in Orinda. The Mokelumne Aqueducts are also at risk of being flooded since it is within the Sacramento-San Joaquin Delta. As previously mentioned, in the last century, there have been 166 levee failures in the Delta region leading to island inundations. Hence, probability that flooding will occur during future storms due to aging storm water systems and levee failures is highly likely.

FEMA prepares 100-year flood maps, called the Flood Insurance Rate Maps (FIRMs), which indicate floodplain boundaries and are the common reference when describing flood hazards. Figure 5.6 below, prepared by the Association of Bay Area Governments Resilience Program, (http://gis.abag.ca.gov/website/Hazards/?hlyr=femaZones) shows the FEMA flood zone within EBMUD service boundary.

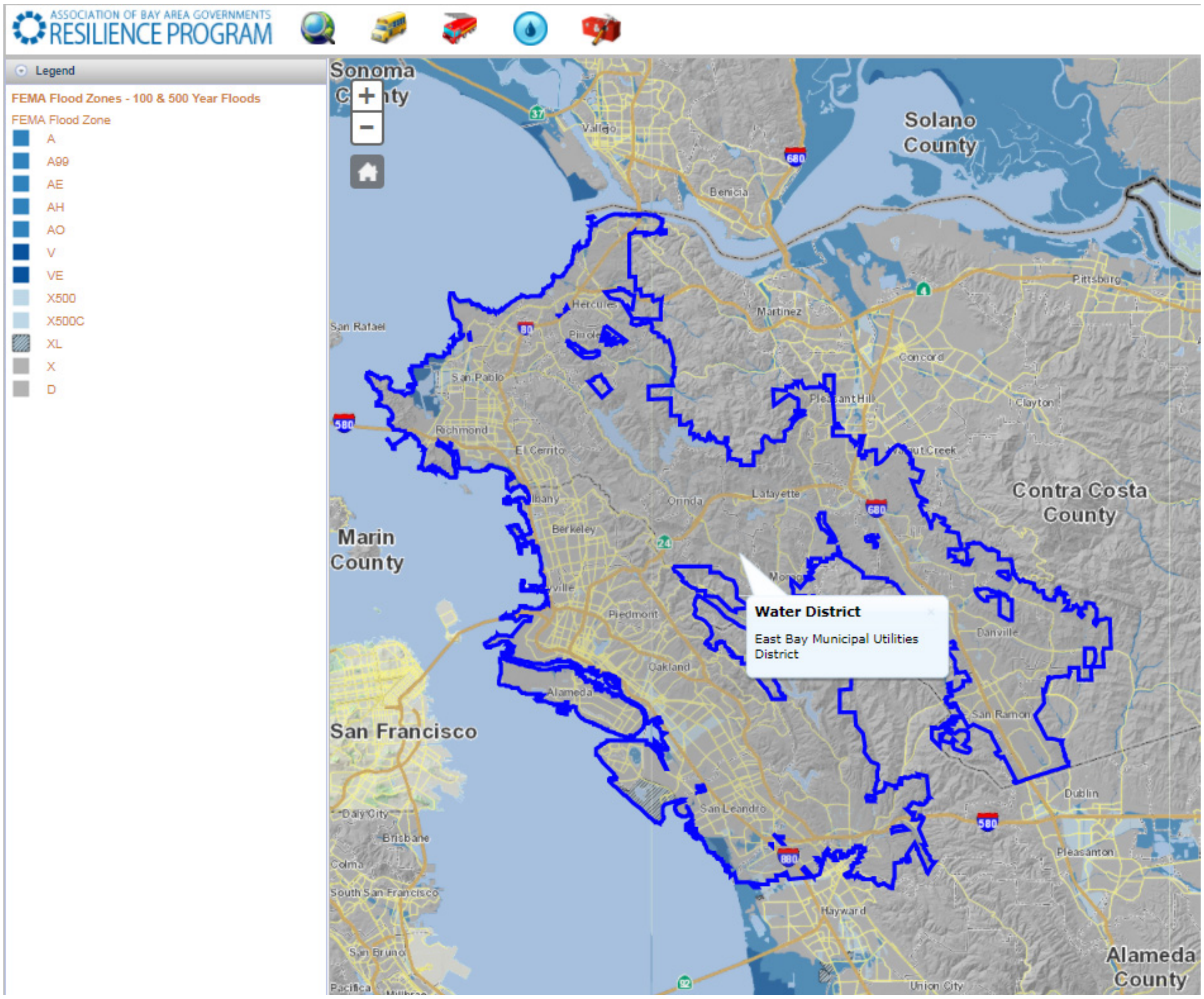

Figure 5.6. EBMUD Service Boundary Flood Zone

Special Flood Hazard Areas (SFHA) are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood, shown in Figure 5.6 above labeled Zone A, Zone AO, Zone AH, Zone AE, Zone A99, Zone V, and Zone VE. Moderate flood hazard areas, labeled Zone X (shaded) are also shown on the FIRM, and are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood.

5.3.4. Geologic Hazard Background

The EBMUD service area lies within the Northern California Coast Ranges geomorphic province and is shaped by the San Andreas Fault system's northwest-trending hills and valleys. The bedrock consists mostly of highly folded and deformed marine sedimentary deposits and volcanic rocks. General non-seismic geologic hazards consist of landslides, erosion, expansive and collapsible soils, subsidence, and corrosive soils.

The Coast Ranges are the result of subduction of the Pacific plate beneath the western border of North America. The Coast Ranges are folded and faulted and have created the ridges and valleys characteristic of California. Many of California's rock units originated farther south from where they lie today, indicating long-distance northern transport approximately 100 million years ago. The southern Coast Ranges are thought to be younger than the northern Coast Ranges. Most of the northern Coast Ranges are Franciscan Rocks (shales and sandstones) that were formed during subduction and are late Mesozoic in age. The Great Valley sequence is a belt of sedimentary rocks along the continental shelf of the Mesozoic ocean.

Serpentine is created when Franciscan sedimentary rocks are intruded by igneous rocks that have been metamorphosed. It is a hydrothermally altered rock that creates ophiolitic, serpentine, ultramafic, or ultrabasic soils in California. They are rich in magnesium and iron, but deficient in calcium, sodium, and potassium. Because of this soil makeup, California is host to many endemic plant species and has many edaphic ecologic islands.

5.3.4.1. Landslides

Landslides are the most common geologic hazard in the EBMUD service area, occurring frequently during high rainfall years. These landslides can be caused by over-steepened slopes due to undermining by creeks and rivers; progressive erosion over time, by weakened soil strength due to rainfall saturation of slopes; and by earthquake-induced land movements. There have been several significant landslides that have occurred on EBMUD watershed land in the past decades that have affected EBMUD facilities. There are also numerous landslides that have occurred on adjacent lands, such as in the Oakland/Berkeley or Lamorinda hills that have severely impacted our distribution pipelines and our ability to provide water service. Although generally confined to site-specific incidences, there is potential for future large landslide or debris flow events.

5.3.4.2. Other Geologic Hazards

Expansive and collapsible soils present geologic hazards to existing structures. These types of soils contain significant amounts of clays that expand when wet. Structures built on such soils experience seasonal wet and dry cycles that cause soils to expand when wet and subside when dry. These soils affect foundations, sidewalks, retaining structures, and other similar structures.

Erosion is the process where soils and rocks are broken or worn down and washed away by water forces. Erosion can cause mudflows on slopes. The resulting sediments can be washed down drainage structures and fill reservoirs, thereby decreasing their available storage capacity.

5.3.5. Landslide Hazard Event History

Landslides do occur annually in the Bay Area during the winter months. Areas susceptible to rainfall-induced landslides are the steep slopes of the Oakland/Berkeley Hills and the Lamorinda areas. Extensive landslides have occurred once every three years since 1950 based on a 2013 report from the Governor's Office of Emergency Services.

In January 1982, a winter storm triggered landslides and floods, damaging over 100 homes and killing 14 people. Costs associated with the slope failure were on the order of about $66M. Another big storm in 1998 caused over $150M in damages in the Bay Area. There were extensive landslides as a result of that storm that affected EBMUD facilities. Severe storms in 2006 similarly caused many landslides in the service area and EBMUD incurred costs over $300,000.

The 2016-17 winter storms caused several landslides in the service area that affected the District's facilities. Some major landslides were along the San Pablo Creek in Orinda that imperiled a 90-inch raw water aqueduct (approximate cost of repair is $400,000), landslide in El Sobrante that is impacting a raw water line to Sobrante Water Treatment Plant (estimated cost of repair is $300,000), landslide in Moraga that blocked portions of Moraga Creek where water is conveyed by EBMUD to Upper San Leandro Reservoir (estimated costs for repair is over $4M). There were many other landslides that affected EBMUD distribution pipe systems that needed to be replaced (estimated cost for repairs is $400,000).

5.3.6. Landslide Future Potential

There are over 75,000 active and dormant landslides mapped in the Bay Area. Earthquakes and heavy storms are likely to trigger landslides on an annual basis. Fifteen percent (178 of 1,154) of EBMUD's facilities are in an area mapped as having significant existing landslides. While 53 of EBMUD's facilities are in areas mapped as study zones for earthquake-induced landslides by the California Geological Survey, and 471 are outside of these areas, the remaining facilities are in areas that have not been mapped. There is limited correlation with the areas of rainfall-induced landslide mapped by the U.S. Geological Survey (described below). Thus, roughly 10-15 percent of EBMUD's facilities should be expected to be subject to this hazard.

Repair costs for future landslides can vary depending on the location and extent of the landslide. Based on past landslide impacts to EBMUD facilities, the repair costs could range from thousands of dollars to millions of dollars.

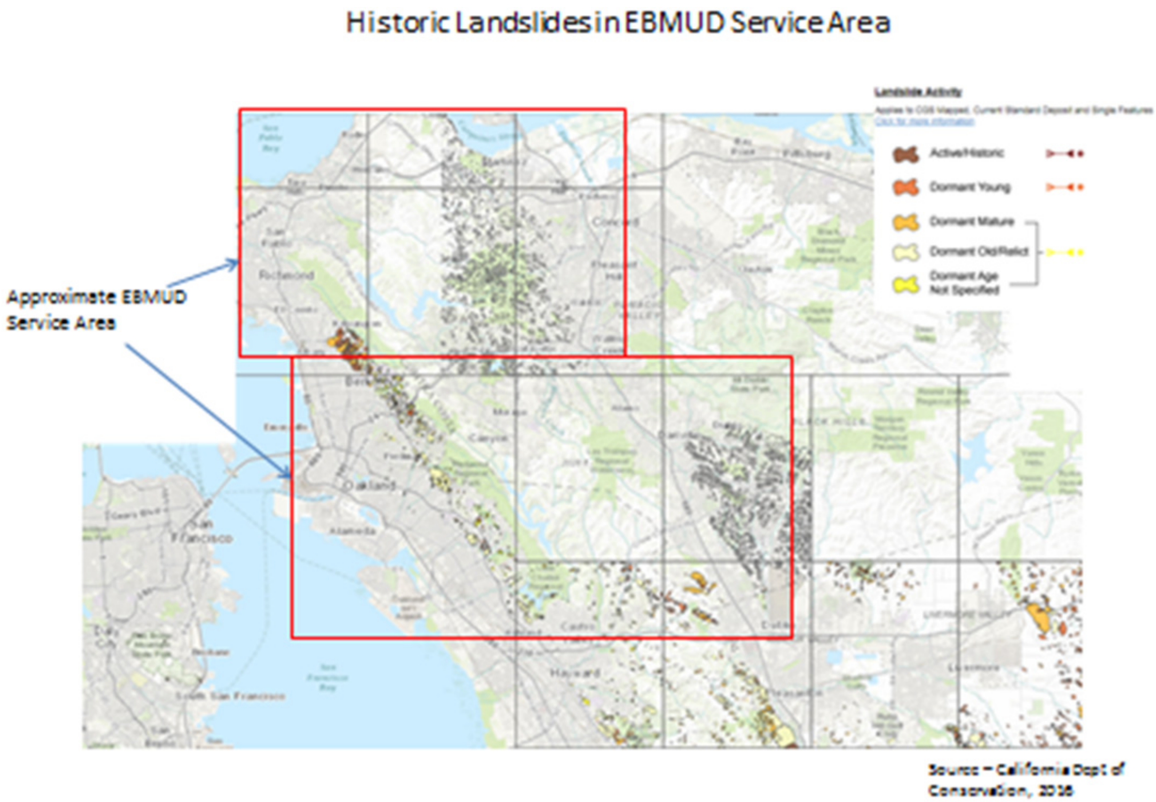

Figure 5.7. Historic Landslides in EBMUD Service Area

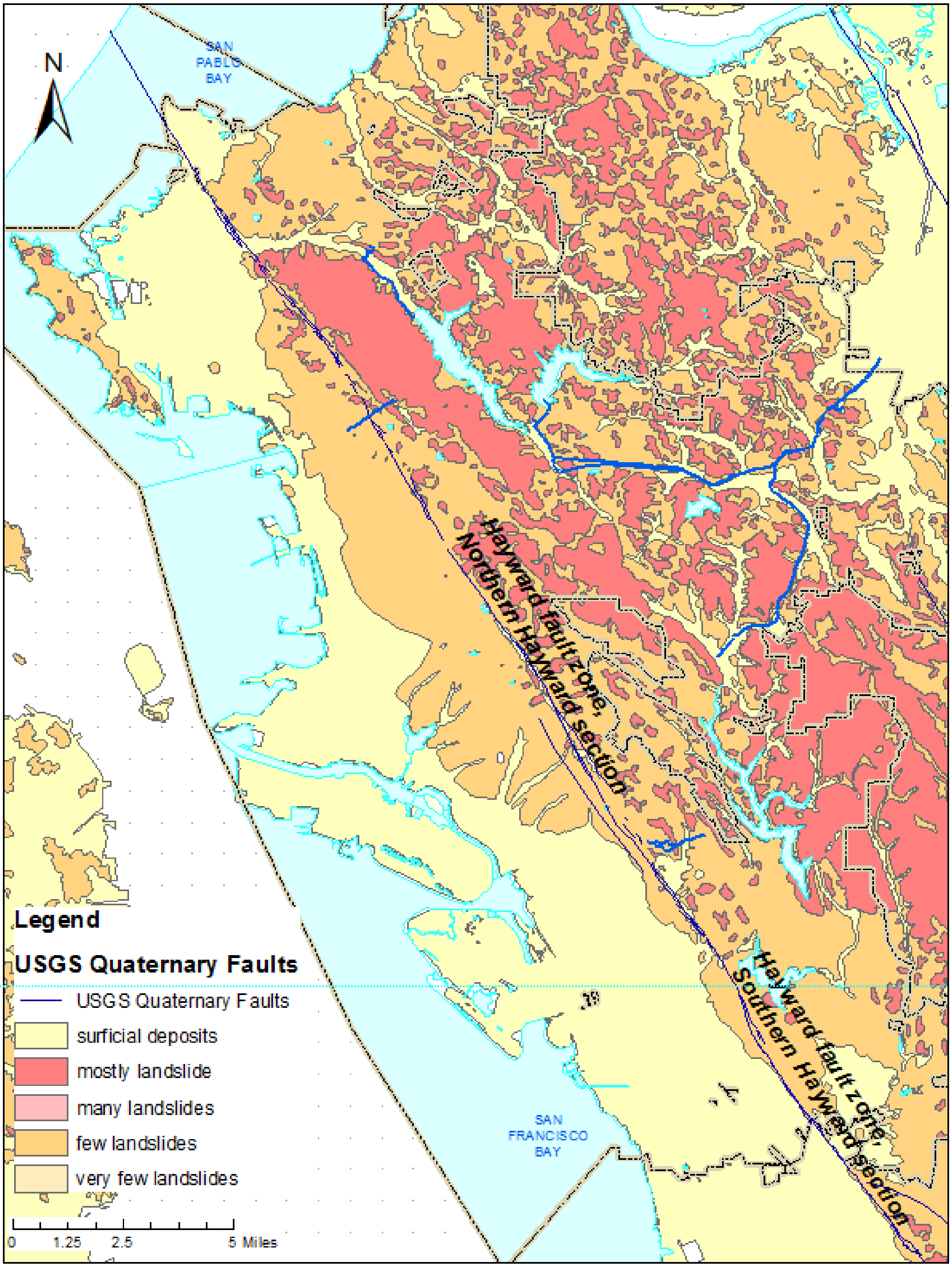

Figure 5.8. Deep Seated Landslide in EBMUD Service Area

Reference: Susceptibility to Deep-Seated Landslides in California, 2011, C. J. Wills, F. G. Perez and C. I. Gutierrez (California Geological Survey), Susceptibility to Deep-Seated Landslides in California, 2011.

Whereas geologic hazards cannot be completely eliminated, EBMUD geotechnical engineers complete geotechnical and geological investigations for all projects in order to identify geologic hazards and implement mitigation measures to at least minimize those risks. Some examples include: Appropriate foundation design for expected displacements, locating site to avoid hazards, in-situ soil improvement techniques, incorporating current and the state-of the art building codes in facility design.

5.4. Wildfire Hazard

EBMUD owns and manages approximately 28,000 acres of land and water surface in the East Bay Area. EBMUD is responsible for watershed management surrounding four reservoirs (Briones, San Pablo, Upper San Leandro, and Lafayette), one non-reservoir watershed basin (Pinole Valley), and a portion of the Chabot Reservoir watershed basin. Within District-managed lands are two developed recreation areas (San Pablo Recreation Area and Lafayette Recreation Area), the California Shakespeare Amphitheater, and an extensive recreational trails system.

The watershed lands are surrounded by encroaching urban interface of the East Bay communities of Hercules, Pinole, Richmond, Oakland, Orinda, Moraga, Lafayette, and Castro Valley. The western perimeter of the watershed lands is shared with East Bay Regional Park District (EBRPD), as are portions of the eastern boundary (Briones Regional Park and Los Trampas Regional Wilderness). The remainder of EBMUD watershed land perimeter is adjacent to undeveloped private lands with highly flammable vegetation.

The Mokelumne River watershed upstream of Camanche Dam is relatively narrow and steep and is located northeast of the Sacramento-San Joaquin River Delta on the western slope of the Sierra Nevada. Above Camanche Dam, the Mokelumne River drains over 600 square miles of mountains and foothills. Most of the Mokelumne River watershed upstream of Camanche Dam is protected and currently undeveloped, consisting of open space and forest land with small concentrations of residential/commercial development along the major highways, and large tracts of designated wilderness. Forest land, located chiefly within the El Dorado and Stanislaus National Forests, accounts for about 75 percent of the watershed land. EBMUD also owns and manages approximately 38,000 acres of land and surface waters in Amador, Calaveras, and San Joaquin Counties. Within these District-managed lands are two reservoirs and five developed recreation areas and an extensive trail system. There also is an extensive system of Mokelumne area trails in the Sierra foothills such as the Coast-to-Crest trail that goes across EBMUD land.

