FINAL REPORT | ALAMEDA COUNTY WATER DISTRICT

Brown AND Caldwell

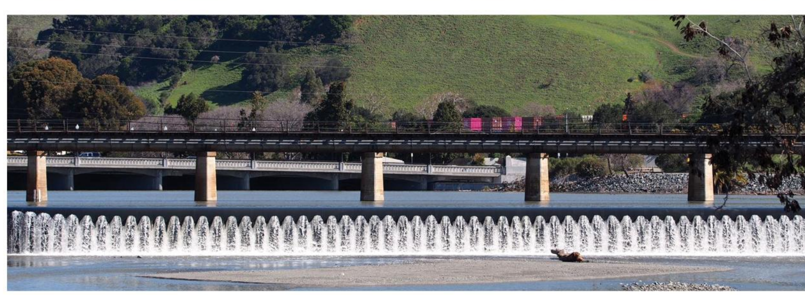
Climate Adaptation Plan (CAP) Final Report

ACWD
ALAMEDA COUNTY WATER DISTRICT

March 2023





Alameda County Water District Climate Adaptation Plan

Prepared for
Alameda County Water District
Fremont, California
March 2023

Project No. 158149

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Acknowledgements

This Climate Adaptation Plan was developed as a coordinated effort between the Brown and Caldwell (BC) consultant team and the Alameda County Water District (District) Climate Adaptation Plan (CAP) Team. These teams worked together to form the collaborative CAP Team.

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List of Abbreviations

AHF	Above-Hayward Fault
AMI	Advanced Metering Infrastructure
AR5	Assessment Report 5
AR6	Assessment Report 6
ARP	Aquifer Reclamation Program
ART	Adapting to Rising Tides
BARR	Bay Area Regional Reliability
BCDC	(San Francisco) Bay Conservation and Development Commission
BHF	Below-Hayward Fault
CAP	Climate Adaptation Plan
CIP	capital improvement program
CO_2	carbon dioxide
CMIP5	Coupled Model Intercomparison Project Phase 5
CPUC	California Public Utilities Commission
CUWA	California Urban Water Agencies
District	Alameda County Water District
DWR	Department of Water Resources
EBMUD	East Bay Municipal Utility District
ERP	Emergency Response Plan
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FHSZ	Fire Hazard Severity Zone
FIRO	Forecast Informed Reservoir Operations
GCM	general circulation model
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
IRP	Integrated Resources Plan
IRWMP	Integrated Regional Water Management Plan
LHMP	Local Hazard Mitigation Plan
LOCA	localized constructed analogues
LoS	level of service
MCDA	multi-criteria decision analysis
MG	million gallons
mgd	million gallons per day
Niles Cone	Niles Cone Groundwater Basin
NOAA	National Oceanic and Atmospheric Administration
OPR	The Governor's Office of Planning and Research
PG&E	Pacific Gas & Electric Company
PSPS	public safety power shutoff
RCP	Representative Concentration Pathway
RCP 4.5	Representative Concentration Pathway 4.5 (stabilization scenario)
RCP 8.5	Representative Concentration Pathway 8.5 (high emissions scenario)
RRA	Risk and Resilience Assessment
RWS	Regional Water System
RWQCB	Regional Water Quality Control Board
SBA	South Bay Aqueduct
SFPUC	San Francisco Public Utilities Commission
SGMA	Sustainable Groundwater Management Act
SLR	sea level rise
Sonoma Water	Sonoma County Water Agency
SWE	snow water equivalent
SWP	State Water Project
USGS	United States Geological Services
UWMP	Urban Water Management Plan
Valley Water	Santa Clara Valley Water District
V/DC	vulnerable/disadvantaged community
WEMP	Water Use Efficiency Master Plan
WRMP	Water Resources Master Plan
WSCP	Water Shortage Contingency Plan
WUCA	Water Utility Climate Alliance

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Executive Summary

The Alameda County Water District (District) has prepared this Climate Adaptation Plan (CAP) as an initial study (Phase 1) to assess the District's vulnerabilities and risks to climate change. During Phase 1, the CAP Team reviewed the District's existing plans and policies to identify available opportunities for building climate readiness. This initial review provided context for vulnerability and risk assessments, which the CAP Team conducted to inform the development of adaptation strategies, recommendations, and suggested direction for future planning. These outcomes strengthen the District's resilience by anticipating and reducing climate-related risks through mid- (up to 2050) and long-term (up to 2100) planning horizons.

Future District planning will continue to build on recommendations from this CAP. This plan will aid in stakeholder engagement efforts and inform other District plans, such as the Water Resources Master Plan (WRMP). The District's 1995 Integrated Resources Plan (IRP) will be updated in the creation of the 2025 WRMP and will include a 30-year outlook on water supply planning that supports the District's mission of providing a reliable, high-quality water supply for its customers.

CAP Objectives

The CAP Team established four key objectives based on review and input from the District's Board of Directors and the public during a March 31, 2022, public workshop. Supporting priorities were developed to describe important steps and considerations for achieving each objective (Table ES-1).

Table ES-1. CAP Objectives and Priorities

Objectives	Priorities
Objective 1: Foster alignment across planning efforts, both internally and externally.	• Align District plans, policies, initiatives • Align the CAP with relevant external plans, policies, initiatives • Understand regulatory drivers and impacts
Objective 2: Identify and prioritize climate risks and vulnerabilities for the District's systems, ecosystems, and communities.	• Identify relevant climate change risks and regulations • Document anticipated impacts and adaptive capacity of District water supplies, infrastructure, and operations • Identify impacts to vulnerable and disadvantaged communities (V/DC)
Objective 3: Prioritize actions for achieving climate readiness and fulfilling climate adaptation goals using best practices.	• Identify set of adaptation and resilience goals, policies, and best practices • Prioritize strategies for achieving climate readiness, with flexibility to adapt • Recommend near- and long-term actions, studies, and potential funding opportunities
Objective 4: Communicate findings in a transparent and accessible manner and identify future opportunities to engage with stakeholders and the public.	• Communicate Phase 1 findings in public-facing summary • Identify opportunities to solicit input from the public and other stakeholders

CAP Methodology

The CAP Team based its approach to this plan on industry standards for resilience planning and climate adaptation efforts, such as guidance from the American Water Works Association Manual 71 and the Water Utility Climate Alliance Leading Practices Report, as well as from a review of other CAPs completed in the San Francisco Bay Area. The main components involve reviewing and summarizing policy and alignment opportunities, conducting a vulnerability assessment and a risk assessment, and preparing recommendations (Figure ES-1).

Steps	1. Objectives and Priorities	2. District Policy Review and Alignment	3. Vulnerability Assessment	4. Risk Assessment	5. Recommendations for Adaptation Strategies	6. Adaptation Pathways and Recommended Studies
Goals	Establish well-vetted direction for Phase 1 CAP study	Apply a climate change lens to improve District policy and identify alignment opportunities	Gain understanding of most relevant physical and regulatory vulnerabilities	Apply and expand policy and vulnerability assessment to understand most significant impacts and capacities	Identify, evaluate, and prioritize adaptation strategies	Create flexible roadmaps for an actionable, forward-looking CAP and provide suggestions for future studies

Figure ES-1. Overview of CAP steps

The vulnerability assessment identifies parts of the District's system that are susceptible to specific climate-related threats, such as sea level rise (SLR), drought, wildfire, and potential climate-related regulatory changes. The risk assessment expands on the vulnerability assessment by identifying the likelihood and consequence of potential impacts of these threats to assess overall risk for each threat. The CAP Team used the outcome of the vulnerability and risk assessments to identify and evaluate potential adaptation strategies, and then developed adaptive pathways (i.e., graphical representations of how to implement adaptation strategies over time). The evaluation of adaptation strategies used a transparent prioritization process for strategies and actions that target the most significant risks and provide the greatest overall resilience. The study leverages this information to generate a list of recommended future studies to continue building climate readiness.

Policy and Alignment Opportunities

To become climate ready, the District will proactively anticipate, plan for, and prepare to overcome challenges from climate change impacts. This view of climate readiness was applied as a lens to review both internal (District) and external (state, region, and other agency) plans and policies. Key areas for the District's internal planning and policy that can align with achieving climate readiness are identified in Table ES-2.

Table ES-2. Internal Plans and Policies Reviewed		
Planning and Policy Area	**Reviewed Plans and Policies**	**Content that Supports Climate Readiness**
Mission and Strategic Planning	• District Mission Statement • Five Year Strategic Plan 2018 • Business Continuity Plan	• Provides direction for high-level policy criteria and communicates climate change as a key uncertainty.
Urban Water Management Planning (UWMP)	• UWMP 2020-2025, including: • Water Shortage Contingency Plan • Drought Risk Assessment • Reduced Delta Reliance Addendum	• Provides a list of planning criteria and identifies initial considerations for a high-level climate risk assessment, specifically for potential impacts to water supplies. Further provides an approach for applying climate change factors to adjust past hydrology data and information used in planning.
Emergency Management	• Risk and Resilience Assessment • Emergency Response Plan	• Identifies specific hazards and vulnerabilities across the District's service area and critical assets while also documenting existing risk mitigation measures.
Groundwater Management Planning	• Groundwater Management Policy (1989, 2001) • Alternative to a Groundwater Sustainability Plan 2016 (Alternative) • Five-Year Periodic Evaluation of the Alternative 2021 (Alternative Update)	• Indicates a longstanding (since the 1970s) practice of groundwater sustainability, while ongoing groundwater management provides programs and projects that support existing adaptive capacity and potential future oversight that can be considered adaptation strategies.
Integrated Resources Planning (IRP)	• 1995 IRP Study • 2006 IRP Study: 10-Year Review • 2013 IRP Review	• Includes policy criteria development, an evaluation of multiple uncertainty scenarios, and re-evaluation of planning assumptions since the 1990s. Efforts in the past decade provide initial overview of climate change as an opportunity and challenge.

Themes and patterns for internal alignment included common criteria and priorities, the identification of plans and actions (e.g., potential adaptation strategies), and a growing awareness, inclusion, and documentation of climate risks and impacts. Along with this progress to date, the study identified areas to improve alignment with climate readiness.

External plans and policies reviewed included climate action plans and other CAPs, and hazard mitigation plans (HMP) from cities within the District's service area, Alameda County, and other Bay Area agencies. Key partnerships, such as the Bay Area Regional Reliability (BARR) Partnership, Delta Stewardship Council, and the Alameda Creek Watershed Forum were also considered for identifying potential alignment opportunities. A summary of this review is provided in Table ES-3.

Table ES-3. External Plans and Policies Reviewed (Local and Regional Summary)

Local and Regional Focus	Reviewed Plans and Policies	Alignment Opportunities to Support Climate Readiness
Cities	• City of Fremont 2016-2021 Local Hazard Mitigation Plan • City of Fremont Climate Action Plan (2012 and update process) • City of Newark Climate Action Plan (2010) • Union City Climate Action Plan (2010)	• Coordinate with future updates for mapping and hazard data • Coordinate use of same data sources and emergency planning approaches and protocols • As CAPs are updated, continue discussions for integrating effective adaptation strategies and seek funding partnership opportunities • Coordinate with and leverage joint stakeholder engagement opportunities
County	• Alameda County Climate Action Plan for Government Services and Operations through 2020 • Alameda County (Unincorporated Areas) Community Climate Action Plan 2014 (General Plan Element) • Union City/Newark Multi-Jurisdiction Hazard Mitigation Plan	• Align development of adaptation strategies with priority areas of Alameda County Climate Action Plans (including the CAP for Government Services and Operations through 2020 update and the Community Climate Action Plan [Alameda County, 2010 and 2014]) and seek funding partnership opportunities • Coordinate with and leverage joint stakeholder engagement opportunities • Similar to city HMPs, coordination with future updates for mapping and hazard data; coordinate use of same data sources, emergency planning approaches, and protocols
Other Bay Area Agencies	• Valley Water Climate Change Action Plan • EBMUD Wastewater Climate Change Plan • Sonoma Water Climate Adaptation Plan	• Leverage opportunities to conduct regional adaptation strategy projects and continued partnerships • Coordinate use of same regional data
Partnerships	• Bay Area Regional Reliability Partnership • Delta Stewardship Council • Alameda Creek Watershed Forum	• Leverage partnerships to support more flexible regional operations, available storage, and supply reliability for times of scarcity and extreme events • Pursue opportunities for watershed-scale management and improvement, shoreline protection projects, and coordination of coastal land use planning

The internal and external policy and planning review also included policies at state and regional levels, including those that have a regulatory component. Areas of state- and regional-level policy included SLR guidance, state-level climate and resilience strategies and assessments, and sustainable groundwater management and policy around Bay Delta Region management. Reviewed state- and regional-level plans and policies and their respective alignment opportunities are summarized in Table ES-4.

Table ES-4. External Plans and Policies Reviewed (State-level Summary)

Planning and Policy Area	Reviewed Plans and Policies	Alignment Opportunities to Support Climate Readiness
Sea Level Rise	• Critical Infrastructure at Risk: Sea Level Rise Planning Guidance for California's Coastal Zone • Sea Level Rise Guidance 2018 Update • State Agency Sea Level Rise Action Plan for California 2022	• Leverage planning tools to coordinate cross-jurisdictional projects for SLR adaptation and support for environmental justice when considering project benefits • Consider further development of District policy to align with seven principles and six goals of the State Agency Sea Level Rise Action Plan for California 2022 (focal points include equity, nature-based solutions, best available science, protecting coastal habitat, pursuing partnerships)
Climate & Resilience	• California Climate Adaptation Strategy 2021 • State of California's Fourth Climate Change Assessment San Francisco Bay Area Region Report • California Water Resilience Portfolio 2020 (Water Resilience Portfolio) • California's Water Supply Strategy 2022	• Develop planning and policy criteria that align with Climate Adaptation Strategy's climate resilience priorities, corresponding goals, and actions (especially public health and safety, nature-based solutions, collaborative partnerships, and decision making using best available science) • Leverage information on status and trends of California's water-dependent natural resources, climate science, and state supply planning policies • Develop adaptation strategies that align with range of options and opportunities in the Water Resilience Portfolio
Sustainable Groundwater Management Act	• 2014 Sustainable Groundwater Management Act	• Continue updates with state-of-science and leverage and expand on Department of Water Resources-provided tools and approaches, especially for Five-Year Periodic Evaluation updates • Pursue Sustainable Groundwater Management Grant Program funding opportunities for project implementation
The Delta	• The Delta Plan • Delta Adapts Initiative (Delta Adapts): Creating a Climate Resilient Future (current state)	• Continue to engage with Delta Adapts project and the Delta Stewardship Council's regional SLR Adaptation Plan; stay invested in research, planning, and policy updates

Regulatory components of reviewed policy enabled documentation of climate-related regulatory uncertainties and risks (Table ES-5). These complement the physical risks and are included in the overall vulnerability and risk assessment steps of this CAP.

Table ES-5. Regulatory Uncertainties and Risks	
Regulatory Area	**Potential Change and Impact**
Sustainable Groundwater Management Act	• Potential change: Requirement to re-evaluate climate change analysis in Five-Year Periodic Evaluation updates based on changing regulations and best available science • Impact: May need more staff time and/or change in approach (e.g., applying new data/models)
Urban Water Management Planning	• Potential change: Requirement to assess supply reliability on a longer planning horizon and/or demonstrate compliance with new water use efficiency targets. • Impact: May need more staff time to develop UWMP planning documents and/or change in approach (e.g., applying new data/models and demand management techniques)
Endangered Species Act	• Potential change: Requirements that constrain Delta pumping and may mandate additional upstream reservoir releases; potential increased species protection requirements • Impacts: Limitations on State Water Project (SWP) and San Francisco Public Utilities (SFPUC) Regional Water System (RWS) supply; potential restrictions on groundwater recharge operations
Bay-Delta Plan (Bay Delta Water Quality Control Plan)	• Potential change: New in-stream flow requirements for Delta tributaries • Impact: Reduced storage and dry-year supply reliability for SWP and SFPUC RWS supplies
State Water Project Contract Amendments	• Potential change: Amendment to SWP contract impacting Table A allocation (Table A allocations are based on State Water Contractors contracts and the allocation is proportional to a contractor's ownership share) • Impact: Reduced water supply
Conservation Legislation	• Potential change: Implementation of long-term water use efficiency standards; potential short-term emergency conservation legislation • Impact: Greater efforts for demand management and conservation

System Vulnerabilities and Risks

The CAP uses California's Fourth Climate Change Assessment as the scientific basis for climate change projections and scenarios; it leverages the Intergovernmental Panel on Climate Change (IPCC)'s most recent Assessment Report 6 (AR6) as an additional reference for climate change trends. The results of this assessment indicate likelihoods and trends for various potential climate threats. Climate threats for the District's CAP include wildfire, drought, SLR, increased storm intensity and flooding (e.g., from atmospheric rivers), and higher temperatures (Figure ES-2). Threats like drought, higher temperatures, and changing storm and precipitation patterns can influence seasonal snowpack and the timing of snowmelt, which affects water supply reliability. The District's system is vulnerable to saltwater intrusion, which is a result of SLR and can adversely impact groundwater supplies and below-ground infrastructure. Saltwater intrusion is included in the figure due to its importance for the District's system.

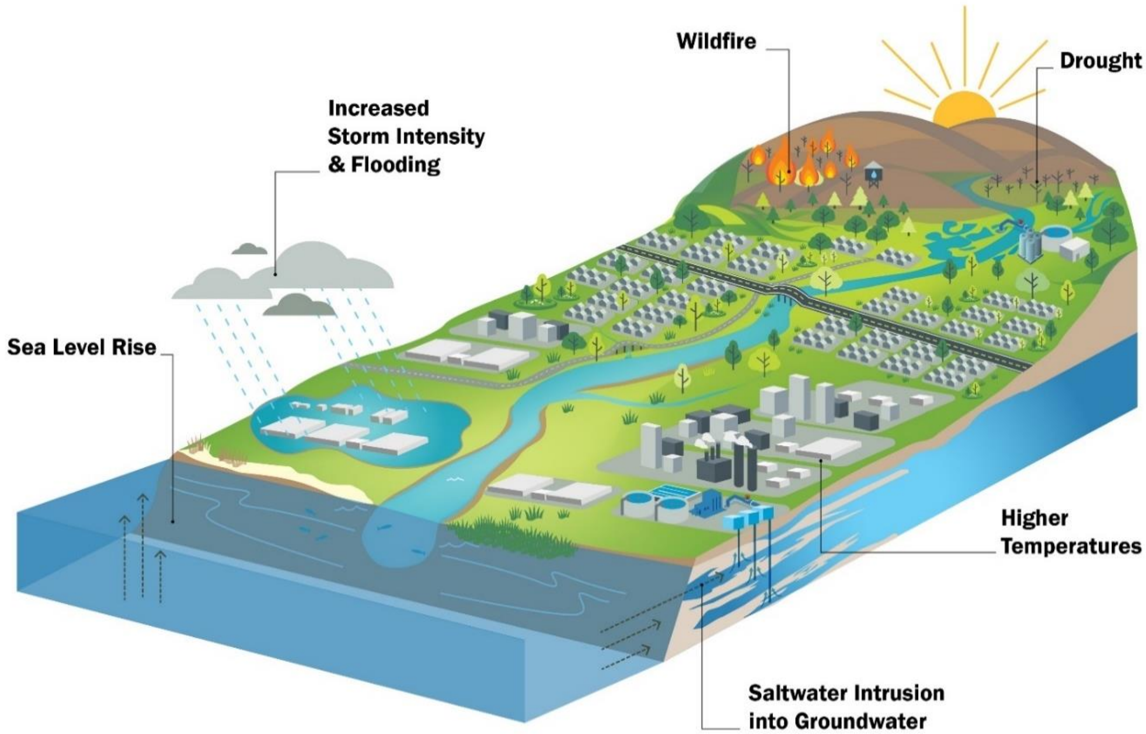

Figure ES-2. Potential climate-related threats across the watershed

The CAP includes 15 climate risk scenarios that pair plausible climate-change-related threats with potential adverse events the threat may cause.[1] This provided a descriptive baseline of a range of potential future conditions that may impact the District's system, operations, and communities it serves. Climate risk scenarios were further detailed in the CAP's vulnerability and risk assessment content. In the vulnerability assessment, scenarios were expanded to include information on the potential impacts and assets and/or operations impacted; the potential spatial distribution of these impacts were depicted in the form of "hot spot" maps.

The risk assessment then further detailed each scenario by identifying relative likelihood and consequence scores. Likelihood scores were based on trends from the existing state-of-science (i.e., California Fourth Climate Change Assessment Report and IPCC AR6). Each climate risk scenario was scored within a range of 1 (rare) to 5 (almost certain) for a mid-term (2050) and long-term (2100) likelihood of impact based on existing scientific data. Consequence criteria were developed qualitatively and were equally weighted for this initial study before also being scored within a range of 1 (negligible) to 5 (severe) potential impact. For future studies, consequence criteria can be assigned different weights to determine relative importance of one criterion to another. This assumption may be adjusted, e.g., with input from stakeholders or in future planning efforts and/or CAP updates. The combination of the likelihood and consequence provided a total risk score. Figure ES-3 provides a visual summary of the risk score components and basic equation. The top row depicts how the likelihood and consequence determine the overall risk score. The bottom row provides the scoring range and an example score to demonstrate how overall risk scores are determined.

[1] The analysis began with more than 30 climate risk scenarios, which were then aggregated to 15 scenarios that demonstrated a range of climate threats and risk events for continued analysis.

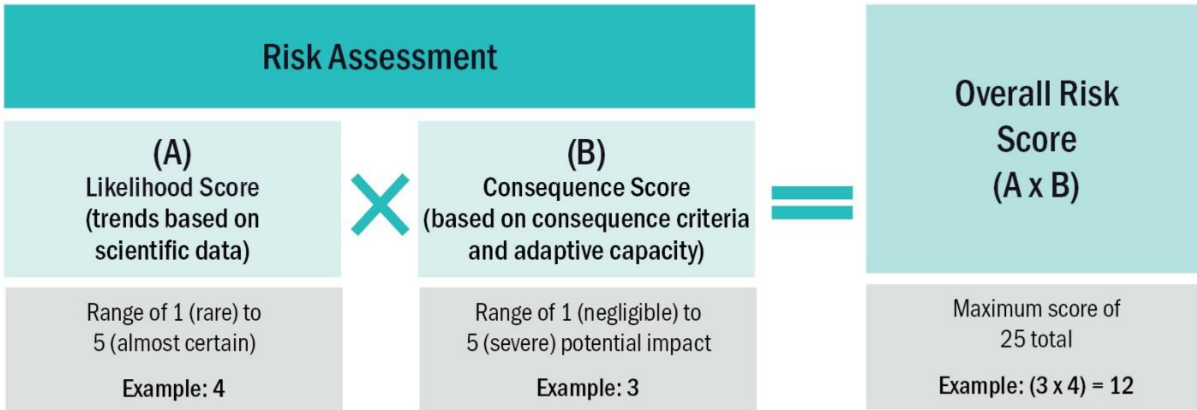

Figure ES-3. Visual summary of risk score components

The goal in understanding the risks and impacts is to reduce overall risk and increase overall resilience for the District. The risk score provides a baseline understanding of the potential climate threat and risk event. This score can be adjusted in the future depending on:

- Adaptive capacity: considered qualitatively as either high, medium, or low. This ranking depended on the ability of the District's existing plans, actions, or programs to reduce vulnerability in different parts of the system. In the current assessment, the adaptive capacity is factored into the scores for potential consequence criteria. For example, if the District already has adequate backup power for critical assets in place, then the consequence score for a public safety power shutoff caused by wildfire is going to be low.
- Adaptation strategies: plans, actions, or programs that are not currently in place that would further reduce climate risk. The strategies are not focused on one specific project but include a range of options to be considered and further developed. These were considered after the development of the risk scores. These strategies can be implemented to go beyond the current actions and can reduce the "current actions only" risk score.

Risk scores were determined for both mid- and long-term planning horizons. These risk scores reflect the relative risk given the continuation of current actions only. The scores in Table ES-6 account for adaptive capacity to help understand the influence of existing activities and provide a baseline to compare with the potential benefits of implementing future adaptation strategies.

Table ES-6. Climate Risk Scenarios 1-15			
Scenario ID No.#	Scenario (Climate threat: risk event)	Risk Score (Mid-term, 2050)	Risk Score (Long-term, 2100)
1	Increasing Temperature: Reduced local supply	16.9	16.9
2	Increasing Temperature: Increased demand	14.4	14.4
3	Drought: Imported supply reductions (SFPUC)	13.1	13.1
4	Drought: Imported supply reductions (SWP)	12.5	12.5
5	Wildfire: Non-salinity water quality degradation in local surface water (e.g., mobilized by wildfire)	13.1	13.1
6	Increasing Temperature: Non-salinity water quality degradation in the Delta	12	15
7	Flooding: Saline intrusion in the Delta	11.5	14.4
8	SLR: Non-salinity groundwater contamination mobilization in Niles Cone Groundwater Basin (Niles Cone)	11.5	14.4
9	SLR: Saltwater intrusion in Niles Cone	13.8	13.8
10	Drought: Reduced groundwater recharge to Niles Cone	12.5	15.6
11	SLR: Sea level rise damaging infrastructure or resulting in loss of access	9	11.3
12	Storm: Storm intensity damaging infrastructure or resulting in loss of access	9.0	9.0
13	Wildfire: Wildfire damaging infrastructure or resulting in loss of access	7.5	7.5
14	Wildfire: Public safety power shutoff (PSPS)	9.0	9.0
15	Regulatory/legislative changes	17.5	21.9

Scores were used to understand potential planning implications for understanding risks across mid- and long-term planning horizons (Figure ES-4). The figure's lists represent the relative importance of these risks. All 10 should be considered in future planning efforts; however, some risks are anticipated to become even more critical after 2050.

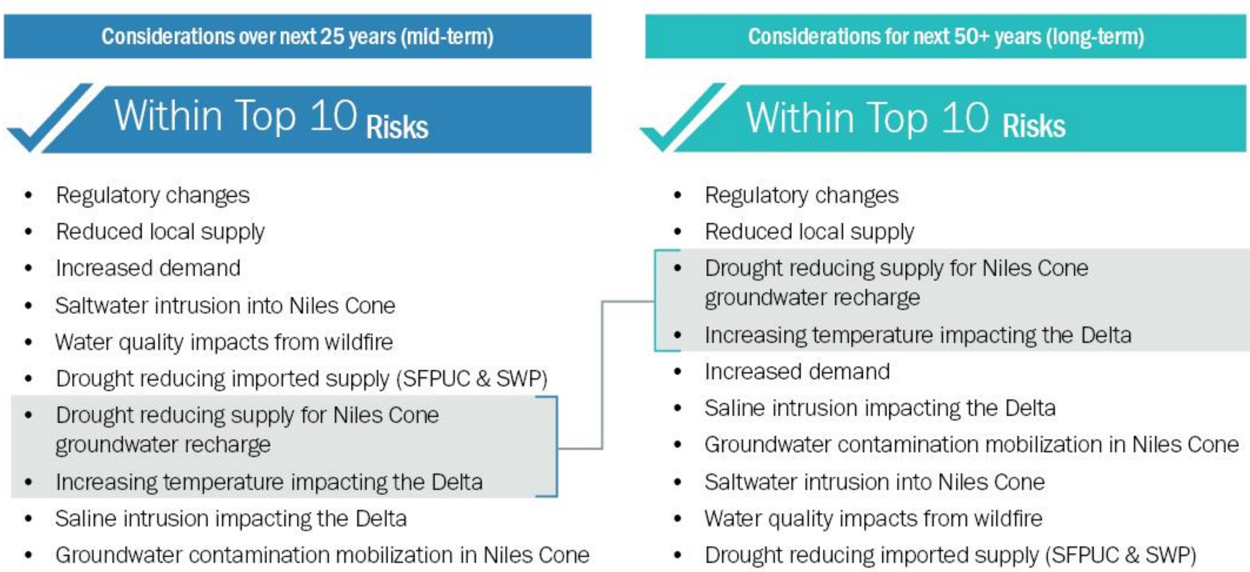

Figure ES-4. Top 10 potential risks for mid- and long-term planning horizons listed by relative importance

Lower-priority risks (not featured in Table ES-4) include damage to infrastructure and loss of access to facilities. These are assumed to continue to be lower risks, especially given the limited potential spatial overlap with areas impacted by wildfire, SLR, and storm climate threats and considering the existing adaptive capacities the District has in place (e.g., backup power for PSPS). Adaptation strategies were then evaluated at a high level based on relative potential benefit. This is measured by a strategy's ability to improve the overall risk score for each climate risk scenario.

Recommendations for Adaptation Strategies

The CAP considers a variety of adaptation strategies and how these can reduce the overall risk scores for the top 15 climate risks scenarios. Adaptation strategies were qualitatively evaluated across the benefits they provide, which were determined based on their ability to reduce potential impacts from climate risks using consequence criteria for the following levels of service categories: water delivery, water quality, water supply, production facility reliability and redundancy, financing, environmental stewardship, safety, and equitable service. These criteria were scored and were evaluated using a multi-criteria decision analysis (MCDA) tool. Table ES-7 presents a summary of the climate-related threats and their corresponding recommended adaptation strategies.

Table ES-7 Adaptation Strategy Types by Climate Threat

Adaptation Strategy Types	Rising Temperatures	Sea Level Rise	Drought	Wildfire	Storm	Regulatory (climate-related risk)
Demand management *(e.g., short-term dry year conservation efforts, long-term water use efficiency measures)*	Helps address climate threat	Helps address climate threat	Helps address climate threat	Limited or no improvement	Limited or no improvement	Helps address climate threat
New or expanded supplies *(e.g., develop new local/regional supplies, expanding existing local/regional supplies, secure new imported [non-local] supplies, bolster existing imported supplies)*	Helps address climate threat	Helps address climate threat	Helps address climate threat	Limited or no improvement	Limited or no improvement	Helps address climate threat
Operations *(e.g., new or expanded surface storage, increase groundwater recharge/storage for Niles Cone and/or for groundwater banked in the Semitropic Groundwater Bank system, adjust dry year operating rules, improve distribution system flexibility, expand monitoring and remote operations)*	Helps address climate threat	Helps address climate threat	Helps address climate threat	Helps address climate threat	Helps address climate threat	Helps address climate threat
Watershed and ecosystem management *(e.g., green infrastructure and nature-based solutions, forest/ vegetation management)*	Helps address climate threat	Helps address climate threat	Limited or no improvement	Helps address climate threat	Helps address climate threat	Helps address climate threat
Regional partnerships *(e.g., San Francisco Bay Shoreline, Delta Partnerships, Bay Area Regional Supply, Alameda Creek Watershed)*	Helps address climate threat	Helps address climate threat	Helps address climate threat	Helps address climate threat	Helps address climate threat	Helps address climate threat
Critical facilities and infrastructure protection *(e.g., capital projects to increase resilience [new or rehabilitated infrastructure], improve emergency preparedness, response protocols/procedures)*	Limited or no improvement	Helps address climate threat	Limited or no improvement	Helps address climate threat	Helps address climate threat	Limited or no improvement
Water quality and treatment *(e.g., mitigate/treat groundwater contamination, reservoir water quality management, adjust or expand surface water treatment)*	Limited or no improvement	Helps address climate threat	Limited or no improvement	Limited or no improvement	Limited or no improvement	Helps address climate threat

Helps address climate threat   Limited or no improvement

Adaptation Pathways

Considering the uncertainties surrounding climate change projections, a flexible approach is needed to consider how to employ adaptation strategies as conditions change. Adaptation pathways (i.e., graphical roadmaps) were developed that represent long-term adaptation strategies responding to a changing condition like SLR or saltwater intrusion. Pathways depict potential future actions as a series of key decision points, where each new decision is triggered by a specified condition or parameter that can be monitored over time (Figure ES-5). For example, if saltwater intrusion is a risk to the District's local groundwater supplies, then salinity can be monitored to anticipate the need to take action. Triggers are specified at appropriate points where the action can be effective by the time it is needed. Pathways also indicate terminal points, where certain actions are no longer viable (they are no longer able to reduce risks and potential impacts to acceptable levels). Some actions extend indefinitely because they represent "low- to no-regret" strategies that are expected to yield benefits regardless of the changing condition.

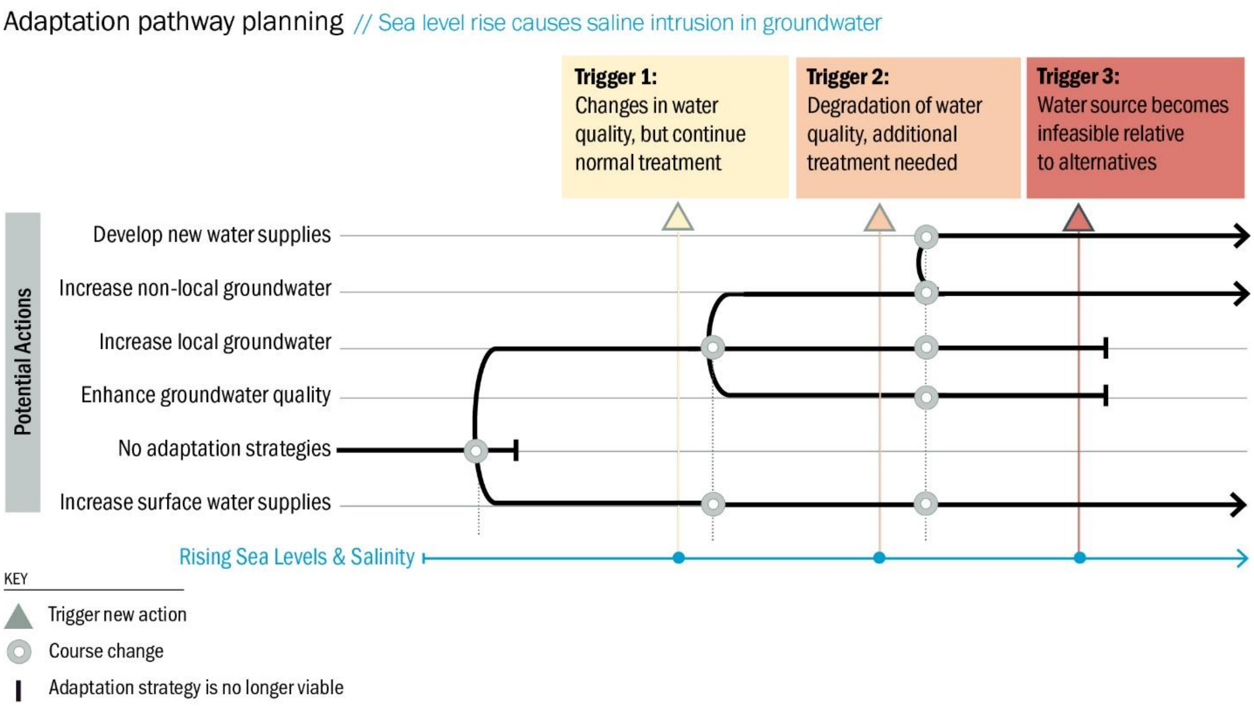

Figure ES-5. Example of simplified adaptation pathway map

Adaptation pathways provide guidance for potential sequencing of adaptation strategies, including potential future studies, and support potential discussions with stakeholders for future phases of work and planning efforts. Future studies are recommended to define quantifiable triggers thresholds.

Findings Summary

Figure ES-6 provides a summary of the CAP findings and how the study objectives have been fulfilled. The items listed in the figure also support the recommendations elaborated in the next section.

Figure ES-6. Findings-oriented summary of how CAP Phase 1 objectives were fulfilled and direction for future planning efforts

Recommendations

Recommendations for policy and planning are broken down into internal and external actions, as well as recommendations for future studies and development of recommended adaptation strategies.

Internal Policy and Planning

As a result of the policy review and analysis, recommended actions for aligning internal District policy and planning for climate readiness include:

- **Update criteria and refine planning priorities:** Establish a consistent set of planning criteria and priorities for "climate readiness" in future WRMP processes. This includes refining and adopting criteria as well as establishing criteria weighting to support future project prioritization and selection transparency. This will provide a transparent accounting of how the District selects future projects and tracks progress to achieve planning climate readiness goals. The District could use the consequence criteria created in this CAP as a starting point. It is recommended that this process include efforts to better understand and communicate the District's equity and environmental stewardship goals.
- **Leverage identified adaptive capacities and potential adaptation strategies in future capital improvement program (CIP) updates:** Establish a practice of identifying and documenting future CIP projects to mitigate the highest climate risks and align future CAP updates with CIP planning cycles. This encourages documentation and tracking of climate risk reduction, which may be helpful for future insurance and credit-worthiness reporting requirements that require accounting for climate risk.
- **Develop internal goals to enhance understanding of SLR impact:** This includes identifying and engaging in studies to remedy current knowledge gaps for potential SLR impact (e.g., movement and extent of saline intrusion, impacts to Niles Cone and local ecosystems, location and extent of emergent groundwater), performing additional modeling, and developing triggers for both salinity and potential emergent groundwater.
  - **Partnership opportunity:** Partner with neighboring groundwater sustainability agencies, as well as the cities of Fremont, Newark, and Union City; Alameda County; and entities such as the Bay Conservation and Development Commission and the San Francisco Estuary Institute.
- **Expand on the original 1995 IRP uncertainty scenarios:** This includes updating the assumptions used in the previous three uncertainty scenarios for a best-, middle-, and worst-case future scenario that considered the level of development for demand forecast, potential changes in imported supply deliveries, and treatment plant capacity. Assumptions could be updated to include a revised understanding that considers climate change impacts (e.g., increased demand potential, reduced imported supply, and potential changes in treatment based on impacts to source water quality).
- **Translate existing resilience and sustainability actions into adaptation strategies:** Although the CAP begins to address this recommendation, this can become a standard protocol for pending and proposed projects. This is especially relevant for identifying projects and actions that may be identified as "low- to no- regret" strategies.
- **Apply a common definition of "climate readiness" across planning efforts:** For all planning efforts, communicate and enumerate directly within the plan's introduction the ways in which that plan (or study) helps proactively anticipate, plan for, and prepare to overcome challenges from climate change impacts. For specific planning efforts:
  - **Business contingency planning:** Update business contingency planning to account for climate risk as a business risk that includes the cost of inaction.
  - **Strategic planning:** Apply a climate lens to strategic planning by expanding Water Supply Goal 2: Sustain a Reliable, High Quality Water Supply for District Customers. This could

include using climate change risks to support prioritization and timing of strategic planning and initiatives. This could be developed as an additional metric.

- **Mission statement:** Communicate how the District's mission builds climate readiness. For example, "responsiveness" can be expanded to include an anticipatory and preventative focus for known climate risks. "Ethical actions" can support coordination that maintains services and opportunities for capital improvements in V/DCs. "Safe practices" can be understood to include safety from different climate hazards. "Environmental stewardship" can include the District's responsibility to sustainably that considers how practices contribute to, and help reduce adverse impacts of, climate change within the watershed.

- **Adopt a resolution to formalize priorities and align internal and external policy:** The District and its Board of Directors could also consider adopting a resolution that supports aligning with the priorities and potential collaboration activities of municipalities, Bay Area agencies, and state and regional agencies. This resolution could include a concise summary of potential actions.

External Policy and Planning

Recommendations to align with external policy and planning include:

- **City and county level:** The study recommends coordination with the cities of Fremont, Newark, and Union City for future updates for mapping and hazard data, and use of the same data sources and emergency planning approaches and protocols. This coordination includes sharing climate projections used for planning purposes and establishing potential triggers for collaborative action, such as specific SLR elevations. As city CAPs are updated, the study also recommends continuing discussions around integrating effective adaptation strategies and seeking funding partnership opportunities, as well as leveraging joint stakeholder engagement opportunities. These recommendations also hold true for Alameda County. The study recommends aligning the development of adaptation strategies with priority areas of the Alameda County Climate Action Plan for Government Services and Operations through 2020 update and the Community Climate Action Plan (Alameda County, 2010 and 2014).
- **Other Bay Area agencies:** Leverage opportunities to conduct regional adaptation strategy projects and continue regional partnerships and coordinate on use of same regional data. This is especially applicable to agencies that have already completed CAPs or CAP equivalents that focus on adaptation (e.g., East Bay Municipal Utility District, SFPUC, Santa Clara Valley Water District, Sonoma County Water Agency). Pursue development of joint adaptation strategies and projects collaborating on efforts for the Bay Area Integrated Regional Water Management Plan and BARR Drought Contingency Plan (see list Table 9-1 for recommended studies).
- **State level can be divvied up into several areas:**
  - **Sea Level Rise:** Leverage planning tools and guides to coordinate cross-jurisdictional projects for SLR adaptation and support environmental justice efforts when considering project benefits. Consider further development of District policy to align with principles and goals of the State Agency Sea Level Rise Action Plan for California 2022. This can include focusing policy on equity and nature-based solutions, using best available science, protecting coastal habitat, and pursuing partnerships.
  - **Climate and Resilience:** Develop planning and policy criteria that align with the Climate Adaptation Strategy's climate resilience priorities, corresponding goals, and actions (especially public health and safety, nature-based solutions, collaborative partnerships, and decision making using best available science). Leverage information on status and trends of California's water-dependent natural resources, climate science, and state supply planning

policies. Develop adaptation strategies that align with California Water Resilience Portfolio 2020 (Water Resilience Portfolio) options and opportunities.

- **Groundwater Sustainability:** Continue updates using the state-of-science, and leverage and expand on Department of Water Resources-provided tools and approaches (e.g., for Five-Year Periodic Evaluation updates to consider interannual variability). Pursue Sustainable Groundwater Management Grant Program funding opportunities for project implementation.
- **The Delta Plan:** Continue to engage with the Delta Adapts Initiative (Delta Adapts) project and the Delta Stewardship Council's regional SLR Adaptation Plan. Stay invested in research, planning, and policy updates, especially for the phase two Delta Adapts Adaptation Plan.

Recommended studies and strategies

This study recommends a range of further studies and strategies to address climate risk scenarios and help reduce impacts the District is likely to face from climate change. Additional modeling and analysis can address key data gaps, help better inform future emergency contingency plans, and support greater opportunities for watershed partnerships. Table E-8 provides recommendations based on the findings from this study. These include studies to help define change-in-condition trigger thresholds for high-risk climate change scenarios. These thresholds would need to be accompanied by a monitoring program to track changing conditions.

Recommended strategies that support addressing impacts from the high-risk climate risk scenarios are identified in Table E-9. The table includes the full list of applicable strategies that are anticipated to benefit the District by reducing potential impacts. These are listed with their corresponding strategy category (i.e., A-H) and number (e.g., A2: increasing long-term water use efficiency measures) This benefit is measured in the MCDA tool (Section 7.2) and is based on the strategies' estimated potential to reduce impacts across a set of consequence criteria.

For regulatory risks, the study recommends continued tracking of regulatory developments through:

- Partnerships **for knowledge sharing and regional planning.** This includes continuing to leverage participation in key partnerships and working groups, such as the California Urban Water Agencies and Delta Adapts. This is particularly relevant for improving and understanding development and timing of potential new legislation (e.g., expectations for new water use efficiency targets and when these will be enacted).
- **Alignment of planning priorities.** Aligning planning priorities with state and federal policy supports meeting requirements for emerging funding opportunities for climate resilience. Specifically, the District can align planning priorities with criteria and priorities identified in state and federal policy. The District can also document benefits of developed strategies and projects to clearly demonstrate this alignment. Areas of interest based on existing policy direction are anticipated to include a greater focus on equity and environmental stewardship as well as strengthening regional reliability.
- **State-of-science updates for key planning assumptions.** Pursuing regular updates with the evolving state-of-science supports best practices for staying current with changing conditions. This includes staying abreast of updated guidance and projections from State agencies. These regular updates help the District improve planning assumptions and technical analysis ahead of changing regulatory requirements. For example, this includes updating the District's modeling parameters, assumptions for the WRMP, and the CAP along the same timeframe as the release of the future updates for the San Francisco Bay Area California Climate Change Assessment regional report.

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Table ES-8. Recommended Studies to Address High-risk Climate Risk Scenarios			
Recommended Studies	Climate Risk Scenarios	Relevant Adaptation Strategies	Climate Impacts Reduced
Define change-in-condition trigger thresholds and develop monitoring program for increased evaporative losses of local surface water supplies and increased evapotranspiration in soils due to temperature rise	Scenario 1: Increasing Temperature Causing a Reduction in Local Supply	• F3: implement real-time weather monitoring and forecasting	Reduces potential loss in supply through better monitoring and planning of potential losses tracked over time
Conduct analysis to determine projected demand response to increase in temperature, and include in supply and demand analysis to determine at what demand threshold new supplies would be required (update and expand on current UWMP analysis beyond 2045)	Scenario 2: Increasing Temperature Causing an Increase in Demand	• A1: expanding short-term (i.e., dry year) conservation efforts • A2: increasing long-term water use efficiency measures • (threshold may also support strategies for expanded and new supply development, e.g., B1-4, D1-5)	Reduces potential difficulty in meeting demands beyond 2045 horizon, improves long-term water supply planning
Analyze specific reduced imported supply scenarios for single dry and multiple dry years, especially beyond the 2045 horizon, and consider a potential scenario that includes implementing the Voluntary Agreement (alternative to the Bay-Delta Plan) to understand range of changing conditions	Scenario 3: Increasing Drought Conditions Causing a Reduction in Imported Supply (SFPUC)	• B1: developing new local and regional supplies • B2: expanding existing local and regional supplies • B3: securing new imported (non-local) supplies • D1: implementing new or expanded surface storage	Minimizes reduction of overall supply due to reduced SFPUC supply (consideration of Voluntary Agreement implementation could also address reductions in SWP supply)
Conduct watershed-scale analysis to determine range of potential water quality impacts from wildfire for source water and runoff and determine potential thresholds (triggers)	Scenario 5: Increasing Wildfires Causing Non-saline Water Quality Degradation in Local Surface Water Supply	• F1: modeling climate impacts on surface water • G1: implementing green infrastructure and nature-based solutions • G2: investing in forest and vegetation management • H4: developing Alameda Creek Watershed partnerships	Study should produce understanding of erosion and sediment transport, increased nutrient loading, changes in source-water chemistry, and changes in runoff patterns; informs potential watershed-based partnerships and reduces risk at watershed-management level
Conduct analysis for emergent groundwater in coordination with San Francisco Regional Water Quality Control Board for existing contamination sites	Scenario 8: Sea Level Rise Causing Water Quality Changes in the Niles Cone Due to Non-saline Contamination	• D6: expanding monitoring and remote operations • F2: modeling climate impacts on groundwater • E1: mitigating or treating groundwater contamination	Study should provide indication of potential extent and location of contamination sites that could produce harmful water quality impacts when inundated and/or interacting with saltwater
Update SLR saline intrusion study to simulate the predicted mobility, time of travel, and extent/travel distance of chlorides into the Niles Cone to define potential thresholds for changes in water quality and triggers for changes in treatment (this will need to be done using the upgraded Integrated Water Flow Model)	Scenario 9: Sea Level Rise Causing Water Quality Changes in the Niles Cone Due to Saline Intrusion	• D6: expanding monitoring and remote operations • F2: modeling climate impacts on groundwater • G1: implementing green infrastructure and nature-based solutions • H1: developing San Francisco Bay shoreline partnerships	Study should produce data to improve understanding of change in water quality as saline intrusion increases over time
"Perfect storm" analysis to develop a design drought to characterize a credible climate-driven drought scenario considering all supplies, imported and local.	Scenario 10: Drought Resulting in Potential Reduced Augmented Groundwater Recharge to Niles Cone	• F1: modeling climate impacts on surface water • F2: modeling climate impacts on groundwater • F3: implement real-time weather monitoring and forecasting • (threshold may also support strategies for expanded and new supply development, e.g., B1-4, D1-5)	Study should provide range of potential supply-side impacts from a credible, worst-case scenario drought. The scenario should include simultaneous impact to imported and local supply to help limit impacts from future drought. This study should also flag which conditions provide a "catastrophic" drought with >20% supply reduction.
Coordinate and conduct an Alameda Creek Watershed boundary climate study in partnership with cities, Alameda County Flood Control & Water Conservation District, and Alameda Creek Watershed Forum	Many scenarios: Scenario 1 (increased temperature and reduced local supply), 5 (wildfire and water quality degradation), 8 and 9 (non-saline and saline contamination, respectively), 10 (drought and reduced augmented water recharge)	• F1: modeling climate impacts on surface water • F2: modeling climate impacts on groundwater • G1: implementing green infrastructure and nature-based solutions • H1: developing San Francisco Bay shoreline partnerships • H3: developing Bay Area and regional partnerships	Study should provide local- to regional-scale range of projected changes in temperature and precipitation, including a watershed-level stress test. This may also serve as a precursor study to help develop green infrastructure and nature-based solutions projects in partnership with city, county, NGO, and other agency entities.

Table ES-9. Recommended strategies to address high-risk climate risk scenarios from highest to lowest risk (long-term)		
Climate Risk Scenario	Recommended Adaptation Strategies	Benefits (based on consequence criteria impact reduction)
Scenario 15: Regulatory changes resulting in potential changes needed in operations, planning, and or policy	Partnerships (H1-H3), expand existing and develop new local/regional supplies (B1-B2), green infrastructure & nature-based solutions (G1), model climate change impacts on groundwater and surface water (F1-F2), treat/mitigate groundwater (E1), new/expand surface storage (D1), increase augmented groundwater recharge (D2)	Water quality, water supply, and environmental stewardship
Scenario 1: Increasing temperatures resulting in potential reduced local supply	Green infrastructure & nature-based solutions (G1), distribution system improvements (D5), Bay Area regional supply partnerships (H3), increasing augmented recharge/banking (D2-D3), short-term conservation and long-term water use efficiency (A1- A2), adjust dry-year operating rules (D4), expand existing and develop new local/regional and imported supplies (B1-B3), real-time weather monitoring (F3)	Supports a wide range of criteria (including water quality, water supply, facility reliability, and environmental stewardship)
Scenario 10: Drought resulting in potential reduced augmented groundwater recharge to Niles Cone	Bay Area regional supply partnerships (H3), green infrastructure & nature-based solutions (G1), expand existing and develop new local/regional supplies (B1-B2), increasing augmented recharge/banking (D2-D3), short-term conservation and long-term water use efficiency (A1- A2), model climate change impacts on groundwater and surface water (F1-F2), real-time weather monitoring (F3)	Water supply, facilities reliability, and environmental stewardship
Scenario 6: Increasing temperatures resulting in potential non-salinity water quality degradation in the Delta	Delta partnerships (H2), adjust or expand surface water treatment (E3), expand existing and develop new local/regional supplies (B1-B2)	Water quality, facilities reliability, supply, and environmental stewardship
Scenario 2: Increasing temperatures resulting in potential increased demand	Green infrastructure & nature-based solutions (G1), Bay Area regional supply partnerships (H3), short-term conservation and long-term water use efficiency (A1- A2), increasing augmented recharge/banking (D2-D3), distribution system improvements (D5)	Supports a wide range of criteria
Scenario 7: Flooding resulting in potential saline intrusion in the Delta	Expand existing and develop new local/regional supplies (B1-B2), Delta and Bay Area regional supply partnerships (H2, H3), new local and imported supply, modeling climate impacts on surface water (F1)	Water quality, facilities reliability, supply, and environmental stewardship
Scenario 8: SLR resulting in potential non-salinity groundwater contamination mobilization in Niles Cone	Green infrastructure & nature-based solutions (G1), SF Bay shoreline and Bay Area regional supply partnerships (H1, H3), increase groundwater storage banking (D3), new local and imported supply (B1, B3-B4), treat/mitigate groundwater (E1), model climate change impacts on groundwater (F2), expand monitoring and remote operations (D6)	Water quality, environmental stewardship, and water supply
Scenario 9: SLR resulting in potential saltwater intrusion in Niles Cone	SF Bay shoreline and Bay Area regional supply partnerships (H1, H3), green infrastructure & nature-based solutions (G1), treat/mitigate groundwater (E1), increasing augmented recharge/banking (D2-D3), expand existing and develop new local/regional and imported supplies (B1-B4), expand monitoring and remote operations (D6), short-term conservation and long-term water use efficiency (A1-A2), model climate change impacts on groundwater (F2)	Facilities reliability, water quality, environmental stewardship, supply
Scenario 5: Wildfire resulting in potential non-salinity water quality degradation in local surface water	Green infrastructure & nature-based solutions (G1), invest in forest/vegetation management (G2), modeling climate impacts on surface water (F1), expand monitoring and remote operations (D6), reservoir water quality management (E2), adjust or expand surface water treatment (E3), Alameda Creek Watershed partnership (H4)	Environmental stewardship, safety, financing, water quality
Scenario 3: Drought resulting in potential reduction of imported supply - SFPUC	Bay Area regional supply partnerships (H3), expand existing and develop new local/regional and imported supplies (B1-B3), treat/mitigate groundwater (E1), distribution system improvements (D5), increasing augmented recharge/banking (D2-D3), new/expand surface storage (D1), short-term conservation (A1), adjust dry-year operating rules (D4)	Water delivery, water quality, supply, and facilities reliability
Scenario 4: Drought resulting in potential reduction of imported supply - SWP	Delta and Bay Area regional supply partnerships (H2, H3), distribution system improvements (D5), new/expand surface storage (D1), expand existing and develop new local/regional and imported supplies (B1-B4), short-term conservation and long-term water use efficiency (A1-A2), increase augmented recharge (Niles Cone) (D2), adjust dry-year operating rules (D4)	Water quality, financing, supply, and environmental stewardship

Section 1

Introduction

The Alameda County Water District (District) has prepared this Climate Adaptation Plan (CAP) Phase 1 to better understand, plan for, and be prepared for the impacts of a changing climate. The District is taking a phased approach to first establish a baseline understanding of existing climate change risks and develop an initial direction for how to approach these risks (Phase 1). The District plans to leverage this Phase 1 understanding to pursue recommended studies and more in-depth analysis in future phases (e.g., developing and implementing adaptation strategies to address risks identified in Phase 1). By preparing a CAP, the District is responding to climate change and what it means for its operations and supply sources, and how these risks may impact the service area and District customers.

