Final Report

Appendix B. Vulnerability Assessment

October 2021

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Contents

Tables

Figures

SECTION 1

Vulnerability Assessment

1.1 Introduction

The vulnerability assessment evaluated the degree to which each of Sonoma Water's systems is susceptible to, and unable to cope with, the adverse effects of climate and climate change. The vulnerability assessment was performed for current and historical conditions in order to establish the current vulnerabilities as well as for future conditions incorporating climate change to estimate future vulnerabilities.

This section describes the approach used to assess vulnerability, includes a summary of each system's vulnerability assessment, and summarizes the overall vulnerability assessment findings.

1.2 Vulnerability Assessment Approach

The vulnerability assessment was conducted using a combination of field visits, interviews with Sonoma Water operations, maintenance, and engineering staff, review of historical vulnerabilities, and mapping of historical and future conditions. The vulnerability assessment was performed using both qualitative and quantitative information. The qualitative assessment helped to improve understanding of local climate and variables of interest, engaged those who manage, operate, and maintain the system, and identified the areas that required further investment of resources to improve the assessment. The quantitative assessment focused on areas of the most critical need and for which system models or other quantitative tools that could refine estimates of vulnerability and risk.

The qualitative vulnerability assessment began with an in-depth review of Sonoma Water's Facility Guide and a tour of each system led by facility operators and managers. Existing reports, hazard mapping, photos, critical elevations, and climate projections were reviewed to arrive at preliminary vulnerability findings. Workshops were then conducted with Sonoma Water staff to confirm and modify findings of vulnerability at each of the major system components or facilities, to help in determining the thresholds for performance, to identify the system component's sensitivity to climate and climate changes, and qualitatively address the adaptive capacity inherent in the certain system components. Sonoma Water personnel including members of the management team as well as water supply, flood control, and sanitation system managers and operators participated in the workshops.

The workshops covered the following items:

- Brief presentation of the regional/local climate and projected changes for the region, including maps that showed key climate variables and system assets
- Overview of the vulnerability and/or risk assessment process
- Overview of vulnerability-risk assessment table that was used to collect participant feedback and qualitative assessments
- Pictures and descriptions of historical climate events that proved challenging to the system
- Review of the consultant's initial findings following the facility tours and discussion of the vulnerability ratings in the vulnerability-risk table

Following the workshops, the findings were summarized in facility summaries. The facility summaries are included in Sections 1.4, 1.5, and 1.6 of this appendix.

Quantitative information was introduced for flood elevation mapping at critical facilities and specific modeling and technical analyses were developed to investigate some climate vulnerabilities and risks further. Areas with large uncertainty, or where additional technical information would be valuable, were identified as the focus for the more detailed quantitative assessment.

1.2.1 Climate Scenarios for Vulnerability Assessment

For the vulnerability assessment, a range of climate scenarios were utilized to support the assessment. These scenarios include changes in temperature, sea level rise, changes in precipitation, changes in drought, changes in wildfire, and changes in river flooding. Figure B-1 shows the range of climate changes considered in the vulnerability assessment.

Table B-1. Summary of the Range of Climate Change Considered in Vulnerability Assessment

Hydroclimate Variables		Projected Trends
	Temperature	• Increases up to 1.3 to 3.1°C by mid-century • Increased frequency of temperature extremes (days hotter than 30°C or 86°F)
	Sea Level Rise	• MSL increases by 0.1 to 0.6 meter (0.3 to 2 feet) by mid-century • Storm surge will cause additional increases
	Precipitation	• Extreme precipitation increases (ARs) by 15% • Increased winter, decreased summer precipitation (more variability)
	Drought	• Increasing intensity of drought conditions • Increasing frequency and duration of dry weather conditions

Hydroclimate Variables		Projected Trends
	Wildfire	• More frequent and intense wildfires due to warmer temperatures and drier conditions • Increase in probability of wildfires by 15 to 33%
	River Flooding	• Potential increase in AR-driven floods on Russian River • 100-year flood magnitudes could increase by 10 to 20%

1.2.2 Vulnerability Matrix and Rating Scale

For this assessment, vulnerability is a function of an asset's or system's sensitivity (how susceptible the system or asset is to changing climate conditions) and adaptive capacity (ability of a system or asset to respond to changing climate conditions). Sensitivity and adaptive capacity are combined in a vulnerability rating.

The *sensitivity* of the system to current climate and climate changes is assessed through a standard five-point rating scale ranging from low to high. The sensitivity rating is based on the responsiveness of the system to changes in climate without consideration of the ability to adapt. The current *adaptive capacity* is then assessed based on the ability of the system, operations, or management to adapt with little or no changes in the current system function or operational/management structure. As with the sensitivity rating, a standard five-point rating scale is also used for adaptive capacity. The combined rating of sensitivity and adaptive capacity results in a qualitative assessment of *vulnerability*. A system component that is highly sensitive (high) to climate changes and has little adaptive capacity (low) represents a high vulnerability. However, not all system components that show high sensitivity to climate are considered highly vulnerable. If substantial operational flexibility exists to adapt to such changes, then the component may be considered to have only low to moderate vulnerability. Tables B-2 and Table B-3 define the vulnerability rating scales for sensitivity and adaptive capacity, respectively.

Adaptive Capacity \ Sensitivity	Low = 1	Moderate/Low = 2	Moderate = 3	Moderate/High = 4	High = 5
Low = 1	L	M/L	H	H	H
Moderate/Low = 2	L	M	M/H	H	H
Moderate = 3	L	L	M	M	H
Moderate/High = 4	L	L	L	M	M
High = 5	L	L	L	L	M

A five-point rating scaled was used in vulnerability and risk assessments (L=low, M=moderate, H=high)

Table B-2. Sensitivity Rating Scale

Level	Descriptor	Description
1	Low	Low sensitivity: Climate and climate changes have little to no influence on asset or operations.
2	Low to Moderate	Intermediate between Low and Moderate sensitivity
3	Moderate	Moderate sensitivity: Climate and climate changes have influence on asset or operations.
4	Moderate to High	Intermediate between Moderate and High sensitivity
5	High	High sensitivity: Climate and climate changes have a high influence on asset or operations.

Table B-3. Adaptive Capacity Rating Scale

Level	Descriptor	Description
1	Low	System component has little inherent capacity to adapt to climate-induced changes.
2	Low to Moderate	Intermediate between Low and Moderate
3	Moderate	System component has some inherent capacity to adapt to climate-induced changes.
4	Moderate to High	Intermediate between Moderate and High
5	High	System component has substantial inherent capacity to adapt to climate-induced changes.

1.3 Vulnerability Assessment Summary

The combined rating of sensitivity and adaptive capacity results in an assessment of vulnerability. A system component that is highly sensitive (high) to climate changes and has little adaptive capacity (low) represents a high vulnerability. However, not all system components that show high sensitivity to climate are considered highly vulnerable. If substantial operational flexibility exists to adapt to such changes, then the component may be considered to have only low to moderate vulnerability. Table B-4 provides a summary of the vulnerabilities identified in the various systems evaluated for this study.

Table B-4. Vulnerability Assessment Summary

System	Planning Area	System Component (Asset)	Vulnerability Rating
Water Supply System	Potter Valley Project (PVP)	Lake Pillsbury/Scott Dam	Moderate to High
Water Supply System	Coyote Valley Dam (CVD) Project	Lake Mendocino/CVD	**High**

System	Planning Area	System Component (Asset)	Vulnerability Rating
Water Supply System	Russian River Project	Lake Sonoma/Warm Springs Dam	Moderate
Water Supply System	Russian River Project	Dry Creek	Moderate
Water Supply System	Russian River Diversion Facilities	Wohler Ranney Collector - Collector No. 1	Moderate to High
Water Supply System	Russian River Diversion Facilities	Mirabel Ranney Collector - Collector No. 3	Moderate to High
Water Supply System	Russian River Water Treatment	River Road Chlorination and Control Facility	Moderate
Water Supply System	Russian River Water Treatment	Mirabel Chlorination Facility	Moderate to Low
Water Supply System	Russian River Water Treatment	Wohler Chlorination and Corrosion Control Facility	Moderate to High
Water Supply System	Transmission System	Booster Pump Station - Ely Booster	**High**
Water Supply System	Transmission System	Booster Pump Station - Kawana Booster	Moderate
Flood Management System	Zone 4A	Russian River Engineered Levees (Cloverdale)	Moderate
Flood Management System	Russian River Project (Zone 5A)	Lower Russian River	Moderate
Flood Management System	Central Sonoma Watershed Project (Zone 1A)	Detention Basins (Santa Rosa Creek Reservoir/Spring Lake, Matanzas Creek Reservoir, Piner Creek Reservoir, Brush Creek Reservoir, Spring Creek Reservoir)	**High**
Flood Management System	Central Sonoma Watershed Project (Zone 1A)	Engineered Flood Control Channels in Zone 1A	**High**
Flood Management System	Sonoma Creek (Zone 3A)	Sonoma Creek Main Channel	Moderate to High
Flood Management System	Petaluma River (Zone 2A)	Petaluma River Main Channel and Flood Control Project components	**High**
Sanitation System	Airport/Larkfield/Wikiup Sanitation Zone	Wastewater Treatment Plant	Moderate

System	Planning Area	System Component (Asset)	Vulnerability Rating
Sanitation System	Airport/Larkfield/Wikiup Sanitation Zone	Collection system	Moderate
Sanitation System	Geyserville Sanitation Zone	Wastewater Treatment Plant	Moderate
Sanitation System	Geyserville Sanitation Zone	Collections System	Moderate
Sanitation System	Occidental County Sanitation Zone	Wastewater Treatment Plant	Moderate to High
Sanitation System	Occidental County Sanitation Zone	Collections System	Moderate to High
Sanitation System	Penngrove Sanitation Zone	Collections System	**High**
Sanitation System	Russian River County Sanitation District	Wastewater Treatment Plant	**High**
Sanitation System	Russian River County Sanitation District	Collections System	**High**
Sanitation System	Sonoma Valley County Sanitation District	Wastewater Treatment Plant	Moderate to High
Sanitation System	Sonoma Valley County Sanitation District	Collections System	**High**
Sanitation System	Sonoma Valley County Sanitation District	Recycled Water	**High**
Administration Buildings	SCWA Service Area	Administrative Offices	Moderate to Low

A summary of the vulnerability assessment results for the water supply system are shown in Table B-5.

- Russian River water supply is projected to be impacted by increasing climate variability and severity of drought. While not well simulated in General circulation models (GCMs), some projections suggest future droughts through mid-century up to 20% more severe than historical droughts. All GCMs analyzed suggest future increases in wildfire intensity and frequency which could contribute to high sediment and organic carbon loading in the Russian River.
- Wohler and Mirabel diversion facilities have risk due to flooding and wildfire/post-fire threats. Projected future floods under climate change will exceed historical 100-year floods with river stage exceeding critical elevations of caissons, roads, ponds, and wells.
- Post-wildfire storm runoff carrying burn-area sediment and dissolved organic carbon (DOC) to Wohler and Mirabel diversion facilities has been identified as a risk. Projections under future climate change indicate growing wildfire risks in terms of both severity and frequency of occurrence. Large increases in DOC in the Russian River may impact riverbank

infiltration water quality and severely limit the ability to chlorinate without generating higher levels of disinfection byproducts.

