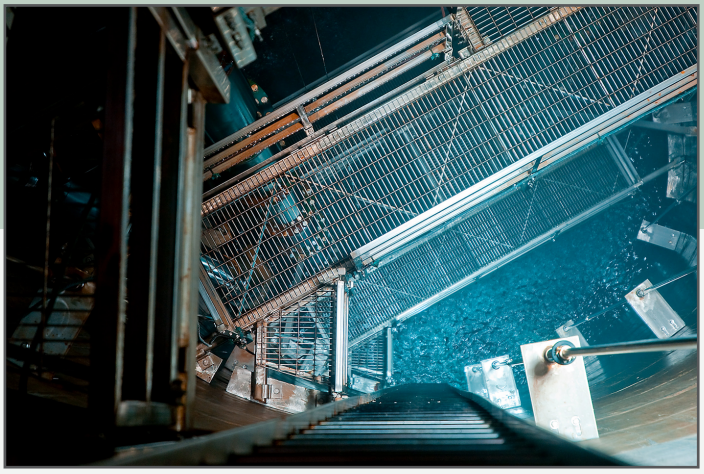
2012 UPDATE

SONOMA COUNTY WATER AGENCY

LOCAL HAZARD MITIGATION PLAN



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2012 Update

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Local Hazard Mitigation Plan

Prepared By
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1.0 INTRODUCTION

On January 8, 2008, the Board of Directors of the Sonoma County Water Agency (Water Agency) adopted a local hazard mitigation plan (LHMP) with a vision to incrementally reduce its exposure to natural hazards and improve the reliability of the its services to the public. The plan was developed in accordance with the federal Disaster Mitigation Act (DMA) 2000 (Public Law 106-390) and subsequently approved by the Federal Emergency Management Agency (FEMA). A FEMA approved LHMP is a prerequisite for receiving pre-disaster mitigation grant funds and other federal assistance during declared emergencies.

This update to the 2008 LHMP is intended to meet the requirements of DMA 2000. The update is based on a review of the present understanding of natural hazards that impact the Water Agency and an assessment of the vulnerability of its infrastructure to these hazards. This update also documents the progress towards the mitigation projects identified in the 2008 plan and provides a vision for the next five years to help further reduce the Water Agency's exposure to these hazards.

1.1 WATER AGENCY PROFILE

The Sonoma County Water Agency was created as a special district in 1949 by the California Legislature to provide flood protection and water supply services to portions of Sonoma and Marin counties. Legislation enacted in 1995 added the treatment and disposal of wastewater to its responsibilities. Although the Sonoma County Board of Supervisors acts as the Water Agency's Board of Directors, it is a separate legal entity created by State law, having specific limited purposes and powers, and separate sources of funding. The Water Agency is thus different from County departments, which are created by the Board of Supervisors for administrative purposes, but are not separate legal entities.

The Water Agency is a wholesale water supplier to eight primary water contractors, several smaller communities and water companies, a range of surplus (curtailable) customers and off-peak customers. The total population served by the Water Agency is approximately 600,000 people in southern Sonoma County and Marin County. The projected total annual average water demand from its customers is approximately 62 million gallons per day (mgd) for 2015 to 71 mgd for 2035.

The Water Agency's primary water supply customers include the City of Santa Rosa, North Marin Water District, City of Petaluma, City of Rohnert Park, Valley of the Moon Water District, City of Sonoma, City of Cotati and Town of Windsor. Approximately 2% of the water supply is provided to customers such as California-American Water

Company (Larkfield District), Penngrove Water Company, Lawndale Mutual Water Company, Kenwood Village Water Company, Forestville Water District, and various government entities. Depending upon the transmission system capacity and the availability of excess water in the Russian River, the Water Agency sells as much as 12% of its water to the Marin Municipal Water District (MMWD). MMWD's rights to the transmission system capacity are subordinate to the rights of the Water Agency's eight prime contractors. Less than 1% of the total water deliveries are provided to several curtailable (surplus) customers such as local vineyards and wineries.

Water to its various contractors is provided through tie-ins into the Water Agency's aqueducts. Each of the water contractors is responsible for maintaining their own retail distribution system, including storage tanks and pumping stations. Most of the water contractors maintain some local source of supply in addition to water purchased from the Water Agency, but in most cases that constitutes a very small percentage of their total water requirements. Therefore, the population served by the Water Agency's contractors mostly depends on water provided by the Water Agency. In addition to the contractor tie-ins, the Water Agency's system is also connected to about 30 unmetered fire hydrants. The primary fire-fighting capability, within the Water Agency's service area, is borne upon each contractor's retail distribution system. Although the Water Agency is not directly responsible for providing water for firefighting, it is indirectly responsible due to the heavy dependence by the contractors on the water supplied by the Water Agency.

The Water Agency provides wastewater collection and treatment services and recycled water distribution and disposal services to approximately 22,000 residences and businesses in four County Sanitation Zones consisting of Airport/Larkfield/Wikiup, Geyserville, Penngrove and Sea Ranch and four County Sanitation Districts consisting of Occidental, Russian River, Sonoma Valley, and South Park.

For flood control purposes, the Water Agency has helped build and manage the Warm Springs Dam, Spring Lake, Coyote Valley Dam, Matanzas Creek Reservoir, Piner Creek Reservoir and Brush Creek Reservoir. The Water Agency maintains levees, fish ladders and embankment protection for Russian River and is responsible for more than 70 miles of engineered flood control channels and over 80 miles of natural channels.

1.2 PURPOSE OF THE PLAN

As has been shown numerous times in the past, natural disasters can result in enormous cost to the public through loss of life, human suffering, property damage and economic loss. Lack of preparedness can make recovery a very long and arduous process, which can last for many months or years and can depress a region for a time long after the physical signs of the disaster have disappeared. Recognizing this, the

Federal Government passed the Disaster Mitigation Act of 2000 (DMA 2000), which encourages and rewards pre-disaster planning at all levels of local, tribal and state government. DMA 2000 was signed into law (Public Law 106-390) by the President on October 10, 2000.

As an incentive for pre-disaster mitigation planning, the DMA 2000 has established a pre-disaster hazard mitigation program and incorporated new requirements for the national post-disaster Hazard Mitigation Grant Program (HMGP). Accordingly, a larger amount of HMGP funds are available for communities that have developed a comprehensive mitigation plan prior to a disaster. States, tribes and communities must have an approved mitigation plan in place before receiving HMGP funds. To reward pre-disaster planning, the Federal Emergency Management Agency (FEMA) has instituted a Pre-Disaster Mitigation (PDM) program that provides funds to states, territories, Indian tribal governments, communities, and universities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event. Funding these plans and projects reduces overall risks to the population and structures, while also reducing reliance on funding from actual disaster declarations. PDM grants are awarded on a competitive basis and without reference to state allocations, quotas, or other formula-based allocation of funds. An approved Local Hazard Mitigation Plan (LHMP) is a pre-requisite for applying for a PDM grant.

Sonoma County is located in an area impacted by multiple natural hazards. Historically it has been subjected to many floods, wildfires, landslides and mudflows. Due to its proximity to the San Andreas Fault system, one of the major active fault systems in the world, Sonoma County also has a very high earthquake hazard.

The Water Agency's water, wastewater and flood control systems are distributed over a large geographical area and traverse zones of varying geology and potential hazards. A comprehensive LHMP is prepared in recognition of the Water Agency's responsibility to the community and its role in preserving the economic vitality of the region. As stated in the Sonoma County Emergency Operations Plan, the public places trust in the operators of water systems to provide high quality drinking water, even after a disaster. An uninterrupted supply of clean drinking water and water for firefighting is essential for the health and safety of the community and to minimize the potential for loss of life and property damage following a major natural disaster.

1.3 2008 PLAN DEVELOPMENT PROCESS

Recognizing its obligation to provide high quality water to the public, the Water Agency on its own initiative embarked on a natural hazard reliability improvement program for its water supply system in 2004. This multi-phase project was initiated by the Department of Engineering and Resource Planning, with the Agency's Capital

Projects Manager, Mr. Cordel Stillman, as the Project Manager for the project. The Water Agency contracted the services of MMI Engineering (MMI), a specialty engineering firm with expertise in the assessment of natural and man-made hazards and their impact on water system reliability. The MMI team included specialists in structural/earthquake engineering, geotechnical/foundation engineering, geology and tectonics, engineering seismology, pipeline performance, hydrology, risk analysis, water resources and economic analysis.

Throughout the course of the reliability improvement project Deputy Chief Engineers from the Water Agency's Engineering and Resource Planning Division (Mr. James Jasperse[1]), Maintenance Division (Mr. Michael Thompson) and Operations Division (Ms. Pamela Jean) were involved in setting the course of the project, attended meetings, reviewing technical memoranda and final reports.

The natural hazard reliability study served as the basis for the Water Agency's LHMP. To obtain broad public support, the LHMP process included stakeholder and public involvement as discussed in the subsequent sections.

Insights developed through the water system reliability assessment were extended for the initial evaluation of the Water Agency's sanitation system. Detailed assessment of the sanitation system was identified as a goal of the LHMP.

1.3.1 Water System Reliability Study

The water system reliability study, which spanned over a period of almost three years, consisted of two phases; a preliminary assessment phase [1]followed by a comprehensive assessment phase [2].

The initial phase of the study consisted of the identification of all credible natural hazards that could impact the system. The effects of each hazard (for example, expected ground accelerations in an earthquake, available fuel for wild fires, flood maps and zones of liquefaction and landslide hazard) were plotted on a Geographical Information System (GIS) map of the water system. This information was used for a preliminary assessment of the water system vulnerabilities to these hazards using a simplified network analysis approach. During this phase, threats to the system that resulted in the greatest impact in the Water Agency's ability to reliably meet its mandate were identified and ranked.

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[1] Mr. James Jasperse is now the current Sonoma County Water Agency Chief Engineer

The preliminary assessment identified earthquakes and earthquake related hazard as the most significant hazards to the water transmission infrastructure. Earthquake related hazards were followed by flood and fire but the vulnerability associated with these hazards was significantly lower than that from earthquakes.

Following this preliminary assessment a more comprehensive assessment of water transmission facilities identified as potentially vulnerable was performed. During this phase of the work, detailed structural, geotechnical and geological analyses including, as needed, subsurface investigations were performed. The impact of these hazards and system vulnerabilities in terms of water supply to the Water Agency's contractors was studied through a detailed hydraulic model of the system. Based on these assessments a set of recommendations were developed that identified mitigation actions through a combination of pre-hazard planning, system upgrades, component retrofits and plans for post-hazard repair.

The results of the preliminary and comprehensive assessments were documented in a series of reports and technical memoranda [1-8]. Prior to finalizing, the reports and memoranda were submitted in draft form and circulated within the Water Agency to the Deputy Chief Engineers of the Engineering and Resource Planning, Maintenance and Operations Divisions for their comments.

1.3.2 Document Review

The plan development process included an extensive review of available information on hazards, Water Agency's emergency response plans [9, 10], Water Agency's urban water management plans [11, 12], engineering drawings and reports for the water transmission facilities, historic aerial photographs and available geotechnical and geologic data. A detailed list of engineering drawings and reports reviewed is included in Appendix A. In addition to data from the Water Agency, data from outside sources such as California Geological Survey (for detailed fault investigation reports) and California Department of Transportation (for geotechnical reports) was reviewed and utilized in the study.

Other documents such as the FEMA 386 [13-17] series of documents, the Sonoma County's County Hazard Mitigation Plan [18, 19], and FEMA approved plans for other entities [20, 21] were consulted during the LHMP development process.

An overview of the vulnerabilities of the Water Agency's wastewater and flood control facilities was also included in the development of this plan.

1.3.3 Public Involvement

Stakeholder involvement during this process included meetings with the Water Agency's eight primary water supply contractors. The purpose of the meetings was to describe the Agency's objectives to the contractors, apprise them of the findings of the hazard assessments and solicit their input. The Agency's General Manager and Board of Directors (who are also the County's Board of Supervisors) were also kept informed of the ongoing work.

To involve the Agency's staff at all levels and not just management and to obtain their buy-in, a one day workshop was conducted to discuss the philosophy of the program, its approach and to obtain feedback. During the course of this three year project, MMI's engineers interacted with Agency's maintenance, operations and engineering staff at many levels to obtain intelligence and operational knowledge of the Agency's system.

After completing the preliminary water system reliability study, the Agency's contractors were briefed in a series of two hour meetings attended by the contractor representatives, MMI Project Manager, the Agency's Capital Projects Manager and the Deputy Chief Engineer of Engineering and Resource Planning [22-26].

The following additional activities were performed as part of public involvement process:

- The draft hazard mitigation plan was posted on the Water Agency's website on November 6, 2007 for public review and comment.
- The draft hazard mitigation plan was presented to the Agency's contractors for review and comment as follows:
    - City of Santa Rosa, October, 2007
    - City of Sonoma, October, 2007
    - City of Petaluma, October, 2007
    - Town of Windsor, October, 2007
    - City of Rohnert Park, October, 2007
    - City of Cotati, October, 2007
    - North Marin Water District, October, 2007
    - Valley of the Moon Water District, October, 2007
- The draft hazard mitigation plan was presented to the Water Agency's Water Advisory Committee (WAC) on November 5, 2007 for review and comment.

- The draft hazard mitigation plan was presented to the Agency's Technical Advisory Committee (TAC) on November 5, 2007 for review and comment.
- The draft hazard mitigation plan was presented to the Water Agency's Board of Directors on January 8, 2008 for review, comment and formal adoption.

1.4 WATER SUPPLY STRATEGY ACTION PLAN

The Water Supply Strategy Action Plan (WSSAP) is the Water Agency's framework document describing its strategies and prioritized actions to promote more resilient regional water resources.

The original WSSAP was developed after numerous public meetings and hundreds of comments from stakeholders. The plan is implemented in consultation with the Water Agency's water contractors and is used as a basis for budgeting.

The WSSAP was updated in 2011 and is currently being updated (anticipated update by February 2013). Demonstrating the high priority that the Water Agency places on improving the reliability of its facilities, Strategy Six (Implement Projects to Improve Transmission System Reliability) specifies approximately 15 priority capital projects aimed at improving the natural hazard and operational reliability of the Water Agency's facilities. In addition, Strategy Six also contains emergency response planning and training programs.

1.5 2012 PLAN UPDATE PROCESS

Since the formal adoption of the 2008 LHMP, the Water Agency has been actively engaged in furthering the goals and objectives laid out in the LHMP and the natural hazard reliability study. To this effect, the number one stated goal in the Water Agency's proposed 2012 Strategic Plan is related to natural hazard reliability as follows:

Goal 1: Increase Organizational Efficiency, Effectiveness and Resilience to Natural Disasters.

Strategy 1: Conduct hazard and emergency preparedness activities.

Objective 1: Perform individual and multi-agency emergency response preparedness, trainings and exercises.

Objective 2: Evaluate infrastructure vulnerabilities and impacts on our customers.

Objective 3: Continue implementation of Local Hazard Mitigation Plan and infrastructure improvement projects (see Water Supply, Sanitation and Flood Control Sections for further information).

Objective 4: Incorporate GIS into emergency preparedness and response activities.

During the last five years, the Water Agency has initiated several high priority projects identified in the LHMP to help reduce exposure to natural hazards and improve the reliability of its system. The Agency has also reassessed some of the priorities associated with the mitigation projects identified in the natural hazard reliability study and added additional objectives towards the implementation strategy for the 2012 LHMP Update.

The 2012 plan update process included:

- A detailed review of current understanding of natural hazards that can impact the Water Agency's infrastructure.
- An assessment of progress towards the goals and objectives laid out in the 2008 LHMP.
- Creation of a new list of priority and actionable projects intended to increase system resiliency to damage from natural disasters.
- Communication of this information to the public and stakeholders and solicitation of their input.

1.5.1 Natural Hazard Assessment

As part of the 2012 plan update, new and current information was sought on the most significant natural hazards. Hazards such as earthquakes, earthquake induced geotechnical related hazards, flood and fire hazard were researched. Updated maps of each hazard were prepared with the Water Agency's water and sanitation systems overlaid. This updated information was reviewed in terms of impact on these systems to evaluate if any change in the assessment of the system response was warranted.

1.5.2 Progress towards Implementation of LHMP Goals and Objectives

In the 2008 LHMP, the Water Agency identified a series of actions as part of its implementation strategy and has made significant progress towards these actions. The Water Agency continues to work on these items as summarized in Table 1.

Table 1: 2008 LHMP First Tier Objectives - Progress Summary

No.	2008 LHMP Objectives	Description	Anticipated Implementation Schedule Identified in 2008 LHMP[1]	Current Status
1	1.3.1 (partial)	Develop and implement design strategy to mitigate fault rupture hazard at Rodgers Creek fault crossing of Santa Rosa aqueduct	4 - 10 years	• Obtained FEMA PDM grant • Construction in progress
2	1.1.4	Install flow measuring devices at key turnouts for real time monitoring of flow	4 - 10 years	• In progress • Currently 46 out of 175 turnouts report at 15 minute intervals
3	1.1.1	Minimize potential for uncontrolled release of water by providing isolation valves at strategic locations	4 - 10 years	• Requested FEMA HMGP grant in 2009 • FEMA environmental review pending
4	1.3.2 (partial)	Develop and implement design strategy to mitigate the liquefaction and lateral spread hazard at the Russian River crossing	4 - 10 years	• Requested FEMA PDM grant in 2009 • FEMA environmental review pending
5	1.3.2 (partial)	Develop and implement design strategy to mitigate the liquefaction and lateral spread hazard at the Mark West Creek crossing	4 - 10 years	• Requested FEMA PDM grant in 2010 • FEMA environmental review pending
6	1.2.1 (partial)	Develop and implement retrofit design for Collectors 3 and 5 against liquefaction and lateral spread hazard	4 - 10 years	• Preliminary design consultant selected • Design alternatives work in progress
7	1.2.1 (partial)	Develop and implement retrofit design for Collector 6 against liquefaction and lateral spread hazard	15 - 25 years	• Preliminary design consultant selected • Design alternatives work in progress
8	1.1.2	Plan, design and add redundant/emergency supply sources to minimize dependence on the Russian River aquifer as the main source of water supply. Install new emergency ground water wells located strategically throughout the system (assumed three locations)	15 - 25 years	• Working with contractors for options
9	1.3.2 (partial)	Develop and implement design strategy to mitigate the liquefaction and lateral spread hazard at the Santa Rosa Creek crossing	15 - 25 years	• Planning work to commence following the completion of other higher priority projects
10	1.2.2	Develop and implement design strategy to mitigate liquefaction and lateral spread hazard to the RDS	15 - 25 years	• Preliminary design consultant selected • Design alternatives work in progress

1. Years from the date of adoption of 2008 LHMP, depending on the availability of funding

In addition to progress towards specific high priority objectives (Table 1, items 1 – 6) identified in the 2008 LHMP, the Water Agency has undertaken activities towards meeting some of the other goals and objectives stated in the 2008 plan. A summary of these activities is included in Table 2. These activities are ongoing and the Water Agency plans to continue making progress towards meeting these objectives in the coming years.

Table 2: 2008 LHMP – Progress Towards Selected Additional Objectives

No.	2008 LHMP Objectives	Description	Current Status
1	1.1.3	Provide seismic restraints to electrical and communication equipment at various facilities	• Ongoing work
2	1.1.5	Develop a GPS based system map with real-time monitoring at critical locations	• Ongoing work
3	1.1.6	Procure large diameter flexible hose and its deployment and retrieval system for emergency use.	• Procured approximately 1,300 feet of large diameter flexible hose • Planned purchase of additional lengths and deployment and retrieval system
4	1.5.1	Perform piping retrofit by replacing existing rigid piping with piping with flexible joints at the storage reservoirs	• Ongoing work
5	1.5.2	Implement other retrofits such as removing overconstrained conditions at storage reservoirs identified in the natural hazard reliability study	• Ongoing work
6	1.6.1	Plan and procure stock pile material for use in emergency	• Ongoing procurement of material, such as isolation valves and flange coupling adaptors
7	1.6.2	Conduct first responder training of a broad pool of Agency's personnel to respond in an emergency.	• Initial planning work has been initiated
8	1.6.3	Plan and develop a dedicated Emergency Operations Center such that the operators and decision makers are in close proximity to each other	• EOC has been established at 204 Concourse Avenue in close proximity to 404 Aviation Boulevard • EOC procedures and protocols under development
9	1.7.1	Develop and implement design and operations plans to mitigate liquefaction related damage to electric power lines feeding collectors and pump stations	• New redundant cable installed
10	1.7.2	Procure and install additional UPS units at each facility to prolong the ability to communicate with the system beyond the current 4 hour limit.	• Additional UPS units purchased • Continued capital expenditure is planned
11	2.1.1	Perform a multi-hazard vulnerability assessment of the sanitation systems.	• Consultant selected • Study for Russian River County Sanitation District and Sonoma Valley Sanitation District underway

1.5.3 Public/Stakeholder Involvement

During the 2012 plan update process the public and stakeholders were kept fully informed and their input sought and incorporated in the updated plan. The following steps were taken:

- A meeting with the Water Agency's Chief Engineer and key management staff from operations, maintenance, planning, engineering/design, risk management and grants departments was held on August 14, 2012 to discuss 2012 plan update and solicit input from each department.
- An announcement requesting public input on the 2008 LHMP for the 2012 plan update was posted on the Water Agency's website in early September of 2012.
- The draft 2012 plan update was posted on the Water Agency's website in early November 2012 for comment.

- Meetings with the Technical Advisory Committee (TAC) consisting of representatives of Water Agency's contractors were held on September 10, 2012 and October 1, 2012.
- A meeting with the Water Advisory Committee was held on November 5, 2012 to solicit their input.
- Draft copy of the plan was provided to the Water Agency contractors for their comments.

1.6 PLAN ADOPTION

The 2008 LHMP was formally adopted by the Sonoma County Water Agency Board of Directors on January 8, 2008. The formal resolution of adoption is included in Appendix B.

The 2012 LHMP update was formally adopted by the Sonoma County Water Agency Board of Directors on December 11, 2012. The formal resolution of adoption is included in Appendix B.

2.0 WATER AGENCY FACILITIES

2.1 WATER SUPPLY SYSTEM

The Water Agency's water system is shown in Figure 1. The primary source of water for the system is a ground water aquifer located in the Mirabel Park area just north of the town of Forestville. The aquifer is located adjacent to the Russian River and is charged by the river by natural filtration through an approximately 60 feet thick sand and gravel riverbed. Water from the aquifer is pumped by six Ranney type collector wells and released into 83 miles of large diameter pipelines (aqueducts) that transmit water throughout the Water Agency's service area. Three out of the six collectors are located along the eastern bank of the river in the Wohler area and are referred to the Wohler collectors, while the remaining three are located along the western bank of the river in the Mirabel area and are known as the Mirabel collectors. On average, the Mirabel and Wohler collectors can provide a sustained flow of approximately 15 mgd each. In addition to the collector wells, the water supply system has ten conventional wells (with an average sustained flow of 7 mgd) that can supplement the water supply from the collectors. Seven of these wells are located along the Russian River in the general vicinity of the collectors, while the remaining three are located in the Laguna De Santa Rosa area near Sebastopol.

The transmission system has eight booster pump stations that provide the necessary head to move the water through the system. Water storage is provided by 18 steel storage tanks with a collective storage capacity of 122.1 million gallons. The Agency maintains two major reservoirs; Lake Mendocino impounded by the 160 (or 164) feet high Coyote Valley Dam and Lake Sonoma impounded by the 319 feet high Warm Springs Dam. Other facilities include an inflatable rubber dam on Russian River, a system of ditches, infiltration ponds and a dike, three water treatment facilities, an electric power substation, a hydroelectric plant, and several emergency power generators.

The key facilities that constitute the water supply system are summarized below:

- **Russian River system** – includes the Russian River, the Russian River aquifer and the Warm Springs (319 feet high) and Coyote Valley (164 feet high) earth-fill embankment dams.
- **Diversion system** – includes collector wells, inflatable dam, River Diversion Structure (RDS), Mirabel well field, dikes and diversion channels in the Wohler-Mirabel area and infiltration ponds.

- **Transmission system** – includes all of the aqueducts that transport water from the diversion system facilities to storage tanks and to the Water Agency's contractors through tie-ins throughout the system.
- **Storage system** – includes 18 storage tanks at nine locations (Annadel, Los Guilicos, Cotati, Eldridge, Forestville, Kastania, Kawana, Ralphine, and Sonoma) that provide 122.1 million gallons of storage.
- **Pumping facilities** – includes 8 booster stations (Eldridge, Ely, Forestville, Kastania, Kawana, Sonoma Booster No. 1, Sonoma Booster No. 2 and Wilfred).
- **Treatment facilities** – includes three chlorination and corrosion control facilities.
- **Power system** – includes the electric substation at the Wohler corporation yard, fixed and portable emergency generators and the 12kV power line.
- **Supplementary facilities** – includes Laguna de Santa Rosa wells and the Water Agency's office and operations buildings.
- **Equipment and non-structural components** – Most of the water system facilities house a range of equipment and non-structural components, which if unanchored are vulnerable to damage and can either cause injury or damage to an adjacent critical piece of equipment.

2.2 SANITATION SYSTEM

The Water Agency's sanitation system includes a combination of systems owned by the Agency known as Sanitation Zones and independent special districts operated by the Agency known as Sanitation Districts. The system has four sanitation zones and four sanitation districts. Figure 2 shows the location of the different sanitation districts and zones.

The four sanitation zones include Airport/Larkfield/Wikiup, Geyserville, Penngrove and Sea Ranch and four sanitation districts include Occidental, Russian River, Sonoma Valley, and South Park. These zones and districts provide wastewater collection and treatment services and recycled water distribution and disposal services to approximately 22,000 residences and businesses and cover service areas ranging from 70 to 4,600 acres.

Each district/zone has its own wastewater collection system that typically includes gravity flow in pipelines. Out of the eight districts/zones, six have wastewater treatment plants. The remaining two, the Penngrove Sanitation Zone and the South Park County Sanitation District, collect wastewater and transport it to the City of

Petaluma and the City of Santa Rosa treatment facilities, respectively. The total pipeline length for each district/zone ranges from as little as one mile for the Occidental County Sanitation District to over 100 miles for the Sonoma Valley Sanitation District. The wastewater treatment plants treat wastewater to either secondary or tertiary standards and include a series of aeration basins, settling ponds, clarifiers, holding ponds, chlorination chambers, dechlorination facilities and ultra-violet light disinfection systems.

The average dry weather flow for the treatments plants vary from 2000 gallons per day (Sea Ranch Central Sanitation Zone) to 2.8 mgd (Sonoma Valley County Sanitation District). After treatment, the wastewater is either used for irrigation or discharged to percolation ponds or waterways. The Geyserville and Sea Ranch North Sanitation Zone use percolation ponds to discharge the treated wastewater. Some recycled water from the Sonoma Valley County Sanitation District is discharged through Schell Slough which ultimately flows into the San Pablo Bay. Recycled water from the Russian River County Sanitation District and Occidental County Sanitation District ultimately flows into the Russian River.

In addition to the treatment plants, the Agency has 29 lift stations located across these systems.

2.3 FLOOD CONTROL SYSTEM

The Water Agency, in cooperation with the United States Army Corps of Engineers (USACE) and the Natural Resources Conservation Services (NRCS), is responsible for maintaining specific federal and non-federal flood control improvement projects on the Russian River. Some of these projects include Lake Mendocino, Lake Sonoma, the Central Sonoma Watershed Project and the Laguna De Santa Rosa.