California is already experiencing climate change, and its effects are likely to increase over the coming decades (Bedsworth et al., 2018). California currently experiences floods, atmospheric rivers, droughts, wildfires, and hot temperatures and is projected to experience increasing sea levels and more intense storms. At the time of this CAP, the state is in its third driest year on record and the District is set to be in its driest 3-year period in its local history. In the coming decades, climate impacts across the state are likely to increase in severity and intensity, potentially worsening the risks posed to California's water systems and water resources. According to California's Fourth Climate Change Assessment (Bedsworth et al., 2018, pg. 56):

> "Available science indicates that there is a significant potential for frequent and severe water availability and water quality problems resulting from a combination of increased volatility in precipitation, continued reductions in snowpack, unsustainable use of groundwater, a tendency toward decreased soil moisture, and higher overall in-stream temperatures."

Understanding potential climate risk informs short-term and mid-term investments that support long-term cost recovery. According to the National Institute of Building Sciences' Natural Hazard Mitigation Saves 2017 Interim Report, every $1 invested in risk mitigation has the potential to save up to $6 in recovery (Multihazard Mitigation Council, 2017). The District recognizes the benefits of preparing for a more uncertain and potentially more costly future. Being fiscally responsible is an important part of how the District fulfills its mission and is supported through this CAP by establishing a better understanding of climate risks, potential impacts, and how to address or reduce these impacts as conditions change.[2]

The CAP provides a high-level assessment and understanding of the District's vulnerability to climate change and supports climate-risk-informed planning. The CAP provides direction for building resilience and a foundational understanding to use and expand on, and for engaging with stakeholders in ongoing, parallel, and future planning processes. One of these processes is the District's Water Resources Master Plan (WRMP), which is an update to the original 1995 Integrated Resources Plan (IRP). The WRMP will establish water supply management objectives and actions

[2] Greenhouse gas mitigation is outside the scope of this Phase 1 CAP, but an updated greenhouse gas inventory assessment and documentation of existing and future mitigation efforts are recommended for future planning phases. The Phase 1 CAP presents known and anticipated climate risks the District faces as a utility and potential strategies to reduce those risks.

that will be implemented over the next 30 years and includes a more rigorous stakeholder engagement process.

This CAP will help the District anticipate and reduce risks, get ahead of potential regulatory changes, leverage infrastructure updates, identify key future studies, and build partnerships. This approach further supports the District's alignment with local, regional, and state plans; supports sound investments; and supports funding applications.

The District's CAP Team developed the contents of this CAP in partnership with the Brown and Caldwell Team. These teams worked together to form the collaborative CAP Team. A glossary of definitions used by this team and in this document is provided in Appendix A.

1.1 Phase 1 Objectives and Priorities

The District identified four primary CAP objectives to guide Phase 1 outcomes, then developed a list of key priorities for achieving each objective. The combination of objectives and priorities described below were reviewed and discussed with the District's Board of Directors and the public during a public workshop on March 31, 2022.

Objective 1. Foster alignment across planning efforts, both internally and externally. Aligning both internally and externally with plans, policies, and initiatives helps the District better enable potential partnerships and strengthens the cohesiveness of internal District policy related to water resources management and emergency management under changing environmental conditions. Aligning with and getting ahead of regulatory drivers can improve partnerships and support potential future requirements. Key priorities include:

- Aligning District plans, policies, initiatives
- Aligning with relevant external plans, policies, and initiatives
- Understanding regulatory drivers and impacts

Objective 2. Identify and prioritize climate risks and vulnerabilities for the District's systems, ecosystems, and communities. Identifying and documenting high-level climate risks and vulnerabilities within this Phase 1 study forms a foundation for understanding impacts and prioritizing these risks. These include both physical and regulatory risks and impacts to the natural and built environment as well as people served. Mapping and identifying where risks may impact vulnerable and disadvantaged communities (V/DC) supports the District's role in collaborating with local and regional agencies to reduce adverse impacts of climate change for these communities. Key priorities include:

- Identifying relevant climate change risks and regulations
- Documenting anticipated impacts and adaptive capacity of District water supplies, infrastructure, and operations
- Identifying impacts to V/DC[3]

Objective 3. Prioritize actions for achieving climate readiness and fulfilling climate adaptation goals using best practices. Objective 3 priorities support creating near- and long-term actions with flexibility to adapt based on changing conditions. These actions will also include identifying gaps where further studies are needed. During the March workshop, the public stressed flexibility and consideration of equitable solutions. Along with providing a near- and long-term set of recommended

[3] Although the District is not the primary responsible agency for mitigating impacts to local communities, the District acts in a collaborative role with other agencies to support efforts to build community resilience.

actions, understanding what kind of potential funding opportunities exist helps support solution implementation. Key priorities include:

- Identifying a set of adaptation and resilience goals, policies, and best practices
- Prioritizing strategies for achieving climate readiness that have the flexibility to adapt
- Recommending near- and long-term actions, studies, and potential funding opportunities

Objective 4. Communicate findings in a transparent and accessible manner and identify future opportunities to engage with stakeholders and the public. Although the District is not responsible for land use management or urban planning, it plays a collaborative role in providing information and coordinating with local planning agencies, especially municipal organizations. During the March workshop, the public stated that this CAP process should communicate accountability and demonstrate responsibility toward future generations. Clear and transparent communication also supports the District's desire to work with neighboring and county entities (e.g., for shoreline projects) to more fully understand vulnerabilities and to implement solutions to reduce risk for local communities. Identifying opportunities for engagement can encourage cooperation regionally and within the District's service area and can support continued stakeholder participation in future climate adaptation planning phases and the District's WRMP public engagement process. Key priorities include:

- Communicating Phase 1 findings in a public-facing summary
- Identifying opportunities to solicit input from the public and other stakeholders

1.2 Collaboration and Continued Engagement

CAP development involved interdisciplinary participation across District teams, including the Water Resources Department (including Conservation, Groundwater Resources, and Water Supply and Planning), the Engineering Department, the Operations & Maintenance Department (including the Emergency Management team), and the Communications team. Leveraging an interdisciplinary team provides a greater understanding of potential impacts and facilitates opportunities for improved internal alignment on climate adaptation planning. Interdisciplinary collaboration supports climate adaptation as another component of risk management and encourages regular consultation with experts throughout the District. Interdisciplinary collaboration also supports improved connectivity between ongoing and upcoming planning processes, which is a leading practice emphasized in the Water Utility Climate Alliance (WUCA) 2021 Leading Practices in Climate Adaptation report.

As part of ongoing and future planning processes, the CAP provides a baseline understanding and direction for assessing climate risks that can be expanded upon and leveraged in a later phase, and in the continued efforts of the WRMP 2025 Update. It is anticipated that information provided within this Phase 1 study will support the WRMP stakeholder and advisory group engagement process.

To foster collaboration and greater opportunities for potential future partnerships, climate action and climate adaptation plans from the county level, local cities, and neighboring agencies were reviewed and considered when developing this Phase 1 study.[4] Results of this review are found in Section 3 of this CAP. Reviewing these planning efforts also included reviewing existing data and studies of entities such as the California Department of Water Resources (DWR), United States Geological Survey (USGS), the National Oceanic and Atmospheric Association (NOAA), the San Francisco Bay Conservation and Development Commission (BCDC), and SCRIPPS Institute of Oceanography, among others. This additional review supports a broader understanding of available data and other agencies

[4] This also reflects leading practices encouraged by WUCA to learn from earlier climate change planning efforts.

that may be beneficial to engage with in future collaborations to leverage the best state-of-science and practices.

1.3 CAP Approach

This CAP is based on industry-standard approaches, including the America's Water Works Association Manual 71 (AWWA, 2021), the U.S. Environmental Protection Agency CREAT tool, and the WUCA Leading Practices in Climate Adaptation report (2021), and a review of CAPs completed by other Bay Area agencies. Figure 1-1 provides an overview of the steps involved in developing the CAP and the goal for each step.

Steps	**1. Objectives and Priorities**	**2. District Policy Review and Alignment**	**3. Vulnerability Assessment**	**4. Risk Assessment**	**5. Recommendations for Adaptation Strategies**	**6. Adaptation Pathways and Recommended Studies**
Goals	Establish well-vetted direction for Phase 1 CAP study	Apply a climate change lens to improve District policy and identify alignment opportunities	Gain understanding of most relevant physical and regulatory vulnerabilities	Apply and expand policy and vulnerability assessment to understand most significant impacts and capacities	Identify, evaluate, and prioritize adaptation strategies	Create flexible roadmaps for an actionable, forward-looking CAP and provide suggestions for future studies

Figure 1-1.. Overview of the CAP steps and intended goals

These steps are reflected in the sections of this CAP. Each section builds on previous sections' content to provide a high-level but comprehensive understanding of climate risks, direction for future studies, and District next steps.

Section 2

District Service Area

The contents of a climate adaptation plan uniquely depend on the local and regional context, including the specific geography, the climate resilience history, and the service area's characteristics. To adequately plan for strategies that best serve the District, the existing conditions of the District's water supply system and the area's future climate projections must be well understood to identify existing vulnerabilities, risks and likelihood of these risks, and the gaps that need to be bridged to achieve greater climate resilience. This section outlines various attributes of the District's system, which helps build an understanding of the natural, physical, and built environments in which changing climatic conditions may occur. Section 3 documents previous policy and planning efforts to build climate resilience, and Section 4 identifies future climate projections for the area.

The District is located in the San Francisco Bay Area approximately 20 miles southeast of San Francisco. The San Francisco Bay delimits the service area on the west side, the hills of the Diablo Range on the east side, most of the City of Hayward to the north, and the Coyote Creek Slough to the south. On the west side, salt evaporation ponds and saltwater marshes cover approximately 35 square miles of the District's service area.

With a service area of approximately 105 square miles, the District provides retail water service to industrial, commercial, institutional, landscape, and residential users. Most of the water system's supply, approximately 69 percent, is directed to the estimated 345,000 residents in the cities of Newark, Union City, and Fremont. The average annual production is 37 million gallons per day (mgd) with a maximum day production of 55.66 million gallons (MG) in fiscal year 2017-2018. In addition to distribution system use, the District provides water for groundwater system use, which includes private groundwater pumping, the District's Aquifer Reclamation Program (ARP) pumping with 11 ARP wells, and groundwater recharge and storage to protect water quality.[5] Figure 2-1 shows the District's service area and major pipelines and facilities that are part of the water system.

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[5] According to the Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan) Chapter 2 Beneficial Uses, groundwater recharge as a beneficial use includes "[u]ses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting saltwater intrusion into freshwater aquifers" (Basin Plan, Section 2.1.7)

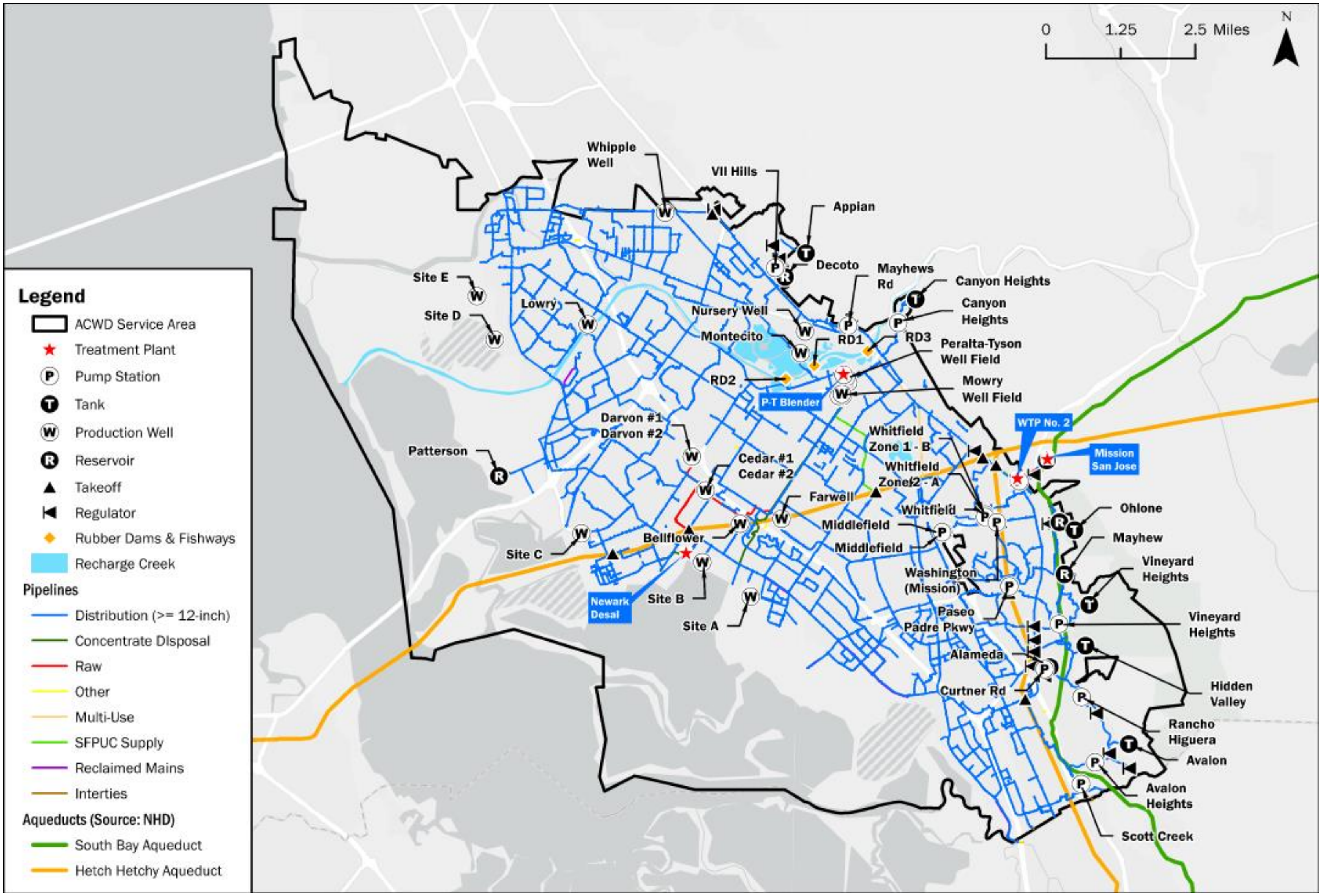

Figure 2-1. District service area system map

Source: National Hydrography Dataset (date accessed: 4/14/2022); District GIS data (date received: 3/8/2022)

Since its founding in 1914, the District has expanded its source water portfolio to include water supplies from three primary sources:

- Surface water from the State Water Project (SWP) via the South Bay Aqueduct (SBA) makes up 40 percent of supply.[6]
- Finished water from the San Francisco Public Utilities Commission (SFPUC) Regional Water System (RWS) via the Hetch Hetchy Aqueduct represents 20 percent of supply.[7]
- Local supplies make up 40 percent of supply from:
  - Fresh and brackish groundwater (recharged Alameda Creek water and Niles Cone Groundwater Basin [Niles Cone])
  - Surface water from Lake Del Valle Reservoir

The Niles Cone is primarily recharged from percolation of runoff from the Alameda Creek watershed. If Alameda Creek supplies are insufficient, a fraction of the District's SWP supplies are used for supplemental groundwater recharge. The District also diverts local runoff from the Alameda Creek Watershed using two inflatable dams. This runoff percolates into the groundwater basin via the Quarry Lakes groundwater recharge system. If local runoff is not available, water from Lake Del Valle Reservoir or SBA may be used for groundwater recharge.

Before distribution, the District provides water treatment at the following facilities:

- 12.5-mgd reverse osmosis groundwater plant for brackish water (Newark Desalination Facility) from the ARP wells
- 48-mgd groundwater and finished water blending facility for SFPUC's water with local fresh groundwater for distribution
- 26-mgd surface water treatment plant (Water Treatment Plant 2) that treats SBA water for distribution

The distribution system consists of:

- 13 reservoirs and tanks (for a combined 80 MG of storage)
- 15 pump stations
- 16 production wells
- 900 miles of pipe

As a safeguard against SWP supply deficits during dry years, the District also acquired water storage through participation in the Semitropic Groundwater Banking Program. Under this Semitropic Water Storage District program, the District has secured 150,000 acre-feet of groundwater storage capacity. In dry years, the District can use the banked supply, while in wet years the District delivers surplus SWP supplies to the Semitropic Water Storage District program for storage in the Semitropic Water Storage District groundwater basin.

While the District has a diverse water supply portfolio and has decreased dependence on imported water sources, climate change poses many uncertainties for future water supply availability, which may also vary depending on the supply source. Prolonged droughts and sea level rise (SLR) will impact water quantity with less water available and will impact water quality as saltwater intrusion and blue green algae growth may increase. The District has past experience successfully managing and recovering water supply availability and has already taken several steps to incorporate climate

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[6] This source originates from Northern Sierra runoff and snowpack.

[7] This source originates from Central Sierra runoff and snowpack.

change into its planning processes and criteria. The next section identifies District policy and the move toward defining climate readiness as a key District planning objective.

Section 3

Policy and Alignment Opportunities

The section defines what is meant by "climate readiness" and considers how to apply this definition to the District's planning policy[8] and practice. The CAP Team reviewed and analyzed existing and relevant anticipated plans and policy, including the District's existing mission, goals, and level of service (LoS).

This section also includes a review of external plans at the local, regional, and state levels to produce a list of alignment opportunities that encourage potential partnerships. Also included is a list of potential regulatory areas and their impacts to consider for future policy development. The goal of this section is to support an alignment of District policies under a common climate change lens, both internally and with current and foreseeable future regulations.

3.1 Defining Climate Readiness

The District strives to maintain a forward-thinking policy in its approach to climate readiness. This includes understanding and documenting potential climate-change-related impacts to water demand, water supply, and the District's service area. **To be "climate ready" as defined in this study means to proactively anticipate, plan for, and overcome challenges from climate change impacts.** This definition can be applied to the District in the following way:

- Policy: Guidelines that reflect consideration of climate change impacts, understanding climate risks, and encouraging opportunities to reduce those risks.
- Practice: Translating policy into practice means designing and implementing strategies, actions, and potential projects that address identified climate-change-related impacts. These especially include "low- to no-regret" actions that reduce adverse impacts and can provide sound long-term investments regardless of the severity of future changes.

3.2 Internal District Policies

Internal and external policies were selected for review based on their relevance for the CAP and the District's service area, operations, and communities served. CAP relevance was determined by whether the document considered or referred to climate change, changing conditions, and/or environmental extremes (critical dry-year planning, scenarios planning, etc.). Documents reviewed are identified on Figure 3-1.

Review findings were organized into several high-level categories: mission and strategic planning, integrated resources planning, groundwater planning, urban water management planning, and emergency management. Documents not included in this review analysis are the Engineering Report and the Clean Energy Initiative Study due to their limited relevant policy content; the latter especially given that this CAP is focused on adaptation and not greenhouse gas (GHG) mitigation.

[8] Policies in the CAP are defined as sets of rules, guidelines, or practices that support actions followed or generated by the District.

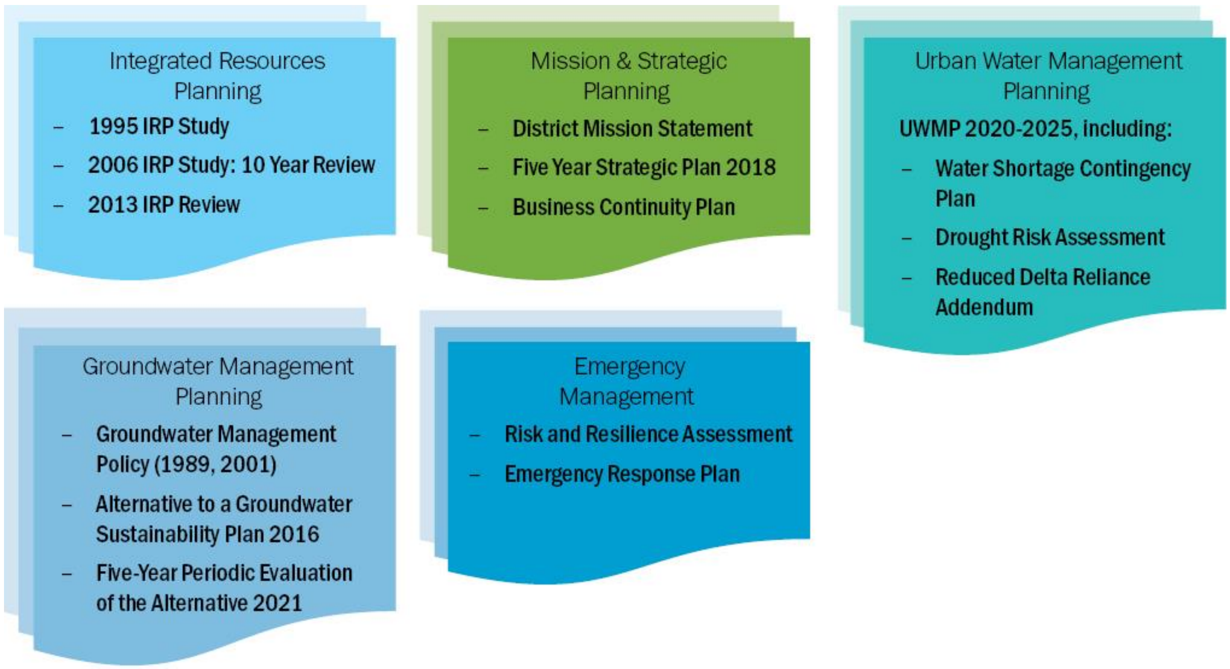

Figure 3-1. Areas of relevant planning and policy for climate readiness

A summary of how each of these documents support the District's progress to date in building climate readiness is provided on Figure 3-2.

Figure 3-2. Summary of progress to date for relevant policy and planning areas

More detailed elaboration for each of these areas is provided in subsections 3.2.1 through 3.2.5.

Brown AND Caldwell

3.2.1 Mission and Strategic Planning

The District's mission to provide a reliable supply of high-quality water at a reasonable price to customers indicates responsive service, ethical actions, safe practices, and responsibility for environmental stewardship as key to fulfilling this mission. The mission is reaffirmed in the District's Business Continuity Plan (ACWD 2020c) and in the 2018 Five Year Strategic Plan (Strategic Plan), and components originating from the mission statement such as cost, water supply reliability, and ethical practice (e.g., transparency in finance and communication) can be seen in the Strategic Plan's five strategic goals: cost-effectiveness and value, water supply, finance, workforce, and communication). Climate change is identified as one of the uncertainties for District planning to overcome within the Strategic Plan water supply goal.

The CAP has integrated the foundational direction provided by both the District's mission and strategic planning and has leveraged this along with policy content described later in this section to develop LoS categories and consequence criteria for the purpose of this study. These criteria refer to what services the District could try to maintain regardless of changing climatic conditions. Other content from strategic planning provided input on direction for potential adaptation strategies to help reduce climate risk impacts. Strategic Plan objectives include collaboration with partners for water stewardship (e.g., Alameda Creek Watershed Forum), coordination with local partners for regional reliability and resilience, and an emphasis on conservation (promoting the "Conservation as a California Way of Life" direction from the state level).

3.2.2 Integrated Resources Planning

In 1995, the District completed its first IRP, which analyzed long-term water needs, including future uncertainties, and assessed a variety of supply- and demand-side alternatives based on cost, reliability, water quality, environmental impacts, local control, and risk. Although the 1995 IRP was not explicitly a climate change adaptation plan, it identified uncertainties in future demand, supply availability (driven by climatic and legal/institutional conditions), and regulations as critical to the District's resource decisions (ACWD, 1995). As the impacts of climate change on California's water resources have become better understood over the past few decades, the District has more explicitly integrated climate change into its planning and decision making.

IRP-related documents, including the original 1995 IRP, the 2006 Integrated Resources Planning Study 10-Year Review (2006 IRP Review [ACWD, 2006]), published content in 2014 from the 2013 IRP Review, and 2019 workshops provide a range of key policy criteria and guidance related to District efforts toward climate readiness. The 1995 IRP was created out of the recognized need to enhance supply reliability, especially given uncertainty of imported supply availability. This original 1995 IRP provided policy criteria to guide planning, including cost, reliability,[9] water quality, environmental impacts, local control, and risk. It also clarified three primary water supply objectives: increase reliability, specifically the ability to meet customer demands consistently; maintain sustainable water levels in the Niles Cone; and maximize District control over water sources.

The 2006 IRP Review considered the status of meeting these objectives and included recommendations such as regular re-evaluation of key planning assumptions for the IRP and confirming the ability to meet goals. Several other recommendations included continuing to investigate new supply opportunities that are cost effective and reliable, continued use of demand management strategies, options for improved facility planning, and operations optimization (especially for use of Semitropic and local groundwater storage). The review also suggested investigating opportunities for supplemental supplies under critically dry year scenarios and

[9] Reliability policy criteria in the 1995 IRP specifies acceptable shortage during drought conditions as not greater than 10% of annual demand in 1 in 30 years.

suggested that an increase in demand during dry scenarios (extended drought conditions) is anticipated to further draw down groundwater levels, potentially to sea level conditions. Recommendations also included evaluating a catastrophic loss of supply scenario in which SWP supplies would be lost due to levee failures, and recommended consideration of loss of SFPUC RWS supply. These recommendations and suggestions were considered in the development of different climate risk scenarios (Section 4) and during the development of potential adaptation strategies for the CAP (Section 7).

Discussions and documentation based on the 2013 IRP Review describe climate change as both an opportunity and a challenge for water resources planning and define climate change adaptation planning as “[t]he process of developing strategies for responding to the potential effects of climate change, including sea level rise, changes in local precipitation, and changes in the availability of imported water” (ACWD 2014, p. 32). The 2013 IRP Review states that the District will begin developing a climate change adaptation plan, which supports the development of this Phase 1 CAP. Several climate risks are described as challenges in the 2013 IRP Review and are provided in Table 3-1. These were considered in identifying different scenarios and in cataloguing potential impacts for the CAP vulnerability assessment (Section 5).

Table 3-1. Climate Risks Identified in 2013 IRP Review

Climate Risk	Risk Event and Potential Impacts
Higher temperatures	Increase local landscaping water demands
Changes in local precipitation patterns	Reduce groundwater recharge
Smaller Sierra Nevada snowpack	Reduce the availability of imported supplies
Sea level rise	Reduce the effective storage capacity of the Niles Cone

In its 2014 document the District recognizes that the magnitude of impacts is highly uncertain and that it will follow a “low- to no-regret” approach when identifying strategies and actions to address climate change impacts, especially those that improve reliability and reduce operating costs. Examples for these kinds of approaches include investments to first reduce hot weather water demands (e.g., from cooling towers and outdoor irrigation), and then to subsequently consider alternatives to new storage. Low- to no-regret approaches support the highlighted objective that the District prepare “to adapt to change and provide reliable water in the future, while optimizing operations and containing costs today” (ACWD 2014, p. 31). Additionally, goals for the IRP process included minimizing cost, improving water quality, and mitigating environmental impacts, which are not directly related to supply and demand.

In 2019, the District’s Board considered climate readiness as a new objective and discussed potential updates to current planning criteria of cost, reliability, water quality, local control, environmental impact, and low risk. Discussions also highlighted pursuing and continuing current regional partnerships, emphasized cost considerations, and considered uncertainties, such as future water use efficiency targets, changes to the Bay-Delta Plan, and potential development of the Delta Conveyance Project. Many of these uncertainties were considered as part of the climate-related regulatory risks within the CAP. The District further considered how to leverage existing planning policies, including potentially changing the reliability LoS goal, potentially cycling a lower level of groundwater during critical droughts, and potentially considering further conservation, all of which were considered within the CAP adaptation strategies content (Section 7).

3.2.3 Groundwater Management Planning

Although the ability of local supply models to account for climate change is currently limited, the District is working to develop new tools to better capture the projected impacts of climate change on the Niles Cone. Additionally, the District diligently manages the groundwater basin to protect and improve water supply for all users and the environment. While the District's resilience planning dates back to their development as an agency, projects beginning in the 1970s, such as the Salinity Barrier Program (now wholly replaced by ARP, mark the development of programs to protect groundwater resources from climate change risks, such as rising sea levels and seawater intrusion. Since the 1980s, the District's Groundwater Management Policy has guided how the District maintains a resilient and reliable water supply using eight groundwater management programs. The following four programs were especially considered when developing this CAP to understand current direction and potential climate change adaptive capacity for the District's groundwater management activities and opportunities for potential adaptation strategies:

- Groundwater Replenishment Program – optimizes runoff capture, replaces water extracted, and maintains groundwater levels to prevent seawater intrusion
- Aquifer Reclamation Program – pumps brackish water from aquifer, manages seawater intrusion
- Watershed Protection and Monitoring – helps protect the watershed against increased sediment loads
- Groundwater Protection Program – helps regulatory agencies identify potential groundwater contamination

The District's Groundwater Management Policy also serves as a baseline for the District's many projects, groundwater-focused reporting, and the most recent Five-Year Periodic Evaluation of the Alternative 2021 (Alternative Update) (ACWD, 2021c). The Alternative Update includes the Niles East Bay Integrated Model (NEBIM), which integrates DWR-provided change factors for estimating future climate conditions for four what-if scenarios. These included an estimated 2030 conditions scenario and a typical, dry, and wet scenario for 2070. The four scenarios were compared against a 2070 baseline scenario and included stressors such as pumping, artificial recharge, and SLR. Results from the scenario analysis indicated that the region may become slightly wetter on average based on near-term climate change scaling factors. This could increase local water supply; however, there may be a high degree of uncertainty in using the output of these models to predict future conditions given the complexity of predicting future weather patterns at a large scale. This finding and caveat is also stated in the District's Urban Water Management Plan (UWMP) (ACWD, 2021a).

The scenarios in the Alternative Update also included SLR boundary conditions based on "high" emission scenario values and the medium-high risk-aversion level from the California Natural Resources Agency and California Ocean Protection Council guidance. An SLR of 0.8 feet for 2030 and 3.5 feet for the 2070 scenarios was used based on this guidance. Findings indicated no breach of undesirable results for the Niles Cone. However, under the 2070 dry scenario, groundwater levels are simulated using the NEBIM to dip below the -5 feet operating condition for a very brief period in 1935 over the 82-year historical period. This model provided an indication of future climate change impacts based on DWR change factors within these scenarios. For further analysis and understanding of potential climate change conditions, the Alternative Update also refers to the analysis and guidance provided in the District's UWMP.

3.2.4 Urban Water Management Planning

The District's UWMP guides water resources planning for the 2045 planning horizon. It includes the Water Shortage Contingency Plan (WSCP) and preliminary work on the District's climate risk assessment. This preliminary work includes initial considerations for adaptation planning, a summary of climate change inclusion in the UWMP, and a summary of potential future factors (including climate change) that may influence District water supply reliability, and planning criteria (reliability, water quality, environmental impacts, and local control). In the 2020 UWMP Update, the District's demand forecast assumes that higher temperatures will lead to increases in weather-dependent demand. The demand forecast makes use of the SWP reliability data (provided by DWR) and applies annual climate change factors to adjust past planning hydrology. However, DWR's approach for the SWP does not capture potential changes in inter-annual weather patterns, such as more frequent or longer-duration droughts (ACWD, 2021).

The WSCP includes scenarios for water supply shortages of up to and greater than 50 percent and details generalized actions the District would take in an actual emergency under various degrees of severity. This includes setting voluntary/mandatory water use reduction targets in extreme dry periods. The District uses the Niles Cone to indicate the health of the integrated water system and to manage its water supplies to maintain target aquifer levels because the level of shortage corresponds loosely to groundwater levels. The UWMP also includes a Drought Risk Assessment that evaluates the District's water supply reliability under severe drought conditions that last for 5 consecutive years. Dry periods tend to increase demands because low rainfall and higher temperatures result in increased evapotranspiration; approximately 35 percent of the District's water demand comes from landscape irrigation.

The UWMP identifies a list of general climate change impacts and adaptation planning considerations that were reviewed when preparing this CAP. These impacts include potential future climate-change-related factors influencing water supply reliability on the District's imported and local supplies as follows:

- SLR causing risk of failure, saltwater intrusion, and/or loss of supply for the Delta: consider alternative conveyance opportunities
- SLR influencing saltwater intrusion into Niles Cone: consider revising groundwater operating rules, evaluating ARP wells to mitigate salt intrusion, and increasing Above-Hayward Fault (AHF) aquifer levels to 50 feet
- Reduced snowpack reducing imported supply reliability: consider storage and supply options for dry and critically dry year shortfall
- Warmer weather increasing demand: focus on conservation programs to reduce weather-dependent demand
- Longer droughts increasing shortage: consider enhancing demand management, storage, and potential Niles Cone re-operation
- Water quality concerns impacting Quarry Lakes management: consider nutrient management programs, aeration, and algal harvesting

The UWMP also includes an appendix for "Alameda County Water District's Reduced Delta Reliance Reporting." This reporting allows agencies to document consistency with Delta Plan Policy WR P1 to "Reduce Reliance on the Delta Through Improved Regional Water Reliance" and relates to the following concerns from climate change: SLR; water quality; timing, frequency, and magnitude for runoff surplus; potential regulatory uncertainties; and legal challenges that may impact SWP supplies.

Potential opportunities to support long-term planning include minimizing dependency on imported supplies by maximizing use of local water supplies (local groundwater and surface water, brackish groundwater desalination, and recycled water), increasing dry year reserves, and potential expansion of the demand management program. Additional potential mitigation measures include re-operation of local and other storage available to the District, non-SWP water storage options such as Los

Vaqueros Reservoir Expansion, and alternative dry year supply programs. The UWMP communicates benefits of some of these options. Desalination facility benefits include improved dry year water supply reliability, improved water system reliability and security, increased water production capacity, improved water quality, reduced future reliance on imported supplies, groundwater basin protection, and reclamation. Benefits of indirect potable reuse could create a greater volume of usable supply that is drought-proof, locally controlled, and without restricted uses.

The UWMP also describes the District's Water Use Efficiency Master Plan (WEMP) that identifies strategies to meet both short- and long-term water use efficiency goals and potential state requirements (ACWD, 2021b). The WEMP analysis supports the new WRMP, which will evaluate water use efficiency measures at the same level of detail as other supply-side options. District water use efficiency measures include water waste prevention, metering with commodity rates, retail conservation pricing, water loss control, water use efficiency rebate and incentive programs, a direct install program for income-qualified customers, and public outreach. Potential new measures planned for implementation include residential outdoor water surveys, leak repair and emergency plumbing assistance, advanced metering infrastructure, and fixture retrofit, and adding new technology and increasing targets.

3.2.5 Emergency Management Planning

The District's Risk and Resilience Assessment (RRA) evaluates critical assets for a full system assessment and the identifies the system's vulnerability to specific hazards (ACWD, 2020a), while the Emergency Response Plan (ERP) details emergency management procedures, resources, and potential risk mitigation measures (ACWD, 2020b). These documents are confidential but were reviewed as part of the key documentation to understand critical system components and already-identified areas of higher risk within the District's service area.

3.3 Internal District Policy Alignment Opportunities

Common themes emerged within the review and analysis of internal District policy. These themes influenced LoS development created for this CAP and helped determine the selection of consequence criteria (Section 6). Themes included common terms central to the foundation of District policy, including:

- Continued and robust water supply reliability
- Water quality
- Local control
- Environmental stewardship (including watershed management planning)
- Safe practices
- Reasonable cost

As a result of the internal review and analysis, recommended actions for aligning internal District policy and planning for climate readiness included:

- **Update criteria and refine planning priorities:** This applies especially to efforts surrounding equity and environmental stewardship. Establishing a consistent set of planning criteria and priorities for reducing climate risk will provide a transparent accounting of how the District selects future projects and tracks progress over time to achieve planning goals.
- **Develop internal goals to enhance understanding of SLR impact:** This includes elucidating goals to identify and engage in studies to remedy potential SLR impact knowledge gaps. Activities that may help support potential studies include partnerships with neighboring groundwater

sustainability agencies; the cities of Fremont, Newark, and Union City; Alameda County; and entities such as the BCDC and the San Francisco Estuary Institute.

- **Expand on the original 1995 IRP uncertainty scenarios:** This includes updating the assumptions used in the previous three uncertainty scenarios for a best-, middle-, and worst-case future scenario that considered level of development for demand forecast, potential changes in imported supply deliveries, and treatment plant capacity. Assumptions could be updated to include a revised understanding of each original parameter (demand, imported supply reductions, and treatment capacity) that includes impacts of climate change (e.g., increased demand potential, reduced imported supply, and potential changes in treatment depending on impacts to source water quality).
- **Translate existing resilience and sustainability actions into adaptation strategies:** Although the CAP begins to address this recommendation, this can become a standard protocol for current pending and future projects. This is especially relevant for identifying those projects and actions that may be identified as "low- to no-regret" strategies.
- **Apply a common definition of "climate readiness" across planning efforts:** For all future planning efforts, communicate and enumerate directly within the introduction of the plan the ways in which this plan or study helps to proactively anticipate, plan for, and prepare to overcome challenges from climate change impacts. For specific planning efforts:
  - **Business contingency planning:** Update business contingency planning to include accounting for climate risk as a business risk. This would include estimating impacts for the cost of inaction.
  - **Strategic planning:** Apply climate lens to strategic planning by expanding on Water Supply Goal 2 to use climate change risks to support prioritization and timing of strategic planning and initiatives. This could be developed as an additional metric.
  - **Mission:** Communicate how the District's mission supports climate readiness. For example, "responsiveness" can be expanded to include an anticipatory and preventative focus for known climate risks. Where possible, "ethical actions" can support coordination to maintain services and opportunities for capital improvements for V/DCs within the service area. "Safe practices" can be understood to include safety from different potential climate hazards. "Environmental stewardship" can include the District's responsibility to consider how practices contribute to or reduce adverse impacts of climate change within the watershed.
- **Adopt a resolution to formalize priorities and align internal and external policy:** The District and its Board of Directors could also consider adopting a resolution. This resolution could communicate alignment with the priorities and collaboration activities identified by cities, the county, other Bay Area agencies, and state and regional agencies (see subsection 3.4). This resolution could include a concise summary of potential actions.

3.4 External Policies

The District has the opportunity to align not only with state priorities and planning but with priorities and planning of regional cities and Alameda County.

3.4.1 City and County Policy

External plans and policies reviewed included climate action plans and climate adaptation plans, as well as hazard mitigation plans (HMP) from cities within the District's service area, Alameda County, and other Bay Area agencies. Key partnerships, such as the Bay Area Regional Reliability (BARR) Partnership, Delta Stewardship Council, and the Alameda Creek Watershed Forum were also considered for identifying potential alignment opportunities. Alignment opportunities are summarized in Table 3-2 and described in subsequent text.

Table 3-2. External Plans and Policies Reviewed (Local and Regional Summary)

Local & Regional Focus	Reviewed Plans and Policies	Alignment Opportunities to Support Climate Readiness
Cities	• City of Fremont 2016-2021 Local Hazard Mitigation Plan • City of Fremont Climate Action Plan (2012 and update process) • City of Newark Climate Action Plan (2010) • Union City Climate Action Plan (2010)	• Coordinate with future updates for mapping and hazard data • Coordinate use of same data sources and emergency planning approaches and protocols • As CAPs are updated, continue discussions for integrating effective adaptation strategies and seek funding partnership opportunities • Coordinate with and leverage joint stakeholder engagement opportunities
County	• Alameda County Climate Action Plan for Government Services and Operations through 2020 • Alameda County (Unincorporated Areas) Community Climate Action Plan 2014 (General Plan Element) • Union City/Newark Multi-Jurisdiction Hazard Mitigation Plan	• Align development of adaptation strategies with priority areas of Alameda County Climate Action Plans (including the CAP for Government Services and Operations through 2020 update and the Community Climate Action Plan) and seek funding partnership opportunities • Coordinate with and leverage joint stakeholder engagement opportunities • (Similar to city HMPs) Coordination with future updates for mapping and hazard data, and on use of same data sources, emergency planning approaches, and protocols
Other Bay Area Agencies	• Valley Water Climate Change Action Plan • EBMUD Wastewater Climate Change Plan • Sonoma Water Climate Adaptation Plan	• Leverage opportunities to conduct regional adaptation strategy projects and continued partnerships • Coordinate on use of the same regional data
Partnerships	• BARR Partnership • Delta Stewardship Council • Alameda Creek Watershed Forum	• Leverage partnerships to support more flexible regional operations, available storage, and supply reliability for times of scarcity and extreme events • Pursue opportunities for watershed-scale management and improvement, shoreline protection projects, and coordination of coastal land use planning

Cities of Fremont, Newark, and Union City: Coordination opportunities exist with future updates to hot-spot mapping and hazard data, especially encouraging the use of the same data sources and emergency planning approaches and protocols. As climate action plans and CAPs are updated, discussions between these cities and the District should focus on integrating effective adaptation strategies, seeking joint funding opportunities, and coordinating and leveraging joint stakeholder engagement opportunities.

County and Multi-jurisdictional Level: There are opportunities to align with adaptation strategy development, e.g., with priority areas identified in the Alameda County Climate Action Plan for Government Services and Operations through 2020 update[10] and the Community Climate Action Plan, as well as opportunities to seek funding partnerships and coordinate with and leverage stakeholder engagement activities. Similar to the cities, additional coordination and use of common data with future planning updates (e.g., with hot-spot mapping and hazard data) and the use of

[10] This update is anticipated for 2023.

similar emergency planning approaches and protocols may provide further benefits and enable shared use of resources, especially when preparing for and responding to extreme events.

Other Bay Area agencies and partnership opportunities: Leveraging existing partnerships to support more flexible regional operations, available storage, and supply reliability for times of scarcity and extreme events creates opportunities. This is especially relevant for watershed-scale management and improvements, shoreline protection projects, and coastal land use planning coordination. The District has the opportunity to align with regional efforts on SLR impacts on the Bay shoreline, flooding in low-lying neighborhoods, and water quality impacts for beneficial uses.

Climate action plans and climate adaptation plans from other Bay Area agencies include lists of potential adaptation strategies, priorities, and projects. There are opportunities to leverage this information to conduct regional adaptation projects and strengthen continued partnerships, and coordinate use of the same regional data, especially for any coastal projects.

The District can also align with regional priorities and planning through the Alameda Creek Watershed Alliance and regional water supply reliability collaboration, such as through the Bay Area Integrated Regional Water Management Plan (IRWMP). The IRWMP offers regional-scale alignment and funding opportunities for projects that improve water supply reliability, protect water quality, manage flood protection, maintain public health standards, protect habitat and watershed resources, and enhance the overall health of the San Francisco Bay. The goals of the IRWMP are to provide a valuable venue for regional collaboration across agencies, improve responsiveness to regional needs and priorities, help effectively integrate water resources management activities, and serve as a platform to secure state and federal funding.

A growing number of Bay Area local governments, regional agencies, non-profits, and private-sector stakeholders are taking actions that advance climate adaptation and resilience. These actions include conducting comprehensive vulnerability assessments, planning infrastructure improvements, developing new governance structures, and implementing on-the-ground projects to address SLR, drought, and other climate impacts. San Mateo County’s resilience group and Marin County are leading the Bay Area in climate change adaptation; staying connected to their ongoing research and projects could be fruitful for discovering lessons learned in the Bay Area. Additionally, connecting with other Bay Area water utilities offers an opportunity to learn from peers what has worked well, determine how best to engage with stakeholders and the community, identify the best available science for the Bay Area, and address local challenges. Utilities such as Sonoma County Water Agency (Sonoma Water), Santa Clara Valley Water District (Valley Water), East Bay Municipal Utility District (EBMUD), and SFPUC that have completed climate-change-focused plans could make great partners for collaborating, leading, and better defining and understanding the Bay Area’s unique climate change challenges.

Groups that are actively working on climate change in the Bay Area and that could offer further opportunities for alignment are:

- Advancing to Rising Tides (ART)
- Bay Adapt, BCDC’s regional SLR adaptation strategy
- Bay Area Climate Adaptation Network (i.e., BayCAN)
- The BARR Project
- Bay Area Regional Health Inequities Initiative (i.e., BARHII)
- San Francisco Climate & Health Profile
- San Francisco Bay Regional Coastal Hazards Adaptation Resiliency Group (i.e., CHARG)
- RISeR SF Bay

- Marin County C-SMART
- San Mateo County OneShoreline/Flood and SLR Resiliency District
- Resilient by Design: Bay Area Challenge
- Sonoma County Regional Climate Authority
- Climate Ready North Bay
- The San Francisco Bay Restoration Authority
- State policy (see relevant plans and agencies in Table 3-3 and subsequent text)

External policy and planning review also included policies at state and regional levels. Areas of state- and regional-level policy included SLR guidance, state-level climate and resilience strategies and assessments, and sustainable groundwater management and policy around Bay Delta Region management. Alignment opportunities are summarized in Table 3-3 and elaborated on in subsequent text.

Table 3-3. External Plans and Policies Reviewed (State-level Summary)

Planning and Policy Area	Reviewed Plans and Policies	Alignment Opportunities to Support Climate Readiness
Sea Level Rise	• Critical Infrastructure at Risk: Sea Level Rise Planning Guidance for California's Coastal Zone • Sea Level Rise Guidance 2018 Update • State Agency Sea Level Rise Action Plan for California 2022 (2022 Action Plan)	• Leverage planning tools in planning guides to coordinate cross-jurisdictional projects for sea level rise adaptation and support for environmental justice when considering project benefits • Consider further development of District policy to align with the seven principles and six goals of the State Agency Sea Level Rise Action Plan for California 2022 (focal points include equity, nature-based solutions, best available science, protecting coastal habitat, pursuing partnerships)
Climate & Resilience	• California Climate Adaptation Strategy 2021 • State of California's Fourth Climate Change Assessment San Francisco Bay Area Region Report • California Water Resilience Portfolio 2020 (Water Resilience Portfolio) • California's Water Supply Strategy 2022	• Develop planning and policy criteria that align with Climate Adaptation Strategy's climate resilience priorities, corresponding goals, and actions (especially public health and safety, nature-based solutions, collaborative partnerships, and decision making using best available science) • Leverage information on status and trends of California's water-dependent natural resources, climate science, and state supply planning policies • Develop adaptation strategies that align with a range of options in the Water Resilience Portfolio
Sustainable Groundwater Management Act	• 2014 Sustainable Groundwater Management Act (and DWR Guidelines)	• Continue updates with state-of-science leveraging and expanding upon DWR-provided tools and approaches, especially for Five-Year Periodic Evaluation updates • Pursue Sustainable Groundwater Management Grant Program funding opportunities for project implementation
The Delta	• The Delta Plan • Delta Adapts Initiative (Delta Adapts): Creating a Climate Resilient Future (current state)	• Continue to engage with the Delta Adapts project and the Delta Stewardship Council's regional sea level rise adaptation plan, and stay invested in research, planning, and policy updates

Sea Level Rise: The review considered the state SLR Guidance (the 2018 Update and Coastal Zone Guidance as well as the recent State Agency SLR Action Plan for California 2022 [2022 Action Plan]). The review identified opportunities to leverage planning tools provided in existing SLR planning guides, to coordinate cross-jurisdictional projects for SLR adaptation, and to support environmental justice when considering project benefits. There is also opportunity to further develop District policy to align with the 2022 Action Plan's seven principles and six goals. These principles and goals provide guidance on how to coordinate a roadmap for how California will address SLR over the next 5 years. Focal points include equity, nature-based solutions, best available science, protect coastal habitat, and pursuing partnerships.

Opportunities for the District to align with this policy include supporting the seven principles and six goals and adopting SLR adaptation plans (including considerations in the Local Coastal Program), Local Hazard Mitigation Plans (LHMP), and General Plans.

The Critical Infrastructure at Risk Sea Level Rise Planning Guidance for California's Coastal Zone (Nov. 2021), governed by the California Coastal Commission, aims to promote resilient coastal infrastructure and protect coastal resources by providing local governments, asset managers, and other stakeholders with policy and planning information to help inform SLR adaptation decisions that are consistent with the California Coastal Act. Opportunities for the District to align with this policy include cross-jurisdictional efforts to implement a SLR adaptation plan, and especially efforts to address the disproportionate burdens and benefits to both California Tribes and environmental justice communities through meaningful consultation and engagement practices. This could include consideration of phased, trigger-based solutions for adaptation.

Climate and Resilience: The review considered the California Climate Adaptation Strategy 2021, the California Climate Change Assessment San Francisco Bay Area Region Report, California Water Resilience Portfolio 2020 (Water Resilience Portfolio), and the California Water Supply Strategy 2022. The California Climate Adaptation Strategy (2022), mandated by Assembly Bill 1482, links the state's existing and planned climate adaptation efforts, and demonstrates how they fit together to achieve California's six climate resilience priorities. The six priorities laid out in this strategy are 1) strengthen protections for climate-vulnerable communities, 2) bolster public health and safety to protect against increasing climate risks, 3) build a climate-resilient economy, 4) accelerate nature-based climate solutions and strengthen climate resilience of natural systems, 5) make decisions based on the best available climate science, and 6) partner and collaborate to leverage resources.

Alignment opportunities are found in developing criteria that align with the California Climate Adaptation Strategy's six climate resilience priorities, corresponding goals, and actions (especially public health and safety, nature-based solutions, collaborative partnerships, and decision making using best available science). Further opportunities are found in developing potential adaptation strategies that align with a range of suggested activities and desired goals in the Water Resilience Portfolio and the California Water Supply Strategy 2022.

The State of California's Fourth Climate Change Assessment San Francisco Bay Area Region Report summarizes current climate change science for the State of California and for the Bay Area. Opportunities for the District to align with this state research are found in forming connections with the local Bay Area researchers and groups who put together this research (e.g., Lawrence Berkeley National Laboratory, USGS, University of California Berkeley, and the Bay Area Regional Collaborative) to stay on top of the best new available science for climate change in the Bay Area. Additional opportunities include leveraging information on status and trends of California's water-dependent natural resources, climate science, and state supply planning policies in the regional reporting and climate assessment updates.

The California Water Plan is DWR's strategic plan for sustainably managing and developing water resources for current and future generations. Required by Water Code Section 10005(a), it presents the status and trends of California's water-dependent natural resources; water supplies; and agricultural, urban, and environmental water demands for a range of plausible future scenarios.

Opportunities for the District to align with this plan include working with DWR's Climate Change Program, including local and regional support staff, and DWR's Watershed Resilience Initiative, which fosters regional collaboration through its Watershed Networks and provides state support for local agencies to conduct vulnerability assessments and adaptation plans.

Sustainable Groundwater Management Act (SGMA) and the Delta (regulatory focus): Other areas overlapping with regulatory components include state-level sustainable groundwater management policy and management of the Bay Delta Region. Opportunities for alignment in these areas include the SGMA and the Bay Delta Water Quality Control Plan. Both are further discussed in the next subsection.

3.5 Regulatory Review

Reviewing policy for regulatory components enabled documentation of climate-related regulatory uncertainties and risks (Table 3-4). These complement the physical risks and are included in the overall vulnerability and risk assessment steps of this CAP.

Table 3-4. Regulatory Uncertainties and Risks

Regulatory Area	Potential Change and Impact
Sustainable Groundwater Management Act	• Potential change: Require more rigorous climate change analysis in Five-Year Periodic Evaluation updates • Impact: May need more staff time and/or change in approach (e.g., applying new data/models)
Urban Water Management Planning	• Potential change: Requirement to assess supply reliability on a longer planning horizon and/or demonstrate compliance with new water use efficiency targets • Impact: May need more staff time to develop UWMP planning documents and demand management strategies for compliance
Endangered Species Act	• Potential change: Requirements that constrain Delta pumping and may mandate additional upstream reservoir releases; require protection for more species • Impacts: Limitations on SWP and SFPUC RWS supply; potential restrictions on groundwater recharge operations
Bay Delta Water Quality Control Plan (Bay-Delta Plan)	• Potential change: New in-stream flow requirements for Delta tributaries • Impact: Reduced storage and dry year supply reliability for SWP and SFPUC RWS supplies
State Water Project Contract Amendments	• Potential change: Amendment to SWP contract impacting Table A allocation (Table A allocations are based on State Water Contractors contracts and the allocation is proportional to a contractor's ownership share). • Impact: Reduced water supply
Conservation Legislation	• Potential change: Implementation of long-term water use efficiency standards; potential short-term emergency conservation legislation • Impact: Greater efforts for demand management and conservation

With the acceleration of especially state-level guidance, regulations, policies, and funding for climate resilience and efforts to improve datasets (e.g., within Cal-Adapt), it is assumed within this study that regulatory changes may occur within mid- (2050) and especially within long-term (2100) planning horizons. These changes and their potential impacts to the District are identified below.