- Both River Road Chlorination Facility and Wohler Chlorination and Corrosion Control Facility will experience increased risk due to extreme precipitation, river flooding, and wildfires. Both facilities are likely to experience flooding impacts under future climate change and may be impacted with changing water quality conditions post-wildfire. Loss of power during extreme events is a risk and limited backup power exists, particularly at River Road.
- Ely Booster Pump Station is at high risk due to extreme precipitation and localized flooding. Historical flooding has already presented risk at this facility and future climate change will increase the flood stage.
- Kawana Booster Station is susceptible to localized flooding from the adjacent creek and Highway 12. Projected increased precipitation extremes will exacerbate the current periodic flooding/drainage issues.

Table B-5. Vulnerability Assessment Summary for the Water Supply System

System Component	Temperature	Sea Level Rise	Extreme Precipitation	River Flooding	Drought	Wildfire
Upper Russian River Supply (Watershed and Lake Mendocino)	Moderate	N/A	N/A	N/A	High	Moderate
Lake Sonoma	Moderate	N/A	N/A	N/A	Moderate	Moderate
Mirabel Diversion Facilities	N/A	N/A	N/A	High	Moderate	High
Wohler Diversion Facilities	N/A	N/A	N/A	High	Moderate	High
Wohler Chlorination and Corrosion Control	N/A	N/A	Moderate to High	Moderate to High	N/A	Moderate to High
Mirabel Chlorination and Corrosion Control	N/A	N/A	Low	Low	N/A	Low
River Road Chlorination	N/A	N/A	Moderate to High	High	N/A	N/A
Ely Booster	N/A	N/A	High	N/A	N/A	N/A
Kawana Booster	N/A	N/A	Moderate	N/A	N/A	N/A

A summary of the vulnerability assessment results for the flood management system are shown in Table B-6.

- Highest risk is related to flood management facilities for which Sonoma Water has responsibility is in Central Sonoma Watershed (Zone 1A). These facilities are currently unable to adequately manage flood flows greater than historical 25-year flood on Santa

Rosa Creek and Matanzas Creek. Future extreme precipitation is projected to increase by 10 to 30% and will exacerbate the detention basins, culvert, and channel capacity to manage high flows. Increasing runoff and wildfire potential will lead to higher sediment loading to these facilities and may exceed sediment removal resources.

- Flood related vulnerabilities in the Upper Russian River near Cloverdale are related to increased peak discharges and potential levee overtopping or risks due to more extreme precipitation events. In addition, increased sediment loading near Big Sulphur Creek is projected to further challenge flood conveyance.
- On the lower Russian River, increased flood flows and sea level rise will exacerbate river flooding and challenge the management of the Russian River Estuary. Rising sea levels will change the depositional environment and tidal influence (upstream) at the estuary and will alter the stability and location of the natural berm, frequency and duration of closure events, and timing of breach.
- Flood conveyance channels in the Petaluma River and tributaries (Zone 2A) are highly sensitive to climate change due to increases in extreme precipitation and sea level rise. Increased runoff volumes associated with increased precipitation rates and intensities could exceed channel conveyance capacity in the Petaluma River and its tributaries.
- Moderate vulnerability is evaluated for Sonoma Creek due to increased flood flows and sea level rise. Flooding vulnerability for tributaries Nathanson Creek and Fowler Creek is high. Sea level rise is anticipated to cause more extensive flooding in lower Sonoma Creek impacting marshes near San Pablo Bay and along Highways 37 and 121, but is not likely to cause increased flood levels near the upstream urban areas.

Table B-6. Vulnerability Assessment Summary for the Flood Management System

System Component	Temperature	Sea Level Rise	Extreme Precip	River Flooding	Drought	Wildfire
Central Sonoma Watershed Project (Zone 1A) – Detention Basins	N/A	N/A	**High**	**High**	N/A	**Moderate**
Central Sonoma Watershed Project (Zone 1A) – Triple Box Culvert	N/A	N/A	**High**	**High**	N/A	**Moderate**
Central Sonoma Watershed Project (Zone 1A) – Channels	N/A	N/A	**High**	**High**	N/A	**Moderate**
Petaluma River (Zone 2A)	N/A	**High**	**High**	**High**	N/A	N/A
Sonoma Creek (Zone 3A)	N/A	**Moderate**	**Moderate**	**Moderate**	N/A	N/A

System Component	Temperature	Sea Level Rise	Extreme Precip	River Flooding	Drought	Wildfire
Upper Russian River (Zone 4A)	N/A	N/A	N/A	**Moderate**	N/A	N/A
Lower Russian River (Zone 5A)	N/A	**Moderate**	N/A	**Moderate**	N/A	N/A

A summary of the vulnerability assessment results for the sanitation system are shown in Table B-7.

- Russian River Wastewater Treatment Plant (WWTP) and collection system already experience substantial flooding risk due to high river stage, low lying developments, high infiltration and inflow (I/I), road access, and power outages. Climate change will exacerbate all of these risks due to increased river flooding and extreme precipitation events and will substantially challenge the operability during flood events.
- Sonoma Valley WWTP, collection system, and recycled water system have moderate to high vulnerability to climate change. The collection system suffers from aging sewer lines and insufficient capacity in some areas which contribute to vulnerability to increased I/I and sanitary sewer overflows (SSOs) during high precipitation events. The WWTP is moderately vulnerable to increasing sea level which will impact the discharge capacity during high tide events and over time at Schell Slough. Similarly, the recycled water system is vulnerable to increased river flooding and sea level rise including tide gate operations in Hudeman Slough and roads and levees adjacent to the wetland management units.
- In the Penngrove Sanitation Zone, the Penngrove Lift Station is highly vulnerable to creek flooding. The lift station is located within the current 100-year floodplain and electrical equipment is near ground floor. Climate change will further increase the extent and frequency of flooding, damage equipment, and limit lift station operation during these events. Tidal influence in adjacent Lichau Creek is projected to become more pronounced with increased sea levels.
- Geyserville WWTP and lift station are located within the Russian River 100-year floodplain and are highly vulnerable to climate change. Increased river flooding will inundate access roads, causing increased flooding at the lift station, and limit the percolation capacity of the WWTP ponds.
- Moderate vulnerability is assessed for Occidental collection system due to projected increase I/I during flood events causing additional SSO incidences.
- At the Airport Sanitation Zone, moderate climate vulnerability is assessed due to increased creek flooding that inundates the road to North Pond (effluent storage pond), limiting access to the pond and to several valves, as well as the access road to Site D (an offsite storage pond). In addition, portions of the collection system and the lift station are vulnerable to increasing wildfires associated with climate change.

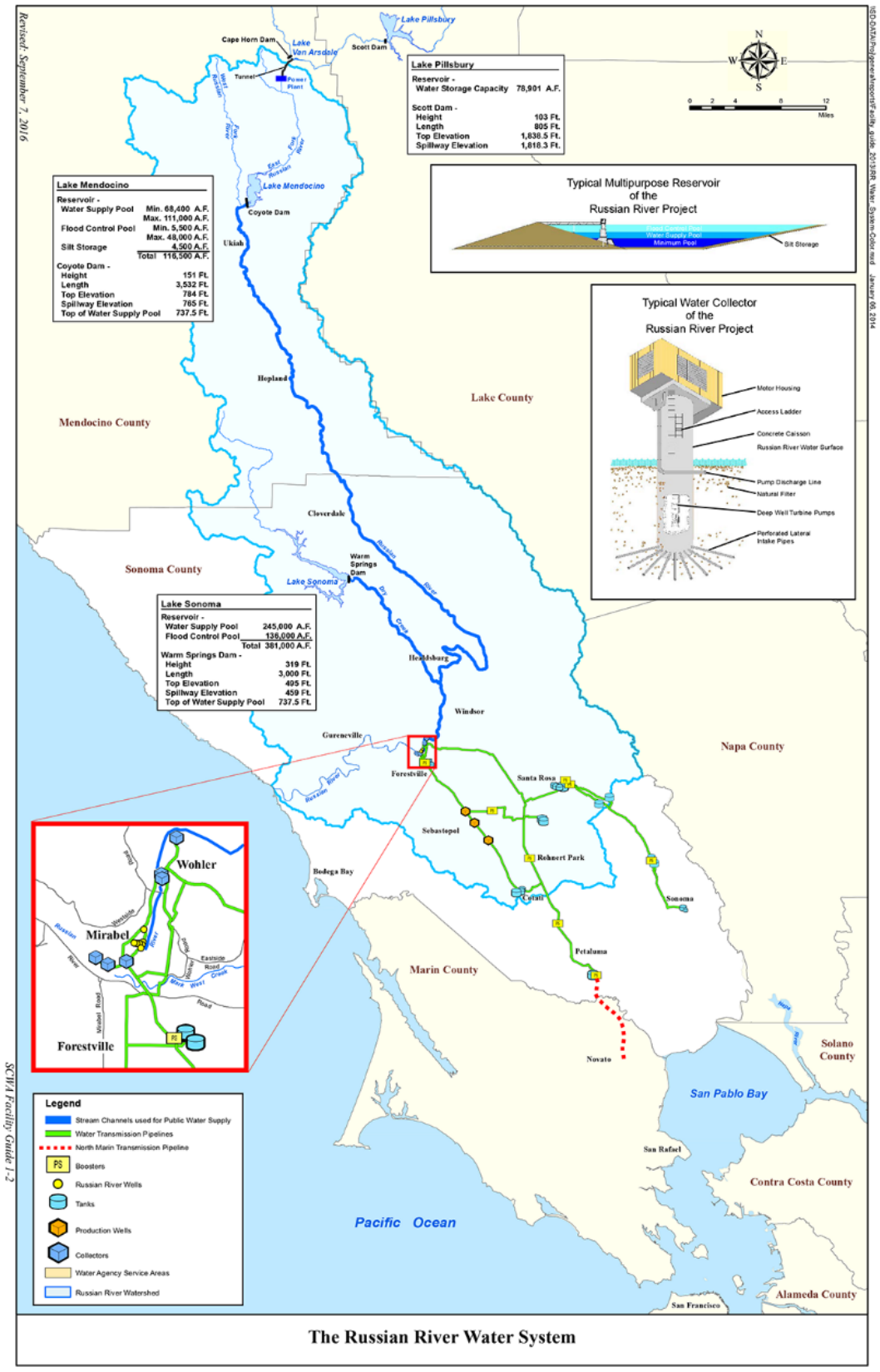
Table B-7. Vulnerability Assessment Summary for the Sanitation System

System Component	Temperature	Sea Level Rise	Extreme Precip	River Flooding	Drought	Wildfire
Russian River CSD - WWTP	N/A	N/A	**High**	**High**	N/A	**Moderate**
Russian River CSD - Collection	N/A	N/A	**High**	**High**	N/A	**Moderate**
Sonoma Valley CSD - WWTP	N/A	**Moderate to High**	**Moderate**	**Moderate**	N/A	**Moderate to Low**
Sonoma Valley CSD – Collection	N/A	N/A	**High**	**High**	N/A	**Moderate**
Penngrove Sanitation Zone (SZ) – Collection	N/A	**Low**	**High**	**High**	N/A	**Moderate to Low**
Occidental County SZ – WWTP & Collection	N/A	N/A	**Moderate**	N/A	N/A	**Moderate**
Geyserville SZ - WWTP	N/A	N/A	**Moderate**	**Moderate**	N/A	N/A
Geyserville SZ – Collection	N/A	N/A	**High**	**High**	N/A	N/A
Airport SZ – WWTP	N/A	N/A	**Moderate**	**Moderate**	N/A	N/A
Airport SZ - Collection	N/A	N/A	**Low**	**N/A**	N/A	**Moderate**

1.4 Water Supply System Vulnerability Assessment

Sonoma Water's water supply system is divided into three main facility types: diversion, transmission, and treatment facilities. Detailed vulnerability assessments are described for each of these facility types. Figure B-1 provides an overview of Sonoma Water's water supply system.