Lake Mendocino is located on the East Fork Russian River three miles northeast of Ukiah. It was formed by the construction of the Coyote Valley Dam by the USACE in 1959. The dam is a 160-foot high rolled earth embankment used for water storage and flood control purposes. The Water Agency and the Mendocino County Russian River Flood Control and Water Conservation Improvement District share permits by the State for rights to store up to 122,500 acre-feet of water per year in the reservoir. The Water Agency has the exclusive right to control the releases of water from the water supply pool in Lake Mendocino because it was the local sponsor for the dam project. When the water level rises above the top of the water supply pool and into the flood control pool the USACE assumes control of releases.

Lake Sonoma is located approximately 14 miles northwest of Healdsburg at the confluence of Warm Springs Creek and Dry Creek. The reservoir was formed by the construction of Warm Springs Dam, a 319-foot high rolled earth dam, in 1982 by the

USACE. Similar to Lake Mendocino, the Agency has exclusive rights to control the rate of release of water from the water supply pool in Lake Sonoma. When the water level in the Lake rises above elevation 451 feet and goes into the flood control pool, the USACE assumes control of the water release. The Agency has constructed and operates a 2.6 megawatt hydropower plant at the dam.

The Central Sonoma Watershed Project has four flood control reservoirs that include the Santa Rosa Creek Reservoir (Spring Lake), Matanzas Creek Reservoir, Piner Creek Reservoir, and the Brush Creek Middle Fork Reservoir. Each of these reservoirs are equipped with appurtenant structures but unlike the Warm Springs and Coyote Valley dams they are not equipped with flood gates and instead operate passively either as detention basins or bypass systems. In cooperation with the NRCS, several waterways have also been shaped and stabilized as part of the Central Sonoma Watershed Project.

The Laguna de Santa Rosa is a natural overflow basin covering 254 square miles and connects the Mark West creek and other smaller creeks with the Russian River.

The Water Agency provides maintenance services for over 150 miles of engineered and natural channels (creeks) in addition to the maintenance of the Central Sonoma Watershed reservoirs and upper Russian River channel and levee maintenance. The maintenance activities include debris removal, bank stabilization and protection, maintenance of inlet/outlet structures, silt removal, vegetation management, levee repair, service road maintenance and dam and reservoir structure maintenance. The Water Agency also maintains several gauging stations along the Russian River that provide information on rainfall intensity, river height and discharge that is essential to flood forecasting.

2.4 EMERGENCY POWER

Electrical power to operate the Water Agency's facilities is delivered by the Power and Water Resources Pooling Authority (PWRPA) and Pacific Gas and Electric Company (PG&E). Power to the collector wells is provided by a substation located at the Wohler Corporation Yard that is owned and operated by the Water Agency. Power from the substation is delivered to the collectors at Wohler and Mirabel through a 12-kV power-line that runs along the river and infiltration ponds as shown in Figure 3.

The Water Agency has provisions to provide emergency electrical power to its main pumps at the collector wells. Three fixed place emergency generators are located at the Wohler Corporation Yard. Each of these generators is 4160 volt, 2MW and can run any combination of pumps, up to a maximum of six, at both the Wohler and Mirabel collectors. The Mirabel facility has two fixed place 480 volt, 1,100 kW diesel generators that can operate two of the main pumps at the Mirabel collectors. The

diesel generators are fueled by two diesel fuel tanks (10,000 and 20,000 gallon capacity) located at each generator site.

Emergency power to the booster pumping stations and emergency wells can be provided by portable trailer mounted 480 volt generators. In addition, a fixed place diesel generator is also located at the Sonoma No. 2 booster station.

2.5 ADMINISTRATIVE INFRASTRUCTURE

The Water Agency occupies three office facilities located at 404 Aviation Boulevard, 204 Concourse Boulevard and 2150 College Avenue in Santa Rosa.

The Aviation Boulevard facility is the Administration Building and houses a majority of the engineering, administration, accounting, environmental, public affairs and executive management staff. The Administration Building is powered by solar photovoltaic panels that have been installed on the building roof and on ground-mounted power canopy.

The Concourse Avenue facility is located close to the main administration building at 404 Aviation Boulevard. This facility houses SCADA control room, emergency operations center, office and cubicle space, locker rooms, dispatch area, tool room, water, electrical, and industrial waste labs, wood, metal, welding, and repair shops, central supply, additional parking, secure parking for motor vehicles (as well as bicycles inside and outside the building).

The College Avenue facility is occupied by stream maintenance and collection system maintenance crews and a water quality laboratory. In the near future all of these functions are planned to be moved to a different location.

3.0 HAZARD ASSESSMENT

For the development of this LHMP, close to 30 natural hazards were reviewed and their impact on the Water Agency's infrastructure evaluated. Table 3 provides a summary of different natural hazards for the Water Agency.

Table 3: Hazards Summary for Sonoma County Water Agency

Hazards	History	Frequency	Probability	Impact	Comments
Natural Hazards					
Avalanche	No	Low	Low	No	Snow uncommon
Coastal Erosion	Yes	Low	Low	No	No infrastructure near coast
Coastal Storm	Yes	Low	Low	No	No infrastructure near coast
Corrosive Soils	Yes	Medium	Medium	Yes	Active corrosion control program
Dense Fog	Yes	Low	Low	Low	Limited impact
Earthquake	Yes	Low	High	High	Included in the plan
Expansive Soils	No	Low	Low	Low	High in some portions of Sonoma County
Extreme Heat	Yes	Low	Low	Low	Short duration event
Flood	Yes	High	High	High	Included in the plan
Hailstorm	Yes	Low	Low	Low	Limited impact
Hurricane	No	Low	Low	Low	Limited impact
Land Subsidence	Yes	Low	Low	High	Part of earthquake hazard
Landslide	Yes	Medium	Medium	Low	Facilities located outside of hazard area
Severe Winter Storm	Yes	Medium	Medium	High	Included in the plan as part of flood
Tornado	Yes	Low	Low	Low	Low hazard, limited impact
Tsunami	No	Low	Low	Low	Facilities located outside of hazard area
Volcano	No	Low	Low	Low	No active volcanoes
Wildfire	Yes	High	High	Low	Facilities located outside of hazard area
Windstorm	Yes	Low	Low	Low	Limited impact
Agricultural Hazards					
Drought	Yes	Low	Low	Med.	Part of urban water management plan
Freeze	Yes	Low	Low	Low	Limited impact
Pest	Yes	Low	Low	Low	No impact to the Agency
Salmon Fishing	Yes	Low	Low	Low	Private sector economic loss
Technological Hazards					
Dam Failure	No	Low	Low	Med.	Included in plan
Power Failure	Yes	Low	Low	Low	Emergency power at critical locations
Hazmat Release	Yes	Medium	Low	Med.	Emergency plans in place
Pandemic Influenza	Yes	Low	Unknown	Low	Public health issue
Radiological	No	Low	Low	Low	Limited impact
Terrorism/Bioterrorism	No	Low	Unknown	Unknown	SVA study performed

Some of the most significant hazards that impact the Water Agency include earthquake and earthquake related hazards such as surface fault rupture, strong ground shaking and liquefaction followed by flood, wildfire and other geologic hazards such as landslides. Figure 7 to Figure 17 show the Water Agency's water supply system overlaid on GIS maps of significant natural hazards in Sonoma County.

Similarly, Figure 19 through Figure 28 show sanitation districts and zones overlaid on GIS maps of significant natural hazards in Sonoma County.

These hazards are discussed in more detail in the following sections.

3.1 EARTHQUAKE HAZARD

Sonoma County is the northernmost of the nine counties that constitute the seismically active San Francisco Bay Area. Earthquakes in the Bay Area occur due to a sudden slip on one of the several major faults of the San Andreas Fault system. The slip releases a tremendous amount of strain energy stored along these faults from the relative movement (approximately 2 inches per year) between the Pacific oceanic plate and the North American continental plate. When the accumulated strain on the fault reaches the threshold strength of rock in the earth's crust, it is released in an earthquake by sudden rupture that could be several miles long along the fault. Depending on the size and nature of the earthquake the fault rupture can be manifested as surface dislocation of several feet along the surface trace of the fault. Some of the major faults in the San Andreas Fault system include the Hayward, Calaveras, San Gregorio, Rodgers Creek and Maacama faults. Several of these faults have been seismically active in historical time and have produced large earthquakes with surface rupture. Figure 4 shows the fault map of the Bay Area.

3.1.1 Historic Seismicity

The Bay Area has experienced at least nineteen earthquakes greater than Magnitude[2] 6.0 during the last 150 years. The largest of these has been the April 21, 1906 Great San Francisco earthquake [27, 28]. The Magnitude 7.8, 1906 earthquake caused extensive damage in the San Francisco Bay Area including Sonoma County. Other significant historic earthquakes that caused substantial damage in the Bay Area include the 1838 earthquake, the 1868 earthquake on the Hayward Fault and the recent Loma Prieta earthquake in 1989.

For the Bay Area, a plot of moderate to large earthquakes on a time scale (Figure 5) shows that the seismic activity in the region prior to the 1906 earthquake was significantly higher than that following it. Most likely, this is because the 1906 earthquake created a stress shadow by substantially relaxing stress on all of the Bay Area faults that form the San Andreas Fault system [29]. As shown in Figure 5 there

[2] Magnitude is a quantitative measure of energy released in an earthquake. Due to the logarithmic nature of the magnitude scale, an increase in magnitude by one unit produces 30 times more energy. A qualitative descriptor of the effects of earthquake on the built environment or those experienced by humans is the Modified Mercalli Intensity. It ranges from I (not felt) to XII (complete destruction) with intermediate values such as VI described as felt by everyone, many frightened and run outdoors or IX described as general panic, complete destruction of poorly constructed masonry.

appears to be an increased earthquake activity in the last two decades suggesting that the Bay Area might be emerging from the 1906-induced stress shadow, and that faults that have been quiescent during the past century, may now once again become more seismically active. Recent work by the Working Group on California Earthquake Probabilities (WGCEP), a group of leading scientists, practitioners and academics has estimated very high probabilities (63%) of a major earthquake in the Bay Area in the next 30 years (Figure 6) [28]. The most significant contributor to this probability is the Hayward-Rodgers Creek fault zone. The Rodgers Creek fault, which is considered the northern extension of the Hayward fault runs through the Water Agency's service area and cuts across one of its major water pipelines (Figure 7). The fault also runs close to the lift station for the Airport/Larkfield/Wikiup Sanitation Zone as shown in Figure 19. The WGCEP has estimated a 31% probability for a major earthquake on the Hayward-Rodgers Creek fault zone within the next 30 years. This value has been increased from their 2002 estimate of 27%. The probability of earthquake on the Hayward-Rodgers Creek fault zone is also higher than any other fault in the Bay Area including the San Andreas Fault. Research studies show an average earthquake recurrence interval of 131-370 years for the portion of the fault located in the Water Agency's service area [30-32].

The most recent earthquakes on the Rodgers Creek fault occurred on October 1, 1969 near Santa Rosa as two Magnitude 5.6 and 5.7 events located within a kilometer of each other [33-36]. The earthquakes struck within a span of about 1.5 hours and resulted in considerable damage in Santa Rosa including significant damage to water distribution system including cracks in the Lake Ralphine Dam. Prior to the 1969 events, the other known earthquake on the fault was the 1898 Mare Island event with a magnitude in the 6.2 to 6.7 range.

3.1.2 Surface Fault Rupture Hazard

In large magnitude earthquakes fault rupture can extend to the ground surface resulting in one side of the fault moving relative to the other by as much as several feet. Structures located within the fault rupture zone are subjected to excessive ground deformations. Most structures are not designed to withstand such large deformations and can experience major damage.

From the surface fault rupture hazard viewpoint, the Water Agency's facilities are most severely impacted by the Rodgers Creek Fault, which passes through Sonoma County and cuts across the Water Agency's Santa Rosa aqueduct near Doyle Park in the City of Santa Rosa. Paleoseismic observations on the Rodgers Creek fault show three surface-rupturing earthquakes between about AD 1000 and 1776. The studies show that the events likely produced approximately 5.1 to 7.2 feet of maximum fault

offset. The CDMG Special Publication 112, the Planning Scenario for a major earthquake on the Rodgers Creek fault prepared by the California Geological Survey [37] considers a Magnitude 7.0 earthquake with an average offset of 3 feet as most likely. Surface displacements on this order of magnitude are almost certain to rupture the Santa Rosa aqueduct, which is not designed to withstand such large displacements.

In addition to the Rodgers Creek fault, recent studies by the USGS [38, 39] show that a segment of the Bennett Valley Fault, a fault previously considered inactive, may be accommodating fault slip between the Rodgers Creek fault and the Maacama fault to the north. This fault segment has been recently labeled the 'Spring Valley Fault' [39] (Figure 7). The Spring Valley fault segment of the Bennett Valley fault zone forms the eastern boundary of a prominent structural pull-apart basin beneath Santa Rosa and Rincon and Bennett Valley [39].

Mapping of the Spring Valley fault in the Spring Lake area shows that the fault crosses the Water Agency's Sonoma aqueduct and the Oakmont pipeline near the Sonoma booster stations. The fault is well expressed in this area and crosses beneath the Sonoma Booster Station No. 2. The amount of possible lateral slip and/or vertical offset across the mapped fault traces is currently unknown. However, significant transfer of slip between the Maacama and Rodgers Creek fault zones is believed to occur across the eastern margin of the pull-apart structure on the Spring Valley fault [39]. The inferred high slip rate [38, 39] on the fault implies a correspondingly high potential for surface fault rupture.

3.1.3 Strong Ground Shaking

Seismic waves generated as a result of fault rupture propagate through the earth's crust from the rupture front and cause strong shaking of the ground. The intensity of ground shaking at a particular location is measured in terms of ground acceleration that generally decreases with distance from the earthquake source unless modified by local subsurface conditions. The maximum acceleration recorded at a location is referred to as the peak ground acceleration (PGA) and is reported as a fraction of earth's gravitational acceleration (g). The total force experienced by a structure can be related directly to the level of acceleration it experiences.

The distance of the Water Agency's water supply and administration facilities from the nearest major Bay Area faults is shown in Table 4. The table also shows updated scenario and probabilistic estimates of PGA values compared to those included in the 2008 LHMP. The scenario PGA values include median and median plus one standard deviation estimates of PGA from a Magnitude 7.0 earthquake on the Rodgers Creek fault and were computed using the latest ground motion prediction equations [40-43].

The probabilistic PGA values are those estimated by the United States Geological Survey (USGS) for a 10% probability of exceedence in 50 years (mean return period of 475 years) and a 2% probability of exceedence in 50 years (mean return period of 2,475 years) and are based on a detailed treatment of uncertainty [44]. These probability levels are typically used in seismic design of structures and form the basis of the seismic design codes such as the International Building Code [45] and the California Building Code [46]. The 2,475 year return period is considered as an acceptable upper bound for design against collapse.

The estimated median PGA values at the Agency's water supply and administration facilities from a Magnitude 7.0 earthquake on the Rodgers Creek fault range between 0.2g to 0.5g and the median plus one standard deviation values range from approximately 0.4g to 0.9g. Similarly, the probabilistic estimates for 475 year and 2,475 year return period range from approximately 0.4g to 0.6g and 0.6g to 1.1g, respectively. The highest predicted PGA values are at the Kawana and Ralphine tanks, Sonoma Booster station and at the Agency's administration facilities due to their proximity to the Rodgers Creek fault. Figure 8 shows the Agency's system together with a plot of USGS estimates of PGA contours in Sonoma County.

The 475 year PGA values at the Water Agency's sanitation facilities range from 0.3g for the Russian River County Sanitation District, Occidental County Sanitation District and portions of Sonoma Valley Sanitation District to 0.6g for portions of the Airport/Larkfield/Wikiup Sanitation Zone and South Park County Sanitation District (Figure 20).

Table 4: Peak Ground Acceleration (g) at Agency's Facilities

Facilities	Name	Distance to Fault (km)	Deterministic (M = 7)		Probabilistic 10% in 50 Years	Probabilistic 2% in 50 Years
			Median	Median + σ		
Diversion Facilities	Wohler Collector No 1	10.0	0.25	0.42	0.42	0.71
	Wohler Collector No 2	10.0	0.25	0.42	0.42	0.71
	Mirabel Collector No 3	12.0	0.22	0.37	0.38	0.63
	Mirabel Collector No 4	11.9	0.22	0.37	0.38	0.63
	Mirabel Collector No 5	11.6	0.22	0.38	0.38	0.63
	Wohler Collector No 6	9.5	0.25	0.43	0.42	0.71
	River Diversion Structure (RDS)/Inflatable Dam	10.9	0.23	0.40	0.39	0.65
	Occidental Road Well	9.8	0.25	0.43	0.39	0.65
	Sebastopol Road Well	9.8	0.25	0.43	0.41	0.70
	Todd Road Well	9.1	0.26	0.45	0.40	0.67
Storage Facilities	Ralphine Tanks	3.3	0.41	0.71	0.49	0.88
	Cotati Tanks	8.8	0.27	0.45	0.41	0.70
	Forestville Tank	11.4	0.23	0.38	0.38	0.64
	Annadel No. 1 Tank	6.4	0.32	0.54	0.45	0.78
	Annadel No. 2 Tank	8.3	0.28	0.47	0.42	0.72
	Eldridge Tanks	8.5	0.27	0.46	0.40	0.67
	Sonoma Tanks	7.0	0.30	0.52	0.38	0.62
	Kastania Tank	7.8	0.29	0.49	0.49	0.87
	Kawana Springs Tank	1.0	0.50	0.86	0.55	1.01
Pump Stations	Forestville Booster Station	11.4	0.23	0.38	0.38	0.64
	Sonoma Booster Station	4.1	0.39	0.66	0.50	0.91
	Ely Booster Station	6.8	0.31	0.53	0.42	0.72
	Eldridge Booster Station	8.5	0.27	0.46	0.40	0.67
	Wilfred Booster Station	5.5	0.34	0.58	0.46	0.80
	Kastania Booster Station	7.8	0.29	0.49	0.49	0.86
	Kawana Booster Station	6.9	0.31	0.52	0.44	0.76
Treatment Facilities	River Road Chlorination Facility	11.4	0.23	0.38	0.38	0.64
	Mirabel Chlorination Facility	12.0	0.22	0.37	0.39	0.65
	Wohler Chlorination and Corrosion Control Facility	10.0	0.25	0.42	0.42	0.71
Administration Facilities	404 Aviation Boulevard, Santa Rosa	2.4	0.45	0.76	0.59	1.07
	2150 W. College Ave, Santa Rosa	4.5	0.37	0.63	0.50	0.90
	204 Concourse Ave, Santa Rosa	2.4	0.45	0.76	0.59	1.07

NOTE:

The peak ground acceleration values are for rock/dense soil conditions with average shear wave velocity of 760m/s for top 30m.

Deterministic ground motions were computed using the NGA relationships [40-43]

Probabilistic ground motions computed by USGS were based on an average of multiple attenuation equations

3.1.4 Liquefaction and Lateral Spread

Liquefaction is a phenomenon in which loose granular soils saturated with water lose their ability to carry load when subjected to strong shaking. The shaking causes an increase in pressure exerted by the entrapped water within the pores of soil matrix and causes the soil to flow as a liquid. This subsurface process manifests itself in the form of large ground deformation and sand volcanoes at the ground surface. When liquefaction occurs near a free face such as a stream or river bank large horizontal movement of ground can occur as the overlying soil layers slide over the liquefied layer towards the free face. This phenomenon known as lateral spread is very detrimental to buried pipelines and pose a much greater hazard to facilities and

pipelines than liquefaction alone.[47,48] Lateral spreads can develop on gentle slopes (less than 3 degrees) and may produce horizontal displacements of as much as tens of feet [49].

The potential for liquefaction depends on both the susceptibility of a soil deposit to liquefy as well as the opportunity for ground motions to exceed a specified threshold level. Given the proximity of Sonoma County to the San Andreas and Rodgers Creek faults, virtually all parts of the County are exposed to long duration peak ground accelerations in excess of 0.15g (Figure 8). To assess the liquefaction and lateral spread hazard to the Water Agency's facilities, potentially liquefiable soils that consist of young alluvial deposits and artificial fill present within Sonoma County are overlain on the Agency's water supply system as shown in Figure 9 and sanitation facilities in Figure 21. The figure also shows locations where the pipelines cross streams and open slope faces. Such stream crossing locations coupled with high liquefaction potential have a very high likelihood of lateral spread and resulting pipeline damage.

All of the Agency facilities that lie in areas marked as moderate, high and very high will likely experience liquefaction because the estimated ground acceleration at all Agency facilities is greater than 0.3g, the triggering threshold for a moderate susceptibility rating. As shown in Figure 9and Figure 21, significant portions of the Water Agency's facilities are vulnerable to liquefaction.

Areas of high and very high liquefaction potential exist at the water supply facilities that include collector sites, Mirabel well-field and Ely booster station. A high susceptibility to liquefaction exists along the water transmission lines, the Wohler Intertie, most of the Santa Rosa aqueduct, significant portions of Petaluma aqueduct and localized areas of the Cotati and Sonoma aqueduct. Creek crossings along these portions of the transmission system have a very high potential for damage due to the potential for lateral spread. The main power line from the Wohler substation to the collectors is also located in an area of very high liquefaction potential.

3.1.5 Earthquake Induced Landslides

Earthquake-induced slope failures or landslides commonly occur over wide areas on hill slopes during large (magnitude 6.5 or larger) earthquakes and can produce significant damage. The most common earthquake-induced failures are rockfalls, rock and soil slides, and soil avalanches, slumps and flows. Rockfalls, avalanches, and flow-type failures are especially hazardous because they often occur rapidly and travel great distances from the point of initiation. These types of rapid failures present significant impact to structures sited on slopes or valley areas downhill from

the initiation site, and can distort or break shallow-buried pipelines crossing the sliding plane of the slope failure.

The opportunity for seismically induced slope failure is dependent on the potential for appropriately high levels of ground shaking to initiate movement. The susceptibility for failure is based on conditions that predispose the slope to failure including static stability, local geology, slope inclination, groundwater conditions, rock strength, and the duration and intensity of shaking. The potential for landslides is higher during seasonal wet periods when hill slopes are saturated with water.

Figure 10 and Figure 22 show updated regional landslide susceptibility mapping for Sonoma County produced by the California Geological Survey. Though various workers have mapped the geology of Sonoma County, most published geologic maps of the Agency's service area do not delineate active or recently active landslides or slope failures. Therefore, there is a possibility of small localized landslides that could result in damage to pipelines especially along the runs that connect to the tanks located on hills.

Figure 10 shows that most of the Water Agency's water system is located outside of active landslide areas with only a few locations such as a portion of the Santa Rosa aqueduct near the collectors, a small portion of the Russian River-Cotati Intertie south of Forestville tanks and areas near the Kastania, Eldridge, Cotati and Los Guilicos tanks may be somewhat susceptible to landslide hazard. More detailed assessments show that the landslide hazard at these locations is low. Figure 22 shows similar observations for the sanitation system.

3.2 FLOOD HAZARD

Flooding is defined as the overflow of excess water from a water body onto adjacent floodplain lands. Flooding typically results from large-scale weather systems generating prolonged rainfall or on-shore winds. Other causes of flooding include locally intense thunderstorms, snowmelts, ice jams and dam failures. Floods are capable of undermining buildings and bridges, eroding shorelines and riverbanks, tearing out trees, washing out access routes, and causing loss of life and injuries.

Flash floods pose more significant safety risks than other riverine floods because of the rapid onset, the high velocity of water, the potential for channel scour, debris load and increase in turbidity of water that can directly impact the Water Agency's water supply. In addition, more than one flood crest may result from a series of fast moving storms.

Sonoma County has had significant flooding in the past and is expected to have floods in the future. Table 5 shows the highest recorded stage of the Russian River at

Guerneville between 1940 and 2006 [50, 51]. According to the National Weather Service (NWS) of National Oceanic and Atmospheric Administration (NOAA) various flood related stages at the Guerneville station are defined as, action stage at 29 feet, flood stage at 32 feet, moderate flood stage at 35 feet and major flood stage at 40 feet [50, 52]. Other sources [53] provide additional details such as various road intersections and landmarks flooded at different river stages. Water level in the Russian River as high as 17.5 feet above the flood stage (32 feet) has occurred in the past as shown in Table 5.

The flood hazard within Sonoma County prepared by the Federal Emergency Management Agency (FEMA) is shown in Figure 11 and Figure 23. These maps use computed or estimated water surface elevations combined with topographic mapping data to represent the flood hazard. The 100-year flood represents a compromise between minor floods and the greatest flood likely to occur in a given area. In most cases the 100 year flood is less than the flood of record and has been widely adopted as the common design and regulatory standard in the US. It was formally established as a standard for use by Federal agencies in 1977 and later confirmed by FEMA in 1982.

Figure 11 shows the Water Agency's water system overlain on the FEMA flood maps. The figure also shows the locations where the pipelines cross creeks. These locations together with areas of high flood hazard are at the highest risk of damage due to channel scour. Debris flow in streams and the potential for bottom scour and the resulting pipeline damage is also a potential hazard. As shown in the figure, the water supply facilities with the highest risk of flooding include those located in the Mirabel and Wohler area, Ely booster station, the Sebastopol and Todd Road wells, significant sections of the Russian River-Cotati Intertie, Forestville aqueduct and Wohler Intertie and some portions of the Santa Rosa aqueduct. Stream crossing locations of the transmission lines located in the areas of high flood hazard are most vulnerable to damage due to flood related scour. In addition, there are three locations where a pipeline is suspended from a bridge at the stream crossing location. At these locations, the pipeline is vulnerable to damage by impact from floating debris.

The Russian River area poses the greatest flood threat to water agency assets. However, all Water Agency water facilities located in the Russian River floodplain have been elevated to be above the 100-year flood elevation, including booster pumping stations and emergency generators. The seven vertical wells located in the Russian River floodplain are vulnerable to flooding but are sealed when flood alerts are issued to prevent contamination. Due to proximity to the Russian River, all six existing water collectors are subject to flooding.

Table 5: Historic Floods in Sonoma County

No.	Date	Historical Crests for Russian River at Guerneville
1	February 18, 1986	49.50
2	January 10, 1995	48.00
3	December 23, 1955	47.62
4	December 23, 1964	47.35
5	February 28, 1940	46.87
6	January 1, 1997	44.99
7	January 2, 1997	44.25
8	January 5, 1966	42.50
9	January 1, 2006	41.81
10	March 10, 1995	41.45
11	January 24, 1970	41.30
12	February 1, 1963	41.10
13	January 17, 1974	40.70
14	January 27, 1983	40.40
15	February 25, 1958	40.20
16	January 17, 1978	39.50
17	January 14, 1969	39.50
18	January 22, 1943	39.50
19	January 21, 1967	39.30
20	December 20, 1981	39.00
21	February 6, 1942	39.00
22	January 17, 1954	38.35
23	January 8, 1960	38.10
24	January 12, 1973	37.90
25	February 4, 1998	36.60
26	February 13, 1975	36.60
27	December 4, 1970	36.50
28	January 21, 1993	36.30
29	February 7, 1998	36.04
30	January 14, 1980	36.00
31	February 13, 1962	35.80
32	December 28, 1945	35.22
33	December 4, 1950	34.70
34	December 25, 1983	34.20
35	January 10, 1953	34.15
36	February 20, 1998	33.06
37	February 16, 1959	32.50
38	April 5, 1941	31.80

Sonoma County complies with the flood plain management requirements of the National Flood Insurance Program (NFIP) compliance through the implementation of its Flood Damage Prevention Ordinance regulations set forth in chapter 7B of the County Code. These procedures have been in place since January, 1982, when the county elected to participate in the NFIP and first received flood insurance rate maps, floodway maps and the attendant certification requirements. The ordinance provisions, definitions, and requirements were modeled after language recommended by the NFIP and were reviewed and found fully compliant by the NFIP. The County's flood zones and mapping in the General Plan Safety Element and other documents are based on the 100-year flood zones and floodways shown in the Flood Insurance Rate Map.