SGMA: With potential updates to this act, alignment opportunities include future updates with the current state-of-science that leverage and expand on DWR-provided tools and approaches. This is especially the case for Five-Year Periodic Evaluations and potential funding opportunities for Sustainable Groundwater Management Grant Program project implementation.

SGMA provides statewide guidance and regulations for maintaining a sustainable yield for groundwater resources. DWR has provided guidelines for considering climate change impacts, including a methodology (via best management practices) for applying specific climate change factors for specific planning horizons. This includes considering extreme future conditions for 2070. It is plausible to assume that these methodologies will be refined from the original 2018 guidance and may include additional requirements (e.g., additional planning horizons, new parameters or different general circulation model [GCM] ensembles for climate data, and improvements to spatial downscaling).

If SGMA is revised to require more-rigorous climate change analysis (e.g., the data and methods described in the DWR Guidance Document are no longer optional and/or are replaced with additional requirements), this revision would require more staff time (i.e., more full-time employees) and a change in approach to climate change factors within Five-Year Periodic Evaluation updates.

Urban Water Management Planning: UWMP requirements could change in response to climate change pressures. For example, the current 20-year planning horizon for supply reliability might be expanded over a longer timeframe to account for potential mid- or long-term impacts of climate change; similarly, demand management targets might be updated with new, stricter per capita urban water consumption targets as a result of climate-stressed state water supplies. These changes could result in more staff time (i.e., more full-time employees) and potentially greater efforts for demand management and conservation.

Conservation Legislation ("Making Conservation a Way of Life"): Changes to conservation-related regulations may impact UWMP efforts. Trends in current state-level conservation policy and regulation indicate a potential continuation and intensification of conservation efforts, especially for water use efficiency and reduction goals. The District developed a WEMP in 2019-2020 that identifies strategies to meet both short-term (to 2025) and long-term (to 2050) water use efficiency goals, including consideration of the new prospective urban water use reduction targets soon to be established by the state. The District has also seen success in water use efficiency savings over the past 10 fiscal years (FY 2010/11 - FY2019/20), which has enabled the District to meet distribution and groundwater system demands. If water use efficiency targets become more restrictive (e.g., targets are established beyond the targets set in Assembly Bill 1668 and Senate Bill 606 that the District will need to achieve by 2023), the District will need to update WEMP assumptions to reflect more aggressive water conservation goals.

Endangered Species Act (ESA): If ESA requirements to maintain adequate temperatures for cold-water species like steelhead trout require reduced Delta pumping, then SWP-imported supply may be impacted and potentially reduced. If ESA requirements demand additional reservoir releases, SFPUC's RWS may be impacted and imported SFPUC supply may be reduced. If ESA requirements change, such as requiring climate science integration to identify endangered and threatened species or habitat boundaries, groundwater recharge operations (e.g., restrictions related to protecting groundwater-dependent ecosystems or surface water supplies providing recharge) may be impacted.

Bay-Delta Water Quality Control Plan (Bay-Delta Plan): The Bay-Delta Plan was created through the Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act), which established the Delta Stewardship Council to create a comprehensive, long-term, legally enforceable plan to guide how multiple state, federal, and local agencies manage the Delta's water and environmental resources. With anticipated further amendments to the Bay-Delta Plan and continued work from Delta Adapts Initiative (Delta Adapts) to better understand the Delta's vulnerability to climate change impacts, opportunities will likely occur for continued engagement with Delta Adapts and future development of the upcoming Draft Adaptation Strategy.

In general, the District should continue to anticipate potential reductions in imported supply delivered through the Delta given current proposed amendments to the Bay-Delta Plan, which are evaluated in the Supplemental Environmental Document and include amendments that set a minimum requirement for 40 percent unimpaired flow on the Hetch Hetchy supply to SFPUC's RWS. Importantly, the State Water Project Final Delivery Capability Report 2021 (p.4) states that:

> "Under 2040 conditions, the estimated average annual delivery of Table A water (2,111 TAF) is projected to be 9% lower than under existing conditions. This finding is for a median or most likely future condition. Significant uncertainty exists about future conditions; actual future conditions could end up being considerably worse."

This report, published in September 2022, suggests that impacts will include reduced imported supply availability as a regular component of future conditions. If Bay-Delta Plan flow requirements on the Sacramento River change, then storage and dry year supply reliability for SWP supplies may be reduced. If Bay-Delta Plan flow requirements on the Tuolumne/San Joaquin rivers change, storage and dry year supply reliability for SFPUC's RWS may be reduced.

Like the continued development of Delta Adapts and the continued evaluation of SWP delivery capabilities, other regional- and state-level policy and regulation development are anticipated to be updated with new and emerging science, especially with regard to climate change.

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Section 4

Climate Impacts

If GHG emissions go unchecked, the end of the century could have carbon dioxide (CO_2) concentrations three times higher than in pre-industrial times (Alameda County et al., 2021). According to the National Aeronautics and Space Administration, “The current warming trend is unequivocally the result of human activity since the 1950s and is proceeding at an unprecedented rate over millennia” (NASA, 2022). The severity of climate change impacts will depend on future emissions, mitigation measures to curb emissions, and efforts to sequester CO_2 and other GHGs.

Warming temperatures and increasing frequency of extreme weather events are being observed at global and local levels (Bedsworth et al., 2018). Potential impacts from global warming over the next century are expected to include SLR, increased riverine flooding, higher temperatures (including extreme heat events and wildfires), decreased air quality, and extended periods of drought. Additionally, humans can expect to see energy shortages, heat-related mortality and illnesses, failing infrastructure, food and water insecurity, and more (Bedsworth et al., 2018).

According to California’s Fourth Climate Change Assessment, “California is one of the most ‘climate-challenged’ regions of North America and must actively plan and implement strategies to prepare for and adapt to extreme events and shifts in previously ‘normal’ averages. Currently, temperatures are warming, heat waves are more frequent, and precipitation has become increasingly variable. California has experienced a succession of dry spells, and with warmer conditions the impacts of these droughts have increased” (Bedsworth et al., 2018, pg. 13). The effects of climate change include severe moisture deficit, coastal erosion and inland flooding, and wildfires, which have already impacted Alameda County (Alameda County et al., 2021).

4.1 Climate Projections

To understand climate change effects under future conditions, GHG concentration trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) called Representative Concentration Pathways (RCPs) are used to model future emissions scenarios with various GHG concentrations. RCPs are not based on specific policies or economic futures but are based on the total radiation in and out of the Earth’s surface due to the accumulation of GHGs (Bedsworth et al., 2018). These RCPs provide inputs into GCMs that simulate the future effects of increased GHG concentrations.

California’s Fourth Climate Change Assessment, which is the scientific basis for this report, uses two RCPs from the Fifth IPCC Assessment Report (AR5) on Climate Change. While the IPCC released the Sixth Assessment Report (AR6), this information was not yet available to the State of California during the writing of its Fourth Climate Change Assessment. According to California’s Fourth Climate Change Assessment, “The higher of the two RCPs represents accumulating GHG concentrations under a higher emissions pathway (RCP 8.5) that would result in atmospheric CO_2 concentrations exceeding 900 parts per million (ppm) by 2100, more than triple the level present in the atmosphere before human emissions began to accumulate. The more moderate GHG concentration pathway (RCP 4.5), a scenario where GHG emissions rise until the mid-21st century and then decline, results in a CO_2 concentration of about 550 ppm by 2100” (Bedsworth et al., 2018, pg. 20).

California's Fourth Climate Change Assessment used temperature and precipitation projections from 32 downscaled GCMs using a statistical downscaling technique known as localized constructed analogues (LOCA). Downscaling GCMs to finer spatial scales adds additional uncertainty. The LOCA downscaling method uses historic patterns as a basis for the model; however, future climate change might lead to changes in local weather patterns that would not be captured by this approach. For example, how fog will change in the Bay Area is an area for future research and would not be captured in GCMs because the models are too coarse, nor in LOCA downscaling because it is based on historic data (Bedsworth et al., 2018). Coastal marine-layer clouds, or fog, patterns are an area of active research for the Bay Area.

Table 4-1 and Table 4-2 provide summaries of climate change and expected impacts from California's Fourth Climate Change Assessment. These tables summarize the best available science for how climate change will impact California.

Table 4-1. Qualitative Description of Current Understanding of Historical and Expected Climate Impacts in California

Climate Impact	Historical Trends	Future Direction of Change	Confidence for Future Change
Temperature	Warming (last 100+ years)	Warming	Very High
Sea Levels	Rising (last 100+ years)	Rising	Very High
Snowpack	Declining (last 60+ years)	Declining	Very High
Annual Precipitation	No significant trends (last 100+ years)	Unknown	Low
Intensity of Heavy Precipitation Events	No significant trends (last 100 years)	Increasing	Medium-High
Drought Frequency	No significant trends (last 100+ years)	Increasing	Medium-High
Marine-layer Clouds (Fog)	Some downward trends; mostly not significant (last 60+ years)	Unknown	Low
Acres Burned by Wildfire	Increasing (last 30+ years)	Increasing	Medium-High

Source: Bedsworth et al., 2018 / California's Fourth Climate Change Assessment.

Table 4-2. Climate Impacts in California Under Different Emission Scenarios

Climate Impact in California	Scenarios			
	Baseline: 1976-2005	RCP 8.5 End of Century	Paris Agreement 1.5°C	Paris Agreement 2°C
Annual Average Temperature	14°C (57°F)	19°C (66°F)	15.2°C (59°F)	15.6°C (60°F)
Number of Extreme Hot Days: Sacramento	1.6	13.2	2.4	2.9
April 1 Snow Water Equivalent	18.8 inches	-74%	-22%	-22.8%
Soil Moisture	11.8 inches	-10%	-1.3%	-2.5%
Wildfires: areas burned	484.5 thousand acres	+63%	+20%	+20%
SLR (2100 relative to 2000: mean values)	NA	137 centimeters (54 inches)	28 centimeters (11 inches)	41 centimeters (16 inches)

Source: Franco et al., 2018 / California's Fourth Climate Change Assessment

California's future climate varies depending on the emission scenario (e.g., RCP) used for analysis. When considering projected impacts using the RCP 8.5 (high emissions) scenario the following ranges can be considered for future changing conditions by end of the century (2100):

- **Change in temperature:** Compared to the baseline, which is California's historical climate from 1976 to 2005, temperature may rise by between 2 degrees Fahrenheit (°F) to 9°F
- **Change in number of extreme heat days:** Compared to the baseline, the number of extreme heat days in Sacramento may go from the baseline of 1.6 days to between a range of 2.4 to 13.2 days
- **Change in snow water equivalent (SWE):** Compared to the baseline, the April 1 SWE may reduce by between 22 percent and 74 percent
- **Change in soil moisture:** Compared to the baseline, soil moisture may reduce by 1.3 percent to 10 percent
- **Change in wildfire coverage:** Compared to the baseline, wildfires may increase by between 20 percent and 63 percent
- **Change in sea level:** Sea level rise is anticipated to rise between 11 inches to 54 inches

4.2 Regional Impacts

While the above climate projections may cause potential risks to the District's infrastructure and operations, there may be broader impacts to the region at large. This section summarizes the potential regional impacts that could be seen at the Bay and Delta ecosystem scale.

4.2.1 Impacts to Ecosystems

It is projected that, because of climate change, nearly every aspect of the Bay-Delta ecosystems will be affected due to SLR, rising temperatures, precipitation changes, sediment supply changes, and snowfall changes, among other factors (Ackerly et al., 2018). All shoreline areas of the Bay-Delta will need to adapt or transform as temperatures change and sea levels rise. It is estimated that the Bay Area will become less suitable for evergreen forests (e.g., redwoods and Douglas fir) and will transition to chaparral shrub land. It is also possible that vegetation can get "out of sync" with the climate by transitioning too slowly and become vulnerable to heat and drought (Ackerly et al., 2018). The ability of vegetation to respond to a rapidly changing climate, however, is poorly understood. Coastal ecosystems, such as wetlands and their wildlife, are most threatened by impacts of SLR. Wetlands wildlife will need migration space further upland to survive. Less rainfall, higher temperatures, and increased drought will also negatively impact streamflow for amphibians and reptiles, while heat and wildfires may negatively impact habitat for upland birds, mammals, amphibians, and reptiles. Some wildlife species may need to shift locations entirely as the habitats they need transform with a changing climate (Ackerly et al., 2018).

4.2.2 Impacts to the Delta

The Delta provides water to a majority of California, including the District, through the SWP. Understanding how climate change will impact the Delta will help water utilities and farmers across the state who rely on this water better prepare for changes to Delta water supplies. The Delta faces two major climate risks when it comes to water supply reliability: SLR and reduction of fresh water due to changes in snowpack and increased temperatures. Reduced snowpack and increased temperatures may reduce the availability of fresh water in the Delta and may require less water to be taken out of the Delta by water users to ensure environmental flow requirements are met.

On the Delta islands, flood control is managed through century-old levees. Levees were built to support farming and land reclamation practices; however, water pumping practices exposed the soil to oxygen, which led to the degradation of organic soil, which in turn caused substantial land subsidence in the areas behind the levees and increased flood risks. Nearly every island in the Delta is from 0 to 15 feet below sea level, meaning the water level is higher than the land, which creates sunken islands solely protected by levees (Adapting to Rising Tides, 2020).

DWR has designed eight of these Delta islands as salinity barrier islands, meaning these islands play an important role in blocking saline water from the tidally influenced Bay from coming up into the freshwater Delta. The tidal influence from the Golden Gate goes all the way up to the Delta, and flooding of these salinity barrier islands could allow the movement of more saline water further upstream the Delta, which would affect water supplies, including the SWP, Central Valley Project, and water users in the Bay and throughout California (Adapting to Rising Tides, 2020). The top two hazards levees face are from earthquakes and high water levels that could overtop or cause seepage. Delta levees currently have an average of 3 to 4 percent annual baseline probability of flooding. Adding a high SLR scenario in 2050 doubles the probability of flooding when compared to 2012 under normal sea level conditions (Adapting to Rising Tides, 2020).

New measurements found mean subsidence rates for some of the levees in the Sacramento-San Joaquin Delta of about 0.4 to 0.8 inches per year. This subsidence compounds the risk that SLR and storms could cause levee overtopping or failure that could expose natural gas pipelines and other infrastructure to damage or structural failure. At this rate of subsidence, the levees may fail to meet the federal levee height standard between 2050 and 2080, depending on the rate of SLR (Bedsworth et al., 2018). SLR also causes additional hydrostatic pressure on the levees, which adds additional risk to a levee failing over time.

4.3 Climate Risk Scenarios

Scenario planning can be used to understand and plan for a changing climate. The goal of scenario planning is not to predict specific events but to identify and assess several potential futures that together capture relevant uncertainties and drivers influencing future conditions. Using a scenario planning approach encourages decision makers to identify solutions to future challenges that focus on robust, low- or no-regret strategies, which is important given that uncertainty and range of potential future changes can increase over time (Figure 4-1).

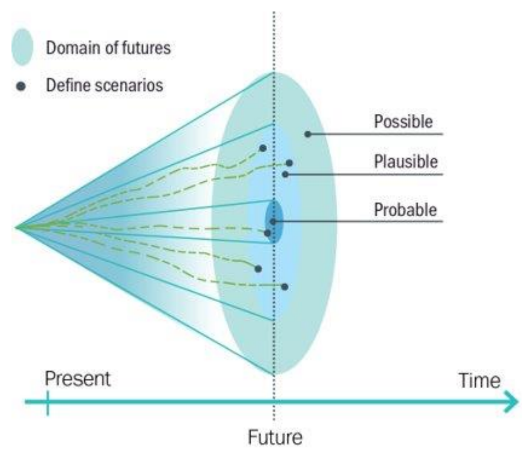

Figure 4-1. Scenario planning considers increasing uncertainty and a domain (or range) of potential future conditions over time

This CAP uses scenario planning to understand a range of potential futures that represent different climate threats or combinations of climate threats as well as potential climate risk events that can be a result of these threats. For example, a climate threat can be SLR, and a risk event (should that climate threat occur) could be inundation of coastal infrastructure.

Past planning documents, including risk and vulnerability assessments and regional and state climate change assessments, were reviewed to identify potential climate-related threats and risk events relevant to the District. Information on the climate threat and the risk event describe the basic condition for a potential scenario (Table 4-3).

Table 4-3. Descriptive Scenario Contents	
Scenario: The description of future conditions should a climate-change-related threat occur. This includes the different risk events a threat might cause and potential adverse impacts.	
Climate Threat Information • The type of physical or regulatory change, often represented as a physical hazard, with assumptions based on climate science as to trends in changing frequency and intensity.	Climate Risk Event Information • The change to the system (e.g., a water utility or water district's water supply, distribution system, facilities, operations, and community served) caused by the climate risk. Typically, this can be represented as the potential "damage" (or adverse impact) that climate-related hazard could cause.

Each climate threat can have several potential risk events that the threat can cause. This CAP identified more than 30 risk events across the following climate threats:

- Rising temperatures
- Increased drought
- Regulatory changes
- Flooding
- SLR
- Wildfire

Evaluated climate threats also included combinations of threats that could occur at the same time or with only a relatively short period in between. These were included due to their relevance for the District and are:

- SLR and drought
- SLR and a seismic (non-climate-driven) event[11]
- Wildfire and flooding
- Wildfire, drought, and flooding

[11] Seismic risk is not considered a climate-change-induced risk; however, this was applied as part of a combined risk threat given its relevance for the District's geographic area.

A list of the climate threats and their respective risk events were documented and were used to generate potential future changes and challenges for the District. These are provided in Table 4-4.

Table 4-4. Full Range of Climate Threats and Risk Events Used to Determine Climate Risk Scenarios

Climate Threat	Climate Risk Event
Rising Temperatures	• 1.1 Reduced local supply availability • 1.2 Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation)
Drought	• 2.1 Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Reduced SWP allocations (impacting groundwater banking) • 2.4 Reduced SWP allocations (impacting dry year water supply) • 2.5 Reduced surface water capture for Lake Del Valle (stormwater capture)
Regulatory Change	• 3.1 SGMA requirements change • 3.2 UWMP requirements change • 3.3 SWP system and regulations change • 3.4 Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 ESA requirements change (impacting SFPUC RWS supply) • 3.8 ESA requirements change (impacting groundwater recharge)
Flooding	• 4.1 Increased storm intensity and atmospheric rivers expand the 100- and 500-year floodplains and expose critical infrastructure to flooding • 4.2 Loss of facility access (flooding) • 4.3 Upstream flooding causing Delta levee failure • 4.4 Increased storm intensity and atmospheric rivers expand the 100- and 500-year floodplains and create larger sediment load (sediment in Quarry Lakes)
Sea Level Rise	• 5.1 SLR causes rising groundwater levels • 5.2 Loss of facility access • 5.3 Reduced fresh groundwater supply and storage in Niles Cone • 5.4 SLR causes rising groundwater levels (mobilizing contaminants)
Wildfire	• 6.1 Loss of facility access • 6.2 Public safety power shutoff (loss of power due to wildfire shutoffs) • 6.3 Increased frequency and intensity of wildfires that may damage sensitive equipment • 6.4 Increased frequency and intensity of wildfires negatively impact water quality by mobilizing contaminants
Combined Threats	• 7.1 Increased wildfire frequency and intensity combined with flooding (strong precipitation events) negatively impact water quality by mobilizing contaminants (wildfire and flooding) • 7.2 Increased landslide potential due to wildfires and increased storm intensities (wildfire, drought, and flooding) • 7.3 Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)

These climate threats and risk events were aggregated into 15 scenarios that demonstrated a range of climate threats and risk events for continued analysis (Table 4-5).

Table 4-5. CAP Climate Risk Scenarios

Scenario ID #	Climate Risk Scenario
Scenario 1	Increasing temperatures resulting in potential reduced local supply
Scenario 2	Increasing temperatures resulting in potential increased demand
Scenario 3	Drought resulting in potential reduction of imported supply - SFPUC
Scenario 4	Drought resulting in potential reduction of imported supply - SWP
Scenario 5	Wildfire resulting in potential non-salinity water quality degradation in local surface water
Scenario 6	Increasing temperatures resulting in potential non-salinity water quality degradation in the Delta
Scenario 7	Flooding resulting in potential saline intrusion in the Delta
Scenario 8	SLR resulting in potential non-salinity groundwater contamination mobilization in Niles Cone
Scenario 9	SLR resulting in potential saltwater intrusion in Niles Cone
Scenario 10	Drought resulting in potential reduced augmented groundwater recharge to Niles Cone
Scenario 11	SLR resulting in potential damaged infrastructure or loss of access
Scenario 12	Storm/flooding resulting in potential damaged infrastructure or loss of access
Scenario 13	Wildfire resulting in potential damaged infrastructure or loss of access
Scenario 14	Wildfire resulting in potential public safety power shutoff
Scenario 15	Regulatory changes resulting in potential changes needed in operations, planning, and or policy

The vulnerability assessment takes these 15 climate risk scenarios and details the potential impacts and/or "cascading effects" they may cause for the District. This includes a description of the District's system components that could be impacted and the spatial distribution of potential consequences (i.e., through hazard "hot spot" maps). Section 6 contains the risk assessment, which further describes potential likelihood, adaptive capacity, and potential consequences to indicate the relative risk for each risk event. In Section 7, potential adaptation strategies are matched and considered for different climate scenarios. Potential pathways and triggers for these implementing strategies are outlined in Section 8.

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Section 5

Vulnerability Assessment

The CAP Team conducted a vulnerability assessment to identify operations and infrastructure that are susceptible to climate threats. The vulnerability assessment provides a high-level understanding of where and how the District's systems and LoS could be impacted by changing climate conditions.

The vulnerability assessment was conducted using a review of historical vulnerabilities, expert input from District staff, and mapping of future vulnerabilities to understand risk for planning horizons of present day to 2050 (mid-term) and up to 2100 (long-term). These planning horizons were selected based on their alignment with key years used in state-of-climate-science analyses, as well as the lifetime of existing and newly implemented District assets. Existing reports, hazard mapping, critical elevations, and climate projections were reviewed to arrive at preliminary vulnerability findings. Meetings were conducted with District staff to discuss these vulnerabilities for major system components and facilities, identify a system component's sensitivity to climate and climate changes, and qualitatively address the adaptive capacity inherent in certain system components. No modelling was completed as part of this task, and only existing information for historical, current, and future climate change projections were used. The data assumptions and projections are documented within each climate vulnerability subsection listed below.

To identify and understand which of the District's water system infrastructure and operations may be impacted by both single- and multi-event risks, "hot spot" maps were produced using various climate-related data sources and District-provided information. Given that this CAP is made publicly available, maps are provided that feature the estimated spatial extent of the climate-related threat; physical vulnerable assets are listed within the text. Detailed information on the sources and assumptions used to generate the maps are described in the following subsections. By mapping these vulnerabilities, the District can better prioritize its efforts and resources.

5.1 Vulnerability to Climate Impacts

The following section describes the District's vulnerabilities to climate change, which include the extent, severity, and impact of potential climate threats. See Appendix B for further background information on climate impacts.

5.1.1 Increasing Temperatures

Extent and Severity. Rising temperatures and extreme heat will likely affect the District's entire service area; however, areas in the county's interior or areas that lack sufficient tree canopy and/or have large amounts of impervious and dark surfaces will experience more extreme heat. The number of extreme heat days are expected to rise, and inland or exposed county areas are expected to experience days with temperatures that exceed 100°F more frequently (Bedsworth et al., 2018). The Union of Concerned Scientists estimates that "Alameda County will experience over 30 days a year by mid-century that feel like 90 degrees or higher, as opposed to a historical average of 11 such days per year." Although the District's service area does not match the Alameda County administrative boundary, this is still a relevant local data point.

By mid-century (2040-2069), the projected mean annual maximum surface temperature (the yearly average of the highest temperature on every day of the year) for the Bay Area, across multiple climate models, exceeds the maximum historical annual mean, regardless of which emissions trajectory is chosen (Ackerly et al., 2018). Thus, even with significant efforts to mitigate climate change as seen in RCP 4.5, the Bay Area will likely see annual mean warming on the order of approximately 3.3°F by mid-century. This increment increases to 4.4°F warming by mid-century under the high-emissions RCP 8.5 scenario. The difference between emissions scenarios becomes more apparent by end of century (2070-2100), with warming on the order of 4.2°F for RCP 4.5 and 7.2°F for the RCP 8.5 scenario (Ackerly et al., 2018). Table 5-1 summarizes the projected temperature increases for early, mid-, and late century.

Table 5-1. Projected Temperature Increases

Scenario	Early Century: 2006-2039	Mid-century: 2040-2069	Late Century: 2070-2100
RCP 4.5	+2.5°F (72.6°F)	+4.4°F (74.5°F)	+5.6°F (75.5°F)
RCP 8.5	+2.7°F (72.8°F)	+5.8°F (75.9°F)	+8.8°F (78.9°F)

Source: Pierce et al., 2018

Note: Projected increase in annual average maximum daily temperature under RCP 4.5 and 8.5. Projected annual average temperature shown in parentheses.

While the above summarizes the change in annual average maximum temperature, Figure 5-1 shows the average spatial change in the hottest day of the year. The top image represents the average hottest day of the year in the historical (1976-2005) period, and in the late-21st century (2070-2100) under RCP4.5 and RCP8.5. The bottom row provides change (late-21st century minus historical) in the hottest day of the year under RCP4.5 and RCP8.5. Note that these images do not explicitly account for fog and sea breeze. According to California's Fourth Climate Change Assessment's San Francisco Bay Area Report, "Under RCP 8.5, the average hottest day of the year is projected to increase by a minimum of 6.3°F near the coast and up to 10°F further inland. Under RCP 4.5, warming trends for the average hottest day of the year reduces to 3.9°F near the coast and up to 6.4°F further inland" (Ackerly et al, 2018, pg. 15).

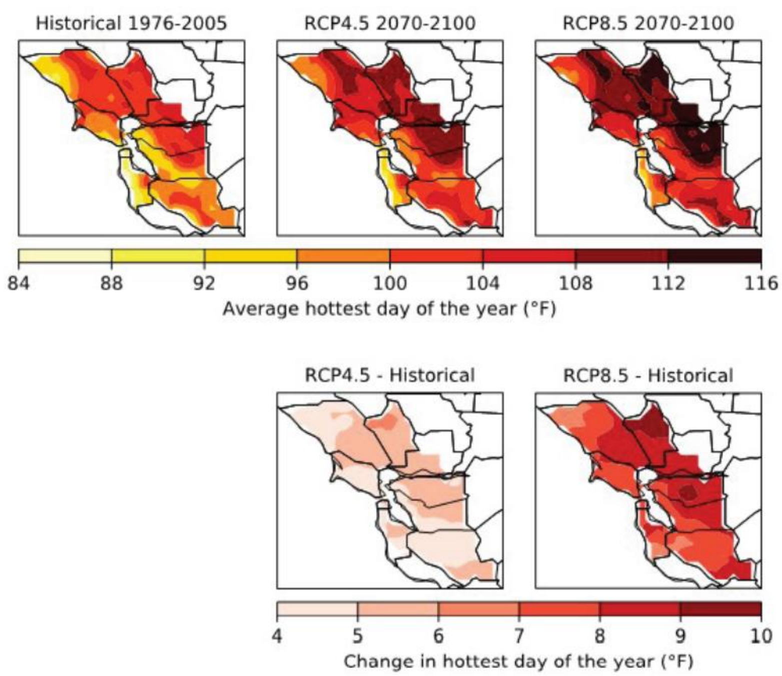

Figure 5-1. Average spatial changes in the hottest day of the year

Source: Ackerly et al., 2018

According to California's Fourth Climate Change Assessment, "[t]he mean snow water equivalent (SWE)[12] declines to less than two-thirds of its historical average by 2050, averaged over several model projections under both RCP 4.5 and 8.5 scenarios. By 2100, SWE declines to less than half the historical median under RCP 4.5, and less than one-third under RCP 8.5. Importantly, the decline in spring snowpack occurs even if the amount of precipitation remains relatively stable over the central and northern California region; the snow loss is the result of a progressively warmer climate" (Bedsworth et al, 2018, pg. 27). For the Bay Area under a high emissions scenario, average Sierra Nevada snowpack is projected to decline by nearly 20 percent in the next two to three decades, 30 percent to 60 percent in mid-century, and by more than 80 percent in late century (Ackerly et al., 2018).

In 2018, Scripps Institution of Oceanography developed daily climate projections for California, available through Cal-Adapt, with a resolution of approximately 3.7 miles. This data used the LOCA statistical method to downscale global climate models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) archive to determine the average annual maximum temperature projections for 2006 to 2100. Figure 5-2 presents the projected data for 2100 overlaid with the District's service area and select assets.

Impacted system components may include: water supply (Alameda Creek Watershed, Quarry Lakes), capital assets for distribution, peak day production and potable storage capacity constraints, and water treatment facilities.

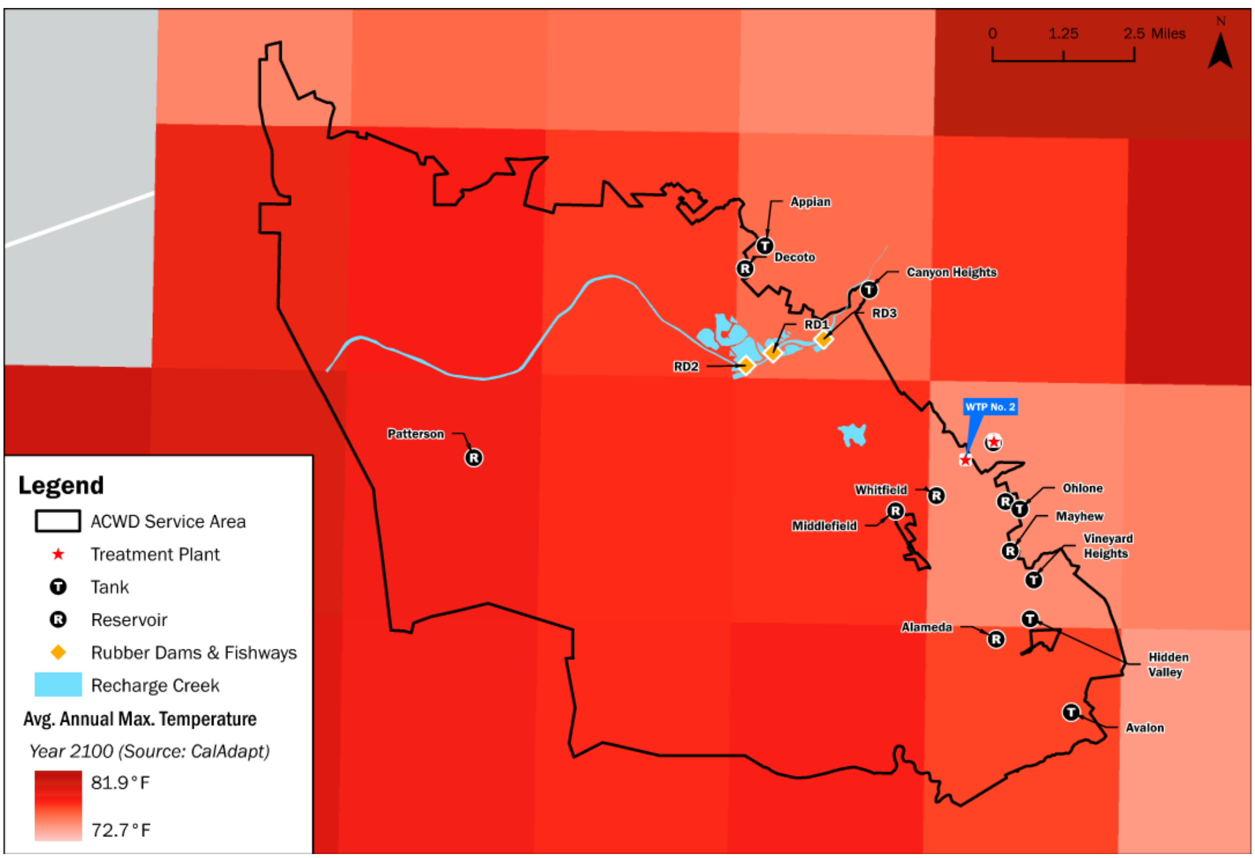

Figure 5-2. Average annual maximum temperature (year 2100)

Source: CalAdapt (date accessed: 4/4/2022); District GIS data (date received: 3/8/2022)

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[12] A snowpack measurement to understand the amount of liquid water contained within the snowpack.

Impacts. Increasing temperatures may cause:

- More heat-stress-related hazards for field workers
- Warmer surface water that can degrade water quality
- Warmer surface water that can increase evaporation and water loss
- Longer droughts
- Reduced snowpack
- Increased water demand
- Stress to ecosystems

Extreme heat can trigger a variety of heat stress conditions, such as heat stroke, which could pose a hazard to workers in the field. Other impacts include warmer surface water (both storage and in-stream flows), which can decrease the amount of dissolved oxygen in the water and worsen aquatic health and cause more blue green algae blooms that could impact water treatment operations. There can also be increased surface water evaporation in reservoirs or open tanks that could lead to water loss. Increased temperatures also have secondary impacts of worsening droughts, reducing snowpack, and increasing water demand.

5.1.2 Sea Level Rise

Extent and Severity. California has two statewide projections for SLR: The Governor's Office of Planning and Research's (OPR) State of California Sea Level Rise Guidance (2018) and California's Fourth Climate Change Assessment, which uses a broader range of SLR estimates than OPR's. Given that there is still considerable uncertainty in these results, the Fourth Assessment projections are meant for research purposes, while the OPR projections are meant for regulatory and planning purposes. The OPR SLR projections only include estimations for elevated sea levels and do not include the addition of king tides (i.e., especially high tides that occur twice annually) or storm surge (e.g., from an atmospheric river or El Niño event). Tide levels fluctuate with astronomical forces and storm surge (including pressure and wind). That fluctuation is part of natural variability that can be superimposed onto SLR.

Of note is that there are a large range of SLR projections depending on which risk aversion and emissions scenario is chosen. The SLR projections provided by the State of California Sea-Level Rise Guidance (2018 Update) provide a range of values, with the medium-high risk aversion under a high-emissions scenario as the recommended conservative range to use during planning. These values include a range between 13.2 inches (1.1 feet) for a low risk aversion projection under high emissions for 2050, and up to 32.4 inches (2.7 feet) for an extreme risk aversion projection under high emissions by 2050. This range also includes 1.8 feet of SLR in 2040 under the extreme risk aversion projection, which is the chosen future conditions assumption for the 2021 DWR SWP Delivery Capability Report. The 2018 Update recommends using the extreme risk aversion projection in planning analyses "[f]or highly vulnerable or critical assets that have a lifespan beyond 2050 and would result in significant consequences if damaged" (OPC & CNRA, 2018, pg. 25). To see all SLR projections under different risk scenarios, see Table 13 in Appendix 3 of the State of California Sea-Level Rise Guidance for San Francisco.

As noted, ART conducted a Bay Area Sea Level Rise Analysis and Mapping Project in September 2017. The project included publicly available inundation data for all San Francisco Bay Area counties, including Alameda County, for SLR scenarios with a wide range of regularly occurring levels of inundation as well as temporary flooding impacts. To develop the SLR "hot spot" maps, the CAP provides two examples from this range: the 24-inch SLR scenario and the 84-inch SLR scenario. These two scenarios were modeled for inundation in the ART study and use the mean higher high water (which is the average of the highest daily high tides) tidal datum. These scenarios were chosen as they also represent a close existing height to the OPR's SLR projections for a medium-high risk aversion under high emissions. These maps are shown on Figure 5-3 and Figure 5-4 and exemplify a range of potential inundation levels given different levels of SLR.

Impacted system components may include: shoreline pipelines and wells (e.g., potentially Site E, Site D, 18-inch in Cushing Parkway, 20-inch pipe in Bayside Parkway, 30-inch pipe near Patterson Reservoir), Westerly Wells, and Niles Cone groundwater.

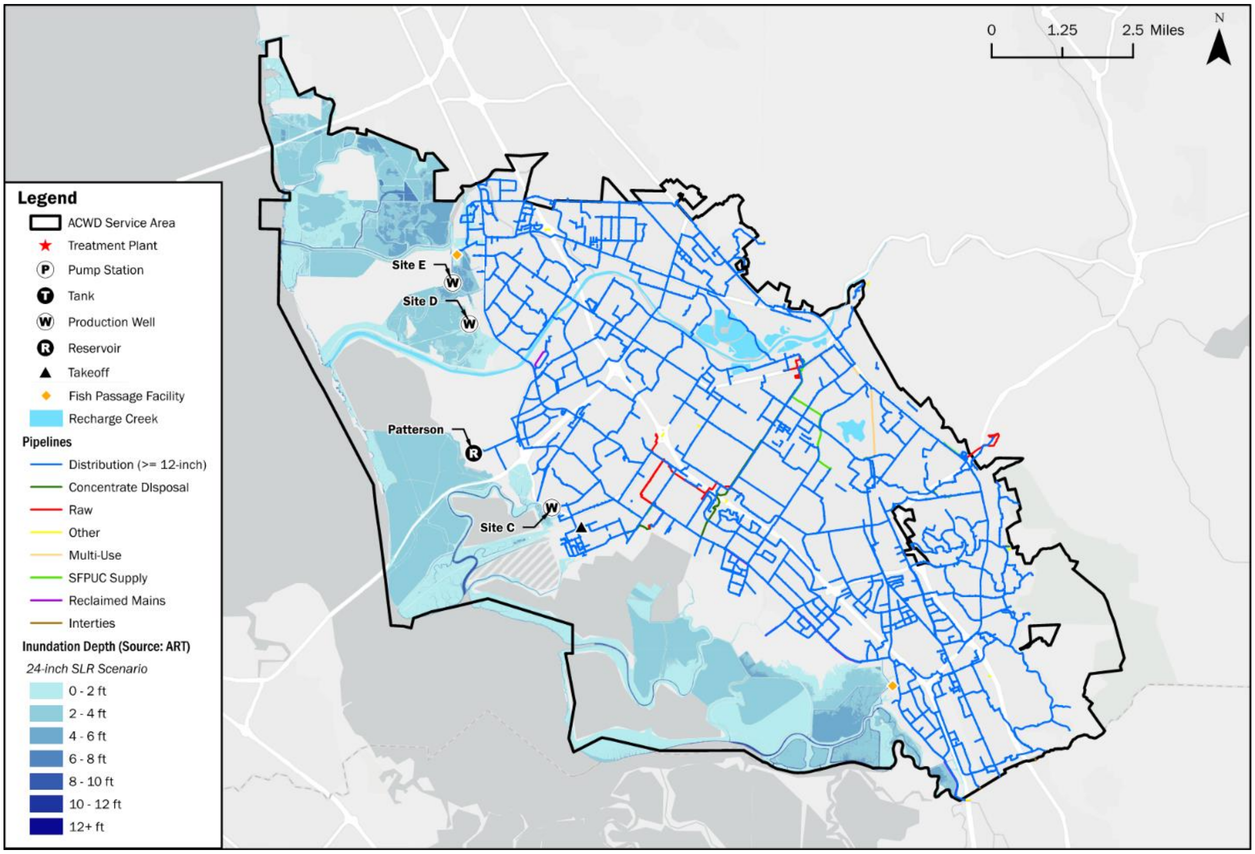

Figure 5-3. SLR "hot spot" map – (24-inch scenario accounting for SLR and average highest daily high tides)

Source: Adapting to Rising Tides (date accessed: 1/18/2022); District GIS data (date received: 3/8/2022)

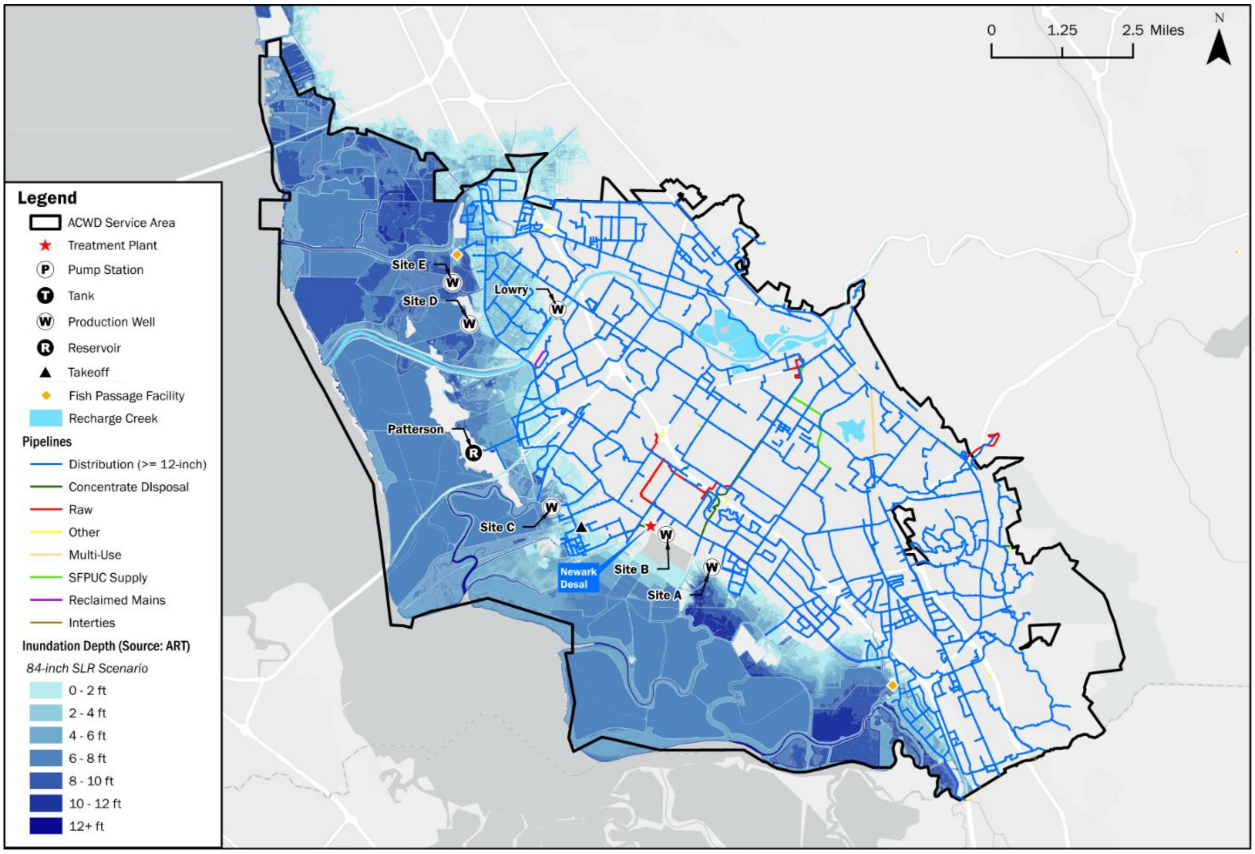

Figure 5-4. SLR "hot spot" map – (84-inch scenario under medium-high risk aversion and high-emissions scenario accounting for SLR and average highest daily high tides)

Source: Adapting to Rising Tides (date accessed: 1/18/2022); District GIS data (date received: 3/8/2022)

Impacts. Sea level rise may cause:

- More extensive flooding due to higher sea level and higher water levels in tidal creeks and channels.
- Expanded zones of liquefaction.
- Pipe buoyancy, causing gas, wastewater, petroleum, or water pipeline breaks.
- Destructive erosion.
- Contamination of aquifers or soil with saltwater.
- Contamination of aquifers or soil with flood waters containing mobilized contaminants.
- Loss of habitat for fish, birds, and plants.
- Disruption and/or delay of transportation or construction-related activities.
- Damages to buildings and infrastructure on a more regular basis.
- Blocked access to facilities.
- Useable freshwater storage constraints of the Niles Cone.
- Added stress to the Delta levee system, including risk of failure and saltwater intrusion to Delta.
- Saltwater intrusion by raising the interface between saltwater and the overlying freshwater.
- Coastal erosion.

SLR can expand zones of liquefaction due to seismic events because fully or partially saturated soil causes the soil to lose its soil strength and act as a liquid. Liquefaction "occurs when seismic waves pass through saturated granular soil distorting its granular structure and causing some of the empty spaces between granules to collapse. Liquefaction causes lateral spreads (i.e., horizontal movements of 10 to 15 feet most commonly but up to 100 feet), flow failures (i.e., massive flows of soil, typically hundreds of feet but up to 12 miles), and loss of bearing strength (i.e., soil deformations causing structures to settle or tip). Liquefaction can cause severe damage to property" (Alameda County et al., 2021, pg. 31). Expanded liquefaction zones could cause severe damage to infrastructure or facilities, such as water pipelines.

Contamination Risk from SLR

SLR may cause contaminate mobilization into surface water or groundwater by 1) increasing the land area impacted by liquefaction due to SLR and higher groundwater tables, which could compromise the stability of hazardous waste sites (e.g., landfills or remediated sites) during an earthquake, 2) SLR or higher groundwater tables inundating sites not designed to be under water, leading to the potential leaching of contaminants from the site, 3) creating pipe buoyancy that could cause broken or leaking pipelines (e.g., gas pipelines along the Bay shoreline), and 4) corroding infrastructure (e.g., underground storage tanks) through exposure to brackish water. Previously remediated sites, closed landfills, Superfund sites, and/or underground storage tanks may not have been designed for permanent inundation. Many older landfills that are now closed were not lined (e.g., Turk Island Landfill in Union City) or were lined inadequately to prevent leachate contamination of surrounding lands and/or waters (SFBCDC, 2012). However, it's important to note that different contaminate types are vulnerable to SLR in different ways because of how they interact with water (e.g., water soluble) or sediments (e.g., bind to sediments). For more information, see Appendix B

5.1.2.1 Rising Shallow Groundwater

Extent and Severity. The USGS has analyzed how emergent shallow groundwater may rise due to rising sea levels. With 1 meter of SLR, areas extending 50 to 130 meters inland could be flooded, depending on the coastal topography (Befus et al., 2020a). All scenarios estimate that areas with shallow coastal water tables will shrink as they are inundated by overland flooding or are topographically limited from rising inland (Befus et al., 2020a). The USGS model results, published in 2020, are available by county using Local Mean Sea Level and mean higher high water marine boundary conditions (Befus et al., 2020b). The data is provided as shapefiles with water table depths in specific depth ranges for different hydraulic conductivities and different SLR scenarios.

The District modeled a potential inundation scenario of the Niles Cone to simulate future groundwater conditions to determine the sensitivity of simulated piezometric heads in the Newark Aquifer to SLR during a period of maximum piezometric heads. This model also evaluated the extent of artesian groundwater conditions under an SLR scenario, projecting piezometric head intersection with the ground surface elevation. The Newark Aquifer is the shallowest regional aquifer in the Below-Hayward Fault (BHF) subbasin/management area. This aquifer is confined except within the hydrogeologic region called the forebay area where aquitards are thin to absent. The model does not include the shallow water-bearing zone, perched over the confined part of the Newark Aquifer; however, there are assumed to be some interconnected zones between the confined Newark Aquifer and the unconfined/perched shallow zone. Further studies should assess the extents of the interconnectivity. The model ran both SLR and non-SLR conditions, subtracted the two values from each other, and mapped the output. The piezometric heads on Figure 5-5, shown as green lines, outline the extent of areas where the pressurized condition of the confined aquifer could lead to artesian conditions if a conduit for groundwater flow was available (i.e., an artesian well).

Impacted system components may include: Whipple, Darvon #1 & #2, Site B, Cedar #1 & #2, Farwell, Nursery Well, Peralta-Tyson Well Field, Mowry Well Field, Bellflower, Farwell, many pipelines including 24-inch, 30-inch, and 36-inch size pipes, Site C, Lowry, and Site A.

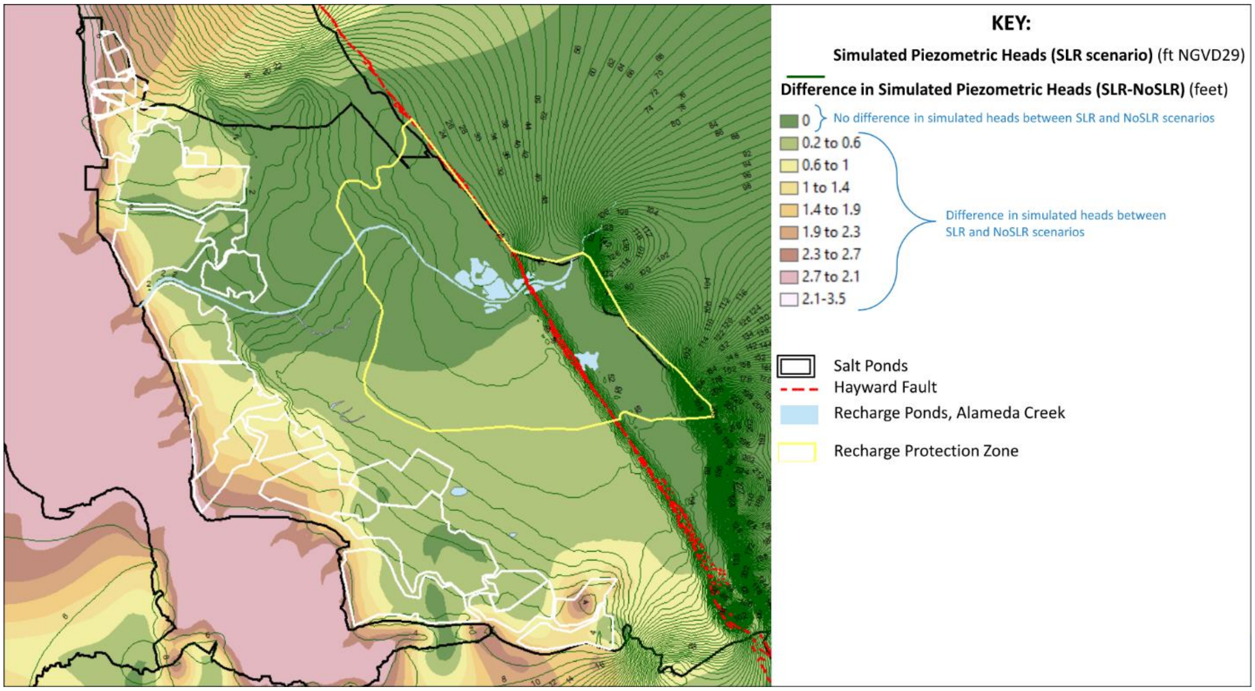

Figure 5-5. Preliminary analysis of SLR conditions using simulated change in pressure (piezometric head)

Source: District GIS data (date received: 9/13/2022)

Impacts. Flooding due to rising shallow groundwater may cause:

- Compound flood impacts from SLR, groundwater inundation, and precipitation flooding.
- Reduced soil storage capacity (i.e., reduced retention-pond capacity) and increased peak flows during storms.
- Expanded zones of liquefaction.
- Pipe buoyancy, causing gas, wastewater, petroleum, or water pipeline breaks.
- Contamination of aquifers or soil with saltwater.
- Movement of contamination in aquifers or soil due to surfaced groundwater containing mobilized contaminants.
- Loss of habitat for fish, birds, and plants.
- Disruption and/or delay of transportation or construction-related activities.
- Damages to buildings and infrastructure on a more regular basis.
- Blocked access to facilities.

Rising shallow groundwater may extend far past areas of SLR inundation, potentially inundating areas not designed for inundation and causing them to potentially leach contaminants into the floodwaters.

5.1.3 Drought

Extent and Severity. Precipitation in the Bay Area will continue to exhibit high year-to-year variability, with very wet and very dry years. Impacts to snowpack at the state level are likely to impact source flows into the Bay Area. Dry years may have consecutive years of low or no snowpack for the state (Ackerly et al., 2018). According to California's Fourth Climate Change Assessment, "Warming air temperatures throughout the 21st century will increase moisture loss from soils, which will lead to drier seasonal conditions even if precipitation increases. Warming air temperatures also amplify dryness caused by decreases in precipitation. These changes affect both seasonal dryness and drought events. Climate projections from the previous and present generation of global climate models show that seasonal summer dryness in California may become prolonged due to earlier spring soil drying that lasts longer into the fall and winter rainy season. The extreme warmth during the drought years of 2014 and 2015 intensified some aspects of the 2012-2016 drought and may be analogous for future drought events" (Bedsworth et al, 2018, pg. 26).