Wildfire in the Mokelumne watershed can drastically affect the performance of the inline water treatment plants (WTPs) that are fed from Pardee Reservoir (Orinda, Lafayette, and Walnut Creek WTP). These WTPs do not have any means to remove sediment, heavy metals, organic matter, nutrient, or high pH that are typical following a large wildfire in the watershed.

Water quality that has been observed in other water agencies following a large wildfire event would likely shutdown or severely hinder operations at EBMUD WTPs. EBMUD has the ability to feed water from Briones Reservoir for all three of these inline WTPs. However, Briones Reservoir contains only 180 days of storage, while wildfire effects on a watershed can last up to three years.

5.4.1. Wildfire Hazard Background

Wildland fires, particularly wildland/urban interface fires, have historically occurred in Alameda and Contra Costa counties. In addition to the East Bay service area, wildland/urban interface fires and large forest fires occur in the Mokelumne watershed counties of Amador, Calaveras and Alpine.

These types of fires have the potential to disrupt basic infrastructure elements of water treatment and conveyance, as well as impairing critical watershed ecosystem functions such as water infiltration, water quality and soil stabilization. Fires in the peat soils of San Joaquin County along the alignment of the Mokelumne Aqueducts have the potential to destabilize aqueducts by burning the wood or combustible footings and supports, or by burning peat soil under or surrounding the footings.

To minimize impacts on natural resources in each watershed, a strategic approach is used to reduce wildfire risk and to establish fire protection protocols. Existing barriers to wildland fire, fire roads, greenbelts, riparian areas, and low hazard vegetative types are interlinked into a Strategic Fuel Modification Network for wildland fire control. Fuel management activities required to establish the level of desired fire protection are linked with these natural barriers to minimize the amount of impact on the land.

EBMUD has historically maintained modest programs for both fuel management and fire suppression. Fuel management activities in the watershed have included grazing, prescribed burns, firewood collection of hazardous fuels, mechanical vegetation removal and limited chemical vegetation control. EBMUD has also constructed and maintains over 100 miles of fire roads and fuel breaks on watershed property to facilitate fuel management and provide safe emergency access.

All hazard abatement and fire protection measures are designed to obtain an optimum level of fire protection for all of EBMUD’s watershed lands. This proactive approach maximizes fire protection, while minimizing impacts of pre-suppression, suppression, or post-suppression activity.

EBMUD’s Mokelumne Watershed and Recreation Division (MWRD) maintain limited fire suppression capabilities and have training and equipment to perform incident assessment, initial response and suppression for small events. EBMUD staff has and continues to provide assistance to Cal Fire and other local fire departments for larger events.

5.4.2. Wildfire Event History

In the 21-year period from 1989 through 2009, EBMUD staff responded to 349 fires in the Mokelumne River watershed within or adjacent to EBMUD property. Most of these fires were very small (less than 1 acre burned). There have been only five large (greater than 200 acres) fires in or adjacent to EBMUD's watershed lands in the past 25 years. All but one of these fires started off of EBMUD property. All of these fires occurred during periods of strong north winds and direction of spread was to the south/southeast. Table 5.2 below provides a list of fire ignitions by years. The data in this table was compiled from data in the East Bay Watershed Fire Management Plan (January 2000) representing the period of 1980 through 1997 and Watershed & Recreation Fire Reports for the period of 1998 to 2017. These data are not intended to represent an exhaustive list of all fire incidents responded to by EBMUD staff but reflect the database of incidents compiled by Natural Resources staff.

As shown in Table 5.2, the most common fires cause category is "unknown" and the second most common cause traced to human related activity. Examples of human related causes are improper disposal of hot coals, fireworks, sparks from equipment, and arson. Fire Reports also indicate that many fires originate near roads that border watershed and open space lands or in recreation areas. Over the period of 1980 to 2017 there are an average of about 7 events per year although there have been no more than 10 events logged per year since 1985.

The data reported in Table 5.3 represent fire incidents that occurred on, adjacent to, or near EBMUD watershed lands. A detailed breakdown of the location of fires that occurred between 1998 through 2005 is provided in Table 5.3. These data were compiled by Water & Natural Resources staff to provide more detailed information regarding breakdown of the location and extent of fire incidents on and off EBMUD property for the period indicated.

In terms of extent burned, most fires are generally small—less than 1 acre—and contained relatively quickly due to quick response times from first responders. However, it is not uncommon for a few fires in a given year to grow large enough to burn several acres due to certain characteristics such as meteorological conditions and location of the fire. Table 5.4 presents the breakdown of the areal extent of burned acreage for each fire from 1980 through 2017. Note that complete annual data are available for the period of 1998 through 2005 as reported in Table 5.4. Data for the periods of 1980 through 1997 and 1980 through 2017 are presented as period of record totals in each acreage range as these data are compiled from other sources.

Table 5.2. Fire Occurrence by Year

Cause Category						
Year	**Unknown**	**Human Related**	**Natural**	**Abatement**	**Rekindle**	**Total**
1980	8	10		1	1	20
1981	10	5			1	16
1982		10				10
1983	7	5				12
1984	16	10	1	1		28
1985	5	4		1		10
1986	2	4				6
1987	2	7				9
1988	4	3	3			10
1989	1	2				3
1990	5	3				8
1991	8	2				10
1992	2	2				4
1993	7	1	1	1		10
1994	3	2	1			6
1995	3	3	1	1		8
1996		2				2
1997	1	1				2
1998	5	3		*N/A*	*N/A*	8
1999	2	3		*N/A*	*N/A*	5
2000	1	3		*N/A*	*N/A*	4
2001	1	2	1	*N/A*	*N/A*	4
2002	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2003	1	2		*N/A*	*N/A*	3
2004	2	2	1	*N/A*	*N/A*	5
2005	1	3		*N/A*	*N/A*	4
2006	1	1		*N/A*	*N/A*	2
2007	1			*N/A*	*N/A*	1
2008	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2009	3	4		*N/A*	*N/A*	7
2010	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2011	1			*N/A*	*N/A*	1
2012	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2013	4	2		*N/A*	*N/A*	5
2014		1	1	*N/A*	*N/A*	2
2015		1		*N/A*	*N/A*	1
2016	1	1		*N/A*	*N/A*	2
2017	1			*N/A*	*N/A*	1

Notes:

- ∗ Human Related category includes causes such as: Arson, child play, fireworks, smoke (e.g., cigarette), camping, and auto.
- ∗ Natural category includes category power line (i.e. caused by animals or downed trees), and other natural causes like lightning.
- ∗ 1998-2017 data are compiled from Watershed and Recreation Fire Reports via Natural Resources staff.
- ∗ 1980-1997 are from East Bay Watershed Fire Management Plan (January, 2000).
- ∗ *N/A* is an abbreviation for no data available.
- ∗ Blank or empty cells represent a value of "0."

Table 5.3. Breakdown of Fires Location and Extent for the period 1998 through 2005

Year	Wildland Fires	Other Fires	Total Fires	On EBMUD Land	Off EBMUD Land	Fires ALA Co	Fires CC Co	EBMUD Acres* Burned	Non-EBMUD Acres* Burned	Total Acres* Burned
1998	7	1	8	5	3	4	4	1	24	25
1999	4	1	5	4	1	0	5	6.25	0.5	6.75
2000	4	0	4	4	0	4	0	3	0	3
2001**	5	0	5	4	1	1	4	1.7	0.25	1.95
2002	1	0	1	1	0	0	1	0.5	0	0.5
2003	2	1	3	3	0	0	3	0.25	0	0.25
2004	3	2	5	3	2	3	2	1.75	5.25	7
2005	3	1	4	4	0	1	3	9.25	0	9.25
TOTAL	29	6	35	28	7	13	22	23.7	30	53.7

Notes:

- ∗ All acreages are approximate.
- ∗∗ There is no data available for a fire on July 3, 2001.

Table 5.4. Historical Fire Event Extent Data for 1980-2017

Estimated of Acreage Burned							
Year	**50+**	**49 to 10**	**9 to 5**	**4 to 2**	**1 to 0.25**	**Spot**	**Total**
1998		1	2		2	3	8
1999			1		2	2	5
2000				1		3	4
2001					2	3	5
2002					1		1
2003						3	3
2004			1		2	2	5
2005			1		1	1	3
1980 – 1997	2	7	13	15	36	101	174
1998 – 2005	0	1	5	1	10	17	34
2005 – 2017*	2	2	0	3	6	4	17
Totals (1980 – 2017)	4	10	18	19	52	122	225

Note:

* The period of 2005 through 2017 is compiled from Watershed & Recreation Fire reports; data for 2008, 2010, and 2012 were not available.

The remainder of this section describes some significant examples of fire hazard in the East Bay and Mokelumne Watershed. These examples are intended to provide a few detailed examples of wildfires that occurred historically.

One noteworthy example of a fire in the East Bay was the Oakland-Berkeley East Bay Hills firestorm in 1991. This fire resulted in a failure of water supply due to the disruption of power lines and fire damage to EBMUD facilities. As a result, local fire agencies did not have water to fight fires in critical areas. Since the firestorm, EBMUD has taken measures to provide quick connects to allow rapid restoration of power using portable generators, installed hydrants to provide emergency service across pressure zone boundaries, and worked with local and state agencies to develop consistency of fire department connections and protocols for the delivery of emergency water supplies.

In mid-October of 2004, a wildfire—designated as the Power Fire—occurred at the north side of the North Fork Mokelumne River in an area between PG&E facilities upstream of EBMUD's reservoirs, the Salt Springs Reservoir and the Tiger Creek Powerhouse. The 2004 Power Fire in Amador County burned more than 16,000 acres of forestland adjacent to the North Fork Mokelumne River. Water quality monitoring after the fire revealed elevated concentrations of many water quality constituents at sampling stations below the burned area.

The 2015 Butte Fire in Amador and Calaveras counties burned 18,000 acres in the Mokelumne Watershed. The fire straddled both sides of the main stem of the Mokelumne River for nine miles. During the emergency, EBMUD staff temporarily relocated operations to the Camanche Reservoir Control Center when the Pardee Station became too smoky for employees to remain. Camanche South Shore recreation area was opened as an evacuation site. EBMUD Rangers patrolled the watershed throughout the fire emergency as extra eyes and ears on the ground and helped rescue horses and other animals. Governor Jerry Brown declared a state of emergency on September 11, 2015 triggering emergency response actions. FEMA assisted by funding firefighting and recovery efforts. Thirteen active employees were evacuated from their homes and three employees lost their home to the wildfire. Cal Fire reported that the Butte fire destroyed 2 facilities, 356 outbuildings, and 545 residences.

Both the 2004 Power Fire and 2015 Butte Fire events created the potential for large scale soil and woody debris movement into the Mokelumne River and Pardee Reservoir. Actual impacts from these fires were modest with no resulting significant impacts to reservoir operation, water treatment processes, or water delivery. The reason the fire impacts were mitigated was largely due to slope stabilization and other fire mitigation measures post fire, combined with favorable hydrologic conditions.

5.4.3. Wildfire Event Future Potential

The California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP) publishes data for California describing the areas in the state that are at risk from wildfire (http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_maps). Significant portions of Amador and Calaveras counties are considered to be high or very high fire-hazard areas. There are several communities in Amador, Calaveras, and Alpine counties that are at risk from fires from forested lands.

Figure 5.9 through Figure 5.12 shows areas adjacent to reservoirs in the EBMUD service boundary (i.e. Briones, San Pablo, and Upper San Leandro) and areas surrounding Mokelumne River watershed to be in high to very high fire hazard zones. As stated earlier, from 1989 through 2009, EBMUD staff responded to 349 fires in the Mokelumne River watershed within or adjacent to EBMUD property. Therefore, the probability of wildfire in EBMUD service boundary and Mokelumne River watershed is highly likely.