The Water Agency participates in the NFIP under the umbrella of Sonoma County. As the custodian of a sizeable portion of the flood control in Sonoma County the Water Agency's role in flood protection and its impact on NFIP compliance is significant. These activities are discussed in more detail in the Flood Control Section of this document.

3.3 GEOLOGIC HAZARDS

3.3.1 Landslides

Hill slopes along the Water Agency's pipeline corridors and their facilities have been modified by mass wasting processes, including landslides, debris flows, soil creep, gully and stream erosion, and sheet wash. These processes are episodic, with failures typically occurring during or shortly after periods of heavy precipitation. Types of slope failure that are usually caused by prolonged rainfall include rotational slumps, earthflows, and rapidly moving debris flows. Figure 10 and Figure 22 show overall susceptibility of hillslopes in Sonoma County to slope failure and Figure 12 shows historic landslides in Sonoma County during El Nino storms of 1997-1998.

Most of the landslides present along the Water Agency's water pipeline corridors fall into two primary types: (1) rotational and translational landslides involving bedrock and colluvium, and (2) debris or earth flows involving colluvium.

Rotational and translational landslides pose the primary slope stability hazard along the water pipeline corridors. The landslides commonly are distinguished by vegetation changes and characteristic slope morphology, including undulating, hummocky ground surface. Deep rotational and translational landslides typically involve underlying bedrock and are mainly associated with steep slopes greater than 15˚ and showing signs of water seepage. As shown in Figure 10 the overall landslide hazard within the water supply system is low.

Debris and/or earthflows typically occur where colluvium collects in topographic swales on hillslopes. During heavy rainfall, saturated colluvium may flow rapidly down drainage channels. Poorly sorted debris within a flow may be deposited where the slope angle decreases or may increase in volume with distance traveled downslope. The primary potential hazard posed by debris flows to the pipeline is the relatively rapid movement of soil surrounding the pipeline, and associated displacement of the pipeline. Pipeline displacement is more likely at the debris-flow headscarp than in lower parts of a debris flow. Figure 13 shows debris flow hazard in Sonoma County mapped by the USGS. Because debris flows travels downslope and downstream from the source area, the hazard associated with debris flows extends

beyond the mapped areas. The map also shows debris-flow sources (represented by black dots on the map) mapped after the major storms of January 1992.

3.3.2 Corrosive Soils

Potential external corrosion hazards to pipeline systems are dependent in part on the conductivity of the ground and the corrosive nature of soils in which the pipeline is buried. Corrosivity of soils is dependent on soil texture, soil pH, moisture content, and geochemical composition of fluids within the soil. These factors, in turn, are influenced by the physical and mineralogical composition of soils. Soil composition often is directly derived from the characteristics of the underlying geologic deposits on which they develop. Silty and clayey soils tend to have the highest corrosion potential in contrast with granular soils (sands and gravels). In addition, the topography of the land, depth to groundwater, and native vegetation all influence the soil corrosivity potential.

Although soil corrosivity can exist within a broad range of soil conditions, the extent of acidity or alkalinity of a soil, as expressed by pH, directly influences corrosion susceptibility. Soil with pH generally less than 9.0 has been found to be among the more corrosive types. Typically soils with a pH of 0.0 to 4.0 are acidic and, when saturated, can serve as a corrosive electrolyte. Soils with a near neutral pH of 6.5 to 7.5 and low Redox conditions are optimum for sulfate reduction by bacteria, which can cause localized corrosion.

Soil resistivity also has a strong influence on the corrosion rate. Generally, the higher the resistivity of the soil, the lower is its corrosion rate. Soil resistivity arises from a number of factors, but fine-grained soils (silts and clays) typically have the lowest resistivity and thus the greatest corrosion susceptibility.

The distribution and type of soils within Sonoma County were digitized from Department of Agriculture Soil Conservation Service (SCS) county soil report. Soils are generally sampled only to a depth of 5 to 6 feet (most pipelines are buried within this zone); therefore, soil descriptions are limited to that depth and may not be representative of deeper soil conditions. Soil surveys typically generalize soil properties and thus soil corrosivity estimates likely are conservative. In the SCS report, soil unit codes were referenced to the shrink-swell and corrosivity engineering properties and the corrosion potential as Low, Medium, or High. Corrosivity values compiled from SCS soil surveys, although unit less, are calculated by the SCS based on the rate uncoated steel and concrete might corrode when buried in a soil. These index values are derived from soil texture, drainage, acidity, and electrical conductivity data. Both sets of values are depicted in the soil corrosion maps for the Water Agency's service area as shown in Figure 14 and Figure 15 for the water supply

system. The figures show that except for the Sonoma aqueduct, which has a limited exposure to corrosive soils, all of the Agency's aqueducts lie in highly corrosive soils. The Agency has an active corrosion control program, and as a result there are no indications of prevalent corrosion related damage to the water transmission system. Similar observations are made for the sanitation system (Figure 25 and Figure 26).

3.4 FIRE HAZARD

Fire is relevant to the Water Agency's system from two perspectives: (a) potential damage that fires may directly cause to the Agency's facilities, and (b) firefighting demands on the Water Agency's water supply system – that is, the emergency water supply needs of fire departments who may be relying on the Agency to supply that water. Both aspects are driven by the fire hazard in Sonoma County.

Periodic fires are part of the natural environment and consist of four categories that include wildland fires, urban-wildland interface fires, firestorms and prescribed fires. Wildfires are fueled by naturally occurring trees, brush and grasses; the urban-wildland interface fires are fueled by vegetation and built environment; firestorms occur during extreme weather and generally burn until conditions change or the available fuel is exhausted and; prescribed fires are controlled burns intentionally set for fire management.

The behavior of wildfires is impacted by three principal factors that include topography, fuel and weather. Topography is important because the movement of air over the terrain tends to direct a fire's course and gulches and canyons can funnel air and act as a chimney. Saddles and ridgetops tend to offer lower resistance to the passage of air and will draw fires. Water tanks, which are usually located on ridge tops, are susceptible to fire with south facing slopes being more susceptible because they receive higher solar radiation. Steeper uphill slopes tend to increase the rate of spread, whereas downhill slopes tend to slow down the rate of spread.

Fuel for fires is provided by the amount of vegetative material available. Different fuels have different burn qualities. For example grasses, release little energy but can sustain very high rates of spread. Moisture and continuity of fuel is also very important for the spread of fire.

Figure 16 shows the fire threat map in Sonoma County prepared by the California Department of Forestry. The map shows five threat classes that range from no threat to extreme threat. The figure shows that most of the Water Agency's water system is in an area of low fire hazard except for the facilities in the Wohler and Mirabel area. The figure also shows a high fire threat near the Los Guilicos tank. However, a more detail examination during the site reconnaissance confirmed a low fire hazard because of a clearing zone around the facilities. The Agency has an active

maintenance program to address such issues. Furthermore, since the Agency is a wholesaler it does not have direct responsibility for firefighting. Figure 27 shows the fire hazard for the sanitation facilities.

Table 6 shows some of the major fires in Sonoma County that burned over 1,000 acres. The burn area of these fires is shown in Figure 17. The figure shows that none of these historic fires have impacted the Water Agency's water supply system. Because of the wholesale nature of the water supply system, the Water Agency does not have a direct responsibility to provide water for firefighting, except for a very limited number of fire hydrants located along the aqueducts. Therefore, the direct impact to the water system from wildfires is limited.

Table 6: Major Historic Fires in Sonoma County

Date	Location	Acres Burned
Sep-64	Series: Hanley, Mt. George, Nunns Canyon in Napa and Sonoma County	71,500
	Hanley (Sonoma County)	52,700
	Nunns Canyon (Sonoma County)	10,400
1965	Series of nine fires in Glenn, Napa and Sonoma County	113,766
	Knight's Valley (Sonoma County)	6,000
	Pocket Ranch (Sonoma County)	4,000
	Arrowhead (Sonoma County)	4,000
	Chileno Valley (Sonoma County)	5,000
	Pressley (Sonoma County)	5,500
	Coleman Valley (Sonoma County)	1,500
	Austin Creek (Sonoma County)	7,000
1972	Bradford	1,760
Aug-78	Creighton Ridge	11,405
Aug-88	Cloverdale	1,833
Sep-88	Geysers	9,000
Aug-96	Cavedale	2,100
Oct-99	Geyser Road	1,300
Jun-00	Berryessa (Napa and Sonoma)	5,731
Sep-04	Geysers (Sonoma and Lake)	12,525

3.5 DROUGHT

Unlike typical natural disasters such as earthquakes, floods or fires, drought occurs gradually over a multi-year period. One dry year does not normally constitute a drought in California. For example the driest single year of California's measured hydrologic record was 1977. California's most recent multi-year statewide drought was in 2007-2009 [54] and prior to that in 1987-1992.[55, 56] The 2008-2011 statewide drought declaration was made by the Governor after three years of low water levels. The 2006-2007 water-year was one of the driest year on record with the Sierra

snowpack at its lowest in nearly 20 years. A state of emergency was declared in 2009 by the Governor's office. The National Weather Service's Climate Prediction Center October 2012 seasonal outlook shows drought like conditions in most of California [57].

The Water Agency's extensive system of water supply infrastructure consisting of its reservoirs, groundwater basins, and inter-regional conveyance facilities help mitigate the effect of short-term dry periods for most water users in its service area.

Defining when a drought begins is a function of drought impacts to water users and therefore, there is no universal definition of when a drought begins or ends. Impacts of drought are typically felt first by those most reliant on annual rainfall such as ranchers engaged in dryland grazing, rural residents relying on wells in low-yield rock formations, or small water systems lacking a reliable source. Drought impacts increase with the length of a drought, as carry-over supplies in reservoirs are depleted and water levels in groundwater basins decline.

The historical record of California hydrology is brief in comparison to the time period of geologically modern climatic conditions. As a result, measured hydrologic data for droughts prior to 1900 are minimal. Multi-year dry periods in the second half of the 19th century can be qualitatively identified from the limited records available combined with historical accounts but the severity of the dry periods cannot be directly quantified. Paleoclimatology data based on tree ring studies suggest sustained drought throughout much of the continental U.S. during the mid-1500s that may have lasted as long as 50 years. In addition, some climate researchers describe a "Medieval Megadrought" to describe a series of long duration droughts in the Western U.S. during the 900 to 1400 A.D. time period. Researchers identified two epic drought periods from these remains, one lasting more than two centuries prior to A.D. 1112, and the other lasting more than 140 years prior to 1350.

Droughts, in California within the recorded history, that span over several years include: 1912-1913, 1918-1920, 1923-1924, 1929-1934, 1947-1950, 1959-1961, 1976-1977, 1987-1992 and 2008-2011. The criteria commonly used in designing storage capacity and yield of large Northern California reservoirs was established as a result of the 1929-1934 drought. The 1987-1992 drought was notable for its six-year duration and the statewide nature of its impacts. However, droughts exceeding three years are relatively rare in Northern California, the source of much of California's developed water supply.

In the 1987-1992 drought, water users served by most of the State's larger suppliers did not begin to experience shortages until the third or fourth years of the drought. Reservoir storage provided a buffer against drought impacts during the initial years of the drought. During this time period groundwater extraction increased substantially

and wells or springs serving several small water systems in the Russian River corridor went dry such that water haulage became necessary.

Droughts can have a significant impact on society that can include lost jobs and revenues in the landscaping and nursery industries, unemployment and other socioeconomic impacts in farming dependent regions, increased risk of wildfire, additional cost for homeowners to replace lawns and landscaping, loss of forests, decline in fish population, lost revenues to water based recreation businesses and reduced hydroelectric power generation. Droughts result in a decline of revenues and an increase in operational costs for water agencies. The former occurs due to voluntary or mandatory reductions in water use and the later due to additional cost of purchasing water, deepening wells, or implementing water education and conservation campaigns.

It is not easy to predict droughts because climate is inherently variable and predicting drought depends on the ability to forecast two fundamental meteorological surface parameters, precipitation and temperature. Anomalies of precipitation and temperature may last from several months to several decades and how long they last depends on many factors such as air–sea interactions, soil moisture and land surface processes. Generally, the immediate cause of drought is the predominant sinking motion of air (subsidence) that results in compressional warming or high pressure, which inhibits cloud formation and results in lower relative humidity and less precipitation. Much of California enjoys a Mediterranean-like climate with cool, wet winters and warm, dry summers. An atmospheric high pressure belt results in fair weather for much of the year, with little precipitation during the summer. The high pressure belt shifts southward during the winter, placing the State under the influence of Pacific storms bringing rain and snow. Most of California's moisture originates in the Pacific Ocean. As moisture-laden air moves over mountain barriers such as the Sierra Nevada, the air is lifted and cooled, dropping rain or snow on the western slopes. This orographic precipitation is important for the State's water supply. The majority of California's groundwater production occurs from alluvial materials in the large basins. Groundwater levels in such basins typically decline during droughts due to increased extractions.

The fundamental drought impact to water agencies is a reduction in available water supplies. As a result, historic occurrences of drought have encouraged water agencies to review the reliability of their water supplies and to initiate planning programs addressing identified needs for improvement. In addition, public and media interest in droughts fosters heightened awareness of water supply reliability issues in the Legislature. More than 50 drought-related legislative proposals were introduced during the severe, but brief 1976-77 drought. About one-third of these eventually

became law. Similar activity on drought-related legislative proposals was observed during the 1987-92 drought. One of the most significant pieces of legislation was the 1991 amendment to the Urban Water Management and Planning Act, in effect since 1983, which requires water suppliers to estimate available water supplies at the end of one, two, and three years, and to develop contingency plans for shortages of up to 50 percent. The Sonoma County Water Agency's 2010 Urban Water Management Plan [12] presents water supply to demand comparisons through 2035. The plan also presents water supply to demand comparisons for single dry to multiple dry year scenarios. The comparisons show that the Agency has adequate supply through 2035.

3.6 OTHER WEATHER RELATED HAZARDS

Data obtained from NOAA [58] and presented in Table 7 shows major weather related events in Sonoma County. Description for some of the most significant weather related hazards is provided in the following sections.

Table 7: Historic Weather Related Hazards in Sonoma County

Hazard	Date	Time	Magnitude	Deaths	Injuries	Property Damage	Crop Damage
Blowing Dust	November 2, 1994	5:21 AM	N/A	0	0	0	0
	November 10, 1994	10:43 PM	N/A	0	0	0	0
Dense Fog	December 2, 1994	11:22 AM	N/A	0	0	0	0
	December 3, 1994	1:20 PM	N/A	0	0	0	0
	December 8, 1994	12:45 PM	N/A	0	0	0	0
	December 9, 1994	5:04 PM	N/A	0	0	0	0
	December 10, 1994	6:18 AM	N/A	0	0	0	0
Excessive Heat	August 15, 1996	4:00 PM	N/A	4	0	0	0
	June 14, 2000	12:00 PM	N/A	9	102	0	0
Flash Flood	January 20, 1993	7:15 AM	N/A	0	0	$500K	0
	March 9, 1995	10:34 AM	N/A	0	0	$3.5M	$0.5M
	February 2, 1998	6:50 PM	N/A	0	0	$2.0M	0
	February 3, 1998	4:00 AM	N/A	0	0	$5.0M	0
	February 3, 1998	9:30 AM	N/A	0	1	$200K	$159K
	February 4, 1996	10:00 AM	N/A	0	0	0	0
	December 31, 1996	7:00 PM	N/A	1	0	0	0
	January 3, 1997	8:00 PM	N/A	1	0	0	0
	February 5, 1998	6:00 PM	N/A	0	0	0	0
	February 6, 1998	12:22 PM	N/A	0	0	0	0
	February 7, 1998	1:18 PM	N/A	0	0	0	0
	February 13, 2000	10:00 AM	N/A	0	0	0	0
	February 13, 2000	9:00 PM	N/A	0	0	0	0
	January 11, 2001	10:00 AM	N/A	0	0	$7.0M	0
	December 16, 2002	2:00 AM	N/A	0	0	0	0
	January 25, 2008	8:00 PM	N/A	0	0	$800K	0
Hail	December 9, 2003	11:15 PM	0.75 in.	0	0	0	0

Hazard	Date	Time	Magnitude	Deaths	Injuries	Property Damage	Crop Damage
Heavy Rain	December 12, 1995	2:45 AM	N/A	0	0	0	0
	December 29, 1996	12:00 AM	N/A	0	0	0	0
	January 2, 1998	4:00 AM	N/A	0	1	0	0
	January 1, 2002	3:00 AM	N/A	0	0	$200K	0
	December 15, 2002	8:00 PM	N/A	0	0	0	0
	December 16, 2008	7:00 AM	N/A	0	0	$25K	0
	May 5, 2009	6:30 AM	N/A	1	1	$50K	0
	October 24, 2010	11:00 AM	N/A	0	0	0	0
	February 16, 2011	-	N/A	0	0	0	0
	March 24, 2011	5:00 AM	N/A	0	0	$28.5K	0
	June 4, 2011	1:00 AM	N/A	0	0	0	$20M
Heavy Snow	February 11, 2001	8:00 AM	N/A	0	0	0	0
High Wind	February 4, 1993	9:00 PM	0 kts.	0	0	$500K	0
	July 16, 1996	3:30 PM	35 kts.	1	0	0	0
	November 29, 1998	10:00 PM	75 kts.	0	0	$1.8M	0
	February 9, 1999	11:00 AM	60 kts.	0	0	$1.0M	0
	April 3, 1999	8:00 AM	85 kts.	1	2	0	0
	February 13, 2000	10:00 AM	0 kts.	0	0	$250K	0
	March 19, 2000	3:10 PM	72 kts.	0	0	$250K	0
	October 21, 2000	9:45 PM	97 kts.	0	1	0	0
	March 4, 2001	10:54 AM	71 kts.	0	0	$2.7M	0
	November 24, 2001	7:00 AM	85 kts.	0	0	$7.1M	0
	November 7, 2002	4:00 PM	100 kts.	0	0	$1.0M	0
	December 30, 2002	11:21 PM	63 kts.	0	0	$600K	0
	December 14, 2003	4:33 AM	61 kts.	0	0	0	0
	February 25, 2004	8:29 AM	58 kts.	0	0	0	0
Lightning	January 25, 2001	12:00 PM	N/A	0	1	$1.0M	0
Storm Surge	February 25, 2004	10:00 AM	N/A	0	0	0	0
Tornado	June 1, 1958	7:55 AM	F2	0	0	$25K	0
	February 17, 1959	6:45 AM	F	0	0	$3K	0
	November 10, 1964	3:34 AM	F	0	0	$3K	0
	February 27, 1983	7:20 AM	F1	0	0	$25K	0
	December 2, 1992	5:00 PM	F1	0	0	$25K	0
	December 2, 1992	5:00 PM	F1	0	0	$25K	0
	December 2, 1992	5:00 PM	F1	0	0	$250K	0
	February 22, 1996	1:00 AM	F1	0	0	0	0
	December 23, 1996	11:30 AM	F0	0	1	$1K	1K
	December 5, 1998	6:20 PM	F1	0	0	$1.0M	0
	March 18, 2011	9:15 AM	F1	0	0	$50K	0
Winter Storm	February 16, 1994	8:00 PM	N/A	0	0	$500K	0
	December 9, 1995	10:00 AM	N/A	1	15	$60.0M	5.0M
	March 10, 1995	5:09 AM	N/A	0	0	0	0

3.6.1 Tornadoes

While California does have tornadoes, it is relatively low-risk compared to states in the Midwestern and Southern United States as shown in Figure 18 [59].

Since 1950, 292 tornadoes have occurred in 42 counties in California, resulting in 103 injuries. However, no deaths have occurred, and none of the California tornadoes since 1950 have been over F2 on the Fujita Scale (Table 8). Of these 292 tornadoes, only eight percent reached F2, whereas 53 percent were at F0, the least severe type and 39 percent reached F1. No major tornadoes (those of F3-F6) have occurred after 1880 in California. The biggest risks of tornadoes in California include light to moderate damage to homes, destruction of mobile homes, and injuries caused by light object projectiles during F2 scale tornadoes. In the 52 years between 1950 and 2002, the average occurrence of an F2 scale tornado has been approximately once every 2.36 years [60].

Table 8: Fujita Scale for Tornado Intensity

Scale Value	Wind Speed Range and Description of Damage
F0	**40-72 mph (17.8-32.6 m/s)**: Light damage. Some damage to chimneys; tree branches broken off; shallow-rooted trees pushed over; sign boards damaged. Average number per year, 1953-1989: 218 (29 percent).
F1	**73-112 mph (32.7-50.3 m/s)**: Moderate damage. The lower limit is the beginning of hurricane wind speed. Roof surfaces peeled off; mobile homes pushed off foundation or overturned; moving autos pushed off road. Average number per year, 1953-1989: 301 (40 percent).
F2	**113-157 mph (50.4-70.3 m/s)**: Considerable damage. Roof torn out from houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated. Average number per year, 1953-1989: 175 (23 percent).
F3	**158-206 mph (70.4-91.9 m/s)**: Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown. Average number per year, 1953-1989: 43 (6 percent).
F4	**207-260 mph (92.0-116.6 m/s)**: Devastating damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown; large missiles generated. Average number per year, 1953-1989: 10 (1 percent).
F5	**261-318 mph (116.7-142.5 m/s)**: Incredible damage. Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile-sized missiles fly through the air in excess of 100 yards; trees debarked. Average number per year, 1953-1989: 1 (0.002 percent).

* Wind speeds in the range are defined by Fujita to be "the fastest 1/4-mile wind"

Source: Golden and Snow, "1991: NOAA, NWS Disaster Survey Report", 1991

3.6.2 Hurricanes

California is also at very low risk of hurricanes, although it is possible for one to threaten the southern California coast [61]. No hurricanes have hit California in recorded history because tropical storm winds generally blow from east to west, however, the State is affected by heavy rain resulting from tropical winds that blow north from Mexico and become colder by the time they hit California [62].

Risk to the Water Agency's facilities from tornadoes or a hurricane is low compared to earthquakes and flood because any damage will be localized and not likely to be system wide. Therefore, it would be possible to respond in a timely manner to repair the damage with small downtime. The most vulnerable system components to tornados, hurricanes, high wind and lightning strike will be the power and SCADA systems. The Agency has the ability to operate its system from three locations that include the Concourse Boulevard facility, the Sonoma Valley County Sanitation District (SVCSD) reclamation plant and the Russian River County Sanitation District (RRCSD) treatment facility. In the event the Concourse Boulevard facility is nonfunctional, radio communications to the other two locations most likely cannot be maintained, which makes the Concourse Boulevard facility a critical link and damage to this facility could result in loss of SCADA link to other facilities.

3.6.3 Tsunami Hazard

A tsunami is a series of waves generated in a body of water by a rapid disturbance that vertically displaces the water. These changes can be caused by an underwater fault rupture (that generates an earthquake) or underwater landslides (typically triggered by earthquakes). The hazard to Sonoma County is limited to areas of coastal exposure, between Jenner and Bodega Head including Salmon Creek and Bodega Bay, and along the northern margin of San Francisco Bay, including between Sears Point and Petaluma Point. No Agency facilities are located in these areas and therefore are not exposed to tsunami hazards.

3.6.4 Climate Change

Projected climate changes over the next century have the potential to significantly impact water supply and associated hazards in Sonoma County, including flooding and increased fire hazard. Global warming likely will cause shifts in the timing and amount of flow in the Russian River while accompanying sea-level rise likely will impact the hydraulic response and sediment carrying capacity of the River along with major streams feeding the San Francisco Bay to the south.

Sea level rise is projected to proceed at a rate of 50 cm over the next 100 years [63, 64], an acceleration of the recent historical rate of 23 cm/century [65]. Projected sea level rise likely will result in changes to stream hydraulic gradients and may increase upstream backwater flooding. Decreased precipitation in the Russian River watershed and associated decreased flow in the Russian River has the potential to impact the Water Agency's water supply. Decreased precipitation from climate change also has the potential negative impact of increased fire danger, although regional landslide hazards (related to rainfall) may be decreased.

4.0 VULNERABILITY ASSESSMENT

Damage to water supply and wastewater collection systems following a major disaster, especially an earthquake, can lead to significant disruption. This is based on observations from several recent earthquakes such as the 1989 Loma Prieta earthquake, the 1994 Northridge earthquake, the 1995 Kobe, Japan earthquake and the September 2010, February 2011, June 2011 and December 2011 Christchurch, New Zealand earthquakes. During the 2010-2011 Christchurch earthquakes more than 78 km of water pipelines were damaged with majority of damage occurring in areas of high liquefaction [66] requiring hundreds of pipeline repairs. Most of the downtown Christchurch area became uninhabitable due to widespread liquefaction related damage [66].

In Kobe water pipelines sustained severe damage with numerous breaks that resulted in lack of service in several communities. Approximately 29,000 people were without water supply for a month following the earthquake [67]. Over 100 fires broke out within minutes after the earthquake. Water for firefighting was available for only 2 to 3 hours, and subsequently water was available from tanker trucks only. For several days after the earthquake there were long lines of people waiting for water and food. Similarly there was significant disruption of water service following the Northridge earthquake. There was damage at 15 locations in the three transmission system pipelines that transmit water to the south from Northern California and at 74 locations in large diameter trunk lines and 1,013 locations in the Los Angeles Department of Water and Power's (LADWP) distribution pipeline network including damage to tanks and other facilities. Water system damage was distributed over approximately 1,200 square kilometers [68].

During the 1989 Loma Prieta earthquake 20 million gallons of raw sewage were reportedly dumped into the Oakland Estuary in a six hour period following the earthquake. Damage to sewage treatment facilities during the 1994 Kobe and the 2004 Chuetsu, Japan earthquakes resulted in release of polluted water to flow directly into public bodies of water. Damage resulted from the lifting of pipes and manholes in zones of liquefaction. Damage to sewage systems can also create a public health hazard through backing up of sewage in homes and uncontrolled release of untreated water.

4.1 WATER SUPPLY

A vulnerability assessment of the Agency's water supply facilities was performed through a review of available drawings, site reconnaissance and as needed engineering calculations (ranging from simplified to detailed). The Agency's water transmission system is shown in Figure 1. Figure 7 through Figure 18 show the water

system overlain on maps of most credible hazards. A review of the overall system shows that portions of the system lack redundancy and a single pipe break or loss of a single component such as a key pump station can result in significant disruption. The natural hazard reliability study assessed the impact of these vulnerabilities on system response through a detailed hydraulic model of the system. A range of damage scenarios were postulated and the system response in terms of loss of pressure at the contractor turnout and loss of storage in the tanks was studied. The analyses showed that within a matter of hours one or more such failures can deplete water storage and cause significant pressure loss at turnouts serving the contractors.

In addition to the vulnerability assessment of the Water Agency's water supply infrastructure, an overview of water distribution systems of Agency's contractors and a qualitative assessment of their potential seismic vulnerabilities was performed. The purpose of this work is to assess the potential for major breaks in the distribution systems and their likely impact on the Water Agency's water transmission system. A major break or multiple leaks within the contractor's system could impose significant additional demands on the water transmission system during and after an emergency. The assessment showed that the contractor systems are subject to similar hazards and are vulnerable to significant damage. An uncontrolled release of water from the contractor system will impose excessive demands on the Water Agency's water system, and means to monitor contractor system response through flow measuring devices at turnouts was recommended.

The sections below describe the significant vulnerabilities to the water supply infrastructure associated with the identified hazards.