Impacted system components may include: water supply, groundwater banking program, water quality blending operations, and take-offs.

Impacts. Worsening droughts may impact:

- Reduced water availability.
- Reduced aquifer recharge ability.
- Water-use shortages.
- Heat-related illnesses.
- Increased wildfires.
- Environmental degradation.
- Worsening surface water quality (e.g., algal blooms).
- Worsening groundwater quality (e.g., groundwater salinity increases from reduced recharge).

5.1.4 Increased Storm Intensity and Atmospheric Rivers

Extent and Severity. As the climate continues to warm, atmospheric rivers may carry more moisture (Lavers et al., 2015), and extreme precipitation may increase (Polade et al., 2017). The recent wet winter of 2017, in which total precipitation was dominated by a small number of huge storm events, may provide a glimpse of the future. According to the Bay Area Regional Report of California's Fourth Climate Change Assessment, "Percent increases in the largest precipitation events (measured in inches of rain per day) range from 6% to 21% in RCP 4.5 and as high as 37% in RCP 8.5 by end of century… under RCP 8.5, what is currently considered a 20-year return frequency one-day storm event for the Bay Area would increase in frequency by a factor of three or more by end of century. A once-in-20-year storm could become a once-in-seven-year or more frequent storm. Similarly, [the study by] Swain et al. (2018) [mentioned earlier] estimates that a once-every-200-year sequence of storms comparable to that which caused the great California flood of 1862 could occur every 40-50 years by 2100 under a high emissions scenario (RCP 8.5)" (Ackerly et al, 2018, pg. 20).

Most of the flood control systems in Alameda County were built in the 1960s and 1970s, which were designed to meet the 15-year flood event (Ackerly et al., 2018). Today, the United States Army Corps of Engineers and Federal Emergency Management Agency (FEMA) require such infrastructure to meet the 100-year flood event standards. With the combination of El Niño and climate change, flooding events in the county could worsen over time unless major drainage upgrades to creeks and storm sewers are made.

While storm intensity is expected to increase over time, the high variability of annual precipitation in California makes it hard to detect whether total precipitation will increase or decrease. Historical records indicate a range of almost 50 inches in total rainfall between the driest and wettest years. Climate projections for California do show a small increase in annual precipitation (i.e., 2.5 inches per year in RCP 4.5 and 4.6 inches per year in RCP 8.5 by end of century (2070-2100) relative to the baseline period of 1976-2005); however, these changes are extremely small when compared to the huge differences in the year-to-year annual precipitation (Bedsworth et al, 2018). Across North America, even under the strongest emissions scenario (RCP 8.5), little change is projected for summer and fall precipitation, but larger changes may occur in winter and spring (USGCRP, 2017).

Finally, climate change may also impact the patterns of El Niño years, as the 2015–16 El Niño was one of the three largest in historical record (Bedsworth et al, 2018).

The magnitude of flooding that is used as the standard for floodplain management in the United States is a flood with a 1 percent probability of occurrence in any given year, or a 100-year flood; and the 0.2 percent chance in any given year, or the 500-year flood. These are considered Special Flood Hazard Areas and are identified on FEMA's Digital Flood Insurance Rate Maps (DFIRM) and FEMA's National Flood Hazard Layer (NFHL). The DFIRM for the District service area identifies 49.18 square miles (46.84 percent) with a 1 percent annual chance of flooding. In the 1 percent annual chance of flood area, Zone VE is closest to the shoreline. Zone VE is used on flood maps to indicate areas where wave action and fast-moving water can cause extensive damage with wave heights of 3 feet or higher. The District's service area includes 9.09 square miles (8.66 percent) of land in Zone VE. In addition, the DFIRM identifies 4.77 square miles (4.54 percent) with a 0.2 percent annual chance of flooding. The NFHL is shown on Figure 5-6 for the 100-year and 500-year floodplains. These 100- and 500-year floods do not include precipitation changes from climate change or SLR and rising shallow groundwater.

Impacted system components may include: water supply (Alameda Creek), pump stations (Mayhews Rd, Middlefield, Curtner), wells (Cedar #1 & #2, Sites A-E, Lowry, Westerly Wells), reservoirs (Middlefield), and Vallecitos Channel.

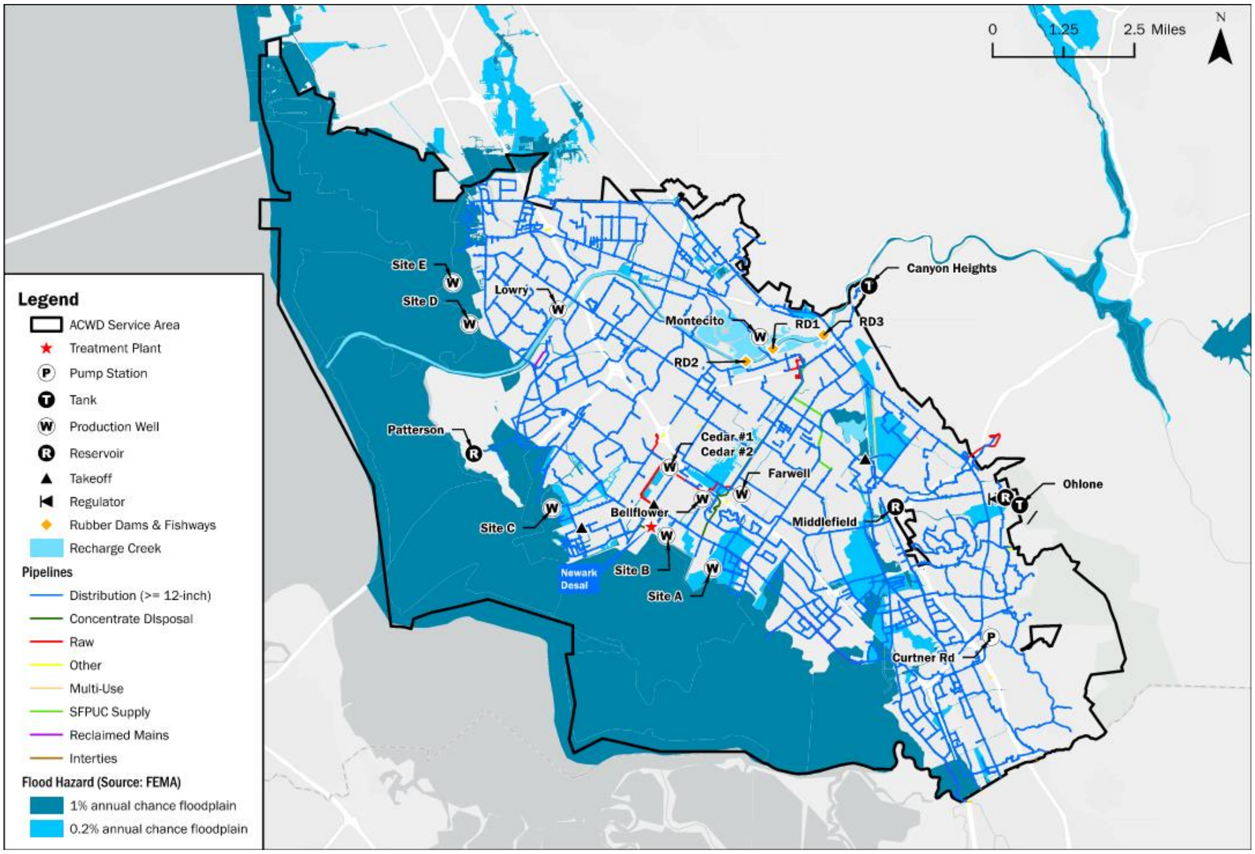

Figure 5-6. Existing 100-year and 500-year floodplain hazard zones

Source: FEMA (date accessed: 1/18/2022); District GIS data (date received: 3/8/2022)

Impacts. Increased storm intensities can:

- Block access to facilities.
- Damage sensitive equipment or infrastructure.

Secondary impacts from flooding can include:

- Erosion or scouring of stream banks, roadway embankments, foundations, footings for bridge piers, and other features.
- Damage to structures, roads, bridges, culverts, and/or other structures from high-velocity flow and debris carried by floodwaters (such debris may also accumulate on bridge piers and in culverts, increasing loads on these features or causing overtopping or backwater effects).
- Release of sewage and hazardous or toxic materials when treatment plants are inundated, storage tanks are damaged, and/or pipelines are broken.

While a common cause of landslides and debris flows are earthquakes, they can also occur from the combination of wildfires followed by intense rainstorms. According to the Alameda County LHMP, "Debris flows are created when surface soil on steep slopes becomes completely saturated with water. Once the soil liquefies, it loses the ability to hold together and can flow downhill at very high speeds, taking vegetation and/or structures with it. Slide risks increase during a wet winter after an earthquake" (Alameda County et al., 2021, pg. 40).

5.1.4.1 Landslides

Extent and Severity. Landslides can be triggered by heavy precipitation events (e.g., storms). In 2011, the California Geological Survey created a map to show the relative likelihood of deep-seated landslides in California. The map looks at landslide inventory, geology, rock strength, slope, average annual rainfall, and layers with earthquake-shaking potential to create classes of landslide susceptibility. Very high landslide susceptibility, classes VIII, IX, and X, includes very steep slopes in hard rocks and moderate to very steep slopes in weak rocks. The areas that are most susceptible to landslides within the District's service area are predominately along the northeastern border and in the southeastern portions of the District, as shown on Figure 5-7(Bedsworth et al, 2018).

Impacted system components may include: water supply, tanks, reservoirs, pump stations, water quality blending operations, regulators, take-offs, and the SBA (SBA is not owned by the District, but has high supply relevancy).

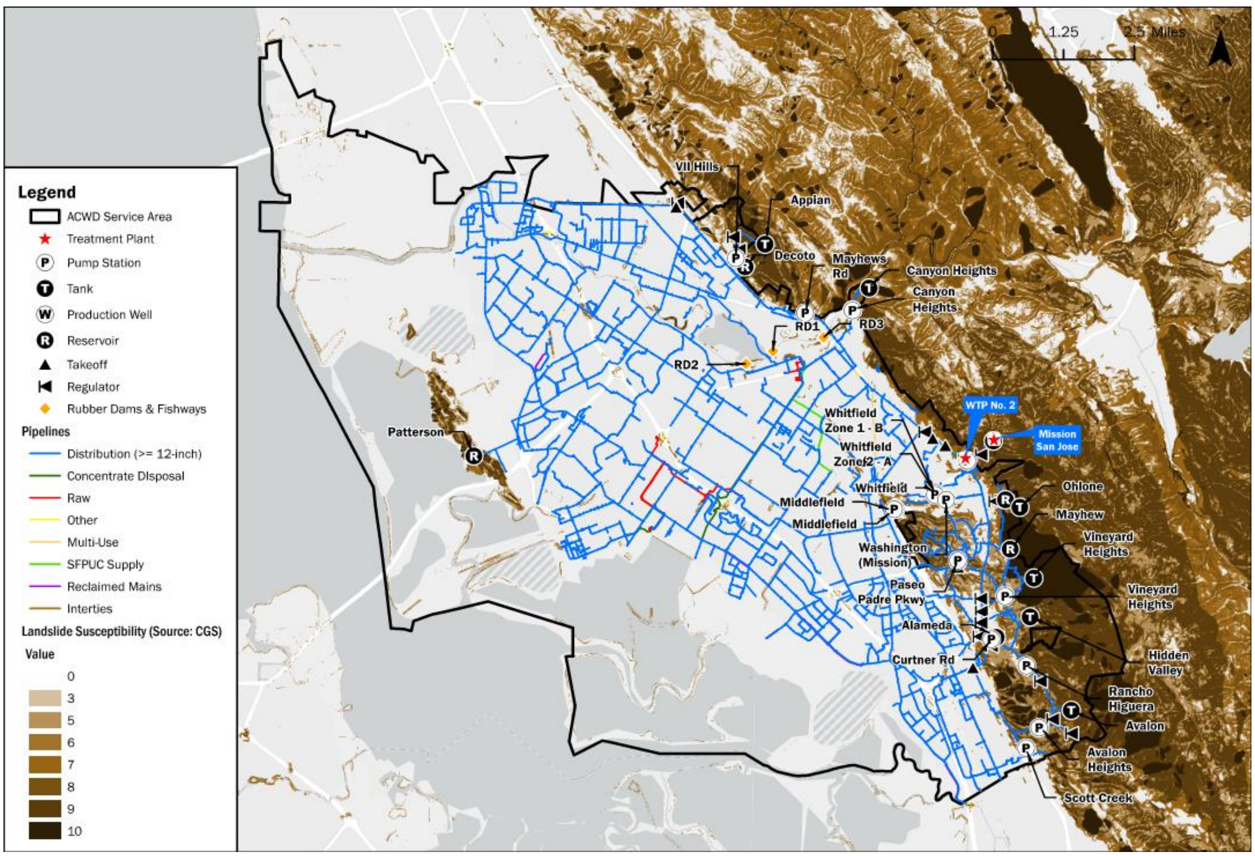

Figure 5-7. Landslide susceptibility

Source: California Geological Survey (date accessed: 3/15/2022); District GIS data (date received: 3/8/2022)

Impacts. Worsening landslides may cause:

- Loss of or damage to homes (including potential impacts to District employees), businesses, and critical facilities.
- Loss of facility access.
- Transportation and utility interruptions.
- Damage to utility infrastructure and critical facilities.

5.1.5 Wildfires

Extent and Severity. Drier, hotter conditions will make wildfires more frequent and intense, particularly in high and very high Fire Hazard Severity Zones (FHSZ) defined by Cal FIRE. Wildfires in California are predicted to continue or worsen, with more seasons with multiple large wildfires across the state (Bedsworth et al, 2018; Gross et al., 2020). Since wildfires are affected by multiple, complex drivers, California wildfire projections range from modest changes to large increases in wildfires (Bedsworth et al, 2018). One study under the high-emissions scenario (RCP 8.5) showed that by 2100, if GHG emissions continue to rise, the frequency of extreme wildfires (burning more than approximately 25,000 acres) would occur 50 percent more frequently, and the average area burned statewide could increase 77 percent (compared to 1961-1990) (Westerling, 2018).

Since wildfire activity peaks at the wildland-urban interface, future patterns of land use, together with climate change, are crucial for assessing what fire regimes may emerge in the coming decades (Ackerly et al, 2018). Wildfire frequency and severity sometimes result from other hazard impacts beyond human influence, such as lightning, drought, and infestations (e.g., damage caused by spruce-bark beetles). In the Bay Area, although there is a strong moisture gradient from the coast inland due to coastal fog, fire is not fuel-limited. There are more consistent projections of increased fire activity (i.e., more frequent wildfires or larger areas burned) due to a warmer climate (Ackerly et al, 2018). Figure 5-8 presents how climate change may alter Bay Area wildfires projections. The left side of the figure (A) provides predictions for increase (red) or decrease (green) in fire frequency for 2026-2050 (as compared to baseline of 1976-2000), showing areas of agreement across a collection of climate models. The right side of the figure (B) provides composite projections for mid-century (2035-2064) average annual area burned under RCP 4.5 (results for RCP 8.5 are very similar).

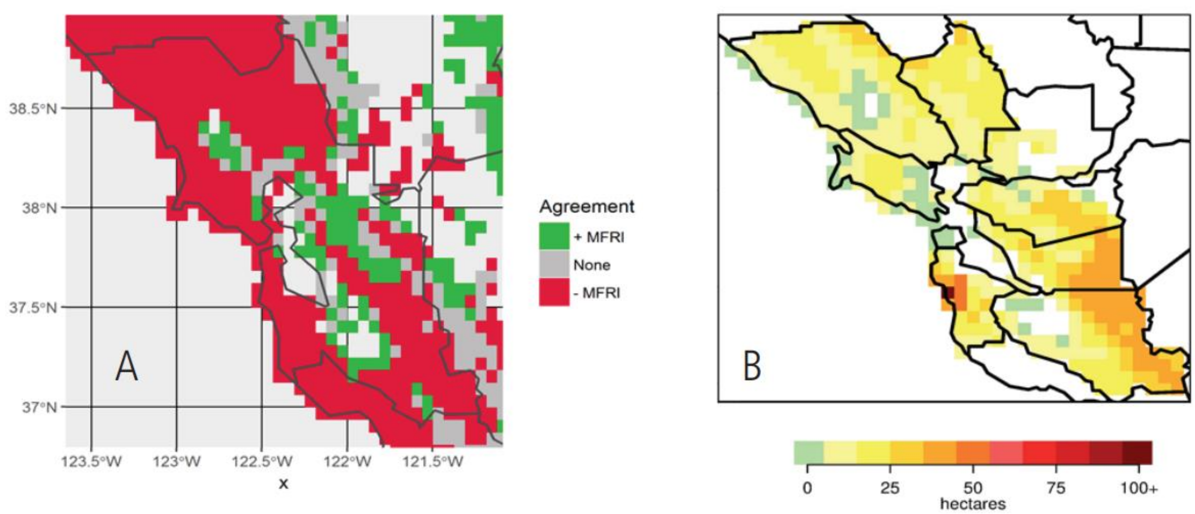

Figure 5-8. Projections for future changes in wildfire

Source: Ackerly, 2018.

Cal FIRE's Fire Resource and Assessment Program provides data on California's forests and rangelands through mapping tools. The Fire Resource and Assessment Program's FHSZ maps fire hazards based on factors such as fuel, terrain, and weather. The FHSZ areas are represented as moderate, high, and very high, as seen in Figure 5-9. The areas most susceptible to wildfire in or around the District's service area are along the wildland-urban interface in the hillside, in the Mission San Jose neighborhood, and in vegetated areas upland of the salt ponds and wetlands.

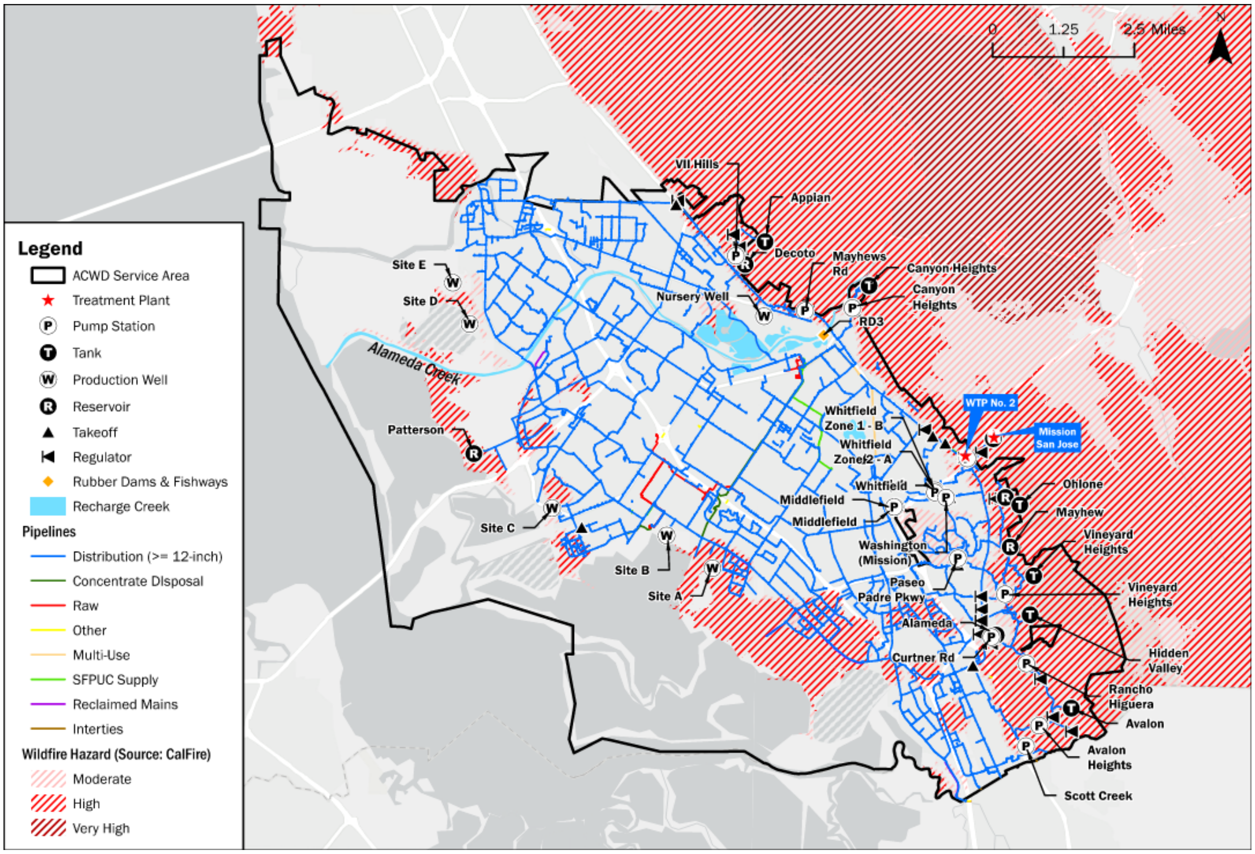

Figure 5-9. Wildfire hazard

Source: CalFire (date accessed: 1/18/2022); District GIS data (date received: 3/8/2022)

Impacted system components may include: pump stations (Vil Hills, Canyon Heights, Mayhews Rd, Middlefield, Paseo Padre Parkway, Vineyard Heights, Curtner Rd, Rancho Higuera, Avalon Heights, Scott Creek), tanks (Appian, Canyon Heights, Vineyard Heights, Hidden Valley, Ohlone, Avalon, Mission San Jose), water supply (Alameda Creek, Lake Del Valle [not operated nor owned by the District], Niles Cone groundwater), and Water Treatment Plant 2.

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Impacts. Worsening wildfires may cause:

- Loss of homes, businesses, and critical facilities.
- Loss of facility access.
- Distribution system disruption.
- Higher water demand for fire fighting.
- Water-pressure changes (e.g., low pressure due to firefighting or higher pressure when filling storage facilities).
- Transportation and utility interruptions (such as public safety power shutoffs [PSPS]).
- Reduced air quality.
- Death or injury to people and animals.
- Evacuation.

Secondary impacts from worsening wildfires may include:

- Loss of vegetation.
- Erosion, which can harm ecosystems (e.g., contaminant mobilization, creek siltation) and cause increased flooding.
- Release of contaminates into water supplies through rain events.
- Harm to soil, waterways, and the land itself (e.g., soil exposed to heat can lose its ability to absorb moisture or support life).
- Harm to ecosystems (e.g., creek siltation).

Water Quality Contamination Risk from Wildfire

Wildfires can contribute to water supply contamination. The California Urban Water Agencies (CUWA) has done research on how wildfires can impact certain water quality parameters and what monitoring strategies can be used to determine the short- and long-term consequences to water systems.

It is important to note that the impacts of wildfires on water quality can vary largely based on the wildfire location and sites affected (CUWA, 2021). Wildfires in watersheds or near untreated reservoirs can negatively impact water quality both during active burning and for months or even years after the fire has been contained. During active burning, ash and contaminants can settle on lakes or reservoirs used for drinking water. After active burns, storms can mobilize large amounts of ash, sediment, nutrients, and contaminants into streams, rivers, and reservoirs, especially in areas where burned vegetation has exposed soil.

If the wildfire is located near a water treatment plant, potential impacts could include increased chemical treatment consumption (e.g., coagulants) and associated solids production; limited use of ozone treatment due to impacts from power variability, smoke, and/or dust; and dangerous plant conditions that impact operations and monitoring.

A summary of water quality parameters that can impact water supplies and water treatment plant processes are listed in the Wildfire section of Appendix B.

For more information on wildfire impacts to water services, please see the Wildfire section of Appendix B and the California Urban Water Agencies' (CUWA) website.

5.1.5.1 Public Safety Power Shutoff

Extent and Severity. In 2012, the California Public Utilities Commission (CPUC) developed a statewide map (the CPUC Fire-Threat Map) to identify areas associated with increased risk for utility-associated wildfires. The map incorporates historical power-line wildfires and ranks fire-threat areas based on the risk utility wildfires pose to people. The majority of Tier 2 (Elevated) CPUC Fire-Threat Areas are in the southeastern portion of the county, and the Tier 3 (Extreme) CPUC Fire-Threat Areas are in the north-central portion of Alameda County, as shown on Figure 5-10. The figure demonstrates close proximity but limited spatial overlay with the District's service area.

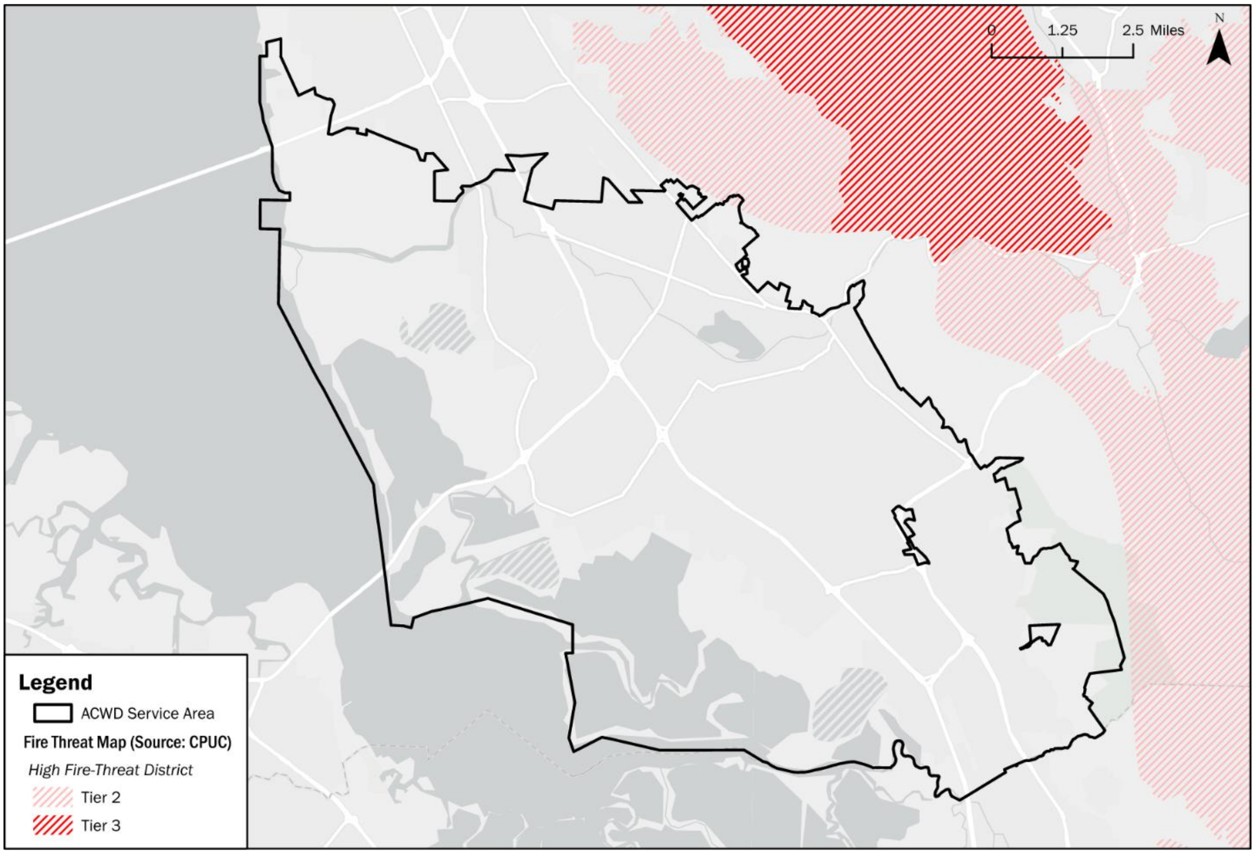

Figure 5-10. CPUC fire-threat map

Source: CPUC (date accessed: 3/24/2022); District GIS data (date received: 3/8/2022)

Impacted system components may include: electrical equipment with no backup power supply.

Impacts. Losing grid power can:

- Impact the District's ability to monitor or maintain water supplies and/or operations, especially for areas with no backup power supply or that require mobilization of a backup generator.
- Result in a loss of traffic control systems that prevent evacuation or access to critical facilities to, for example, mobilize backup generators.
- Limit the capabilities of local agencies to respond to wildfire due to loss of alert, warning, and public information communications systems, including internet and cellular towers.

Section 6

Risk Assessment

The CAP Team performed a risk assessment to analyze the likelihood and consequence of potential future climate scenarios with respect to the District's system. This process evaluated the potential impacts of climate threats identified in the vulnerability assessment by identifying plausible probabilities (likelihoods) for mid- and long-term planning horizons using best available research for the region. This work also involved developing LoS goals and consequence criteria to determine potential impacts of climate threats and documenting existing adaptive capacities that may influence these impacts given the District's existing actions, plans, and programs.

6.1 Risk Matrix

The team prepared a Risk Matrix to document the likelihood and consequence determinations for potential climate scenarios (Appendix C). The Risk Matrix documents information from the potential scenarios and includes information developed during the vulnerability assessment and expanded upon during the risk assessment. As defined in Section 4, climate threats and risk events were identified to form the baseline of the CAP's 15 climate risk scenarios. These were developed to understand the potential damage or adverse impacts that could be anticipated with changing future conditions. The vulnerability assessment described each of the risk events' potential impacts, including potential cascading effects, and identified the asset or operations that might be impacted and potential spatial distribution of this impact.

For the risk assessment, each climate risk scenario underwent a likelihood and consequence analysis. This included assigning a likelihood score based on trends in scientific data from a range of 1 (rare) to 5 (almost certain) to occur for a mid- (through 2050) and long-term (through 2100) planning horizon. Consequence scores are based on impacts to consequence criteria developed in this study from a range of 1 (negligible) to 5 (severe) impact. These scores also consider the District's existing adaptive capacity (see Subsection 6.4). The combination of both scores provides the overall risk score for each climate risk scenario (Figure 6-1). The purpose of the overall risk scores is to understand the relative potential impacts of changing future conditions represented by the different climate risk scenarios.

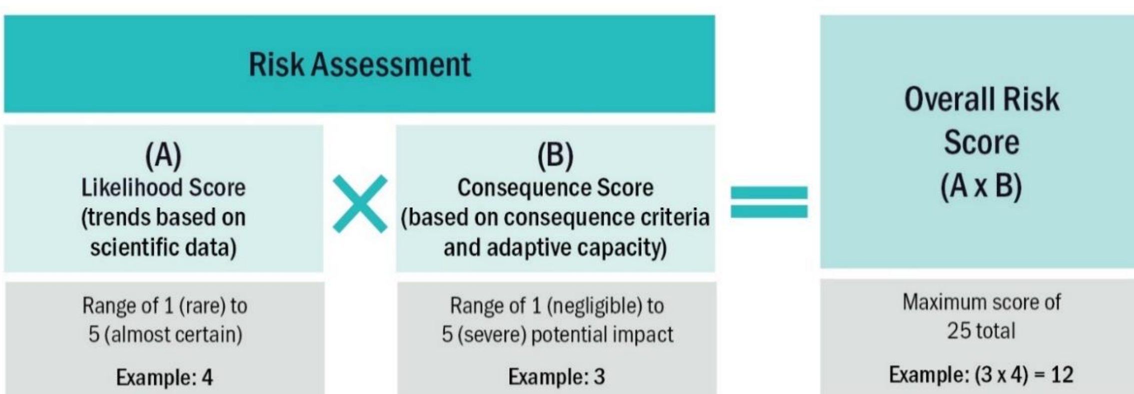

Figure 6-1. Calculating risk: the probability of occurrence is multiplied by the total weighted impact to create the risk score

6.2 Likelihood Scores

Likelihood is the probability that an event will or will not occur and has the ability to produce adverse impacts. Impacts are covered separately within the consequence part of the analysis (see Subsection 6.3).

For each climate risk scenario, a likelihood score was assigned that considers existing scientific evidence to indicate trends in climate threats for future planning horizons. Table 6-1 presents the potential range of likelihood scores used in this study's Risk Matrix. As discussed earlier, the likelihood scores are just one factor used to determine overall risk scores. The more likely the event is to occur, the higher the risk score. There are two likelihood scores assigned to each climate risk scenario that correspond to the two planning horizons considered in this study: mid-term (through 2050) and long-term (through 2100).

Table 6-1. Likelihood Scoring Rubric Applied in the Risk Matrix

Likelihood Score	Rating	Mid-term Planning Horizon Description (by 2050)	Long-term Planning Horizon Description (by 2100)
5	Almost Certain	Event is either inevitable or highly likely to occur by 2050	Event is either inevitable or highly likely to occur by 2100
4	Likely	Event more likely than not to occur by 2050	Event more likely than not to occur by 2100
3	Possible	Event possible, but uncertainty is too great to determine whether it is more likely to occur than not by 2050	Event possible, but uncertainty is too great to determine whether it is more likely to occur than not by 2100
2	Unlikely	Event not likely to occur by 2050 (more unlikely than likely to occur within planning horizon)	Event not likely to occur by 2100 (more unlikely than likely to occur within planning horizon)
1	Rare	Event is very unlikely to occur by 2050	Event is very unlikely to occur by 2100

To determine the likelihood scores of each risk event listed in the Risk Matrix, the BC project team worked in partnership with District staff to discuss and determine likelihood scores. Final likelihood scores can be seen in Appendix D. Table 6-2 provides a qualitative summary of the likelihood trends based on scientific evidence that was considered in determining likelihood scores for this analysis.

Table 6-2. Summary of Likelihood Scores by Climate Threat Based on Scientific Data Trends			
Climate Threat	Mid-term Likelihood (2050)	Long-term Likelihood (2100)	Justification
Increasing Temperatures	5	5	Annual average temperature anticipated to increase in both mid- and long-term (Cal-Adapt, 2021). Western North America regions have observed increase in hot extremes (IPCC, 2021)
Droughts	5	5	State of CA (and this region) assume continued increase in severity and frequency of droughts (California 4th Climate Change Assessment)
Flood	4	4	Frequency and intensity have increased since 1950; trend likely to continue (IPCC, 2021), though there is less certainty at medium and high emission scenarios for mid and long term (Cal-Adapt, 2021)
Storms	4	4	(Same data and justification for "Flood" above, Cal-Adapt 2021 and IPCC 2021)
Wildfire	5	5	Wildfires already experienced within this region with increasing severity and frequency, trend assumed to continue based on state guidance (California 4th Climate Change Assessment)
Sea Level Rise	4	5	Degree of rise uncertain; however, several estimates include 3 feet by 2050/2060 and potentially 6 feet by 2100 (California Coastal Commission, 2021) (reiterated with NOAA climate data - Sea Level Rise viewer)
Regulatory Change	3	4	Varies by regulation, but higher likelihood to occur with greater passage of time (within 80 years from current year, 2023)

Along with the final likelihood criteria, the Risk Matrix contains a description of the likelihood justification. This information, and full descriptions of the risk events, can be found in the Risk Matrix in Appendix C.

6.3 Level of Service Goals and Consequence Criteria

LoS statements and consequence criteria were determined based on findings from results of the policy review (Section 3). Plans and policies leveraged to support development of these categories, and descriptions provided for LoS statements include the District's mission statement, Business Continuity Plan, and the original 1995 IRP policy criteria, goals, and targets, among others. The LoS statements describe what the District would strive to achieve to maintain the desired LoS. These LoS statements and their corresponding consequence criteria are presented for the purpose of this Phase 1 CAP and are not intended to be applied as LoS for the District as a whole (Table 6-3).

Table 6-3. LoS Goal Statements and Consequence Criteria

Consequence Criteria	LoS Statements Developed for the Phase 1 CAP
Water Delivery	• Maintain reliable and continuous water delivery through the distribution system (from both surface and groundwater resources). • Avoid impacts to revenues associated with water delivery due to planned and unplanned outages from acute climate shocks (e.g., wildfire, storm, flood).
Water Quality	• Maintain drinking water standards and consistent water quality delivered to District customers, regardless of change in temperature and flow for surface water sources. • Maintain groundwater quality and quality monitoring according to minimum threshold criteria per SGMA Five-Year Periodic Evaluation updates.
Water Supply	• Ensure customer demands are met, including current LoS of 90% demand met during drought based on water supply portfolio reliability. • Invest in and collaborate with other agencies on source protection. • Maintain contingency plans for alternative supply options (e.g., transfers/exchanges, recycled water).
Production Facility Reliability and Redundancy	• Provide equipment and facility reliability that minimizes non-emergency downtime and maintains key functions and equipment for system reliability. • Maintain flexibility to meet water quality objectives through multiple facilities and operations.
Financing	• Design, construct, operate, and maintain facilities in a way that minimizes lifecycle costs. • Account for significant facility costs or other unanticipated cost impacts in the case of acute climate shocks (contingency budget and insurance), and costs to prepare for slow-onset climate risks (e.g., drought and SLR).
Environmental Stewardship	• Manage facilities to enable recreational public benefits. • Manage system to support sustainable management of Alameda Creek Watershed.
Safety	• Design, construct, operate, and maintain system facilities to ensure health and safety of workforce and public safety, considering impacts from, for example, enhanced wildfire risk and or flooding.
Equitable Service	• Provide equal access to services across District's service area. • Maintain reasonable water rate pricing.

Each of these consequence criteria and the LoS statements are used to describe what may be important to the District to achieve for future planning. The study considers how climate risk scenarios may impact the ability to achieve these desired criteria in the risk assessment.

Consequence scores were assigned to each consequence criterion for each climate risk scenario. Consequence scores are relative and based on a high-level assessment for the Phase 1 study. A more detailed assessment of consequences may be performed for subsequent planning phases.[13] Consequence scoring is organized on a scale of 1 to 5 with 1 being negligible (little to no impact), 2 as low, 3 as moderate, 4 as high, and 5 as severe impact (an extreme condition) (Table 6-4). These criteria are used to understand relative differences in consequences for different climate risk scenarios.

It is important to note that the development of criteria and the 1 through 5 scores in Table 6-4 were applied to the extent practicable and were supported by discussion and existing data where possible when conducting consequence criteria scoring. Given the high-level nature of this assessment, the descriptions provide an understanding of potential differences between the scores and are used as a helpful reference point that could be further refined to solidify definitive quantitative thresholds for each score and could support future project selection criteria for continued planning efforts.

[13] For example, the water quality criteria could be refined based on existing IRP policy criteria to include specifications for desired hardness (as calcium carbonate) as a determinate of taste (goal of 150 parts per million [average] and 175 parts per million [max]. The District prioritizes health and regulatory water quality.

These criteria were used to understand potential impacts of climate risk scenarios given the District's current plans, actions, and programs. These "current actions" include activities that already help reduce potential impacts from climate risk scenarios and, therefore, contribute to the District's adaptive capacity, which is presented in the Subsection 6.4.

For comparative purposes, the criteria are also used to understand what kind of plans, actions, and programs are not yet implemented but could reduce potential impacts. These activities are adaptation strategies and are evaluated at a later step in this study (Subsection 7.2).

An understanding of how the statements in Table 6-4 support consideration of both current actions and future strategies can be summarized as follows:

- **Water delivery** statements support identifying current actions and future strategies that encourage implementation of robust distribution systems to distribute treated water to customers.
- **Water Quality** statements support identifying current actions and future strategies to secure source water quality.
- **Water Supply** statements address potential current actions and future strategies to secure redundant sources of supply.
- **Production Facility Reliability and Redundancy** statements help identify current actions and future strategies that result in resilient treatment systems.
- **Financing** statements support current actions and future strategies to mitigate monetary costs associated with climate risk events and avoid rate shock.
- **Environmental Stewardship** statements encourage current actions and future strategies to protect sustainable water management for natural systems; they are not supply focused.
- **Safety** statements support identifying current actions and future strategies to protect workers and consumers. These statements are human-health focused (drinking water impacts are accounted for elsewhere).
- **Equitable Service** encourages identifying current actions and future strategies to protect the services for V/DCs in the case of a climate risk event.

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Table 6-4. Consequence Criteria Rating Scale from 1 (negligible) to 5 (severe) Impact					
Consequence Criteria (LoS Category)	Negligible = 1	Low = 2	Moderate = 3	High = 4	Severe = 5
Water Delivery	No more than 1 month per year (≤ 8.3% of months) on average with more than 167 accounts disrupted for 0 to 4 hours	More than 1 month per year (> 8.3% of months) on average with more than 167 accounts disrupted for 0 to 4 hours	More than 1 month per year (> 8.3% of months) on average with more than 40 accounts disrupted for 4 to 12 hours	2 months per year (= 16.6% of months) on average with accounts disrupted for 12+ hours	More than 2 months per year (> 16.6% of months) on average with accounts disrupted for 12+ hours
Water Quality	No impact	Some measurable impact but does not affect ability to meet water quality goals and does not require additional treatment	Minor impact to water quality not meeting District water quality goals	Recognizable impact to water quality not meeting District water quality goals but manageable within existing treatment capability	Extended water quality impact exceeding District's current treatment capability
Water Supply	No to minimal impact (approx. < 5% of supply reduced)	Reduced supply (approx. 5% to 10%)	Reduced supply (approx. >10% up to 20%)	Significantly reduced supply (approx. >25% up to 50%)	Severely reduced supply (approx. >50% up to 100% reduced supply); impacts District deliveries and water quality
Production Facility Reliability and Redundancy	Treatment system outage or significant limitation resolved within 1 day	Treatment system outage or significant limitation resolved in less than 1 month	Treatment system outage or significant limitation resolved in 1 to 3 months	Treatment system outage or significant limitation resolved in 3 to 6 months	Treatment system outage or significant limitation takes 6 months or more to resolve
Financing	Costs resulting from the risk event are less than or equal to a 1% single-year impact on rates, or less than or equal to $22M in resulting capital cost	Costs resulting from the risk event are less than or equal to a 2% single-year impact on rates, or greater than $22M but less than $43M in resulting capital cost	Costs resulting from the risk event are less than or equal to a 4% single-year impact on rates, or greater than $43M but less than $87M in resulting capital cost	Costs resulting from the risk event are less than or equal to a 5% single-year impact on rates, or greater than $87M but less than $109M in resulting capital cost	Costs resulting from the risk event are less than or equal to a 7% single-year impact on rates, or greater than $109M in resulting capital cost
Environmental Stewardship	No harm to public or environmental benefits and sustainability	Some measurable impact to public or environmental benefits but does not result in adverse impacts	Reduced public benefits or some adverse impacts to natural systems	Significant reduction in public benefits or significant adverse impacts to natural systems	Loss of public benefits or substantial adverse impacts to natural systems
Safety	No risk of incident or threat to safety	Measurable risk of incident or threat to safety (one facility or site with safety risk for employees or community served)	Limited risk of incident or threat to safety (one to two facilities or sites with safety risk for employees or community served)	Significant risk of incident or threat to safety (one to two facilities or sites with safety risk for employees or community served)	Multiple facilities or sites with safety risk for employees or community served
Equitable Service	No impact to services accessibility	Limited impact to V/DCs within service area (up to 5% without service or with limited service for more than 1 day)	Moderate impact to V/DCs within service area (>5% up to 10% without service or with limited service for more than 1 day)	Significant impact to V/DCs within service area (>10% up to 20% without service or with limited service for more than 1 day)	Substantial impact to V/DCs within service area (>20% without service or with limited service for more than 1 day)

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6.4 Adaptive Capacity

Adaptive capacity is the combination of the strengths, attributes, and resources available to help prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities from climate change (IPCC, 2012). In this CAP, adaptive capacity includes existing plans, programs, and actions that contribute to the District's ability to adapt or change over time to be better prepared against potential impacts of climate risk scenarios. Table 6-5 summarizes how the CAP defined the adaptive capacity scores of high, medium, and low. Areas in which the District has high adaptive capacity can help reduce the overall consequence of risk events. Existing programs, plans, and actions that enable high capacity were, therefore, taken into consideration when discussing and determining consequence scores for each climate risk scenario.

Table 6-5. Definitions for Adaptive Capacity Rating in the Risk Matrix

Rating	Definition	Examples
High	High capacity to change/adapt to risk; asset or operation can easily be reconfigured without completely rebuilding or revising	Expanding local water supply
Medium	Medium capacity to change/adapt to risk; asset or operation can be reconfigured with renovations or revisions, respectively	Flood proofing at risk facilities (within FEMA flood zone)
Low	Minimal to no capacity to change/adapt to risk without completely rebuilding asset or revising operation	Managing saline intrusion; regulating water temperature in reservoirs

To determine the adaptive capacity to reduce impacts from each climate risk scenario, a list of projects (only those in place or planned) that would improve the impacted assets or operations' adaptive capacity to the risk event were included in the Risk Matrix (Appendix C). These projects were determined by reviewing relevant plans (Section 3), such as the District's Capital Improvement Plan, and through District staff workshops to confirm what projects are already underway or planned to address each scenario. Appendix E summarizes the adaptive capacity activities underway that will contribute to reducing risk event consequences. Many of these activities contribute to more than one climate risk scenario. Table 6-6 provides examples of current programs, plans, and projects that support reducing potential impacts from climate change (adaptive capacity activities) by relevant climate risk scenario. The existing programs, plans, and actions identified in Table 6-6 were leveraged when considering the development of potential impacts to consequence criteria if only current actions continued into the mid- and long-term planning horizons. Specifically, for climate risk scenarios where the District has a potentially high adaptive capacity for confronting and reducing impacts, impacts are assumed to be lower and are likely not going to reflect a value of 5 (the highest relative impact score representing "severe" impacts). This means that the study assumes existing adaptive capacity will likely reduce the potential impact to less than a "severe" impact.

Table 6-6. District Adaptive Capacity Examples	
Climate Threat (including relevant scenarios)	Adaptive Capacities (examples of relevant existing programs, plans, and projects) [a]
Rising Temperatures • Reduced local supply (Scenario 1) • Increased peak demand (Scenario 2) • Water quality degradation (Scenario 6)	• Advanced Metering Infrastructure Water Shortage Contingency Plan • Enhanced stormwater capture for Quarry Lakes • Existing water conservation • Groundwater Replenishment Program • Improved reliability of Newark Desal Facility • Semitropic banking of District's SWP supplies (esp. during wet years) • Water Shortage Contingency Plan (WSCP) • Water supply reliability alternatives • Water Use Efficiency Master Plan (WEMP) • Watershed Protection and Monitoring Program
Sea Level Rise • Saline intrusion in Delta (Scenario 7, linked to flooding) • Non-salinity groundwater contamination mobilization in Niles Cone (Scenario 8) • Saltwater intrusion in Niles Cone (Scenario 9) • Damaged infrastructure or loss of access (Scenario 11)	• Aquifer Reclamation Program (BHF) • Corrosion control • Enhanced groundwater use of AHF • Groundwater Protection Program/Well Ordinance Administration • Improved reliability of Newark Desal Facility • Old Jarvis Road Irrigation Well Destruction Project • Operation of Quarry Lakes replenishment facility • Salinity Barrier Project (Salinity Barrier Wells) • Shinn Pond Rediversion to enhance artificial recharge • Well Ordinance Program
Drought • Reduced imported supplies (Scenarios 3 and 4) • Reduced augmented recharge to Niles Cone (Scenario 10)	Same adaptive capacity items as Rising Temperatures and Enhanced groundwater use of AHF
Wildfire • Water quality degradation in local surface water (Scenario 5) • Damaged infrastructure or loss of access (Scenario 13) • PSPS (Scenario 14)	• Backup power for Water Treatment Plant 2 • Electrical redundancy and reliability for Information Technology systems • Emergency action plans and standard operating procedures • Goat grazing • On-site energy generation • Stationary backup generators and portable generators • Watershed Protection and Monitoring Program • Vegetation management
Storms • Storm intensity damaging infrastructure or causing loss of access (Scenario 12)	• Curtner Road Booster Station Upgrade • Emergency action plans and standard operating procedures • Enhanced stormwater capture for Quarry Lakes • Shinn Pond Rediversion • Water supply reliability alternatives (e.g., Delta levee failure) • Watershed Protection and Monitoring Program • Vallecitos Channel Betterments and Repairs
Regulations • Regulatory/legislative changes (Scenario 15)	• Existing water conservation • Groundwater Replenishment Program • Groundwater SGMA Enhancement Project • Participation in CUWA partnership • Salinity Barrier Project (Salinity Barrier Wells) • Water Shortage Contingency Plan (WSCP) • Water supply reliability alternatives • Water Use Efficiency Master Plan (WEMP)

a. *The full list of relevant adaptive capacity activities is provided in Appendix E. This table includes a short sampling of these activities across climate threats.*

Existing plans, programs, and actions demonstrate previous and existing efforts the District has invested in to become more resilient over its years of operation. The District's existing financial planning includes a range of projects and plans (see Appendix D) that can help establish preventative and preparative measures that reduce the financial impacts of climate change. Financial impacts include affordability as well as "rate shock," or the abrupt increase in water rates for large, unplanned expenses.

In addition to several near-term climate adaptation projects (i.e., advanced metering infrastructure [AMI], corrosion control programs, and enhanced water conservation, among others) the District is making financial plans for three significant future expenses for water supply initiatives which are, in large part, climate change risk reduction measures. The specific projects are the Indirect Potable ReUse Project, partnership in the Los Vaqueros Reservoir Expansion, and the Delta Conveyance Project. In total, the District's anticipated share of costs for these projects is approximately $350 million. While these three projects may not be solely focused on climate change adaptation when ultimately built, inclusion of these costs in financial planning helps ensure that large, climate-driven expenses will not result in rate shock, although these may contribute to affordability pressure.

6.5 Risk Scores with Current Actions Only

Risk scores were determined for each climate risk scenario using the combination of the estimated likelihood scores and consequence criteria scores for mid- (2050) and long-term (2100) planning horizons. Table 6-7 and Table 6-8 provide a list of scenarios from highest to lowest risk scores demonstrated in a colored gradient for the two planning horizons. These scores were also reviewed, and a score sensitivity analysis was conducted after a first and second round of consequence criteria scoring.

Table 6-7. Risk Scores by Climate Risk Scenario for Mid-term Likelihood (ordered high to low)

Scenarios		Mid-term Risk Score
Scenario 15	Regulatory/legislative changes	17.5
Scenario 1	Increasing Temperature: Reduced local supply	16.9
Scenario 2	Increasing Temperature: Increased demand	14.4
Scenario 9	SLR: Saltwater intrusion in Niles Cone	13.8
Scenario 5	Wildfire: Non-salinity water quality degradation in local surface water	13.1
Scenario 3	Drought: Imported supply reductions (SFPUC)	13.1
Scenario 4	Drought: Imported supply reductions (SWP)	12.5
Scenario 10	Drought: Reduced groundwater recharge to Niles Cone	12.5
Scenario 6	Increasing Temperature: Non-salinity water quality degradation in the Delta	12
Scenario 7	Flooding: Saline intrusion in the Delta	11.5
Scenario 8	SLR: Non-salinity groundwater contamination mobilization in Niles Cone	11.5
Scenario 11	SLR: SLR damaging infrastructure or causing access loss	9
Scenario 12	Storm: Storm intensity damaging infrastructure causing access loss	9
Scenario 14	Wildfire: PSPS	9
Scenario 13	Wildfire: Wildfire damaging infrastructure or causing access loss	7.5

The placement of Scenarios 10, 6, 7, 8, and 11 increase when considering the long-term risk score compared to the mid-term risk score.

Table 6-8. Risk Scores by Climate Risk Scenario for Long-term Likelihood (ordered high to low)

Scenarios		Long-Term Risk Score
Scenario 15	Regulatory/legislative changes	21.9
Scenario 1	Increasing Temperature: Reduced local supply	16.9
Scenario 10	Drought: Reduced groundwater recharge to Niles Cone	15.6
Scenario 6	Increasing Temperature: Non-salinity water quality degradation in the Delta	15
Scenario 2	Increasing Temperature: Increased demand	14.4
Scenario 7	Flooding: Saline intrusion in the Delta	14.4
Scenario 8	SLR: Non-salinity groundwater contamination mobilization in Niles Cone	14.4
Scenario 9	SLR: Saltwater intrusion in Niles Cone	13.8
Scenario 5	Wildfire: Non-salinity water quality degradation in local surface water	13.1
Scenario 3	Drought: Imported supply reductions (SFPUC)	13.1
Scenario 4	Drought: Imported supply reductions (SWP)	12.5
Scenario 11	SLR: SLR damaging infrastructure or causing access loss	11.3
Scenario 12	Storm intensity damaging infrastructure or causing access loss	9
Scenario 14	Wildfire: PSPS	9
Scenario 13	Wildfire: Wildfire damaging infrastructure or causing access loss	7.5

Several assumptions were made in this study that influenced the above scoring output. These assumptions include:

- All criteria are equally weighted for this initial study.
- SLR scenarios (Scenarios 8, 9, and 11) reflect a high level of uncertainty for potential damage. These could be refined via further studies.
- The high score for Scenario 15 Regulatory/legislative changes assumes high likelihoods for both the mid- and long-term planning horizons and also assumes that regulatory changes will potentially dramatically impact a broad range of consequence criteria.
- For Scenario 5 Wildfire: Non-salinity water quality degradation, the study assumes high impact for environmental stewardship and significant impact for personnel safety.
- Delta scenarios (Scenarios 6 and 7) do not assume catastrophic Delta failure. These scenarios assume the Delta is still functioning but with reduced pumping and exports.
- The score for Scenario 4 Drought: Imported supply reductions (SWP) is influenced by the current equal weighting scheme for the consequence criteria. The score for this scenario could be refined with adjustments to criteria weighting.