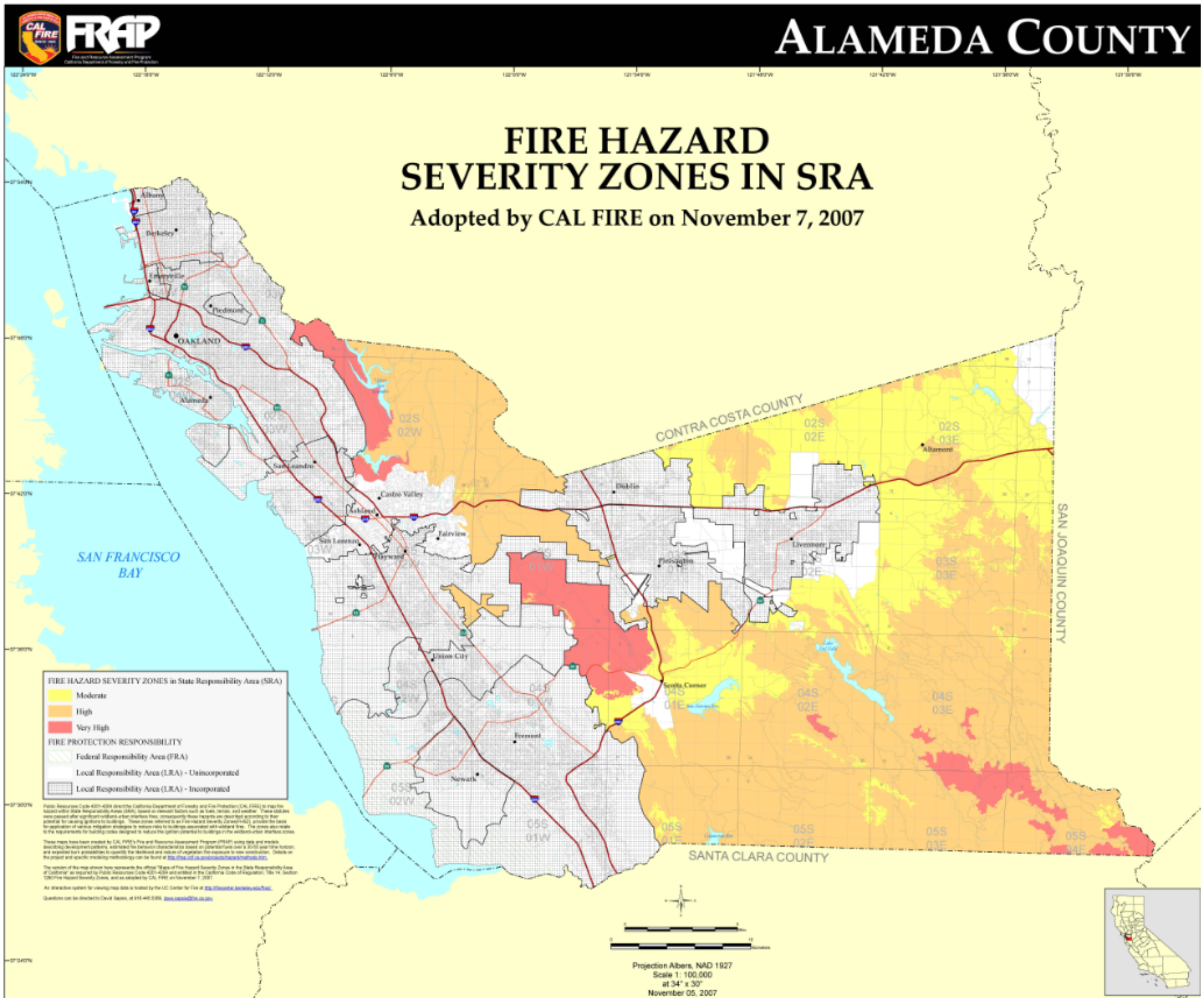

Figure 5.9. Alameda County Fire Hazard Severity Zones

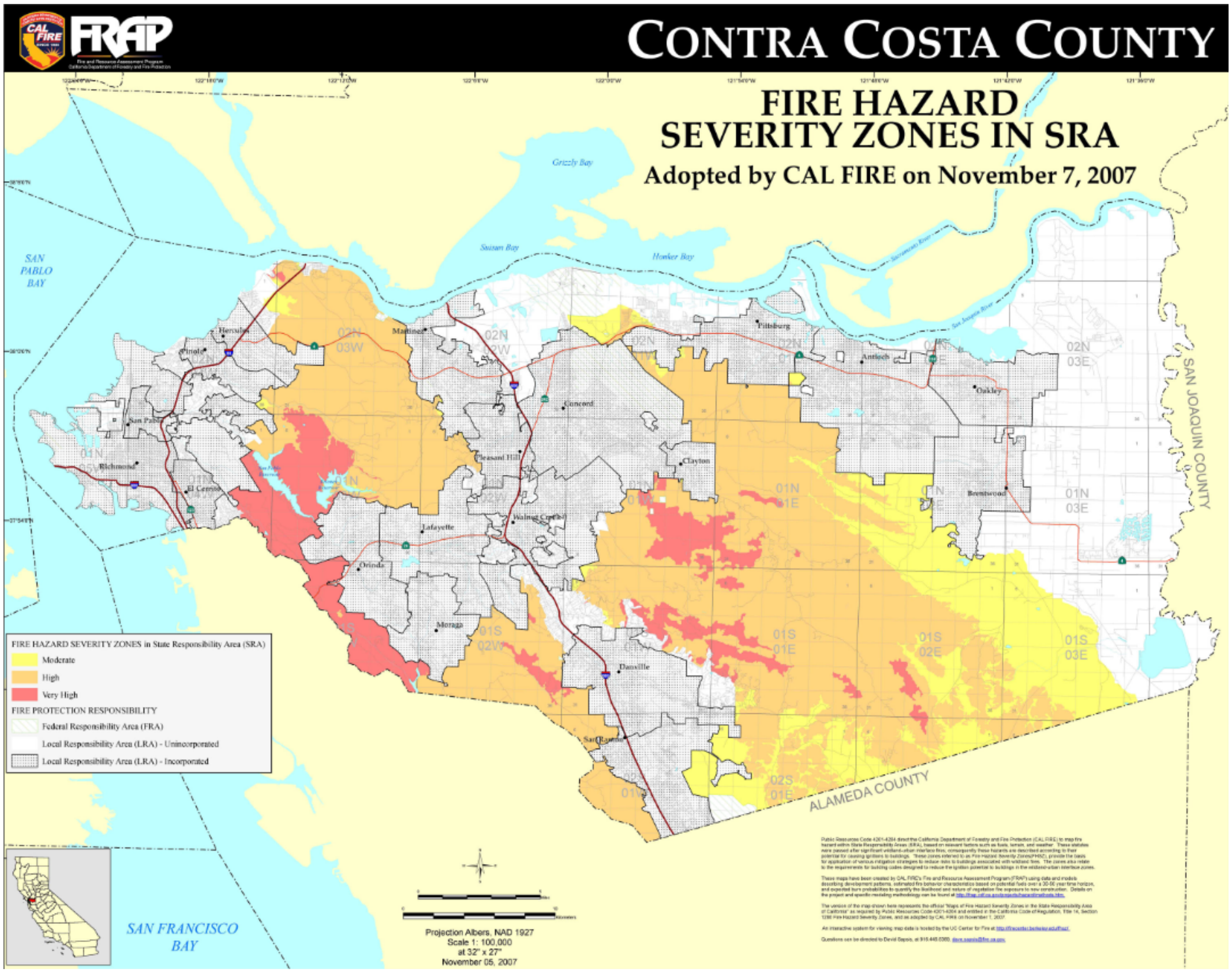

Figure 5.10. Contra Costa County Fire Hazard Severity Zones

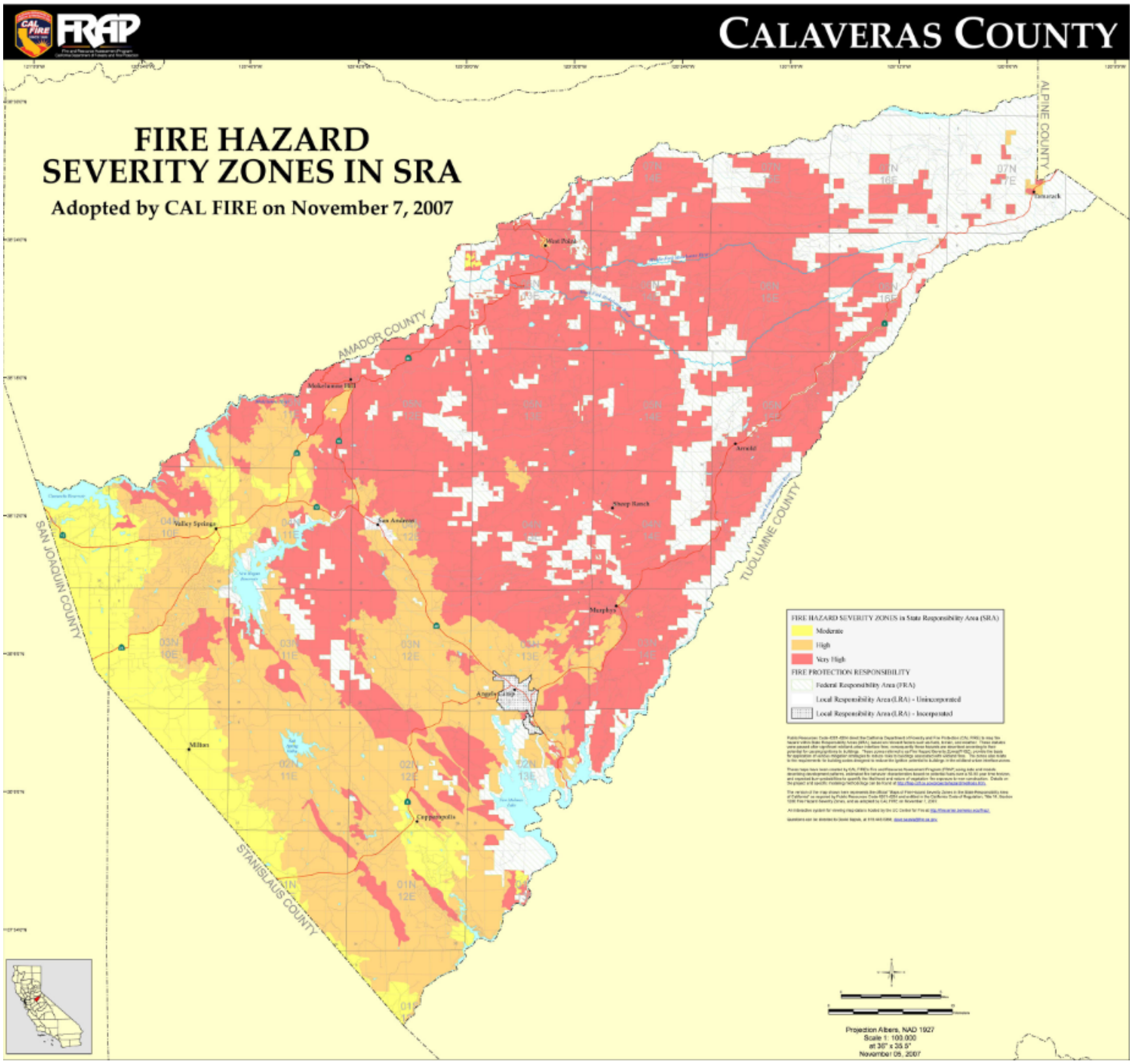

Figure 5.11. Calaveras County Fire Hazard Severity Zones

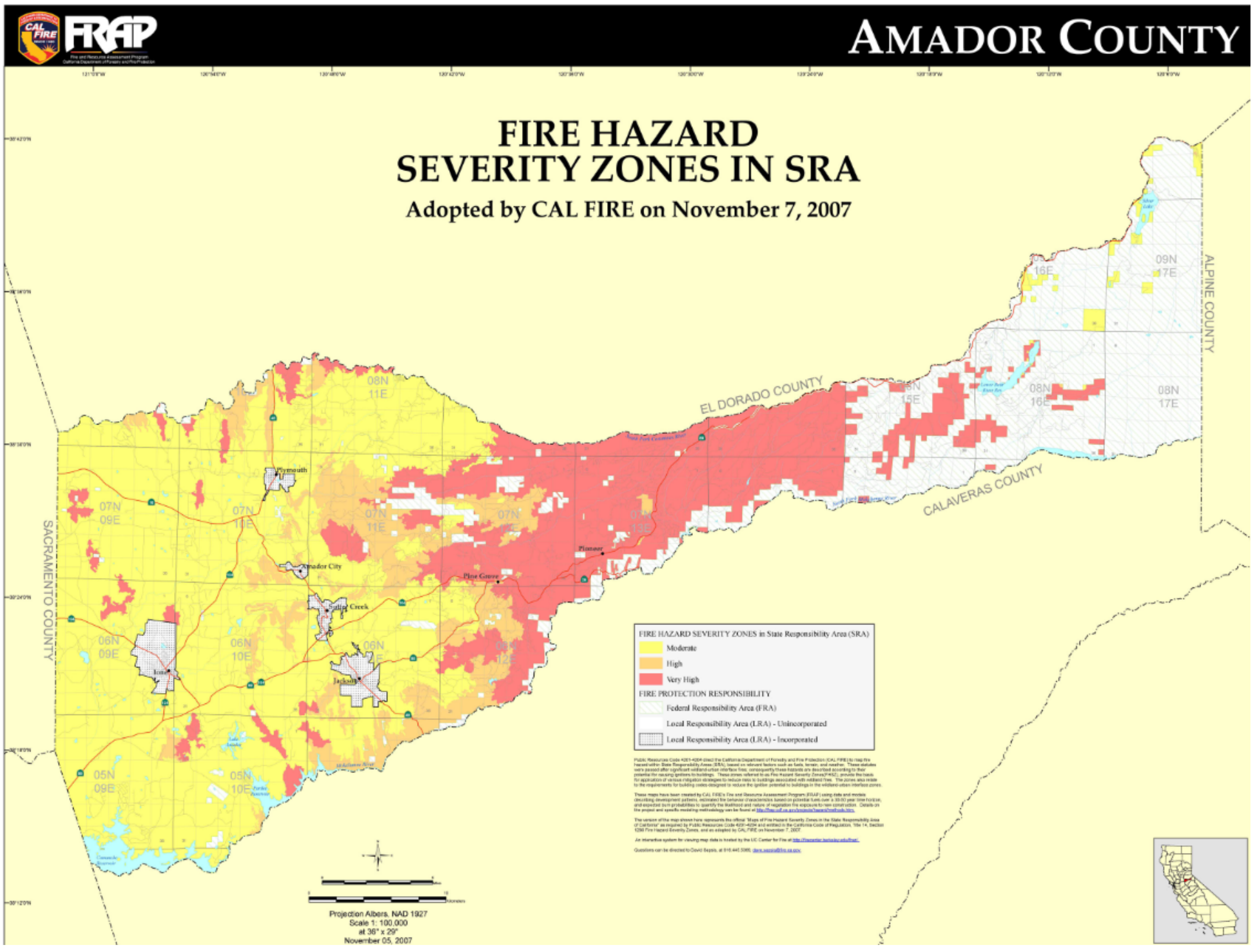

Figure 5.12. Amador County Fire Hazard Severity Zones

Eight percent (94 of 1,154) of EBMUD facilities are in an area mapped as subject to high wildfire threat, 7 percent (84 of 1,154) are in an area mapped as subject to very high wildfire threat, and none are mapped as subject to an extreme wildfire threat. In addition, 73 percent (839 of 1,154) of EBMUD facilities are within the area mapped by CAL FIRE as within the wildland/urban interface fire threat area.

EBMUD has developed Fire Management Plans and Fire Suppression Plans for its watershed property in the East Bay and Mokelumne Area. EBMUD is a member of the Upper Mokelumne River Watershed Authority and routinely supports grant applications for forest health improvements and fuel management projects within the Mokelumne Watershed, primarily focusing on US Forest Service managed lands. The fire management plans are located in the Appendices section of this document.

5.5. Drought Hazard

Northern California's water resources, including EBMUD's supplies, have historically been affected by periodic drought cycles. Multi-year droughts in particular have significantly diminished the supply of water available to EBMUD's customers. Figure 5.13, which includes data from the 2014-2015 drought, illustrates the variability in runoff in the Mokelumne Watershed since 1929.

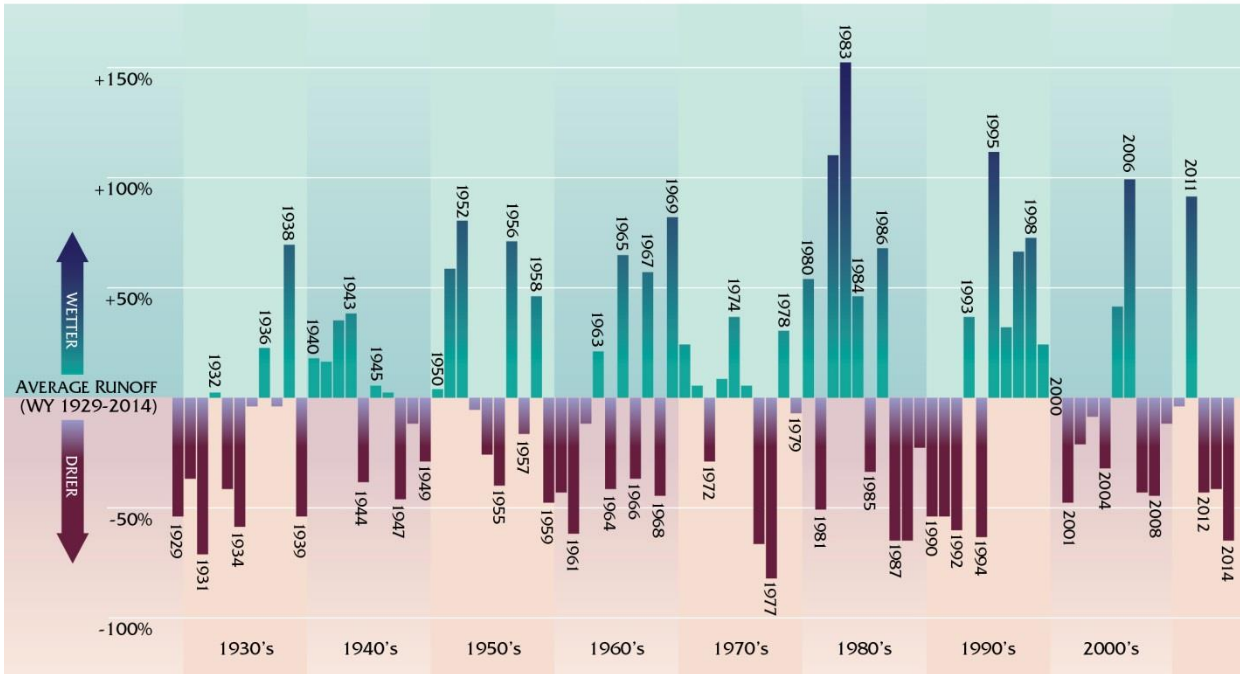

Figure 5.13. Variability in Runoff in the Mokelumne Watershed (1929-2015)

5.6.1. Drought Event History

During historical dry periods, when runoff from the Mokelumne River Basin was insufficient to meet service area demands, EBMUD relied on stored water in its reservoirs to meet most of its customer water needs.

The worst hydrologic drought event in EBMUD history was the 1976-1977 drought, when runoff was only 25 percent of average and total reservoir storage decreased to 39 percent of normal. EBMUD successfully managed water demand during mandatory and voluntary rationing periods, when supplies were limited in calendar years 1976-1978, 1987-1994, 2007-2010, and 2014-2015.

For a long term drought, the Mokelumne River and local runoff cannot meet EBMUD's projected customer demands, even with mandatory water use restrictions in place. Furthermore, EBMUD's Mokelumne River supply is expected to be reduced as demands on the Mokelumne River increase from the growing needs of users in Amador, Calaveras, and San Joaquin counties. These counties have water rights senior to those of EBMUD's.

EBMUD's efforts to identify additional sources of supply to meet long term demand began in the mid-1960s. In 1970, EBMUD executed a contract with the United States Bureau of Reclamation

(USBR) for delivery of Central Valley Project (CVP) water from the American River. In 2000, USBR, EBMUD, and Sacramento region parties reached an agreement to develop a joint water supply intake on the Sacramento River, rather than the American River. This agreement led to the construction of the Freeport Project.

The completion of the Freeport Project allowed EBMUD to implement its Long Term Renewal Contract (LTRC) with USBR to take up to 133,000 acre-feet of water in a single 'dry' year, not to exceed a total of 165,000 acre-feet in three consecutive 'dry' years. The CVP supply constitutes a critical component of EBMUD's water supply reliability during drought periods. EBMUD exercised its LRTC and delivered CVP water for the first time during the 2014-2015 drought.

In 1992, as part of the Urban Water Management Plan, EBMUD adopted its first Water Shortage Contingency Plan (WSCP). The WSCP, which has since been updated in 2010 and 2015, prepares EBMUD for a variety of situations that could affect its water supply, including short-term emergencies and longer-term droughts.

A critical component of the WSCP is the Drought Management Program (DMP) that provides guidance and potential actions for EBMUD to implement to manage a water shortage. EBMUD's WSCP and can be found at: http://www.ebmud.com/water-and-drought/about-your-water/water-supply/urban-water-management-plan/.

5.5.1. Drought Event Potential

EBMUD has developed a process and policies for monitoring, assessing, and responding to water supply availability. EBMUD considers not just a single, dry year in its planning, but the potential for sustained, multi-year droughts as well.

EBMUD uses historical hydrologic data to inform its modeling and planning for future droughts. Although the 1976-1977 drought had only lasted for two years, to plan for the possibility of an extended drought lasting three years, EBMUD uses a three year drought planning sequence (DPS) to assess the adequacy of its water supply. The first and second years of this DPS are modeled using the actual runoff that occurred in 1976 and 1977, the driest recorded two-year period. The simulated runoff in the third year is the average from 1976 and 1977. In the UWMP 2015, EBMUD uses its DPS to model a multi-year drought and evaluated a few different supply scenarios to assess its need for water under potential future conditions (through year 2040). The results inform EBMUD in planning its supplemental supply portfolio so it is robust enough to be used in the uncertain future conditions.

EBMUD's Water Supply Availability and Deficiency Policy provide a framework for evaluating the adequacy of its water supplies each year. The report informs the decisions by EBMUD's Board of Directors regarding whether to declare a water shortage emergency and implement a drought management program, institute mandatory water use reductions, and/or obtain/pursue supplemental supplies.

A key challenge in estimating "drought frequency" is in defining a drought. In general, drought is a prolonged period of abnormally low rainfall that results in a shortage of water. There are policies and guidelines adopted by the EBMUD Board of Directors that set the parameters for defining a supply limited condition. Under certain conditions, a drought is declared and other actions that mitigate for a shortage in supply are triggered such as supplemental supplies and customer rationing.

A central component of the District's policy in this area is the District's Demand Management Program (DMP) guidelines. Figure 5.14 below is an excerpt from EBMUD's 2015 UWMP that depicts the DMP guidelines. Under the DMP guidelines Drought Stage 1 is initiated when the projected end-of-September Total System Storage is equal to 500 thousand acre-feet (TAF) or less. Note that this criterion incorporates both aspects of supply *and* demand into a forecasted storage threshold in each water year that is used to trigger a "drought" condition. This is the same criterion that defines eligibility criteria for the District's CVP supply as defined by the District's Long-Term Renewal Contract with USBR (Contract No. 14-06-200-5183A-LTR1).

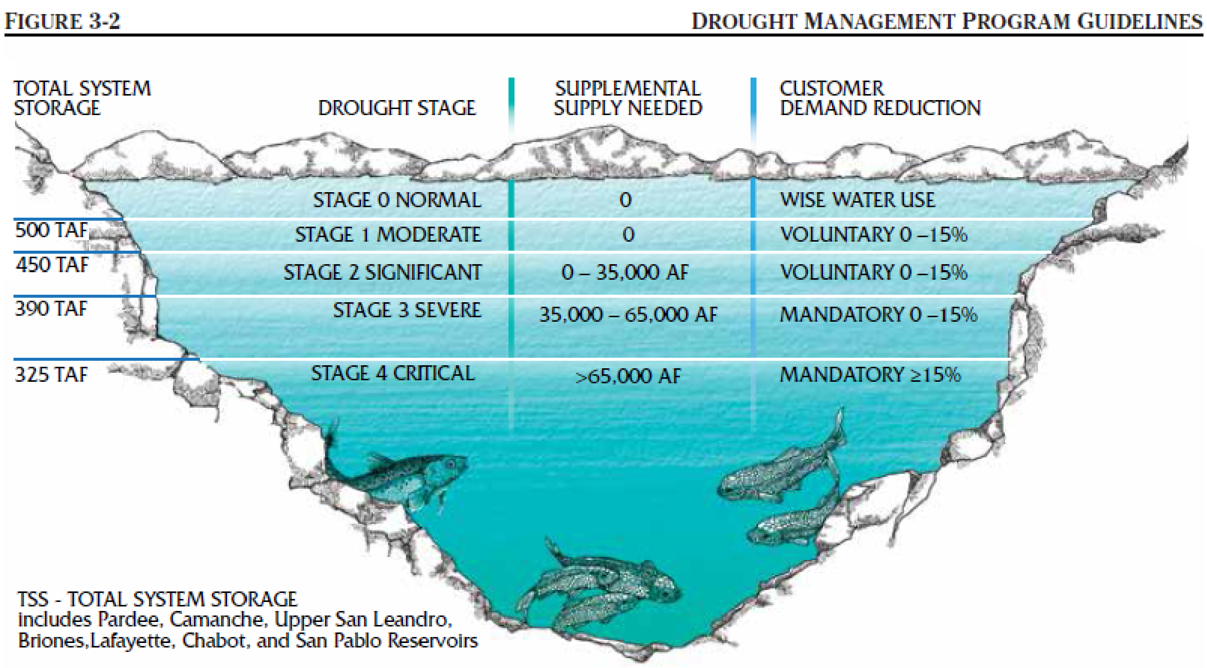

Figure 5.14. EBMUD's Demand Management Program Guidelines[1]

For the purposes of estimating drought frequency, EBMUD defines a "drought" using the projected end-of-September Total System Storage criteria equal to 500 TAF. We can determine the frequency of time above and below this threshold by running the Districts' water resources planning simulation model (EBMUDSIM) under existing conditions. Model results show that there are 27 years (29 percent or approximately 3 in 10 years) over the historical period of

[1] EBMUD, *2015 UWMP*, Figure 3-2, p. 31

hydrology spanning 1921 through 2012 in which the end-of-September Total System Storage would fall below the Stage 1 threshold and a drought condition would be declared.