4.1.1 Russian River System

The primary source of water for the Water Agency's water system is the Russian River that charges an aquifer beneath and adjacent to the river through the overlying gravel layer by natural filtration. The most significant vulnerabilities to the water source consist of possible contamination and increase in turbidity during major floods, wildfires, debris flow and landslides. A hazardous material spill from an accident can also result in possible contamination. The effect of such contamination can be minimized, depending upon its extent, by releasing water from the upstream dams and flushing the contaminants. The Water Agency's emergency operations plan addresses such events. During a major earthquake there could be a loss of permeability of the aquifer due to liquefaction or dynamic densification of the gravel resulting in compression or dilation of the aquifer. Significant loss of production capacity during a short time following a major earthquake can occur, but generally

the aquifers tend to recover after a period of time. Such changes have been observed in past earthquakes.

The Water Agency's Warm Springs and Coyote Valley dams are located within close proximity of major active faults. The dams were constructed in 1982 and 1959, respectively. The Warm Springs dam is located 4 kilometers from the Healdsburg fault, a northward extension of the Rodgers Creek fault, and 10 kilometers from the Maacama, 23 kilometers from the Hayward and 29 kilometers from the San Andreas Fault. The Coyote Valley dam is located 1.4 kilometers from the Maacama fault, and more than 50 kilometers from the San Andreas, Rodgers Creek and Healdsburg faults. Both dams are part of the flood control system, and the US Army Corps of Engineers is responsible for dam safety.

4.1.2 Diversion Facilities

The components of the Water Agency's system that facilitate the diversion of water from the source (the Russian River aquifer) to the transmission system are referred to as the diversion facilities. The diversion facilities can be grouped into those that draw water from the aquifer and those that help recharge it. The former include the six collector wells and the Mirabel well field, while the latter include the inflatable dam, the RDS (river diversion system) caisson, infiltration ponds, diversion channels and the main dike.

The earliest of the six collector wells were built in 1958 and the latest in 2005. The general construction of the collector well includes a large diameter (ranging from 13 to 18 feet inside diameter and 18 to 33 inch thick walls) concrete caisson that extends from the ground surface into the aquifer. The caissons range in length from about 108 feet to 123 feet. At the bottom of each caisson, perforated pipes (known as laterals) extend radially into the aquifer. Each lateral is over a 100 feet long and ranges in size from 8 to 10 inch diameter for the older five collectors and 12 to 18 inches for the newest sixth collector. Each caisson supports a pump house with two pumps that draw water collected inside the caisson. All of the supporting electrical and communication systems to operate the pumps remotely are located in the pump house.

The pump houses of each collector well are located well above the maximum flood levels and have a low likelihood of direct damage from flood or debris impact. The diversion system facilities are located in an area of very high liquefaction hazard and because of the proximity to a free face of the river bank the collectors are also subject to a very high lateral spread hazard. Structural assessment of the collector wells and the RDS, performed as part of the natural hazard reliability study, show that three of the six collectors and the RDS have a high likelihood of sustaining

irreparable damage. Strong earthquake shaking can also cause damage to the electrical and communication equipment that is not adequately anchored.

Other diversion system facilities such as the inflatable dam, the diversion dike, ditches and the infiltration ponds are also located in an area of high liquefaction and flood hazard. Recently portions of the dike were severely damaged due to overtopping of flood waters. The seven conventional wells of the Mirabel well field are susceptible to flood related debris impact, although the wells are not in active use and are only for emergency purposes. The overall water quality during floods and wild fires is also a concern.

4.1.3 Aqueducts

The water transmission system consists of 85 miles of aqueducts (pipelines) ranging in size from 16 inches to 54 inches. The system transports water from the Russian River diversion facilities, located in the Wohler-Mirabel area, southwards and eastwards to the water supply service area. The transmission system consists of 11 pipeline segments that include the Russian River Cotati Intertie, the Santa Rosa Aqueduct, the Sonoma Aqueduct, the Petaluma Aqueduct, the Oakmont Pipeline, the Wohler-Forestville Pipeline, the Wohler-Mirabel Intertie, the Kawana Pipeline, the North Marin Aqueduct, the Collector 6 Pipeline and the Eldridge-Madrone Pipeline. The configuration of the water transmission system is shown in Figure 1.

The water transmission system is distributed over a large geographical area and traverses zones of varying geology and topography, and is subject to a range of natural hazards. The system was built incrementally over a period of several decades (ranging from 1959 to 2003) and under a range of evolving design standards and construction techniques. Pipeline construction consists of predominantly Bar-Wrapped Steel Cylinder Concrete Pressure Pipe. Typical joint types consist of gasket joints, welded bell-and-spigot joints, and welded butt-strap joints. Most river and stream crossings include concrete encasement over some or most of the pipeline between the banks of the river or stream.

Major hazards to the pipeline system include earthquakes, floods and landslides, with the earthquakes and earthquake induced hazards such as liquefaction, surface fault rupture, lateral spread and strong ground shaking being the most significant.

In general, buried pipelines, such as the water transmission aqueducts, are designed for internal pressure with limited consideration to large relative displacements of ground along its length. Such pipelines are typically designed with bell and spigot type connections (also known as segmented pipelines) and do not perform well when subjected to ground failure resulting from earthquakes, floods and landslides. In the

1964 Anchorage, Alaska earthquake more than 100 water pipe breaks were reported. In 1971 San Fernando earthquake, the City of San Fernando temporarily lost water, gas and sewage services due to liquefaction induced lateral spreading along the eastern and western shores of Upper Van Norman reservoir. For relatively small ground displacements associated with earthquake ground shaking, the pipelines perform reasonably well with certain amounts of random damage that can usually be handled as part of emergency repairs following an earthquake.

The water transmission pipelines cross many locations where they may be subjected to ground deformation. The most obvious location is the Rodgers Creek fault crossing of the Santa Rosa aqueduct. Surface fault rupture displacement of several feet is expected during a major earthquake on the fault, which the pipeline is not designed for.

The Sonoma aqueduct and the Oakmont pipelines cross the Spring Valley segment of the Bennett Valley fault zone and will likely fail in a surface rupturing event on this fault. Other vulnerable locations include the Russian River crossing of the Russian River Cotati intertie and multiple stream crossings within the system. Depending upon the geometry of the stream bank and the potential for liquefaction, these locations could have large lateral spread displacements and consequently the pipelines would fail. The Sonoma aqueduct is also vulnerable to damage from debris impact in a high flood scenario at three locations where the pipeline is suspended from bridges across creeks.

4.1.4 Storage Facilities

The Water Agency has a total of 18 flat bottom steel tanks located at eight independent sites. Out of the 18 tanks, 8 are anchored while the other 10 are unanchored. The tanks range in size from 0.3 M.G. to 18 M.G. Most of the tanks have overconstrained piping, which consist of a pipe that is rigidly attached to the tank shell and restrained by burial near the tank or connection to an adjacent nearby tank. Such connections are vulnerable to damage in an earthquake because the piping is unable to accommodate uplift movement of the tank caused by earthquake induced overturning moments. Most of the water tanks also have bottom penetrating inlet/outlet and drain piping. Typically, the steel tank base plate is relatively thin (typical thickness of ¼ inch) and is vulnerable to tearing if tank uplift occurs at the bottom penetration piping connection.

4.1.5 Booster Pump Facilities

The Water Agency has eight booster stations. Out of the eights stations, the Sonoma Booster Station is the most critical and is essential for water supply to a significant

segment of the Water Agency's customers. The remaining stations are an important part of the system but not necessary for providing continuous supply of water.

Five booster stations consist of single-story buildings while the other three are open to air. The most significant vulnerabilities include potential damage to the booster station building and electrical control cabinets. Minor to moderate damage to the building may not necessarily be a significant hazard since the stations are not manned. However, major damage or collapse of the building can result in associated damage to the pump motor or motor control centers (MCC) by falling debris. A building that is significantly damaged may also prevent or delay any required manual reset of pump controls thereby impeding system operations.

In terms of the potential for major collapse, the most vulnerable is the Sonoma Booster Station because it is situated within the fault deformation zone of the Spring Valley segment of the Bennett Valley fault.

4.1.6 Treatment Facilities

The Russian River aquifer water is naturally filtered and typically tests absent for coliform without disinfection. To maintain regulatory levels of residual chlorine in the transmission system, the water system has three chlorination facilities. Two of the three chlorination facilities are also corrosion control facilities to chemically treat the water's pH to minimize the potential for corrosion. The three facilities include the Wohler chlorination and corrosion control facility located at the Water Agency's corporation yard on Wohler Road, the Mirabel chlorination facility located near the Mirabel collectors and the River Road chlorination and corrosion control facility located on River Road. The River Road facility is currently used only for corrosion control.

The Mirabel and the Wohler facilities are single story reinforced masonry buildings that generally perform adequately in an earthquake provided the buildings have adequate roof to wall connections. The River Road facility is a two story masonry building with a soft first story and has been retrofitted by the addition of braces at some of the open bays at the first floor. Typically buildings with soft first story perform poorly in earthquakes with excessive damage. The extent of potential damage to this building will depend upon the adequacy of the retrofit scheme. The most significant hazard at the treatment facilities is the potential for a chlorine release or damage to the contents and non-structural elements.

4.1.7 Supplementary Water Sources

In addition to the main water source, the Russian River aquifer, the water supply system has three conventional wells located in the Santa Rosa Plain as supplementary water sources. The three wells known as the Occidental Road Well, the Sebastopol Road Well and the Todd Road Well collectively provide a sustained flow of about 7 mgd. Two of the three wells are located in FEMA flood zone with the third located close to the boundary of the flood zone. Flooding at the site can significantly impact water quality and cause damage to the well infrastructure in terms of electric short circuiting due to inundation and direct physical damage due to debris impact. All of the wells are located in medium to low liquefaction hazard areas. The most significant hazard from an earthquake viewpoint is the damage to the above ground infrastructure, communication and electrical control systems from strong ground shaking.

4.1.8 Emergency Power

The Water Agency's water facilities receive power from PWRPA and PG&E including power to the Water Agency owned substation at Wohler. This substation is a key component of the power network for the Wohler and Mirabel collectors. Emergency power to all feeders in the substation is provided by three 2000kW diesel generators, located near the Wohler Chlorination Building. The generators require manual start and can run for approximately 2.5 days before re-fuelling. Fuel for the generators is provided by a 25,000 gal diesel tank located onsite. In addition, two 1250kW diesel generators are located near the Mirabel chlorination building. Fuel to these generators is provided by a 25,000-gal fuel tank located onsite. These generators can run for approximately 5 days without refueling. When all five generators are run at full power, nine out of ten pumps at the collectors (excluding Collector #6) can be operated simultaneously.

The chlorination facilities also have emergency generators for operating the chlorine sensors and scrubber systems. Emergency power to two of the eight booster stations is provided by generators located at the Sonoma Booster Station and the Ely Booster Station site. The Water Agency has a series of uninterruptible power supply (UPS) units located at essentially all of their facilities to operate the communication and SCADA systems for a period of three to four hours after a major power loss.

4.2 SANITATION

The Water Agency is in the process of performing independent vulnerability assessment of Sonoma and Russian River sanitation facilities and expects to complete the study by 2013. Considering that the sanitation facilities are located in the same geographical region as the water system facilities, they are subject to the same types of hazards with similar types of vulnerabilities as the water system. Figure 19 through Figure 28 show the sanitation facilities overlain on maps of significant hazards in Sonoma County. A general overview of the sanitation system vulnerabilities is as follows:

- Treatment facilities and lift stations within the Sea Ranch Sanitation Zone are located in close proximity to the San Andreas Fault (Figure 19) and are subject to strong ground shaking hazard with PGA exceeding 0.5g (Figure 20).
- The lift station for the Airport/Larkfield/Wikiup is located adjacent to the Rodgers Creek fault (Figure 19) and is subject to strong ground shaking hazard with PGA exceeding 0.6g (Figure 20).
- Sanitation facilities not in immediate proximity to the San Andreas or Rodgers Creek fault are still located close enough to be subject to signification ground shaking with PGA exceeding 0.4g.
- Figure 21 shows the liquefaction and lateral spread hazard for the sanitation facilities. Facilities of the Geyserville Sanitation Zone, the treatment plant for the Russian River Sanitation District and portions of the Sonoma Valley Sanitation District are located in high to very high liquefaction zones. A significant number of the Agency's sanitation facilities are located in medium liquefaction zones with some in zones of low liquefaction hazard. Pipelines, especially the pipeline connections to fixed facilities, are most vulnerable to damage within zones of potential liquefaction hazard.
- Most of the Water Agency's sanitation facilities are located outside the landslide hazard zone, though with some facilities, for example, lift stations of the Occidental County Sanitation Zone and the Airport/Larkfield/Wikiup Sanitation Zone and treatment plants for the Occidental County Sanitation Zone and the Russian River County Sanitation Zone are located in areas of potential landslide hazard (Figure 22).
- Figure 23 shows that the potential for flooding hazard is high at the Geyserville Sanitation Zone and the Russian River County Sanitation District.
- Figure 24 shows that the debris flow hazard exists at several of the Water Agency's sanitation facilities.

- Figure 25 and Figure 26 show that several facilities are located in areas that have corrosive soils, however, based on discussions with the Agency corrosion is not a predominant hazard.
- Facilities at the Sea Ranch Sanitation Zone, Occidental County Sanitation District, Russian River County Sanitation District and the Airport/Larkfield/Wikiup Sanitation Zone are located in areas of high fire hazard (Figure 27), with some of the facilities of the Russian River County Sanitation District and the Airport/Larkfield/Wikiup located close to the boundary of historic fire zones (Figure 28).
- The Airport/Larkfield Wikiup Sanitation Zone and the Sonoma Valley Sanitation District have wastewater treatment ponds with high embankments (California Division of Safety of Dams (DSOD), jurisdictional embankments) that could be subjected to high liquefaction and ground shaking hazard and therefore, require detailed vulnerability assessment.

A detailed multi-hazard reliability assessment of Agency's sanitation facilities is currently underway. It is anticipated that mitigation of vulnerabilities identified at the completion of this study will be included in the future update of the LHMP.

4.3 FLOOD PROTECTION

Independent vulnerability assessment of Agency's flood protection facilities has not yet been performed. Considering that these facilities are located in the same geographical region as the water system facilities, they are also subject to similar exposure and vulnerabilities as the water system. Multi-hazard reliability assessment of Agency's flood protection facilities is one of the goals for this LHMP update.

While the Agency is responsible for the management of Lake Sonoma and Lake Mendocino, the primary responsibility for these lies with the U.S. Army Corps of Engineers. The Agency will work with the Corps to develop a plan to address the identified vulnerabilities in the future LHMP updates. The Agency is responsible for the reliability of reservoirs associated with the Central Sonoma Watershed Project.

4.4 ADMINISTRATIVE INFRASTRUCTURE

Independent vulnerability assessment of Agency's administrative infrastructure has not yet been performed. The Aviation Boulevard and Concourse Avenue facilities are located less than 2.5 kilometers from the Rodgers Creek fault. Very strong ground shaking is expected at these facilities. Vulnerability assessment of Agency's office facilities is an identified goal of this LHMP.

5.0 MITIGATION GOALS, OBJECTIVES AND ACTIONS

Sonoma County Water Agency is directly responsible for providing water to over 600,000 people in the rapidly developing and expanding North Bay Area. The Water Agency is the primary wholesale provider of water to eight cities and water agencies who maintain their own distribution networks but very little redundant sources of supply. The Water Agency's contractors and in turn the public relies on the water supplied by the Water Agency for domestic water supply and for both emergency and non-emergency, use such as irrigation and other domestic and industrial needs.

The Water Agency's water system and its facilities stretch over an area of multiple natural hazards. The system has a range of vulnerabilities to these hazards. Hydraulic analysis conducted as part of the natural hazard vulnerability assessment of the water system show that damage to one or more such facilities can deplete water storage and cause significant pressure loss at turnouts serving the contractors within a matter of hours. Loss of water supply will leave the contractors vulnerable in their ability to provide fire flow and drinking water to the public.

The Water Agency takes this responsibility seriously and has developed this plan to systematically address the vulnerabilities of its water supply, sanitation and flood control systems. In this capacity, the Water Agency's goals are in line with the goals of the community as addressed in the Sonoma County (County) hazard mitigation plan. The County's main goals are to reduce the vulnerability of people and property exposed to earthquake, landslide, flood, and wild-land fire hazards. One of the objectives identified by the County for meeting these goals is to promote the implementation of disaster mitigation projects identified as high priority through the Water Agency's multi-hazard reliability assessment study and to increase the disaster resistance and reliability of the water supply system. Keeping in view the desires of the community, as expressed in the County's plan and the understanding of the system vulnerabilities, the Water Agency has formulated the following three main goals:

Goal 1: Provide safe and reliable water supply to the public during and after a natural disaster to reduce the vulnerability of people and property

Goal 2: Provide reliable wastewater collection, treatment and disposal services during and after a natural disaster to reduce risk to the public's health and environmental damage

Goal 3: Maintain reliable flood control works to reduce the vulnerability of people and property to flood hazard

Based on the insights obtained from a comprehensive multi-hazard reliability assessment of the Water Agency's water system, a series of mitigation goals and actions are included in this plan. In addition, first tier objectives and actions for the Water Agency's sanitation and flood control systems are also presented. The Water Agency believes that the upgrades and safe operations of its systems require an ongoing program in which the most obvious vulnerabilities and those with the highest probability of occurrence are mitigated first followed systematically by vulnerabilities with lower probabilities, or newly identified vulnerabilities based on new information, with a continued improvement in the reliability of the system. This process will be managed through continuous maintenance of this hazard mitigation plan through a five year update cycle.

Goal 1: Provide safe and reliable water supply to the public during and after a natural disaster to reduce the vulnerability of people and property

Objective 1.1: *Implement system-wide improvements that reduce the overall system vulnerability by adding redundancy to the system and by enhancing Agency's response through better monitoring of its system.*

1.1.1 Minimize potential for uncontrolled release of water by providing isolation valves at strategic locations.

1.1.2 Plan, design and add redundant/emergency supply sources to minimize dependence on the Russian River aquifer as the main source of water supply. Install new emergency ground water wells located strategically throughout the system.

1.1.3 Provide seismic restraints to electrical and communication equipment at various facilities.

1.1.4 Install additional flow measuring devices to improve real time flow monitoring.

1.1.5 Develop a GPS based system map with real-time monitoring at critical locations. For example, significant portions of the Agency's aqueducts run through large zones of undeveloped areas and pipe leaks in such areas are hard to precisely locate.

1.1.6 Procure large diameter flexible hose and its deployment and retrieval system for emergency use.

1.1.7 Install emergency manifolds at strategic locations to connect emergency hoses.

Objective 1.2: *Perform diversions system improvements*

1.2.1 Develop and implement designs to retrofit collectors against liquefaction and lateral spread hazard.

1.2.2 Develop and implement design strategy to mitigate liquefaction and lateral spread hazard to the RDS.

Objective 1.3: *Perform transmission system improvements*

1.3.1 Develop and implement a design strategy to mitigate fault rupture hazard to the aqueducts that cross the Rodgers Creek fault and the Spring Valley segment of the Bennett Valley fault zone.

1.3.2 Develop and implement a design strategy to mitigate the liquefaction and lateral spread hazard at the several river and creek crossings identified in the natural hazard reliability assessment. Some of the most vulnerable include the aqueduct crossings at Russian River, Petaluma River, Mark West Creek, Santa Rosa Creek and Calabasas Creek.

1.3.3 Develop and implement a design strategy to mitigate the liquefaction, lateral spread and flood hazard for the Sonoma aqueduct suspended at the two pedestrian and one traffic bridge over Sonoma Creek at Lawndale Road, Madrone Road and Verano Avenue.

1.3.4 Develop and implement a design or operational strategy to mitigate lateral spread damage to the Wohler-Mirabel Intertie.

1.3.5 Develop plans to relocate or parallel the pipeline that crosses beneath the Spring Lake and the Spring Lake dam.

1.3.6 Develop a design or operational strategy to respond to unexpected pipeline damage within the Wohler-Mirabel area.

1.3.7 Develop a long term strategy to address lower probability damage to transmission system pipelines. Due to the non-redundant nature of the transmission system such damage can be just as disruptive as that due to damage with a high probability of occurrence.

Objective 1.4: *Perform pumping system improvements*

1.4.1 Develop and implement a retrofit design for mitigation of liquefaction and lateral spread hazard at the Ely Booster station.

1.4.2 Develop and implement a seismic retrofit design for the Kastania pump station building.

1.4.3 Develop and implement a seismic retrofit design or replacement of the Wilfred booster station building.

1.4.4 Develop and implement a design or an operational solution to mitigate the fault rupture hazard to the Sonoma Booster Station from the Spring Valley segment of the Bennett Valley fault zone.

Objective 1.5: *Perform storage system improvements*

1.5.1 Perform a piping retrofit by replacing existing rigid piping with piping with flexible joints at the storage reservoirs.

1.5.2 Implement other retrofits such as removing overconstrained conditions identified in the natural hazard reliability study.

Objective 1.6: *Improve the Agency's emergency response capabilities*

1.6.1 Plan and procure stockpile material for use in emergency.

1.6.2 Conduct first responder training of a broad pool of Agency's personnel to respond in an emergency.

1.6.3 Plan and develop a dedicated Emergency Operations Center such that the operators and decision makers are in close proximity to each other.

1.6.4 Procure a mobile EOC.

Objective 1.7: *Reliable emergency power systems*

1.7.1 Develop and implement design and operations plans to mitigate liquefaction related damage to electric power lines feeding collectors and pump stations.

1.7.2 Procure and install additional UPS units at each facility to prolong the ability to communicate with the system beyond the current 4 hour limit.

Objective 1.8: *Reduce supply vulnerability*

1.8.1 Assess vulnerability of Russian River upstream of the aquifer to earthquake and non-earthquake induced landslides that could potentially block the river channel.

1.8.2 Assess vulnerability of Russian River upstream of the aquifer to contamination from accidents and wildland fire.

1.8.3 Design and implement mitigation schemes for reducing the potential of flood damage to the well fields in the Mirabel and Laguna de Santa Rosa area.

Objective 1.9: *Minimize life safety risk and reduce operational vulnerability*

1.9.1 Conduct seismic vulnerability assessment of structural and non-structural elements of the Agency's facilities located at 404 Aviation Boulevard and 204 Concourse Avenue.

Objective 1.10: *Improve understanding of fault rupture hazard*

1.10.1 Work with the United States Geological Survey (USGS) to perform a geologic study including trenching of the Spring Valley segment of the Bennett Valley fault zone to more accurately define the fault activity and paleoseismic history of the fault, the rupture zone and the extent of surface rupture across the Water Agency's facilities.

Objective 1.11: *Minimize economic exposure to the Agency*

1.11.1 Work with the U.S. Army Corps of Engineers to expedite the earthquake safety assessment of Warm Springs and Coyote Valley dams.

1.11.2 Conduct a detailed seismic vulnerability assessment of electric power station at the Warm Springs dam.

1.11.3 Develop project design criteria document for new construction.

Goal 2: Provide reliable wastewater collection, treatment and disposal services during and after a natural disaster to reduce public health risk and environmental damage

Objective 2.1: *Improve the understanding of the vulnerability of the sanitation systems under the Agency's control.*

2.1.1 Perform a multi-hazard vulnerability assessment of the sanitation systems.

2.1.2 Develop project design criteria document for new construction.

Goal 3: Maintain reliable flood control works to reduce the vulnerability of people and property to flood hazard

Objective 3.1: *Improve the understanding of the vulnerability of the Agency's flood protection works.*

3.1.1 Perform a vulnerability assessment of the flood control works for multiple flood recurrence intervals with consideration to potential impacts from global and local climate change.

3.1.2 Work with the U.S. Army Corps of Engineers to expedite reassessment of Coyote and Warm Springs dam under the revised PMF (probable maximum flood) conditions as impacted by the recent PMP (probable maximum precipitation) study results included in the hydro-meteorological report HMR57 for Pacific Northwest and HMR 58 and HMR59 for California.

3.1.3 Work with the U.S. Army Corps of Engineers to develop and implement a plan for the assessment of flood control levees within the Upper Russian River area between Cloverdale and Healdsburg.

3.1.4 Develop project design criteria document for new construction.

6.0 IMPLEMENTATION STRATEGY

The implementation strategy for the 2012 LHMP update builds on the strategy adopted in the 2008 plan. It maintains the first tier objectives identified in the 2008 plan since work towards these objectives is progressing but not yet completed. A summary of progress towards the first tier objectives is provided in Table 1. The first tier objectives remain as the highest priority for the Agency and once implemented will result in substantial improvement in the overall reliability of the system.

In addition to the first tier objectives, the 2008 LHMP identified several highly desirable objectives that the Agency had undertaken as part of its ongoing maintenance program. These objectives represent a very high benefit to cost ratio and once implemented will result in a substantial improvement in the overall reliability of the system. To provide additional focus, these objectives are now included as part of the first tier objectives.

The Agency's objectives have been prioritized based on the following:

- Impact to the Water Agency's water system from the identified vulnerability. The system impacts were studied through detailed hydraulic modeling of the system. Factors such as time to significant loss of pressure or significant loss of storage and the population impacted. For example, a break at Rodgers Creek fault will result in loss of flow to the entire Sonoma Valley and is considered a high priority
- Overall cost/benefit of the mitigation strategy. For example, anchorage of equipment at the Water Agency's facilities is considered a high priority because of very high benefit to cost ratio.

The Water Agency's first tier objectives include:

1. **Mitigation Action 1.3.1 (partial)** – Develop and implement design strategy to mitigate fault rupture hazard at Rodgers Creek fault crossing of Santa Rosa aqueduct (project underway).
2. **Mitigation Action 1.1.4** – Install additional flow measuring devices to improve real time flow monitoring.
3. **Mitigation Action 1.1.1** – Minimize potential for uncontrolled release of water by providing isolation valves at strategic locations.

4. **Mitigation Action 1.3.2 (partial)** – Develop and implement design strategy to mitigate the liquefaction and lateral spread hazard at the Russian River crossing.

5. **Mitigation Action 1.3.2 (partial)** – Develop and implement design strategy to mitigate the liquefaction and lateral spread hazard at the Mark West Creek crossing.

6. **Mitigation Action 1.2.1 (partial)** – Develop and implement retrofit design for Collector 5 against liquefaction and lateral spread hazard.

7. **Mitigation Action 1.2.1 (partial)** – Develop and implement retrofit design for Collector 3 against liquefaction and lateral spread hazard.

8. **Mitigation Action 1.2.1 (partial)** – Develop and implement retrofit design for Collector 6 against liquefaction and lateral spread hazard.

9. **Mitigation Action 1.2.2** – Develop and implement design strategy to mitigate liquefaction and lateral spread hazard to the RDS.

10. **Mitigation Action 1.1.3** – Provide seismic restraints to electrical and communication equipment at various facilities.

11. **Mitigation Action 1.5.1** – Perform a piping retrofit by replacing existing rigid piping with piping with flexible joints at the storage reservoirs.

12. **Mitigation Action 1.5.2** – Implement other retrofits such as removing overconstrained conditions identified in the natural hazard reliability study.

13. **Mitigation Action 1.3.6** – Develop a design or operational strategy to respond to unexpected pipeline damage within the Wohler-Mirabel area.

14. **Mitigation Action 1.6** – Improve Agency's emergency response capabilities. In this regard, plan activities that make substantial progress towards meeting Objectives 1.6.1, 1.6.2 and 1.6.3.

15. **Mitigation Action 1.3.2 (partial)** – Develop and implement design strategy to mitigate the liquefaction and lateral spread hazard at the Santa Rosa Creek crossing.

16. **Mitigation Action 1.4.4** – Develop and implement design or an operational solution strategy to mitigate the fault rupture hazard to the Sonoma Booster Station from the Spring Valley segment of the Bennett Valley fault zone.

17. **Mitigation Action 1.3.1 (partial)** – Develop and implement design strategy to mitigate fault rupture hazard to the aqueducts that cross the Spring Valley segment of the Bennett Valley fault zone.