Results of the risk assessment indicated differences between the mid-term and long-term planning horizons as shown on Figure 6-2.

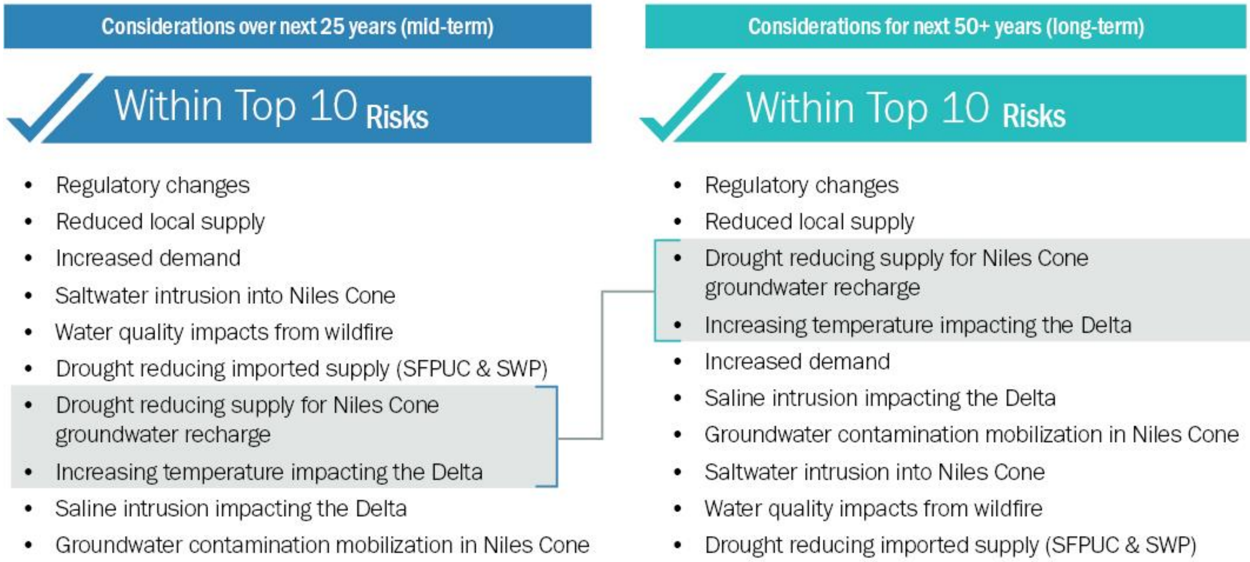

Figure 6-2 Top 10 potential risks for mid- and long-term planning horizons listed by relative importance

The "current actions only" scores were used as a baseline for comparison with potential adaptation strategies (Section 7) and how these might help further reduce potential impacts and overall climate risk. This information can be used and applied within the mid- and long-term planning horizons to consider future adaptation pathways (i.e., when to implement which types of adaptation strategies as conditions change over time), which is the focus of Section 8.

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Section 7

Recommendations for Adaptation Strategies

Adaptation strategies were identified for each of the 15 climate risk scenarios. These strategies help reduce risk from climate threats, which can be seen by the ability of these strategies to reduce climate risk scores. These strategies also help fill gaps in planning for and managing risks that are currently not addressed by existing adaptive capacity. These strategies are broad approaches that can be achieved through multiple plans, projects, and actions. Specific projects or actions within each of these strategies can be considered for further development in future phases of work beyond this CAP.

7.1 Adaptation Strategies

Adaptation is defined as the process of adjusting to actual or expected climate risks and the ability to moderate or avoid harm or exploit beneficial opportunities (IPCC, 2014). An adaptation strategy is defined as a general plan of action for addressing the impacts of climate change, which may include a mix of policies and measures that have the overarching objective of reducing vulnerability to climate change impacts (IPCC, 2014). Adaptation strategies support reducing impacts from possible climate risk scenarios (future conditions) that are described in the vulnerability assessment (Section 5) and analyzed in the risk assessment (Section 6).

Table 7-1 presents the 15 climate risk scenarios and matches them to their applicable adaptation strategies. The strategies have been grouped into eight categories (A to H) and labeled with a letter and number (e.g., “B2 Expand Existing Local/Regional Supplies” is the second strategy in the “B. New or Expanded Supplies” category). Each adaptation strategy addresses multiple climate risks—some more than others. Table 7-1 summarizes the climate risk scenarios and associated adaptation strategies; examples of projects or actions within each adaptation strategy are provided in Table 7-2.

Adaptation strategies are further described in Subsections 7.1.1 to 7.1.8 and were analyzed to understand which of these strategies are low- to no-regret strategies that can be implemented in the near term, which strategies may need to occur within a mid- vs. long-term planning horizon, and which strategies will provide the greatest total benefit. Total benefit is measured using a multi-criteria decision analysis (MCDA) tool (Appendix F, attached as separate Excel document). The use and output of the tool are detailed in Section 7.2. Results indicate which strategies help address multiple climate risk scenario impacts, and which strategies provide multiple benefits (measured in the strategies’ ability to reduce potential impacts to consequence criteria).

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Table 7-1. Adaptation Strategies Identified for Each of the 15 Climate Risk Scenarios

Adaptation Strategies (A - H)

	A. Demand Management		B. New or Expanded Supplies				C. Critical Facilities & Infrastructure Protection			D. Operations						E. Water Quality & Treatment			F. Modeling, Research, and Innovation			G. Watershed and Ecosystem Management		H. Regional Partnerships			
Climate-Related Risk Events (1-15)	A1. Expand short-term (i.e., dry year) conservation efforts	A2. Increase long-term water use efficiency measures	B1. Develop new local/ regional supplies	B2. Expand existing local/ regional supplies	B3. Secure new imported (non-local) supplies	B4. Bolster existing imported supplies	C1. Capital projects to increase resilience (new or rehabilitated)	C2. Improve emergency preparedness	C3. Response protocol/ procedures	D1. New or expanded surface storage	D2. Increase groundwater recharge/storage: Local (Niles Cone)	D3. Increase groundwater recharge/storage: Banked (Semitropic)	D4. Adjust dry year operating rules	D5. Improve distribution system flexibility	D6. Expand monitoring and remote operations	E1. Mitigate/treat groundwater contamination	E2. Reservoir water quality management	E3. Adjust or expand surface water treatment	F1. Model climate impacts on surface water	F2. Model climate impacts on groundwater	F3. Implement real-time weather monitoring and forecasting	G1. Implement green infrastructure and nature-based solutions	G2. Invest in forest/ vegetation management	H1. SF Bay shoreline partnerships	H2. Delta partnerships	H3. Bay Area regional supply partnerships	H4. Alameda Creek Watershed partnership
1. Reduced local supply	●	●	●	●	●	●				●	●	●	●	●							●	●				●	
2. Increased demand	●	●	●	●	●	●				●	●	●	●	●							●	●				●	
3. Imported supply reductions (SFPUC)	●	●	●	●	●					●	●	●	●	●		●										●	
4. Imported supply reductions (SWP)	●	●	●	●	●	●				●	●		●	●											●	●	
5. Non-salinity water quality degradation in local surface water (e.g., wildfire)															●		●	●	●			●	●				●
6. Non-salinity water quality degradation in the Delta			●	●														●	●						●	●	
7. Saline intrusion in the Delta			●	●															●						●	●	
8. Non-salinity groundwater contamination in Niles Cone			●		●	●						●			●	●				●		●	●			●	
9. Saltwater intrusion in Niles Cone	●	●	●	●	●	●					●	●			●	●				●		●		●		●	
10. Reduced groundwater recharge to Niles Cone	●	●	●		●	●					●	●							●	●	●	●				●	
11. Sea level rise damaging infrastructure or loss of access							●	●	●					●	●							●		●			
12. Storm intensity damaging infrastructure or loss of access							●	●	●					●	●						●	●		●			●
13. Wildfire damaging infrastructure or loss of access							●	●	●					●	●						●	●	●				●
14. Public Safety Power Shutoff								●	●														●				
15. Regulatory/ legislative changes	●	●	●	●						●	●					●			●	●		●		●	●	●	●

Table 7-2. Examples of Each Adaptation Strategy

Adaptation Strategies & Examples (A-D)

Adaptation Category	A. Demand Management		B. New or Expanded Supplies				C. Critical Facilities & Infrastructure Protection			D. Operations					
Adaptation Strategy	**A1. Expand short-term (i.e., dry year) conservation efforts**	**A2. Increase long-term water use efficiency measures**	**B1. Develop new local/ regional supplies**	**B2. Expand existing local/ regional supplies**	**B3. Secure new imported (non-local) supplies**	**B4. Bolster existing imported supplies**	**C1. Capital projects to increase resilience (new or rehabilitated)**	**C2. Improve emergency preparedness**	**C3. Response protocol/ procedures**	**D1. New or expanded surface storage & conveyance**	**D2. Increase groundwater recharge/ storage: Local (Niles Cone)**	**D3. Increase groundwater recharge/ storage: Banked (Semitropic)**	**D4. Adjust dry year operating rules**	**D5. Improve distribution system flexibility**	**D6. Expand monitoring and remote operations**
Examples	Drought messaging campaign, drought surcharge/ penalties	Rebates/ retrofits, leak detection, targeted messaging based on AMI data	Water reuse, regional desalination, BARR, Los Vaqueros Reservoir capacity	Expand brackish groundwater desalination, increase Alameda Creek diversions, and use of AHF aquifer	Short or long-term transfer	Delta Conveyance	New interties, standby wells	Fire protection measures, backup pumps/ generators, stockpiling chemicals	Emergency response training, mutual aid agreement for fuel	Los Vaqueros Reservoir, Transfer-Bethany Pipeline, SBA improvements, Lake Del Valle reoperation	Increase recharge of Niles Cone via Quarry Lakes, with new or existing water supply source (e.g., IPR)	Bank more SWP supply in Semitropic	Flex use of dry year reserves	Distribution system enhancements (e.g., to enable supplies to serve different parts of service area)	SLR, saltwater intrusion, corrosion

Adaptation Strategies & Examples (E-H) (cont.)

Adaptation Category	E. Water Quality & Treatment			F. Modeling, Research, and Innovation			G. Watershed and Ecosystem Management		H. Regional Partnerships			
Adaptation Strategy	**E1. Mitigate/ treat groundwater contamination**	**E2. Reservoir water quality management**	**E3. Adjust or expand surface water treatment**	**F1. Model climate impacts on surface water**	**F2. Model climate impacts on groundwater**	**F3. Implement real-time weather monitoring and forecasting**	**G1. Implement green infrastructure and nature-based solutions**	**G2. Invest in forest/ vegetation management**	**H1. SF Bay shoreline partnerships**	**H2. Delta partnerships**	**H3. Bay Area regional supply partnerships**	**H4. Alameda Creek Watershed partnership**
Examples	Prevent contaminant mobilization, mitigate saltwater intrusion, install PFAS/ hardness treatment, reverse osmosis	Aeration/ mixing	New treatment measures to address shifting Delta water quality, wildfire impacts	Evaluate Delta and local reservoir water quality changes	Simulate impacts on Niles Cone (e.g., saltwater intrusion, contaminant mobilization)	Forecast Informed Reservoir Operations at Lake Del Valle, monitoring conditions in fire-prone areas	Improve drainage and runoff capture, prevent flooding, restore habitat (e.g., beavers)	Selective tree and brush removal (e.g., fuel treatments)	Shoreline protection, SLR, land use planning	Delta Stewardship Council	Bay Area Regional Reliability (BARR), Los Vaqueros JPA, BAWSCA, SGMA, local water agencies, SF RWQCB	Alameda County Flood Control and Water Conservation District, Alameda Creek Alliance

The following sections outline each major adaptation category and describe the suite of adaptation strategies and examples included within each category.

7.1.1 Strategy A: Demand Management

Demand management includes strategies to reduce water use on a temporary (short term) or more permanent basis. Adaptation strategies to help mitigate the risk of increased climate-driven demand and help adapt to reduced water supplies include:

- **A1. Expand new short-term (e.g., dry year) conservation efforts,** such as enhanced drought messaging or increasing drought surcharges/penalties and water use restrictions. These efforts help reduce water use during drought or other emergency conditions.
- **A2. Increase long-term water use efficiency measures,** such as rebates for water-efficiency fixtures and landscape retrofits, improved leak detection, and other efforts that produce long-term water savings. For example, the District is already planning to leverage AMI data to identify potential leaks or water use anomalies to target customer messaging.[14]

7.1.2 Strategy B: New or Expanded Supplies

While the District already has a diverse supply portfolio, certain supplies could be further expanded and/or new supplies could be explored to mitigate risks associated with increasing demands and reduced water supplies. Adaptation strategies include:

- **B1. Develop new local/regional supplies,** such as water reuse or regional desalination and increase the District's share of storage in the Los Vaqueros Reservoir. Continuing to participate in the BARR partnership will help further advance regional supply efforts.
- **B2: Expand existing local/regional supplies,** such as developing new brackish groundwater treatment facilities in other parts of the service area, adjusting Alameda Creek diversions to capture greater peak flows, and expanding the use of the AHF aquifer for groundwater supply.
- **B3. Secure new imported (non-local) supplies,** such as a short- or long-term water transfer from another SWP contractor or other agency.

7.1.3 Strategy C: Critical Facilities and Infrastructure Protection

Critical facilities and infrastructure protection includes strategies to prepare and protect critical infrastructure from climate risks, such as loss of access or facility damage from flooding or wildfires. Adaptation strategies include:

- **C1. Capital projects to increase resilience (new or rehabilitated),** such as constructing new interties or standby wells.
- **C2. Improve emergency preparedness through policies or operations and maintenance measures,** such as increased fire protection at critical sites (e.g., installing automated sprinklers or keeping a fire barrier wrap on site), maintaining backup pumps/generators, and stockpiling chemicals.
- **C3. Response protocol/procedures that could be implemented in the event of an acute shock or disaster,** such as emergency response protocols and tools and mutual aid agreements for fuel. This can also include emergency response training that takes place prior to an acute shock.

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[14] AMI is an integrated system of smart meters, data management systems and communication networks that enable two-way communication between the utilities and the customers.

7.1.4 Strategy D: Operations

The operations category includes strategies and policies to mitigate a variety of climate risks by expanding storage and operational flexibility. Adaptation strategies include:

- **D1. New or expanded surface storage and conveyance,** such as the Los Vaqueros Reservoir Expansion and the new Transfer-Bethany Pipeline, improving SBA conveyance capacity, or re-operating Lake Del Valle (i.e., adjusting the flood pool to allow more supply storage).
- **D2. Increase groundwater recharge/storage: Local (Niles Cone),** which includes increased recharge via Quarry Lakes with new or expanded supply sources (e.g., purified water).
- **D3. Increase groundwater recharge/storage: Banked (Semitropic),** which includes banking more SWP water supply in Semitropic.
- **D4. Adjust dry year operating rules** to allow flexible use of dry year groundwater reserves.
- **D5. Improve distribution system flexibility,** such as new pipelines or pump stations that enable the District to serve larger parts of the service area with different supply sources.
- **D6. Expand monitoring and remote operations,** such as monitoring for SLR, saltwater intrusion, and pipeline corrosion (beyond current efforts) in Niles Cone or enhancing remote operation of treatment facilities to mitigate risks associated with loss of facility access.

7.1.5 Strategy E: Water Quality and Treatment

Water quality and treatment includes strategies and policies that focus on improving and protecting surface water and groundwater quality and mitigating risks from contamination, saltwater intrusion, and rising temperatures. Adaptation strategies include:

- **E1. Mitigate/treat groundwater contamination,** e.g., by preventing contaminant mobilization, mitigating saltwater intrusion, installing PFAS treatment, and exploring reverse osmosis treatment for hardness and other constituents.
- **E2. Reservoir water quality management,** such as aeration/mixing and nutrient management to mitigate for dissolved oxygen loss.

7.1.6 Strategy F: Modeling, Research, and Innovation

The modeling, research, and innovation category includes strategies and policies that improve modeling of future climate impacts, such as changes in surface and groundwater quality, reservoir evaporation rates, saltwater intrusion, and contaminant mobilization, along with weather forecasting, to improve real-time operational decisions. Adaptation strategies include:

- **F1. Model climate impacts on surface water,** which includes evaluating changes to the Delta, Alameda Creek watershed, and local reservoirs.
- **F2. Model climate impacts on groundwater,** including simulating impacts on Niles Cone (e.g., modeling saltwater intrusion, contaminant mobilization, and surface-groundwater interactions).
- **F3. Implement real-time weather monitoring and forecasting,** such as Forecast Informed Reservoir Operations (FIRO) at Lake Del Valle or monitoring conditions in fire-prone areas.

7.1.7 Strategy G: Watershed and Ecosystem Management

Watershed and ecosystem management include strategies that leverage use of nature-based solutions, such as green infrastructure, to improve water quality, manage flooding, capture stormwater, and reduce wildfire risk. Adaptation strategies include:

- **G1. Implement green infrastructure and nature-based solutions** to improve drainage and runoff capture, prevent flooding, and restore habitat (e.g., see "How beavers support nature-based adaptation" callout box). Green infrastructure can improve water quality by managing excess nutrients or contaminants and can help mitigate urban heat island effect and retain moisture to protect against wildfires.
- **G2. Invest in forest/vegetation management,** such as selective tree and brush removal in the Alameda Creek Watershed to reduce a fuel source for wildfires and create buffer zones around critical facilities.

How beavers support nature-based adaptation:

An extensive scientific review supported by California's Fourth Climate Change Assessment found that reducing tree density and restoring beneficial fire can improve long-term resilience to California's forests.

Beavers have been found to help address wildfire risk since they can dramatically increase the wetted area of a stream—by up to 1300% in just a couple of years—which provides cool water refugia not only for themselves but for other wildlife during wildfires and decreases wildfire risk or spread. Beavers can also help reduce urban heat island effect, increase areas for infiltration, increase water quality benefits, and improve biodiversity.

Historic beaver populations used to exist on Alameda Creek, but this is not currently the case. Unique tools exist to prevent beavers from clogging culverts or creating high flood waters, and urban beaver populations exist in harmony with the community in Martinez, California.

7.1.8 Strategy H: Regional Partnerships

Although many of the strategies in categories A through G involve regional partnerships, there are several specific partnerships worth noting as standalone climate adaptation strategies. The following strategies include coalitions or partnerships with other agencies, nonprofits, utilities, and government entities:

- **H1. San Francisco Bay shoreline partnerships,** which include partnerships with other agencies, cities, and land use planning agencies that border the San Francisco Bay, that focus on protecting and managing the shoreline, understanding SLR impacts, and incorporating climate-smart development into land use.
- **H2. Delta partnerships, such as working with the Delta Stewardship Council,** Delta Protection Commission, State Water Contractors, and other stakeholder groups to monitor, manage, and adapt to changing Delta conditions.
- **H3. Bay Area regional supply partnerships,** to explore and implement regional water supply reliability solutions, such as through BARR, Los Vaqueros Joint Powers Authority, and the Bay Area Water Supply & Conservation Agency. This strategy also includes coordinating with the San Francisco Regional Water Quality Control Board (SF RWQCB) and neighboring entities through SGMA.
- **H4. Alameda Creek Watershed partnerships,** such as partnering and coordinating with the Alameda County Flood Control and Water Conservation District, Alameda Creek Alliance, and East Bay Regional Park District on strategies that impact Alameda Creek watershed.

7.2 Multi-criteria Decision Analysis for Adaptation Recommendations

To provide recommendations for preferred adaptation strategies, the CAP leveraged a decision-support framework that enables developing and weighting multiple criteria and encourages engagement with stakeholders in the decision-making process. In this Phase 1 study, stakeholders included District staff from several departments; the participant pool can be expanded to include other stakeholder groups in future updates and planning efforts. The steps of the decision-support process are outlined on Figure 7-1.

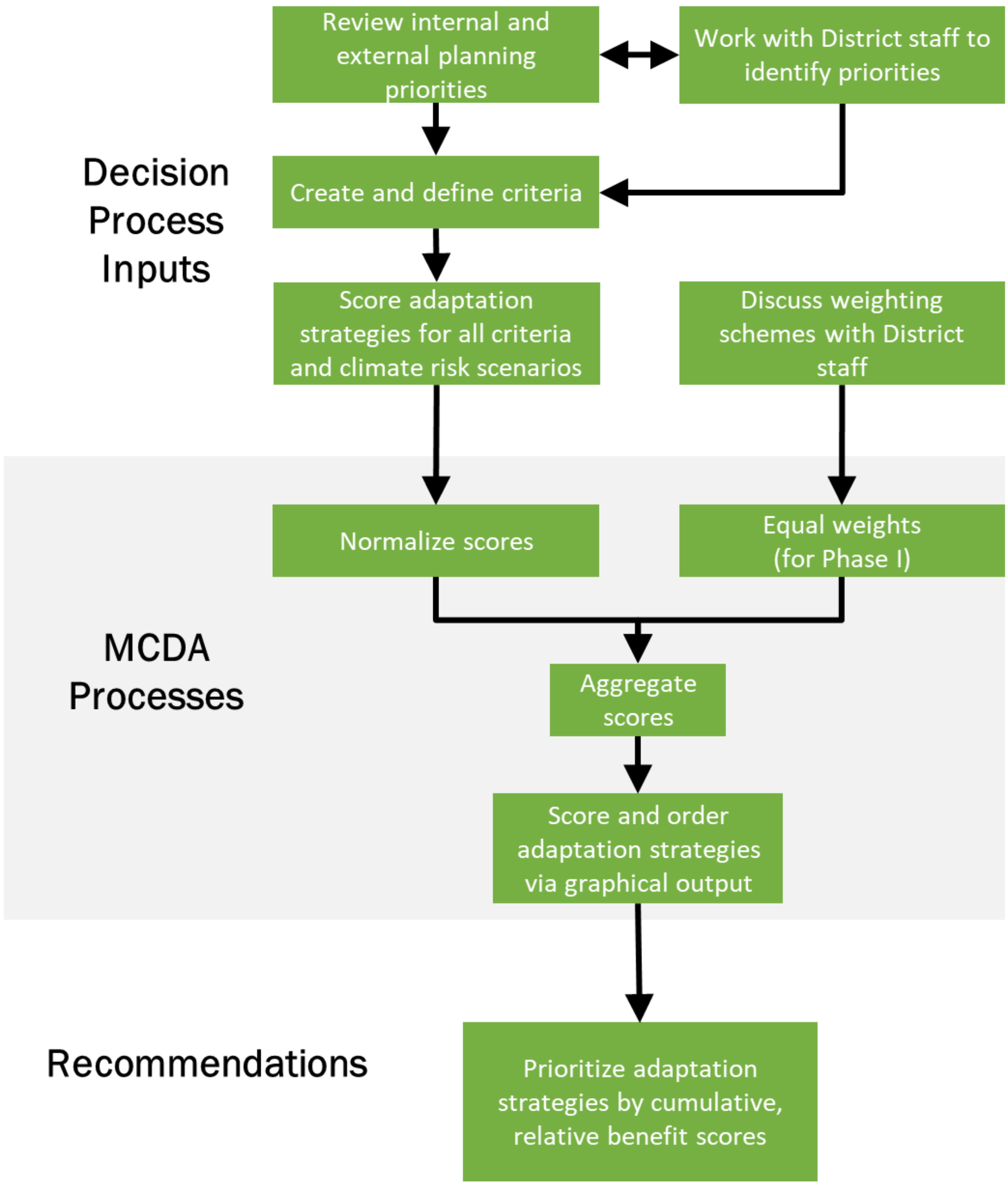


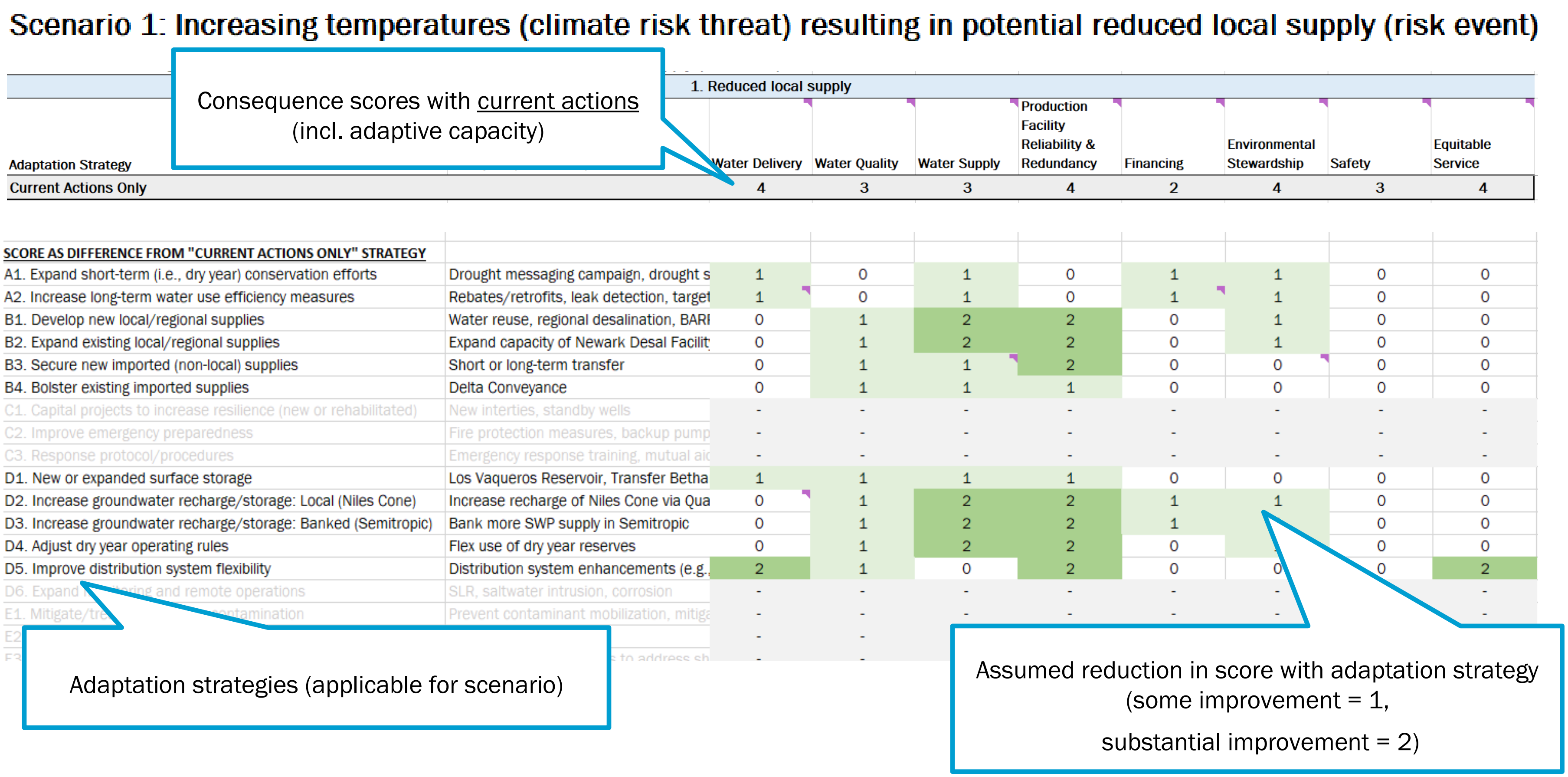
Figure 7-1. MCDA decision support process flow diagram

Information based on the internal and external policy review (Section 3) and collaborative workshops with District staff supported identifying and defining consequence criteria (Section 6.3). Scores were given to each criterion for the 15 scenarios. These scores were used to provide a high-level, relative understanding of impacts represented by an overall risk score for mid- and long-term planning horizons for each climate risk scenario if no additional action is taken (the “current actions only” case) (Section 6.5).

The study then considered how applicable adaptation strategies could reduce potential impact for each criterion. The total potential reduction of impacts across each criterion is considered the benefit an adaptation strategy provides for a given climate risk scenario.

7.2.1 Scoring Process

Potential impact reduction for each consequence criterion were qualitatively represented by reducing scores by a value of 1 for strategies that would provide “some improvement” and reducing scores by a value of 2 for strategies that could provide “substantial improvement.” This process is documented in a separate spreadsheet in Appendix G (attached as a separate Excel document) and is demonstrated in a screenshot presented on Figure 7-2.



Adaptation Strategy		1. Reduced local supply: Water Delivery	Water Quality	Water Supply	Production Facility Reliability & Redundancy	Financing	Environmental Stewardship	Safety	Equitable Service
Current Actions Only		4	3	3	4	2	4	3	4
SCORE AS DIFFERENCE FROM "CURRENT ACTIONS ONLY" STRATEGY									
A1. Expand short-term (i.e., dry year) conservation efforts	Drought messaging campaign, drought s	1	0	1	0	1	1	0	0
A2. Increase long-term water use efficiency measures	Rebates/retrofits, leak detection, target	1	0	1	0	1	1	0	0
B1. Develop new local/regional supplies	Water reuse, regional desalination, BARI	0	1	2	2	0	1	0	0
B2. Expand existing local/regional supplies	Expand capacity of Newark Desal Facilit	0	1	2	2	0	1	0	0
B3. Secure new imported (non-local) supplies	Short or long-term transfer	0	1	1	2	0	0	0	0
B4. Bolster existing imported supplies	Delta Conveyance	0	1	1	1	0	0	0	0
C1. Capital projects to increase resilience (new or rehabilitated)	New interties, standby wells	-	-	-	-	-	-	-	-
C2. Improve emergency preparedness	Fire protection measures, backup pump	-	-	-	-	-	-	-	-
C3. Response protocol/procedures	Emergency response training, mutual aic	-	-	-	-	-	-	-	-
D1. New or expanded surface storage	Los Vaqueros Reservoir, Transfer Betha	1	1	1	1	0	0	0	0
D2. Increase groundwater recharge/storage: Local (Niles Cone)	Increase recharge of Niles Cone via Qua	0	1	2	2	1	1	0	0
D3. Increase groundwater recharge/storage: Banked (Semitropic)	Bank more SWP supply in Semitropic	0	1	2	2	1	[illegible]	0	0
D4. Adjust dry year operating rules	Flex use of dry year reserves	0	1	2	2	0	[illegible]	0	0
D5. Improve distribution system flexibility	Distribution system enhancements (e.g.,	2	1	0	2	0	0	0	2
D6. Expand [illegible] and remote operations	SLR, saltwater intrusion, corrosion	-	-	-	-	-	-	[illegible]	-
E1. Mitigate/tre[illegible] contamination	Prevent contaminant mobilization, mitiga	-	-	-	-	-	-	[illegible]	-
E2 [illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E3 [illegible]	[illegible] to address sh	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 7-2. Screenshot from analysis of adaptation strategies' potential to reduce climate risk impacts

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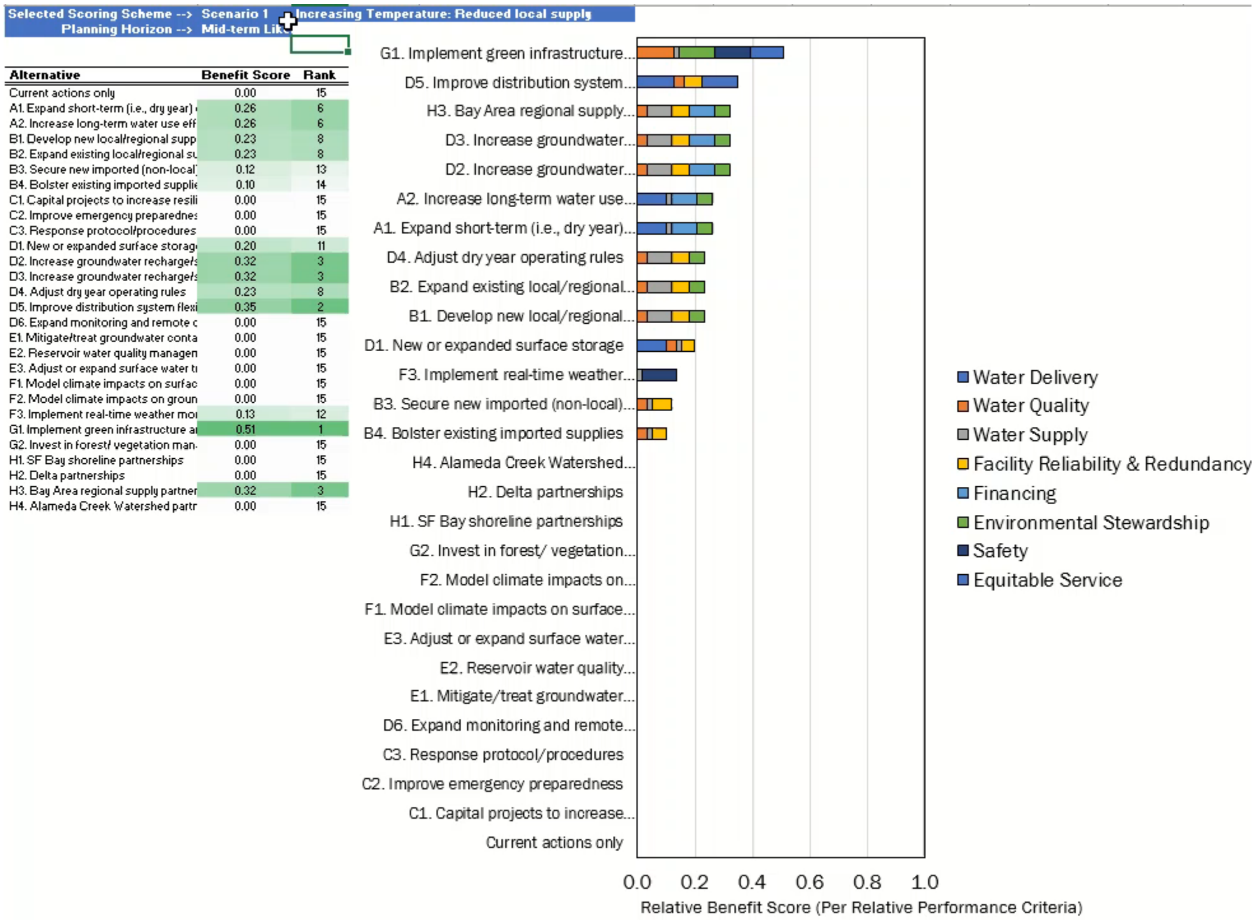
The reduced consequence criteria scores were input into the MCDA tool for each climate risk scenario. This tool is provided to District staff for future use. The qualitative reduced consequence scores were normalized in the MCDA tool by determining the percentile of a selected adaptation strategy's benefits compared with other adaptation strategies for each qualitative criterion, thus avoiding pitfalls associated with qualitative criteria (Cinelli et al., 2021). Specifically for qualitative scores, the order-of-magnitude difference in scores assigned may not represent the magnitude difference in relative benefit (e.g., a 2 is not necessarily two times better than a 1 in a qualitative scoring framework), which makes the percentile approach a more accurate representation of the known relative benefits of one alternative over another. This approach identifies the relative performance (measured in the potential to reduce consequence scores) across different adaptation strategies. High consequence scores were inverted so that high consequence scores received low relative benefit scores. For example, consequence scores of 5 were translated to 1/5 for the MCDA, and scores of 1 were translated to 1/1. This ensured that lower consequences were associated with higher relative benefit.

Normalized scores were multiplied by their component weights, which are equally weighted in this study, and summed to represent their aggregate benefit. Figure 7-3 shows an example from the results of the MCDA tool of strategies prioritized in order of highest to lowest benefit for Scenario 1: Increasing Temperatures (climate threat), Reduced Local Supply (risk event) with a mid-term planning horizon. The figure demonstrates how one can select from one of the 15 climate risk scenarios and select whether to consider a mid- or long-term planning horizon. The output represented in a bar chart provides the relative benefits of each adaptation strategy across the consequence criteria (i.e., water delivery, water quality, water supply, facility reliability and redundancy, financing, environmental stewardship, and equitable service).



Alternative	Benefit Score	Rank
Current actions only	0.00	15
A1. Expand short-term (i.e., dry year)	0.26	6
A2. Increase long-term water use eff	0.26	6
B1. Develop new local/regional supp	0.23	8
B2. Expand existing local/regional su	0.23	8
B3. Secure new imported (non-local)	0.12	13
B4. Bolster existing imported supplie	0.10	14
C1. Capital projects to increase resili	0.00	15
C2. Improve emergency preparednes	0.00	15
C3. Response protocol/procedures	0.00	15
D1. New or expanded surface storag	0.20	11
D2. Increase groundwater recharge/s	0.32	3
D3. Increase groundwater recharge/s	0.32	3
D4. Adjust dry year operating rules	0.23	8
D5. Improve distribution system flexi	0.35	2
D6. Expand monitoring and remote c	0.00	15
E1. Mitigate/treat groundwater conta	0.00	15
E2. Reservoir water quality managen	0.00	15
E3. Adjust or expand surface water t	0.00	15
F1. Model climate impacts on surfac	0.00	15
F2. Model climate impacts on groun	0.00	15
F3. Implement real-time weather mo	0.13	12
G1. Implement green infrastructure a	0.51	1
G2. Invest in forest/ vegetation man	0.00	15
H1. SF Bay shoreline partnerships	0.00	15
H2. Delta partnerships	0.00	15
H3. Bay Area regional supply partner	0.32	3
H4. Alameda Creek Watershed partr	0.00	15

Figure 7-3. Example assessment for the relative benefit of adaptation strategies for Scenario 1: Increasing Temperature: Reduced Local Supply

This output provides the user with an indication of the relevant adaptation strategies and which of these strategies may provide greater potential benefit compared to other strategies. As a result of this scoring process and employed methods, the relative added benefits compared to the current-actions-only case were identified for every adaptation strategy across every scenario.

As identified on Figure 7-4, no single adaptation strategy provides an added benefit under every scenario; however, some adaptation strategies are expected to provide significant relative benefits under multiple scenarios. This may be seen by viewing the summation of relative benefit scores for adaptation strategies in each scenario multiplied by their likelihood. Figure 7-4 and Figure 7-5 demonstrate this using the mid- and long-term planning horizons, respectively, for each scenario.

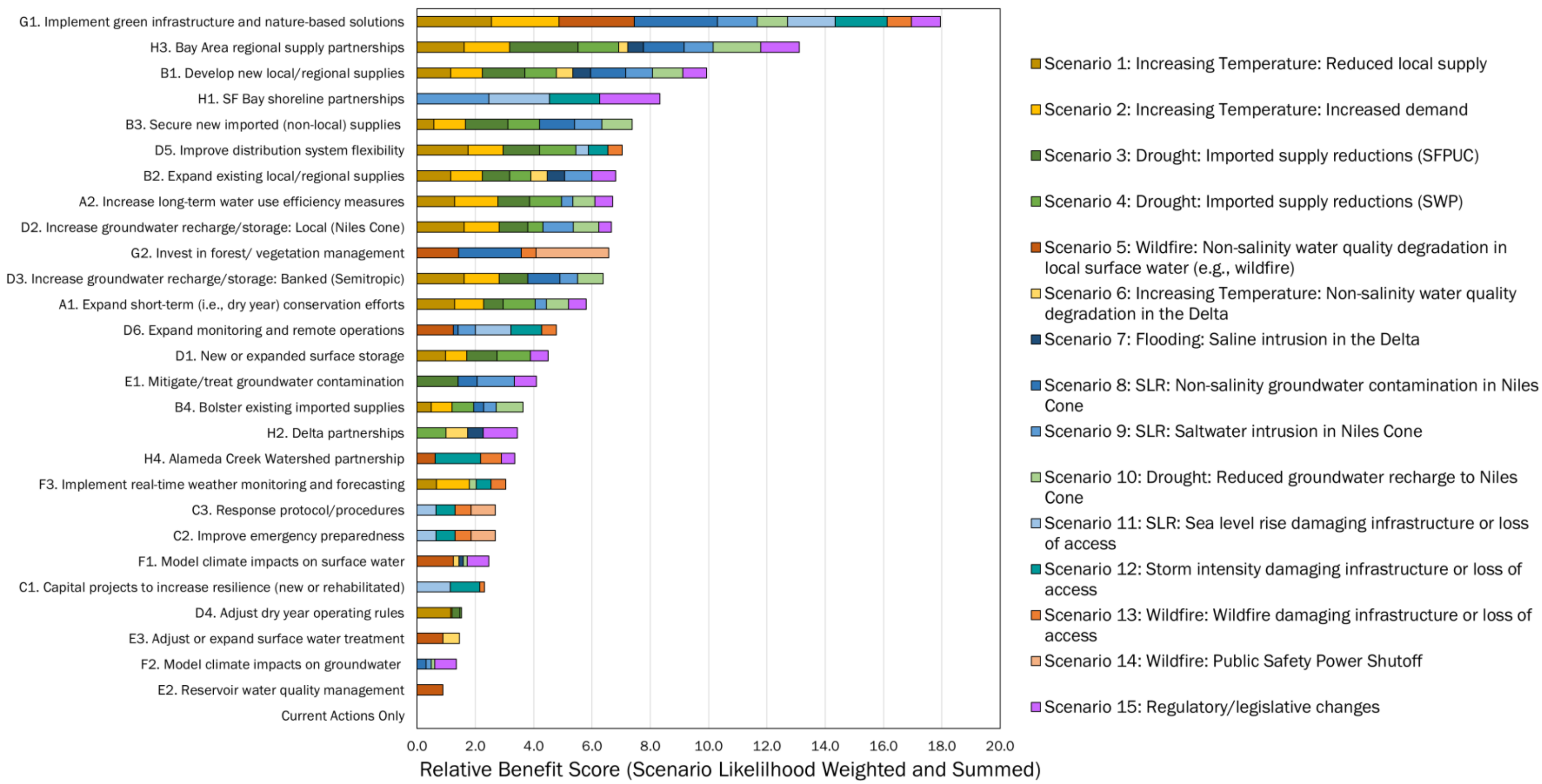


Figure 7-4. Mid-term likelihood weighted summation of individual scenario relative benefit scores

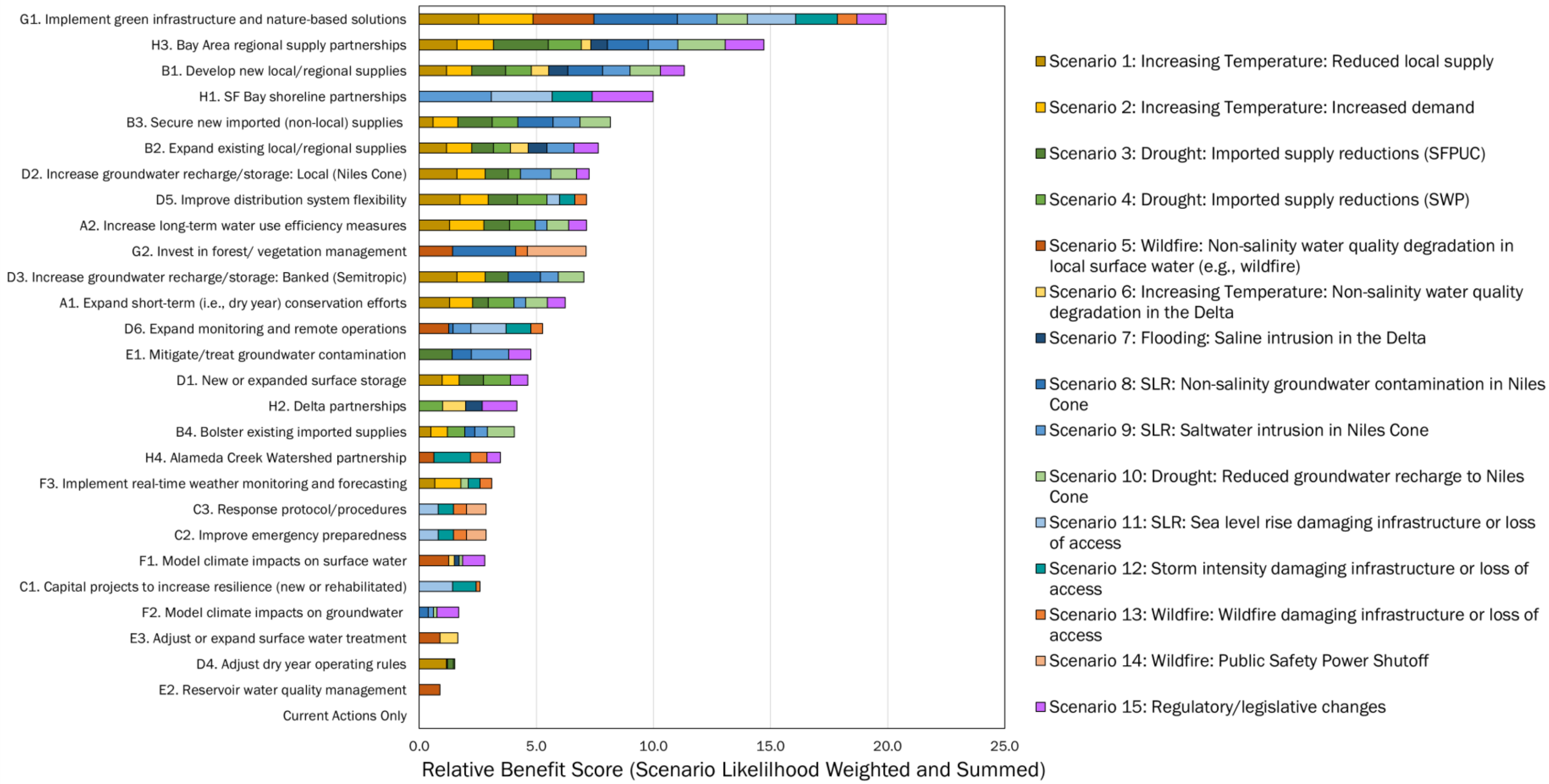


Figure 7-5. Long-term likelihood weighted summation of individual scenario relative benefit scores.

Figure 7-4 and Figure 7-5 also indicate a wide range of potential benefits across adaptation strategies, with some strategies providing benefits across multiple scenarios (the multi-benefit strategies) and some providing benefits to a limited set of specific scenarios (focused or strategic strategies). The left-hand side of the figures provides the list of adaptation strategies arranged with greatest cumulative benefit at the top. Comparing the lists across the two figures demonstrates the difference between which strategies may provide more benefit when considering a mid- vs. a long-term planning horizon. Differences between the two planning horizons are noted in the next section on scenario evaluation results.

7.2.2 Scenario Evaluation Results

Several observations were made for the criteria scoring results, including differences between potential benefits using a mid- vs. a long-term planning horizon, identification of multi-benefit strategies, identification of low- to no-regret strategies, and general trends observed for various climate risk scenarios and consequence criteria.

Mid- to long-term comparison: Comparing between mid- and long-term results indicates that the top five performing strategies (those with the highest cumulative, relative benefit compared to other strategies) remain the same for both mid- and long-term. These include:

- G1: Implement green infrastructure and nature-based solutions
- H3: Bay Area regional supply partnerships
- B1: Develop new local/regional supplies
- H1: San Francisco Bay shoreline partnerships
- B3: Secure new imported (non-local) supplies

A few strategies have a notable change in relative cumulative benefit from mid- to long-term likelihood:

- B2: Expand existing local/regional supplies (shifted up)
- D5: Improve distribution system flexibility (shifted down)
- A2: Increase long-term water use efficiency measures (shifted down)
- D2: Increase groundwater recharge/storage: Local (Niles Cone) (shifted up)

The above strategies that “shifted up” indicate that these could produce a greater relative, cumulative benefit in the long-term planning horizon compared to the mid-term planning horizon. In contrast, those strategies that “shifted down” indicate that these strategies have slightly less cumulative benefit relative to other strategies in the long-term.

Multi-benefit strategies: Nearly all strategies included in the analysis benefit more than one climate risk scenario. However, strategies that perform well across the highest number of scenarios and, therefore, demonstrate high potential for multi-benefit strategies, included:

- G1: Implement green infrastructure and nature-based solutions (10 scenarios)
- H3: Bay Area regional supply partnerships (10 scenarios)
- B1: Develop new local/regional supplies (10 scenarios)
- B2: Expand existing local/regional supplies (8 scenarios)

Some honorable mentions include B3: Secure new imported (non-local) supplies, D2: Increase groundwater recharge/storage (Local, Niles Cone), D5: Improve distribution system flexibility, A1: Expand new short-term (e.g., dry year) conservation efforts, and A2: Increase long-term water use efficiency measures. These were all applicable to (i.e., assumed to benefit) seven scenarios.

Low- to no-regret strategies: Many strategies can also be considered low- to no-regret strategies, which provide a benefit to the District regardless of whether the impacts from climate risk scenarios occur. These strategies include (arranged by modeling and monitoring efforts, conservation and efficiency efforts, partnerships, and green infrastructure and nature-based solutions):

- F2: Model climate impacts on groundwater
- D6: Expand monitoring and remote operations
- A1: Expand new short-term (e.g., dry year) conservation efforts
- A2: Increase long-term water use efficiency measures
- H1: San Francisco Bay shoreline partnerships
- H3: Bay Area regional supply partnerships
- G1: Implement green infrastructure and nature-based solutions

Limited strategies for equitable services criteria: As a general observation, not many strategies identified in this analysis provide benefits to support the equitable service consequence criteria; however, some of these scores could be adjusted in the future depending on what kinds of actions or projects are implemented and where these are implemented. For example, for Scenario 11 (SLR damaging infrastructure or loss of access), the adaptation strategy C1: Capital projects to increase resilience (new or rehabilitated) could benefit V/DCs depending on the location of the capital project site. Scoring assumptions generally assumed that adaptation strategy D5: Improve distribution system flexibility would improve equitable services across scenarios given the focus on providing and maintaining service to all parts of the District's service area.

Specific scenario observations that point to further studies needed:

- For Scenario 8 (SLR causing water quality changes in Niles Cone), the analysis does not currently integrate benefits of existing Regional Water Board partnerships that are addressing this issue within one of the current adaptation strategies. More information may be needed to better grasp the impact of these collaborative efforts for this scenario. This may include, for example, potential quantifiable benefits and understanding the extent to which the potential contamination mobilization issue is mitigated through actions with existing partnerships.
- For Scenario 9 (SLR causing saline intrusion into Niles Cone), the relationship between SLR and saline intrusion into the basin is not well understood. This item is flagged as a data gap and requires further study.
- Across various scenarios, there is an observable overlap between adaptation strategies D6 (expand monitoring and remote operations) and F2 (model climate impacts on groundwater). This overlap depends on what is being modeled. For example, in F2, if saltwater intrusion is modelled (as suggested in the above bullet), this strategy may provide guidance for expanding monitoring operations in D6. This depends on the monitoring strategy.
- **Assumed benefits for green infrastructure and nature-based solutions across the board:** G1 (Green infrastructure and nature-based solutions) is assumed to provide benefits across a high number of scenarios and also have the highest relative, cumulative benefit. A callout box (below) provides additional reference information for the green infrastructure part of this adaptation strategy (see also previous callout box in this section on how beavers support nature-based solutions).

How green infrastructure supports climate resilience:

Green infrastructure refers to vegetated or permeable systems that mimic natural processes to slow, store, infiltrate, and evapotranspire rainfall; manage flooding; reduce urban heat islands; and protect coastal areas. On a city or county scale, green infrastructure can create a patchwork of natural areas that act to treat or remove pollutants in stormwater runoff, infiltrate rainfall into groundwater basins, reduce air pollution, mitigate carbon, cool the air by increasing evapotranspiration, as well as create habitat refugia and improve neighborhoods with additional park space and trees. The figure below shows green infrastructure implemented at a site scale.

Examples of green infrastructure:

Rain gardens, also called bioretention systems, act to filter, store, and infiltrate rain.

Bioswales are similar to rain gardens but are linear: more like a constructed, vegetated creek system.

Green or vegetated roofs or walls use special media to cover building rooftops or walls with plantings. Green roofs reduce the energy needed for cooling on the floor below the roof by more than 50 percent (NRDC, 2012).

Constructed wetlands can be used to capture and treat stormwater or wastewater and can be installed along rivers as a flood mitigation strategy to restore natural floodplains.

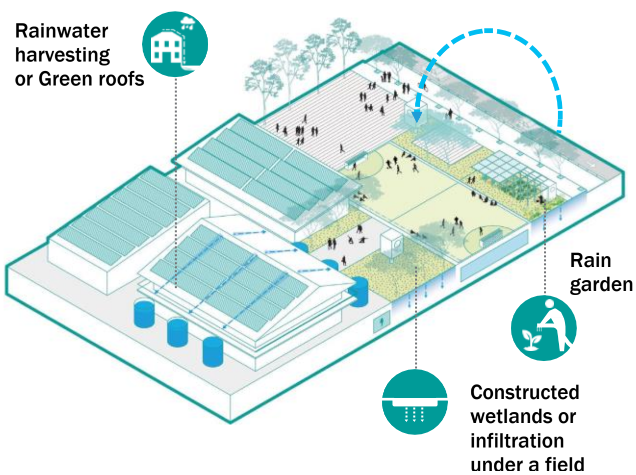
Trees and restoration of urban or suburban tree canopy are simple green infrastructure interventions that create shade and mitigate carbon, among countless other benefits.