Historical records show that several droughts have occurred in the last 40 years in California. Drought period consists of 1976-1978, 1987-1994, 2007-2010, and 2014-2015. The year 2015 surpassed the year 1977 as the driest year on record in California. With changing climate, it is expected there will be more severe, longer droughts, and more days of extreme heat. Because EBMUD service boundary and Mokelumne Watershed have been subject to drought in the last few years, the probability that drought in some form will continue to affect EBMUD service boundary is highly likely

5.6. Other Hazards

5.6.2. Climate Change

Climate change is an emerging hazard that has received widespread recognition in the last decade. Scientific literature developed over the past several decades has confirmed that the release of greenhouse gases is creating changes to the earth's climate. This climate change is leading to a variety of negative effects that can cause or contribute to the intensity or frequency of several types of hazards and natural disasters events.

The state of California's 2010 Hazard Mitigation Plan indicates that climate change is expected to lead to more extreme weather events, avalanches, coastal erosion, flooding, sea level rise, extreme heat, drought, landslides, severe weather and storms, and wildland fires. The changes in weather can also result in changes in growing regions for different plants and agricultural crops, as well as changes in range of pests and disease, which could result in huge economic impacts to the state and county agricultural industries.

Though climate change was recognized as a hazard mitigation issue in the State's 2010 Hazard Mitigation Plan and identified as a factor that intensifies many natural hazards, climate change is not included in the list of hazards suggested for consideration by the Hazard Mitigation Plan checklist or guidelines.

EBMUD recognizes the contributing role that climate change plays with respect to hazard vulnerability. Rather than discuss and analyze it as a separate hazard, this 2018 LHMP has discussed the contributory role that climate change may have on EBMUD's vulnerability to wildland fires, flooding, sea level rise, and storm events, and identifies the other potential hazards that climate change could cause or exacerbate.

EBMUD is also actively pursuing the implementation of measures to reduce greenhouse gases. To the extent that FEMA or the Cal EMA considers greenhouse gas reduction measures or climate change adaptation measures as hazard mitigation, it is the intent of this 2018 LHMP to include such measures in its hazard mitigation strategies.

5.6.3. Terrorism/ Bioterrorism/ Security Event

EBMUD works daily to protect drinking water sources and ensure the delivery of reliable, high-quality water to people and communities.

Following the 1991 Oakland Hills firestorm, EBMUD developed a detailed emergency operations plan to protect water supplies from natural hazards such as earthquake and fire. A team of experts reviewed the emergency operations plan after the events of 9/11 and expanded it to address security threats.

EBMUD's drinking water security program supplements physical security features, such as fencing, sensors, cameras, and alarms, with carefully designed operational security procedures and technology applications that remotely monitor facilities and protect critical computerized information resources.

5.6.2.1. Physical Security Features

Over the past decade, EBMUD has invested nearly $20M in upgrades to physical security features that protect our facilities. A new restricted key system controls unauthorized entry and prevents key duplication. Where needed, new fences have been installed and existing fences have been repaired. Cameras, sensors, and alarms are in place at critical operational facilities, administrative offices and service centers. Staff remotely monitors these systems 24 hours per day and dispatches personnel to investigate any suspicious activities. As we renovate existing facilities and build new facilities, we ensure they meet current security requirements.

5.6.2.2. Operational Security Procedures

EBMUD participates in local, regional, and national associations that share intelligence and best practices relating to security. EBMUD staff also works with law enforcement, fire agencies, the FBI, and Homeland Security staff to ensure they understand security issues related to water supplies.

EBMUD's expert team of security professionals provides clear guidelines to employees and contractors on security related topics and enforces security procedures and protocols that relate to facility access, information security, and document control. The team investigates all reported security incidents, analyzes incident data, and recommends changes as needed.

5.6.2.3. Information System Security

EBMUD works to protect all forms of sensitive electronic data from unauthorized access and to ensure that critical business systems will be up and running following a disaster.

EBMUD encrypts confidential computer data and routinely monitors networks to detect and respond to intrusions. The computerized system that monitors and controls EBMUD's water supply operations is isolated both from the World Wide Web and from EBMUD's own internal business network. Access to the computerized monitoring system is tightly controlled.

Recognizing the seismic vulnerability of the East Bay, EBMUD built a backup data center at a distant, offsite location. The emergency notification system is regularly tested to prepare staff to communicate following a security incident or natural disaster.

EBMUD continuously improves its security program based on new information, and updates it to reflect changing water and wastewater industry standards and evolving national security regulations.

6. Vulnerability Assessment

EBMUD staff conducts risk assessments to determine the potential impacts of hazards to customers, the economy, and the environment. Risk assessments provides a base for the rest of the mitigation planning process and helps in identifying and prioritizing actions to reduce the risk from hazards.

6.1. Water Supply Facilities

6.1.1. EBMUD Facilities within the Bay Area

6.1.1.1. Embankment Dams and Reservoir Towers

6.1.1.1.1. Embankment Dams and Reservoir Towers Exposure and Vulnerability

Over the years, EBMUD has completed seismic safety evaluations of all its dams. Of EBMUD dams, only Piedmont, Dunsmuir, San Pablo, Pardee, and Chabot were assumed to need seismic upgrades. Other minor issues have been identified at other dams and towers are being addressed as part of EBMUD's capital program or have been addressed by establishing lower operating levels to ensure adequate freeboard.

To date, the upgrade work on the dams has either been completed or is currently underway. Piedmont Dam was removed from service, along with Seneca Reservoir. The rest of the dams are considered safe for continued operations under the Maximum Considered Earthquake (MCE) rating.

EBMUD has completed structural and seismic evaluations of the reservoir towers. The reservoir towers at the following dams are deemed to be vulnerable to a major seismic event: Briones, Lafayette, Chabot, Upper San Leandro (USL), and San Pablo.

Retrofit design on the reservoir towers has been completed for Chabot and USL Dams, and construction is expected to be completed in 2017. Design efforts are underway for the towers at Briones and Lafayette Dams. Since the Lafayette Tower also serves as the dam's spillway, failure could create an additional mode of failure. Failure of the tower could cause an uncontrolled release of reservoir water that will affect the City of Lafayette's business district. An additional tower at San Pablo Dam is currently not used but could be used to supply water to San Pablo Water Treatment Plant.

6.1.1.1.2. Impact on Embankment Dams and Reservoir Towers and Loss Estimates

The loss of a dam would have dire safety and economic consequences. At this time, dams have been retrofitted or have restricted operating levels to prevent an uncontrolled release of reservoir water.

However, significant deformation could cause the reservoirs to be drained or lowered and will significantly reduce the availability of water for distribution. Extensive damage to the reservoir towers will have similar impact by restricting EBMUD's ability to release water from the facility for use. For instance, Briones Reservoir serves as EBMUD's local emergency raw water storage and supply in case of disruption of its water supply from Pardee Dam. Failure of the Briones Tower will curtail its ability to supply water from the reservoir to be treated and distributed to the 1.4 million EBMUD customers.

6.1.1.1.3. Embankment Dams and Reservoir Towers Vulnerability Summary

Embankment dams and reservoir towers are vulnerable mainly from seismic events. On-stream reservoirs are vulnerable from extreme rainfall and flood events that could cause the dams to uncontrollably release its water contents and flood the areas downstream of the dams.

6.1.1.2. Reservoir Tanks

6.1.1.2.1. Reservoir Tanks Exposure and Vulnerability

The seismic design criteria required by building code *ASCE 07 – Minimum Design Loads for Buildings and Other Structures* and reservoir design standards (i.e. AWWA D100) have evolved over the years. Many of the reservoirs in the distribution system do not meet current building code and the latest design standards for new reservoirs.

Reservoirs may not meet current standards for required sloshing wave freeboard height, piping flexibility, and seismic safety. The precast concrete panel roof systems at several reservoirs have been deemed to be seismically deficient and unreliable. Over-constrained piping and connectors could potentially lead to water leakage and emptying of tanks in a seismic event. In addition, twenty-two percent of the EBMUD's distribution reservoirs are beyond the average useful life when compared to the EBMUD's Engineering Standard Practice (ESP) 461.2.

Many of the reservoirs that are beyond their useful life are open-cut reservoirs. Although open-cut reservoir replacement costs are substantial, replacements and rehabilitations are needed for the following reasons: Many open-cut reservoirs have roofs that are unsafe for EBMUD personnel, cracks in the roofs that lead to stormwater leakage and water quality concerns, hazardous materials present in some reservoir linings, and the majority of EBMUD's treated water is stored in open-cut reservoirs.

A small percentage of EBMUD's distribution reservoirs are redwood tanks and hydropneumatic tanks. These redwood tanks are not seismically anchored to their foundations and could overturn during an earthquake.

Steel reservoirs make up the largest group within EBMUD's 167 distribution reservoirs. EBMUD's experience with steel reservoirs demonstrates that the average lifespan of their coating systems is 25 years. EBMUD's historic recoating efforts have been inconsistent. The historic average rehabilitation rate has been 1.3 steel reservoir rehabilitations per year.

During the 1990's EBMUD installed cathodic protection systems in painted steel reservoirs to prevent corrosion of the interior surfaces that are in contact with water. However, the cathodic protection system does not address the coating above the water level. The coating system above the water level is exposed to constant moisture and tends to fail before coating failure below the water level. Reservoirs with poor ventilation tend to have coating system failures earlier than those with good ventilation (such as wood roofs).

Flooding can cause an erosion of tank foundations, causing cracks and/or partial cave-in of the tanks. If a large part of the tank is underground, flooding combined with high ground water levels.

The distribution reservoir facilities are monitored and controlled by EBMUD's supervisory control and data acquisition (SCADA) system. Operational control and security data is transmitted from the reservoir facilities through remote terminal unit (RTU) equipment. The RTUs at many of the reservoir facilities are obsolete and require replacement to ensure data communication reliability.

Facility rehabilitations and repairs increase in complexity when outage mitigations are required. When a facility rehabilitation requires the reservoir to be taken out of service, a planning evaluation is needed to determine if mitigations are necessary to maintain the level of service in the pressure zone during the outage.

6.1.1.2.2. Impact on Reservoir Tanks and Loss Estimates

The impact to the functionality of the water system for drinking and firefighting if reservoir tanks are damaged following a major disaster, especially an earthquake, could be significant.

The volume of water stored in reservoir tanks can be very large, resulting in large demands placed on tanks in an earthquake. Tanks, regardless of their material of construction, can suffer from damage such as cracks or buckling of the tank structure, cave-in of the roof or interior columns, loss of connection between the tank and connecting pipes, and a total collapse of the structure leading to an uncontrolled release of water.

The RTUs at several facilities are located within the valve pit. In the event that the valve pit becomes flooded, there is a potentially significant safety hazard to maintenance staff and a danger to the electrical equipment, in addition to a loss of monitoring and controlling capabilities of the distribution facilities.

6.1.1.2.3. Reservoir Tanks Vulnerability Summary

The integrity of reservoir structures must be preserved to safeguard its contents. Even with regular maintenance, these structures have average service lives beyond which replacement is generally recommended depending on the condition of the reservoir. Continued use of these facilities beyond its average useful service life may incur risks towards system reliability, operational efficiency, and liability to EBMUD.

6.1.1.3. Pumping Plants

6.1.1.3.1. Pumping Plants Exposure and Vulnerability

Surface fault rupture, strong ground shaking, earthquake-induced liquefaction, and earthquake-induced landslides can all cause failure of pumping plants, rendering them inoperable or causing them to operate in a reduced mode. These pumping plant failures can be due to ground movement causing pipeline breaks and failure of equipment that is not properly secured against movement associated with seismic events. Minor to moderate damage to the pumping plant structures may not necessarily be a significant hazard since the pumping plants are not manned. However, major damage or collapse of the building can result in associated damage to the pumps, pump motors, or motor control centers (MCC) by falling debris. In addition, a building that is significantly damaged may also prevent or delay any required manual reset of pump controls, thereby impeding system operations.

Flooding of pumping plant structures can cause electrical equipment failures and damage to building structures. Landslides can cause pumping plant failures by inducing pipeline breaks, damage to electrical and motor control center equipment, and damage to pumping plant structures in large landslide or debris flow events. Pumping plant buildings constructed of wood materials are vulnerable to fire. Many pumping plants have external electrical equipment that is subject to additional risk from fire. However, not all pumping plants have EBMUD standard security fencing and can be vulnerable to intrusion and disruption of operation by trespassers.

6.1.1.3.2. Impact on Pumping Plants and Loss Estimates

Pumping plants are used to maintain pressure in the system and move water throughout the system, particularly into higher elevation portions of the service area. Many pressure zone cascades are supplied by a single pumping plant. Loss of operation of these single feeds can leave large numbers of customers without water service for the duration of a pumping plant outage.

6.1.1.3.3. Pumping Plants Vulnerability Summary

Pumping plants located throughout EBMUD service area are vulnerable to a variety of hazards that could leave customers without water service until the pumping plants can be restored to service or portable pumps or emergency generators can be deployed. The best defense against long outages as a result of pumping plant damage is installation of electrical quick connects and pumper tees at vulnerable pumping plants. Electrical quick connects allow for placement of portable electrical generators to provide supplemental power. Pumper tee connections installed on the suction and discharge piping of pumping plants accommodate the placement of a portable pump to supply needed water to the pressure zone.

6.1.1.4. Transmission/Distribution Pipelines

6.1.1.4.1. Transmission/Distribution Pipelines Exposure and Vulnerability

Following the 1989 Loma Prieta Earthquake, EBMUD completed a $189M Seismic Evaluation Program (SEP) to examine the performance of its water distribution system. In 1994, the SEP completed several studies to estimate the level of damage that would result from various scenario earthquake events. The results of these prior pipeline studies, as well as results from EBMUD's recent damage prediction modeling efforts, are summarized in the following subsections.

The EBMUD service area is located within a seismically active geologic region with four active faults. The Hayward Fault, the most severe geohazard, runs directly through the service area. As a result, EBMUD's water distribution system is susceptible to damage triggered by excessive ground shaking, liquefaction zones, landslides, and fault crossings.

In addition, certain pipe materials and joint types are more vulnerable to damage caused by seismic geohazards. Seismic permanent ground deformation or ground settlement specifically threatens cast iron and asbestos cement pipelines. Since both pipe materials are unrestrained and brittle, any ground movement creates a strong likelihood for joint pull-out or elevated bending stress along the pipe, leading to a break. Following a significant seismic event within the EBMUD service area, cast iron and asbestos cement pipelines will suffer the majority of the damage within the water system.

6.1.1.4.2. Impact on Transmission/Distribution Pipelines and Loss Estimates

In 1994, the SEP estimated the damage extent to EBMUD's distribution pipelines may be more than 4,000 leaks/breaks as a result of a Hayward M-7 earthquake. Nearly 90% of the pipe damage resulted from breaks in cast iron and asbestos cement pipe, which account for over 60% of the distribution system.

In 2015, the Pipeline Infrastructure Division conducted a large diameter pipeline seismic fragility assessment to understand the vulnerability of EBMUD's transmission system from a HayWired 7.05 Mw earthquake scenario event. The assessment used the results of an EBMUD developed damage prediction model that focused only on transmission pipelines. The model calculated 334 large diameter pipelines main breaks following the HayWired scenario event that would require some kind of repair.

Liquefaction produced nearly 60% of the main breaks in the damage prediction model due to permanent ground deformation and type of pipe material. The remaining pipe damage was divided up between Fault Zone (25%) and Landslide (15%) caused main breaks. Approximately 65% of the predicted main breaks were associated with unrestrained pipelines (cast iron and reinforced concrete cylinder).

6.1.1.4.3. Transmission/Distribution Pipelines Vulnerability Summary

In a seismic event, the large number of pipe breaks would quickly overwhelm EBMUD's four service centers. As a result, EBMUD would require that aid be provided from outside sources to assist with the main break repairs.

To address this emergency response issue, EBMUD has taken a number of steps including use of regional interties with adjoining water agencies and inter-agency cooperation and agreements.

6.1.1.5. Water Treatment Facilities

6.1.1.5.1. Water Treatment Facilities Exposure and Vulnerability

EBMUD currently operates six WTPs. EBMUD has three WTPs that are known as "inline filtration" plants and three conventional treatment plants. Table 6.1 below lists EBMUD's WTPs, type, and capacity.

The inline filtration WTPs rely on pristine water quality in order to operate. The Orinda, Walnut Creek, and Lafayette WTPs are all inline WTPs. These plants primarily receive water from Pardee Reservoir via the Mokelumne Aqueducts, but can also receive water from Briones Reservoir, located near the Orinda WTP.

The other three WTPs that EBMUD operates (San Pablo, Sobrante, and Upper San Leandro WTPs) are conventional treatment plants. These WTPs treat water from the San Pablo and Upper San Leandro Terminal Reservoirs, located in the East Bay Hills. Water from the terminal reservoirs comes from local runoff, Pardee Reservoir, and from the Freeport Water Project (Sacramento River). Conventional WTPs have the ability to treat difficult water qualities that occur in the terminal reservoirs. These plants can remove significant amounts of solids and organic matter, and treat water with taste-and-odor compounds.

Table 6.1. EBMUD's Water Treatment Plants – Type and Capacity

Water Treatment Plant	Plant Type	Maximum Permitted Capacity (MGD)	Water Source
Orinda	Inline	175	Primary: Mokelumne Aqueducts (Pardee Reservoir) Back-up: Briones Reservoir, and Freeport Emergency Connection: Los Vaqueros
Walnut Creek	Inline	115	
Lafayette	Inline	45	
Sobrante	Conventional	60	San Pablo Reservoir
San Pablo (standby)	Conventional	50	San Pablo Reservoir
Upper San Leandro	Conventional	60	Upper San Leandro Reservoir

Orinda and Walnut Creek WTPs operate year round. Lafayette, Sobrante, and Upper San Leandro WTPs are operated to either supplement supply during summer months, drought, or emergency operations, or to support wintertime outages of the Orinda WTP. San Pablo WTP is only used during drought operations, emergency operations, and planned outages of Orinda WTP.