Figure B-1. The Russian River Water System, including the Potter Valley Project



Source: Sonoma Water Facility Guide (2017)

1.4.1 Diversion Facilities

The diversion facilities of Sonoma Water's water supply system include the Mirabel and Wohler diversion facilities, Lake Mendocino and Coyote Valley Dam, Lake Sonoma and Warm Springs Dam, Dry Creek, and the PVP. The facilities source, store, or provide water for Sonoma Water's customers.

1.4.1.1 Potter Valley Project

The PVP is comprised of Scott Dam and Lake Pillsbury, Cape Horn Dam and Van Arsdale Reservoir, a trans-basin tunnel, penstocks and piping, and the Potter Valley Power Plant. The PVP facilities are owned and operated by Pacific Gas and Electric (PG&E). Some of the water released from the powerhouse is diverted by the Potter Valley Irrigation District (PVID) under both a water supply agreement with PG&E and an appropriative water rights license. Water diverted by PVID is sold to agricultural contractors in the Potter Valley. Water not diverted by PVID and agricultural return flows through Potter Valley in the East Fork Russian River to Lake Mendocino.

Climate sensitivity is considered **Moderate** for PVP. Potential earlier snowmelt occurrence, more precipitation falling as rain instead of snow, and reductions in the volume of overall snowpack may negatively impact the operations of PVP and less release of water to the Russian River. Reduced volume of diversions is also very likely to occur. Future flooding would increase river flows and thus hydropower generation, as long as the excess river flow remains within the dam's reservoir capacity. Hydroelectric power works best when water releases are reliable and steady, so varied and unpredictable future water supply to the PVP is expected to negatively impact hydroelectric power production Powerful masses of water can exceed a dam's rated storage capacity and damage important structural components. Future flooding could carry large sediment and debris loads that can block dam spillways. Climate change is expected to cause longer and more intense droughts, decreasing water supply reliability and hydroelectric power generation. Increased temporal variability of precipitation events due to climate change is expected to pose significant problems for hydroelectric power generation. Reservoir levels at Lake Pillsbury will become more variable in the future due to a shift in the timing and magnitude of precipitation.

Adaptive capacity is considered **Low** for PVP. Federal Energy Regulatory Commission (FERC) process and aging infrastructure further limiting ability top operational flexibility.

A high climate sensitivity and low adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **High.**

1.4.1.2 Lake Mendocino and Coyote Valley Dam

Lake Mendocino is located on the East Fork Russian River, about 4 miles northeast of the City of Ukiah in Mendocino County, California. Lake Mendocino was created by the construction of the CVD Project, an earth embankment dam approximately 160 feet high with a crest length of 3,500 feet. Russian River flow downstream of CVD and above Dry Creek is comprised of natural drainage and streamflow during the rainy season (November through April). Water released from Lake Mendocino accounts for most of the water in the Russian River upstream of Dry Creek during the dry season months of May through October. Lake Mendocino has a total

current storage capacity of 116,500 acre-feet, which includes a water supply pool of between 68,400 acre-feet and 111,000 acre-feet, depending on the time of year.

Lake Mendocino and CVD serve as a drinking water source, source of hydroelectric power, and location of a fish hatchery. Downstream cities of Ukiah, Healdsburg, Cloverdale and Hopland divert unimpaired Russian River flow and water transferred from the Eel River through the PVP through pre-1914 water rights. Lake Mendocino provides water to Sonoma Water's Russian River water supply system. The hydroelectric facility at CVD (owned and operated by the City of Ukiah) utilizes incidental reservoir releases and has two turbine/generator units, with capacities of 2.5 and 1 megawatts (MW). The power plant has a minimum flowrate of 22 cubic feet per second (cfs) and maximum flowrate of 398 cfs, with a maximum flow rate of 116 cfs through the 1 MW unit and 282 cfs through the 2.5 MW unit. At the base of CVD, the California Department of Fish and Wildlife, under a contract with the U.S. Army Corps of Engineers (USACE), operates a fish hatchery facility called the Coyote Valley Dam Egg Collection Facility, which is managed in conjunction with the Don Clausen Fish Hatchery at Warm Springs Dam on Dry Creek to support a steelhead population.

Climate sensitivity is considered **High** for Lake Mendocino. More variable hydrology may impact Lake Mendocino operations and release of water to Russian River Project. Decreases in precipitation will increase already tenuous operation during drought years. Reductions in the volume of overall snowpack under changing climate in the Eel River Watershed may impact release of water from the PVP and hence less inflow into Lake Mendocino. The potential increase in Atmospheric River magnitude or intensity may exacerbate the current flood operation impacts on Sonoma Water water supply. Lake Mendocino's water supply reliability has decreased in recent years due to reduced spring inflow and amendments to the PVP FERC license in 2006 that caused a change in PVP operations. Uncertainty on the PVP diversions would have significant impacts to downstream water users, ecosystems, and groundwater aquifers. Climate change is expected to increase temporal variability of precipitation events, causing more severe and frequent floods and droughts. More large precipitation events in the winter and less precipitation events in the summer will cause more variable reservoir storage levels, decreasing reliability of reservoir releases and power generation. Climate change is expected to increase the potential of fire hazard in the Lake Mendocino watershed. This will increase the risk of greater sedimentation in the reservoir and impacts to water quality.

Adaptive capacity is considered **Moderate** for Lake Mendocino. Ongoing efforts to improve forecasting and to address improved operations with USACE will provide some adaptive capacity. Lake Mendocino's water supply reliability has decreased in recent years due to reduced inflow and amendments to the PVP FERC license in 2006 that caused a change in PVP operations. Uncertainty on the PVP diversions would have significant impacts to downstream water users, ecosystems, and groundwater aquifers. However, multiple efforts that would enhance adaptive capacity already in progress and/or in discussion, including the efforts described below. Additionally, uncertainty in the PVP relicensing (license expires in April 2022) or discontinuation of the PVP will impact the operations of Lake Mendocino and streamflow management in the Upper Russian River.

Lake Mendocino relies on year-to-year rainfall to fill and water diverted from the PVP. Future rainfall variability may increase and there is the possibility of continued reduced water releases

from the PVP. Sonoma Water is currently collaborating with academic, state, and federal partners to conduct a demonstration project using Lake Mendocino as a model for testing forecast informed reservoir operation (FIRO) and its potential application at other reservoirs. FIRO is a developing science which has the potential to provide enhanced weather and hydrologic forecasting, thereby improving water supply reliability and flood control capability.

On December 17, 2014, a Corps SMART (Specific, Measurable, Attainable, Risk-Informed and Timely) Planning meeting for the CVD Raising Feasibility Study was held. The purpose of the meeting was to re-scope the dam raising feasibility study for compliance with the Corps' SMART Planning 3x3x3 policy and determine what steps are necessary to reach the Alternatives Milestone. At the meeting, a preliminary assessment of cost estimates and schedules for post-meeting study activities was made, which indicated that the feasibility study on raising the dam would be completed within three years and for $3 million or less, pending receipt of an optimal funding stream.

Future conservation and demand management in the Sonoma Water service area also contributes to Lake Mendocino's adaptive capacity.

A high climate sensitivity and moderate adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **High.**

1.4.1.3 Lake Sonoma and Warm Springs Dam

A majority of Sonoma Water's customers receive their drinking water from Lake Sonoma. The lake is about four times larger than Lake Mendocino and relies primarily on rainwater as a water supply source. Releases from Lake Sonoma support a fragile ecosystem in Dry Creek that contains endangered Coho salmon and threatened steelhead trout. It was created by the construction of the Warm Springs Dam (WSD), and has a total storage capacity of 381,000 acre-feet, which is comprised of a water supply pool of 225,000 acre-feet, a flood control pool of 136,000 acre-feet, and an inactive pool of 20,000 acre-feet. A 2.6 MW hydroelectric turbine/generator was installed at WSD in 1989 as a result of collaboration between Sonoma Water and USACE. Sonoma Water operates a FERC-licensed hydroelectric facility at WSD with a maximum discharge capacity of 190 cfs. Additionally, the Don Clausen Fish Hatchery (DCFH) is located at the base of WSD. The DCFH diverts flow from the controlled outlet of WSD to support hatchery operations. Diverted water used by the hatchery is returned back to Dry Creek downstream of the hatchery.

Climate sensitivity is considered **Moderate** for Lake Sonoma. Changes in hydrology, through either later storms or reduced annual inflows, may affect Lake Sonoma operations and shift the quantity and timing of releases that support the Dry Creek ecosystem and the Sonoma Water's service area. More variable hydrology may affect Sonoma operations and release to Dry Creek. Sonoma Water must make higher releases during periods of insufficient unimpaired flow to ensure that required minimum instream flow requirements are met at downstream compliance points all along the Russian River and Dry Creek. Future decreases in precipitation will increase stress on already tenuous system operation during drought years. Increased variability in dry season compliance flows is directly tied to more variable reservoir storage levels.

Climate change is generally expected to increase the wildfire risk in the Sonoma region through increased incidence of dry conditions (drought) and higher temperatures over a longer fire season. Fire frequencies are projected to increase regionally on the order of 20% to 30%. Increasing frequency and severity of wildfires in the Lake Sonoma watershed will lead to increased risk of impacts to drinking water quality. Increases in extreme floods may cause changes to flood control operations in Lake Sonoma, further exacerbating the current flood operation impacts on Sonoma Water supply. Increased dry season reservoir releases due to increases in agricultural diversion from the Russian River and Dry Creek are associated with increased summer temperatures. Climate change is expected to increase temporal variability of precipitation events, causing more severe and frequent floods and droughts. More variable hydrology may increase the frequency of under-production at WSD. More large precipitation events in the winter and less precipitation events in the late spring will cause more variable reservoir storage levels, decreasing reliability of reservoir releases and power generation.