Permeable pavement and other non-vegetated infiltration systems can replace traditional pavement and reduce flooding while keeping polluted runoff out of waterways.

Rainwater harvesting can be implemented under parking lots or sports fields, adjacent to residences, and in commercial/industrial buildings to capture and reuse rainwater.

Reference:

NRDC, "Looking Up: How Green Roofs and Cool Roofs Can Reduce Energy Use, Address Climate Change, and Protect Water Resources in Southern California" June 2012 R:12-06-B. https://www.nrdc.org/sites/default/files/GreenRoofsReport.pdf



Analysis of high-risk individual climate risk scenarios: Table 7-3 summarizes the relevant adaptation strategies for the 10 highest climate risk scenarios from highest to lowest risk for the long-term planning horizon. The summary identifies the range of applicable adaptation strategies and consequence criteria that may receive the most benefit from implementing these strategies for the given climate risk scenario.

Table 7-3. Adaptation Strategies for 10 Highest Climate Risk Scenarios from Highest to Lowest Risk (long-term)

Scenario ID#	Climate Risk Scenario	Relevant Adaptation Strategies and (key consequence criteria)
15	Regulatory/legislative changes	Strategy range: wide; includes partnerships, new supplies, and modeling. (Criteria: water quality impacts and environmental stewardship)
1	Increasing Temperature: Reduced local supply	Strategy range: wide; includes monitoring, developing local supply, increasing augmented recharge/banking, conservation, operating rules adjustment, distribution system improvements (Criteria: water quality, supply, facilities, and environmental stewardship)
10	Drought: Reduced groundwater recharge to Niles Cone	Strategy range: wide; includes increasing augmented recharge/banking, short-term conservation and long-term water use efficiency, modeling and monitoring, new local and imported supply. (Criteria: water supply, facilities, and environmental stewardship)
6	Increasing Temperature: Non-salinity water quality degradation in the Delta	Strategy range: limited; includes partnerships, new local and imported supply. (Criteria: water quality, facilities, supply, and environmental stewardship)
2	Increasing Temperature: Increased demand	Strategy range: wide; includes expanding storage, increasing augmented recharge/banking, long-term water use efficiency, developing/expanding supply, green infrastructure, distribution system improvements. (Criteria: water quality, supply, facilities, and environmental stewardship)
7	Flooding: Saline intrusion in the Delta	Strategy range: limited; includes partnerships, new local and imported supply, modeling. (Criteria: water quality, facilities, supply, and environmental stewardship)
8	SLR: Non-salinity groundwater contamination mobilization in Niles Cone	Strategy range: wide; includes green infrastructure, partnerships, new local and imported supply, increase groundwater banking, groundwater treatment. (Criteria: water quality, environmental stewardship, and water supply)
9	SLR: Saltwater intrusion in Niles Cone	Strategy range: wide; includes partnerships, green infrastructure, groundwater treatment, developing/expanding supply, short-term conservation and long-term water use efficiency. (Criteria: facilities, water quality, environmental stewardship)
5	Wildfire: Non-salinity water quality degradation in local surface water (e.g., wildfire)	Strategy range: limited; includes green infrastructure, forest/vegetation management, modeling and monitoring, local partnerships. (Criteria: environmental stewardship, safety, and financing)
3	Drought: Imported supply reductions (SFPUC)	Strategy range: wide; includes increasing recharge/banking, new local and imported supply, increased storage, distribution system improvements, groundwater treatment. (Criteria: water delivery, water quality, and facilities)

The long-term planning horizon was selected for determining the top 10 climate risk scenarios (with the highest risk scores) for Table 7-3 given that this planning horizon is important to consider in developing adaptation pathways that include both mid- and long-term planning efforts presented in Section 8.

Section 8

Adaptation Pathways for Climate Readiness

Over time, the effects of climate change on operations, water sources, and infrastructure systems will become more severe and require further implementation of adaptation strategies to meet local and regional needs. Adaptation pathways provide a visual framework for adaptive planning strategies that respond to changing climate conditions. Pathways depict potential future actions as a series of key decision points, where each new decision is triggered by a specified condition or parameter that can be monitored over time.

8.1 Adaptation Pathway Scenarios

The risk assessment, as described in Section 6, developed risk scores that accompany each risk scenario. From the 15 climate risk scenarios assessed, seven scenarios were selected by considering the 10 highest risk scores using the long-term likelihood planning horizon and considering a range of scenarios that represent different climate threat types. The regulatory-focused Scenario 15 was not included within this list because a separate adaptation pathway is recommended for each of the relevant regulations. Key items for regulatory consideration are found in Section 3. The Delta-focused scenarios, Scenario 6 and 7, are addressed in a specific callout box in this section. This study does not address a catastrophic loss of the Delta due to SLR; however, the study does consider potential reduced imported supply as a result of climate change impacts on the Delta. Scenario 3 also addresses potential triggers for loss in imported supply and is mapped using an adaptation pathway within this section. The selected risk scenarios include the following and represent physical changing conditions mapped using adaptation pathways:

- Scenario 1: Increasing temperatures resulting in potential reduced local supply
- Scenario 2: Increasing temperatures resulting in potential increased demand
- Scenario 3: Drought resulting in potential reduction of imported supply - SFPUC
- Scenario 5: Wildfire resulting in potential non-salinity water quality degradation in local surface water
- Scenario 8: SLR resulting in potential non-salinity groundwater contamination mobilization in Niles Cone
- Scenario 9: SLR resulting in potential saltwater intrusion in Niles Cone
- Scenario 10: Drought resulting in potential reduced augmented groundwater recharge to Niles Cone

8.2 Triggers and Decisions

In practice, adaptation pathways may require a monitoring plan with specific numeric thresholds or “triggers” to determine when a specific study or action should take place. For this high-level analysis, a series of qualitative triggers, or thresholds for action, are presented for selected climate risk scenarios in their respective adaptation pathway. Trigger levels can be quantifiable values but are not part of the scope of this plan; additional studies will be required to further refine action/trigger levels. Defining and refining quantitative triggers to be monitored over time is recommended for future phases of work. The adaptation pathways represented in this analysis are focused on changes in physical climate conditions. For example, for SLR causing saline intrusion to the Niles Cone (Scenario 9), there are multiple triggers as conditions worsen:

- Trigger 1 – Quantifiable changes in water quality; however, current treatment methods can be used
- Trigger 2 – Degradation in water quality; additional treatment methods are required
- Trigger 3 – Water source becomes infeasible relative to alternatives

Each trigger leads to implementation of an adaptation strategy and a decision point. A decision may be to continue the current adaptation strategy or begin planning for one or more additional adaptation strategies; however, certain triggers may indicate a change-in-condition in which an adaptation strategy is no longer able to reduce adverse impacts. In such cases, the strategy would need to be bolstered by additional strategies to continue to mitigate risk.

8.3 Assumptions

The adaptation pathways assume that strategies will be able to reduce impacts of climate risk scenarios; however, more than one strategy may be needed. Adaptation strategies could provide permanent solutions to mitigate the risk in a given scenario; however, the adaptation pathway assumes that pathways progress toward worsening conditions that could reach a "worst case." The pathways also assume that progress will be made in the form of planning, permitting, or designing actions or projects to implement a strategy by the time the relevant changing condition trigger has been reached. Once one trigger has been reached, a subsequent decision must be made on what the next strategy to implement will be when the next action level is triggered. Immediate and near-term adaptation strategies that could be implemented and provide a benefit regardless of whether the impacts from a climate risk scenario occur, and especially those that provide multiple benefits, are considered low- to no-regret strategies. These are suggested for near-term implementation, are anticipated to continue across changing conditions, and support long-term resilience.

Catastrophic Delta Impacts (related to Scenarios 4, 6 and 7)

Climate change impacts to the Delta provide a substantial source of uncertainty for the District. These impacts are related to Scenario 4 (Drought with potential reduction of imported water [SWP]) as well as directly related to Scenario 6 (Increasing temperatures resulting in potential non-salinity water quality degradation in the Delta) and Scenario 7 (Flooding resulting in potential saline intrusion in the Delta).

The Delta Stewardship Council (Council) identified less reliable future exports, vulnerable ecosystems, worsening flooding, and episodic water quality declines as key takeaways from the 2021 Sacramento–San Joaquin Delta Climate Change Vulnerability Assessment (part 1 of the Delta Adapts: Creating a Climate Resilient Future initiative). The Council identified potential consequences, including levee failures; harm to Delta ecosystems from increased temperatures, drought, and extreme heat as well as saline intrusion from SLR; and reduced water supply exports across California. The Adaptation Plan (part 2 of Delta Adapts) is still underway, and currently there is no threshold analysis conducted to identify at what changing conditions thresholds the State would see catastrophic impact to the overall functioning of the Delta.

Impacts from the Delta have been listed by the District as a frequently identifiable factor that could contribute to a severe disruption in water supply. Potential changing conditions that the District could monitor include:

- **Reductions in SWP allocation**, which reduces both surface water supply used to meet immediate demands and reduced surface water to store in Semitropic (i.e., reduces ability of Semitropic to continue to provide the same level of resilient buffer supply via banked groundwater).
- **Reduced Delta pumping,** which can reduce ability to recover water through SWP exchanges and impact SFPUC-imported supply if additional reservoir releases are required to maintain Bay-Delta Plan flow requirements on the Tuolumne/San Joaquin rivers.

However, the above is a reactive approach. Preventative measures taken by the District can include continued enhancement and development of new local water supplies, increasing water use efficiency, and pursuing partnerships (regionally and locally) to reduce impacts from the above.

See also Section 3 and appendix on Alameda County Water District's Reduced Delta Reliance Reporting in the District's 2020-2025 UWMP for further elaboration on the Delta's potential impact to water supply reliability.

8.3.1 Scenario 1: Increasing temperatures resulting in potential reduced local supply

Triggers for Scenario 1 are on a scale of decreasing levels of available local supply due to increasing temperatures, which included the following (Figure 8-1):

- Trigger 1 – Reduction in local supply, but demands and operational needs are met
- Trigger 2 – Reduction in local supply, additional supply required to meet demands and operational needs
- Trigger 3 – Substantial loss of local supply, new supplies required

Low- to no-regret strategies for this scenario include:

- A1: expanding short-term (i.e., dry year) conservation efforts
- A2: increasing long-term water use efficiency measures
- F3: implementing real-time weather monitoring and forecasting
- G1: implementing green infrastructure and nature-based solutions
- H3: developing Bay Area and regional partnerships

If the change-in-condition level for Trigger 1 (Reduction in local supply, but demands and operational needs are met) is met, then a decision must be made to implement a new strategy. It is assumed that these strategies will be implemented concurrently for maximum benefit. These additional strategies include:

- D2: increasing groundwater recharge/storage: Local (Niles Cone)
- D3: increasing groundwater recharge/storage: Banked (Semitropic)
- D4: adjusting dry year operating rules

If the action level for Trigger 2 (Reduction in local supply, additional supply required to meet demands and operational needs) is met, then a decision must be made to implement a new strategy. These additional strategies include:

- D1: implementing new or expanded surface storage
- D5: improving distribution system flexibility

If the change-in-condition level for Trigger 3 (Substantial loss of local supply, new supplies required) is met, then a decision must be made to implement a new strategy. These additional strategies include:

- B1: developing new local and regional supplies
- B2: expanding existing local and regional supplies
- B3: securing new imported (non-local) supplies
- B4: bolstering existing imported supplies

Strategies D2 and D3 will continue to be viable after the loss of local supply as long as there is an imported supply source. In the case of no or significantly limited imported supply source (e.g., SWP allocation reduction), it is assumed other strategies will be needed, such as recycled water to create a new source for local recharge. Similarly, with D1 and D5, these strategies will continue to be viable and necessary after the point at which local supply can no longer meet demand and operational needs as long as there is another available source from a new local or imported supply (i.e., strategies B1-B4), depending on the source.

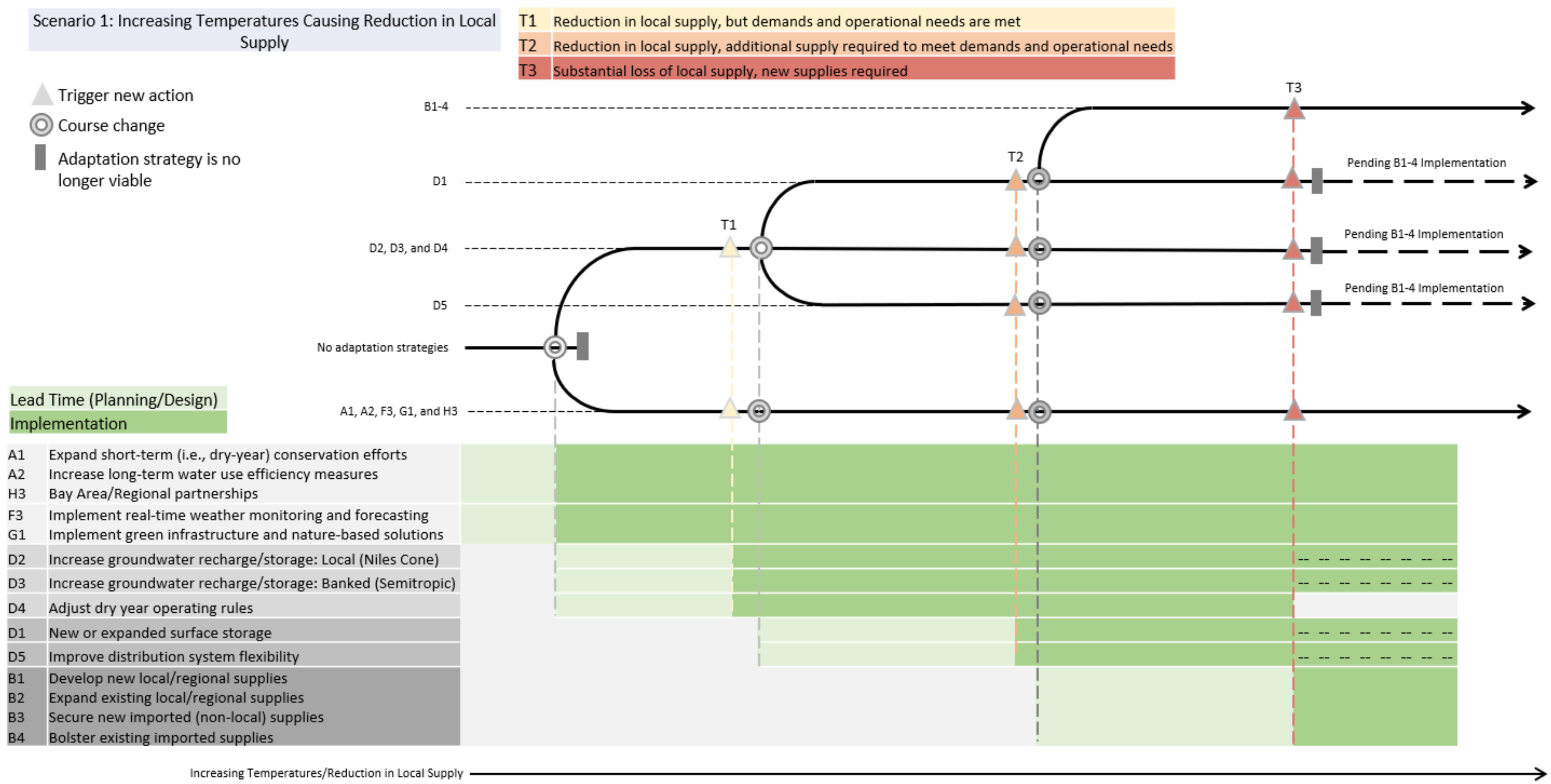


Figure 8-1. Adaptation pathway for Scenario 1: Increasing temperatures resulting in potential reduced local supply

8.3.2 Scenario 2: Increasing temperatures resulting in potential increased demand

Triggers for Scenario 2 are on a scale of increasing demands due to increasing temperatures, which included the following (Figure 8-2):

- Trigger 1 – Increase in demands, but current supply is sufficient
- Trigger 2 – Increase in demands, use of additional existing supply sources required to meet demands and operational needs
- Trigger 3 – Existing supply sources can no longer meet demand, new supply source required

Low- to no-regret strategies for this scenario include:

- A1: expanding short-term (i.e., dry year) conservation efforts
- A2: increasing long-term water use efficiency measures
- F3: implementing real-time weather monitoring and forecasting
- G1: implementing green infrastructure and nature-based solutions

If the change-in-condition level for Trigger 1 (Increase in demands, but current supply is sufficient) is met, then a decision must be made to implement a new strategy. It is assumed that these strategies will be implemented concurrently for maximum benefit. These additional strategies include:

- B4: bolstering existing imported supplies
- D1: implementing new or expanded surface storage
- D4: adjusting dry year operating rules
- D5: improving distribution system flexibility

If the change-in-condition level for Trigger 2 (Increase in demands, additional supply required to meet demands and operational needs) is met, then a decision must be made to implement a new strategy. These additional strategies include:

- B2: expanding existing local and regional supplies
- D2: increasing groundwater recharge/storage: Local (Niles Cone)
- D3: increasing groundwater recharge/storage: Banked (Semitropic)

If the change-in-condition level for Trigger 3 (Supply can no longer meet demand, new supplies required) is met, then a decision must be made to implement a new strategy. These additional strategies include:

- B1: developing new local and regional supplies
- B3: securing new imported (non-local) supplies

Strategies D2 and D3 will continue to be viable after the point at which supply can no longer meet demand, as long as there is a new local or imported supply source. In the case of no or significantly limited new local or imported supply source (e.g., SWP allocation reduction), it is assumed other strategies will be needed, such as recycled water, to create a new source for local recharge. Similarly, with strategies D1 and D5, strategies D2 and D3 will continue to be viable and necessary after the point at which supply can no longer meet demand, as long as there is a need from a new local or imported supply (B1 or B3), depending on the source.

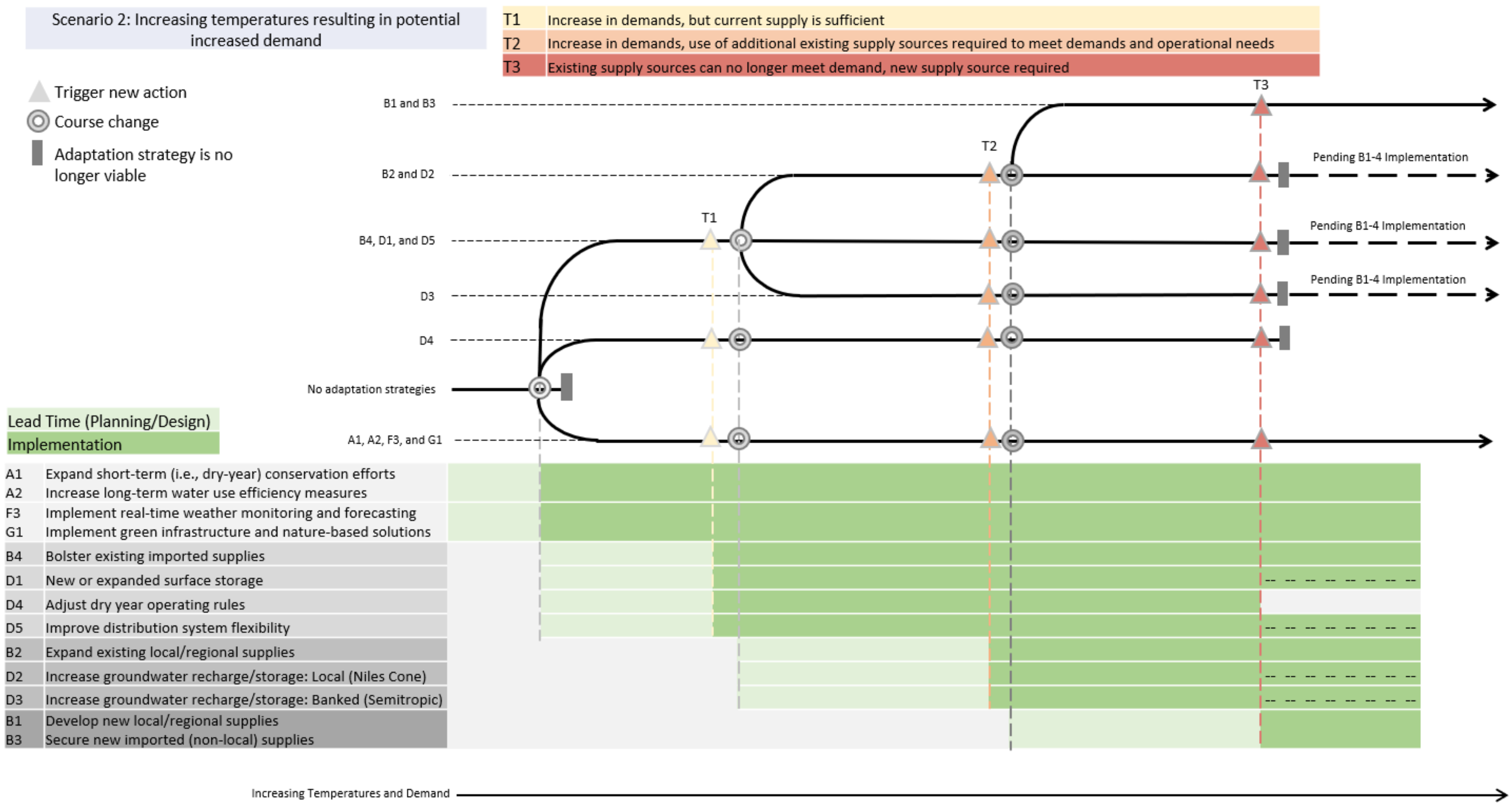


Figure 8-2. Adaptation pathway for Scenario 2: Increasing temperatures resulting in potential increased demand

8.3.3 Scenario 3: Drought resulting in potential reduction of imported supply - SFPUC

Triggers for Scenario 3 are on a scale of decreasing levels of available imported supply (SFPUC) due to increasing drought conditions, which included the following (Figure 8-3):

- Trigger 1 – Reduction in imported supply, but demands and operational needs are met
- Trigger 2 – Reduction in imported supply, additional supply required to meet demands and operational needs
- Trigger 3 – Substantial loss of imported supply, new supplies required

Low- to no-regret strategies for this scenario include:

- A1: expanding short-term (i.e., dry year) conservation efforts
- A2: increasing long-term water use efficiency measures

If the change-in-condition level for Trigger 1 (Reduction in imported supply, but demands and operational needs are met) is met, then a decision must be made to implement a new strategy. It is assumed that these strategies will be implemented concurrently for maximum benefit. These additional strategies include:

- D2: increasing groundwater recharge/storage: Local (Niles Cone)
- D3: increasing groundwater recharge/storage: Banked (Semitropic)
- D4: adjusting dry year operating rules

If the change-in-condition level for Trigger 2 (Reduction in imported supply, additional supply required to meet demands and operational needs) is met, then a decision must be made to implement a new strategy. These additional strategies include:

- B2: expanding existing local and regional supplies
- D1: implementing new or expanded surface storage
- D5: improving distribution system flexibility

If the change-in-condition level for Trigger 3 (Total loss of imported supply, new supplies required) is met, then a decision must be made to implement a new strategy. These additional strategies include:

- B1: developing new local and regional supplies
- B3: securing new imported (non-local) supplies
- E1: mitigating or treating groundwater contamination

Strategies D2 and D3 will continue to be viable after the loss of SFPUC imported supply as long as there is an additional imported or local supply source. In the case of no or significantly limited local or imported supply source (e.g., SWP allocation reduction), it is assumed other strategies will be needed, such as recycled water, to create a new source for local recharge. Similarly, with D1 and D5, strategies D2 and D3 will continue to be viable and necessary after the point at which imported supply can no longer meet demand and operational needs, as long as there is a need from a new local or imported supply, depending on the source. If no supply can supplement the reduction in imported supplies (i.e., B1-B3 are unable to be implemented), then a lack of recharge to the local aquifer would result in an increase in saline intrusion that requires additional mitigation or treatment of groundwater to be implemented.

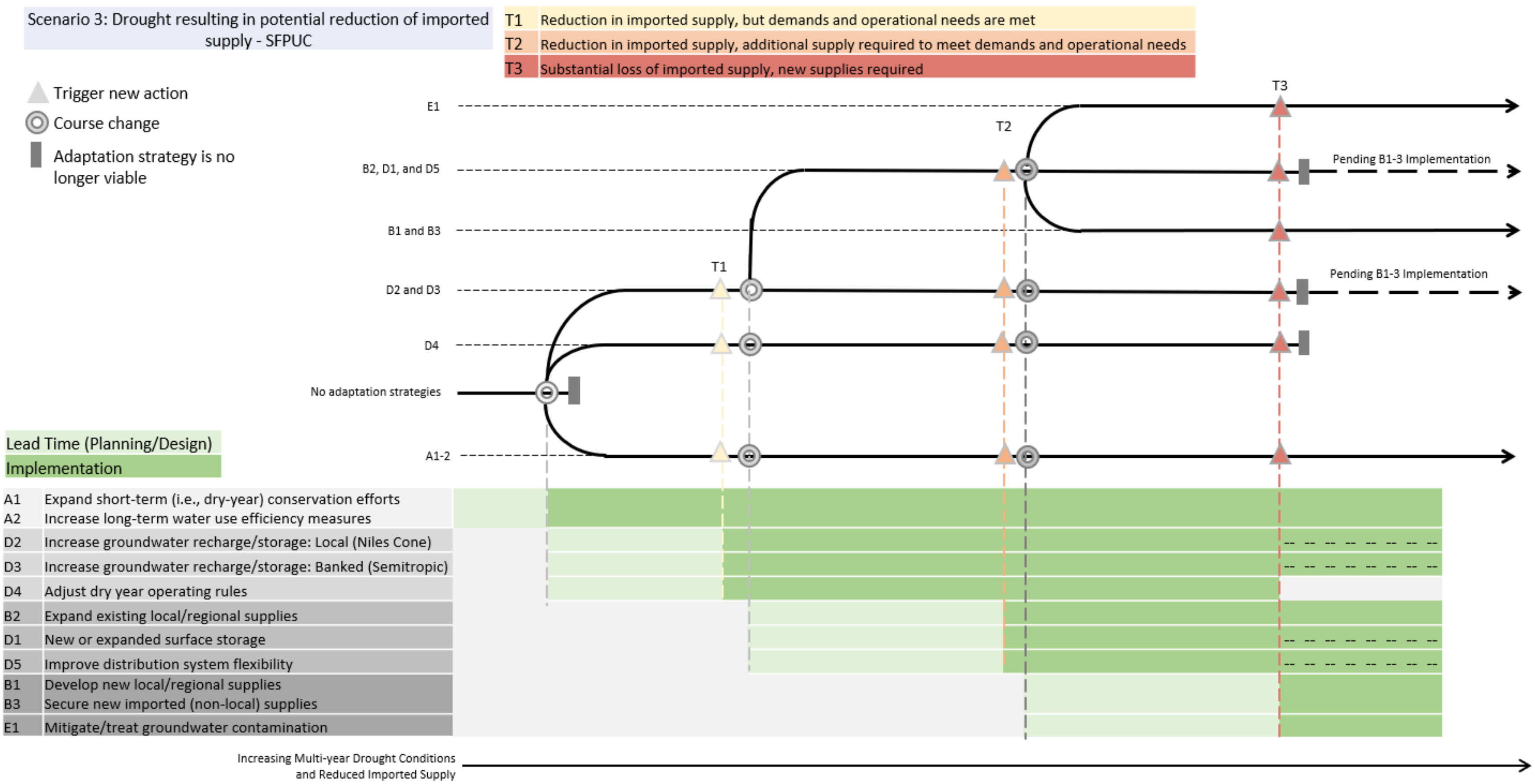


Figure 8-3. Adaptation pathway for Scenario 3: Drought resulting in potential reduction of imported supply - SFPUC

8.3.4 Scenario 5: Wildfire resulting in potential non-salinity water quality degradation in local surface water

Triggers for Scenario 5 are on a scale of increasing levels of non-saline contamination in surface waters due to increasing wildfires, which included the following (Figure 8-4):

- Trigger 1 – Quantifiable changes in water quality, but normal treatment can be used
- Trigger 2 – Degradation in water quality, additional treatment is required
- Trigger 3 – Water source treatment becomes cost prohibitive, new supply required

Low- to no-regret strategies for this scenario include:

- F1: modeling climate impacts on surface water
- G1: implementing green infrastructure and nature-based solutions
- H4: developing Alameda Creek Watershed partnerships

If the change-in-condition level for Trigger 1 (Quantifiable changes in water quality, but normal treatment can be used) is met, then a decision must be made to implement a new strategy. It is assumed that these strategies will be implemented concurrently for maximum benefit. These additional strategies include:

- D6: developing new or expanding surface water storage
- G2: investing in forest and vegetation management

If the change-in-condition level for Trigger 2 (Degradation in water quality, additional treatment is required) is met, then a decision must be made to implement a new strategy. The additional strategy includes:

- E3: adjusting or expanding surface water treatment

If the change-in-condition level for Trigger 3 (Water source treatment becomes cost prohibitive, new supply required) is met, then a decision must be made to implement a new strategy. The additional strategy includes:

- E2: implementing reservoir water quality management

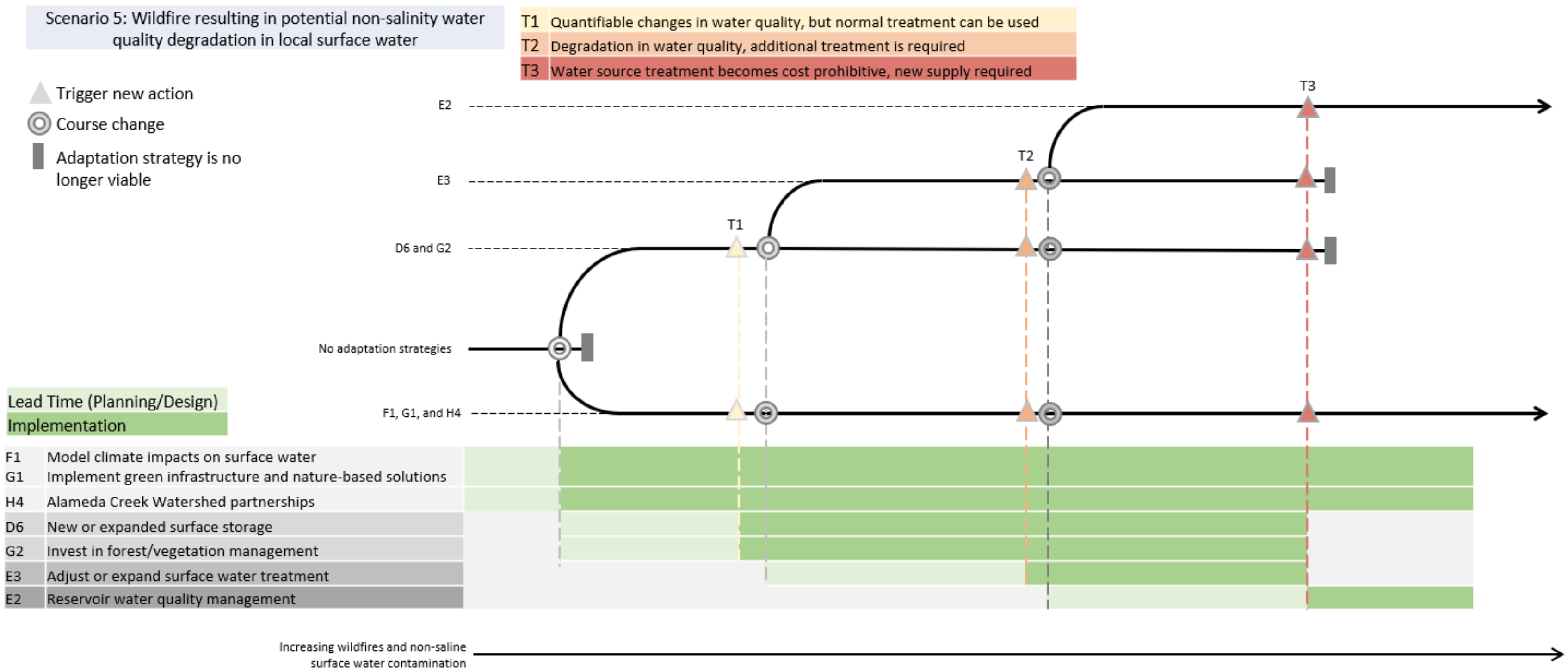


Figure 8-4. Adaptation pathway for Scenario 5: Wildfire resulting in potential non-salinity water quality degradation in local surface water

8.3.5 Scenario 8: SLR resulting in potential non-salinity groundwater contamination mobilization in Niles Cone

Triggers for Scenario 8 are on a scale of increasing non-saline contamination mobilization in the Niles Cone due to rising sea levels, which included the following (Figure 8-5):

- Trigger 1 – Quantifiable changes in water quality, but normal treatment can be used
- Trigger 2 – Degradation in water quality, additional treatment is required
- Trigger 3 – Water source treatment becomes infeasible relative to alternatives

Low- to no-regret strategies for this scenario include:

- D6: expanding monitoring and remote operations
- F2: modeling climate impacts on groundwater
- G1: implementing green infrastructure and nature-based solutions
- H3: developing Bay Area and regional partnerships

If the change-in-condition level for Trigger 1 (Quantifiable changes in water quality, but normal treatment can be used) is met, a decision must be made to implement a new strategy. It is assumed that strategies will be implemented concurrently for maximum benefit. The additional strategy includes:

- H1: SF Bay shoreline partnerships

If the change-in-condition level for Trigger 2 (Degradation in water quality, additional treatment is required) is met, a decision must be made to implement a new strategy. These additional strategies include:

- D3: increasing groundwater recharge/storage: Banked (Semitropic)
- E1: mitigating or treating groundwater contamination

If the change-in-condition level for Trigger 3 (Water source treatment becomes cost prohibitive, new supply required) is met, a decision must be made to implement a new strategy. These additional strategies include:

- B1: developing new local and regional supplies
- B3: securing new imported (non-local) supplies
- B4: bolstering existing imported supplies

Strategy E1 would no longer be viable after the point at which the supply has become unusable and treatment is no longer feasible; therefore, this strategy would be terminated at Trigger 3.

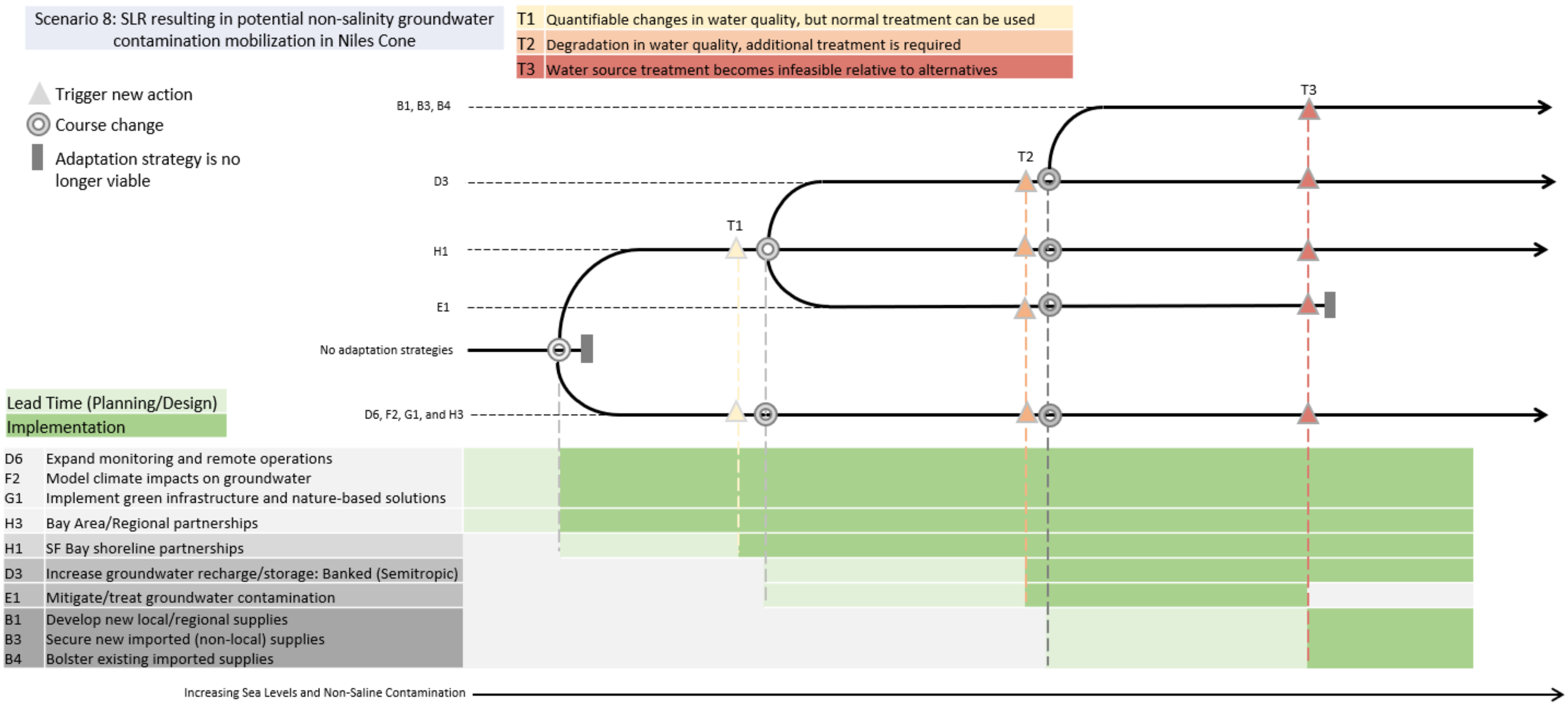


Figure 8-5. Adaptation pathway Scenario 8: SLR resulting in potential non-salinity groundwater contamination mobilization in Niles Cone

8.3.6 Scenario 9: SLR resulting in potential saltwater intrusion in Niles Cone

Triggers for Scenario 9 are on a scale of increasing saline contamination in the Niles Cone due to rising sea levels, which included the following (Figure 8-6):

- Trigger 1 – Quantifiable changes in water quality; however, current treatment can be used
- Trigger 2 – Degradation in water quality; additional treatment methods are required
- Trigger 3 – Water source treatment becomes infeasible relative to alternatives

Low- to no-regret strategies for this scenario include:

- A1: expanding short-term (i.e., dry year) conservation efforts
- A2: increasing long-term water use efficiency measures
- D6: expanding monitoring and remote operations
- F2: modeling climate impacts on groundwater
- G1: implementing green infrastructure and nature-based solutions
- H1: developing SF Bay shoreline partnerships
- H3: developing Bay Area and regional partnerships

If the change-in-condition level for Trigger 1 (Quantifiable changes in water quality, but normal treatment can be used) is met, a decision must be made to implement a new strategy. It is assumed that strategies will be implemented concurrently for maximum benefit. The additional strategy includes:

- D2: increasing groundwater recharge/storage: Local (Niles Cone)

If the change-in-condition level for Trigger 2 (Degradation in water quality; additional treatment is required) is met, then a decision must be made to implement a new strategy. These additional strategies include:

- D3: increasing groundwater recharge/storage: Banked (Semitropic)
- E1: mitigating or treating groundwater contamination

If the action level for Trigger 3 (Water source treatment becomes cost prohibitive; new supply required) is met, then a decision must be made to implement a new strategy. These additional strategies include:

- B1: developing new local and regional supplies
- B2: expanding existing local and regional supplies
- B3: securing new imported (non-local) supplies
- B4: bolstering existing imported supplies

Strategies D2 and E1 will no longer be viable after the point at which the supply has become unusable and treatment is no longer feasible; therefore, this strategy would be terminated at Trigger 3.

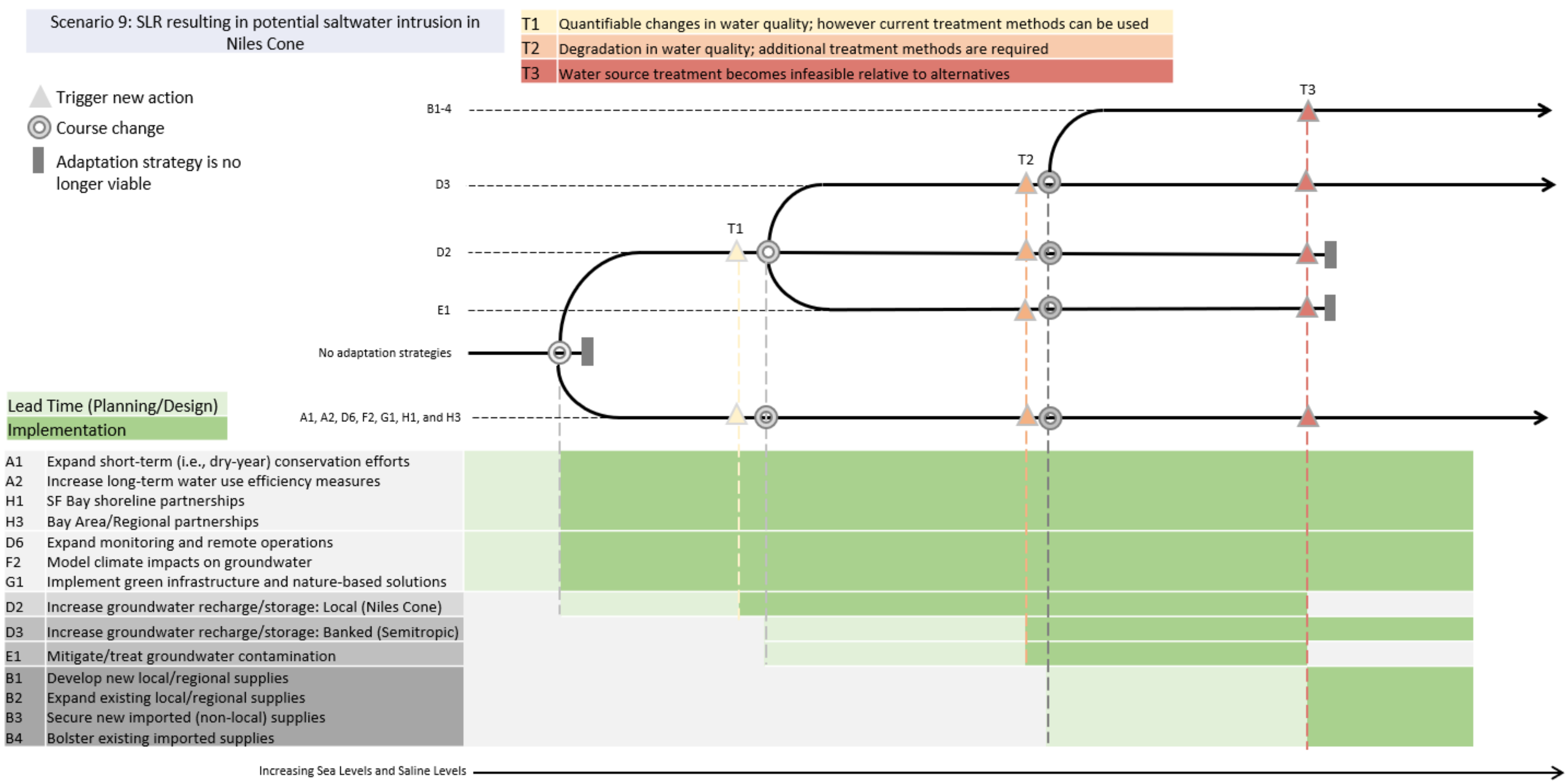


Figure 8-6. Adaptation pathway Scenario 9: SLR resulting in potential saltwater intrusion in Niles Cone

8.3.7 Scenario 10: Drought resulting in potential reduced augmented groundwater recharge to Niles Cone

Triggers for Scenario 10 are on a scale of decreasing levels of available supply for recharge in the Niles Cone due to increasing drought conditions, which included the following (Figure 8-7):

- Trigger 1 – Reduction in supply for recharge, but demands and operational needs are met
- Trigger 2 – Reduction in supply for recharge, additional supply required to meet demands and operational needs
- Trigger 3 – Substantial loss of supply for recharge, new supplies required

Low- to no-regret strategies for this scenario include:

- A1: expanding short-term (i.e., dry year) conservation efforts
- A2: increasing long-term water use efficiency measures
- F1: modeling climate impacts on surface water
- F2: modeling climate impacts on groundwater
- F3: implement real-time weather monitoring and forecasting
- G1: implementing green infrastructure and nature-based solutions
- H3: developing Bay Area and regional partnerships

If the change-in-condition level for Trigger 1 (Reduction in supply for recharge, but demands and operational needs are met) is met, then a decision must be made to implement a new strategy. It is assumed that the strategy will be implemented concurrently with other existing strategies for maximum benefit. The additional strategy includes:

- D4: adjusting dry year operating rules

If the change-in-condition level for Trigger 2 (Reduction in supply for recharge, additional supply required to meet demands and operational needs) is met, then a decision must be made to implement a new strategy. An additional strategy is:

- D3: increasing groundwater recharge/storage: Banked (Semitropic)

If the change-in-condition level for Trigger 3 (Reduction in supply for recharge, additional supply required to meet demands and operational needs) is met, then a decision must be made to implement a new strategy. These additional strategies include:

- B1: developing new local and regional supplies
- B3: securing new imported (non-local) supplies
- B4: bolster existing imported supplies

Strategies D4 and D3 will continue to be viable as long as there is an additional imported or local supply source. In the case of no or significantly limited local or imported supply source (e.g., SWP allocation reduction), it is assumed other strategies will be needed, such as recycled water, to create a new source for local recharge. If no supply can supplement the reduction in supplies available for recharge (i.e., B1, B3, and B4 are unable to be implemented), then a lack of recharge to the local aquifer would result in an increase in saline intrusion that requires additional mitigation or treatment of groundwater to be implemented.

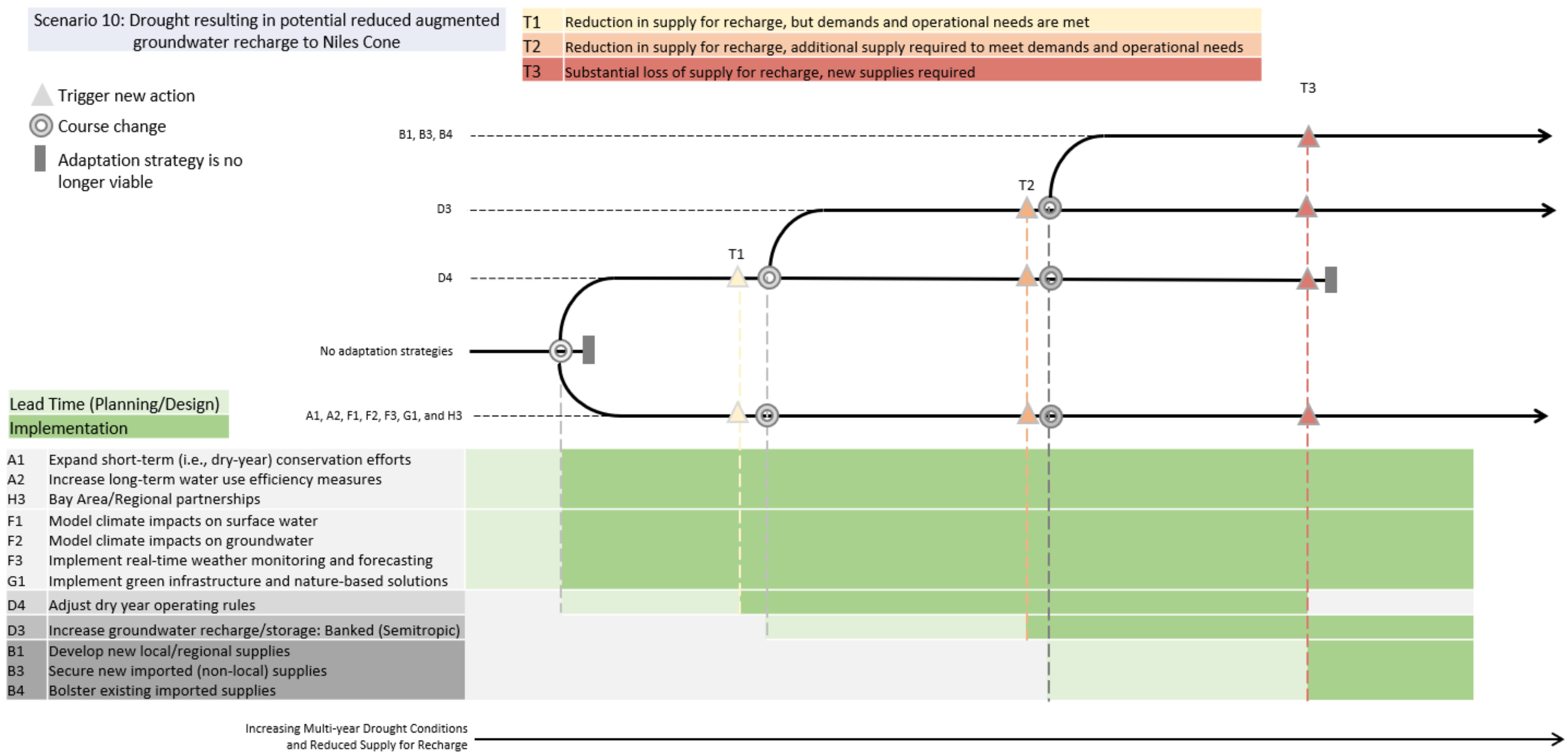


Figure 8-7. Adaptation pathway Scenario 10: Drought resulting in potential reduced augmented groundwater recharge to Niles Cone

8.4 Cost Estimates and Funding Opportunities

Lining up potential cost estimates with funding opportunities is important when considering potential pathways and implementation of adaptation strategies. This CAP provides a high-level summary table of funding opportunity examples. Order-of-magnitude cost estimates for adaptation strategies are provided in Appendix H.

Funding opportunities for climate adaptation can come from a range of sources but can be split into three major categories: federal, state, and regional/county levels. At the national level, organizations such as FEMA, NOAA, U.S. Army Corps of Engineers, U.S. Dept. of Housing and Urban Development, and the U.S. Environmental Protection Agency offer the majority of grants for climate adaptation. The White House's Infrastructure Bill and Inflation Reduction Act will be offering further climate adaptation funding by delivering funds to states to manage. At the state level, California offers a variety of adaptation funding, as creating resilient water utilities is a top priority. At the regional and local level, the Bay Area offers regionwide grants, such as those through the IRWMP, or through partnering with other cities, counties, and agencies.

Additionally, it is recommended that the District consider opportunities through private sector grants, as these can offer a streamlined pathway to external funding and can provide mutual benefit by helping to advance projects that support both local, District, and private sector corporate sustainability goals.

For a full list of funding opportunities, see Appendix I.

Section 9

Recommendations and Next Steps

This section provides recommendations that consider further actions, plans, and programs that work toward a path of climate readiness, including opportunities to improve internal and external policy alignment, recommended studies, and planning strategies. The section concludes with a recap of how the objectives of this study have been fulfilled and provides recommendations for next steps in community engagement for future planning efforts. A few key items are addressed:

- The District can improve internal policy alignment to build climate readiness and strengthen its identity as a leader for utility climate resilience.
- The District can also align with external policies and plans by collaborating with neighboring agencies, cities, and Alameda County (as well as state guidance) to support complementary approaches and data used for adaptation projects and planning across the watershed.
- Actions, plans, and projects are already underway at the District to address high-ranking climate risk scenarios identified in this study.
- Adaptation strategies can be further developed and changing condition thresholds can be quantitatively defined to support implementation of actions and projects to address and better prepare for future changing conditions and impacts.

9.1 Recommendations for Policy and Planning

Recommendations for policy and planning are broken into internal and external actions, as well as recommendations for future studies and development of adaptation strategies.

9.1.1 Internal Policy and Planning

As a result of the policy review and analysis, recommended actions for aligning internal District policy and planning for climate readiness include:

- **Update criteria and refine planning priorities:** Establish a consistent set of planning criteria and priorities for “climate readiness” in future WRMP processes. This includes refining and adopting criteria as well as establishing criteria weighting to support future project prioritization and selection transparency. This will provide a transparent accounting of how the District selects future projects and tracks progress to achieve climate readiness planning goals. The District could use the consequence criteria created in this CAP as a starting point. It is recommended that this process include efforts to better understand and communicate the District’s equity and environmental stewardship goals.
- **Leverage identified adaptive capacities and potential adaptation strategies in future capital improvement program (CIP) updates.** Establish a practice of identifying and documenting future CIP projects to mitigate the highest climate risks and align future CAP updates with CIP planning cycles. This encourages documentation and tracking of climate risk reduction, which may be helpful for future insurance and credit-worthiness reporting requirements that require accounting for climate risk.
- **Develop internal goals to enhance understanding of SLR impact:** This includes identifying and engaging in studies to remedy current knowledge gaps for potential SLR impact (e.g., better understanding movement and extent of saline intrusion and impacts to Niles Cone and local

ecosystems, creating robust SLR salinity monitoring program, refining the District's comprehensive groundwater monitoring program, and modelling and developing triggers both for salinity and potential emergent groundwater).