18. **Mitigation Action 1.6.2** – Conduct First Responder Training of a broad pool of Agency's personnel to respond in an emergency.

19. **Mitigation Action 1.7.2** – Procure and install additional UPS Units at each facility to prolong the ability to communicate with the system beyond the current 4 hour limit

20. **Mitigation Action 1.3.5** – Develop plans to relocate pipeline that crosses beneath the Spring Lake and the Spring Lake dam.

The implementation strategy has been developed based on the recommended Capital Improvement Program developed as part of the multi-hazard reliability project and additional experience gained from the implementation of the 2008 LHMP. Once these objectives are achieved, implementation schedule and planning level budget estimates for the next tier objectives will be developed in future revisions to the plan in consultation with the Agency's management, contractors and the public.

Most mitigation actions identified in this update are included in the Agency's Capital Improvement Program (CIP), which is administered by the Engineering and Resource Planning Division with the other division heads involved in the yearly CIP development cycle.

As with the 2008 LHMP, the Agency will continue to actively work towards identifying funding sources for these projects such as FEMA's pre-disaster mitigation program (PDM) and hazard mitigation grants program (HMGP), Agency's maintenance budget and a possible reliability surcharge within the Agency's rate structure.

FEMA's PDM program has been very successful in providing matching grants to public entities for hazard reduction projects. Additional funding from FEMA is available following a Federal disaster declaration as part of its HMGP.

The Agency is on track to completing the Rodgers Creek fault crossing project and has made substantial progress towards many of the first tier objectives. Depending on the level of funding available, the Agency plans to implement the top six first tier objectives within about 8 years following the adoption of this plan with the remainder of the first tier objectives completed within the next 8 to 20 years.

7.0 PLAN MAINTENANCE

The Agency's commitment to reducing its hazard vulnerability and improving the reliability of its system is demonstrated by the fact that the Agency on its own initiative undertook a comprehensive multi-hazard reliability improvement program. The Agency recognizes that this commitment can only be met through a dedicated effort. Development of the Hazard Mitigation Plan is part of this effort. In meeting the requirements of the DMA 2000, the Agency plans to update the Hazard Mitigation Plan every five years or if new information becomes available, priorities for implementation change or an actual hazard event occurs that may prompt an update to the plan sooner than five years.

7.1 MONITORING EVALUATING AND UPDATING THE PLAN

The Agency will keep the plan "alive" through constant monitoring of the plan goals and objectives. The high priority mitigation actions are being included in the Agency's CIP. Because of the involvement of the Agency's Department heads of Planning, Operations, Maintenance and Capital Improvements in the development of the plan, the entire executive management of the Agency is committed to implement the goals and objectives of the plan.

The Agency will incorporate the hazard mitigation plan in its yearly CIP planning process to monitor progress towards the goals of the hazard mitigation plan. To further facilitate this process, the Agency's Chief Engineer has been identified as the person responsible for monitoring and updating the hazard mitigation plan. As required by DMA 2000, this plan will be updated every five years. The Agency will also update the plan if there is a significant change in the basic assumptions, for example a major hazard event that highlights vulnerabilities in the system not anticipated at the present time.

7.2 CONTINUED PUBLIC INVOLVEMENT

The Agency, with its decision to incorporate the hazard mitigation plan in its yearly CIP planning process, has ensured continued public involvement in this plan. The CIP approval is an open public process. As part of the approval process the CIP is presented to the Agency's Board of Supervisors in an open public meeting and by virtue of this, progress towards achieving Agency's goals and objectives identified in the hazard mitigation plan will also be open for public review and comment.

The Agency will also keep its contractors informed regarding the progress towards meeting its goals and objectives in a public forum through the regularly held Water Advisory Committee (WAC) and Technical Advisory Committee (TAC) meetings.

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23 Meeting June 2, 2005, Sequoia Conference Room, 404 Aviation Boulevard, Santa Rosa: Attendees: Jay Jasperse (Deputy Chief Engineer, Engineering and Resource Planning), Cordel Stillman (Capital Projects Manager) Sonoma County Water Agency, Ahmed Nisar, MMI Engineering, Darin Jenkins, City of Rohnert Park and Mike Ban, City of Petaluma.

24 Meeting June 7, 2005, Alder Conference Room, 404 Aviation Boulevard, Santa Rosa: Attendees: Jay Jasperse (Deputy Chief Engineer, Engineering and Resource Planning), Cordel Stillman (Capital Projects Manager) Sonoma County Water Agency, Ahmed Nisar, MMI Engineering, Krishna Kumar, Valley of the Moon Water District and Al Bandur, City of Sonoma.

25 Meeting August 26, 2005, 404 Aviation Boulevard, Santa Rosa: Attendees: Jay Jasperse (Deputy Chief Engineer, Engineering and Resource Planning), Cordel Stillman (Capital Projects Manager) Sonoma County Water Agency, Ahmed Nisar, MMI Engineering, Chris DeGabriele, North Marin Water District.

26 Meeting September 15, 2005, 404 Aviation Boulevard, Santa Rosa: Attendees: Jay Jasperse (Deputy Chief Engineer, Engineering and Resource Planning), Cordel Stillman (Capital Projects Manager) Sonoma County Water Agency, Ahmed Nisar, MMI Engineering, Miles Ferris, City of Santa Rosa.

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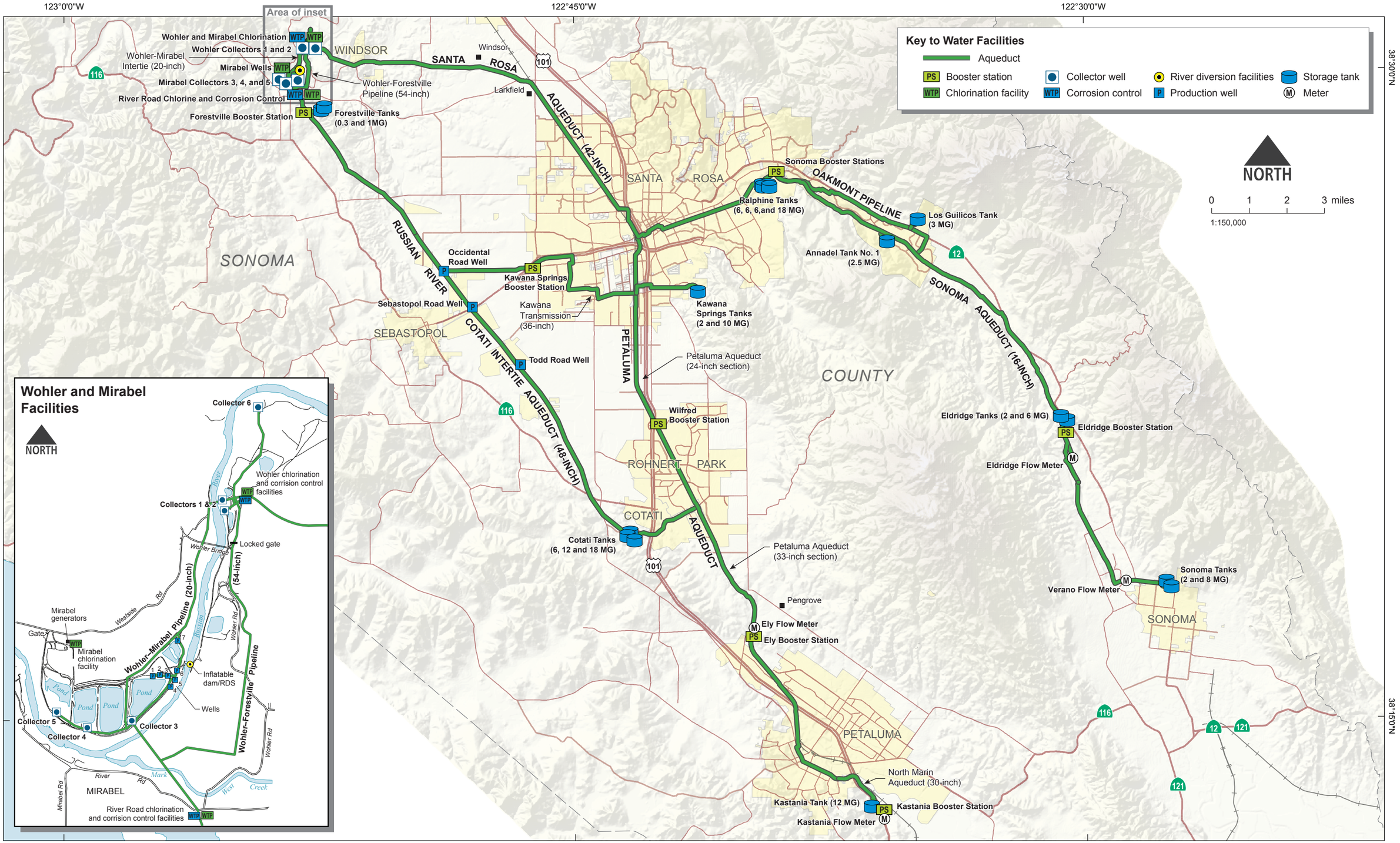


Figure 1

Water Transmission System

21 NOV 2012

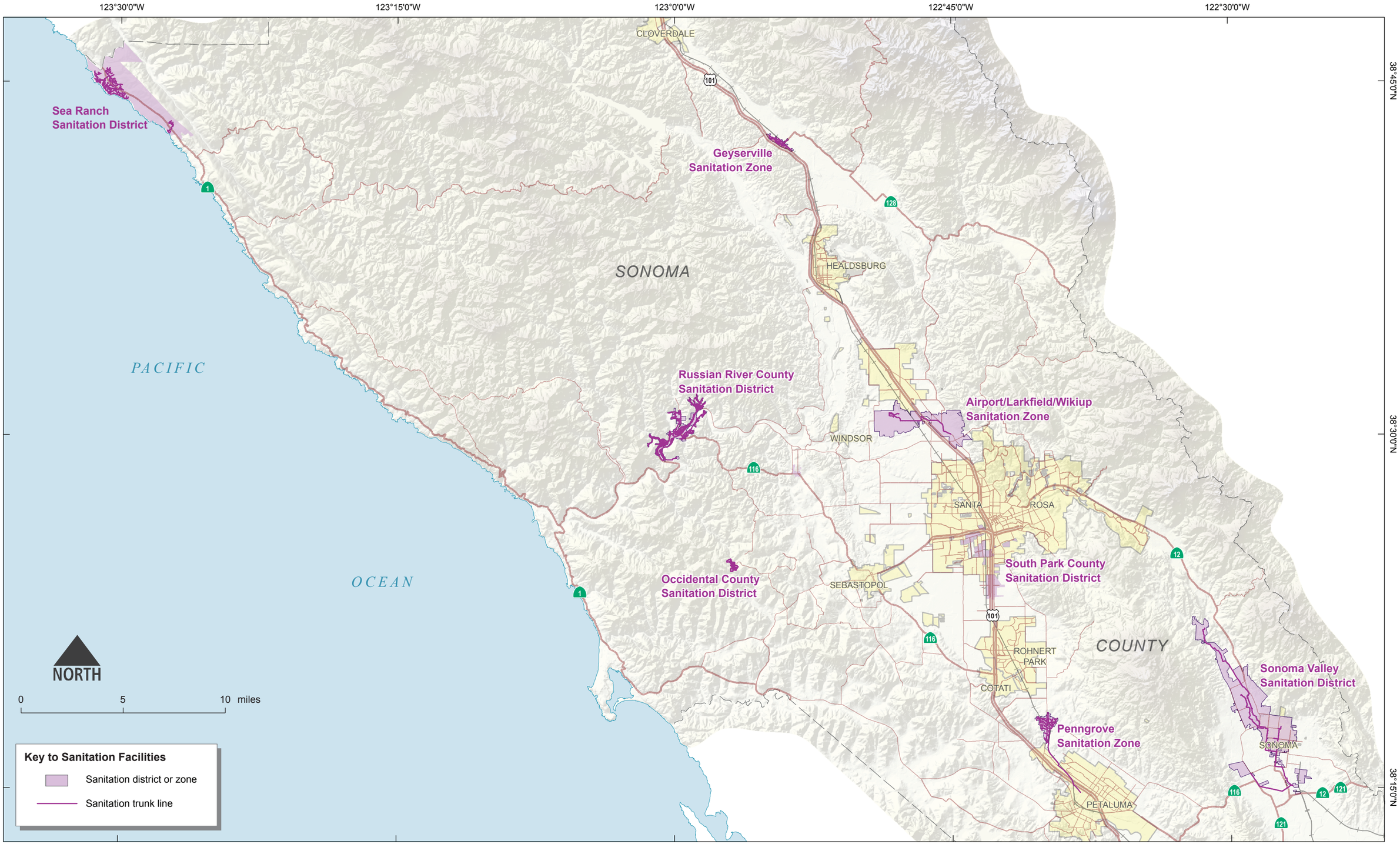


Figure 2

Sanitation System

21 NOV 2012

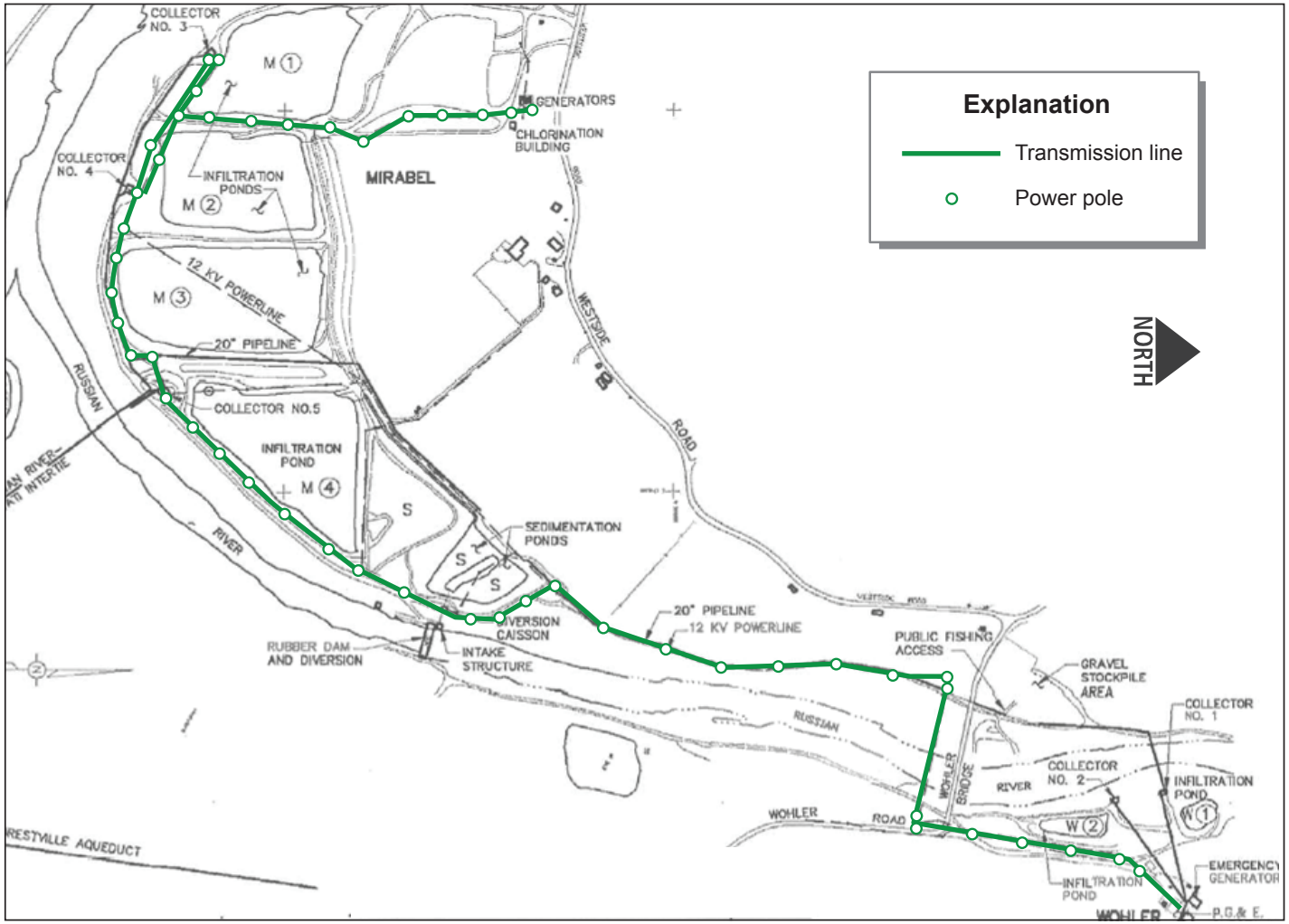
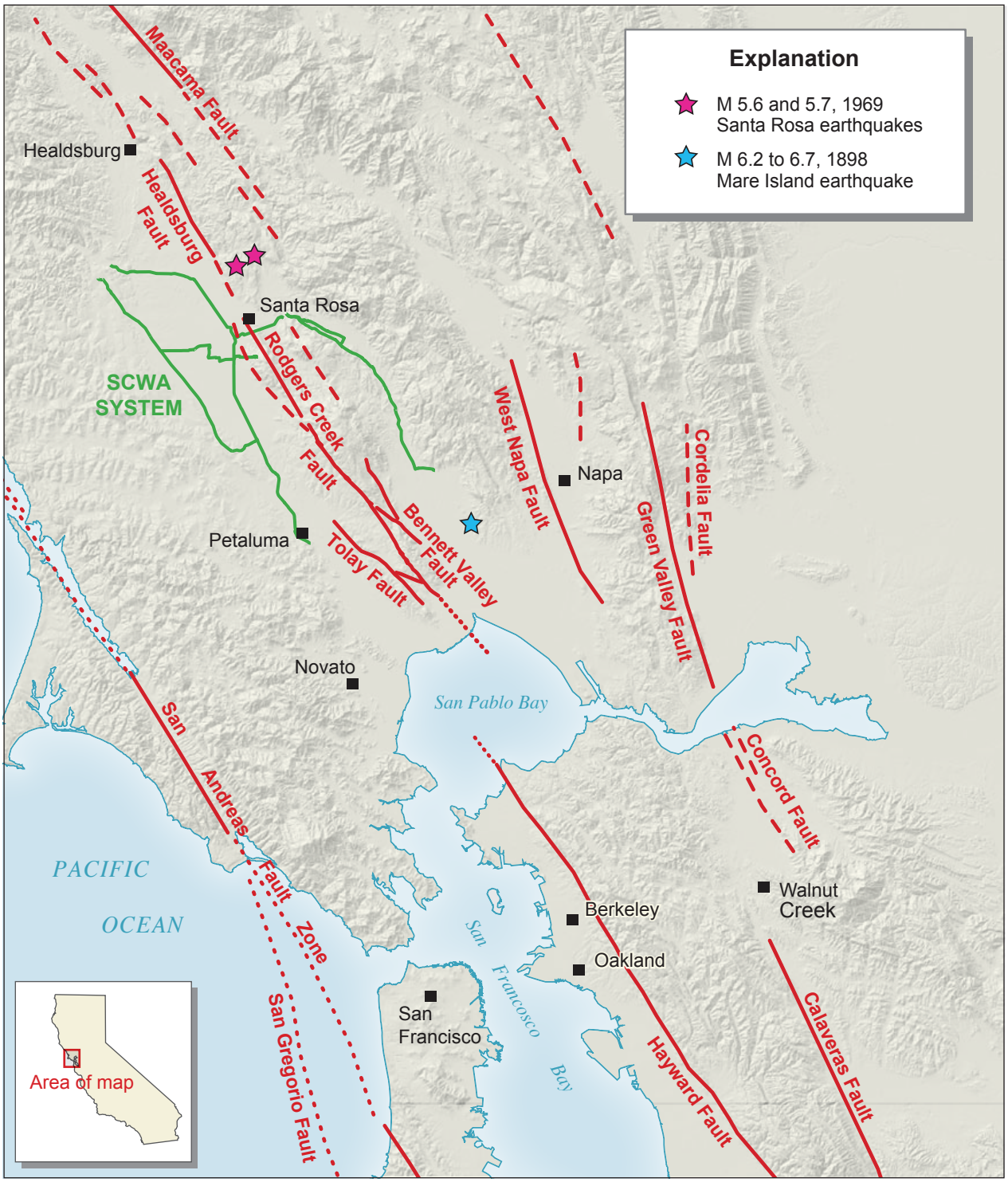


Figure 3

Power System

21 NOV 2012



Faults modified from Jennings (1994)