Adaptive capacity is considered **Moderate** for Lake Sonoma. Storage operations could manage some short duration to seasonal water quality changes.

A high climate sensitivity and moderate adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **High.**

1.4.1.4 Dry Creek

Dry Creek stretches 14 miles from WSD on Lake Sonoma to the confluence of the Russian River. The creek contains endangered Coho salmon, threatened Chinook salmon, and threatened steelhead (including steelhead raised at the DCFH).

Around Dry Creek itself, fire hazard is fairly low due to its classification as Non-Wildland/ Non-Urban land. Many areas surrounding Dry Creek have high or very high fire risk. A fault exists right near the main channel, which could disrupt normal Dry Creek flows during a seismic event. The risk is defined as moderate, and the areas displayed buffer the riverbanks of Dry Creek.

Dry Creek peak flow has been drastically reduced from as high as 32,000 cfs to maximum about 5,000 through 8,000 cfs since construction of the WSD. However, occasional high flows released by the Dam like those during the recent January-February 2017 high flow events could reduce the effectiveness of the downstream habitat enhancement projects.

Climate sensitivity is considered **Moderate** for Dry Creek Habitat Enhancement Project. Habitat enhancement projects have included side channels, riffles, backwaters, and alcoves that aim to slow the speed of the water and create refuges for young fish. Bank stabilization measures are also being pursued to reduce erosion and provide vegetation cover. Increased occurrence of extreme storm events and associated increased sedimentation could damage the recently constructed habitat enhancement features, as seen during the January-February 2017 high flow events. Maintenance following high flow events may be required to restore the sites.

Variability in reservoir storage levels under alternative future climates could lead to increased variability in dry season compliance flows. The historic stability of the coldwater pool in Lake Sonoma indicates that the effect of changes in future climate are not likely to impact the

coldwater pool and thus the temperature in Dry Creek. Increased flows from the Dry Creek watershed and backwater from the lower Russian River under high flow events could increase sediment load in the lower Dry Creek. The increased risk of wildfire in the Lake Sonoma watershed poses a risk to habitat enhancement features and spawning habitat downstream of WSD. The introduction of significant sediment could bury spawning habitat. Nutrients adsorbed to sediments could lead to algal blooms and low dissolved oxygen conditions. Fire retardant chemicals can impact aquatic species.

Adaptive capacity is considered **Moderate** for Dry Creek Habitat Enhancement Project.

Based on ratings for climate sensitivity and adaptive capacity, the overall rating for this asset is **Moderate.**

1.4.1.5 Mirabel Diversion Facilities

Six radial collector wells are located adjacent to the Russian River near Wohler Road and Mirabel. Three radial collector wells are located at the Mirabel facility. Sonoma Water operates these wells to pump groundwater form the alluvial aquifer beneath and adjacent to the Russian River. Other components at the Mirabel facility include a system of four infiltration ponds, an inflatable on the Russian River, a fish screen with six intake bays, and an improved vertical slot fish ladder.

The collector system, river diversion, infiltration ponds are all located at the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) regulatory floodway and 100-year flood zone (Zone AE) and are susceptible to flooding – even at higher frequency events. Seismic may be a moderately low to moderate hazard, as the collectors are located within the moderately low to moderate liquefaction zone. Sediment carried by high river flows has historically caused loss of infiltration capacity in ponds. While collector water is generally of high quality, a large wildfire in the upper watershed could result in high organic being carried by river flows and would impact the natural filtration process at Wohler and Mirabel. Substantial portion of the upper watershed shows “high” fire risk potential. Fire hazards for the collectors are high or moderate. Liquefaction hazards are moderate for collectors 1, 2 and 6 and moderately low for collectors 3, 4 and 5. Mirabel Collector 5 has a historical ongoing turbidity issue due to the influence of surface water. Collector 5 is not in use most of the year, but it is used during summer to accommodate the capture of larger flows. For Collector 5, future levee failure poses an issue.

The Mirabel facility receives a climate sensitivity rating of **High.** Increased flooding potential may cause an increase in direct risk to Russian River collector system infrastructure due to inundation risk. Future flooding vulnerability is expected to grow in the face of extreme precipitation events due to climate change. The base elevation of the existing 100-year flood is 78.12 feet according to the FEMA flood map, which is only about 2 to 3 feet above the critical elevation at these collectors. Climate change will likely increase the 100-year flood by 25 to 30% at these locations. Mirabel ponds, road, wells, and collectors themselves are expected to be inundated up to 5 to 10 feet during the projected future 100-year flood event. Increased flooding potential will impact the operation of Collector Well 5, as it is already being operated under the direct influence of surface water during high flows. Additionally, more frequent pond flooding will result in sediment and fish removal impacts. More variable hydrology could change

river flows and could impact the inflatable dam operation at Mirabel. Changes in river flows and water temperatures may require further protection of flows for instream purposes or a limitation of operation of the inflatable dam. Increased variability in dry season may impact the operation of inflatable dam. Fire frequencies are projected to increase on the order of 20% to 30%. Water quality issues may arise due to increased wildfire in the contributing watershed. Riverbank filtration has been shown to be sensitive to increases in dissolved organic carbon/natural organic matter in the river water. Fire induced water quality changes (DOC and total organic carbon [TOC] increases) may affect riverbank filtration.

The adaptive capacity of the Mirabel facility is **Moderate**. Redundancy of multiple collectors allow diversion to continue if impacts are isolated, but minimal system storage limits ability to provide reliable supply with extensive or extended loss of diversion.

A high climate sensitivity and moderate adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **High.**

1.4.1.6 Wohler Diversion Facilities

There are three collectors at the Wohler Diversion facility, collectors 1, 2, and 6. Collectors 1 and 2 were built in 1959, while collector 6 was built in 2006. There are 6 pumps at the facility, two for each collector. These pumps bring water from the collectors which is derived from the alluvial aquifer through perforated laterals to the facility for conveyance to Sonoma Water customers.

All three collectors at the Wohler Facility are located at the FEMA FIRM regulatory floodway and 100-year flood zone (Zone AE) and are susceptible to flooding – even at higher frequency events. Seismic activity may be a moderate hazard, as the collectors are located within the moderate liquefaction zone. Water quality concerns are significant, particularly associated with organic carbon carried by river flows from the upper watershed. Substantial portion of the upper watershed shows “moderate” to “high” fire risk potential. Fire hazards for the collectors are high or moderate and all of the collectors lie in floodway Zone AE. Liquefaction hazards are moderate for collectors 1, 2 and 6 and moderately low for collectors 3, 4 and 5.

The Wohler collector facility receives a climate sensitivity rating of **High.** Flooding presents a significant risk at the Wohler Diversion facility. The Wohler collectors and Wohler station are located at existing FEMA FIRM 100-year flood levels (78 feet), and these facilities will very likely be inundated during future floods (78+feet). The road to collector #6 is essentially at grade in the floodway, which presents access problem during flood events. Increased flooding potential may increase risk to the Russian River collector system infrastructure at Wohler due to inundation impacts. Fire frequencies are projected to increase on the order of 20% to 30%. Water quality issues may arise due to increased wildfire in the contributing watershed. Riverbank filtration has been shown to be sensitive to increases in dissolved organic carbon/natural organic matter in the river water. Fire induced water quality changes (DOC and TOC increases) may affect riverbank filtration.

The adaptive capacity of the Wohler collector facility is **Moderate**. Redundancy of multiple collectors allow diversion to continue if impacts are isolated, but minimal system storage limits ability to provide reliable supply with extensive or extended loss of diversion.

A high climate sensitivity and moderate adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **High.**

1.4.2 Treatment Facilities

Water treatment is limited to disinfection and pH adjustment throughout the Sonoma Water system. Sand and gravel in the alluvial aquifer naturally filter water into the groundwater table. The groundwater is then pumped by the radical collector wells into the water transmission system. Consequently, water treatment is limited to disinfection and pH adjustment throughout the Sonoma Water system. Before delivery to Sonoma Water customers, gaseous chlorine is added to water pumped by the collector wells to provide a residual amount of disinfection. Each of the three Santa Rosa Plain wells has its own chlorination facility. Sonoma Water also increases the pH of its water to reduce leaching of lead and copper. Although the water contains no detectable levels of lead and copper, naturally corrosive untreated water can corrode lead and copper in indoor plumbing and water fixtures. pH adjustment facilities at Sonoma Water's Wohler Maintenance Yard and adjacent to the River Road Chlorination Building increase the pH of the water from about 7.4 to 7.8 to about 8.5.

1.4.2.1 Wohler Chlorination and Corrosion Control Facility

Wohler Chlorination and Corrosion Control Facility receives a climate sensitivity rating of **Moderate/High.** Wohler station is located at or near existing FEMA 100-year flood levels (78 feet), and these facilities will very likely be inundated during future floods (78+ feet). Additionally, there is a potential loss of power and road access during extreme events.

For adaptive capacity, the Wohler Chlorination and Corrosion Control Facility receives an adaptive capacity rating of **Moderate.** The Mirabel or River Road facilities could provide chlorination for a portion of the system.

A moderate/high climate sensitivity and moderate adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **Moderate/High.**

1.4.2.2 Mirabel Chlorination Facility

The Mirabel Chlorination Facility receives a climate sensitivity rating of **Low**. No appreciable sensitivity has been identified.

For adaptive capacity, the Mirabel Chlorination Facility receives an adaptive capacity rating of **Moderate.** The Wohler or River Road facilities could provide chlorination for a portion of the system.

A low climate sensitivity and moderate adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **Low.**

1.4.2.3 River Road Chlorination and Corrosion Control Facility

River Road Chlorination and Corrosion Control Facility receives a climate sensitivity rating of **Moderate**. The building road and access is within existing flood zones, facility core operations are elevated in upper levels, and there is a potential loss of power during extreme events.

For adaptive capacity, the River Road Chlorination and Corrosion Control Facility receives an adaptive capacity rating of **Moderate.** Backup generator can only run analyzers, but not chlorination.

A moderate climate sensitivity and moderate adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **Moderate/High.**

1.4.3 Transmission Facilities

The transmission system is comprised of pipelines, pumps, and storage tanks. The system conveys water from diversion facilities near the Russian River to service areas in Sonoma and Marin counties. Sonoma Water's transmission system has eight booster pump stations: Eldridge; Ely; Forestville; Kawana; Sonoma No. 1 & No. 2; Wilfred; and Kastania. These booster pump stations are necessary to increase water pressure, move water to higher elevations, and increase flow rates. Eighteen steel water storage tanks provide a total combined transmission system storage capacity of 128.8 million gallons. These tanks provide approximately 1.5 days of storage during Sonoma Water's peak-month demand and provide a constant pressure head in the transmission system.

The Ely Booster Pump Station is located at the FEMA 100-year flood zone (Flood Zone "AE"), and Kawana Booster Pump Station is located at the proximity of FEMA 100-year flood zone. Vulnerability assessments are conducted for these two booster pump stations below. All the other existing pump stations and storage tanks are located at the existing FEMA Area of Minimal Flood Hazard (Zone "X").