  - Partnership opportunity: Partner with neighboring groundwater sustainability agencies, as well as the cities of Fremont, Newark, and Union City; Alameda County; and entities such as the BCDC and the San Francisco Estuary Institute.

- **Expand on the original 1995 IRP uncertainty scenarios:** This includes updating the assumptions used in the previous three uncertainty scenarios for a best-, middle-, and worst-case future scenario that considered the level of development for demand forecast, potential changes in imported supply deliveries, and treatment plant capacity. Assumptions could be updated to include a revised understanding that considers climate change impacts (e.g., increased demand potential, reduced imported supply, and potential changes in treatment based on impacts to source water quality).
- **Translate existing resilience and sustainability actions into adaptation strategies:** Although the CAP begins to address this recommendation, this can become a standard protocol for pending and proposed projects. This is especially relevant for identifying projects and actions that may be identified as "low- to no- regret" strategies.
- **Apply a common definition of "climate readiness" across planning efforts:** For all planning efforts, communicate and enumerate directly within the plan's introduction the ways in which that plan (or study) helps proactively anticipate, plan for, and prepare to overcome challenges from climate change impacts. For specific planning efforts:
  - **Business contingency planning:** Update business contingency planning to account for climate risk as a business risk that includes the cost of inaction.
  - **Strategic planning:** Apply a climate lens to strategic planning by expanding Water Supply Goal 2. This could include using climate change risks to support prioritization and timing of strategic planning and initiatives. This could be developed as an additional metric.
  - **Mission statement:** Communicate how the District's mission builds climate readiness. For example, "responsiveness" can be expanded to include an anticipatory and preventative focus for known climate risks. "Ethical actions" can support coordination that maintains services and opportunities for capital improvements in V/DCs. "Safe practices" can be understood to include safety from different climate hazards. "Environmental stewardship" can include the District's responsibility to sustainably consider how practices contribute to, and help reduce adverse impacts of, climate change within the watershed.
- **Adopt a resolution to formalize priorities and align internal and external policy:** The District and its Board of Directors could also consider adopting a resolution that supports aligning with the priorities and potential collaboration activities of municipalities, Bay Area agencies, and state and regional agencies. This resolution could include a concise summary of potential actions.

9.1.2 External Policy and Planning

Recommendations to align with external policy and planning include:

- **Cities and County Level:** The study recommends coordination with the cities of Fremont, Newark, and Union City for future updates for mapping and hazard data, and use of the same data sources and emergency planning approaches and protocols. This data includes climate projections data used for planning purposes and establishing potential triggers for collaborative action, such as specific sea level rise elevations. As city CAPs are updated, the study also recommends continuing discussions around integrating effective adaptation strategies and seeking funding partnership opportunities, as well as leveraging joint stakeholder engagement opportunities. These recommendations also hold true for Alameda County. The study recommends aligning the development of adaptation strategies with priority areas of the Alameda County Climate Action Plan for Government Services and Operations through 2020 update and the Community Climate Action Plan, seeking funding partnership opportunities, leveraging stakeholder engagement opportunities, as well as coordinating use of the same data sources.

- **Other Bay Area Agencies:** Leverage opportunities to conduct regional adaptation strategy projects and continue regional partnerships, and coordinate on use of same regional data. This is especially applicable to agencies that have already completed CAPs or CAP equivalents that focus on adaptation (e.g., EBMUD, SFPUC, Valley Water, Sonoma Water). Pursue development of joint adaptation strategies and projects collaborating on efforts for the IRWMP and BARR Drought Contingency Plan (see list Table 9-1 for recommended studies).

State level can be divvied up into several areas as follows:

- **Sea Level Rise**: Leverage planning tools and guides to coordinate cross-jurisdictional projects for SLR adaptation and support environmental justice efforts when considering project benefits. Consider further development of District policy to align with principles and goals of the State Agency Sea Level Rise Action Plan for California 2022. This can include focusing policy on equity, nature-based solutions, using best available science, protecting coastal habitat, and pursuing partnerships.
- **Climate & Resilience**: Develop planning and policy criteria that align with the Climate Adaptation Strategy's climate resilience priorities, corresponding goals, and actions (especially public health and safety, nature-based solutions, collaborative partnerships, and decision-making using best available science). Leverage information on status and trends of California's water-dependent natural resources, climate science, and state supply planning policies. Develop adaptation strategies that align with Water Resilience Portfolio options and opportunities.
- **Groundwater Sustainability:** Continue updates using the state-of-science and leverage and expand on DWR-provided tools and approaches (e.g., for Five-Year Periodic Evaluations to consider interannual variability). Pursue Sustainable Groundwater Management Grant Program funding opportunities for project implementation.
- **The Delta Plan:** Continue to engage with the Delta Adapts project and the Delta Stewardship Council's regional SLR Adaptation Plan. Stay invested in research, planning, and policy updates, especially for the phase two Delta Adapts Adaptation Plan.

9.1.3 Recommended studies and strategies

This study recommends a range of further studies and strategies to address climate risk scenarios and help reduce impacts the District is likely to face from climate change. Additional modeling and analysis can address key data gaps, help better inform future emergency contingency plans, and support greater opportunities for watershed partnerships. Table 9-1 provides recommendations based on the findings from this study. These include studies to help define change-in-condition trigger thresholds for high-risk climate change scenarios. These thresholds would need to be accompanied by a monitoring program to track changing conditions.

Recommended strategies that support addressing impacts from the top 10 climate risk scenarios are identified in Table 9-2. The table includes the full list of applicable strategies that are anticipated to benefit the District by reducing potential impacts. This benefit is measured in the MCDA tool (Section 7.2) and is based on the strategies' estimated potentials to reduce impacts across a set of consequence criteria.

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Table 9-1. Recommended Studies to Address High-risk Climate Risk Scenarios.			
Recommended Studies	Climate Risk Scenarios	Relevant Adaptation Strategies	Climate Impacts Reduced
Define change-in-condition trigger thresholds and develop monitoring program for increased evaporative losses of local surface water supplies and increased evapotranspiration in soils due to temperature rise	Scenario 1: Increasing Temperature Causing a Reduction in Local Supply	• F3: implement real-time weather monitoring and forecasting	Reduces potential loss in supply through better monitoring and planning of potential losses tracked over time.
Conduct analysis to determine projected demand response to increase in temperature, and include in supply and demand analysis to determine at what demand threshold new supplies would be required (update and expand on current UWMP analysis beyond 2045)	Scenario 2: Increasing Temperature Causing an Increase in Demand	• A1: expand short-term (i.e., dry year) conservation efforts • A2: increase long-term water use efficiency measures • (threshold may also support strategies for expanded and new supply development, e.g., B1-4, D1-5)	Reduces potential difficulty in meeting demands beyond 2045 horizon, improves long-term water supply planning
Analyze specific reduced imported supply scenarios for single dry and multiple dry years, especially beyond the 2045 horizon, and consider a potential scenario that includes implementation of the Voluntary Agreement (alternative to the Bay-Delta Plan) to understand range of changing conditions	Scenario 3: Increasing Drought Conditions Causing a Reduction in Imported Supply (SFPUC)	• B1: develop new local and regional supplies • B3: secure new imported (non-local) supplies • B2: expand existing local and regional supplies • D1: implement new or expanded surface storage	Minimizes reduction of overall supply due to reduced SFPUC supply (consideration of Voluntary Agreement implementation could also address reductions in SWP supply)
Conduct watershed-scale analysis to determine range of potential water quality impacts from wildfire for source water and runoff and determine potential thresholds (triggers)	Scenario 5: Increasing Wildfires Causing Non-Saline Water Quality Degradation in Local Surface Water Supply	• F1: model climate impacts on surface water • G1: implement green infrastructure and nature-based solutions • G2: invest in forest and vegetation management • H4: develop Alameda Creek Watershed partnerships	Study should produce understanding of erosion and sediment transport, increased nutrient loading, changes in source-water chemistry, and changes in runoff patterns. Informs potential watershed-based partnerships and reduces risk at watershed management level.
Conduct analysis for emergent groundwater in coordination with SF RWQCB for existing contamination sites	Scenario 8: SLR Causing Water Quality Changes in the Niles Cone Due to Non-Saline Contamination	• D6: expand monitoring and remote operations • F2: model climate impacts on groundwater • E1: mitigate or treating groundwater contamination	Study should provide indication of potential extent and location of contamination sites that could produce harmful water quality impacts when inundated and/or interacting with saltwater
Update SLR saline intrusion study to simulate the predicted mobility, time of travel, and extent/travel distance of chlorides into the Niles Cone to define potential thresholds for changes in water quality and triggers for changes in treatment (this will need to be done using the upgraded Integrated Water Flow Model	Scenario 9: SLR Causing Water Quality Changes in the Niles Cone Due to Saline Intrusion	• D6: expand monitoring and remote operations • F2: model climate impacts on groundwater • G1: implement green infrastructure and nature-based solutions • H1: develop SF Bay shoreline partnerships	Study should produce data to improve understanding of change in water quality as saline intrusion increases over time
"Perfect storm" analysis to develop a design drought to characterize a credible climate-driven drought scenario considering all supplies, imported and local.	Scenario 10: Drought resulting in potential reduced augmented groundwater recharge to Niles Cone	• F1: model climate impacts on surface water • F2: model climate impacts on groundwater • F3: implement real-time weather monitoring and forecasting • (threshold may also support strategies for expanded and new supply development, e.g., B1-4, D1-5)	Study should provide range of potential combined supply-side impacts from a credible, worst case scenario drought. The scenario should include simultaneous impact to imported and local supply to help limit impacts from future drought. This study should also flag which conditions provide a "catastrophic" drought with >20% supply reduction.
Coordinate and conduct an Alameda Creek Watershed boundary climate study in partnership with cities, Alameda County Flood Control & Water Conservation District, and Alameda Creek Watershed Forum	Many scenarios: Scenario 1 (increased temperature and reduced local supply), 5 (wildfire and water quality degradation), 8 and 9 (non-saline and saline contamination, respectively), 10 (drought and reduced augmented water recharge)	• F1: model climate impacts on surface water • F2: model climate impacts on groundwater • G1: implement green infrastructure and nature-based solutions • H1: develop SF Bay shoreline partnerships • H3: develop Bay Area and regional partnerships	Study should provide local to regional-scale range of projected changes in temperature and precipitation, including a watershed-level stress test. This may also serve as a precursor study to help develop green infrastructure and nature-based solutions projects in partnership with city, county, non-governmental organizations, and other agency entities.

Table 9-2. Recommended Strategies to Address High-risk Climate Risk Scenarios from Highest to Lowest Risk (long-term)

Climate Risk Scenario	Recommended Adaptation Strategies	Benefits (based on consequence criteria impact reduction)
Scenario 15: Regulatory changes resulting in potential changes needed in operations, planning, and or policy	Partnerships (H1-H3), expand existing and develop new local/regional supplies (B1-B2), green infrastructure, and nature-based solutions (G1), model climate change impacts on groundwater and surface water (F1-F2), treat/mitigate groundwater (E1), develop new/expand surface storage (D1), increase augmented groundwater recharge (D2)	Water quality, water supply, and environmental stewardship
Scenario 1: Increasing temperatures resulting in potential reduced local supply	Green infrastructure and nature-based solutions (G1), distribution system improvements (D5), Bay Area regional supply partnerships (H3), increase augmented recharge/banking (D2-D3), short-term conservation and long-term water use efficiency (A1- A2), adjust dry year operating rules (D4), expand existing and develop new local/regional and imported supplies (B1-B3), implement real-time weather monitoring (F3)	Supports a wide range of criteria (including water quality, water supply, facility reliability, and environmental stewardship)
Scenario 10: Drought resulting in potential reduced augmented groundwater recharge to Niles Cone	Bay Area regional supply partnerships (H3), green infrastructure and nature-based solutions (G1), expand existing and develop new local/regional supplies (B1-B2), increase augmented recharge/banking (D2-D3), short-term conservation and long-term water use efficiency (A1- A2), model climate change impacts on groundwater and surface water (F1-F2), real-time weather monitoring (F3)	Water supply, facilities reliability, and environmental stewardship
Scenario 6: Increasing temperatures resulting in potential non-salinity water quality degradation in the Delta	Delta partnerships (H2), adjust or expand surface water treatment (E3), expand existing and develop new local/regional supplies (B1-B2)	Water quality, facilities reliability, supply, and environmental stewardship
Scenario 2: Increasing temperatures resulting in potential increased demand	Green infrastructure and nature-based solutions (G1), Bay Area regional supply partnerships (H3), short-term conservation and long-term water use efficiency (A1- A2), increased augmented recharge/banking (D2-D3), distribution system improvements (D5)	Supports a wide range of criteria
Scenario 7: Flooding resulting in potential saline intrusion in the Delta	Expand existing and develop new local/regional supplies (B1-B2), Delta and Bay Area regional supply partnerships (H2, H3), new local and imported supply, modeling climate impacts on surface water (F1)	Water quality, facilities reliability, supply, and environmental stewardship
Scenario 8: SLR resulting in potential non-salinity groundwater contamination mobilization in Niles Cone	Green infrastructure and nature-based solutions (G1), SF Bay shoreline and Bay Area regional supply partnerships (H1, H3), Bay Area regional supply partnerships (H3), increase groundwater storage banking (D3), new local and imported supply (B1, B3-B4), treat/mitigate groundwater (E1), model climate change impacts on groundwater (F2), expand monitoring and remote operations (D6)	Water quality, environmental stewardship, and water supply
Scenario 9: SLR resulting in potential saltwater intrusion in Niles Cone	SF Bay shoreline and Bay Area regional supply partnerships (H1, H3), green infrastructure and nature-based solutions (G1), treat/mitigate groundwater (E1), increase augmented recharge/banking (D2-D3), expand existing and develop new local/regional and imported supplies (B1-B4), expand monitoring and remote operations (D6), short-term conservation and long-term water use efficiency (A1-A2), model climate change impacts on groundwater (F2)	Facilities reliability, water quality, environmental stewardship, supply
Scenario 5: Wildfire resulting in potential non-salinity water quality degradation in local surface water	Green infrastructure and nature-based solutions (G1), invest in forest/vegetation management (G2), modeling climate impacts on surface water (F1), expand monitoring and remote operations (D6), reservoir water quality management (E2), adjust or expand surface water treatment (E3), Alameda Creek Watershed partnership (H4)	Environmental stewardship, safety, financing, water quality
Scenario 3: Drought resulting in potential reduction of imported supply - SFPUC	Bay Area regional supply partnerships (H3), expand existing and develop new local/regional and imported supplies (B1-B3), treat/mitigate groundwater (E1), distribution system improvements (D5), increasing augmented recharge/banking (D2-D3), new/expand surface storage (D1), short-term conservation (A1), adjust dry-year operating rules (D4)	Water delivery, water quality, supply, and facilities reliability
Scenario 4: Drought resulting in potential reduction of imported supply - SWP	Delta and Bay Area regional supply partnerships (H2, H3), distribution system improvements (D5), new/expand surface storage (D1), expand existing and develop new local/regional and imported supplies (B1-B4), short-term conservation and long-term water use efficiency (A1-A2), increase augmented recharge (Niles Cone) (D2), adjust dry-year operating rules (D4)	Water quality, financing, supply, and environmental stewardship

For regulatory risks, the study recommends continued tracking of regulatory developments through:

- **Partnerships for knowledge sharing and regional planning.** This includes continuing to leverage participation in key partnerships and working groups such as CUWA and Delta Adapts. This is particularly relevant for improving and understanding development and timing of potential new legislation (e.g., expectations for new water use efficiency targets and when these will be enacted).
- **Aligning planning priorities.** Aligning planning priorities with state and federal policy supports meeting requirements for new funding opportunities for climate resilience. Specifically, the District can align planning priorities with criteria and priorities identified in state and federal policy. The District can also document benefits of developed strategies and projects to clearly demonstrate this alignment. Areas of interest based on existing policy direction are anticipated to include a greater focus on equity and environmental stewardship as well as strengthening regional reliability.
- **Pursuing state-of-science updates for key planning assumptions.** Pursuing regular updates with the evolving state-of-science supports staying current with best approaches for estimating changing conditions. This includes updating approaches and data used in the CAP that are provided by state agencies to guide scenario projections. Performing regular updates helps the District anticipate and efficiently plan resources to improve technical analysis and planning approaches, and to get ahead of changing regulatory requirements. For example, this includes updating the District's modeling parameters, assumptions for the WRMP, and the CAP along the same timeframe as the release of the future updates for the San Francisco Bay Area California Climate Change Assessment regional report.

9.2 Fulfilling CAP Objectives

The following identifies a findings-orientated summary of how objectives for this CAP Phase 1 were fulfilled and how they can guide future planning efforts (Figure 9-1):

Figure 9-1. Findings-oriented summary of how CAP Phase 1 objectives were fulfilled and direction for future planning efforts

9.3 Recommendations for Future Community Engagement

As the District uses the findings of this CAP to inform planning and decision making it will be essential to involve other stakeholders, such as partner agencies and the District's customers, in a collaborative process that considers different perspectives. Specifically, and as expanded in more detail in the Equity Snapshot in Appendix J, vulnerable communities are at higher risk of experiencing disproportionate climate change impacts if they are overlooked in climate resilience planning. Applying an equity lens during the planning process will ensure that the needs and concerns of V/DCs are better understood, and thus can be better addressed in long-term planning.

The study recommends the District further integrate equity in its planning and policy to align with state and regional guidance. The District could consider developing policies or programs similar to the following examples:

- King County Wastewater Treatment Division in Washington applies an equity lens on its facility and system improvements, policies, budget, and workplace and workforce development to focus on the underlying sources of inequities. They also consider equity in project selection using 14 determinants of equity to consider potential positive or negative impacts.
- SFPUC has adopted an Environmental Justice policy that focuses on preventing, mitigating, and lessening disproportionate environmental impacts and ensuring public benefits for all communities. They also maintain a Community Benefits Policy, which supports funding projects that promote community engagement and add value where project work is done.
- The City of Portland's Bureau of Environmental Services' Resiliency Master Plan includes a process for incorporating equity into capital planning that may be useful for the District's CIP and WRMP-related planning efforts. Key considerations from Portland's process include:
  - Assess: Conduct a demographic vulnerability analysis to identify where the District's V/DCs are and identify any disparities in the LoS impacts compared to other communities (best to consult community leaders).
  - Engage: Better engage the community by forming a paid Community Advisors board or work with other municipal groups in the service area that already perform such work. This would help the District evaluate its community outreach and monitor effectiveness.
  - Collaborate: Develop an equitable and transparent prioritization process with Community Advisors for projects and policies. Use weighted criteria that reflect the community's needs and urgent issues.
  - Evaluate: Once the highest-priority projects are identified, proposals could be developed are evaluated to ensure the outcomes align with community concerns.
  - Implement and Adaptively Manage: As projects are implemented, track the outcome with periodic revaluation of baseline metrics and assumptions and engage with stakeholders to see if adjustments are necessary. This in turn will strengthen the relationships with the community and contribute to more equitable projects.

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Section 10

Limitations

This document was prepared solely for Alameda County Water District (District) in accordance with professional standards at the time the services were performed and in accordance with the contract between the District and Brown and Caldwell dated February 19, 2022. This document is governed by the specific scope of work authorized by the District; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by the District and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 11

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Appendix A: Glossary

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Appendix A

Glossary

Adaptation – The process of adjusting to actual or expected climate risks and its effects to moderate or avoid harm or exploit beneficial opportunities (IPCC, 2014).

Adaptation Strategies - A general plan of action for addressing the impacts of climate change, which may include a mix of policies and measures that have the overarching objective of reducing vulnerability to climate change impacts (IPCC, 2014).

Adaptive capacity – "The combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities" (IPCC, 2012). It can also be defined as the ability of systems, institutions, humans and other organisms to adjust to potential damage effectively, to take advantage of potential opportunities, to respond to consequences, and to moderate negative impacts (IPCC 2014; Millennium Ecosystem Assessment, 2005; WUCA, 2021).

Adaptation pathways – An adaptation pathway is a decision-making strategy made up of a sequence of manageable, scheduled steps or decision-points over time. It identifies the decisions that need to be taken now (short-term) and those that may be taken in future (long-term) so that decision makers can plan for, prioritize, and stagger adaptation investments. Examples of adaptation pathways looks like a 'route map' showing various approaches, triggers, and timing of strategies. The approach supports strategic, flexible and structured decision-making. This approach to adaptation planning keeps options open and avoids path dependency/lock-in (Coast Adapt, 2017).

Atmospheric River - The largest California storms are called "atmospheric rivers" as they can carry more water than seven to fifteen Mississippi Rivers combined (Ralph et al., 2011) and can substantially reduce drought conditions (Dettinger, 2013). These storms result in heavy rainfall over a narrow area and contribute an average of 40% of the annual snowpack in California (Guan et al., 2013).

Climate - The prevailing weather conditions (temperature, precipitation, and seasonal patterns) for a particular region.

Climate Change - The long-term shifts in weather patterns, either regionally or globally. These shifts can cause imbalances in ecosystems and adverse impacts to human health and livability (how food is grown, human and wildlife health, water availability, etc.) (Alameda County et al., 2021).

Climate Risk – The potential for consequences to occur due to a climate change-related hazard where something of value is at stake and where the exact outcome is uncertain. Risk is often characterized as the probability or likelihood of occurrence of the hazardous climate event multiplied by the impacts if the climate event occurs. Risk is used to refer to the potential, when the outcome is uncertain, for negative consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure (IPCC, 2014).

Consequence – Consequence can also be used interchangeably with impacts or outcomes and are the potential effects on natural and human systems. In this report, the term consequence is used to refer to the effects on natural and human systems from extreme weather, climate change-related events and from climate change generally. "Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts" (IPCC, 2014, pg. 124).

Drought – Drought is an extended period over which precipitation is below normal (average conditions). Drought severity can be impacted by natural influences, such as high temperatures, high winds, and low relative humidity (Alameda County et al., 2021). Drought severity also depends on the duration, intensity, and geographic extent of the drought.

Exposure – The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to harm (IPCC, 2012).

Global Warming – The atmospheric and oceanic warming due to the anthropogenic release of greenhouse gases (which includes carbon dioxide (CO2), methane, and others), which cause heat to be trapped in Earth's atmosphere.

Greenhouse gas mitigation – "A human intervention to reduce the sources or enhance the sinks of GHGs" (IPCC, 2014).

Landslide – Landslides are the dislodgement and falling of soil, rocks, or even a dislodged mass along a sloped surface. They can include phenomena such as mudflows, mudslides, debris flows, rock falls, and debris slides. Landslides can be a secondary impact of heavy rains and prolonged wet periods, particularly after wildfires have cleared out vegetation, causing soil to be susceptible to erosion.

Likelihood – "A probabilistic estimate of the occurrence of a single event or of an outcome, for example, a climate parameter, observed trend, or projected change lying in a given range. Likelihood may be based on statistical or modeling analyses, elicitation of expert views, or other quantitative analyses" (IPCC, 2012a, pg. 561). In this CAP, this definition may be simplified to the probability, or potential frequency, or occurrence of a climate risk event.

Liquefaction – Liquefaction "occurs when seismic waves pass through saturated granular soil distorting its granular structure and causing some of the empty spaces between granules to collapse. Liquefaction causes lateral spreads (i.e., horizontal movements of 10 to 15 feet most commonly but up to 100 feet), flow failures (i.e., massive flows of soil, typically hundreds of feet but up to 12 miles), and loss of bearing strength (i.e., soil deformations causing structures to settle or tip). Liquefaction can cause severe damage to property" (Alameda County et al., 2021, pg. 31).

Resilience – The ability of a system to cope with a hazardous event, trend, or disturbance and maintain its essential function, identity, and structure, while maintaining the capacity for adaptation and learning (IPCC, 2014). Hazard events can include both acute (severe, short-term events, e.g., wildfire) or chronic hazards (present, recurring events, e.g., sea level rise).

Sea Level Rise - As the air temperature of the Earth continues to warm due to the increase in GHGs, the ocean absorbs this heat and warms along with the air. With the oceans warming, Earth's cryosphere (the frozen water on Earth including glaciers, sea ice, ice sheets, permafrost and snow) will melt. As seawater warms, it also expands. This thermal expansion of the oceans is one contributing factor to sea level rise. The other factor is the melting of the cryosphere, contributing to rising sea levels (IPCC, 2021).

Sensitivity - The level to which a species, natural system, or community, government, etc., would be affected by changing climate conditions (Bedsworth et al., 2018).

Trigger (for adaptation pathways) – Triggers can be physical, regulatory, or driven by other external factors (e.g., external projects or decisions).

Vulnerability – The propensity or predisposition to be adversely affected. Vulnerability includes sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

Water supply reliability – The overall ability of the water utility to meet water demands.

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Appendix B: Climate Impacts

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Appendix B

Climate Impacts

This Appendix contains definitions and the historical context for each climate vulnerability outlined in Section 5 of this report.

B.1 Extreme Heat

Increasing temperatures also means an increase in the number of high heat days. Nineteen heat-related events occurred from 1999 to 2009 that had significant impacts on human health, resulting in about 11,000 excess hospitalizations (Bedsworth et al, 2018), with implications for District staff working in the field.

The Bay Area has seen an annual maximum temperature increase of 1.7°F (0.95°C) from 1950-2005 (Ackerly et al., 2018). With a maximum temperature increase already seen, the built environment, such as roads, sidewalks, and buildings, has a huge impact on magnifying extreme heat in the Bay Area through the urban heat island effect, which can be addressed through urban forestry and the cooling effects of irrigation (Ackerly et al., 2018). For example, landscape irrigation practices can reduce daytime summer temperatures in urban areas of the Bay by an average of 1.8°F (1.0°C) (Vahmani et al., 2017). This has implications for increased water use during heat events, impacting District water delivery.

Finally, several studies suggest that coastal fog along the California coast, which is critical to our Bay Area climate, is less frequent than before (Ackerly et al., 2018). Less fog will cause hotter land temperatures for the Bay Area and could lead to an increase in extreme heat days, impacting District water delivery.

B.2 Reduced Snowpack

With the District receiving 40% of their supply from the State Water Project, which originates as snowpack in the Sierra Nevada, it's important to note that with increasing temperatures, glaciers in the Sierra Nevada have lost an average of 70 percent of their area since the start of the 20th century (Vahmani et al., 2017), and snowpack in the Sierras has decreased over time (Ackerly et al., 2018). According to California's Fourth Climate Change Assessment, "Regional analyses indicate that climate change has already begun to reduce the fraction of precipitation falling as snow and has diminished spring snow water accumulation in the western United States. A census of western snow courses (area where snowpack is measured) reveals that since the 1950s, April 1 snow water storage, averaged across the western U.S., has declined by about 10 percent" (Bedsworth et al, 2018, pg. 26). With reduced snowpack comes a changing in the timing and volume of water deliveries, which may impact future deliveries from the State Water Project.

B.3 Sea Level Rise

As the air temperature of the Earth continues to warm due to the increase in GHGs, the ocean absorbs this heat and warms along with the air. With the oceans warming, Earth's cryosphere (the frozen water on Earth including glaciers, sea ice, ice sheets, permafrost and snow) will melt. As seawater warms, it also expands. This thermal expansion of the oceans is one contributing factor to sea level rise. The other factor is the melting of the cryosphere, contributing to rising sea levels (IPCC, 2021).

It is important to note that regional rates of SLR are highly variable because there are varying ocean and atmospheric circulation patterns, gravitational and deformational effects due to land-based ice mass changes, and tectonics and other drivers of vertical land motion (NRC, 2012). Water bodies can experience varying degrees of SLR compared to other nearby areas because the shape of water bodies (e.g., such as a bay) can vary the influence of SLR.

In California, there has been 5.9” of recorded sea level rise in the last 100 years, with the Bay Area seeing over 8” (20 cm) of SLR (see above note in the “Definition” section on how local conditions may cause regional variations in SLR) (Bedsworth et al., 2018 and Ackerly et al., 2018).

Another important component of SLR is subsidence, which is the gradual settling or sudden sinking of land most often caused by groundwater pumping, sediment compaction, and marsh accretion. According to the Bay Area Report of California’s Fourth Climate Change Assessment, “Extensive groundwater pumping in the Santa Clara Valley from 1916-1966 led to as much as 1 meter of subsidence along the shoreline of South San Francisco Bay, leading to the periodic flooding of low-relief land adjacent to the Bay. Some of the submerged land has been recovered over the last several decades due to more responsible groundwater pumping practices, resulting in recent uplift of 1-2 mm/year.” (Ackerly et al., 2018, pg. 32).

El Niño events can cause elevated water levels, and when combined with SLR, could cause increased coastal flooding. According to the Bay Area Report of California’s Fourth Climate Change Assessment, “Periodic El Niño events exert a dominant control on coastal hazards across the region, driven by seasonally elevated water levels as high as 30 centimeters above normal, and, on average, 30% larger winter wave energy. The powerful El Niño of 2015-16, one of the three largest in the historical record, resulted in elevated water levels of 10-20 cm and winter wave energy that was over 50% larger than the typical winter in the Bay Area, driving unprecedented outer coast beach erosion (i.e., landward shoreline retreat) that was 98% higher than normal” (Ackerly et al, 2018, pg. 33). This could have impacts to the District’s shoreline infrastructure, such as increased flooding or erosion, which could cause loss of access to or damage to infrastructure.

Contamination Risk from Sea Level Rise

Displacement of the ground due to liquefaction in a seismic event could compromise the stability of waste containment facilities, such as landfill caps or liners, caps over remediated sites, and slurry walls constructed to contain contaminants. These contaminants may pose a threat to groundwater supplies.

While contaminants may be released from liquefaction events, they may also be mobilized through sea level rise. The release of hazardous substances occurs through four pathways: groundwater migration, surface water flow, soil exposure, and release to the air (vaporization). These pathways lead to effects on receptors through contamination of drinking water and food chains, as well as direct exposures to human populations and sensitive ecosystems (USEPA, 2022). SLR may inundate areas not designed for temporary or permanent inundation, causing floodwaters to leach contaminants from the site. Previously remediated sites, closed landfills, Superfund sites, and/or underground storage tanks (USTs) may not have been designed for temporary or permanent inundation.

Most sites that have been remediated in place are covered with one to three feet of clean soil under a cap of concrete or other material (sometimes in the form of a road or building). While this method is intended to contain contaminants, such sites are sensitive to flooding and rising groundwater. For example, water-soluble substances, such as solvents, could become mobilized in floodwaters in sites with compromised caps that do not prevent the infiltration of Bay water, and rising groundwater could also become contaminated with water-soluble substances (BCDC, 2012).

Leaking USTs tend to contaminate soil and groundwater in their vicinity. Therefore, they are sensitive to rising groundwater since this impact could expose more groundwater to contaminants. Saltwater intrusion into groundwater could also corrode underground storage tanks and cause additional leaking. USTs are less likely to be sensitive to storm-related flooding unless floodwaters are very high-energy and scour contaminated soils, exposing and possibly moving the tank. Floodwater that remains for a long time period could infiltrate through the soil or enter the tank and become contaminated or cause empty tanks to “float” and pop out of the ground. Tidal inundation could pose more of a problem, due to the frequency and duration of exposure, which could result in greater likelihood of contact with contaminated soils and tank contents, leaching through contaminants to groundwater below, or causing empty tanks to float (BCDC, 2012).

For landfills, releases of leachates, or contaminated waters from active and closed solid waste landfills, pose a potential environmental threat. Many older landfills that are now closed were not lined (e.g., Turk Island Landfill in Union City) or were lined inadequately to prevent leachate contamination of surrounding lands and/or waters. Some old landfills used a layer of bay mud, a natural clay that typically has very low permeability, and acts as a liner. Leaks are generally detected because the majority of these sites are monitored and regulated by the Regional Water Quality Control Board. Despite this, new exposures to water (e.g., due to higher groundwater levels) could lead to leaching. Both groundwater and surface waters at the landfills are monitored regularly, and some of the closed landfills and all active ones have leachate collection systems to prevent environmental contamination (BCDC, 2012). Landfill caps are designed to prevent the vertical migration of water from above the landfill, into and through the waste, and down to the groundwater table. However, tidal inundation or storm event flooding could contribute to the creation of leachate where caps are not watertight. Leachate production could also occur if rising groundwater migrates into the waste, which would necessitate greater leachate removal at some sites where it is already necessary, or the installation of a leachate collection system at sites where it has previously not been necessary (BCDC, 2012).

Contamination at cleanup program sites can include trichloroethylene, polychlorinated biphenyls (PCBs) and other chlorinated hydrocarbons, metals (e.g., lead, chromium, nickel), and solvents such as acetone and benzene (BCDC, 2012). Contamination of USTs could contain gasoline, diesel, or petroleum byproducts like benzene (BCDC, 2012).

Different types of contaminated lands are vulnerable to sea level rise in different ways. Sites contaminated with solvents, for example, are sensitive to rising groundwater because solvents can go into solution in groundwater and spread underground and/or cause air quality problems in buildings constructed on top of the site (BCDC, 2012). Sites with PCBs, on the other hand, may be more sensitive to storm event flooding because PCBs bind to sediment; if floodwaters cause erosion of contaminated sediments, PCBs could be carried to the Bay, where they are already a problem for wildlife and people who consume fish caught in the Bay (BCDC, 2012).

SLR can also cause pipe buoyancy for pipelines that are not anchored or weighted. Pipe buoyancy occurs when a pipe is partially or fully submerged in water and air inside of the pipe causes it to float, potentially causing breakage of gas, petroleum water, and/or wastewater pipelines. This can cause impacts to water quality through groundwater contamination of leaking pipelines or could impact water delivery pipelines if a water pipeline needs to be emptied and fixed. The project area contains various types of liquid fuel and natural gas pipelines that run parallel along the Bay shoreline (but outside of the District service area) and some cross the Bay. In general, these pipelines are buried at a depth of 3 to 4 feet in high-carbon steel pipelines. Many of the pipelines were built in the 1960s and 1970s and are maintained regularly as mandated by state and federal regulations (BCDC, 2012).

Finally, SLR may also expose infrastructure to brackish water which may cause sensitive equipment to corrode, potentially leaking contaminants into the soil or groundwater. Cathodic protection is the predominant way to minimize gas pipelines' corrosion risks in coastal areas at risk to inundation and saltwater intrusion (Bedsworth et al., 2018) and government regulations require pipelines to be coated and cathodically protected against corrosion (BCDC, 2012). However, these protections require regular inspection and maintenance (SoCal Gas, 2016), and the potential for the effectiveness of the coating to diminish over time due to weather-related factors has been raised in public filings (CPUC, 2016).

B.4 Rising Shallow Groundwater

Rising shallow groundwater is a secondary impact from SLR. As sea levels rise, they may also raise coastal groundwater tables, resulting in groundwater flooding hazards. Since sea water is denser than freshwater, as sea levels rise it pushes up freshwater shallow aquifers. Groundwater modelling done along the California coast shows that areas at risk from rising groundwater tables extend beyond the inundated area from sea level rise alone (May, 2020). This means that emerging groundwater can flood low-lying hydrologically disconnected areas (low-lying areas with no direct overland route from flood waters) (BCDC, 2020).

The response of coastal groundwater to sea level rise is largely unknown and the study of rising shallow groundwater due to SLR is a relatively new field. Therefore, historical evidence is limited.

B.5 Drought

Drought is an extended period over which precipitation is below normal (average conditions). Drought severity can be impacted by natural influences, such as high temperatures, high winds, and low relative humidity (Alameda County et al., 2021). Drought severity also depends on the duration, intensity, and geographic extent of the drought.

Drought has been a cyclic part of the climate of California, occurring in both summer and winter, with an average recurrence interval of every 3 to 10 years. The current drought, on its third consecutive year, is the driest on record in California since recordkeeping began in 1895 (NPR, 2022). The second most recent drought from 2012 to 2016 was the second driest 4-year period on record. The recent 2012-2016 drought was exacerbated by unusual warmth (Williams et al., 2015), and disproportionately low Sierra Nevada snowpack levels (Dettinger et al., 2015). The most recent two droughts led to the most severe moisture deficits seen in the last 1,200 years and a 1-in-500 year low for Sierra snowpack (Ackerly et al., 2018). The drought of 2012-2016 has been described as a harbinger of projected dry spells in future decades, whose impacts will likely be worsened by increased heat (Mann et al., 2015).

The National Drought Mitigation Center produces drought monitor maps for the United States. It classifies droughts into five categories: D0 is the least severe, with abnormally dry conditions; D4 is the most severe, with exceptional drought conditions. As of May 2022, Alameda County experienced D2 (severe drought) while California's Central Valley experienced D3 (extreme drought). In October 2022, part of Alameda County moved into D3 (extreme drought), and the Central Valley moved into D4 (exceptional drought).

The droughts that have occurred in Alameda County and California over the past 100 years are listed below (Alameda County et al., 2021):

- 1917–1921, statewide except for central Sierra Nevada and north coast

Brown AND Caldwell

- 1922–1926, statewide except for central Sierra Nevada
- 1928–1937, statewide
- 1943–1951, statewide
- 1959–1962, statewide
- 1976–1977, statewide, except for southwestern deserts
- 1987–1992, statewide
- 2007–2009, statewide, particularly the central coast
- 2012–2016, statewide
- 2021–present, statewide

B.6 Wildfire

The Bay Area's Mediterranean climate combined with the hot, dry Diablo winds of Northern California creates a perfect recipe for starting wildfires. The Diablo winds come from the Sierras, move west and pull heat from the Central Valley, and come over the Central Range mountains in the Bay Area. The excessive wind combined with hot and dry conditions can cause power lines to topple and spark, creating wildfires that can rapidly spread (Alameda County et al., 2021). Fire ignitions in California are primarily due to human activities, though lightning can also spark fires, and the dry, flammable vegetation leads to high fire risk and rapid spread (Alameda County et al., 2021). Human factors such as ignitions, development at the wildland-urban interface, wildfire suppression activities, and infrastructure can all impact wildfires (Bedsworth et al., 2018). Wildfires often occur in forests or highly vegetated areas where there is enough dry fuel to spread the fire. They can be classified as forest, urban, interface or intermix, and prescribed burns (Alameda County et al., 2021).

Fuel, such as the type and condition of vegetation, as well as topography, can impact wildfires (Alameda County et al., 2021). Droughts and increasing temperatures may impact wildfires since moisture content of both living and dead vegetation decreases. Finally, weather is the most variable factor that can impact wildfires. The temperature, humidity, wind, and lightning conditions can impact the chance of ignition and fire spread rate.

According to the Bay Area Report of California's Fourth Climate Change Assessment, "At relatively broad scales, climate affects fire regimes in two different ways, either by altering vegetation growth rates (e.g., fuel accumulation) or through changes in fire season length and severity (e.g., fuel flammability and fire weather). At finer scales, recent studies demonstrate that fire exhibits a "hump-shaped" response to human development, with fire activity peaking in the wildland-urban interface due to increased ignitions and dropping off both in more urbanized areas and in less developed rural regions and open space" (Ackerly et al, 2018, pg. 29).

In recent years, the area burned by wildfires has increased in parallel with increasing air temperatures (Bedsworth et al., 2018). According to California's Fourth Climate Change Assessment, "A changing climate combined with anthropogenic factors has already contributed to more frequent and severe forest wildfires in the western U.S. as a whole" (Bedsworth et al, 2018, pg. 28).

In the Bay Area, autumn wildfires have grown by 20% since the early 1980s due to increases in autumn temperatures (~1 °C) and decreases in autumn precipitation (~30%) over the past four decades. The observed frequency of autumn days with extreme (95th percentile) fire weather (days associated with extreme autumn wildfires) has more than doubled in California since the early 1980s (Gross et al., 2020).

Based on historical Cal FIRE records, Alameda County has averaged approximately 4 to 5 wildfires annually over the past 5 years and there were 100 more wildfire days annually in the Bay Area from

1973 to 2020. Cal FIRE also reported that Alameda County has experienced 221 wildfires since record keeping began 70 years ago. One-third of the recorded fires have been 10 acres or less and 19 wildfires were greater than 500 acres (or three times the size of Disneyland). The largest wildfire to occur in Alameda County occurred in 2020, called the SCU Lightning Complex, which burned 396,624 acres of which 24,064 acres were within Alameda County (Alameda County et al., 2021). There were two large wildfires in the Bay Area and North Coast, particularly the 2015 and 2017 fires, that were large, destructive, and shifted attention towards the Bay Area's need to consider the ongoing fire risk to the region.

In October 2017, a Diablo wind event contributed to fire behavior that led to enormous damage in Sonoma and Napa Counties. According to California's Fourth Climate Change Assessment, "In 2017, a late onset in winter precipitation maintained the availability of dry vegetation during December. When Diablo winds developed that month, the dry vegetation was primed for explosive wildfires. Usually, early winter precipitation will moisten dry summer and fall vegetation, limiting wildfires in December and January even with the presence of dry winds" (Bedsworth et al, 2018, pg. 29).

Figure B-1 shows the Bay Area Report of California's Fourth Climate Change Assessment findings that, "Prior to 2017, the peak year was 1964. The North Bay fires of October 2017 burned more than twice the area of any previous year, following close on the heels of the large and destructive Lake County fires of 2015. As of 2018, six of the top 20 most destructive fires in California history (in terms of buildings lost) have occurred in the Bay Area" (Ackerly et al, 2018, pg. 29).

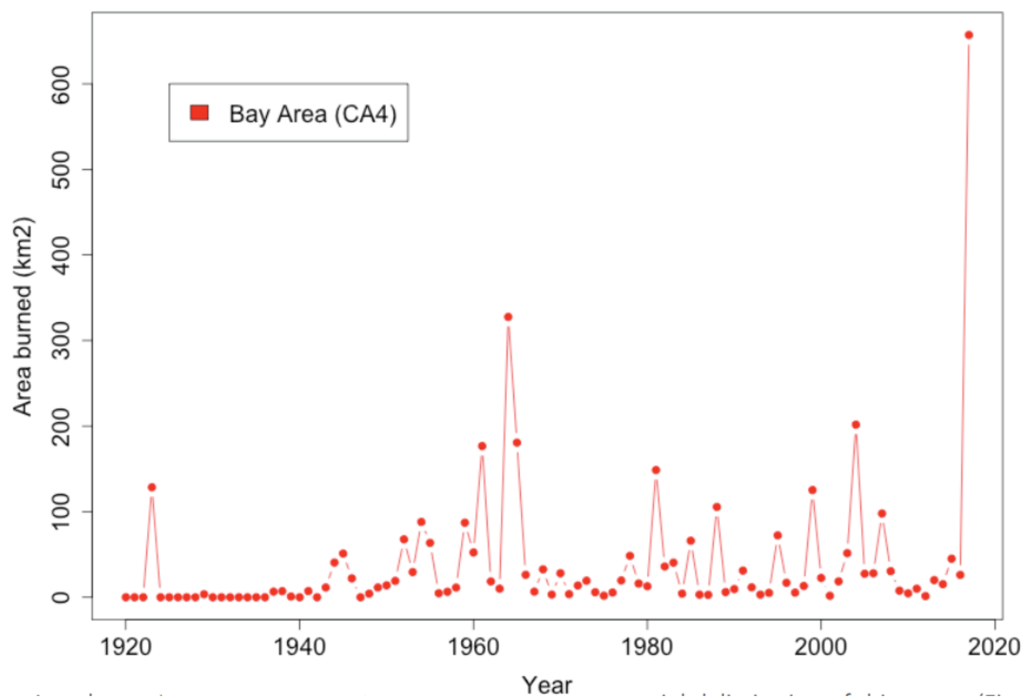

Figure B-1. Area burned by wildfire in the Bay Area (before 1950, only large fires are counted)

Source: Ackerly et al., 2018

Water Quality Contamination Risk from Wildfires

Wildfires may also cause contamination of water supplies through rain events after wildfires—contaminants can be released from wildfires and mobilized through rain. The California Urban Water Agencies (CUWA) has done research on how wildfires can impact certain water quality parameters and what monitoring strategies can be used to determine the short- and long-term consequences for water systems. It is important to note that the impacts of wildfires on water quality can vary largely based on the wildfire location and sites affected (CUWA 2021). From their research, CUWA has determined that wildfires in watersheds or near untreated reservoirs can negatively impact water quality both during active burning, and for months or even years after the fire has been contained. During active burning, ash and contaminants can settle on lakes or reservoirs used for drinking water. After active burns, storms can mobilize large amounts of ash, sediment, nutrients and contaminants into streams, rivers, and reservoirs, especially in areas with exposed soil from vegetation burning away. See the Table B-1 below for a summary of water quality parameters that can be impacted from wildfires.

If the wildfire is located near a water treatment plant, potential impacts could include increased chemical treatment consumption (e.g., coagulants) and associated solids production; limited use of ozone treatment due to impacts from power variability, smoke, and/or dust; and dangerous plant conditions impacting operations and monitoring. Contaminants that can potentially impact water treatment plants are also listed in Table B-1 below.

Table B-1. Contaminants Associated with Wildfires and their Effects on Water Quality

Contaminant	Impact to water quality
General physical-chemical parameters (pH, alkalinity, total dissolved solids, conductivity, hardness, dissolved oxygen)	• pH affects all chemical and biological reactions, including coagulation, flocculation, precipitation, softening, biological treatment, disinfection efficacy and microbial inactivation, disinfection by-product formation, metal dissolution and corrosion, etc. • Alkalinity influences the performance of coagulants, corrosion, and some chemical and biological processes • Total Dissolved Solids (TDS) and conductivity influence corrosion and metal release, scaling, effectiveness of detergents, aesthetic characteristics, and irrigation systems; other impacts are specific to the ions present • Hardness impacts corrosion and scaling • Decreases in dissolved oxygen may lead to algae growth and cyanotoxins, and influence biological treatment, distribution system water quality, metal oxidation, etc.
Particles (turbidity, Total Suspended Solids, Zeta potential and settleability)	• Increase particle loading and turbidity • Decrease dissolved oxygen and increase temperature in untreated water bodies • Provide support for microbial growth • Interfere with disinfection processes • Can harbor pathogens
Metals	• Non-compliance if metals exceed their respective primary or secondary standards • Impact treatment and disinfection processes depending on metals found • Can accumulate in distribution system and be subsequently released • Can affect aesthetic characteristics
Inorganics (nitrate, nitrite, ammonia, sulfate, phosphorus)	• Ammonia and nitrite consume disinfectant residual, which may influence efficacy of pre-disinfection; they can also lead to nitrification in filters • Nitrate can be responsible for non-compliance • Some fire retardants (including Phos-Chek, a common agent used in California) contain ammonia and phosphate, along with undisclosed performance additives • Sulfate consumes disinfectants and can influence disinfectant stability, and taste and odor • Phosphorous enhances algae growth in surface water reservoirs, which can lead to the presence of cyanotoxins
Nutrients and organics (total organic carbon, dissolved organic carbon, UV absorbance)	• Enhance microbial growth • Decrease disinfectant stability • Increase disinfection by-product formation potential
Aesthetic (taste and odor, color)	• Non-compliance with secondary standards • Customer concerns and complaints

B.7 Public Safety Power Shutoff

During periods of high temperatures, high and sustained peak winds, and low humidity, there is an increased chance of wildfire. Pacific Gas and Electric Company (PG&E) may de-energize electrical grids or blocks of an area in advance of or during periods of heightened risk since electrical transmission and distribution lines may ignite fires. Per the California Public Utilities Commission (CPUC), utilities will only de-energize if the utility reasonably believes that there is an 'imminent and significant risk' to strong winds that may topple power lines or cause damage to power lines, leading to increased risk of fire. Approximately 85 percent of all fire ignitions in California are the result of human activities (Bedsworth et al., 2018), and the rest are due to lightning.

In late October 2019, the Bay Area, including Alameda County, had widespread PSPS. In October 2020, 40,000 utility customers in Alameda County were expected to lose power from another PSPS. However, the shutoff was canceled due to a change in weather conditions. In August 2021, a few dozen utility customers were expected to lose power to again, but the public safety power shutoff was cancelled (Alameda County et al., 2021).

B.8 Increased Storm Intensity and Atmospheric Rivers

Riverine flooding occurs when the existing watercourse cannot handle the excess runoff from rainfall or snowmelt, resulting in overflow onto adjacent lands. Pluvial, or overland, flooding occurs during large precipitation events and is a concern for urban areas because it can occur outside of floodplains or waterways. For the coast, flooding occurs during high tides, which can be king tides (exceptionally high tides), storm tides (with storm surge and wave action), or a combination of these. Coastal flooding can be exacerbated by coinciding rain events.

The largest California storms are called "atmospheric rivers" as they can carry more water than seven to fifteen Mississippi Rivers combined (Ralph et al., 2011) and can substantially reduce drought conditions (Dettinger, 2013). These storms result in heavy rainfall over a narrow area and contribute an average of 40% of the annual snowpack in California (Guan et al., 2013). More than other regions of the western United States, the presence or absence of these large storms within a given winter season determines California's water resources because of their contribution to snowpack (Dettinger et al., 2015). However, they also present substantial flood risk and are a major cause of historical floods (Ackerly et al., 2018).

California experiences a wide range of precipitation events with natural variability in year-to-year variations and extremes. The Bay Area can have multiple years that are very dry followed by multiple years that are very wet. Mean annual precipitation in the Bay ranged considerably from year to year over 1950-2005, from 11.7 inches to 61.1 inches (29.7 cm to 155 cm) (Ackerly et al., 2018). According to the Alameda County LHMP, "In Alameda County, floods usually occur during the season of highest precipitation or during heavy rainfalls after prolonged dry periods. Alameda County is dry during late spring, summer, and early fall, receiving most of its rain during the winter months. The rainfall season extends from November through April, with approximately 95% of the annual rainfall occurring during this period…Severe flooding is most likely to occur during strong El Niño events, which generally occur every 2 to 7 years" (Alameda County et al., 2021, pg. 34).

There have been 45 days associated with a flood event from January 1, 2000, to May 31, 2021, in Alameda County according to the National Oceanic and Atmospheric Administration Storm Events Database (Alameda County et al., 2021). Of these, five were federally declared disasters:

- Landslides and Mudslides (DR-4308-CA), February 1, 2017, to February 23, 2017
- California Severe Winter Storms, Flooding, Landslides, and Mudslides (DR-4305-CA), January 18, 2017, to January 23, 2017

- California Severe Winter Storms, Flooding, Landslides, and Mudslides (DR-4301-CA), January 3, 2017, to January 12, 2017
- California Storms, Flooding, Landslides, and Mudslides (DR-1646-CA), March 29, 2006, to April 16, 2006
- California Storms, Flooding, Landslides, and Mudslides (DR-1628-CA), December 17, 2005, to February 3, 2006

B.9 Landslides

Landslides are the dislodgement and falling of soil, rocks, or even a dislodged mass along a sloped surface. They can include phenomena such as mudflows, mudslides, debris flows, rock falls, and debris slides. Landslides can be a secondary impact of heavy rains and prolonged wet periods, particularly after wildfires have cleared out vegetation, causing soil to be susceptible to erosion.

In California, landslides can range from small and shallow that can grow larger, to landslides that can move entire houses, to debris flows from burned areas after wildfires (Alameda County et al., 2021). Landslides are dependent on variations in natural geology, topography, vegetation, and weather. Landslide susceptibility increases on steeper topography. However, development can also impact landslides through building inappropriately, such as cut-and-fill slopes, in unstable areas (Alameda County et al., 2021).

Over the last two decades in Alameda County there have been five major disaster declarations for mudslides and landslides associated with winter storms. In fact, mudslides and landslides associated with severe storms have been among the most common disasters throughout the Bay Area from 1950 to 2009, causing hundreds of millions of dollars in property loss, tens of deaths, and hundreds of injuries (Alameda County et al., 2021).

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Appendix C: Risk Matrix

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Appendix C

Risk Matrix

[Risk Matrix provided in separate Excel document for reference]

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Appendix D: Likelihood Scores

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Appendix D

Likelihood Scores

Likelihood scores are based on identified trends in scientific data. The following provides background information on the scientific understanding supporting the indication of trends for climate threats in the current state-of-science.

Increasing temperature: The California Fourth Assessment on Climate Change states there is a “very high” confidence that warming will occur. All parts of the Bay Area, including Alameda County, are projected to become warmer, with an annual mean warming of approximately 3.3°F by mid-century (Ackerly et al., 2018). By mid-century, the Bay Area will see a significant temperature increase. By century’s end, temperatures will rise, but the trend in global emissions or reductions will determine how much Bay Area temperatures rise or change (Ackerly et al., 2018).