NORTH

0 10 20 km

Figure 4

Fault Map of the Bay Area

21 NOV 2012

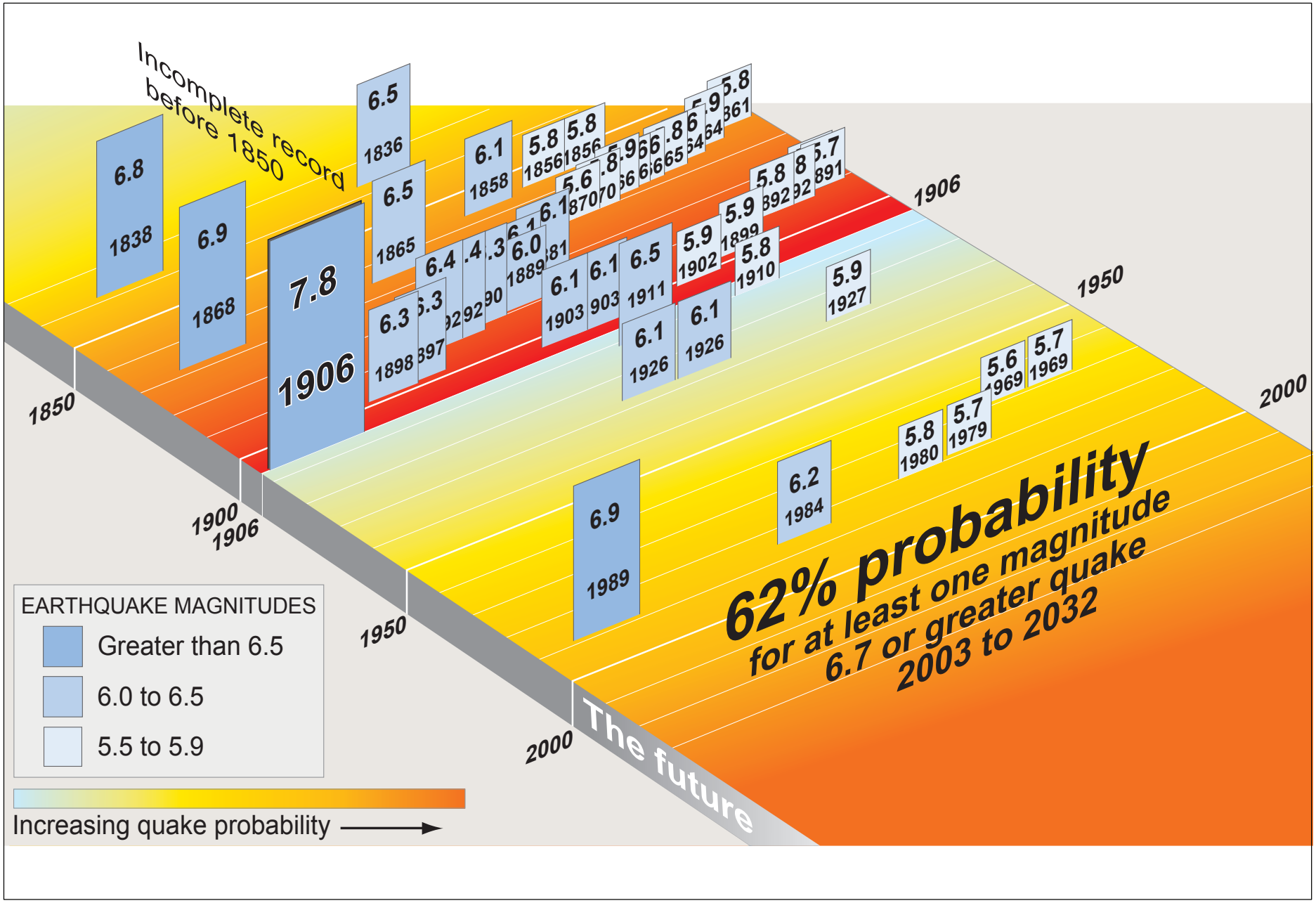


Figure 5

Historic Earthquakes in the Bay Area

21 NOV 2012

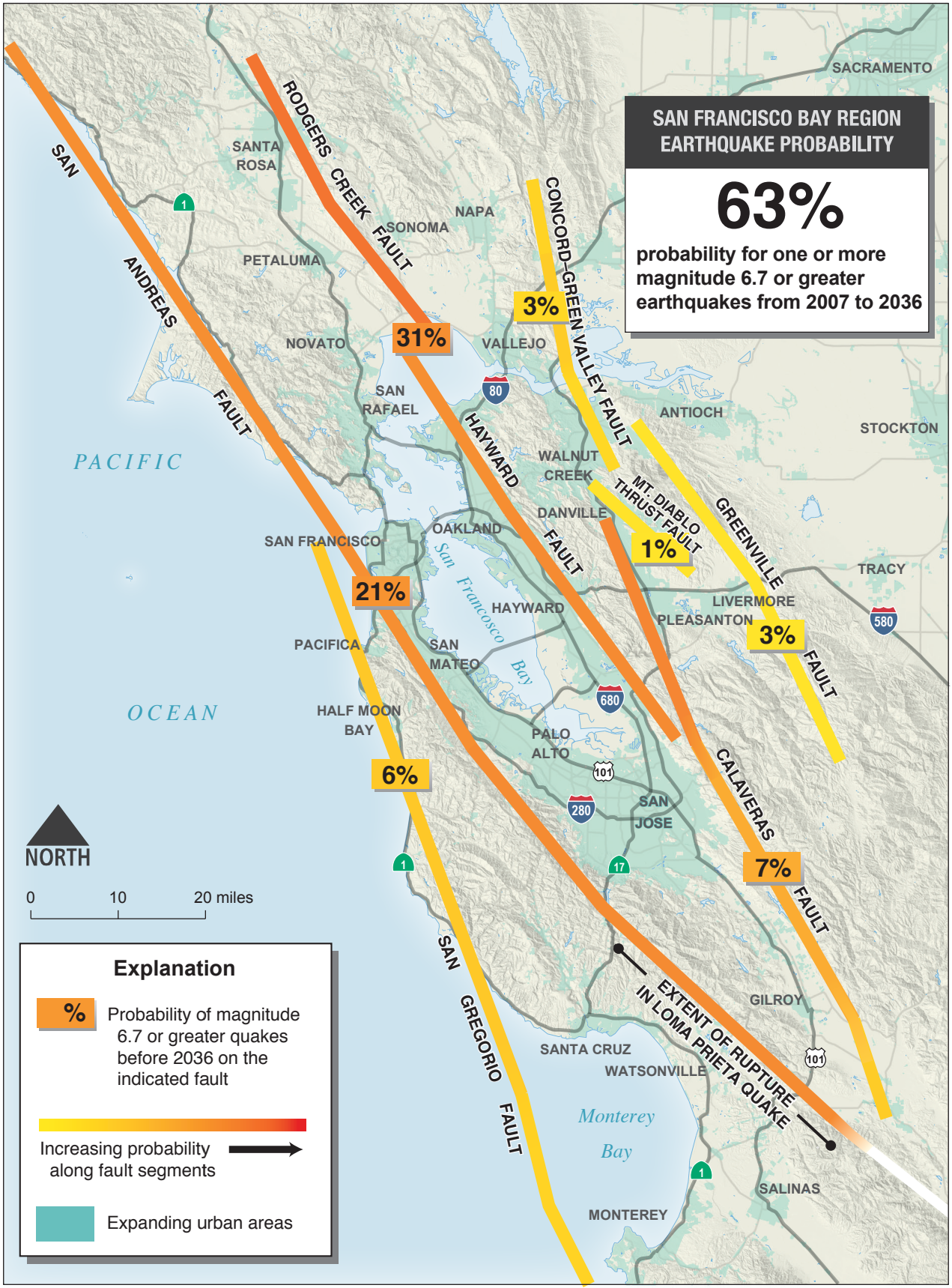


Figure 6

Earthquake Probabilities in the Bay Area

21 NOV 2012

SONOMA COUNTY WATER AGENCY

Figure 7

Water Transmission System – Fault Map

21 NOV 2012

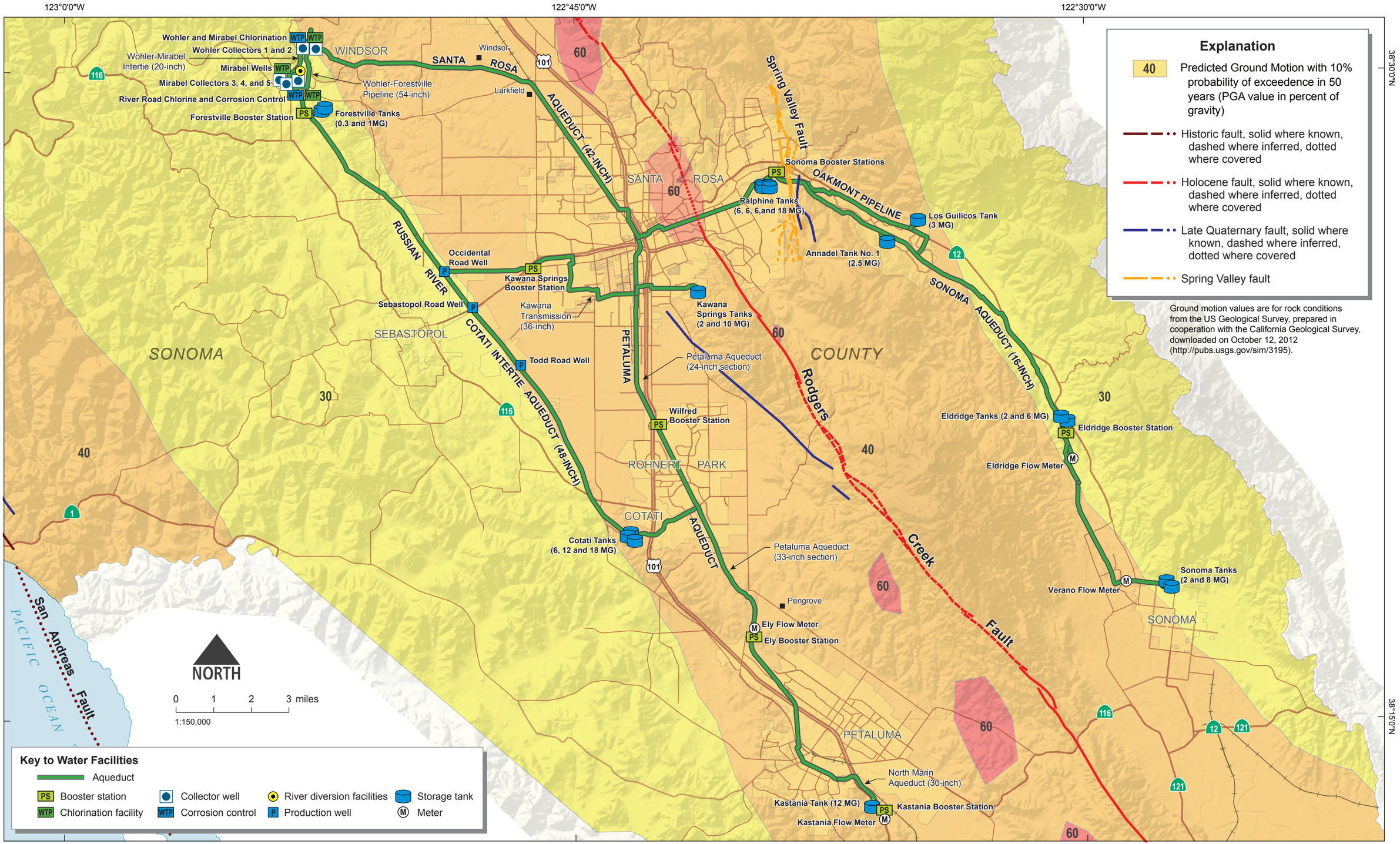


Figure 8

Water Transmission System – Ground Shaking Hazard

21 NOV 2012

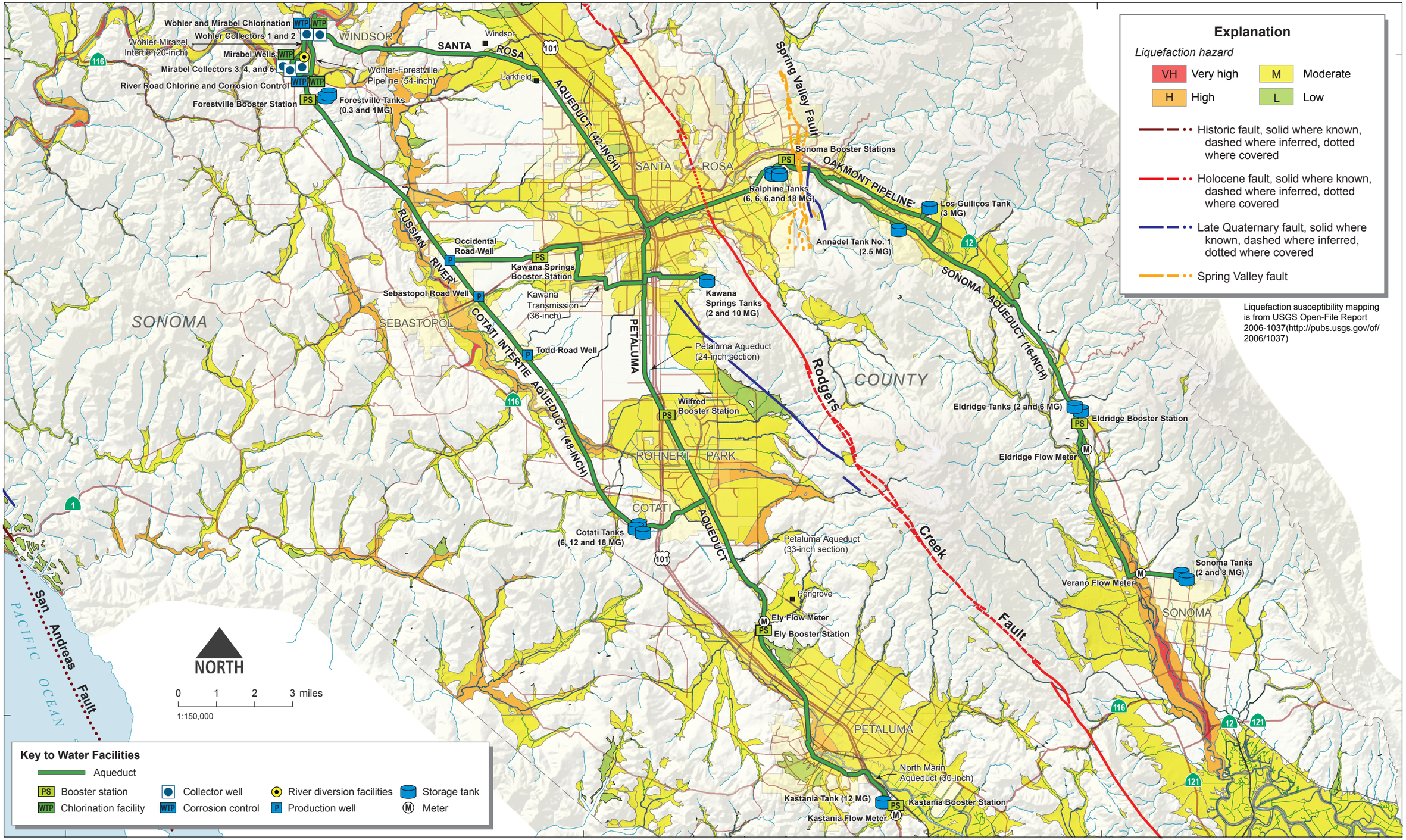


Figure 9

Water Transmission System – Liquefaction Hazard

21 NOV 2012

Figure 10

Water Transmission System – Landslide Hazard

21 NOV 2012

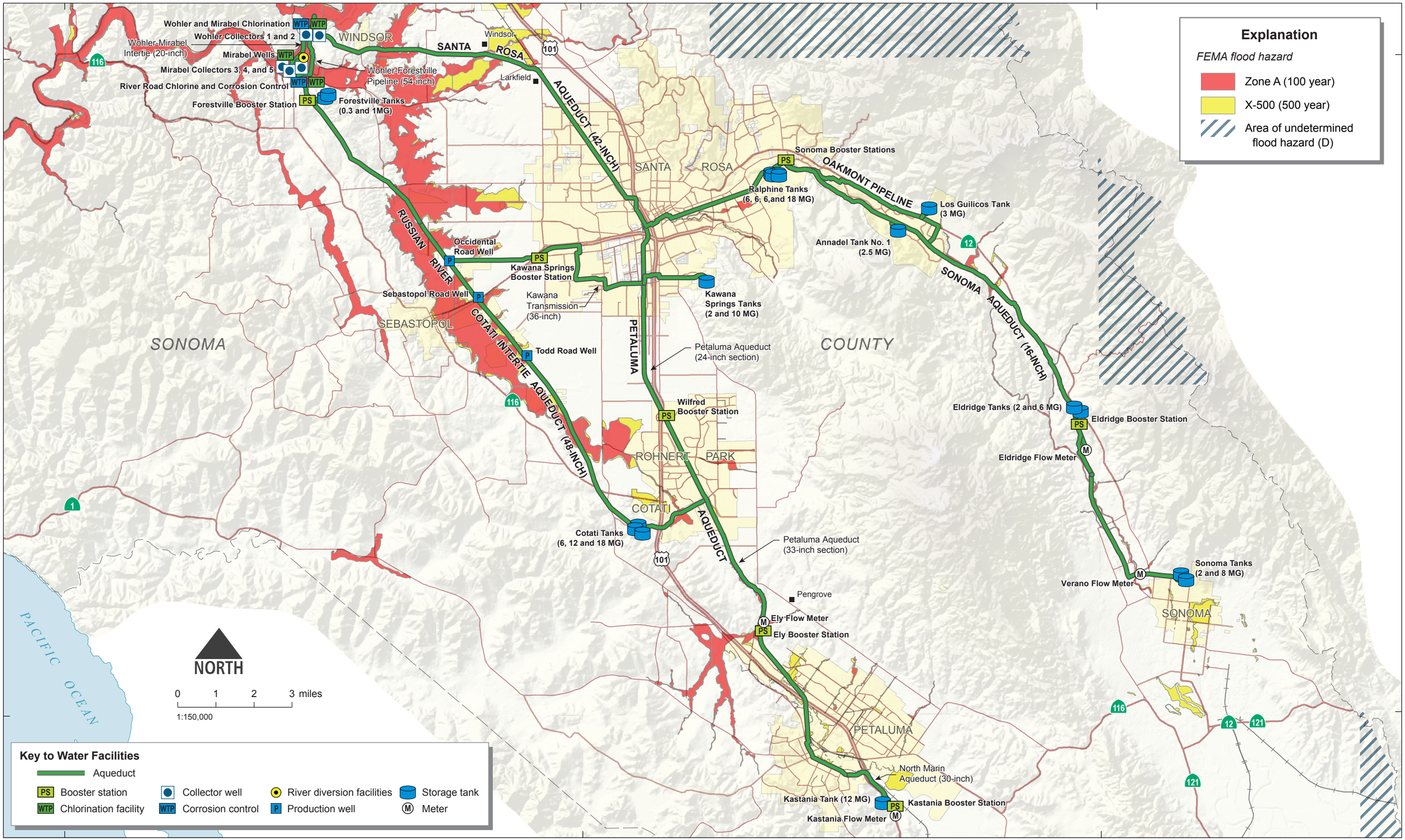


Figure 11

Water Transmission System – Flood Hazard

21 NOV 2012

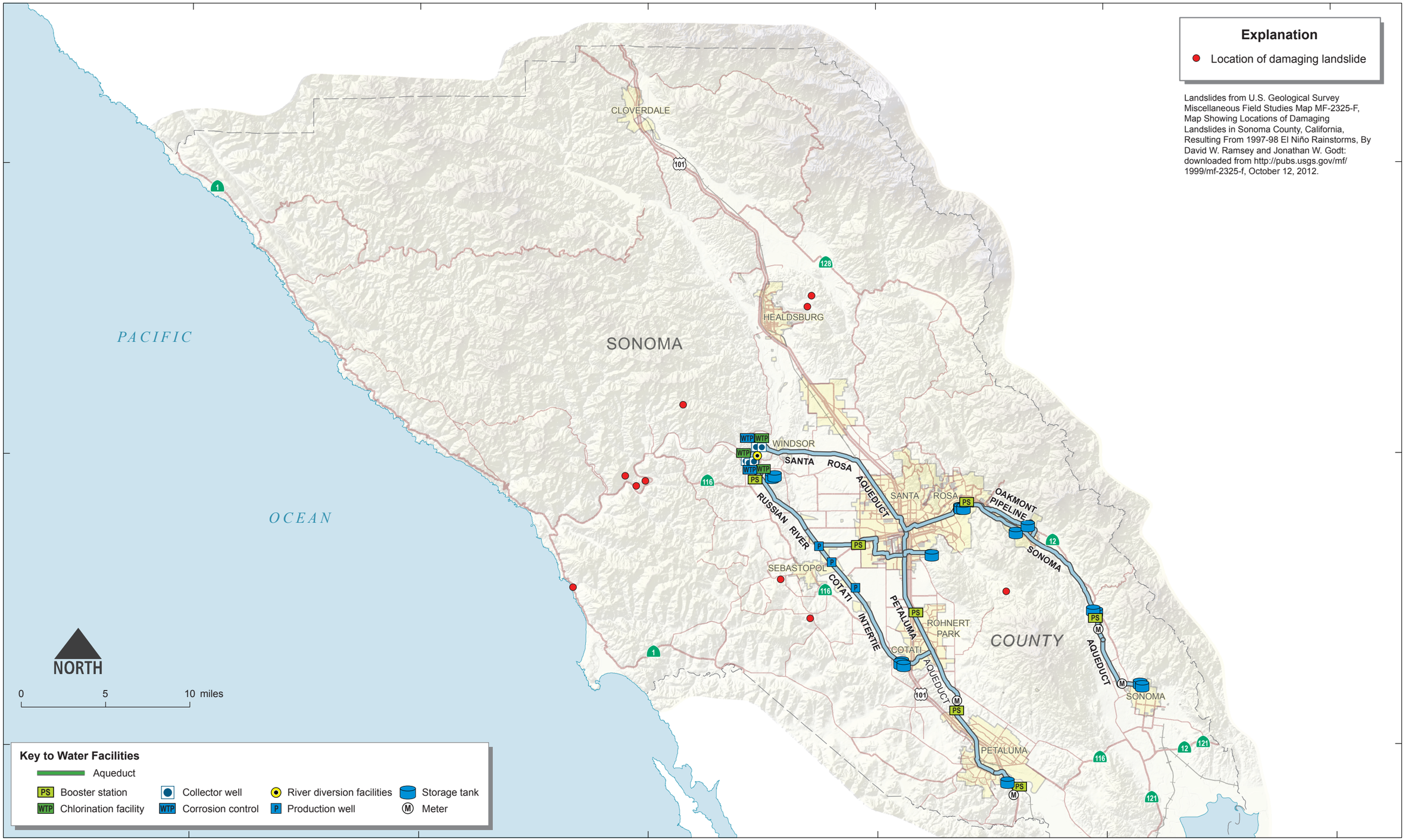


Figure 12

Historic Landslides in Sonoma County during El Niño Storms of 1997-1998

21 NOV 2012

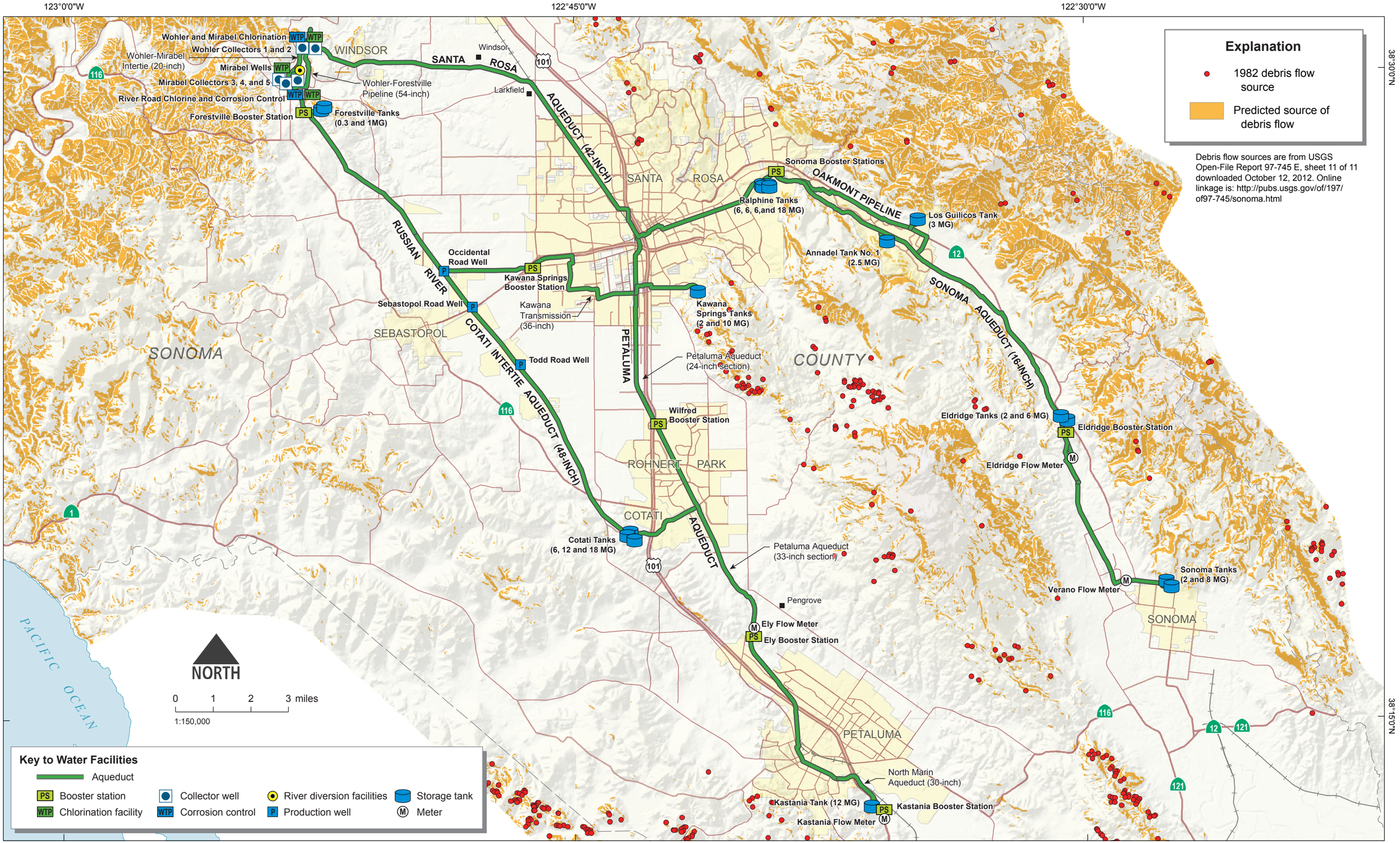


Figure 13

Water Transmission System – Debris Flow Hazard

21 NOV 2012

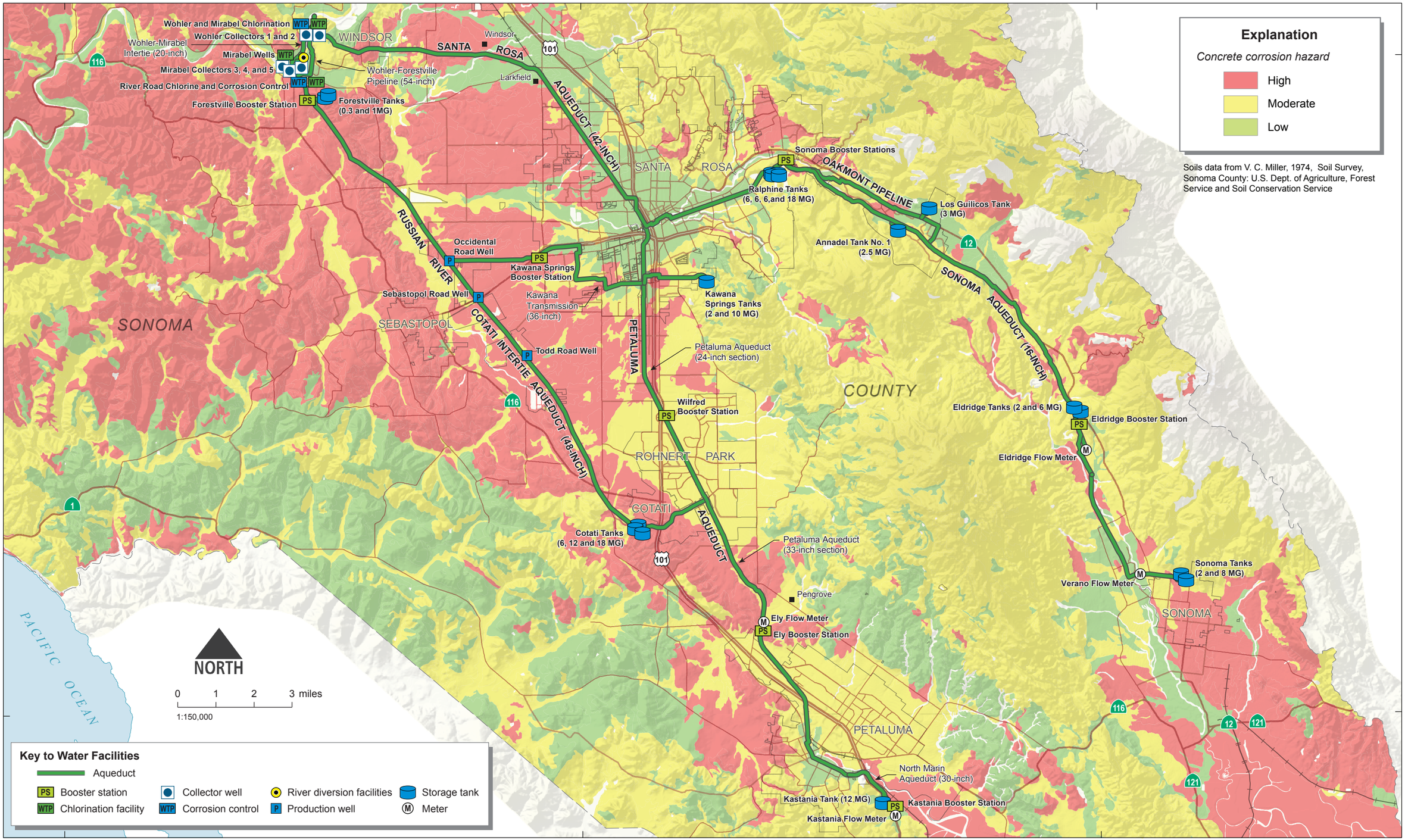


Figure 14