Most of the booster pump stations have a moderate fire risk hazard and have minimal flood risk. Ely Booster Stations 1 and 2 and Wilfred Booster 1 have moderate liquefaction hazards, all other stations have very low or moderately low hazard. Fire risk is moderate all tanks but Sonoma 1 and 2, which have a high fire risk. Flood hazard is minimal at all tanks and liquefaction hazards are very low except for Annadel 2, which has a moderately low liquefaction hazard.

1.4.3.1 Ely Booster Pump Station

There is a historical flooding issue at the Ely Booster Pump Station. It is also located in a low-lying area and has the potential to be flooded from the nearby creek and hillside. Ely Booster Pump Station possesses a backup generator in case of loss of power.

The Ely Booster Pump Station receives a climate sensitivity rating of **High**. The Ely Booster Station is located at the FEMA 100-year flood zone (Flood Zone "AE"), which has the potential to be inundated by several feet during a 100-year flood. Additionally, Rail development is exacerbating problems. The potential of road access during extreme flood events is expected to decrease as well.

The Ely Booster Pump Station receives an adaptive capacity rating of **Low.** There is a limited ability to operate in difficult areas if flooded to this extent. The Ely Booster Flood Control Project may reduce this vulnerability.

A high climate sensitivity and low adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **High.**

1.4.3.2 Kawana Booster Pump Station

There is a historical flooding issue at the Kawana Booster Pump Station, as it is located in a low lying area. There is also the possibility of flooding from the drainage channel passing beside the Booster Pump Station. In addition, this location is vulnerable because there is no fence or backup generator in the case of power failure emergencies.

The Kawana Booster Pump Station receives a climate sensitivity rating of **Moderate**. Small Creek and localized drainage are subject to flooding, as well as the Highway 12 berm and creek that make up the hydrologic boundaries in the area.

The Kawana Booster Pump Station receives an adaptive capacity rating of **Moderate.** Roadway blocks are currently used to divert some runoff.

A moderate climate sensitivity and moderate adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **Moderate.**

1.5 Flood Management System Vulnerability Assessment

Sonoma Water provides flood protection to Sonoma County through maintenance of flood control channels in nine zones and related facilities, including dams at Lake Sonoma and Lake Mendocino, and four detention basins in the Santa Rosa Creek watershed. The qualitative vulnerability assessment focused on five flood control zones, with significant attention on individual system components in Zone 1. Zones 6, 7, 8, and 9 were excluded from the analysis because of the lack of flood control channels in these zones. The primary climate hazards assessed for the flood control system included extreme precipitation and associated river flooding and increased sediment transport. Sea level rise is an additional hazard for portions of zones 2A, 3A, and 5A.

1.5.1 Zone 1A Flood Control Facilities

Sonoma Water flood control facilities in Zone 1A include flood control channels and four detention facilities. Hazards to flood conveyance in Zone 1A include increased precipitation intensity and associated runoff, bank erosion and bank failure with higher runoff, and increased sediment transport and localized deposition in flood control channels. Individual assessments are provided for flood conveyance channels and flood detention basins in Zone 1A.

1.5.1.1 Flood Conveyance Channels

Flood conveyance channels along Santa Rosa Creek and its tributaries provide flood protection for downtown Santa Rosa. The triple box culverts along Santa Rosa Creek and Matanzas Creek, which route these two creeks through downtown Santa Rosa, are of particular concern for climate-induced vulnerabilities. The primary hazard for these culverts is their inability to convey flood flows much larger than a 10-year event. High resolution hydraulic modeling conducted by ESA as part of the Santa Rosa Creek Hydrology and Hydraulics Study (SCWA, 2017) indicate the inability of these culverts to pass flood flows above a return interval event between 10 and

25 years. These results are in stark contrast to assumptions made by Sonoma County Flood Insurance Study.

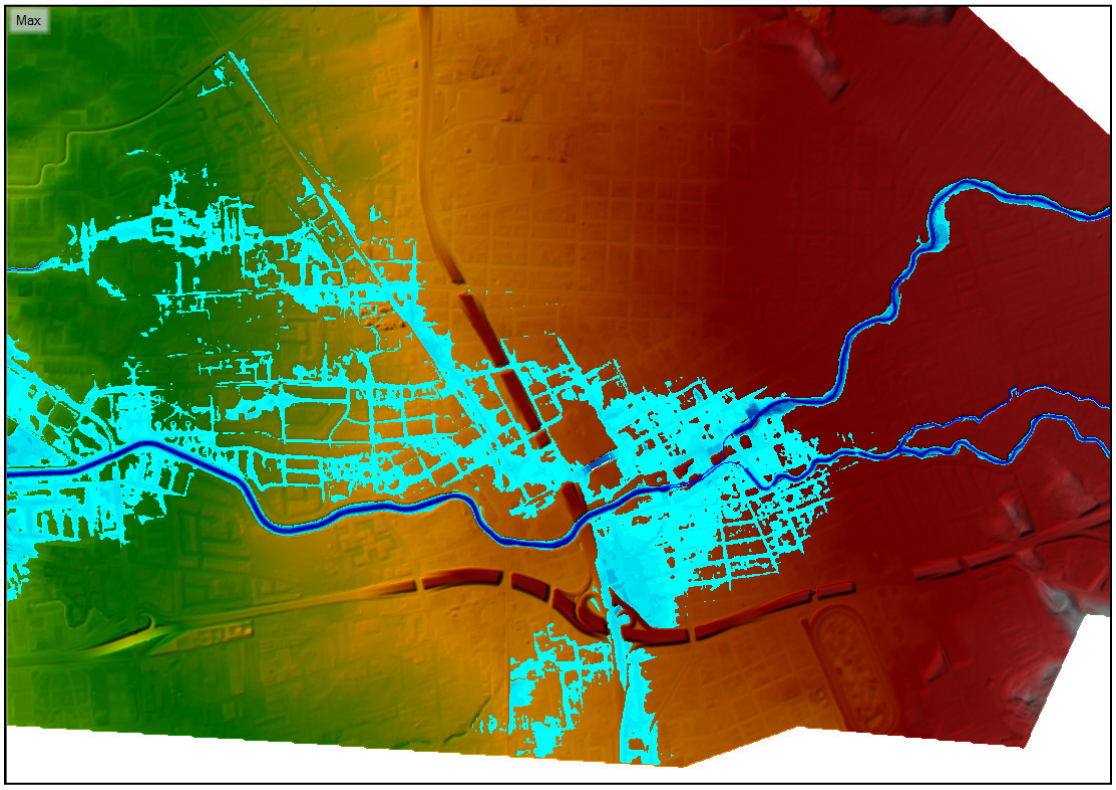
Figure B-2 presents results of the recent hydraulic modeling results for a simulated 25-year flow event, showing inundation depths throughout downtown Santa Rosa. Flood conveyance in Zone 1A is considered sensitive to climate-induced increases in river flow, as the system has current flood vulnerabilities that will occur more frequently under expected future climate scenarios. Modeling analysis indicates that the 50-year event on Santa Rosa Creek is only 17% larger than the peak flow for the 25-year event, and that the 100-year event is only 12% larger than the 50-year event. For Matanzas Creek, the 50-year event is 31% larger than the 25-year event, and the 100-year event is only 12% larger than the 50-year event. The relatively small increases in the 100-year events over the 50-year events are indicative of how potential future climate scenarios could lead to increased frequency of significant flooding events.

The nonlinear nature between flood flow and sediment transport could exacerbate future flood control channel maintenance, as expected increases in precipitation intensity drive increases in runoff and increases in sediment transport. Climate sensitivity is considered HIGH for Zone 1A flood control channels.

Adaptive management of flood conveyance capacity in the Zone 1A is considered **Low**. There is limited adaptive capacity associated with the flow constriction on Matanzas Creek and Santa Rosa Creek imparted by the triple box culvert structure. Further reduction of flood flows to accommodate a shift in the return interval curve will likely require focusing on detention in the upper watershed, as there is limited potential for meaningful improvements in conveyance capacity or detention in the urbanized portion of the watershed. Sonoma Water sediment removal efforts are limited by time, resources, and funding. Increases in the number and extent of required sediment removal projects may exceed available resources, thus compromising flood conveyance capacity.

A high climate sensitivity and low adaptive capacity result in a climate change vulnerability yield a climate vulnerability rating of **High.**

Figure B-2. Predicted Localized Flooding in Santa Rosa for 25-year event



Source: ESA

1.5.1.2 Flood Detention Basins

The Soil Conservation Service constructed four detention basins in the upper reaches of Santa Rosa Creek and its tributaries in the early 1960s. These reservoirs serve a vital role in reducing flood risk for the City of Santa Rosa by attenuating flows on the largest watersheds draining through Santa Rosa. The basins were designed for a 100-year event. Three of these basins are flow through reservoirs, and a fourth, Spring Lake, is fed by diversions from Santa Rosa Creek and Spring Creek. These structures are designed for passive operation. Potential hazards at the detention facilities include

- Reduction in the design outflow rate via accumulation of sediment or debris at the intake to the principal spillway
- Reduction in outflow capacity of the principal spillway due to accumulation of sediment and debris at the downstream end of the principal spillway
- Precipitation events that exceed the design rate, reducing the effectiveness of the detention basins in attenuating peak flows, and potentially leading to overtopping of the dam

The main vulnerability of these three facilities is to increased precipitation intensity coupled with limited reservoir storage capacity. Increased precipitation intensity under future climate scenarios will lead to an increase in the use of the auxiliary spillway and a decrease in the attenuation capacity of the reservoirs as larger outflows occur when the auxiliary spillway is

engaged. This will have impacts on downstream flood conveyance through the City of Santa Rosa. Matanzas Creek Reservoir is likely the most vulnerable because of its earthen embankment that serves as the emergency spillway.

The diversion structure on Santa Rosa Creek is vulnerable to sedimentation and blockage. The vortex drain structure under Montgomery Drive is vulnerable to blockage from sediment and woody debris. This could be exacerbated under future climate conditions with increased precipitation. The diversion structure on Spring Creek is vulnerable to sedimentation reducing flow through the box culvert. Sedimentation is expected to increase under future climate scenarios. The channel leading from the Spring Creek Diversion Structure to Spring Lake is vulnerable to slump failures of the channel banks that would impede flow.

Overall sensitivity to climate-induced changes in hydrology and reservoir flood attenuation is considered **High** based on limited reservoir storage capacity.