The primary hazard exposures to the WTPs are:

- Seismic Risk: The WTPs are located close to major fault crossings. Depending on the magnitude of a seismic event, it is likely that damage to chemical lines, underground piping, tunnels, raw water lines, outlet towers or other structures could occur, in addition to disruptions in filtration and a potential loss of primary power.
- Landslide Risk: The Lafayette, USL, and Sobrante WTPs are sited on locations that have some exposure to landslides. Potential consequences are a loss of critical facilities during a landslide release or movement of critical underground infrastructure during a slide.
- Flooding Risk: The Orinda WTP is located near the San Pablo Creek with many storm drains that drain into it, and when clogged can flood the WTP site.
- Loss of Service in the Mokelumne or Lafayette Aqueducts: A loss of the Mokelumne Aqueducts could result in a loss of water supplied by the inline WTPs.
- Watershed Impacts:
  - Pardee Watershed: The Orinda, Walnut Creek, Lafayette WTPs all rely on pristine water quality, so any impacts to water quality upstream in the Pardee Watershed can result in capacity reductions or loss of service at the treatment plants. In the winter of 1997, a major rain-on-snow event in the Pardee Watershed resulted in record flows in the Mokelumne River with extremely high turbidities and consequently a shutdown of the Mokelumne Aqueducts for 65 days. Wildfires located in the Pardee Watershed can also result in significant operational issues.

- Terminal Reservoirs Watershed: The Briones, USL, and San Pablo Watersheds are also subject to deterioration in water quality due to algae, wildfire, or landslide/mudslides. This deterioration of quality can reduce capacity at the treatment plants that these reservoirs serve.
- Primary Power Interruption: If primary power to the WTPs were to be interrupted, the WTP could be vulnerable if power were not restored in within a handful of days. All plants are equipped with standby power. However, onsite diesel storage is limited to 48-96 hours depending on the WTP.

6.1.1.5.2. Impact on Water Treatment Facilities and Loss Estimates

The impacts and severity from a failure at a WTP vary widely depending on seasonal timing or what kind of failure occurs. If Orinda or Walnut Creek WTP were to fail, EBMUD would experience to the greatest loss in water service. The magnitude of losses depends greatly on what other water treatment plants are also online (See Table 6.2).

The greatest risk for supply to customer loss occurs if Orinda or Walnut Creek WTPs were to fail during winter months, when no other facilities are online. A failure at Orinda WTP could be less severe if other treatment plants are also online.

Table 6.2. Maximum Water Loss for Each Facility

Water Treatment Plant	Maximum Potable Water Loss Estimation	Notes
Orinda	582,000 could potentially be affected in the west-of-hills area including of the distribution system.	In the event of a WTP failure, raw water would be sent to the distribution system along with a boil water notice.
Walnut Creek	303,000 could potentially be affected in the east-of-hills area including of the distribution system.	In the event of a WTP failure, raw water would be sent to the distribution system along with a boil water notice.
Lafayette	83,000 could be affected in the Lafayette and Walnut Creek area if a WTP failure were to occur in summer months.	WTP used in summer months, no loss expected failure occurred during winter months.
Sobrante	150,000 could be affected in the Sobrante, Richmond, Pinole area if a WTP failure were to occur in summer months or in winter months concurrent with a Orinda WTP failure.	WTP used in summer months, no loss expected failure occurred during winter months.
San Pablo	No Loss Expected.	Standby WTP.

Water Treatment Plant	Maximum Potable Water Loss Estimation	Notes
Upper San Leandro	No Loss Expected.	WTP used in summer months, no loss expected failure occurred during winter months.

It should be noted that a WTP failure does not necessarily cause a complete loss of water. All of the WTPs have emergency by-pass systems that could be used to send raw water directly to the distribution system in the event of a plant failure.

6.1.1.5.3. Water Treatment Facilities Vulnerability Summary

Water treatment plants are complicated facilities with many vulnerabilities and risk exposures. Much effort has been made to mitigate each of these vulnerabilities for each of these facilities (See Table 6.3). However, not all risks have been eliminated.

Table 6.3. Vulnerabilities that Impact each Facility

Water Treatment Plant	Vulnerability
Orinda	Watershed Impacts Flooding Seismic Raw Water Pipe Failure Loss of Service in the Mokelumne or Lafayette Aqueducts Landslide Primary Power Interruption
Walnut Creek	Watershed Impacts Flooding Seismic Raw Water Pipe Failure Loss of Service in the Mokelumne or Lafayette Aqueducts Landslide Primary Power Interruption
Lafayette	Watershed Impacts Flooding Seismic Raw Water Pipe Failure Loss of Service in the Mokelumne or Lafayette Aqueducts Primary Power Interruption Landslide

Water Treatment Plant	Vulnerability
Sobrante	Watershed Impacts Flooding Seismic Raw Water Pipe Failure Landslide Primary Power Interruption
San Pablo	Watershed Impacts Flooding Seismic Raw Water Pipe Failure Landslide Primary Power Interruption
Upper San Leandro	Watershed Impacts Flooding Seismic Raw Water Pipe Failure Loss of Service in the Mokelumne or Lafayette Aqueducts Landslide Primary Power Interruption

6.1.1.6. Regulators and Rate Control Stations

6.1.1.6.1. Regulators and Rate Control Stations Exposure and Vulnerability

A significant portion of EBMUD's rate control stations (RCSs) and regulators have one or more of the following deficiencies: ventilation issues, outdated equipment, excessive flooding, corrosion damage, safety hazards, and telemetry failures. Failure would result in widespread water service interruption.

Access hatch size and fall prevention were the primary safety concern for RCSs and regulators. Vaults with small access hatches are difficult to enter and have exhaust vent ducts that obstruct the limited entry space. Some have no handholds for safe entry and exit. Other facilities have no barricade or railings to prevent pedestrians using the sidewalk from falling into the open vault. Vaults with removable railings were found to be difficult to remove and install. Necessary safety measures include replacement of unsafe hatches, installation of handholds for entry, and replacement of removable railings.

Most of the facilities constructed prior to 2000 have ventilation systems that are not set on timers and activate only when the access hatch is opened. The regulator, rate control valve, pipes, and electrical equipment are housed inside underground concrete vaults that have poor ventilation. Poor ventilation leads to excessive moisture and condensation, especially during the winter months. There are several RCSs and regulators whose conditions have deteriorated significantly and require repairs or replacement of the affected components.

Although RCSs and regulators are equipped with sump pumps, an ongoing problem is flooding and water intrusion that can lead to corrosion of the mechanical and electrical equipment. Due to the damp and humid environment within the underground vault, electrical equipment, valves and operators, pipes, and ladders are prone to corrosion damage. Many of the facilities have a history of corroded valves, pipes, flanges, pipe supports, and bolts.

The equipment of the older facilities has exceeded its useful life because of safety issues, flooding and drainage problems, and increased maintenance cost. In addition, the equipment may not meet current EBMUD standards and equipment is often obsolete and in need of replacement. It is vital that these facilities be rehabilitated to maintain system reliability, personnel safety, and operational efficiency.

6.1.1.6.2. Impact on Regulators and Rate Control Stations and Loss Estimates

Failure of regulators and rate control station facilities would result in domestic and fire flow impacts to services in their respective pressure zone areas and pose a risk for equipment failure, major impacts to customers, and personnel safety. Failure of certain RCSs without transmission bypasses during the summer months would result in domestic and fire flow impacts to services in the pressure zones within 24 hours.

Often regulators are the sole supply source to the pressure zone for both potable and fire flow, which makes continuous operation of these regulators critical for residential and fire flow water supply. In addition, failure of these regulator stations could lead to excessive pressures in the service area that could cause pipe failures and over-pressurizing of services to EBMUD customers.

6.1.1.6.3. Regulators and Rate Control Stations Vulnerability Summary

A significant portion of EBMUD's RCS and regulators have one or more of the following deficiencies: ventilation issues, outdated equipment, excessive flooding, corrosion damage, safety hazards, and telemetry failures. Failure would result in widespread water service interruption.

6.1.2. EBMUD Facilities Outside the Bay Area

6.1.2.1. Raw Water System

6.1.2.1.1. Raw Water System Exposure and Vulnerability

The Mokelumne Aqueducts are located in a seismically active zone and is considered vulnerable to earthquakes. Especially vulnerable is the 15-mile stretch of aqueduct where it crosses the Delta. In addition, the Mokelumne Aqueducts were not designed to resist flooding.

An earthquake or storm-induced levee failure in the Delta could cause severe damage to the system, resulting in a complete outage of the Mokelumne water supply for an extended period. These levees and aqueducts are also vulnerable to failure due to an inadequate support structure of the aqueducts and soil conditions in the Delta, including a support failure due to surface or subsurface peat fire.

Hazards to the raw water system include earthquakes, storm flooding, Delta island subsidence, and climatic changes driving sea level rise. EBMUD must protect the aqueducts not only from direct impacts of each hazard, but indirect impacts caused by levee failure.

EBMUD has identified six major hazards to the aqueducts in the Delta region. These hazards are as follows:

- **Scour** – A levee failure in close proximity of the aqueducts would likely damage the aqueducts by scouring the foundation.
- **Ground subsidence** – Ground subsidence contributes to increased water seepage through levees leading to levee instability and decreasing crest elevation of the levees, thereby making them more vulnerable to overtopping in the event of flooding.
- **Earthquake ground shaking** – The aqueducts are vulnerable to direct structural damage from earthquake shaking.
- **Flooding** – The aqueducts are not suited for long-term operation in flooded conditions as the system lacks protection from corrosion, wave impacts and buoyancy.
- **Earthquake Induced Liquefaction** – Aqueduct and levee foundation materials may liquefy during an earthquake.
- **Earthquake-induced lateral spreading** – Lateral spreading of levees caused by an earthquake could damage the aqueducts.

6.1.2.1.2. Impact on Raw Water System and Loss Estimates

The Mokelumne Aqueducts were not designed to resist flooding and the Mokelumne Aqueduct Nos. 1 and 2 are not designed to resist seismic events. Severe damage may occur resulting in a partial or complete outage of the Mokelumne water supply for an extended period. The levees protecting the Aqueducts are also vulnerable to subsidence resulting from seismic events that could lead to flooding. Aqueducts are also vulnerable to failure of pipe support structures due to soil conditions in the Delta or peat soil fires.

Partial or complete loss of the Mokelumne Aqueduct system would result in water shortages in the East Bay service area. EBMUD maintains a six-month water supply in the East Bay terminal reservoirs and has emergency interties with neighbor water agencies. However, failure of the aqueducts at a river crossing, a system failure from flooding, or failure from a seismic event could require more than six months to repair. These failures could result in inadequate water supply for EBMUD service area. EBMUD has prepared designs in advance for addressing the river crossings, which are considered the most likely failure scenario.

6.1.2.1.3. Raw Water System Vulnerability Summary

The continued reliability of the aqueducts depends upon the Delta levee system. In recent years, the levee system has been improved with major funding from the State and 95 percent of the levees protecting the aqueduct system meet or exceed the PL-84-99 standards for agricultural levees. Work on the remaining five percent will be completed by 2020. This will make all the levees protecting the aqueduct system eligible for FEMA and State funds for reconstruction due to failure from flooding or seismic events.

6.1.2.2. Pardee Reservoir

6.1.2.2.1. Pardee Reservoir Exposure and Vulnerability

Federal and State regulation require formal periodic assessment of vulnerabilities of high-risk dams. The most recent assessment for Pardee Reservoir can be found in the report titled "Pardee Dam and Hydroelectric Facility, Seventh Five-Year Part 12D Safety Inspection Report."

The vulnerabilities examined were related to flood and earthquake. Eight different vulnerabilities were examined and all vulnerabilities were given the lowest risk classification as "Unlikely."

6.1.2.2.2. Impact on Pardee Reservoir and Loss Estimates

A failure of Pardee Dam could lead to an inability to meet the water needs of EBMUD's customers, along with potential downstream damage to farmland and residential areas. The monetary loss estimate of such a failure would be in the magnitude of hundreds of millions of dollars.

6.1.2.2.3. Pardee Reservoir Vulnerability Summary

Although the impact and loss estimates of a failure of Pardee Dam are high, the probability of failure occurring is low. All vulnerabilities were given the lowest rating possible of being "Unlikely." Formal inspections of the facilities occur annually by both State and Federal agencies and every five years an even more rigorous inspection occurs. All inspection and maintenance records are reviewed during these inspections to ensure that all requirements are being met.

6.1.2.3. Camanche Reservoir

6.1.2.3.1. Camanche Reservoir Exposure and Vulnerability

Federal and State regulation require a formal periodic assessment of vulnerability of high risk dams. The most recent assessment can be found in the report titled "Camanche Dam and Hydroelectric Facility, Seventh Five-Year Part 12D Safety Inspection Report."

The vulnerabilities examined were related to flood, earthquake, tunneling during normal reservoir condition and reservoir surcharge condition, and uplift during normal reservoir condition and reservoir surcharge condition. Ten different vulnerabilities were examined. Two of the examined vulnerabilities (overtopping a dam or dike during a probable maximum flood condition, and earthquake loading causing liquefaction and failure of Dike 2 foundation) were given the lowest classification of "Classification IV – Unlikely." Two of the examined vulnerabilities (reservoir surcharge during a flood causing dike instability, and earthquake loading causing liquefaction and failure of the main dam foundation) were given a "Category II Classification - Satisfactory Risk, Continue Monitoring."

The remaining six vulnerabilities (failure of the main dam due to internal piping, failure of the main dam due to piping under the foundation area, failure of Dikes 1 or 2 due to internal piping, piping of Dike 2 under the foundation, main dam and Dike 2 uplift pressure in the toe area causing uplift instability, and internal piping in Dikes 3, 4, 5, or 6 when reservoir is surcharged during a spill event) were given a "Category III Rating – Satisfactory Risk, Continue Monitoring, Additional Information Required".

6.1.2.3.2. Impact on Camanche Reservoir and Loss Estimates

A failure of Camanche Dam could lead to an inability to meet the water needs of EBMUD's customers and release requirements of senior water rights holders, along with potential major downstream damage to farmland and residential areas. The monetary loss estimate of such a failure would be in the magnitude of hundreds of millions of dollars.

6.1.2.3.3. Camanche Reservoir Vulnerability Summary

Although the impact and loss estimates of a failure of Camanche Reservoir are high, the probability of a failure occurring is low. All vulnerabilities were given either the lowest rating possible being "Unlikely" or were given the second lowest rating being "Satisfactory Risk, Continue Monitoring." Formal inspections of the facilities occur annually by both State and Federal agencies and every five years an even more rigorous inspection occurs. All inspection and maintenance records are reviewed during these inspections to ensure that all requirements are being met.

6.2. Wastewater Facilities

6.2.1. Main Wastewater Treatment Plant

Seismic evaluations reports prepared in the 1990s[2] provided a comprehensive assessment of the seismic reliability of key MWWTP infrastructure. The reports document recommended retrofits in order to meet the minimum service level identified for the 1994 Seismic Evaluation Program[3] (maintaining hydraulic flow and disinfection).

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[2] Seismic Evaluation of Selected East Bay Municipal Utility District Wastewater Facilities, July 1991, EQE Engineering

[3] Seismic Evaluation Program East Bay Municipal Utility District Wastewater Facilities, March 1994, EQE Engineering

6.2.1.1. Main Wastewater Treatment Plant Exposure and Vulnerability

The MWWTP is located on a relatively flat site in a former tidal marsh that was reclaimed for development by placement of fill. The site is within a seismically active area. No known faults cross the site, however the Hayward fault is located about 4 miles to the east. The studies were based on the fault producing an estimated magnitude 7.05 maximum credible earthquake.

Based on the 1994 study, soil liquefaction as a result of ground shaking poses a moderate to low risk for most of the buildings and structures at the MWWTP. All structures, except one, that were identified in the study as having a high risk of liquefaction have been removed. The remaining high risk structure does not house any key equipment or processes. Loss of bearing capacity due to liquefaction poses the largest potential hazard with resulting settlement reaching two to four inches and damage to structures and utilities. Since no soil mitigation measures have been undertaken, these risks remain.

The power distribution system that ties the MWWTP's Power Generation Station and Main Sub Station to key facilities throughout the MWWTP is critical to maintaining hydraulic flow through the plant and recovery after a seismic event. In 1996, seismic evaluations identified vulnerabilities on the system and examined emergency response alternatives.

The Adapting to Rising Tides Vulnerability and Risk Assessment Report [4]prepared in September 2012 looked at the effect of sea level rise on wastewater facilities in Alameda County. With a sea level rise of 55 inches expected at the end of the century, the MWWTP is expected to see an average of one foot of flooding at high tide or two feet of flooding during a storm. With pipe galleries and other equipment located underground, it is not likely that all structures would be able to be raised above the expected flood level. The Dechlorination Facility, located at the foot of the San Francisco-Oakland Bay Bridge is expected to have approximately two feet of flooding. The Transition Structure, located further west of the Dechlorination Facility, is expected to have six feet of flooding.

6.2.1.2. Impact on Main Wastewater Treatment Plant and Loss Estimates

As long as facilities and structures remain intact, wastewater flow can continue to be received at the MWWTP after an earthquake. After the Loma Prieta earthquake in 1989, the loss of power was the biggest issue. The power outage affected the production of oxygen, which caused the MWWTP to lose the entire biological secondary treatment process. Even after power was restored, it took several weeks before the treatment process fully recovered and the MWWTP was back in full compliance.

Since then, significant improvements have been implemented to reduce the likelihood of a sustained power outage. The MWWTP is fed by two PG&E lines from separate PG&E substations for redundancy. The onsite cogeneration engines and the turbine are fed off different

[4] Vulnerability & Risk Assessment Report, September 2012, San Francisco Bay Conservation and Development Commission Adapting to Rising Tides Program

lines and can be switched in case of a prolonged outage. Installation of flexible connections between non-pile supported bus ducts, key sub stations, and key underground utility penetrations within the MWWTP has not been completed.

While portions of the MWWTP have been identified as low-lying areas in the Adapting to Rising Tides study, they are labeled as disconnected areas so floodwaters would have to crest a higher elevation area before it could reach the MWWTP. Interstate 80 is located between the MWWTP and San Francisco Bay and serves as the MWWTP's protection from northern floodwaters. The Dechlorination Facility and Transition Structure, however, do not have any protection from floodwaters. The two feet of flooding at the Dechlorination Facility could be mitigated via sandbags. The Transition Structure is slightly elevated, only contains sampling equipment and has no staff permanently posted there. The main impact from the 6 feet of expected flooding would be the loss of access to collect the hourly sample as required for the MWWTP's discharge permit.

6.2.1.3. Main Wastewater Treatment Plant Vulnerability Summary

Ensuring that the MWWTP maintains power after an emergency event is important to be able to continue to treat wastewater through the plant. Some improvements have been implemented since the Loma Prieta earthquake but the installation of flexible connections or backup power would provide additional resiliency for the power distribution system.