Water Transmission System – Concrete Corrosion Potential

21 NOV 2012

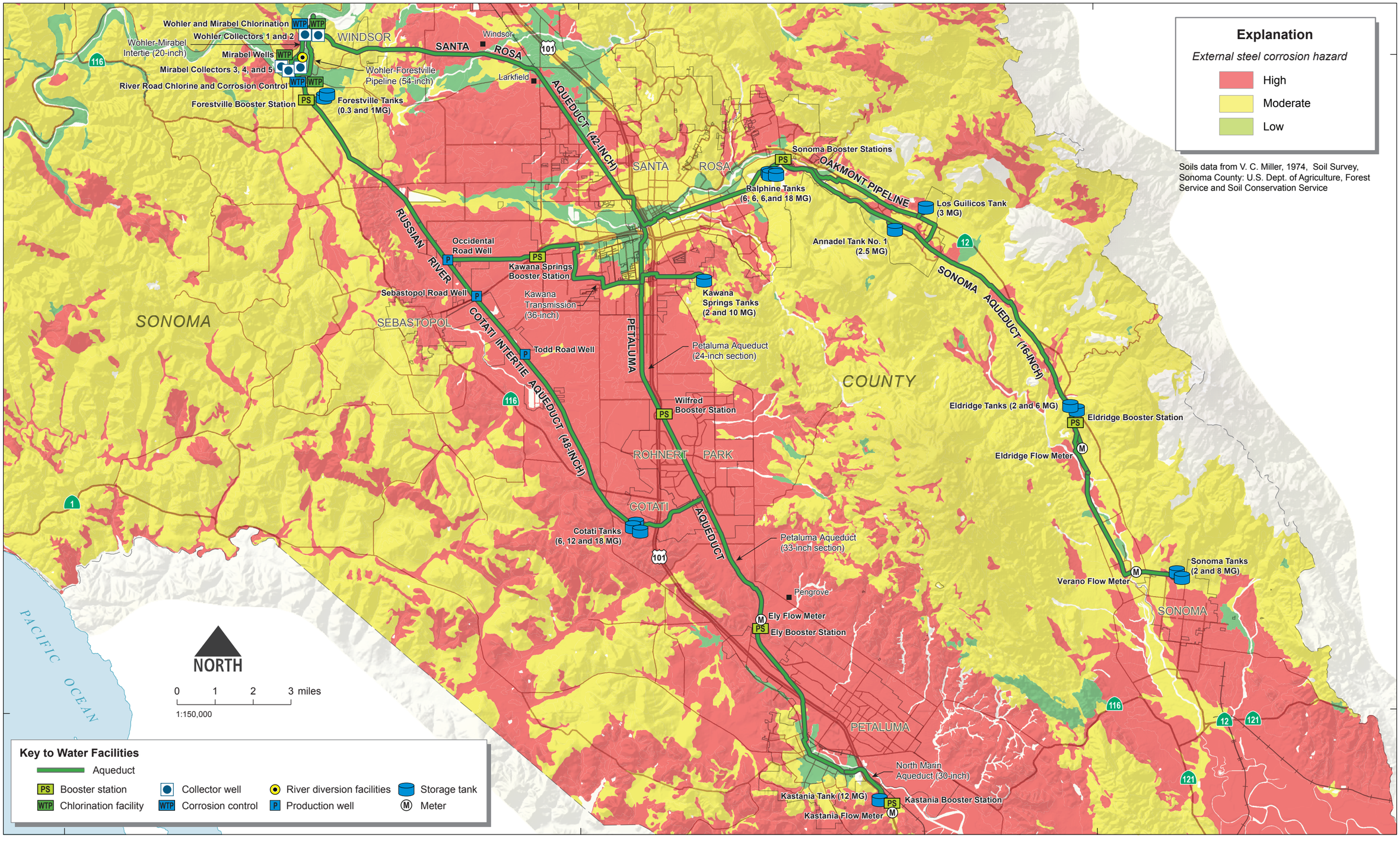


Figure 15

Water Transmission System – Steel Corrosion Potential

21 NOV 2012

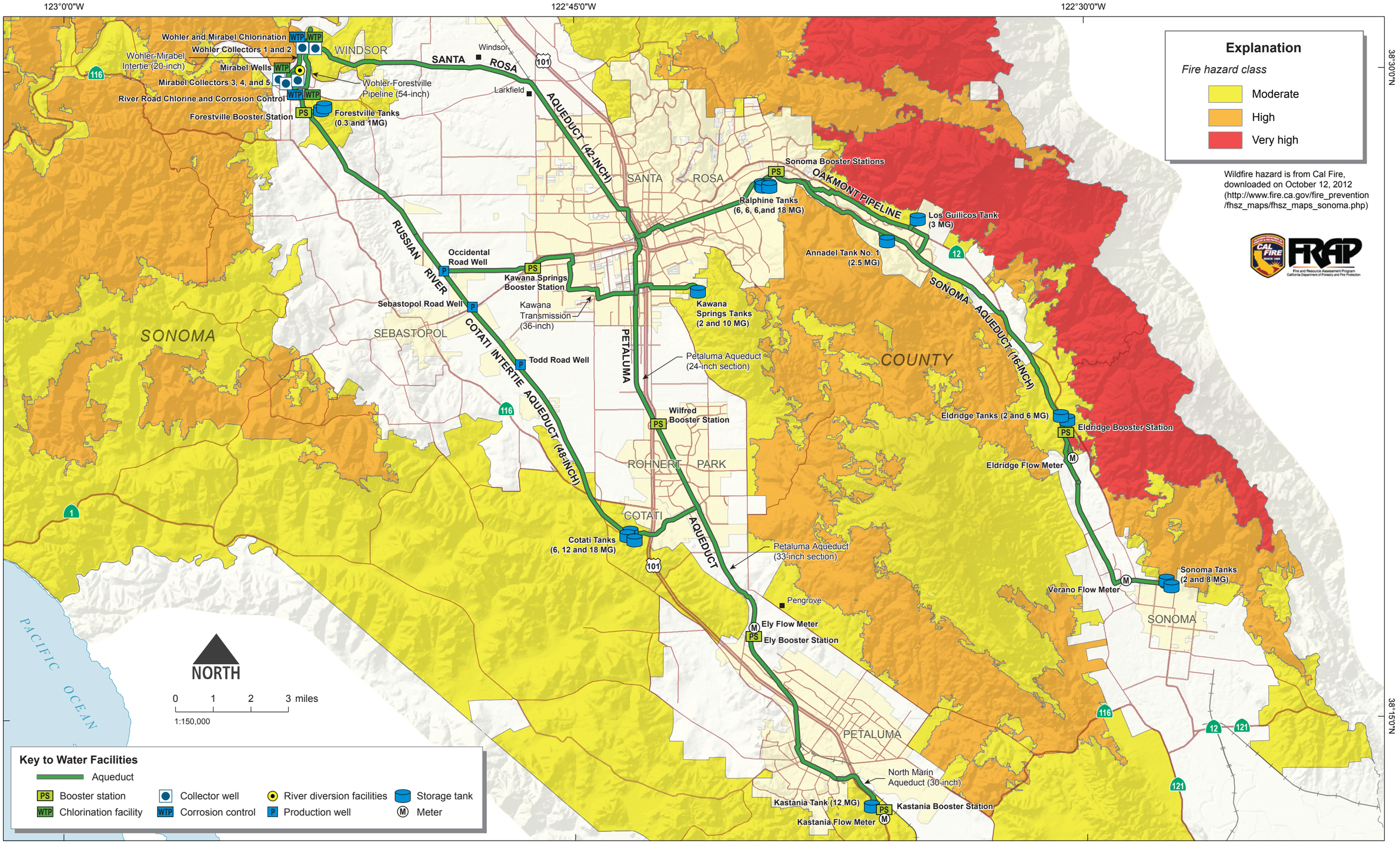


Figure 16

Water Transmission System – Fire Threat

21 NOV 2012

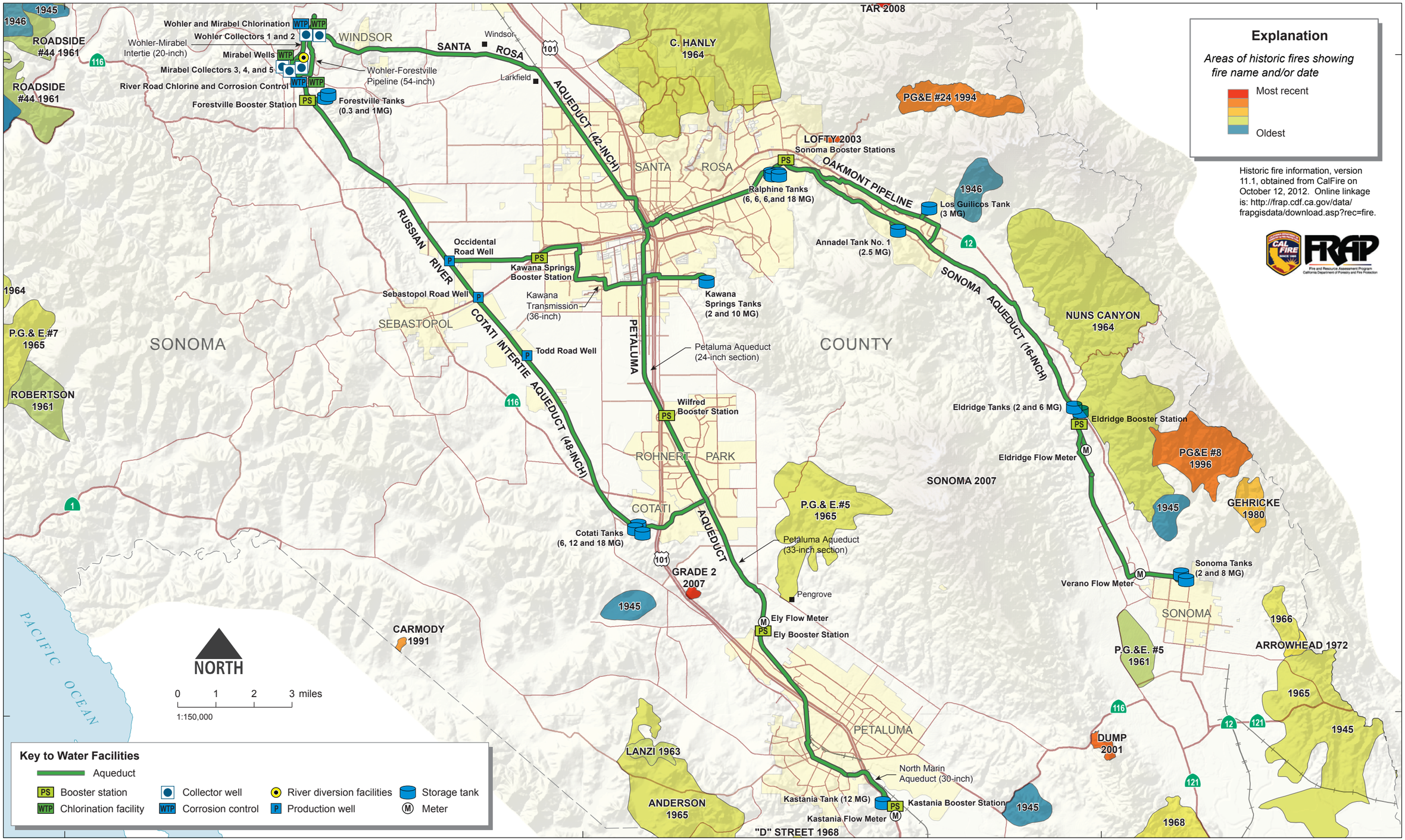


Figure 17

Water Transmission System – Historic Wild Fires

21 NOV 2012

Figure 18

Tornado Hazard in California

12 NOV 2012

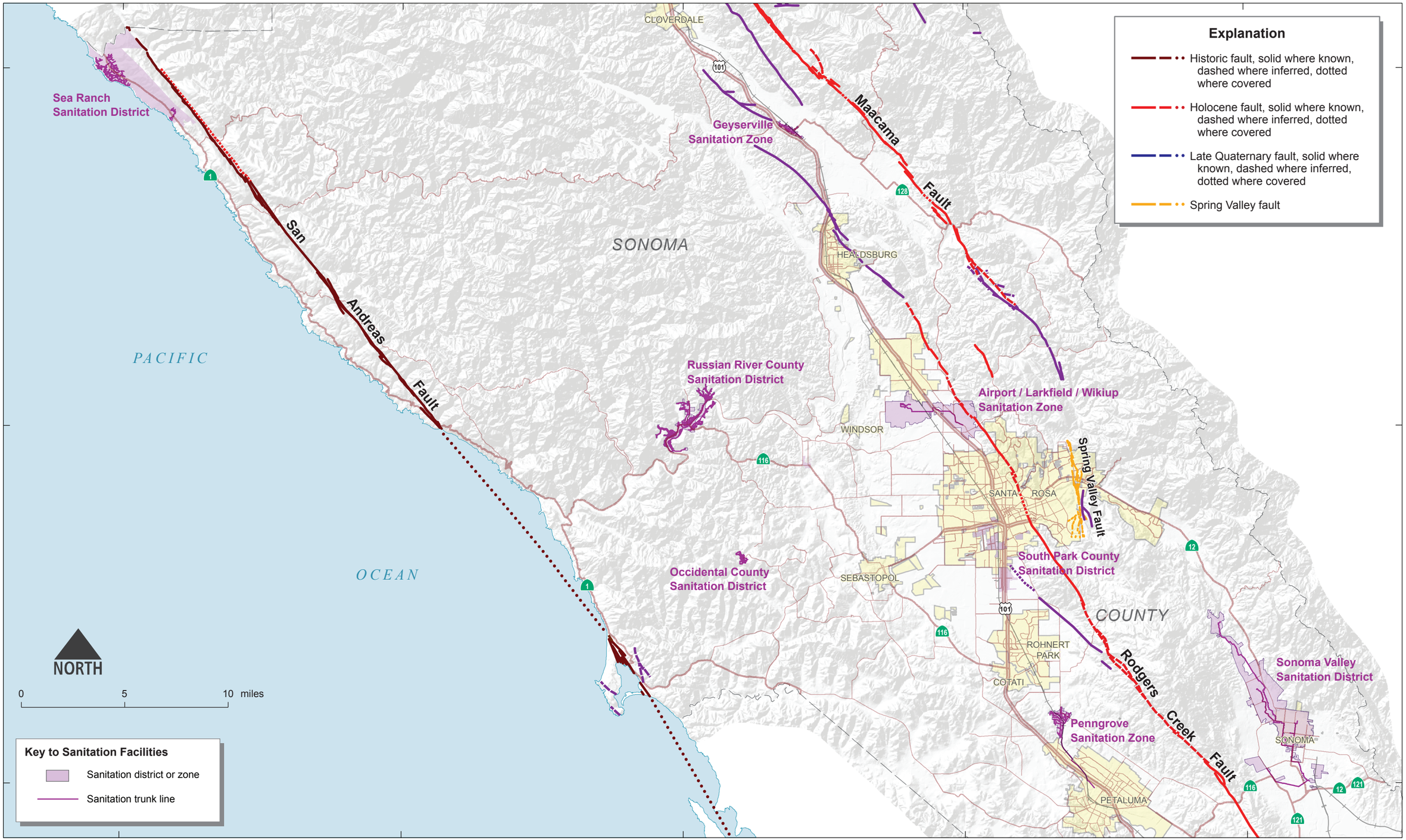


Figure 19

Sanitation System – Fault Map

21 NOV 2012

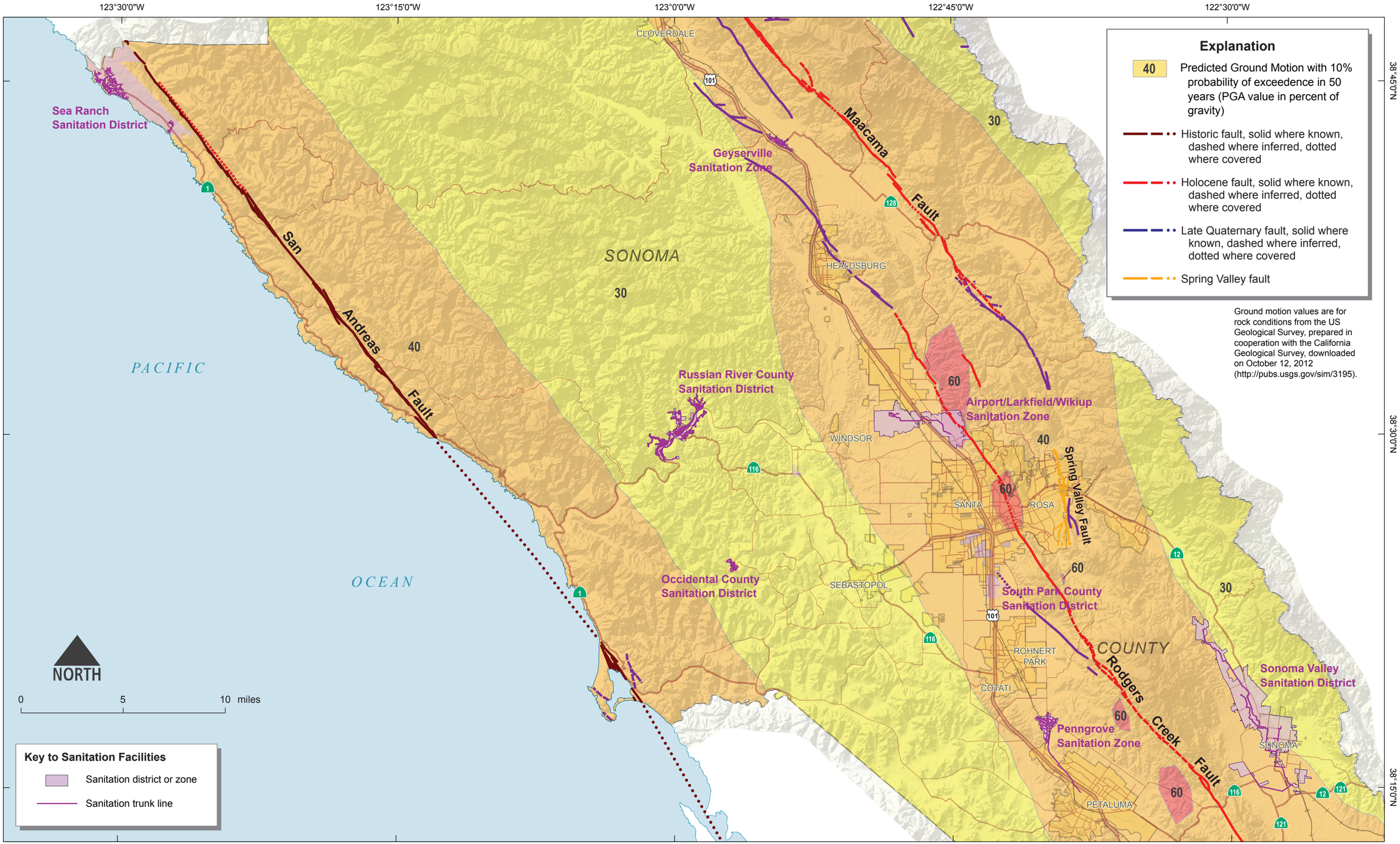


Figure 20

Sanitation System – Ground Shaking Hazard

21 NOV 2012

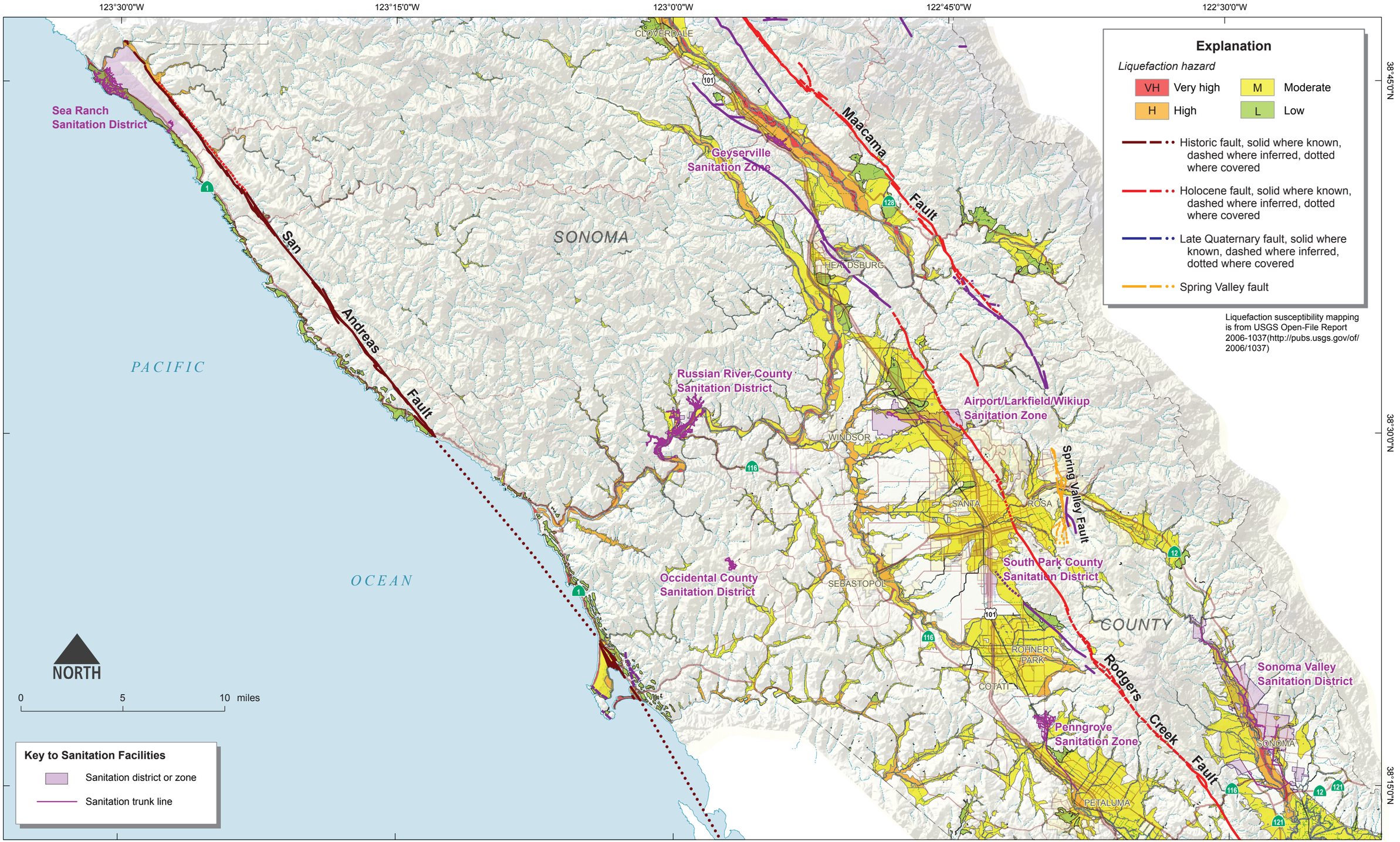
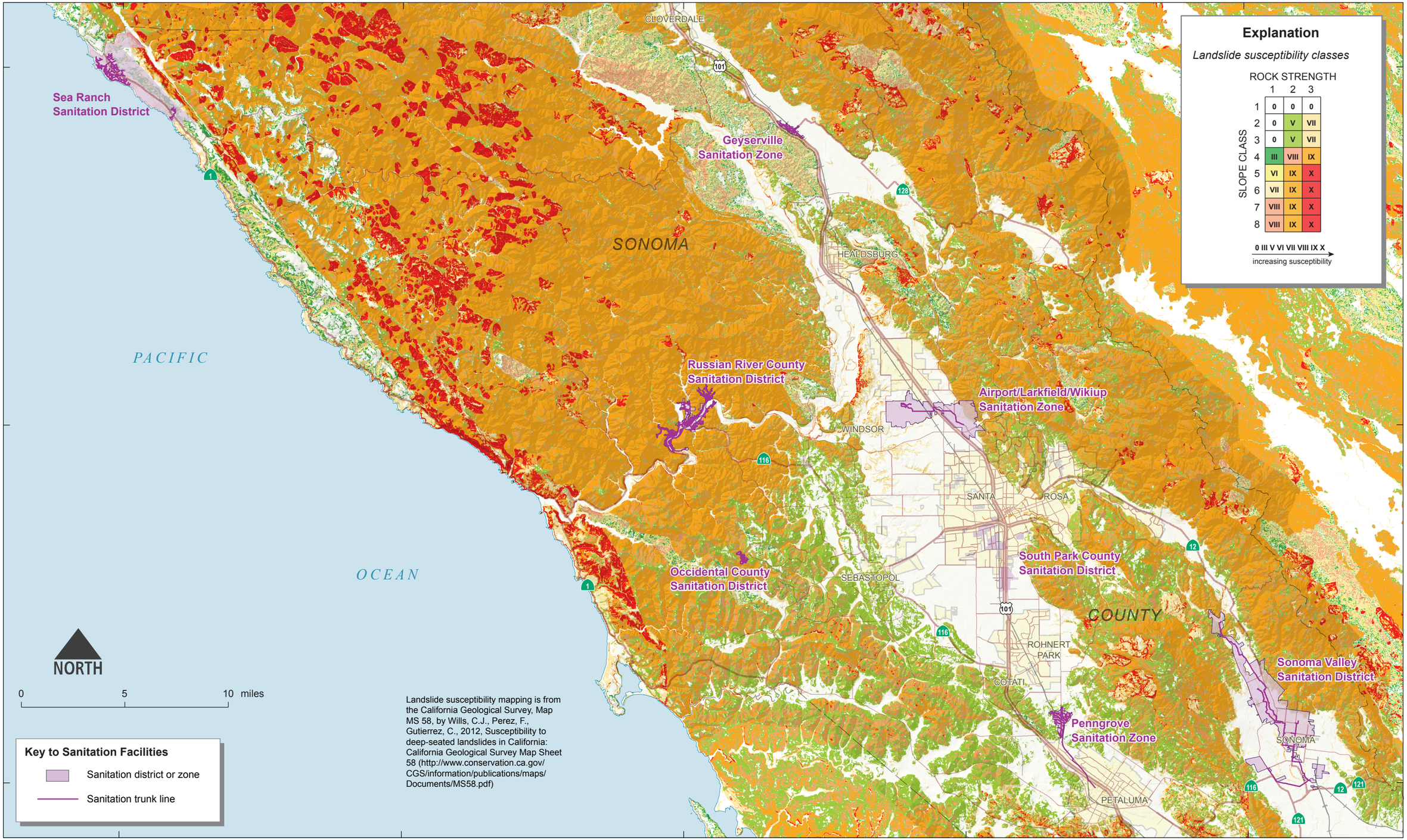


Figure 21

Sanitation System – Liquefaction Hazard

21 NOV 2012



Landslide susceptibility mapping is from the California Geological Survey, Map MS 58, by Wills, C.J., Perez, F., Gutierrez, C., 2012, Susceptibility to deep-seated landslides in California: California Geological Survey Map Sheet 58 (http://www.conservation.ca.gov/CGS/information/publications/maps/Documents/MS58.pdf)