Adaptive Capacity of these structures is considered **Low**, as they are passive structures, and significant costs would be required to increase storage or manage outflow. Improvements to the spillway structures to pass design flows with sufficient freeboard so as not to endanger the main dam at these reservoirs are possible. Spillway structures could be enlarged to provide more outlet capacity and a reduction in the maximum reservoir storage for a given inflow event. There is little in the way of operational flexibility to accommodate changing future inflows and sediment loads

A high climate sensitivity and low adaptive capacity result in a climate change vulnerability rating of **High.**

1.5.2 Zone 2A Flood Control Facilities

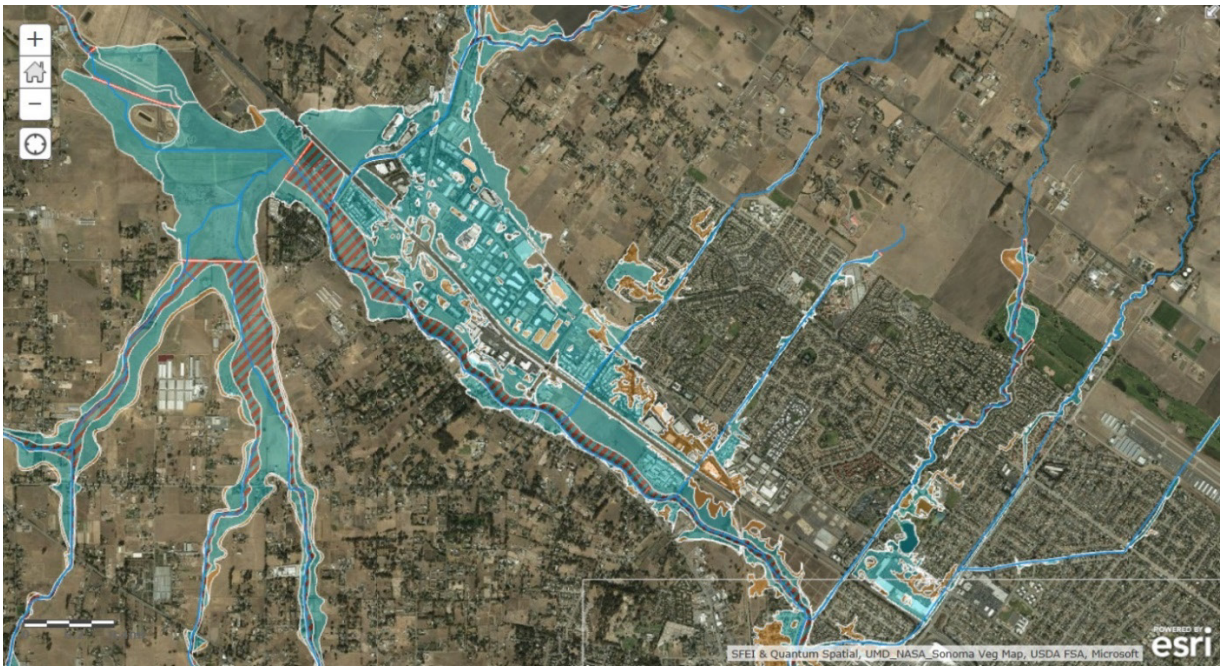
Sonoma Water's Flood Protection Zone 2A primarily contains creeks and streams draining to the Petaluma River. Sonoma Water has several owned in fee engineered channels in Zone 2A, including Lichau Creek, Lynch Creek, Washington Creek, East Washington Creek, McDowell Creek, and Adobe Creek. Sonoma Water has easements on several engineered channels and modified channels.

The 100-year floodplain designated by FEMA indicates Lichau/Willow Brook exceeds it channel capacity spilling primarily south of Willow Brook and east of Highway 101 (Figure B-3). Additional flooding potential exists on the lower portion of the Petaluma River, as shown in maps of the 100-year floodplain.

The Petaluma River is susceptible to elevated flood stages due to sea level rise. Areas adjacent to the river are currently inundated under expected future sea levels without any river flows contributing to higher water levels. FEMA investigated the effects of coastal storm surges on flood elevation in Petaluma. This effort led to a one-foot increase in flood elevation (from 9 to 10 feet) in downtown Petaluma. It is likely that sediment deposition in the lower reached of creeks feeding the Petaluma River will be increased under sea level rise as the river gradient is decreased by an increase in the downstream boundary.

The conveyance capacity in Adobe Creek can be significantly limited by deposited sediment during high flow events. Historic floods have been exacerbated by clogged stormwater pipes and culverts in Adobe Creek.

Figure B-3. 100 Year Flood Hazard, Upper Petaluma River and Tributaries



Source: FEMA 2022.

1.5.2.1 Flood Conveyance Channels

Flood conveyance channels in Zone 2A are considered highly sensitive to climate-induced increases in river flow from increased precipitation as well as sea level rise. Increased runoff volumes associated with increased precipitation rates and intensities could exceed channel conveyance capacity in the Petaluma River and its tributaries. Current flood vulnerabilities, including localized flooding in the upper Petaluma River and tributaries will occur at a higher frequency than the current 10-year period under expected future climate conditions. Climate sensitivity is considered **High** for Zone 2A flood control channels.

Flood conveyance in Adobe Creek is vulnerable to increased flows and associated sediment and debris/trash transport. Future climate may provide multiple storms per year capable of delivering sufficient quantities of sediment to Adobe Creek to limit conveyance and cause localized flooding. Deposition could be shifted upstream due to a decreased gradient in the creek because of sea level rise.

Adaptive management of flood conveyance capacity in Zone 2A is considered **Low**. The Petaluma River Flood Control Project, a $40 million investment of federal and local funds, should be reviewed to see design freeboard levels and whether any allowances were made for future sea level rise. Design freeboard may not be sufficient to accommodate current estimates for sea level rise, and thus significant investment to raise the sheet pile walls to accommodate

future sea level. A high climate sensitivity and low adaptive capacity result in a climate change vulnerability rating of **High.**

1.5.3 Zone 3A Flood Control Facilities

Sonoma Water's Flood Protection Zone 3A primarily contains creeks and streams draining to Sonoma Creek. Sonoma Creek is an incised channel, and thus it is generally able to convey the 100-year flood event. Routine maintenance is primarily performed on Fryer Creek, the primary channel Sonoma Water owns in Zone 3a, and several other modified channels, including Nathanson Creek, Rodgers Creek, Fowler Creek, and Sonoma Creek. Sonoma Water has conducted sediment removal projects on Fryer Creek and Nathanson Creek. Vegetation maintenance is also conducted throughout Zone 3A.

The upper reaches of Sonoma Creek, including the reach through the town of Sonoma, are generally maintained within the banks during the 100-year event, based on FEMA maps. Nathanson Creek shows significant flooding in historic Sonoma during the 500-year event. The estimated 100-year floodplain primarily indicates overbank flooding in the lower reaches of Sonoma Creek, with the floodplain extending to between Watmaugh Road and Highway 121. Highway 37 (Sears Point Road) is inundated by the 100-year event. High water on Sonoma Creek during the 100-year event causes backwater effects on Nathanson Creek, Fowler Creek, Rodgers Creek, Arroyo Seco, and other small creeks terminating near the northern extent of historic tidal marshes in the southern portion of Zone 3A.

1.5.3.1 Flood Conveyance Channels

Sonoma Creek is a flashy creek subject to rapid increases in water level immediately following periods of intense precipitation. Elevated runoff rates associated with more intense rainfall events may exceed the conveyance capacity of Sonoma Creek. The system is therefore vulnerable to increases in precipitation intensity projected under future climate scenarios. Furthermore, steep sided creeks may be more likely to see bank failures under more frequent or higher intensity runoff events. Such failures would reduce conveyance capacity and could lead to localized flooding.

Climate sensitivity for flood conveyance on Sonoma Creek is considered **Moderate.** Current out of bank floods along the lower reaches of Sonoma Creek occur at 100-year events, expected to be exacerbated by climate-induced precipitation variability. Climate sensitivity for flood conveyance on tributaries to Sonoma Creek, namely Nathanson Creek and Fowler is considered **High.**

The town of Sonoma and most residential areas of Zone 3A are not vulnerable to sea level rise because of the local topography. From a flood control perspective, populated areas of Zone 3A are at low risk to sea level rise. The southern portion of Zone 3A is sensitive to sea level rise; projections for future sea level could lead to inundation of Highways 37 and 112. For sea level rise, the flood risk is considered **Moderate.**

Adaptive capacity for flood conveyance in Zone 3A is considered **Low**. Adaptive capacity for sea level rise in Zone 3A is considered **Low**. Based on ratings for climate sensitivity and adaptive

capacity, the overall rating for this asset is **Moderate.** The rating for flood conveyance is Medium/High, and the rating for sea level rise is Medium.

1.5.4 Zone 4A Flood Control Facilities

Sonoma Water has maintenance easements on certain levees along the Russian River as part of their cost share partnership in the CVD Project. Sonoma Water also has maintenance easements under the Stream Management Program on one owned in fee channel (Wood Creek in Geyserville) and a second (Gird Creek) where they have encroachment rights on a modified channel.

The Russian River near Cloverdale is expected to exceed its channel capacity during the 100-year event. FEMA mapping of the 100-year and 500-year floodplains indicate that expected inundation extends over fields on the eastern bank and over light industrial areas, including the All-Coast property, and fields on the western bank.

Sediment load from Big Sulphur Creek is high. The deposition of sediment can cover 90 percent of the channel width bank to bank. The evolution of the main channel through these deposits can focus the river into the levee.

1.5.4.1 Flood Conveyance Channels

The 100-year floodplain will be enlarged under future climate scenarios with higher intensity rainfall events. Based on tabulated percent chance flood events shown in Table B-8, an increase of 26% in the peak flow value for the 10 percent flood event would equal the current 2 percent flood event, and an increase of 26% in the peak flow value for the current 2 percent event would equal the 1 percent event. Significant shifts in the recurrence intervals for given flood flows are expected under future climates. Climate Sensitivity is considered **Moderate.**

Table B-8. Tabulation of Peak Discharges for Various Flood Events along the Russian River

Flooding Source and Location (Russian River)	Drainage Area (Square miles)	10 percent Peak Discharges (cfs)	2 percent Peak Discharges (cfs)	1 percent Peak Discharges (cfs)	0.2 percent Peak Discharges (cfs)
Upstream of confluence of Maacama Canal	707	51,000	73,000	82,000	115,000
Upstream of confluence of Sausal Creek	686	50,000	71,000	81,000	111,000
Upstream of confluence of Lytton Creek	678	50,000	70,000	80,000	110,000
Upstream of confluence of Miller Creek	654	48,000	68,000	79,000	106,000
Upstream of confluence of Gill Creek	642	47,000	67,000	76,000	105,000

Flooding Source and Location (Russian River)	Drainage Area (Square miles)	10 percent Peak Discharges (cfs)	2 percent Peak Discharges (cfs)	1 percent Peak Discharges (cfs)	0.2 percent Peak Discharges (cfs)
Upstream of confluence of Big Sulphur Creek	520	46,000	58,000	73,000	100,000
Upstream of confluence of Oat Valley Creek	502	40,000	56,000	64,000	85,000

The current levees do not appear to provide 100-year flood protection based on the FEMA maps. Modifications to levees would be required to remove lands adjacent to the river from the 100-year floodplain. These structures have a Low adaptive capacity based on cost to raise levee crest elevations.