There could be minor flooding at the MWWTP with sea level rise if there is inadequate protection from neighboring properties. There will be greater flooding at the Dechlorination Facility and the Transition Structure. Staff is not regularly posted at these two locations so staff can be advised to avoid those locations if it is deemed unsafe.

6.2.2. Wet Weather Facilities

6.2.2.1. Wet Weather Facilities Exposure and Vulnerability

The two Wet Weather Facilities in Oakland were examined by the Adapting to Rising Tides 2012 study. The study determined that by 2050, both Oakport and San Antonio Creek WWFs would be subject to storm event flooding. Oakport WWF would have five feet of flooding, while San Antonio Creek would have one to three feet of flooding. In a February 2017 Inundation Study of Contra Costa County[5], the Point Isabel WWF was estimated to be clear of flooding, but the roadways leading to the facility might be flooded.

All three facilities would be at risk to some soil liquefaction due to ground shaking. Oakport and San Antonio Creek WWF are constructed on piles, reducing any structural liquefaction-related damage.

[5] AECOM, 2016, "Contra Costa County Seal Level Rise Vulnerability Assessment," Prepared for San Francisco Bay Conservation and Development Commission's Adapting to Rising Tides, February 2016.

6.2.2.2. Impact on Wet Weather Facilities and Loss Estimates

If flooding is low, the facilities could continue to function. However, if flooding is high enough to inundate the storage basins, the facilities will not be able to operate until the water subsides.

6.2.2.3. Wet Weather Facilities Vulnerability Summary

If the water level is high enough to inundate the storage basins, it would likely be unsafe for staff to be present to operate the facility. If staff cannot access the facility due to floodwaters, the sewer system would be impacted with the potential for sanitary sewer overflows.

The WWFs typically only operate during heavy wet weather events to prevent surcharging in the collection system. If there is damage sustained during an earthquake during dry weather or light wet weather events, there would be little consequence since the WWFs would not likely be operating.

6.2.3. Interceptor Pipelines

Separate risk assessments of the gravity system and force mains were completed in 2014.

6.2.3.1. Interceptor Pipelines Exposure and Vulnerability

Defects and failures in the interceptor due to age and corrosion were the major vulnerabilities examined in the 2014 risk assessments[6][7]. Pipe condition was the main criterion evaluated. For assessment of the force mains, additional criteria such as cathodic protection, environmental factors (soil, sulfide levels, etc.) and interior pipe smoothness were included in the analysis. The effects of earthquakes were not evaluated.

6.2.3.2. Impact on Interceptor Pipelines and Loss Estimates

The gravity system analysis examined consequence of failure on four criteria: disruption to commerce, environmentally sensitive area, traffic impact, and constructability. Each criterion had a score of 1 to 5, with 5 having very serious consequence. A risk value was given to each pipe segment based on the likelihood and consequence of failure. No segments were determined to be high risk. Fourteen pipe segments were determined to be at medium-high risk, accounting for approximately 7,240 feet of the system. The remaining segments were at low to medium risk.

The force main analysis examined similar consequence of failure criteria but also included criteria such as property value, feasibility of bypass, wet well and system storage. Three force main sections, accounting for approximately 14,500 feet of the system, were found to be at high risk. Eight sections were at medium risk. The remaining nine sections were at low risk.

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[6] Pump Station Discharge Pipeline Condition Assessment Project, July 3, 2014, V&A Consulting Engineers
[7] 2014 Gravity Sewer System Pipe and Manhole Risk Assessment and Recommendations for Long-Term Management of Gravity Sewer System Assets, November 13, 2014, EBMUD Wastewater Department

6.2.3.3. Interceptor Pipelines Vulnerability Summary

The gravity pipes with the highest risk had poor condition ratings and were either in high traffic areas or were very large diameter pipe sections. The high traffic areas require more advanced planning due to traffic rerouting and coordination with the City. Large diameter pipe repairs require more advanced planning to find the most cost-effective pipe rehabilitation solutions and coordinating the work with active flows in the line.

The force mains with the highest risk were located in high corrosive soils, contained high sulfide levels, and had low internal smoothness. All of these factors would lead to the deterioration of the force main. Pipelines with the greatest risk were recommended to be given top priority for future rehabilitation or replacement project.

6.2.4. Pump Stations

The Pump Station Master Plan Update completed in December 2015 included a risk assessment to prioritize rehabilitation work. Three of the 15 pump stations were not included in the risk assessment since they had been recently rehabilitated.

6.2.4.1. Pump Stations Exposure and Vulnerability

A Pump Station Overall Risk Assessment examined the risk of the pump station to fail to convey flows and the consequence of failure. Information collected from inspections, and meetings with Operations and Maintenance was used to develop rating values. The main criteria examined in the assessment were safety and regulatory compliance, function and reliability, and maintenance.

The Adapting to Rising Tides Vulnerability and Risk Assessment Report prepared in September 2012 looked at the effect of sea level rise on wastewater facilities in Alameda County. Pump Station G, located near the Oakland Airport, is the most vulnerable with the potential for four to seven feet of flooding, depending on the scenario. Five other pump stations may have one foot of flooding by the end of the century. The results of this study were also summarized in the 2015 Pump Station Master Plan Update.

6.2.4.2. Impact on Pump Stations and Loss Estimates

The consequence of failure criteria included volume of flow, bypassing requirements, environmental impacts, and community impacts. Most of the pump stations have bypass connections so flow can be rerouted if the pump station fails. Those pump stations without bypass connections have overflows where the flow can be contained. There could be a temporary loss of a pump station but it would not affect the overall wastewater collection system since a temporary bypass could be established to get the flow to the MWWTP.

Due to the depth and extent of flooding expected near the Oakland Airport due to sea level rise, it is unlikely that EBMUD could provide adequate flood protection for Pump Station G without the Oakland Airport doing some protection effort in the surrounding area.

6.2.4.3. Pump Stations Vulnerability Summary

The Risk Assessment noted the five pump stations with the greatest risk of failure. Four other pump stations were at moderate risk. Six pump stations were at low risk. The several pump stations at the greatest risk are some of the larger pump stations in the wastewater system but all have bypass connections available that will help mitigate any failures.

With sea level rise, it is expected that the flooding at Pump Station G cannot be mitigated without modification to the surrounding Oakland Airport. If Pump Station G is flooded, it is anticipated that the city's sewer system would also be disrupted due to floodwaters and there would be no sewer service in the area. The flood effects at other pump stations are minor enough that they can be temporarily protected during the high water levels or sensitive equipment can be raised above the expected flood level.

7. Mitigation Goals, Objectives, and Actions

7.1. Mitigation Goals

The goal of the 2018 LHMP is to maintain and enhance a disaster-resistant region by reducing the potential for loss of life, property damage, and environmental degradation from natural disasters, while accelerating economic recovery from those disasters. This goal is unchanged from the 2011 LHMP, and is also the goal of EBMUD in designing its mitigation program.

The specific goals of the LHMP are:

- **Life Safety:** Prevent the loss of life from a failure of any EBMUD facility.
- **Fire Service:** Improve water service in all areas, especially high fire-danger zones.
- **Customer Service:** Restore safe and reliable water supply to the public during and after a natural disaster to reduce the vulnerability of people and property.
- **Water Quality and Public Health:** Guarantee that all water entering the distribution system is fully treated.

7.2. Mitigation Actions

EBMUD has been committed to hazard mitigation for many years. The 10-year $189M SIP was initiated in 1995 to retrofit facilities and minimize earthquake impact on EBMUD's water system. The program was completed in 2005. Work included seismically upgrading 13 building structures, 70 storage reservoirs, 130 pumping plants, 5 water treatment plants, and 56 pipeline fault crossings. Additional work, including 18 upgrades in areas of landslides and liquefaction, and 8 transmission system upgrades have been completed to improve flexibility for transmitting water in the distribution system and to mitigate landslide hazards for key pipes.

In 2010, EBMUD completed the retrofit of their Emergency Operation Center (EOC) to better serve the Emergency Response effort. EBMUD also completed the establishment of an Alternative Emergency Operations Center in the Walnut Creek Area. The Center provides redundancy in response capabilities, and provides widely spaced EOCs to ensure continuous operations due to damage near either center.

EBMUD was the first water agency to put its seismic protections in place, and to provide a model program for the rest of the country to follow. EBMUD continues to receive recognition for its forward-thinking and proactive approach to strengthen, reinforce, and upgrade its water distribution system on such a comprehensive scale.

As a leader among water and wastewater agencies, EBMUD is on the CUEA Board of Directors and chairs the Water and Wastewater Committee that focuses on water and wastewater strategic emergency response and coordination.

7.2.1. Existing Mitigation Strategies

EBMUD has many existing mitigation programs that helps create a more disaster-resistant region and utility systems. Collaboratively working with numerous other agencies at the federal, state, and local levels, EBMUD has implemented institutional as well as physical infrastructure improvements.

7.2.1.1. Water Supply Facilities

7.2.1.1.1. Dams and Reservoir Towers

EBMUD has a comprehensive Dam Safety Program. Engineers monitor dams using instruments, monthly visual inspections and periodic dam safety reviews to prevent loss of life, personal injury, and property damage from the failure of dams. The safety of each dam is reevaluated with advances in geotechnical, structural and earthquake engineering, and also if there is evidence of seepage ongoing ground movement or any other concerns. Most of EBMUD's dams are under the jurisdiction of the California Division of Safety of Dams. Pardee and Camanche Dams are also under the jurisdiction of the Federal Energy Regulatory Commission because they produce hydropower. These regulatory agencies perform independent annual dam inspections.

All the dams and towers have been seismically evaluated. Dams that were deemed vulnerable have either been upgraded (Pardee, San Pablo, Dunsmuir), removed from service (Piedmont), under construction (Chabot Dam and Tower), or are being designed (USL Tower, Briones Tower, and Lafayette Tower). Seismically vulnerable open cut reservoirs (Schapiro, Berryman, and Estates Reservoirs) have been replaced with reservoir tanks. Other reservoirs have reduced maximum water levels to address seismic or freeboard concerns (Argyle #2, Almond, Leland, Maloney, Moraga, North, and San Pablo Clearwell) or reduced levels due to other operational concerns (Central). Seneca was removed from service due to operational reasons.

7.2.1.1.2. Reservoirs

EBMUD is actively carrying out an improvement plan to decrease the system's vulnerability to earthquakes and increase its ability to remain operable after an earthquake. EBMUD has an ongoing practice of evaluating facilities for seismic performance as part of major retrofit projects and in conjunction with facility planning as funding becomes available. In the past few decades, several buildings have been retrofitted in compliance with these evaluations.

EBMUD monitors the interior condition of the reservoirs through routine dive inspections and cleaning on a frequency of once every five years. The schedule for this maintenance program and findings are coordinated under the jurisdiction of the California Department of Public Health.

Based on the findings of a dive inspection, subsequent reservoir cleaning projects may be necessary to remove silt, sand, and debris and/or to perform minor repairs. Maintenance issues (such as vent screen repairs, fall protection needs, roof maintenance repairs, and anode repairs) are often identified during the course of the dive inspection projects. Shop orders are routinely initiated by staff to address the identified deficiencies.

The reservoir conditions documented by EBMUD's dive inspections strongly support the recommended strategy of replacing the coating systems for steel reservoirs on a 25-year frequency. However, the priority of facilities is based on the actual conditions observed through the dive inspections, as under certain conditions reservoirs may need to be rehabilitated sooner, or possibly later.

EBMUD's SIP was implemented from 1995 to 2005 and rehabilitated 55 concrete reservoirs and addressed the majority of the rehabilitation needs of concrete reservoirs. Nearly all of the concrete reservoirs were re-stressed in addition to adding interior curbs and walls. However, these improvements also inadvertently prevent easy assessment of joint or wall leakage. Consequently, careful monitoring, routine inspections by qualified personnel and documentation and review of these findings are performed to assist in determining the useful service life of the re-stressed concrete reservoirs. Concrete reservoirs that were not addressed by the SIP are currently in design for replacement or rehabilitation.

As a group, the open-cut reservoirs represent the largest and oldest storage component of EBMUD's reservoir facilities. Open-cut reservoirs, some exceed 100 years of age, are planned for replacement, demolition, or rehabilitation with a new lining, underdrain system, and roof.

During the last five years, EBMUD has removed the five open cut reservoirs listed below. In most cases, the open cut reservoirs were replaced with new tanks.

- Schapiro Reservoir was completed in 2012.
- Berryman Reservoir was completed in 2013.
- Estates reservoir was completed in 2014.
- South Reservoir was demolished in 2015.
- Summit Reservoir is currently under construction and will be completed in 2018.

Replacing open cut reservoirs with tanks eliminates seismic risks associated with embankment dams, improves reliability, removes hazardous materials, and improves water quality by removing excess storage.

The primary focus of steel reservoir rehabilitation is the minimization of corrosion of the tank structure and interior valves and piping. In addition to replacing reservoir coatings, steel reservoir rehabilitation projects also include other necessary improvements such as the replacement of wooden roofs with aluminum dome roofs, the addition of exterior stairs for safer roof access, the replacement of old or corroded valve pit piping, installation or improvement of ventilation to extend coating life, replacement of corroded interior metals, installation of high level alarms and hatch alarms, roof perimeter safety railings and installation of roof hatches if absent.

RTU replacements and relocations are being addressed through EBMUD's RTU Replacement Program. RTUs are also replaced as part of the reservoir rehabilitation projects.

Security fencing and intrusion alarms are needed at all access points into the reservoirs, water quality cabinet fence, valve pits, and access to communication equipment. These security measures are necessary to help provide a safe working environment for staff and to safeguard EBMUD's water supply. Additional security measures may be necessary at facilities that have been subject to unauthorized access, theft, or vandalism. Security measures are incorporated as part of EBMUD's reservoir rehabilitation efforts.

During the last five years, EBMUD's reservoir rehabilitation program has replaced, rehabilitated, or demolished a total of 18 reservoirs made of steel, concrete, or redwood.

7.2.1.1.3. Pumping Plants

Seismic improvements to pumping plant structures were completed as part of EBMUD's SIP, which was completed in 2005. In addition, EBMUD has an active pumping plant rehabilitation program to upgrade a minimum of three pumping plants per year to conform to current EBMUD standards to ensure efficient, reliable and safe operation. New or replacement pumping plant facilities are constructed from fire-resistant noncombustible materials such as reinforced concrete, masonry, structural steel, or combinations thereof. Flexible pipe connections are also installed to reduce the seismic vulnerability of pipelines entering and exiting the pumping plant building.

All power distribution equipment installed as part of pumping plant rehabilitation projects, or new pumping plants, require seismic qualification to reduce the risk of seismic induced damage. Pumping plants typically include either a pair of pumping hydrants or buried pumping tees for connection to emergency pumps. In general, standby generator connections are also installed at all rehabilitated or replacement pumping plants.

At least two more electric portable pumps will be purchased to support outages of future pumping plant rehabilitation projects during construction and will increase flexibility of system operations during the outages. These portable pumps will be available for emergency usage when not in use for planned construction projects.

During the last five years, EBMUD's pumping plant rehabilitation program has replaced, rehabilitated, or demolished a total of 12 pumping plants. EBMUD currently has nine distribution pumping plants in construction for rehabilitation or replacement. EBMUD currently owns and operates a fleet of diesel-driven and electric portable pumps and generators that can be used to support unplanned outages of pumping plants.

7.2.1.1.4. Transmission/Distribution Pipelines

EBMUD has a pipe repair mitigation plan that includes improving its welding shop's capabilities. The pipe repair mitigation plan will focus on internal fabrication of parts for repair, such as butt-straps, reducers, and manholes. In addition, EBMUD will stockpile larger diameter pipes including 24, 36, and 48-inch diameters to ensure replacement parts required during an emergency repair.

EBMUD has 10 emergency interties with other local water agencies. The interties allow for potable water to be shared, if available, following a significant earthquake event.

EBMUD has several mutual assistance strategies in place to assist in the repair of broken or damaged pipe and restore water service following a regional disaster.

EBMUD has mutual assistance agreements with the Los Angeles Department of Water and Power (LADWP) and the Las Vegas Valley Water District (LVVWD). LADWP and LVVWD are geographically distant from the San Francisco Bay Area and as such would not be exposed to damage from a rupture of the Hayward Fault or a Bay Area rupture on the San Andreas Fault, so they would likely be able to provide repair crews to respond to the Bay Area to assist with pipe repair. Likewise, if either of those agencies experience catastrophic damage to their systems in a regional earthquake or other event, EBMUD would not be impacted by their events and could send mutual assistance to either of those agencies. The mutual agreement was made in recognition that a Hayward Mw 7.05 scenario event would likely overwhelm other local water/wastewater agencies responding to their own emergencies, so bringing in these two large agencies that already do very similar types of pipe repair as EBMUD does is a practical strategic plan. The agreements include:

1. Ability for the assisting party to provide multiple crews and an overhead command team to manage the response crews

2. Ability for the requesting party to provide fuel and other supplies, field communications equipment and instructions, security, food, and lodging

Under these agreements with LADWP and LVVWD, the requesting party pays for all wages, overhead, equipment costs, and consumables.

EBMUD is also one of the original founding members of the California Water/Wastewater Agency Response Network (CalWARN), which was started in 1994. All of the San Francisco Bay Area water agencies are members of the WARN network, and EBMUD has led the effort, over the last five years, to develop the San Francisco Bay Area Water Multi-Agency Coordination (MAC) Group. This group of emergency operations team leaders from EBMUD, SFPUC, Alameda County Water District, Contra Costa County Water District, Santa Clara Valley Water District and others that may join the MAC group have organized meetings of the Operations, Planning, Logistics, Public Communications and Finance sections. The focus of these meetings is establishing communication during and following a regional emergency and how we can work together to bring in resources such as fuel and water while each agency assesses its damage and repair priorities. The SF Bay Area Water MAC and other regional WARN Network agencies have increased planning and coordination between agencies, to reduce administrative conflicts and increase community and customer assistance. A recent example was in response to the Napa earthquake, when EBMUD sent crews to Napa via the CalWARN agreement, along with Alameda County Water District, Contra Costa Water District, and the City of Fairfield. EBMUD crews were in Napa the Monday morning after the earthquake, which occurred on a Sunday. EBMUD sent five repair crews as well as an "Overhead Team," which consisted of an Incident Commander, Safety Officer, Logistics Chief/Liaison, and a Finance Chief (Accountant).

In addition to these inter-agency agreements, EBMUD has worked with other water agencies and the state to develop a statewide plan for emergency drinking water procurement and distribution. This is an important component of EBMUD's emergency response plan, and includes working closely with local cities and/or the counties to seek their assistance in procuring and distributing drinking water. As a result, in the event that EBMUD cannot supply drinking water following a catastrophic earthquake event, the local cities and/or counties will provide drinking water during the outage period.