Figure 22

Sanitation System – Landslide Hazard

21 NOV 2012

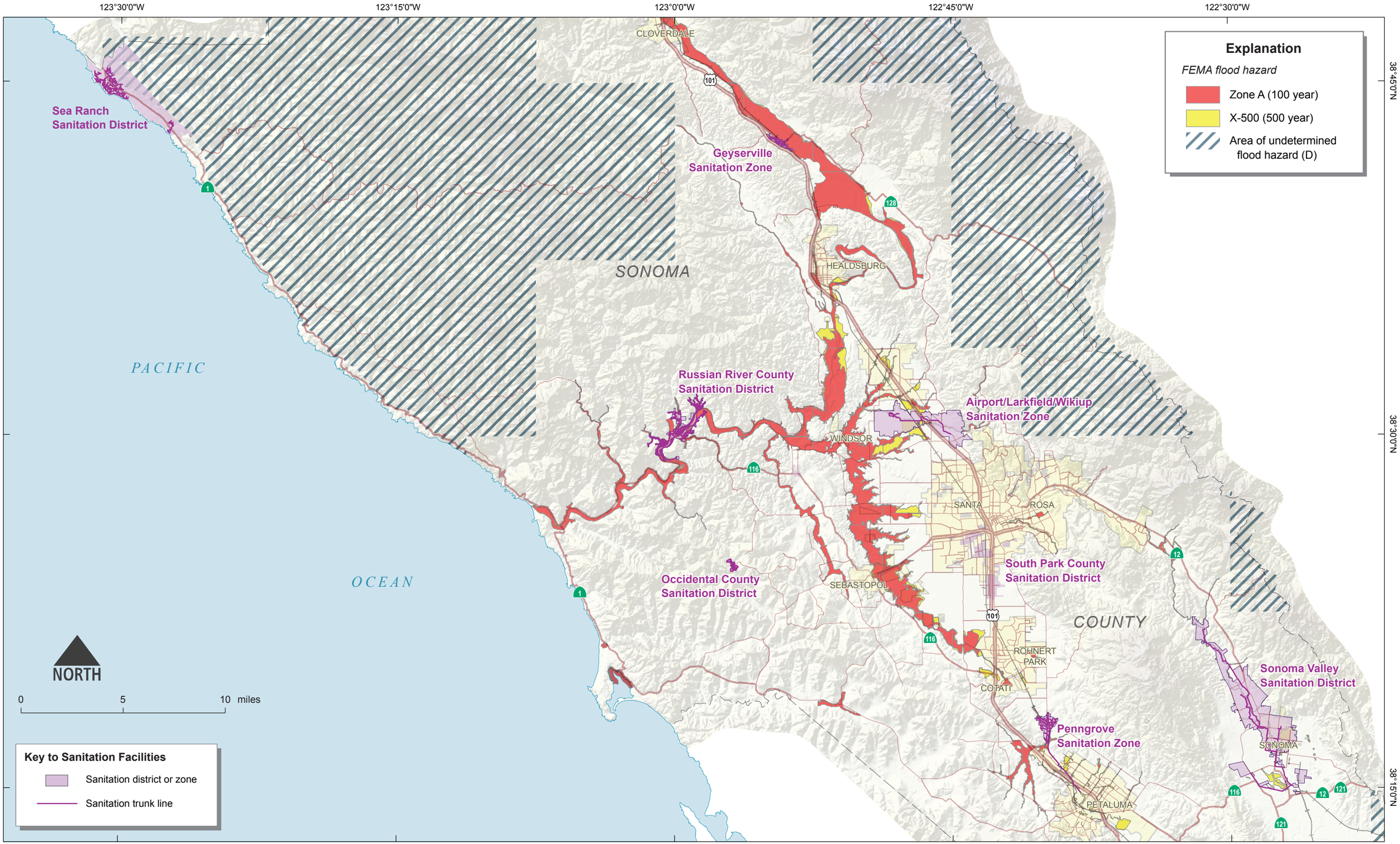


Figure 23

Sanitation System – Flood Hazard

21 NOV 2012

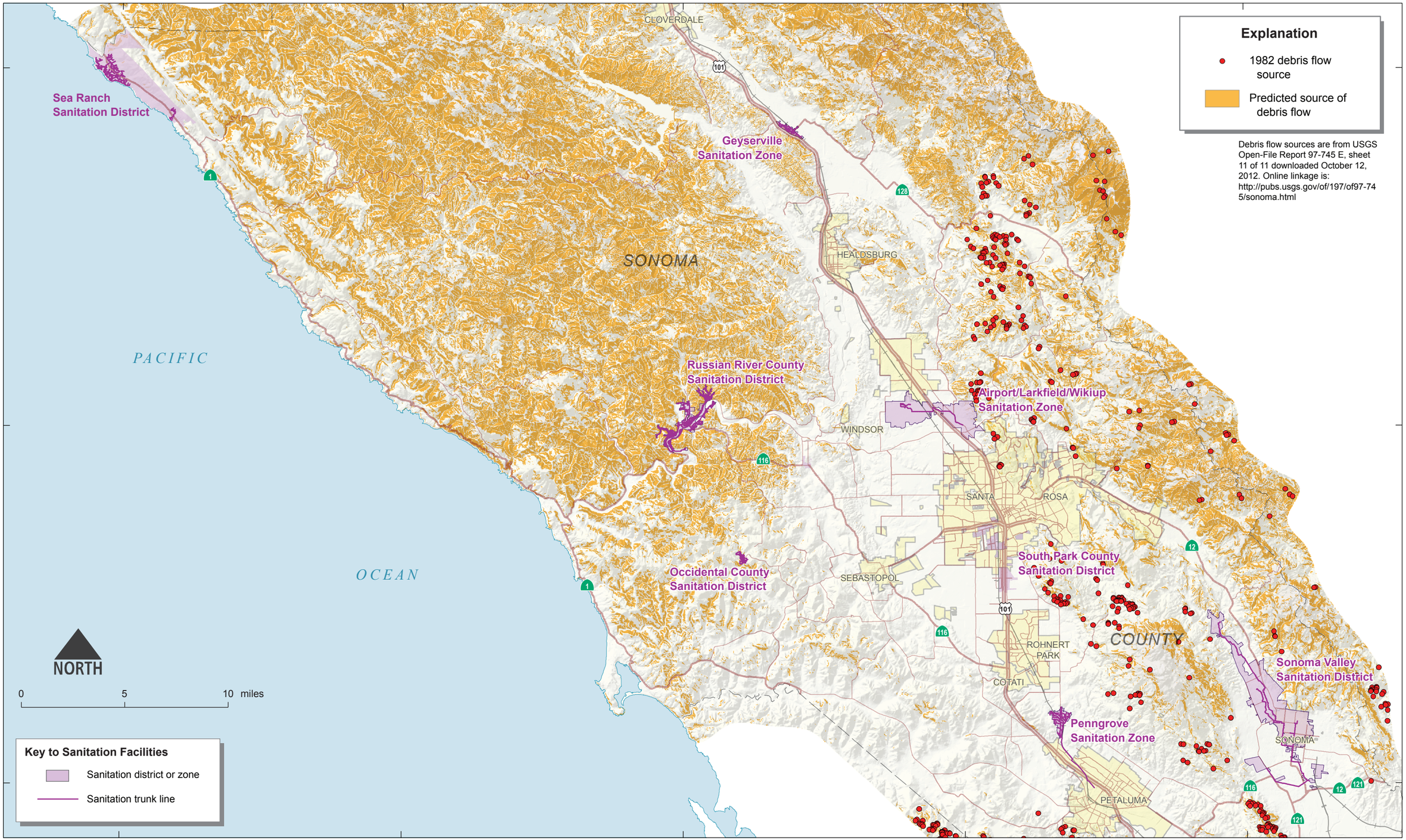


Figure 24

Sanitation System – Debris Flow Hazard

21 NOV 2012

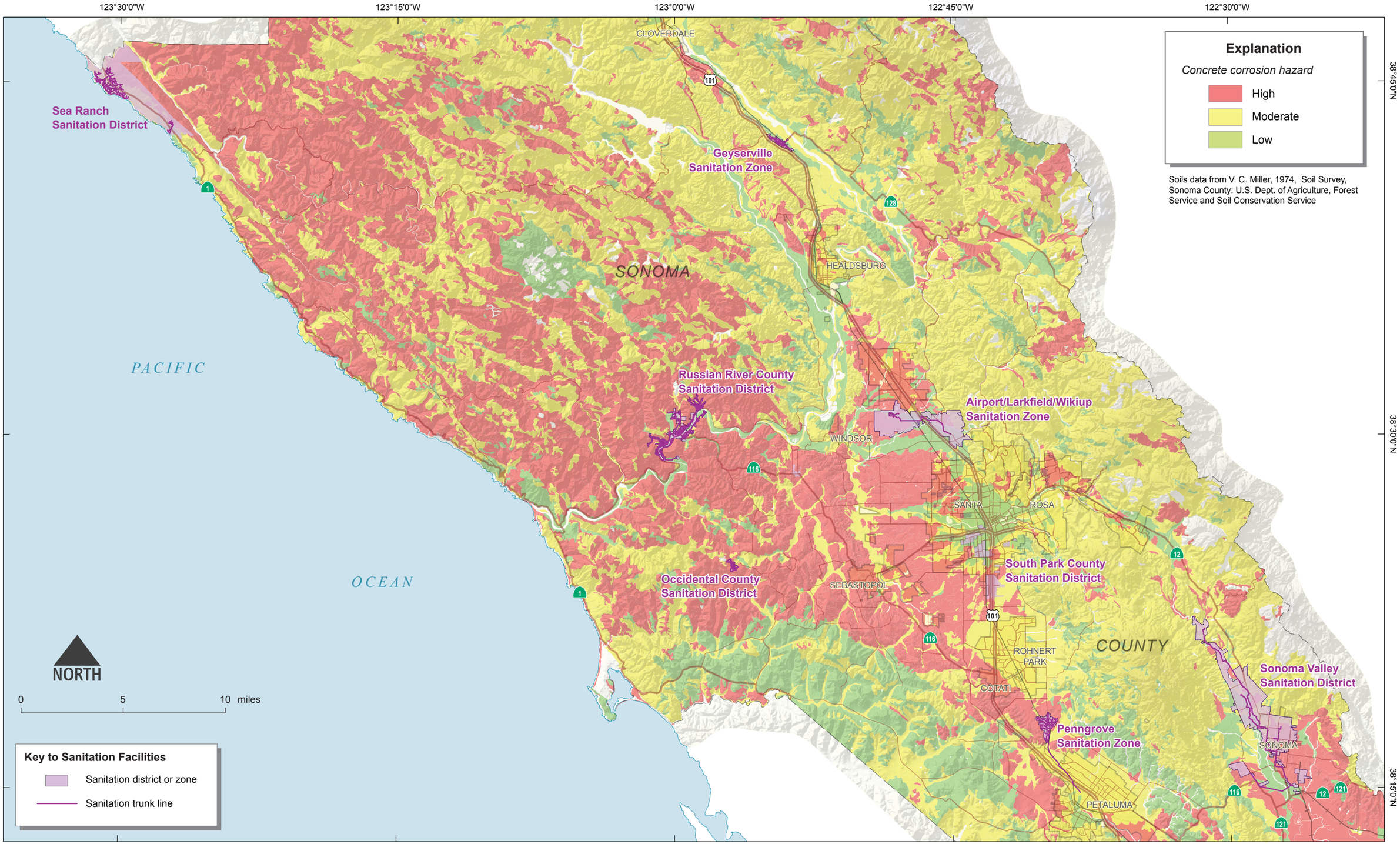


Figure 25

Sanitation System – Concrete Corrosion Potential

21 NOV 2012

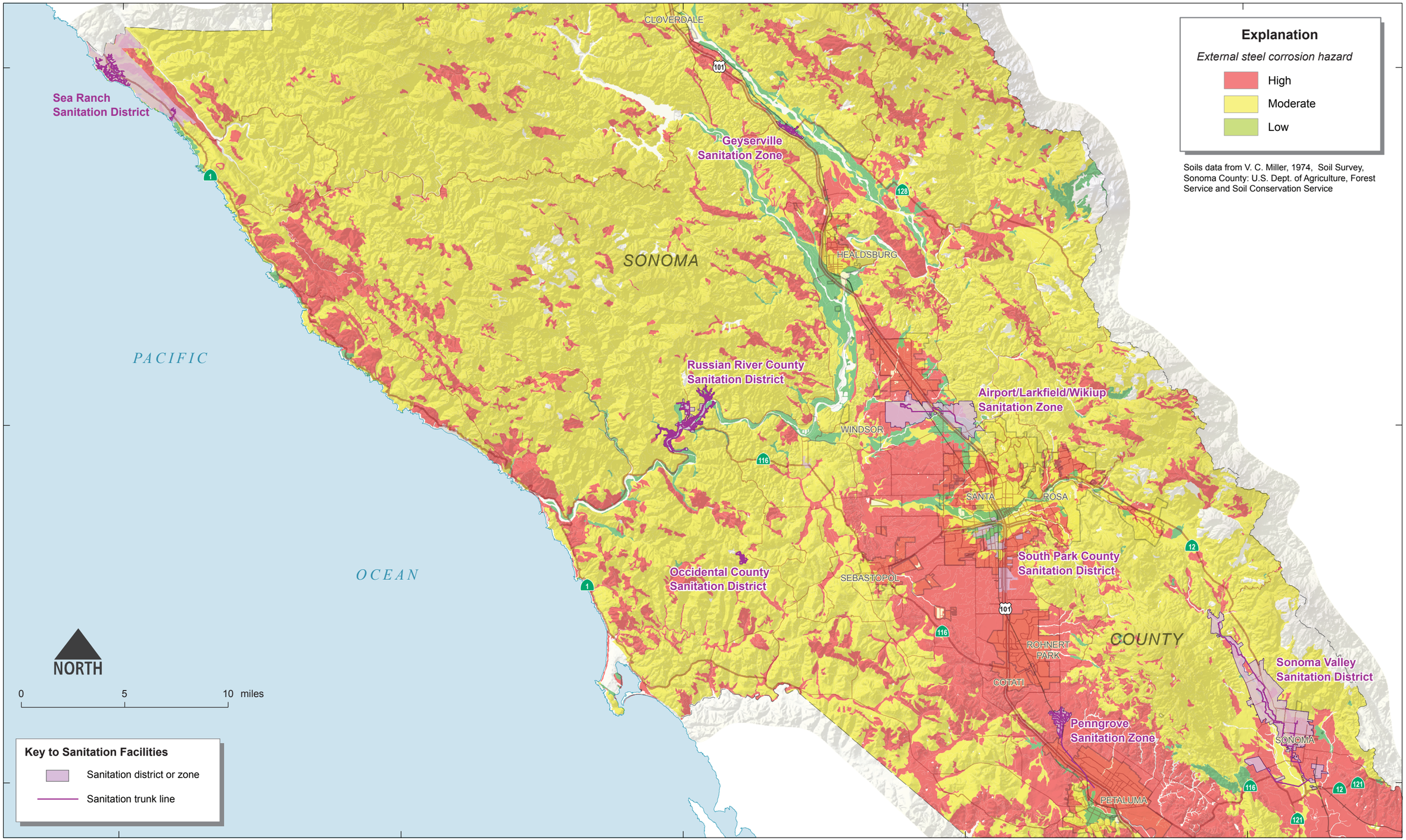


Figure 26

Sanitation System – Steel Corrosion Potential

21 NOV 2012

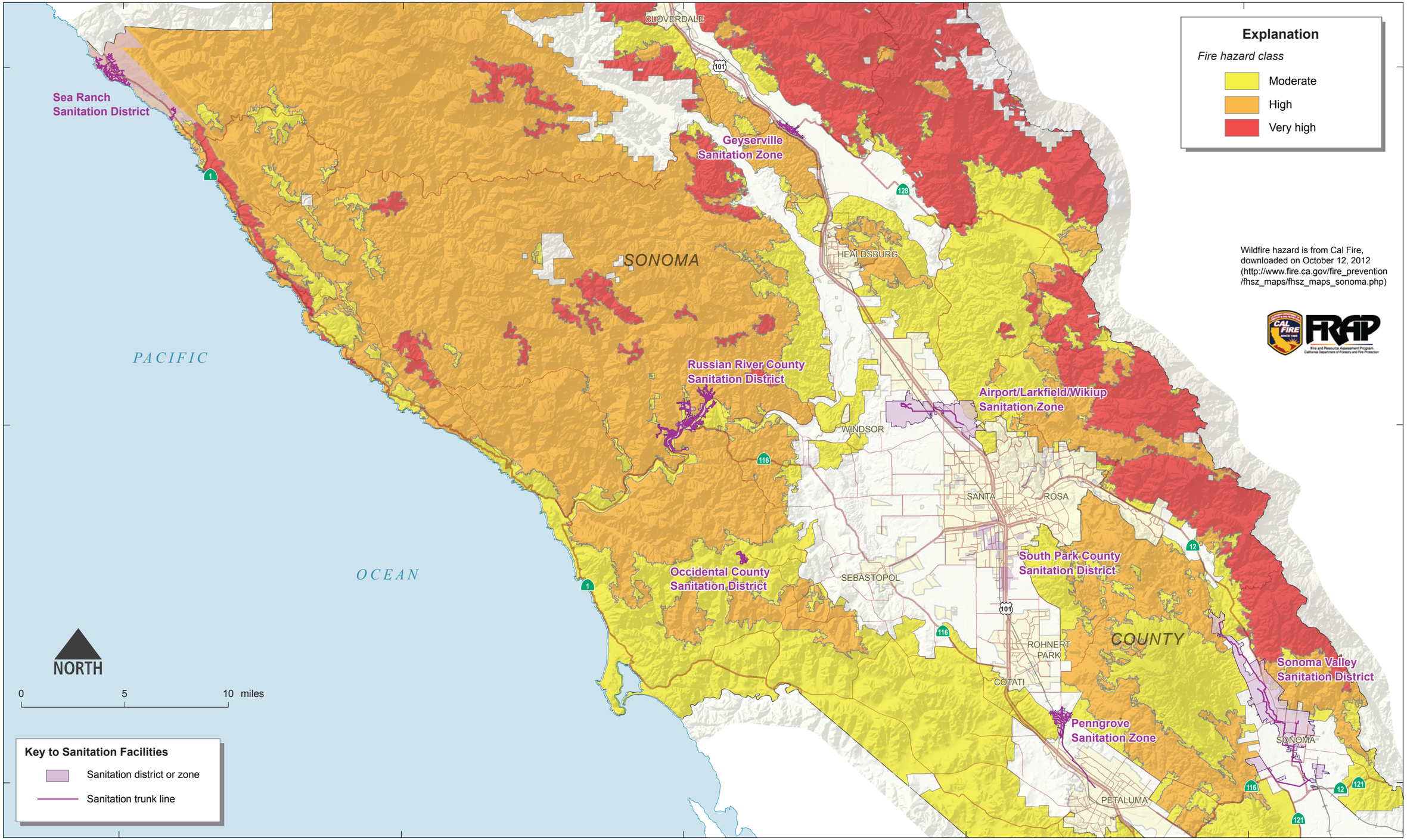


Figure 27

Sanitation System – Fire Threat

21 NOV 2012

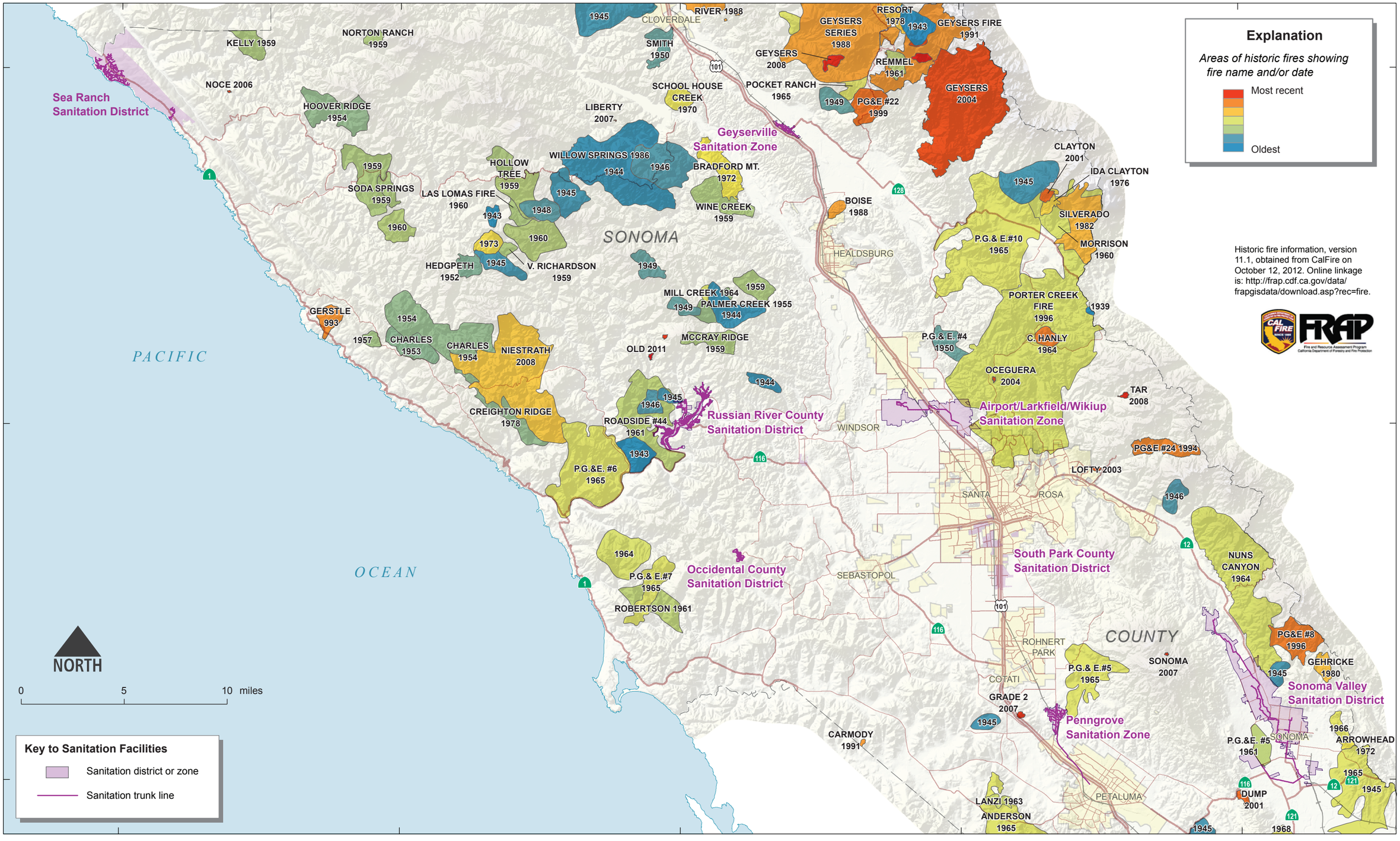


Figure 28

Sanitation System – Historic Wild Fires

21 NOV 2012

APPENDIX A

Table A-1

List of Drawings Reviewed

S. No	Name of the File	Year
1.	Russian River Cotati Intertie Project – Pipe Contract No. 1 Contract No 60-4-7#1	1975
2.	Russian River Cotati Intertie Project – Pipe Contract No. 2 Contract No 60-4-7#2	1975
3.	Russian River Cotati Intertie Project – Pipe Contract No. 3 Contract No 60-4-7#	1975
4.	Special Provisions And Contract Drawings For Construction of Russian River Project – Sonoma Aqueduct Pipeline and Appurtenances	1962
5.	Special Provisions And Contract Drawings For Construction of Russian River Project – Sonoma Aqueduct Glen Ellen Branch	1964
6.	Russian River Project – Aqueduct Number 1	1957
7.	Petaluma Aqueduct Water Transmission Pipeline	1963
8.	Oakmont Pipeline Contract No 60-4-7#5	1988
9.	Eldridge Madarone Pipeline Project	2005
10.	Kawana Springs Pipeline East (Petaluma Aqueduct To Kawana Springs Tank No.1) Contract No. 60-4-7	2001
11.	Pump and Collector Capacity Project – Caisson and Access Road For Wohler Collector No. 6 Contract No. 60-5-7	2001
12.	Pump and Collector Capacity Project Wohler-Forestville Pipeline	2004
13.	Special Provisions And Contract Drawings For Construction of Russian River Project – Horizontal Water Collectors Near Mirabel at The Russian River 60-5-7#1	1973
14.	Special Provisions And Contract Drawings For Construction of Mirabel Collector No. 5 Contract No 60-5-7#5	1982
15.	Project Manual Volume 2 For Pump and Collector Capacity Project – Wohler Forestville Pipeline Contract No 60-4-7#10	2004
16.	Russian River Well Field Development (Equipment) Early Warning System Station No. 1 And Mirabel Inflatable Dam Fabric Replacement	1995
17.	Specifications and Contract Drawings For Wohler Site Improvements: Standby Generator Replacement and Temporary Power Delivery System (PDS) For Substation Replacement Contract No 60-6-7#27	2000
18.	Sonoma County Water Agency: Wohler/Mirabel 12 KV Underground and Overhead Power Line Modifications	2006
19.	Project Manual Volume 2 For Pump and Collector Capacity Project Pump house and Connecting Pipeline For Wohler Collector #6 Contract No 60-4&6-7#1	2002
20.	Project Manual For Eldridge-Madrone Project Contract No 60-4-7#11	2004
21.	Kawana Springs Pipeline West (Vicinity of Wright Road To Petaluma Aqueduct) And Russian River Well Field Valve Replacements (Mirabel Area) Contract No 60-4-7#8 & 60-6-7#19	1999
22.	Special Provisions and Contract Drawings for Ralphine Reservoir No. 3 Contract No 60-7-7 No.2	1970
23.	Special Provisions and Contract Drawings for Grading and Appurtenances For Ralphine Reservoir No. 3 Contract No 60-7-7 No. 1	1970
24.	Project Manual And Contract Drawings For Construction OF Annadel reservoir No.2 And Cotati Reservoir No.3 Contract No 60-7-7 No.23	1992

S. No	Name of the File	Year
25.	Project Manual And Contract Drawings For Grading Piping and Appurtenances For Annadel reservoir No.2 , Cotati Reservoir No.3 and Warm Springs Reservoir Contract No 60-7-7 No.21	1985
26.	Special Provisions and Contract Drawings for Construction of Russian River Cotati Intertie Project: Grading and Appurtenances Cotati Reservoir Contract No 60-7-7 No.7	1974
27.	Special Provisions and Contract Drawings for Construction of Russian River Cotati Intertie Project: Cotati Reservoir Contract No 60-7-7 No.8	1974
28.	Special Provisions and Contract Drawings: Grading and Appurtenances for Ralphine Reservoir No. 4 Contract No 60-7-7 No.5	1973
29.	Special Provisions and Contract Drawings for Construction of Russian River Cotati Intertie Project: Ralphine Reservoir No. 4 Contract No 60-7-7 No.6	1974
30.	Specifications and Contract Drawings For Ralphine Tank No.4 Valve Seismic Control System Contract No 60-7-7 No.51	1999
31.	Special Provisions and Contract Drawings Russian River Project For Construction Of Ralphine Reservoir No.2 For Petaluma Aqueduct	1961
32.	Special Provisions and Contract Drawings for Construction of Russian River Cotati Intertie Project: Grading and Appurtenances Cotati Reservoir No. 2 Contract No 60-7-7 No.10	1980
33.	Special Provisions and Contract Drawings for Construction of Russian River Cotati Intertie Cotati Reservoir No. 2 Contract No 60-7-7 No.11	1980
34.	Specifications and Contract Drawings For Kawana Springs Tank No.1 Contract No 60-7-7 No.45	1998
35.	Special Provisions and Contract Drawings For Construction Kastania Reservoir Contract No 60-7-7 No.14	1983
36.	Specification and Contract Drawings For Seismic Retrofit For Eldridge Reservoir No.1 & Forestville Reservoirs No. 1 & No.2	1995
37.	Special Provisions And Contract Drawings Grading and Appurtenances For Eldridge Reservoir No. 2 Contract No: 60-7-7 #3	1972
38.	Specification and Contract Drawings For Seismic Retrofit For Annadel Reservoir No.1 & Sonoma Reservoir No. 1 Contract No. 60-7-7 #29	1994
39.	Specification and Contract Drawings For Seismic Retrofit for Eldridge Reservoir No.1 & Forestville Reservoir No.1 & No.2 Contract No. 60-7-7 #37	1995
40.	Special Provisions And Contract Drawings For Construction of Grading, Piping and Appurtenances For Forestville Reservoir No. 2 Contract No: 60-7-7 #16	1989
41.	Special Provisions And Contract Drawings For Construction of Forestville Reservoir No. 2 Contract No: 60-7-7 #17	1990
42.	Special Provisions And Contract Drawings: Russian River Project For Construction of Forestville Reservoir No. 1	1961
43.	Special Provisions And Contract Drawings For Construction of Sonoma Reservoir No. 2 Grading Piping and Appurtenances Contract No: 60-7-7 #15	1991
44.	Special Provisions And Contract Drawings: Russian River Project For Construction of Storage Reservoirs For Sonoma Aqueduct Contract No. 52-7-7#2	1962

Table A-2

List of Facility Geotechnical Reports Reviewed

S. No	Title	Consultant	Date
1	Geotechnical Investigation Proposed Seismic Repair Work Mirabel Collectors NOS. 3 AND 4 Sonoma County, California For The Sonoma County Water Agency.	Consulting Engineers	08-13-1985
2	A Geophysical Survey of the Wohler Aquifer Study Area Russian River, California	NORCAL Geophysical Consultants	09-14-1987
3	Hydrogeologic Investigation Wohler Aquifer Study Sonoma County, California	Harding Lawson Associates	12-09-1988
4	Report of Findings Preliminary Soil and Groundwater investigation: Wohler Road Pumping Facility	Brunsing Asociates Inc	09-30-1991
5	Report of Hydrogeologic Evaluation Russian River well Field Investigation (Near Mirabel) Sonoma County, California	Herzog Associates, Inc	12-16-1992
6	Seismic Refraction Survey Russian River Well Field Investigation Sonoma County, California.	Harding Lawson Associates	04-30-1993
7	Hydrogeologic Evaluation Kaiser sand and gravel company property Healdsburg, California.	PES Environmental, Inc	12-17-1998
8	Hydrogeologic Evaluations Westside Farms and Lazy "W" Ranch Healdsburg, California	PES Environmental, Inc	12-11-1998
9	Seismic Refraction Survey Pump and Collector Capacity Project Sonoma County, California	NORCAL Geophysical Consultants	06-07-1999
10	Geotechnical Investigation Sonoma County Water Agency pH Adjustment/Corrosion Control Facility 9750 Wohler Road, Sonoma County, California	Brunsing Associates	02-28-1994
11	Geotechnical Investigation Sonoma County Water Agency Wohler Substation Replacement 9750 Wohler Road, Sonoma County, California	Brunsing Associates	02-15-1999
12	Geotechnical Investigation Wohler Collector 6 Pumphouse Sonoma County, California	RGH Geotechnical and Environmental Consultants	04-26-2002
13	Seismic Refraction Survey Wohler Pipeline	RGH Geotechnical and Environmental Consultants	04-2001
14	Geotechnical Investigation Proposed Seismic Retrofit Annadel Reservoir No. 1 Sonoma County, California	Brunsing Associates	06-25-1995
15	Geotechnical Investigation Collector 6 Pipeline And Wohler-Forestville Pipeline Projects Sonoma County, California.	RGH geotechnical and Environmental Consultants	06-25-1995
16	Geotechnical Investigation Report For Seismic Retrofits of Eldridge Reservoir No.1 AND Forestville Reservoir NOS. 1 & 2 Sonoma County California	Kleinfelder, Inc	03-03-1995
17	Structural Evaluation of the Sonoma County Water Agency Administration Building and O&M Center	MKM & Associates	06-03-1997

S. No	Title	Consultant	Date
	for Seismic Conditions.		
18	Summary of Subsurface Investigations	WLA	04-21-2006
19	Geological Investigation For The Proposed Santa Rosa Creek Dam and Reservoir	Woodward, Clyde, Sherard and Associates	02-24-59
20	Geology of the Healdsburg Quadrangle, California Mineralogy of the California Glaucophone Schists, State of Califonia (Including Maps)		July 1951
21	Geotechnical Assessment of Aqueduct System	WLA	October 2006

APPENDIX B

Board of Supervisors
Resolution for Adoption of
Sonoma County Water Agency Local Hazard Mitigation Plan