A **Moderate.** climate sensitivity and **Low** adaptive capacity result in a climate change vulnerability rating of **Moderate.**

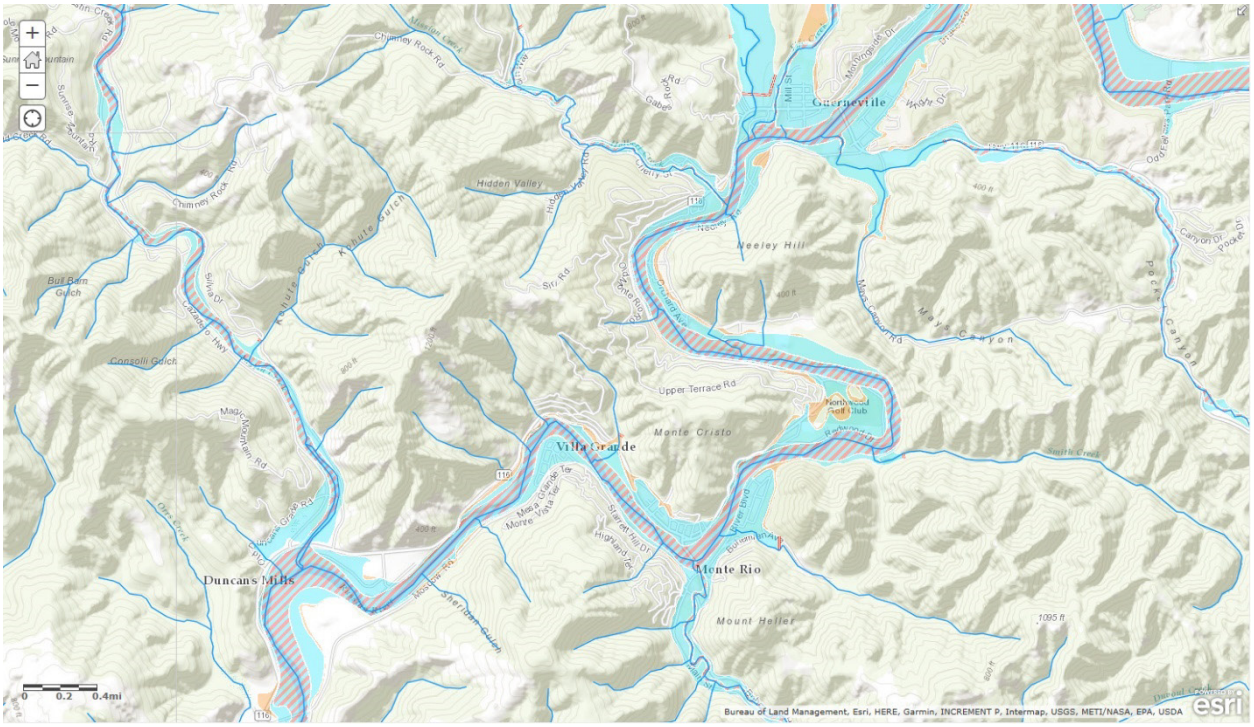
1.5.5 Zone 5A Flood Control Facilities

Sonoma Water has maintenance easements on the lower Russian River and several tributaries, notably Fife Creek and Livereau Creek in Guerneville. Sonoma Water also manages the Russian River Estuary as a freshwater lagoon to increase habitat suitability for anadromous fisheries.

Hazards to flood conveyance in Zone 5A include increased precipitation intensity and associated runoff, bank erosion and bank failure with higher runoff, and increased sediment transport in the Russian River and tributaries. Most populated areas in the lower Russian River are located in the 100-year floodplain, including communities of Guerneville, Monte Rio, Villa Grande, and Duncan Mills (Figure B-4).

Management of the freshwater lagoon in the estuary can be affected by changes in the timing and amount of runoff as well as sea level rise. Projected sea level rise and increased wave action will lead to changes in the beach profile and the effectiveness of the natural sand berm that currently closes the estuary on an annual cycle.

Figure B-4. 100-year Flood Hazard, lower Russian River



Source: FEMA

1.5.5.1 Flood Conveyance Channels

Flood conveyance in Zone 5A is considered moderately sensitive to climate-induced increases in river flow, as the system has current flood vulnerabilities that will occur more frequently under expected future climate scenarios. The management of the Russian River Estuary is sensitive to climate change as sea level rise will increase wave energy at the beach, requiring modifications to the management plan. Given the lack of demonstrable success of the natural berm in maintaining lagoon closure for the desired periods, future climate-induced stressors acting against berm stability could further reduce the viability of this approach. Together, these two factors yield a climate sensitivity rating of **Moderate.**

Adaptive management of flood conveyance capacity in the lower Russian River and associated tributaries is considered **Low**. Adaptive capacity of estuary management is considered low, given constraints on any activities to stabilize the natural berm against wave attack.

A **Moderate** climate sensitivity and **Low** adaptive capacity result in a climate change vulnerability rating of **Moderate** for flood control facilities in Zone 5A.

1.6 Sanitation System Vulnerability Assessment

Sonoma Water operates and manages eight sanitation systems in Sonoma County. These include Russian River County Sanitation District (RRCSD), Occidental County Sanitation District (OCSD), Sonoma Valley County Sanitation District (SVCSD), Penngrove Sanitation Zone (PSZ), Geyserville Sanitation Zone (GSZ), Airport-Larkfield-Wikiup Sanitation Zone (Airport SZ), Sea

Ranch Sanitation Zone, and the Sough Park Sanitation District. The qualitative vulnerability assessment focused on six of the zones and the primary administrative facilities. Sea Ranch Sanitation Zone and South Park Sanitation District were excluded from the analysis as they are small zones that may no longer be managed by Sonoma Water in the near future.

The primary climate hazards assessed for the sanitation system included river flooding, extreme precipitation, sea level rise, and wildfire risk. The below descriptions include the key findings for each sanitation district or zone analyzed as well as the Sonoma Water administrative facilities.

1.6.1 Russian River County Sanitation District

RRCSD includes wastewater collection, treatment, and disposal facilities that serve approximately 8,300 people in unincorporated areas of Rio Nido, Vacation Park, Guerneville, and Guernewood Park. The primary assets assessed included the wastewater treatment plant (WWTP) and the collection system.

1.6.1.1 WWTP

The WWTP treats an average dry weather flow of approximately 0.2 million gallons per day (mgd) and the peak wet weather treatment capacity is 3.5 mgd. Treated wastewater is discharged into the Russian River October 1 through May 14 and used for irrigation May 15 through September 30. The climate change threats that will most severely impact the WWTP include increased river flooding and increased extreme precipitation. These threats will exacerbate existing climate-related hazards including lack of road access, electrical power outages and generator failure, and limited treatment capacity. Because projected climate change scenarios will exacerbate these hazards, the WWTP received a climate sensitivity rating of **High**. The WWTP's adaptive capacity was rated low. The adaptive capacity of the WWTP is relatively medium if the flow reaches the plant and goes through treatment prior to discharge. However, as an integrated system, the adaptive capacity of this asset is considered **Low** given the location of the facility and limited treatment capacity. Additionally, adaptive capacity is limited by access. The WWTP must be manually operated, and the main access road is prone to flooding. The emergency access road is not reliable as well as it requires four-wheel drive and is sometimes impassable due to mudslides. Because the climate sensitivity rating is high and the adaptive capacity rating is low, the climate change vulnerability of the RRCSD WWTP is **High**.

1.6.1.2 Collection System

RRCSD's collection system is comprised of 35 miles of gravity pipelines, 4 miles of pressure main, 750 manholes and main line cleanouts, and 11 lift stations. Similar to the WWTP, the primary climate change threats that will most greatly impact the RRCSD collection system include increased river flooding and increased extreme precipitation. The primary climate hazards that affect the collection system include direct river flooding, infiltration and inundation (I/I) during storm events, lack of road access, electrical power outages and generator failure, and limited treatment capacity at the WWTP. Because projected climate change scenarios will exacerbate these hazards, the collection system received a climate sensitivity rating of high. The adaptive capacity of the system is low. Power source to the lift stations is unreliable and can result in SSOs. During wet weather events, the current system and operating procedures do not always solve the problem of increased I/I and peak flows entering the collection system and WWTP, but rather allow Sonoma Water to manage where the

problem occurs – there are either SSOs in the collection system or blending at the WWTP. Additionally, the WWTP must be manually operated and access to the facility can become limited due to flooding and landslides. This could limit the ability for staff to change system operations during extreme storm events.

Because the climate sensitivity rating is high and the adaptive capacity rating is low, the RRCSD collection system's climate change vulnerability is **High**.

1.6.2 Occidental County Sanitation District

OCSD provides service to approximately 120 parcels utilizing a gravity collection system and treats wastewater from approximately 298 equivalent single-family dwellings (ESDs). The WWTP and collection system were assessed together.

1.6.2.1 WWTP and Collection Station

The OCSD collection system is gravity fed and includes one lift station that pumps wastewater to the WWTP. The WWTP provides secondary treatment for an average dry weather flow of up to .05 mgd and currently treats approximately .02 mgd. Currently, treated effluent is conveyed to Grams Pond, an offsite storage pond, and is then discharged to Dutch Bill Creek, a tributary of the Russian River, October 1 through May 14, and is used for irrigation May 15 through September 30. Due to effluent quality violations, Sonoma Water received a cease and desist order and must stop discharging to Grams Pond by mid-2018. To comply with the order in the short-term, Sonoma Water will discontinue the use of the OCSD WWTP and will truck wastewater to the Airport SZ WWTP for treatment. Potential long-term solutions include construction of a pipeline to convey wastewater to nearby regional facilities for treatment. However, funding for this project is a constraint. Installing a package plant at the existing WWTP site has also been considered, however dismissed due to cost and public opposition. OCSD has a moderately low climate sensitivity. Increased wet weather events have the potential to increase I/I to the collection system and limit access to the facilities. In addition, wildfire poses a moderate risk to the area, and this risk could increase with climate change.

OCSD has a low adaptive capacity because the system's primary hazard is the inability to discharge into Grams Pond. A sustainable long-term solution would require significant capital investment. Because the climate sensitivity rating is moderately low and the adaptive capacity rating is low, OCSD's climate change vulnerability is moderate.

1.6.3 Sonoma Valley County Sanitation District

SVCSD provides service to approximately 36,000 people in the City of Sonoma and unincorporated areas of Glen Ellen, Boyes Hot Springs, El Verano, and Agua Caliente. SVCSD is under a Cease and Desist Order and Administrative Civil Liability (Complaint) (ACL) for violating the National Pollution Discharge and Elimination System (NPDES) permit requirements, the Basin Plan and the Code of Federal Regulations, with respect to the WWTP and its associated collection system. It is also under a lateral ordinance which requires inspections and repairs or replacement when needed. The primary assets assessed included the WWTP, recycled water system and collection system.