Since the 2011 LHMP, EBMUD has completed or begun several projects to ensure water service reliability and reduce future maintenance and repair costs.

One notable project is the Dingee Pipeline and Claremont Center Aqueducts Replacement Project. This $22M construction project started in September 2013 and was completed in January 2016. The replacement project significantly improves the seismic reliability of several large diameter transmission pipelines serving parts of Berkeley and Oakland. The former alignment of the Dingee Backbone Pipeline lay within the Hayward Fault Zone, potential earthquake-induced landslide zones, and three narrow right-of-ways. The new alignment greatly improves access for future maintenance, avoids fault and earthquake-induced landslide hazard zones, and does not follow any narrow right-of-ways.

7.2.1.1.5. Water Treatment Facilities

EBMUD has performed a detailed Infrastructure Rehabilitation Program (IRP) to evaluate each of the six WTPs and determine future maintenance or replacement projects that are required to keep the WTPs in working order. These IRPs are updated every two years to routinely track the status and reliability of each WTP.

The following projects are currently in construction to mitigate plant failures due to reliability concerns.

- The Orinda WTP Reliability and Maintenance - Shutdown, Hypochlorite, and Electrical Improvements Project is a combination of projects that has the following goals:
  - Eliminate single points of plant failure: A number of single points of failure exist in the WTP. If any single failure occurs, a full-plant shutdown would be

    required, possibly impacting customers' water service for a large portion of the service area.
  - Reduce plant outages: Improve ability to maintain the Orinda WTP without a full treatment plant outage.
  - Increase system reliability: A number of important open-cut reservoir replacements are scheduled over the next decade, including San Pablo Clearwell (5.0 MG), Central Reservoir (154 MG), and North Reservoir (70 MG). These reservoir replacement projects have reservoir outages that require the Orinda WTP to operate continuously.
  - Improving the reliability of Orinda WTP: Having Orinda WTP run continuously is critical to successfully preventing impacts to level of service during these reservoir replacements.

The following projects are currently scheduled for design in the next two years:

- USL Reliability Project: This project will rehabilitate the WTPs solids handling system and replace an aging clearwell roof.
- A similar project is planned for Sobrante WTP in the next four years.

In addition to planning for future work, EBMUD has completed a number of hazard mitigation projects since the 2011 LHMP, including:

- Lafayette Clearwell Replacement Project: This project removed from service an existing clearwell and replaced it with a new clearwell that is rated for earthquake stresses and complies with current building codes and industry and waterworks standards.
- Orinda Wash Water Rehabilitation Project: This project seismically strengthened a 0.6 MG concrete reservoir wash water tank built in the 1920s that is used to backwash filters at the Orinda WTP.
- USL and Sobrante Flocculator Rehabilitation Project: This project replaced key mechanical and electrical equipment used in the flocculation process at the USL and Sobrante WTPs. The flocculation process is a key process in the conventional WTPs.
- Sobrante Slope Stabilization and Drainage Improvements Project: In response to a small landslide, EBMUD installed slope drainage at the WTP to reduce the potential for future landslides.

7.2.1.1.6. Regulator and Rate Control Stations

EBMUD has a comprehensive IRP for its Regulators and RCSs. The purpose of the IRP is to examine the facilities, prioritize sites for rehabilitation, and define a reasonable work scope and cost for each project. The IRP is updated periodically to ensure rate control station and regulator issues remain current and to ensure efficient, reliable, and safe operation. The goal of this program is to maintain a high level of public and employee safety and ensure reliability. The RCSs rehabilitation project was updated in FY16 and will be updated every four years. Two RCSs were designed in 2016 and are currently in construction, and seven are currently in design.

The RCSs rehabilitation project will replace deteriorated RCSs in the distribution system. EBMUD operates 36 RCSs with many that are older than 50 years.

The highest ranked facilities have the most critical need for rehabilitation or repairs; therefore, capital funding is spent on these facilities in the order that they are ranked. These facilities are critical to the distribution system and have significant deficiencies that are currently being addressed through design or under construction. The medium ranked facilities have major deficiencies that should be addressed within the next 5 fiscal years and are also critical to the distribution system.

7.2.1.1.7. Mokelumne Aqueducts

Most levees, at a height of four to six feet, protecting EBMUD aqueduct systems were originally built between 1870 and 1975. Since 2010, the levees have been dramatically improved with EBMUD, Reclamation District, and state funding such that most of the levees meet or exceed PL-84-99 standards. Work on the levees is continuing and by 2020 all of the levees will meet this standard.

EBMUD will continue to provide financial assistance to the reclamation districts on Woodward Island, Orwood and Palm Tracts, and the Upper Jones and Lower Jones Tracts to maintain the improved levees. EBMUD also stockpiles rock and gravel materials and aqueduct pipes for minor repairs.

One key criterion for establishing mitigating strategies of alternatives is ensuring that at least 177 million gallons per day (MGD) is available soon after a hazard event. Since the 2011 LHMP, several raw water system improvements projects have either been completed, currently in design or construction, or under consideration. These improvements provide interim security for EBMUD's water supply. Notable mitigation actions and strategies are as follows:

- Aqueduct Cross Connections: Install pipes and valves to inter-connect Mokelumne Aqueduct Nos. 1, 2, and 3 on either side of the vulnerable Delta region. This work will improve hydraulic capacity and flexibility of the aqueducts during emergencies and for maintenance, and provide future utility. To improve operational flexibility, include aqueduct isolation valves upstream of the Walnut Creek East Portal crossover pipeline. The cost of this improvement is approximately $10M.

- Levee Improvements and Repair Materials: Reinforce river crossings by stabilizing the "river-side" of the levees, stockpiling pipe and levee repair material, and installing limited scour protection improvements (i.e., sheet piling) along the aqueduct alignment. This improvement is approximately $83M.

- Temperature Anchor Replacement: Three anchors were replaced since 2010 and a fourth anchor will be replaced by 2018. A study of the base isolators of Mokelumne Aqueduct No. 3 is underway, and the failed isolators will be replaced.

7.2.1.1.8. Pardee Reservoir

EBMUD continuously monitors the reservoir level and release flows remotely from the Pardee Area Control Center (Pardee ACC). EBMUD hydrographers measure the piezometers and drains monthly. Each of the 206 gallery drains is also individually measured once a year. The ten crest monuments are surveyed semi-annually by EBMUD's Survey Section. Crack gage readings are made quarterly. The spillway load cells are tested every five years.

A dam safety surveillance monitoring program has been developed for Pardee Dam. The surveillance program consists of continuous monitoring of the reservoir levels at the Pardee ACC and frequent visits to the dam and powerhouse. All project features are visually monitored whenever viewed or visited by operations personnel. Project personnel are trained to recognize and report anything that appears abnormal. As part of their monthly visits, EBMUD hydrographers complete a "Dam Inspection Report" for each individual structure to document visual observations.

The dam surveillance program includes observation of Pardee Dam, Jackson Creek Dam and Dike, spillway, powerhouse, and associated equipment and facilities. Typical observations that may indicate an abnormal condition include cracks, spalls, discoloration, or unusual moisture on concrete surfaces, vertical or horizontal misalignment of concrete surfaces, roadways, guardrails, or other project features, vortices, swirls, or bubbles on a water surface, any unusual change in instrumentation readings or observations, and any unexpected changes.
The foundation drains at Pardee Dam are a critical dam safety feature because they relieve potential uplift pressure. These drains are periodically cleaned to remove calcification blockage and assure positive drainage. The drains discharge into the gallery gutter. The total gallery drainage is measured remotely as it exits the gallery.

Pardee Dam is inspected annually by the FERC, the California Department of Water Resources DSOD, as well as by trained EBMUD staff during coordinated site inspections. The dam is inspected every five years by an Independent Consultant as part of the FERC Part 12D process.

The current visual inspection and surveillance programs have been determined to be appropriate. Field inspections are made during floods, high reservoir levels, and after felt earthquakes to observe any evidence of potential for overtopping, foundation and abutment seepage or erosion, or movement and cracking of the concrete.

Instrumentation at Pardee Dam consists of 35 standpipe piezometers, 8 pneumatic piezometers, 4 vibrating wire piezometers, 3 drain flow measuring devices, 10 survey monuments, 39 crack gages, and reservoir water level monitoring. Instrumentation at Jackson Creek Dike consists of one standpipe piezometer, ten vibrating wire piezometers, and two flow measuring devices.

There are ten survey monuments on the crest of the dam that are surveyed for horizontal deflections only. The monuments are surveyed twice each year.

Thirty-nine Avongard crack monitoring gauges have been installed across 11 cracks and contraction joints in the gallery of Pardee Dam. The gauges provide a visual indication of movement at the gauge location. The gauge readings were measured and recorded upon installation and set as the baseline of each gauge. The gauges were read monthly in the first two years after installation. Except for minor fluctuations, probably due to temperature effects and reservoir level changes, no significant movements have been observed on any of the gauges since their installation in 2007. In June 2009, the gauge reading frequency was changed to quarterly.

As part of the spillway improvements, 48 high strength cable anchors were installed as part of stabilizing the monoliths for normal, flood, and seismic loading cases. Each of these anchors was equipped with vibrating wire load cells so that load capacity could be monitored over time. EBMUD read the vibrating wire load cells in 2002, 2007 and in October 2012.

7.2.1.1.9. Camanche Reservoir

The mitigation strategy for Camanche Reservoir consists of surveillance, instrument monitoring, and periodic maintenance. The surveillance program consists of continuous monitoring of the reservoir levels at the Pardee ACC and frequent visits to the dam and powerhouse. All project features are visually monitored whenever viewed or visited by operations personnel. Project personnel are trained to recognize and report anything that appears abnormal. As part of their monthly visits, Hydrographers complete a "Dam Inspection Report" for each individual structure to document visual observations.

The dam surveillance program includes observation of the main dam, six dikes, spillway, outlet works, powerhouse, and associated equipment and facilities. Typical observations that may indicate an abnormal condition include bulges, depressions, erosion, unusual moisture or vegetation on embankments and riprap, vertical or horizontal misalignment of roadways, guardrails, or other project features, vortices, swirls, or bubbles on a water surface, any unusual change in instrumentation readings, cloudy or muddy drain water, or observations, and any unexpected changes.

Camanche Dam is inspected annually by the FERC, the DSOD, as well as by trained EBMUD staff during coordinated site inspections. The dam is inspected every five years by an Independent Consultant as part of the FERC Part 12D process.

EBMUD remotely monitors both reservoir level and release flows. The reservoir level is measured with electronic recording sensors. The electronic data is transmitted to the Pardee ACC, continuously monitored, and alarmed for out-of-limit set points. EBMUD staff can view the real-time data in their Web 21 data management system.

Instrumentation at the Camanche Dam facilities consists of 175 standpipe piezometers, 5 pneumatic piezometers, 27 vibrating wire piezometers, 14 observation wells, 26 drain and relief well flow measuring devices, 39 survey monuments, and reservoir water level monitoring.

EBMUD recently reviewed and updated the values of threshold and action level for some of the instruments including piezometers, flow measuring devices, and survey monuments. The revised instrumentation threshold/action levels are considered appropriate for the Camanche Dam piezometers and drain flow measuring.

Geotechnical investigations focusing on evaluations of the shear strength of the Main Dam core and the liquefaction potential of the dam foundation dredge tailing have been performed. The results are documented in a report entitled "Camanche Embankments Safety Review Phase II, Field Investigation and Laboratory Testing Characterization of Core Materials and Foundation Tailings at Main Dam, Data Report" by TERRA/GeoPentech, dated March 2009 (TERRA/GeoPentech, 2009).

7.2.1.2. Wastewater Facilities

Structural retrofit projects in the 1990s mitigated identified life-safety hazards, and anchored critical equipment. In combination with these upgrades, a major reliance has been placed on emergency response procedures to meet the minimum service condition of hydraulic flow and disinfection. A seismic evaluation update is underway and includes the review of structures and geotechnical issues based on current codes and guidelines that have changed significantly since the 1990s.

The pump stations identified as having the highest risk have been included in the Wastewater Capital Improvement Program. Interceptor rehabilitation projects are planned for the interceptor segments with higher risk.

A Tsunami Response Plan was developed in 2014 for the MWWTP and Dechlorination Facility.

7.2.2. Future Mitigation Actions

The future mitigation actions are in the process of being integrated into EBMUD's Water and Wastewater Capital Improvement Programs for the next 15 years, but additional grant funding will be sought to do additional work, and speed up critical improvements.

7.2.2.1. Water Supply Facilities

7.2.2.1.1. Embankment Dams and Reservoir Towers

EBMUD's Dam Safety Program includes periodic comprehensive seismic safety evaluations of all the embankment dams. The program is done through EBMUD's Capital Improvement Project bi-annual budget system. Monthly inspection of the dams and towers ensure timely observation of potential adverse impacts. Requests for minor corrective actions are sent to EBMUD forces for implementation. Major issues are addressed as part of contracting work.

Open cut reservoirs that are currently in the process of being replaced, demolished or are marked for future replacement or demolition due to operational concerns include South Reservoir, Summit Reservoir, Almond Reservoir, San Pablo Clearwell, and Seneca Reservoir.

7.2.2.1.2. Reservoirs

In the next five years, EBMUD has plans to replace the following three open cut reservoirs with tanks:

- South Reservoir's replacement, scheduled for completion in 2018.
- San Pablo Clearwell replacement, scheduled for completion by 2020.
- Almond Reservoir's demolition and replacement, scheduled to start construction by 2020.

In addition, EBMUD's Seneca Reservoir will be demolished by 2019. Replacing open cut reservoirs with tanks eliminates seismic risks associated with embankment dams, improves reliability, removes hazardous materials, and improves water quality by removing excess storage.

EBMUD also rehabilitates three to four steel reservoirs per year. In the next five years, EBMUD's reservoir rehabilitation program will replace, rehabilitate, or demolish a total of 23 reservoirs made of steel, concrete, or redwood.

The reservoir IRP establishes a long-term strategy to address rehabilitation needs for EBMUD's distribution reservoirs. The objectives of the IRP are to: 1) establish an inventory of all the distribution reservoirs; 2) document the condition of candidate reservoirs for rehabilitation or replacement; 3) prioritize facility rehabilitations and replacements within a facility class; and 4) justify appropriation requests for the 10-year CIP. The reservoir IRP provides the following benefits to EBMUD:

1. High level of public and employee safety;
2. Environmental and regulatory compliance;
3. Enhanced distribution system reliability;
4. Improved water quality; and
5. Reduced operation and maintenance costs.

7.2.2.1.3. Pumping Plants

In the next five years, EBMUD plans to start construction of the rehabilitation or replacement of 20 distribution pumping plants.

Seismic improvements to the pumping plant structures will be incorporated for each facility that has not previously undergone seismic improvements. New facilities will be constructed from fire-resistant noncombustible materials such as reinforced concrete, masonry, structural steel, or combinations thereof. Flexible pipe connections will be installed to reduce the seismic vulnerability of pipelines entering and exiting the pumping plant building.

All power distribution equipment installed will require seismic qualification to reduce the risk of seismic induced damage.

All pumping plants will be provided with either a pair of pumping hydrants or buried pumping tees for connection to emergency pumps. In general, standby generator connections will be installed at all rehabilitated or replacement pumping plants.

At least two more electric portable pumps will be purchased to support outages of these distribution pumping plants during construction and will increase flexibility of system operations during the outages. These portable pumps will be available for emergency use when not in use for planned construction projects.

Other future mitigation actions to improve the reliability of EBMUD's system include the Moraga Raw Water Pumping Plant, and in particular, the adjoining substation that is located on or near an active landslide area. Previous landslides have been mapped in the vicinity of the pumping plant. These landslides slope away from the pumping plant and the substation.

The areas around the substation pad foundation have settled and cracked. There are several indications of unstable ground deformation and movement that could affect the stability and/or operation of the pumping plant and substation.

The following steps are needed to thoroughly assess and evaluate the site:

- Perform a geological reconnaissance and mapping of the area to identify potential geological hazards.
- Complete a structural assessment and evaluation of the existing structures.
- Perform a geotechnical evaluation of the site to include potential ground movement and strong seismic motions.
- Complete design and construction of retrofit or relocation, if any, based on the geotechnical and structural assessments.

At this time, there are no signs of immediate impairment to the operations of the pumping plant and substation, or evidence of structural distress to the pumping plant building or pipe penetrations. While the Moraga Raw Water Pumping Plant is safe for current operations, the settlement issues need to be studied and addressed.

Moraga Creek is used to transfer water from Moraga Pumping Plant to Upper San Leandro Reservoir. Several substantial slope movements along the creek channel have occurred recently and new ones could dam the creek and make it impossible to transfer water to the reservoir. Sediments and nutrients from the slope movements will impact flood control capability and water quality as well. Creek restoration to strengthen the creek banks will prevent undercutting and subsequent slope movements toward the creek.

7.2.2.1.4. Transmission/Distribution Pipelines

In 2005, EBMUD completed the $189M SIP, which included significant seismic upgrades to critical facilities to improve overall system performance. These improvements did not fix every component of the system that could be damaged in major earthquake. Despite completion of the

SIP, it is predicted that the impacts on EBMUD's distribution system from a Hayward Mw 7.05 scenario event would still be significant, with an estimated number of leaks/main breaks of on the order of 4,000 including over 300 breaks on large diameter mains. The additional steps that EBMUD is taking to further improve the resiliency of its distribution system are discussed below.

- **Pipeline Rebuild Program:** In 2014, EBMUD initiated a new program to gradually increase its rate of pipeline replacements from approximately 10 miles to as high as 40 miles/year. This program, which will primarily focus on the replacement of smaller diameter cast iron and asbestos cement distribution pipeline (pipes that are most likely to break as a results of an earthquake), will gradually improve the robustness of EBMUD's distribution system.
- **Large Diameter Pipeline Replacement Program:** In 2012, EBMUD developed a new capital program to start replacing its large diameter main, at an approximate rate of three miles per year. These recent improvements, and future projects under this new capital program, will gradually improve the reliability of EBMUD transmission pipelines, which may experience a significant number of breaks (over 300) because of a Hayward 7.05 Mw Scenario Event.
- **Alameda Estuary Crossings:** The City of Alameda is somewhat unique in that it does not have any storage facilities within its city limits, and therefore relies on several estuary crossings for its water supply. EBMUD recently completed a study to assess the reliability of the pipeline crossings, and identified three crossings that should be replaced in the next 10 years to improve reliability.
- **Summit Pressure Zone South Pipeline:** The existing alignment for the Summit Pressure Zone South Pipeline runs along the Hayward Fault Zone and fault creep has caused repeated leaks along this pipeline. One segment of existing pipeline at Clark Kerr Campus in Berkeley has been identified as a priority for replacement based on both likelihood and consequence of failure. The Summit Pressure Zone South Pipeline will install approximately 3.6 miles of 24-inch transmission main at a cost of about $12.5M that will functionally move the water transmission capacity out of the Hayward Fault Zone and will allow EBMUD to restore service more quickly to customers in the area after a major earthquake. The project is located mostly in the City of Berkeley, with a small portion in the City of Oakland

7.2.2.1.5. Water Treatment Facilities

Proposed future improvements for the WTP include the following:

- **Upper San Leandro WTP Reclaim System Improvements:** This project will rehabilitate the existing clearwell roof that is seismically vulnerable. It will rehabilitate processes that contribute to capacity limitations in the solids handling system and will repair raw water valves used for isolation and repair for the raw water line.
- **Sobrante WTP:**
  - Maloney PP: As part of a separate project, the Maloney PP will undergo rehabilitation. The existing WTP switchgear will be replaced and located

    within the WTP property line, away from potential flooding and landslide hazards. This work is proposed in FY19-20.
  - Solids Handling Improvements: A vulnerability of the Sobrante WTP is the structures that comprise the solids handling systems for the WTP. These facilities will be replaced in FY20-21.
- **Walnut Creek WTP Pretreatment:** A longer-term goal is the completion of a pretreatment system at Walnut Creek WTP that would strengthen the facility against upcountry water quality impacts, including wildfire, landslide, algae, or others, which could deteriorate water quality. With increased climate change it is expected that reoccurrence of wildfires and catastrophic landslides will increase due to increased rain intensity, higher temperatures, and prolonged dry seasons in the Pardee Watershed. This work is proposed in FY 21-22.

7.2.2.1.6. Regulator and Rate Control Stations

Proposed improvements for each facility were identified to bring regulators and RCSs into compliance with current design criteria, and to extend the useful life of the facility. Proposed improvements range from repair to complete replacement.

Several regulator and RCS projects will be recommended for completion in the next nine years under EBMUD's CIP budget. It is recognized that other factors, such as operational constraints, funding, and coordination with other rehabilitation programs will impact the actual sequence of implementation of the projects. Over the next five years, EBMUD plans to rehabilitate or replace an average of two RCSs per year.

The RCSs rehabilitation project will improve access safety by replacing manholes and outdated hatches with safer sidewalk hatches, and by replacing ladders and ventilation that is approved by the Occupational Safety and Health Administration. Furthermore, deteriorated structures or enlarged existing structures will be replaced with seismically safe, appropriate sized concrete structures, and deteriorated mechanical equipment and telemetry will be replaced. Site inspections and evaluations will be done to prioritize future regulator and RCS rehabilitations and replacement projects.

7.2.2.1.7. Mokelumne Aqueducts

Although the levees protecting the aqueduct system have been improved to PL-84-99 standards, EBMUD is proceeding with preliminary planning studies for a long term strategy to construct tunnels across the Delta and replace the above ground aqueduct pipelines. The studies are beginning with geotechnical investigations and the total cost of the tunnel strategy will exceed ($1 billion).

The tunnel strategy is to build a tunnel below the Delta to enclose dual pipelines. However, as it will take many years to implement the tunnel alternative due to substantial funding issues, short-term, and incremental improvements have also been completed or are planned.

Short-term improvements included the installation of intertie valve stations on the east and west sides of the delta to mitigate potential failures of the Mokelumne Aqueducts from seismic events and flooding ($10M) and the replacement of four aqueduct temperature anchors ($6M).

EBMUD will continue to support reclamation district maintenance and improvement efforts for the existing levees ($1M per year).

Additional technical studies are needed to complete preliminary planning, geotechnical, and conceptual design studies for the proposed tunnel. These studies would minimize the emergency response time in the event of a catastrophic levee failure occurring over the next several decades. The cost of this element is approximately $20M.

Additional geotechnical studies are proposed between Holt and the San Joaquin River to further study the risk of liquefaction and potential for damage to existing buried aqueducts in that area. Depending on the results of these studies, the recommended tunnel alternative may need to be extended east beyond the San Joaquin River.

7.2.2.1.8. Pardee Reservoir

Pardee Dam and Jackson Creek Dam and Dike do not currently contain accelerometers to record seismic activity. EBMUD is in the process of installing five seismic recorders and GPS monitoring stations for survey monuments at the crest, the left abutment, and inside the gallery of Pardee Dam. The strong motion records will be managed by the USGS.

7.2.2.1.9. Camanche Reservoir

During reservoir spill conditions, enhanced monitoring of Dikes 3, 4, 5, and 6 will occur since these dikes are primarily “freeboard” dikes, and therefore they are usually in a non-wetted state. This monitoring will include any unusual conditions near the downstream toes of dikes.

EBMUD is in the process of installing two reference Global Positioning System (GPS) stations and monitoring target GPS stations at Camanche Dam and Dikes 1 through 6 to improve survey accuracy and efficiency.

7.2.2.2. Wastewater Facilities

EBMUD plans to proceed with pump station improvement projects identified in the 2015 Pump Station Master Plan Update, including but not limited to:

- Pump Station A Improvements (estimated budget: $3.5M)
- Pump Station C Upgrades (estimated budget: $1.9M)
- Pump Station J Upgrades (estimated budget: $1.0M)
- Pump Station L Improvements (estimated budget: $1.5M)
- Pump Station M Improvements (estimated budget: $3.0M)

EBMUD will also proceed with repairs on higher risk interceptor segments identified in pipeline condition assessment reports, including but not limited to:

- 3rd Street Sewer Interceptor Rehabilitation (estimated budget: $33M)
- Interceptor Corrosion Prevention project for cathodic protection and force main valve repairs (estimated budget: $1.4M)

8. 2018 LHMP Maintenance

8.1. Monitoring, Evaluating, and Updating the 2018 LHMP

As required by the Disaster Mitigation Act of 2000, EBMUD will update the 2018 LHMP at least once every five years, or when new information becomes available, priorities for implementation change, or an actual hazard event occurs that may prompt an update. The process to update the plan will begin one year before the current plan expires. The effort to update this plan will be led by the Engineering Design Division, with input from the same divisions who contributed to the creation of this 2018 LHMP. Financial support to update the LHMP will come from in-house resources.

EBMUD's Manager of Security and Emergency Preparedness and Manager of Business Continuity will monitor the 2018 LHMP's goals and objectives in coordination with managers in the Engineering Design Division, Water Supply Engineering Division, Pipeline Infrastructure Division, Engineering Services Division, Wastewater Engineering Division, and other work groups involved in projects completed under this plan.

During the life of this plan, the Local Hazard Mitigation Planning team will meet annually or more frequently, if needed. During these meetings, managers will provide status updates of each mitigation project under their responsibility. Additionally, high priority mitigation actions are included in EBMUD's Capital Improvement Plan (CIP). Inclusion in the CIP allows division managers to track progress toward completion of each critical project.

Managers contribute to the appraisal of the effectiveness of the plan at achieving the stated purpose and goals, with respect to their division's interests and responsibilities. During the annual meetings, the managers will inform the Manager of Security and Emergency Preparedness of assessments.

Because of the involvement of EBMUD's department leaders, the entire executive management of EBMUD is committed to implementing the goals and objectives of the 2018 LHMP.

8.2. Continued Public Involvement

EBMUD is committed to public participation. All EBMUD Board meetings are open to the public and the public is invited to comment on items on the Board Agenda. The public will continue to be involved whenever the 2018 LHMP is updated and as appropriate during the monitoring and evaluation process. Prior to adoption of updates, EBMUD will provide the opportunity for the public to comment on the updates. A public notice will be posted prior to the meeting to announce the comment period and meeting logistics.

9. Mitigation Plan Point of Contact

Name: Steven Frew
Title: Manager of Security and Emergency Preparedness
Mailing Address: East Bay Municipal Utility District
375 11th Street - Oakland, CA 95607-4240
Telephone: 510-867-5292
Email: steven.frew@ebmud.com

Alternate Point of Contact:

Name: Michael Ambrose
Title: Manager of Regulatory Compliance
Mailing Address: East Bay Municipal Utility District
375 11th Street - Oakland, CA 95607-4240
Telephone: 510-287-1256
Email: michael.ambrose@ebmud.com

10. Exhibits

Exhibit A – EBMUD Water Supply System Map

EBMUD's water supply system consists of reservoirs, aqueducts, treatment plants, and distribution facilities from the Mokelumne River Basin in the Sierra Nevada, to the East San Francisco Bay Area

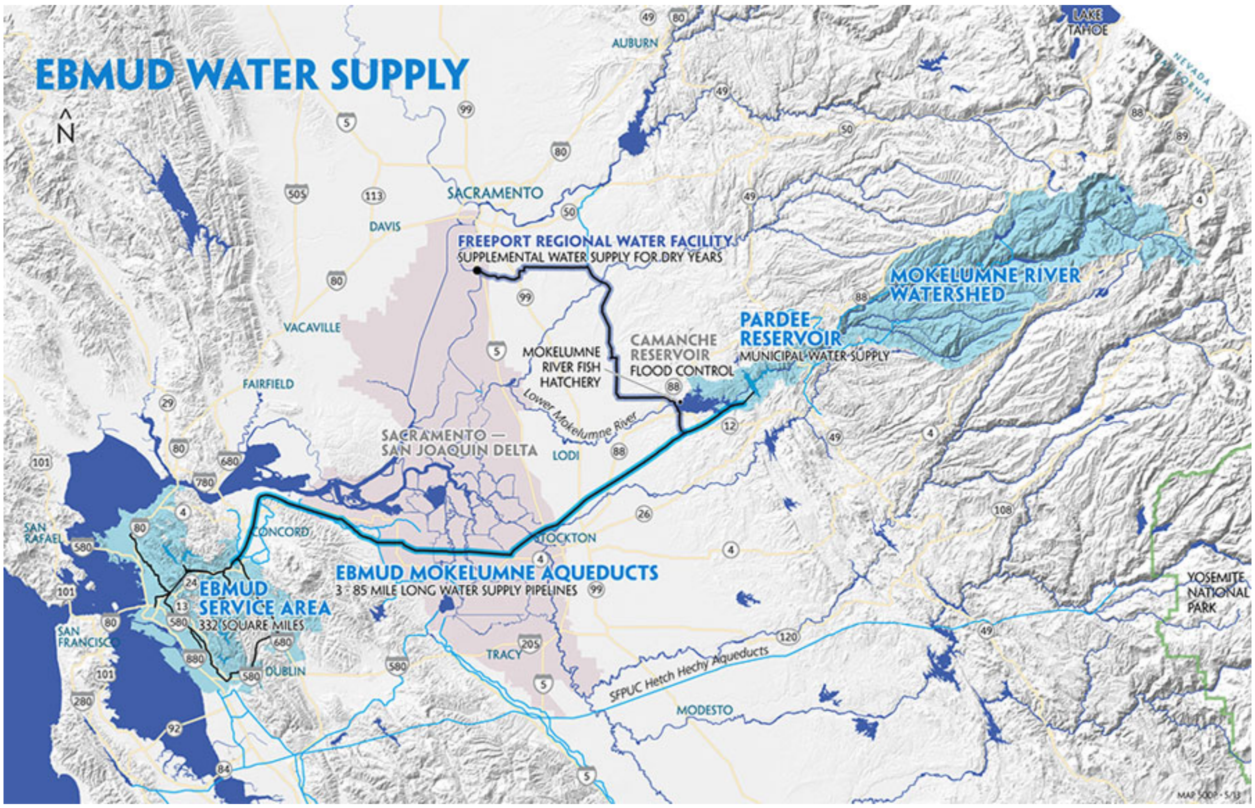

Figure 10.1. EBMUD Water Supply

Exhibit B – Map of EBMUD Water and Wastewater Service Area

EBMUD's water system serves approximately 1.4 million people in a 331-square-mile area extending from Crockett on the north, southward to San Lorenzo (encompassing the major cities of Oakland and Berkeley), eastward from San Francisco to Walnut Creek, and south through the San Ramon Valley. Our wastewater system serves approximately 680,000 people in an 88-square-mile area of Alameda and Contra Costa counties along the Bay's east shore, extending from Richmond on the north, southward to Oakland.

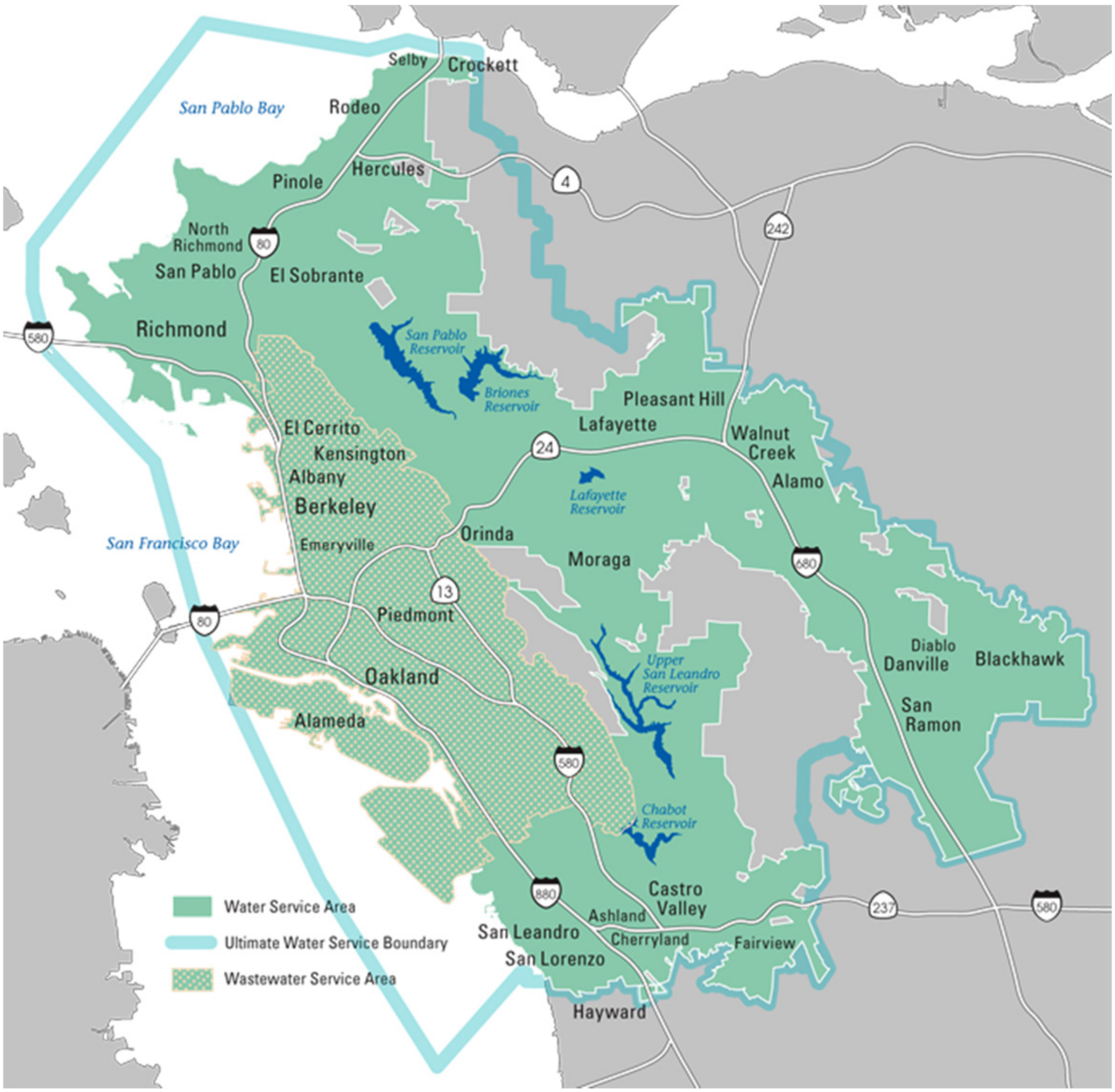

Figure 10.2. EBMUD's Service Area

11. Appendices

APPENDIX A – COMMONLY USED ACRONYMS

Acronyms	Definition
100RC	100 Resilient Cities
2011 LHMP	2011 Local Hazard Mitigation Plan
2016 LHMP	2016 Local Hazard Mitigation Plan
2017 LHMP	2017 Local Hazard Mitigation Plan
2018 LHMP	2018 Local Hazard Mitigation Plan
ABAG	Association of Bay Area Governments
BACRDR	Bay Area Center for Regional Disaster Resilience
Cal EMA	California Emergency Management Agency
CAL FIRE	California Department of Forestry and Fire Protection
Cal OES	California Governor's Office of Emergency Services
CalWARN	California Water/Wastewater Agency Response Network
CEA	California Earthquake Authority
CGS	California Geological Survey
CIP	Capital Improvement Program
CUEA	California Utilities Emergency Association
CVP	Central Valley Project
Delta	Sacramento–San Joaquin River Delta
DMA	Federal Disaster Mitigation Act
DMP	Drought Management Program
DPS	drought planning sequence
DSOD	California Department of Water Resources Division of Safety of Dams
DWR	Department of Water Resources
EBMUD	East Bay Municipal Utility District
EBRPD	East Bay Regional Park District
EERI	Earthquake Engineering Research Institute
EMA	Emergency Management Association
EOC	Emergency Operation Center
EPA	Environmental Protection Agency
ESP	Engineering Standard Practice
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FRWA	Freeport Regional Water Authority
FSCC	Folsom South Canal Connection
FY	Fiscal Year
gpm	gallons per minute
I/I	infiltration/inflow
IP	Office of Infrastructure Protection
IRP	Infrastructure Rehabilitation Program
LADWP	Los Angeles Department of Water and Power

Acronyms	Definition
LP25 Symposium	Loma Prieta 25 Symposium
LTRC	Long Term Renewal Contract
LVVWD	Las Vegas Valley Water District
M	Million
MAC	Multi-Agency Coordination
MCC	motor control centers
MCE	Maximum Considered Earthquake
MGD	million gallons per day
MOU	Memorandum of Understanding
MUD Act	Municipal Utility District Act
MWWTP	Main Wastewater Treatment Plant
Mw	Magnitude
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NSHMP	National Seismic Hazard Mapping Project
OAC	Operational Area Council
Pardee ACC	Pardee Area Control Center
PEER	Pacific Earthquake Engineering Research Center
PG&E	Pacific Gas and Electric Company
PGA	Peak Ground Acceleration
POD	Points of Distribution
RCSs	Rate Control Stations
RTU	remote terminal unit
SCADA	supervisory control and data acquisition
SD-1	Special District No. 1
SEAOC	Structural Engineers Association of California
SEONC	Structural Engineers Association of Northern California
SEP	Seismic Evaluation Program
SIP	Seismic Improvement Program
SOC	State Operations Center
SSMP	Sewer System Management Plan
SSOs	sanitary sewer overflows
UASI	Urban Area Security Initiative
UOC	Utility Operations Center
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
UWMP 2010	Urban Water Management Plan 2010
WSCP	Water Shortage Contingency Plan
WTP	water treatment plants
WWF	Wet Weather Facilities