1.6.3.1 WWTP

SVCSD's WWTP is designed to provide tertiary treatment for peak wet weather flow of up to 16 mgd and treat an average dry weather flow of 3 mgd. Actual dry weather flow is typically less than 3 mgd. During wet weather events, the plant observes peak flows of 17 to 24 mgd. During the wet season (November 1-April 30), treated wastewater is discharged to Schell Slough, a tidally-influenced waterbody downstream of Schell Creek (RWQCB 2014), and to winter recycled water users. During the dry season, tertiary treated effluent is discharged to wetland management units 1 and 3 to maintain freshwater marshlands and ponds for wetland habitat enhancement (RWQCB, 2014). Between May 1 and October 31, treated wastewater is also used for irrigation of dairy fodder crops and vineyards.

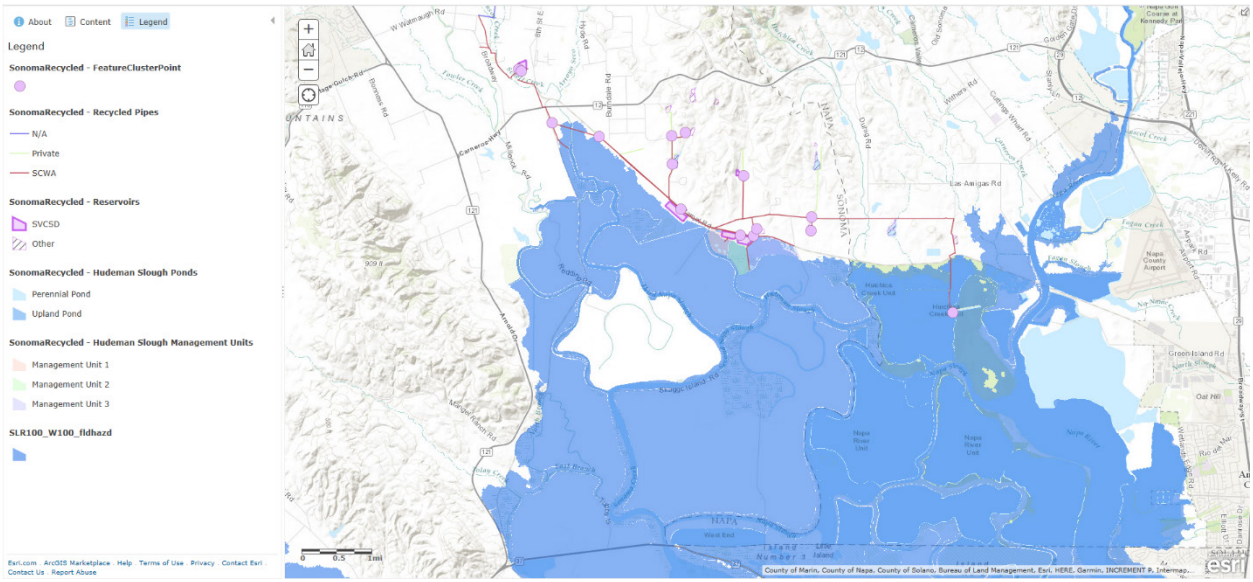
The WWTP's climate sensitivity is moderate due to minor flooding, potential sea level rise impacts, wildfire impacts, and unreliable power. Portions of the WWTP are within the 100-year flood zone, and flood probability will likely increase in the future. While flooding can compromise access to the facility, it does not appear to be a major threat. Sea level rise may limit the discharge capacity for the WWTP by increasing the water level, and head, at the outfall. In addition, wildfire and power outages may also reduce the WWTP's ability to function properly. SVCSD is currently adding effluent pumping capacity at the WWTP and implementing a capital improvements plan for the collection system. While these activities will help increase the WWTP's ability to treat wastewater given its climate sensitivities, sea level rise will likely limit ability to discharge to Schell Slough during the wet season. Because of this, the adaptive capacity of the WWTP is considered **Low**. Because the climate sensitivity rating is moderate and the adaptive capacity rating is low, the SVCSD WWTP's climate change vulnerability is **High**.

1.6.3.2 Recycled Water System

SVCSD's recycled water system includes one recycled water reservoir at the WWTP, several offsite recycled water reservoirs, booster stations, pump stations and wetland management units. Tertiary treated effluent is discharged to Hudeman Slough and wetland management units, and is also used for irrigation. The climate change threats that will most severely impact the recycled water system include river flooding and sea level rise (Figure B-5). In addition, the hydraulic limitations of the tide gates constrain the volume of recycled water discharged to Hudeman Slough. This hazard increases during moderate or high low tides, when the low tide does not get low enough for the tide gates to open to allow the water to exit the management units and enter Hudeman Slough. When this occurs, water backs up in the management units, resulting in higher water levels. This can lead to flooding of roads and pressure on the existing levees.

The climate sensitivity of the recycled water system is **High** due to flooding of facilities and access roads, sea level rise inundation of management units, and limited discharge ability during rising tides and future sea level rise scenarios. The system's adaptive capacity was rated **Low** because much of the system is vulnerable to flooding and sea level rise will greatly impact the operations of the management units. Because the climate sensitivity rating is high and the adaptive capacity rating is low, the SVCSD recycled water system's climate change vulnerability is **High**.

Figure B-5. Future Sea Level Rise Inundation 100-centimeter Increase and 100-year Storm Surge



Source: Point Blue

1.6.3.3 Collection System

SVCSD's collection system is gravity fed with two pump stations in the northern portion of the service area. The system's primary climate change threats include increased river flooding and increased extreme precipitation. The climate sensitivity of the collection system is high. This is primarily due to the aging sewer lines and related I/I, which are sensitive to climatic events such as storm events. SSOs, caused by insufficient capacity, blockages and I/I, result in violations. The SSOs occur throughout the collection system during both wet and dry weather events. Additionally, portions of the collection system are located within moderate fire hazard areas, with select areas in high fire hazard areas. Fire can damage infrastructure, threatening power supply, and generate secondary effects such as increased flooding or landslides.

Operational changes alone cannot help the collection system adapt to climate changes and thus the collection system's adaptive capacity was rated **Low**. However, SVCSD has secured funding to implement a series of projects to upgrade the collection system. Because the climate sensitivity rating is **High** and the adaptive capacity rating is low, the SVCSD collection system's climate change vulnerability is **High**.

1.6.4 Penngrove Sanitation Zone

PSZ provides service to approximately 417 parcels using a gravity collection system and two lift stations. The Penngrove Lift Station is operated by Sonoma Water and is the asset assessed.

1.6.4.1 Penngrove Lift Station

The Penngrove Lift Station is located within the 100-year floodplain and is frequently inundated due to creek flooding. The climate sensitivity rating is high because the lift station, its electrical equipment and the surrounding access roads flood during storm events. The adaptive capacity of the Penngrove Lift Station is **Low**. This is primarily because of the facility's location within the

floodplain and the electrical gear being approximately 1 foot from the floor. There is no backup power at this facility and the backup generator must be physically driven in. During flooding events, the lift station is inaccessible because the surrounding roads flood and the emergency power generator cannot be brought to the lift station. Because the climate sensitivity rating is **High** and the adaptive capacity rating is low, the Penngrove Lift Station's climate change vulnerability is **High**.

1.6.5 Geyserville Sanitation Zone

GSZ is located in northern Sonoma County and provides service to approximately 318 parcels. GSZ consists of a gravity collection system that includes one lift station. The WWTP consists of percolation ponds and treats approximately .077 mgd. The WWTP and collection system were assessed together.

1.6.5.1 WWTP and Collection Station

The GSZ lift station and WWTP are both located within the Russian River 100-year floodplain. The GSZ is vulnerable to inundation from river flooding, and elevated groundwater tables from flooding and increased precipitation. The river flooding has inundated roads in the past, limiting access to the WWTP and the lift station. The WWTP is elevated, and direct flooding does not appear to be a significant hazard at the plant itself. However, elevated groundwater tables from flooding limit the percolation capacity of the WWTP and increased precipitation could exceed the capacity of the percolation pond. Therefore, the climate sensitivity rating is high. The adaptive capacity for these facilities is low because the WWTP and lift station are located directly in the Russian River 100-year floodplain, limiting access and adaptation options. Because the climate sensitivity rating is high and the adaptive capacity rating is low, GSZ's climate change vulnerability is **High**.

1.6.6 Airport-Larkfield-Wikiup Sanitation Zone

Airport SZ provides service to approximately 2,722 parcels using a gravity collection system and treats wastewater from approximately 3,847 ESDs. The primary assets assessed included the WWTP and the collection system.

1.6.6.1 WWTP

The WWTP is designed to provide tertiary treatment for an average dry weather flow of 0.9 mgd and treats approximately 0.62 mgd average dry weather flow. The current discharge capacity is a dry weather flow of 0.9 mgd. The WWTP does not have a NPDES permit and therefore cannot discharge treated wastewater. All treated effluent is disposed of through irrigation. The climate change threats that will most severely impact the WWTP include increased extreme precipitation and increased river flooding. Climate impacts include creek flooding that inundates the road to North Pond (an effluent storage pond), limiting access to the pond and to several valves, as well as the access road to Site D (an offsite storage pond). However, access to the WWTP is not compromised by flooding. Because of this, the climate sensitivity at the WWTP is rated moderate. The adaptive capacity of the Airport SZ WWTP also received a moderate rating. This is because creek maintenance measures could be implemented to help reduce flooding of the road to North Pond. Additionally, the WWTP has a backup generator located onsite that can power the facility in the event of a power outage.

Airport SZ is also considering upgrades to increase the WWTP's treatment capacity (now limited by transfer capacity) and discharge capacity during wet weather events. Because the climate sensitivity rating is moderate and the adaptive capacity rating is moderate, the Airport SZ WWTP's climate change vulnerability is **Moderate**.

1.6.6.2 Collection System

The Airport SZ consists of a gravity collection system and one lift station. The climate sensitivity of the collection system is rated moderate because portions of the collection system, including the lift station, are located within a moderate wildfire risk area. The adaptive capacity of the Airport SZ collection system is also considered moderate. While flooding is not expected to be an issue at the lift station, there is an underground emergency storage reservoir located adjacent to the lift station that could be used to reduce SSOs in the event of extreme precipitation or flooding. Because the climate sensitivity rating is low and the adaptive capacity rating is moderate, the Airport SZ collection system's climate change vulnerability is **Moderate**.

1.6.7 Administrative Facilities

1.6.7.1 Administrative Office, Operations and Maintenance Center, and the Operations and Maintenance Dispatch Center

The Sonoma Water administrative facilities include the Sonoma Water administrative office, the operations and maintenance center, and the operations and maintenance dispatch center. The climate sensitivity for the administrative facilities is low. While there is a small potential for flooding near the facilities, they are not highly sensitive to climate hazards. The adaptive capacity is high. Both the Operations and Maintenance Center and Dispatch Center have backup power available. Because the climate sensitivity rating is low and the adaptive capacity rating is high, the Sonoma Water administrative buildings have a **Low** climate change vulnerability.

SECTION 2

References

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