Sea level rise: For this century, it is virtually certain that sea levels will rise significantly. According to the Bay Area Report of California’s Fourth Climate Change Assessment, “Even with high levels of emissions reductions, research now suggests that at least 2 meters of sea level rise is inevitable over the next several centuries due to the lag of sea level rise in response to increasing global temperatures” (Ackerly et al, 2018, pg. 32-33). However, uncertainty persists in the rate of sea level rise, primarily due to the large uncertainty in ice sheet melting (Bedsworth et al., 2018). The OPR’s State of California Sea-Level Rise Guidance document notes the following likelihoods of SLR meeting or exceeding a certain height, as shown on Figure D-1. Note that the low-emissions scenario starts at 2060 since the globe is already on a high-emissions trajectory through 2050.

SAN FRANCISCO - High emissions (RCP 8.5)

	Probability that sea-level rise will meet or exceed... (excludes H++)									
	1 FT.	2 FT.	3 FT.	4 FT.	5 FT.	6 FT.	7 FT.	8 FT.	9 FT.	10 FT.
2030	0.1%									
2040	3.3%									
2050	31%	0.4%								
2060	65%	3%	0.2%	0.1%						
2070	84%	13%	1.2%	0.2%	0.1%					
2080	93%	34%	5%	0.9%	0.3%	0.1%	0.1%			
2090	96%	55%	14%	3%	0.9%	0.3%	0.2%	0.1%	0.1%	
2100	96%	70%	28%	8%	3%	1%	0.5%	0.3%	0.2%	0.1%
2150	100%	96%	79%	52%	28%	15%	8%	4%	3%	2%

SAN FRANCISCO - Low emissions (RCP 2.6)

	Probability that sea-level rise will meet or exceed... (excludes H++)									
	1 FT.	2 FT.	3 FT.	4 FT.	5 FT.	6 FT.	7 FT.	8 FT.	9 FT.	10 FT.
2060	43%	1.4%	0.2%							
2070	62%	4%	0.6%	0.2%						
2080	74%	11%	2%	0.4%	0.2%	0.1%				
2090	80%	20%	3%	1.0%	0.4%	0.2%	0.1%	0.1%		
2100	84%	31%	7%	2%	0.8%	0.4%	0.2%	0.1%	0.1%	
2150	93%	62%	31%	14%	7%	4%	2%	2%	1%	1%

Figure D-1. OPR's estimated probabilities that SLR will meet or exceed a particular height (in feet) for high- and low-emissions scenarios

Source: State of California Sea-Level Rise Guidance (2018 Update)

Sea level rise may also influence and exacerbate rising shallow groundwater. However, the likelihood of emergent groundwater depends on both SLR and local conditions (e.g., hydraulic conductivity of soil).

Drought: California has a highly variable climate with wet or dry periods that can span years. Climate scientists suggest the possibility of longer and more destructive droughts with climate change. Therefore, drought conditions are likely to occur in Alameda County at least every decade (Bedsworth et al, 2018). For California, future increases in temperature, regardless of whether total precipitation goes up or down, will likely cause longer and deeper droughts that pose major problems for water supplies, natural ecosystems, and agriculture (Ackerly et al., 2018).

Storms: California has a "low" certainty that precipitation will increase over time with climate change and a "medium-high" certainty that storm intensities will increase with climate change (Bedsworth et al, 2018). According to California's Fourth Climate Change Assessment, "On an annual basis, climate model projections do not present a strong consensus towards the whole of California "getting wetter" or "getting drier." The models do show a tendency for the northern part of the state to become wetter…However, this tendency is relatively small compared to the amount of year-to-year variation in precipitation in the region" (Bedsworth et al, 2018, pg. 25). The study by Swain et al. (2018) states that, under the RCP 8.5 scenario, a mega-flood is more likely than not to occur at least once between 2018 and 2060, and that multiple occurrences are plausible by 2100. Additional studies are needed to increase the confidence of this finding, but the results are in general agreement with the increased occurrence of heavy precipitation events.

Shallow landslides can also occur at any time during the winter but are more likely to happen when the ground is nearly saturated, which typically occurs after the first few storms in November and December. However, deep-seated landslides are generally triggered by deep infiltration of rainfall, which may take weeks or months of precipitation; therefore, they tend to occur toward the end of the winter season in March or April (Bedsworth et al, 2018). Every landslide event reported in Alameda County has followed a winter storm or rain event. The probability of a future landslide event will be highly tied to a winter storm event. Based on historic conditions, severe winter storm conditions are likely in Alameda County every 2 to 7 years (Bedsworth et al, 2018). Given that climate change projections show a medium-high certainty that intense storm events will increase over time, landslides may occur more frequently or with greater intensity, particularly after a wildfire.

Wildfires: With a "very-high" confidence of our future seeing increasing temperatures and a "medium-high" confidence of more-frequent droughts, it is very likely that wildfires will worsen over time. Projections are similar for mid-century under RCP 4.5 and RCP 8.5; however, global emissions will play a big role in determining if the end-of-century conditions are similar to or worse than mid-century. Changes in land use will also impact wildfire probability. According to the Bay Area Report of California's Fourth Climate Change Assessment, "Projections of the impact of development and land use change are less-well developed. These effects are incorporated in two modeling studies for the Bay Area (Mann et al. 2016; Westerling 2018). While the studies are not directly comparable, Mann et al. suggest that future fire activity will be driven as much by changes in human development as by changes in climate. Continued development will likely dampen fire probabilities in areas closest to high-density human development, while potentially increasing fire risk where development expands in the wildland-urban interface. Westerling (2018) projected increased fire probability in most of the Bay Area, especially the dry hills around Mt. Hamilton, with reduced fire risk near urban areas and development corridors" (Ackerly et al, 2018, pg. 30).

Wildfires and the risk of wildfires can also result in a PSPS. The Pacific Gas & Electric Company (PG&E) predicts PSPS could happen one to two times a year, though with climate change this may be more. In July 2021, PG&E announced it upgraded its technology to hopefully create fewer and more targeted power shutoffs (Alameda County et al., 2021). With further advances in technology, wildfire from electrical lines may be reduced in the future. California has a "medium-high" likelihood of experiencing an increasing number of acres burned from wildfires (Bedsworth et al., 2018).

Likelihood scores: Likelihood scores determined for each climate threat based on current state-of-science including the summary presented in this appendix. Scores were determined on a scale of 1 (low) to 5 (high) likelihood for mid- (2050) and long-term (2100) planning horizons (Table D-1). Values were adjusted downward when applied to each scenario if there is limited ability to produce adverse impacts for each risk event (Table D-2).

Table D-1. Summary of Likelihood Scores by Climate Threat based on Scientific Data Trends			
Climate Threat	Mid-Term Likelihood (2050)	Long-Term Likelihood (2100)	Justification
Increasing Temperatures	5	5	Annual average temperature anticipated to increase in both mid- and long-term (Cal-Adapt, 2021). Western North America regions have observed increase in hot extremes (IPCC 2021)
Droughts	5	5	State of CA (and this region) assume continued increase in severity and frequency of droughts (California 4th Climate Change Assessment)
Flood	4	4	Frequency and intensity have increased since 1950; trend likely to continue (IPCC 2021), though there is less certainty at medium and high emission scenarios for mid- and long-term (Cal-Adapt, 2021)
Storms	4	4	(Same data and justification for "Flood" above, Cal-Adapt 2021 and IPCC 2021)
Wildfire	5	5	Wildfires already experienced within this region with increasing severity and frequency, trend assumed to continue based on state guidance
Sea Level Rise	4	5	Degree of rise uncertain; however, several estimates include 3 feet by 2050/2060 and potentially 6 feet by 2100 (California Coastal Commission, 2021) (reiterated with NOAA climate data - Sea Level Rise viewer)
Regulatory Change	3	4	Varies by regulation, but higher likelihood to occur with greater passage of time (within 80 years from current year)

Values and justification of likelihood scores from the Risk Matrix (separately attached as Appendix C) are provided in Table D-2 for quick reference. These include all likelihood scores assigned to the full list of over 30 climate risk scenarios prior to aggregating of these scenarios down to a total of 15.

Table D-2. Likelihood Scores in the Risk Matrix

ID	Risk Category	Risk Event	Mid-Term Likelihood	Long-Term Likelihood	Likelihood Justification
1.1	Rising Temperatures	Reduced local supply availability	5	5	Very high likelihood in both mid- and long-term planning horizon for increase with high likelihood for more intense heat days and general upward trend for temperature.
1.2	Rising Temperatures	Increased peak demand	5	5	Very high likelihood in both mid- and long-term planning horizon for increase with high likelihood for more intense heat days and general upward trend for temperature.
1.3	Rising Temperatures	Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation	4	5	Water quality impact events have been observed and are generally anticipated to increase with climate change in the Delta, including: 1) taste & odor events, 2) toxic algal blooms, 3) aquatic macrophyte management, 4) higher salinity. Increases in water temperature associated with climate change can cause water quality impacts. However, likelihood of impact to Delta has greater uncertainty than generally observed and anticipated trend of physical temperature increase.
1.4	Rising Temperatures	Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions	4	5	Existing Biological Opinions (BiOps) would trigger reduced exports, even without change in regulation. Water quality impact events have been observed and are generally anticipated to increase with climate change in the Delta, including: 1) taste & odor events, 2) toxic algal blooms, 3) aquatic macrophyte management, 4) higher salinity. Increases in water temperature associated with climate change can cause water quality impacts.
1.5	Rising Temperatures	Increased surface water temperatures cause water quality degradation	5	5	High likelihood for change in temperature. However, likelihood development of adverse water quality impact less certain. The Water Board has announced Freshwater Harmful Algal Blooms in June 2022 at a "danger" advisory level for Quarry Lakes and Lake Del Valle, which will only expected to get more frequent with rising temperatures.
1.6	Rising Temperatures	Reduced surface water for Lake Del Valle	3	3	High likelihood (high confidence) for upward trend in temperatures for both mid- and long-term planning horizons. Surface warming also highly likely upward trend, with greater increases in temperature projected over time (greater evaporation of surface water). Likelihood kept at 3 because there is a lower likelihood that rising temperatures will reduce Del Valle supply (as compared to the watershed in general).
1.7	Rising Temperatures	Rising surface water temperatures for Lake Del Valle	4	5	High likelihood (high confidence) for upward trend in temperatures for both mid- and long-term planning horizons. Surface warming also highly likely upward trend, with greater increase in temperature projected over time (greater evaporation of surface water). Reservoir has experienced previous water quality issues. The Water Board has announced Freshwater Harmful Algal Blooms in June 2022 at a "danger" advisory level for Quarry Lakes and Lake Del Valle, which will only expected to become more frequent with rising temperatures.
2.1	Increased Drought	Reduced SFPUC RWS availability (reduced snowpack)	5	5	Climate change impacts are already being felt and are likely to increase with respect to drought conditions, e.g., may have shorter time periods between instances of drought. It is anticipated there will be more intense and frequent drought events as conditions change. Two of California's worst droughts were seen in the last decade, and the current year (2022) the state is in its third driest year on record and the District is set to be in its driest three-year period in its local history.

Table D-2. Likelihood Scores in the Risk Matrix					
ID	Risk Category	Risk Event	Mid-Term Likelihood	Long-Term Likelihood	Likelihood Justification
2.2	Increased Drought	Reduced SFPUC RWS availability (reduced water quality/impacts blending & production)	5	5	Climate change impacts are already being felt and are likely to increase with respect to drought conditions, e.g., may have shorter time periods between instances of drought. It is anticipated there will be more intense and frequent drought events as conditions change. Two of California's worst droughts were seen in the last decade, and the current year (2022) the state is in its third driest year on record and the District is set to be in its driest three-year period in its local history.
2.3	Increased Drought	Reduced SWP allocations (impacts to Niles Cone)	5	5	Likely to occur given recent reductions in SWP Table A allocations, especially with anticipated increase in frequency and duration of drought.
2.4	Increased Drought	Reduced SWP allocations (impacts to Semitropic banking)	5	5	Likely to occur given recent reductions in SWP Table A allocations, especially with anticipated increase in frequency and duration of drought.
2.5	Increased Drought	Reduced surface water capture for Lake Del Valle	4	5	It is anticipated there will be more intense and frequent drought events as conditions change. Likelihood of impact for reduced surface water capture anticipated to be higher in long-term.
3.1	Regulatory Change	Sustainable Groundwater Management Act (SGMA) requirements change	3	4	SGMA changes are likely in the mid-term and very likely in the long-term due to California's aggressive stance on addressing climate change issues and ensuring water reliability.
3.2	Regulatory Change	Urban Water Management Plan (UWMP) requirements change	5	5	UWMP changes are anticipated in the mid-term and very likely to certain in the long-term due to California's aggressive stance on addressing climate change issues and ensuring water reliability especially through water efficiency targets and conservation goals.
3.3	Regulatory Change	SWP system and regulations change	3	4	SWP system changes are likely in the mid-term and very likely in the long-term due to the high likelihood of increased drought and reduced snowpack in the Sierras, which would reduce the volume and change the timing of water running off into the Delta. Additionally, climate change and sea level rise put the Delta at risk of levee collapse and saline intrusion, therefore putting Delta supply at risk. Due to these risks, it is very likely that changes to the SWP will occur over the long-term.
3.4	Regulatory Change	Bay-Delta Plan flow requirements change (Sacramento River)	3	5	Delta regulations and California water rights and water quality have changed in the past and are anticipated to continue to change; significant changes should be anticipated over the long-term. There is a high likelihood of increased drought and reduced snowpack in the Sierras, which would reduce the volume and change the timing of water running off into the Delta. Additionally, climate change and sea level rise put the Delta at risk of levee collapse and saline intrusion, therefore putting Delta supply at risk. Due to these risks, it is fairly certain that changes to the SWP will occur over the long-term.
3.5	Regulatory Change	Bay-Delta Plan flow requirements change (Tuolumne/San Joaquin Rivers)	3	5	Delta regulations and California water rights and water quality have changed in the past and are anticipated to continue to change; significant changes should be anticipated over the long-term. There is a high likelihood of increased drought and reduced snowpack in the Sierras, which would reduce the volume and change the timing of water running off into the Delta. Additionally, climate change and sea level rise put the Delta at risk of levee collapse and saline intrusion, therefore putting Delta supply at risk. Due to these risks, it is fairly certain that changes to the SFPUC RWS will occur over the long-term.

Table D-2. Likelihood Scores in the Risk Matrix

ID	Risk Category	Risk Event	Mid-Term Likelihood	Long-Term Likelihood	Likelihood Justification
3.6	Regulatory Change	Endangered Species Act requirements change (reduced Delta exports to maintain cool water temperatures impacting SWP)	5	5	Delta regulations and California water rights and water quality have changed in the past and are anticipated to continue to change; significant changes should be anticipated over the long-term. There is a high likelihood of increased drought and reduced snowpack in the Sierras, which would reduce the volume and change the timing of water running off into the Delta. Due to these risks, it is fairly certain that changes to the SWP will occur over the long-term.
3.7	Regulatory Change	Endangered Species Act requirements change (additional reservoir releases impacting SFPUC RWS supply)	4	5	Delta regulations and California water rights and water quality have changed in the past and are anticipated to continue to change; significant changes should be anticipated over the long-term. There is a high likelihood of increased drought and reduced snowpack in the Sierras, which would reduce the volume and change the timing of water running off into the Delta. Due to these risks, it is fairly certain that changes to the SFPUC RWS flow requirements will occur over the long-term. Assumes less mid-term certainty in timing of reservoir releases as compared to greater certainty of general reduced Delta exports in 3.6)
3.8	Regulatory Change	Endangered Species Act requirements change (restrictions to protect groundwater dependent ecosystems)	4	5	Delta regulations and California water rights and water quality have changed in the past and are anticipated to continue to change; significant changes should be anticipated over the long-term. There is a high likelihood of increased drought and reduced snowpack in the Sierras, which would reduce the volume and change the timing of water running off into the Delta and impact water for native ecosystems. Due to these risks, it is fairly certain that changes will occur especially in the long-term and will very likely impact surface water supplies used for groundwater recharge.
4.1	Flooding	Increased storm frequency and atmospheric rivers expand the 100- and 500-year floodplains and expose critical infrastructure to flooding	4	4	Climate change is expected to increase the frequency of atmospheric rivers. There have already been more federally declared major flood disasters in the Bay Area. Curtner BPS flooding is a known issue documented in the District's RRA.
4.2	Flooding	Loss of access to facilities	4	4	Climate change is expected to increase the frequency of atmospheric rivers. There have already been more federally declared major flood disasters in the Bay Area. Curtner BPS flooding is a known issue documented in the District's RRA. Limited number of assets located within existing floodplain hazard zones.
4.3	Flooding	Upstream flooding causing Delta levee failure	4	5	Frequency and intensity of heavy precipitation events have increased since 1950s (high confidence). However, there is a greater level of uncertainty for estimating the intensity and frequency future precipitation events.
4.4	Flooding	Increased storm frequency and atmospheric rivers expand the 100- and 500-year floodplains and create larger sediment load	4	4	Frequency and intensity of heavy precipitation events have increased since 1950s (high confidence). However, there is a greater level of uncertainty for estimating the intensity and frequency future precipitation events.

Table D-2. Likelihood Scores in the Risk Matrix

ID	Risk Category	Risk Event	Mid-Term Likelihood	Long-Term Likelihood	Likelihood Justification
5.1	Sea Level Rise	Sea level rise causes rising groundwater levels	4	5	Likelihood of sea level rise occurring is high and very likely. The quantifiable impacts and rate of potential emergent groundwater is not well understood. However, sea level rise has potential for damaging infrastructure due to inundation and corrosion.
5.2	Sea Level Rise	Loss of access to facilities	4	5	Likelihood of sea level rise occurring is high and very likely. Most of the District's facilities are located on higher ground, which reduces potential to lose access to facilities from flooding due to sea level rise. However, loss of access can also occur via inundation of roads staff need to take to access these facilities.
5.3	Sea Level Rise	Reduced fresh groundwater storage in Niles Cone	5	5	While sea level rise is a scientifically accepted impact of climate change, the amount of sea level rise and when it will occur and impact storage is not well understood.
5.4	Sea Level Rise	Sea level rise causes rising groundwater levels	4	5	While sea level rise is a scientifically accepted impact of climate change, the amount of sea level rise and when it will occur is not certain. Less certain is likelihood for mobilization of contaminants.
6.1	Wildfire	Loss of access to facilities	4	4	While wildfires are a regular occurrence across the state and locally within the San Francisco Bay region, conditions for wildfires are anticipated to encourage potentially more extreme wildfire events. Although there is potential for impact, District facilities are at currently little spatial overlap with existing wildfire risk map boundaries (which will factor into the consequence score more than the likelihood scores).
6.2	Wildfire	Public safety power shutoff--Loss of power due to wildfire shutoffs	4	4	PG&E power shutoffs already occur and are very likely to increase in frequency with climate change and increasing stress from wildfire conditions.
6.3	Wildfire	Increased frequency and intensity of wildfires that may damage sensitive equipment	4	4	While wildfires are fairly frequent and very likely to certain to occur within both horizons, District facilities are at little risk and wildfires are may have low likelihood to impact reservoir water quality.
6.4	Wildfire	Increased frequency and intensity of wildfires negatively impacts water quality by mobilizing contaminants	5	5	While wildfires are a regular occurrence across the state and locally within the San Francisco Bay region, conditions for wildfires are anticipated to encourage potentially more extreme wildfire events.
7.1	Combined risk: Wildfire; Flooding	Increased frequency and intensity of wildfires combines with flooding (strong precipitation events) negatively impacts water quality by mobilizing contaminants	4	4	Likelihood of individual event occurrence within planning horizons very likely to certain. However, combination (close occurrence) of both has higher uncertainty.
7.2	Combined risk: Wildfire; Drought; Flooding	Enhanced landslide potential due to wildfires and increased storm intensities	4	4	Likelihood of individual event occurrence within planning horizons very likely to certain. However, combination (with close occurrence) has higher uncertainty.

Table D-2. Likelihood Scores in the Risk Matrix					
ID	Risk Category	Risk Event	Mid-Term Likelihood	Long-Term Likelihood	Likelihood Justification
7.3	Combined risk: Sea Level Rise + Drought	Reduced surface water flows causes reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential	4	4	While sea level rise is a scientifically accepted impact of climate change, the amount of sea level rise and when it will occur is not certain. Drought is also considered, especially in this region, to be highly likely, with potential for less recovery time between droughts and potentially more intense periods of drought. Although both individual events are highly likely to occur, the occurrence of both occurring at the same time is less likely than their individual occurrence.
7.4	Combined risk: Sea Level Rise + Drought	Saltwater intrusion from sea level rise and increased drought increase groundwater salinity	4	4	While sea level rise is a scientifically accepted impact of climate change, the amount of sea level rise and when it will occur is not certain. Drought will continue to occur potential for less recovery time between droughts and potentially more intense periods of drought. Although both individual events are highly likely to occur, the occurrence of both occurring at the same time is less likely than their individual occurrence.
7.5	Combined risk: Sea Level Rise and Seismic Event	Sea level rise causes rising groundwater levels; Seismic event may cause liquefaction	4	5	Liquefaction is a known issue and the certainty of sea level rise is a known climate threat. However, there is currently little spatial overlap between existing facilities and assets and the current landslide zones. The potential rate of emergent groundwater is not well understood.

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Appendix E: Adaptive Capacity Activities

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Appendix E

Adaptive Capacity Activities

Table E-1 provides the full range of potential relevant climate risk scenarios for each of the listed adaptive capacity activities. The activities that support reduced use or reduced loss of supply (e.g., AMI, conservation, and the WSCP) reduce the need to rely on imported supplies and reduce competing water needs for in-stream flow requirements. The table also includes a range of regulatory change scenarios in the case of adaptive capacity activities that support reduced use of supplies that could otherwise be used to contribute to in-stream flows. Activities that support maintaining groundwater recharge and enhancing reliability of this component of the system are also able to help offset impacts to other system components.

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix		
Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Advanced Metering Infrastructure (AMI)	AMI will help to reduce water loss (and therefore water demand), allowing the District to stretch supplies further.	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.1 Regulatory Change: SGMA requirements change • 3.2 UWMP requirements change • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 5.3 SLR: Reduced fresh groundwater supply and storage in Niles Cone • 7.3 Combined Risk: Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)
Alternative Update and Model Upgrade Project	Funded through Proposition 68, this project involved updating the District's 2016 Alternative to a Groundwater Sustainability Plan, incorporating DWR's recommendations, and upgrading the District's groundwater model).	• 3.1 Regulatory Change: SGMA requirements change • 5.3 SLR: Reduced fresh groundwater supply and storage in Niles Cone • 7.4 Combined Risk: SLR/Drought (groundwater salinity)

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix		
Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Aquifer Reclamation Program (BHF)	Will help further protect Mowry Wellfield and domestic wells from saltwater intrusion and increase aquifer storage capacity. Aquifer Reclamation Program includes pumping brackish water from degraded aquifers to increase usable basin storage, improve overall water quality, prevent movement of brackish water toward production wells, and provide future supply augmentation through treatment to potable water standards.	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.1 Regulatory Change: SGMA requirements change • 3.2 UWMP requirements change • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 7.3 Combined Risk: SLR/Drought (groundwater recharge & storage) • 7.4 Combined Risk: SLR/Drought (groundwater salinity)
Backup power for Water Treatment Plant 2	WTP2 can also be powered by a turbine generator at the District's hydroelectric facility downstream of its turnout from the SBA. (see RRA, pg. 48)	• 6.2 Wildfire: PSPS
Corrosion control	The District owns and operates 37 impressed current cathodic protection systems. Thirty of these systems protect transmission mains. (see Engineering Report, pg. 161).	• 5.1 SLR: Rising groundwater levels (erosion/inundation) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)

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Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix

Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Curtner Road Booster Station Upgrade	Investigates and compares costs of addressing source of periodic flooding and/or improving ability to respond to such incidents. Selected alternatives may include geotechnical/subsurface solution to eliminate or reduce inflow; prioritization of site for power backup to prevent station flooding in the event of a PG&E electrical outage and restoration. Also includes replacement of booster pumps, electrical gear, and PLC "for reliability and maintainability" as well as improvement of station ventilation to prevent excessive heating.	• 4.1 Flooding: Increased storm intensity and atmospheric rivers • 4.2 Flooding: Loss of facility access (flooding)
Electrical Redundancy & Reliability for IT Systems	Identifies power options for maintaining IT system reliability and redundancy for servers, phone etc. such that critical IT systems are up and running with UPS (not direct PG&E power) even during periods of maintenance of main UPS, Electrical Panels etc.	• 6.2 Wildfire: PSPS
Emergency action plans and standard operating procedures	Emergency action plans and standard operating procedures (e.g., Flooding Response Plan, Landslide Response Plan, Loss of Power Response Plan, Loss of Source Water Response Plan).	• 4.1 Flooding: Increased storm intensity and atmospheric rivers • 6.2 Wildfire: PSPS

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix		
Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Enhanced stormwater capture for Quarry Lakes	Effort represents operations that leverage existing rubber dam and other facilities to enhance potential stormwater capture and storage in Quarry Lakes.	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.1 Regulatory Change: SGMA requirements change • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 4.1 Flooding: Increased storm intensity and atmospheric rivers • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 7.3 Combined Risk: Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix

Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Enhanced groundwater use of Above-Hayward Fault	Effort includes greater use of current AHF aquifer (which would be more resilient to SLR impacts). Previous efforts have historically enabled an increase of 10 feet.	• 1.1 Rising Temperatures: Reduced local supply availability • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 7.3 Combined Risk: SLR/Drought (groundwater recharge & storage) • 7.4 Combined Risk: SLR/Drought (groundwater salinity)
Existing water conservation	Current water supply conversation campaigns and efforts (e.g., current One Saves Water campaign). Previous conservation campaigns have proven effective in reducing overall water demands	• 1.1 Rising Temperatures: Reduced local supply availability • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 7.3 Combined Risk: SLR/Drought (groundwater recharge & storage) • 7.4 Combined Risk: SLR/Drought (groundwater salinity)

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix		
Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Goat grazing	Continue with and expand on the rent-a-goat program to control vegetation along creeks and in flood control channels and to reduce fire fuels. (in coordination with ACFCWCD, ACFD) (see Alameda County LHMP).	• 6.1 Wildfire: Loss of access to facilities • 6.2 Wildfire: PSPS • 6.3 Wildfire: Damage to infrastructure & equipment • 6.4 Wildfire: water quality (contaminant mobilization)
Groundwater Protection Program/Well Ordinance Administration	Includes assisting regulatory agencies with identifying potential groundwater contamination, implementing monitoring systems for hazardous materials storage, technical oversight for investigations - e.g., LUST sites - and cleanups at hazardous spill sites, and participate in development of guidelines, policies and regulations related to groundwater protection activities.	• 5.4 SLR: Rising groundwater levels (contamination mobilization)
Groundwater Replenishment Program	Includes storing and percolating water into Niles Cone behind three inflatable rubber dams and recharge ponds to replenish groundwater extracted to meet local demands and replace brackish water extracted as part of the Aquifer Reclamation Program and maintain groundwater flow toward the SF bay to prevent saline intrusion.	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.1 Regulatory Change: SGMA requirements change • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 4.1 Flooding: Increased storm intensity and atmospheric rivers • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 7.3 Combined Risk: Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix		
Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Groundwater SGMA Enhancement Project	Existing project and further development underway. Groundwater SGMA Enhancement Project includes possible refinement to the Integrated Water Flow Model Upgrade and possible update to the District's MODFLOW/MT3D model).	• 3.1 Regulatory Change: SGMA
Improved reliability of Newark Desal Facility	Improved dry year water supply reliability, improved water system reliability and security, increased water production capacity, improved water quality, reduced future reliance on imported supplies, groundwater basin protection and reclamation (see UWMP, pg. 84)	• 1.2 Rising Temperatures: Increased peak demand • 1.3 Rising Temperatures: Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Rising Temperatures: Reduced summertime freshwater flows at Delta intakes resulting in pumping restrictions • 1.5 Rising Temperatures: Increased surface water temperatures causing water quality degradation • 1.6 Rising Temperatures: Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 5.1 SLR: SLR causes rising groundwater levels • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 7.4 Combined Risk: SLR/Drought (groundwater salinity)
Old Jarvis Road Irrigation Well Destruction Project	Project includes destruction of two abandoned irrigation wells that are potentially acting as pathways for saltwater intrusion into the lower drinking water aquifers.	• 5.3 SLR: Reduced fresh groundwater storage (Niles Cone)
On-site energy generation	This effort is currently in progress to create on-site energy generation for District facilities.	• 6.2 Wildfire: PSPS

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Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix

Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Operation of Quarry Lakes replenishment facility	Replenishment facility for Quarry Lakes used to recharge and maintain freshwater groundwater storage for Niles Cone.	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.1 Regulatory Change: SGMA requirements change • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 4.1 Flooding: Increased storm intensity and atmospheric rivers • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 7.3 Combined Risk: Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)
Patterson Reservoir Remediation Project	Project includes alleviating water quality issues (e.g., stagnation) and alternatives analysis to maintain 4-ft freeboard to prevent catastrophic failures (spilling) due to seismic events.	• 1.5 Rising Temperatures: Increased surface water temperatures cause water quality degradation
Salinity Barrier Project (Salinity Barrier Wells)	Started in the 1970's. Originally consisted of 14 groundwater extraction wells to prevent saline intrusion. 5 of those wells were constructed and the project was put on hold. These wells could benefit cleanup of the Newark Aquifer but require funds to render the wells operational.	• 3.1 Regulatory Change: SGMA requirements change • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 5.4 SLR: Rising groundwater levels (contamination mobilization) • 7.3 Combined Risk: SLR/Drought (groundwater recharge & storage) • 7.4 Combined Risk: SLR/Drought (groundwater salinity)

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix

Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Semitropic banking of District's SWP supplies (esp. during wet years)	The District has secured 150,000 AF of groundwater storage capacity at Semitropic to address the year-to-year variability of SWP supply (see UWMP, pg. 47). However, the District may be limited in its ability to recover its contractual recovery capacity from Semitropic.	• 1.1 Rising Temperatures: Reduced local supply availability • 2.1 Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Reduced SWP allocations (impacting groundwater banking) • 2.4 Reduced SWP allocations (impacting dry year water supply) • 2.5 Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.3 SWP system and regulations change • 3.4 Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 ESA requirements change (impacting SFPUC RWS supply) • 3.8 ESA requirements change (impacting groundwater recharge) • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 7.3 Combined Risk: SLR/Drought (groundwater recharge & storage) • 7.4 Combined Risk: SLR/Drought (groundwater salinity)
Shinn Pond Rediversion	Rediversion to enhance artificial recharge.	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.1 Regulatory Change: SGMA requirements change • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 4.1 Flooding: Increased storm intensity and atmospheric rivers • 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 7.3 Combined Risk: Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix		
Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Slope stabilization at Avalon Tank and Vineyard Heights Tank sites	Avalon Tank site improvements underway; Vineyard Heights is new project proposed in FY22-23 mid-cycle budget workshop.	• 7.2 Combined Risk: Wildfire/Drought/Flooding (landslide potential)
Standby emergency wells	Includes Whipple Well, Nursery Well. Whipple well has an estimated standby capacity of 1.3 mgd and Nursery well has an estimated standby capacity of 1 mgd. These wells are not typically used but may be energized to pump water directly into the distribution system in the event of an emergency. (see Engineering Report, pg. 17)	• 7.2 Combined Risk: Wildfire/Drought/Flooding (landslide potential) • 7.5 Combined Risk: SLR (enhancing liquefaction potential)
Stationary backup generators and portable generators	Stationary backup generators capable of fully powering each asset are in place at Newark Desal and the P-T Blender. Supply of diesel fuel kept on-site at the Garage; fuel tanks kept 80-90% full. Portable generators are stationed at the HQ parking lot and are available for deployment at other sites as needed. The District has mobile and stationary generators that can produce enough electricity to continue to pump, treat, and deliver up to 33 MG of water daily to customers (75% of average deliveries). (see RRA, pg. 48)	• 6.2 Wildfire: PSPS

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix

Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Water Shortage Contingency Plan (WSCP)	WSCP's purpose is to detail the generalized actions that the District would take in an actual emergency under various degrees of severity. (see UWMP, pg. 157)	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.1 Regulatory Change: SGMA requirements change • 3.2 UWMP requirements change • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 5.3 SLR: Reduced fresh groundwater supply and storage in Niles Cone • 7.3 Combined Risk: Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)

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Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix		
Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Water supply reliability alternatives	Includes study of water supply reliability alternatives including recycled water, and Lake Del Valle and Los Vaqueros reservoir storage expansion projects to improve water supply capabilities from catastrophic losses of supply.	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 4.3 Flooding: Upstream flooding causing Delta levee failure • 5.3 SLR: Reduced fresh groundwater supply and storage in Niles Cone • 7.3 Combined Risk: Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix

Adaptive Capacity Activities	Activity Description	Relevant Climate Risk Scenarios
Water Use Efficiency Master Plan (WEMP)	The WEMP documents the planning process, summarizes the analysis, describes various water use efficiency strategies along with their anticipated costs, savings, and cost-effectiveness. It provides a roadmap for the District's Water Use Efficiency Program for the next five years and strategies out to 2050.	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Reduced summertime freshwater flows at Delta from earlier snowmelt resulting in pumping restrictions • 1.5 Increased surface water temperatures causing water quality degradation • 1.6 Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.1 Regulatory Change: SGMA requirements change • 3.2 UWMP requirements change • 3.3 Regulatory Change: SWP system and regulations change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 5.3 SLR: Reduced fresh groundwater supply and storage in Niles Cone • 7.3 Combined Risk: Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)
Watershed Protection and Monitoring Program	Assisting in the protection and monitoring of the watershed to optimize the quality of runoff available.	• 1.5 Rising Temperatures: Increased surface water temperatures causing water quality degradation • 4.4 Flooding: Increased storm intensity (larger sediment load) • 6.4 Wildfire: water quality (contaminant mobilization) • 7.1 Combined Risk: Wildfire/Flooding • 7.3 Combined Risk: SLR/Drought (groundwater recharge & storage)
Well Ordinance Program	Through this program, the District is granted regulatory and enforcement authority over wells, exploratory holes, or other excavations within its service area including in the Cities of Fremont, Newark, and Union City.	• 5.3 SLR: Reduced fresh groundwater storage (Niles Cone) • 5.4 SLR: Rising groundwater levels (contamination mobilization)

Table E-1. Summary of Adaptive Capacity Activities in the Risk Matrix		
Adaptive Capacity Activities	**Activity Description**	**Relevant Climate Risk Scenarios**
Wellhead protection project	Project is focused on wells above the 100-year flood line.	• 4.4 Flooding: Increased storm intensity (larger sediment load)
Vallecitos Channel Betterments and Repairs	Protect against flooding/erosion and increase conveyance volume of channel to improve stormwater and SBA water flows to Alameda Creek. This may help direct more flow to Quarry Lakes for groundwater recharge (think of it as reducing water loss).	• 1.1 Rising Temperatures: Reduced local supply availability • 1.2 Rising Temperatures: Increased peak demand • 1.3 Rising Temperatures: Reduced summertime freshwater flows at Delta intakes resulting in water quality degradation • 1.4 Rising Temperatures: Reduced summertime freshwater flows at Delta intakes resulting in pumping restrictions • 1.5 Rising Temperatures: Increased surface water temperatures causing water quality degradation • 1.6 Rising Temperatures: Reduced surface water for Lake Del Valle (higher evaporation) • 2.1 Increased Drought: Reduced SFPUC RWS availability (from reduced snowpack, impacting groundwater banking) • 2.2 Increased Drought: Rising Temperatures: Reduced SFPUC RWS availability (reducing water quality blending and peak day production capacity) • 2.3 Increased Drought: Reduced SWP allocations (impacting groundwater banking) • 2.4 Increased Drought: Reduced SWP allocations (impacting dry year water supply) • 2.5 Increased Drought: Reduced surface water capture for Lake Del Valle (stormwater capture) • 3.1 Regulatory Change: SGMA requirements change • 3.4 Regulatory Change: Bay-Delta Plan flow requirements change (on Sacramento River) • 3.5 Regulatory Change: Bay-Delta Plan flow requirements change (on Tuolumne/San Joaquin rivers) • 3.6 Regulatory Change: ESA requirements change (Delta pumping restrictions impacting SWP supply) • 3.7 Regulatory Change: ESA requirements change (impacting SFPUC RWS supply) • 3.8 Regulatory Change: ESA requirements change (impacting groundwater recharge) • 4.1 Flooding: Increased storm intensity and atmospheric rivers • 4.2 Flooding: Loss of access to facilities • 4.4 Flooding: Increased storm intensity (larger sediment load) • 5.3 SLR: Reduced fresh groundwater supply and storage in Niles Cone • 7.2 Combined Risk: Wildfire/Drought/Flooding (landslide potential) • 7.3 Combined Risk: Reduced surface water flows cause reduced groundwater recharge to Niles Cone while rising groundwater constrains storage potential (SLR and drought) • 7.4 Combined Risk: Saltwater intrusion from SLR and increased drought increase groundwater salinity (SLR and drought)
Vegetation management	Utilize vegetation management to reduce risks in existing development. Participated in the development of the Alameda County Community Wildfire Protection Plan. (see Fremont LHMP, pg. 138)) (also in Union City/Newark Multi-Jurisdiction HMP)	• 6.1 Wildfire: Loss of access to facilities • 6.2 Wildfire: PSPS • 6.3 Wildfire: Damage to infrastructure & equipment • 6.4 Wildfire: water quality (contaminant mobilization) • 7.1 Combined Risk: Wildfire/Flooding • 7.2 Combined Risk: Wildfire/Drought/Flooding (landslide potential)

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Appendix F: MCDA Tool

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Appendix F

MCDA Tool

[MCDA tool provided in separate Excel document for reference]

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Appendix G: Consequence Scores Output

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Appendix G

Consequence Scores Output

[Consequence Scores Output provided in separate Excel document for reference]

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Appendix H: Cost Estimates

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Table H-1. Cost Estimates

Actions/Plans/Programs	Relevant Adaptation Strategies	Example Projects and Costs				
		Example	Description	Costs	Comment/Caveat/Assumptions	Source
Drought message campaign, drought surcharge/penalties messaging campaign, drought surcharge/penalties	A1	Public Information/Conservation	Previous community outreach campaigns by the District	$1 million/yr	Planned annual budget for FY20/21 out to FY22/23. Included under "Administrative and General" operating expenses as "Public Information/Conservation"	The District's FY 2021/22 & FY 2022/23 Adopted Budget (https://www.acwd.org/DocumentCenter/View/3850/ACWD-Adopted-Budget-FY-2021-23)
Rebates/retrofits, leak detection, targeted messaging based on AMI data	A2	Advanced Metering Infrastructure (AMI)	Install AMI to obtain better data on water use, which can help with detecting leaks and target large water users	$77 million	The estimated 25-year projected cost of installing AMI is $75.3M (FY21-22 CIP). It is assumed rebates and outreach are ~$1.7M.	The District's FY21-22 CIP, 25-yr projection (https://www.acwd.org/DocumentCenter/View/3850/ACWD-Adopted-Budget-FY-2021-23) - page 152
Regional Desalination	B1	Bay Area Regional Desalination Project (BARDP)	Construct a brackish water treatment plant at CCWD's existing Mallard Slough Pump Station to provide a supplemental water supply and enhance regional resilience during dry water years and emergencies (e.g., earthquakes, levee failures, and maintenance-related outages). The project partners (CCWD, EBMUD, SCVWD, SFPUC, and Zone 7) would work together to leverage and optimize existing infrastructure and assets to convey the desalination product water	(see comments)	The UWMP 2020-2025 found this to be cost prohibitive for the District stating that the cost of water for bay-water desalination would be $4,500/AF. This is compared to the Newark facility at $800/AF and SFPUC water at $2,200/AF. Total capital cost for participating agencies in development of this project was estimated at $175 million in 2017.	BARR-DCP-Final-12.19.17-reissued.pdf (bayareareliability.com)
Expand Los Vaqueros Reservoir	B1, D1	Los Vaqueros Reservoir Expansion (LVE)	The LVE Project would upgrade existing conveyance facilities, construct new conveyance, and re-operate existing facilities. It would divert water from the Sacramento-San Joaquin Delta at CCWD's Rock Slough, Old River, and Middle River intakes, and at the Freeport Intake on the Sacramento River. The LVE Project would deliver water to agencies within CCWD's service area, the Bay Area, the Delta, neighboring regions, and the south-of-Delta wildlife refuges	$98.5 million	This project is in the District's FY21-22, 25-yr CIP spread out over the entire 25 years for a total of $98.5 million. Total project cost (across participating agencies) $795 million.	Costs: The District's FY21-22 CIP, 25-yr projection (https://www.acwd.org/DocumentCenter/View/3850/ACWD-Adopted-Budget-FY-2021-23) - page 152 Other info: https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Los-Vaqueros-Reservoir-Expansion-Project
Water Reuse	B1, D2	Water Reclamation, Phase 1	This project could be a recommendation from the ACWD-USD Purified Water study (Provide new purified water supply utilizing USD's treated wastewater. Water is transmitted to the Quarry Lakes Groundwater Recharge Area to supplement recharge into the Niles Cone Groundwater Basin or put to other uses in the District's service area)	$134.5 million	Project listed in CIP from the budget workshop (cost is 25-yr projection), but the details of the project are not clear.	The District's FY21-22 CIP, 25-yr projection, cost occurring in FY43-44 - (https://www.acwd.org/DocumentCenter/View/3850/ACWD-Adopted-Budget-FY-2021-23) - page 152
Expand brackish groundwater desalination	B2	Expand brackish groundwater desalination (treatment facilities)	Develop new brackish groundwater treatment facilities in other parts of the service area and develop a potential project to treat currently discharged concentrate at the Newark Desalination Facility to potable standards	(see comments)	Expansion of brackish groundwater desalination through this potential project would result in lower groundwater pumping to produce at a similar rate. This concept and potential project should be studied and evaluated, and a cost estimate should be generated.	
Increase Alameda Creek diversions[1]	B2	Operational changes to increase Alameda Creek diversions	Project could involve changing how they operate their rubber dams to increase diversions from Alameda Creek.	(see comments)	Cost is a potential increase in annual O&M. Further study or estimation with District staff needed.	
Short or long-term transfer	B3	BARR SWAP: Pilot 1a	Supply exchange concept that assumes future Los Vaqueros Reservoir Expansion (LVE) infrastructure is already in place. The District would receive up to 4,000 AF of water. The exchange would allow the District to forego an equivalent amount of water purchases from SFPUC	$40 million in capital	O&M estimated at $2.7 million/yr	District staff and BARR SWAP project reference material
Delta Conveyance	B4	Delta Conveyance Project (DCP) Participation	A proposed single tunnel project to connect a new diversion intake along the Sacramento River in the north Delta to the Clifton Court forebay in the south Delta.	$0.5 million	Cost for FY20/21 budget under water supply costs - this is a capital cost, not a 25-year projected cost. Noted as an "extraordinary expense". The cost is assumed to be a participation cost for ongoing studies and efforts. The 2019 DCR does not include this project. If the project were built, it would likely improve reliability for the District.	The District's FY 2021/22 & FY 2022/23 Adopted Budget (https://www.acwd.org/DocumentCenter/View/3850/ACWD-Adopted-Budget-FY-2021-23)

Table H-1. Cost Estimates

Actions/Plans/Programs	Relevant Adaptation Strategies	Example Projects and Costs				
		Example	Description	Costs	Comment/Caveat/Assumptions	Source
New Interties, standby wells	C1	Niles-Newark Intertie Pipeline, Fremont Phase		$17.6 million	This is a 25-year projected cost from the FY21-22 CIP.	The District's FY21-22 CIP, 25-yr projection - (https://www.acwd.org/DocumentCenter/View/3850/ACWD-Adopted-Budget-FY-2021-23) - page 152
Fire protection measures, backup pumps/generators, stockpiling chemicals	C2	Curtner Road Booster Station Upgrade	Project includes consideration of backup power to prevent station flooding in the event of a PG&E electrical outage. Also includes replacement of booster pumps, electrical gear, and PLC "for reliability and maintainability" as well as improvement of station ventilation to prevent excessive heating.	$4.3 million	This is a 25-year projected cost from the FY21-22 CIP.	The District's FY21-22 CIP, 25-yr projection - (https://www.acwd.org/DocumentCenter/View/3850/ACWD-Adopted-Budget-FY-2021-23) - page 152
Bank more SWP supply in Semitropic	D3	Purchased Water - State Water Project (SWP) or Semitropic	SWP supplies are imported into the District service area through the South Bay Aqueduct.	SWP: $10,000 /yr Semitropic: $3-4,000/yr	Cost can vary from year to year depending on use. It is uncertain which cost (SWP or Semitropic) may be more relevant for this strategy to bank more SWP supply in Semitropic.	The District's FY 2021/22 & FY 2022/23 Adopted Budget (https://www.acwd.org/DocumentCenter/View/3850/ACWD-Adopted-Budget-FY-2021-23)
Distribution system enhancements (e.g., to enable supplies to serve different parts of service area)	D5	Various pipeline projects in current CIP	Peralta-BART Wellfield Pipeline 2600ft x 36-in; Gallegos Avenue - MSJWTP2 Zone 3 Intertie, Phase 2 - 18"; Zone 4 Intercom Pipeline, Phase 2 - 3,640 ft x 12-inch	$3 to 4 million/project	These are 25-year projected costs from the FY21-22 CIP.	The District's FY21-22 CIP, 25-yr projection
Monitoring for SLR, saltwater intrusion, corrosion	D6	Well Site Evaluation Project	Project will evaluate three potential locations in the central portion of the basin to determine their potential suitability for future brackish groundwater extraction facilities to remove brackish groundwater from the Centerville-Fremont Aquifer	$1.2M	Well site eval project is $1.2M - annual cost in FY21/22. Grant reimbursement amount is $0.613.	The District's 2021 Alternative Update, Niles Cone Groundwater Basin
Prevent contaminant mobilization, mitigate saltwater intrusion	E1	Brackish Groundwater Reclamation Project	Based on the results of the "Well Site Evaluation Project", this project will install 1 groundwater extraction system at up to 3 sites to remove impacted groundwater due to saltwater intrusion.	$13 million	A grant is being utilized for this project; project cost shown is 25-year projection.	The District's FY21-22 CIP, 25-yr projection
Install PFAS/hardness treatment, reverse osmosis (RO)	E1	PFAS Treatment		$2.7 million	Additional costs noted in the CIP for studies and monitoring (see PH0108a in source CIP)	The District's FY21-22 CIP, 25-yr projection
Aeration/mixing	E2	Patterson Reservoir Water Quality Enhancement	Chemical addition & mixing to improve chlorine residual, avoid nitrification	$4.4 million	Project cost shown is 25-year projection	The District's FY21-22 CIP, 25-yr projection
Simulate impacts on Niles Cone (e.g., saltwater intrusion, contaminant mobilization)	F2	Groundwater SGMA Enhancement		$0.204 million	Project cost shown is 25-year projection	The District's FY21-22 CIP, 25-yr projection
Improve drainage and runoff capture, prevent flooding	G1	Various Proposition O projects completed by LASanitation	A variety of green infrastructure projects that include catch basin inserts and screen covers, wetlands restoration, neighborhood greenways, and stormwater capture	$6 million	Cost shown is for a typical project. The Westwood Greenway project, for example, cost $6M and diverts 2,400 acres of runoff for sediment and trash removal, sand filtration, and treatment in a bioswale before being released to a creek. It also provides a recreational path and adds vegetation. The Orange Memorial Park regional capture project in South San Francisco cost $16M and recharges 55 million gallons to the groundwater per year, removes trash and pollutants, and provides flood mitigation and new sports fields for the community. Costs are highly dependent on scale, site and type of green infrastructure. Smaller green street projects may cost $1 - 5M.	Projects (lacitysan.org)
Restore habitat	G1	Beaver Management	Beaver management techniques to restore habitat	$0.2 million/yr	There is also a Beaver Restoration Guidebook: https://www.beaverinstitute.org/wp-content/uploads/2021/03/The-Beaver-Restoration-Guidebook-v2.01.pdf). Cost will depend on scale of the need. Sources have indicated costs of prevention have been less than reactive costs. Public outreach efforts should also be considered in estimated budget.	Book: Eager (per Thomas Niesar, the District's Water Resources Planning Manager)

Table H-1. Cost Estimates						
	Relevant Adaptation Strategies	Example Projects and Costs				
Actions/Plans/Programs		Example	Description	Costs	Comment/Caveat/Assumptions	Source
Selective tree and brush removal (e.g., fuel treatments)[2]	G2					
Shoreline protection, SLR, land use planning[2]	H1					
Delta Stewardship Council, etc.[2]	H2					
Bay Area Regional Reliability (BARR)[3]	H3	BARR Participation	Bay Area Regional Reliability partnership program. Joint partnership with 8 other Bay Area agencies.	$5000/yr	Cost here is from an operating expense that was listed for FY 19/20. Assumes similar and regular level of participation in BARR Partnership (or similar partnership program)	The District's FY 2021/22 & FY 2022/23 Adopted Budget (https://www.acwd.org/DocumentCenter/View/3850/ACWD-Adopted-Budget-FY-2021-23)
Alameda County Flood Control and Water Conservation District, Alameda Creek Alliance, etc.[2]	H4					

Notes:

1. *Expanded use of the AHF aquifer can also support B2 but requires further study*
2. *These programs require partnerships and further study/investigation is needed to develop costs*
3. *There are additional regional partnerships to consider including Los Vaqueros JPA, BAWSCA, SGMA, local water agencies, SF RWQCB, etc. The District has additional budget line items for these partnership efforts.*

Additional operational actions/plans/programs that could be further developed with input from District staff include:

- Emergency response training, mutual aid agreement for fuel (C3)
- Transfer-Bethany Pipeline, SBA improvements, Lake Del Valle reoperation (D1)
- Flex use of dry year reserves (D4)
- New treatment measures to address shifting Delta water quality, wildfire impacts (E3)
- Evaluate Delta and local reservoir water quality changes (F1)
- Forecast Informed Reservoir Operations (FIRO) at Lake Del Valle, monitoring conditions in fire-prone areas (F3)

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Appendix I: Funding Opportunities

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Table I-1. Summary of Federal Funding Opportunities				
Funding Program Name	Funding Entity	Description	Loan or Grant?	Relevant Adaptation Strategy (A-H)
LIFT SEE IT, Scholarship Exchange Experience for Innovation & Technology Program	WRF, WEF, NACWA	The Scholarship Exchange Experience for Innovation & Technology Program (SEE IT) is an initiative spearheaded by The Water Research Foundation (WRF), the Water Environment Federation (WEF), and the National Association of Clean Water Agencies (NACWA) to provide scholarships for utility personnel to visit other utilities with innovations of interest and to share experiences with their peers. Innovations may include new technologies and processes, but also novel approaches to service, operations, and finance.	Travel Grant	All
Safeguarding Tomorrow Revolving Loan Fund	FEMA	A new program to fund resilience projects that will make communities safer from natural hazards. The Safeguarding Tomorrow Revolving Loan Fund program will make $50 million available in capitalization grants to states to fund low-interest loans to local governments. Guidelines for this funding are currently being developed, to be released at the end of 2022.	Loan	N/A (Dependent on final guidelines, to be released at end of 2022)
Hazard Mitigation Grant Program (HMGP)	FEMA	Post-disaster funding. HMGP can be used for both traditional hazard mitigation planning projects, as well as provide funding for mitigation and project planning post disaster, building code development and application or enforcement in some circumstances. "Hazard mitigation" is any sustainable action that reduces or eliminates long-term risk to people and property from future disasters. Businesses cannot apply for a grant. However, a local community may apply for funding on their behalf. Includes mitigation projects for flood protection, retrofitting, and construction.	Grant	C
Hazard Mitigation Grant Program (HMGP) Post Fire	FEMA	FEMA's Hazard Mitigation Grant Program (HMGP) has Post Fire assistance available to help communities implement hazard mitigation measures after wildfire disasters. States, federally recognized tribes and territories affected by fires resulting in a Fire Management Assistance Grant declaration on or after October 5, 2018, are eligible to apply.	Grant	C and G (fire-related only)
Flood Mitigation Assistance (FMA) Grant	FEMA	Funds projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the NFIP. Funds can go towards project scoping, technical assistance, community or private property flood mitigation projects, and management costs.	Grant	C, G (flood-related only)
Building Resilient Infrastructure and Communities (BRIC)	FEMA	Building Resilient Infrastructure and Communities (BRIC) will support states, local communities, tribes and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards. The BRIC program guiding principles are supporting communities through capability- and capacity-building; encouraging and enabling innovation; promoting partnerships; enabling large projects; maintaining flexibility; and providing consistency. Projects would need to be submitted by local governments.	Grant	C, G
Pre-Disaster Mitigation (PDM) Grant	FEMA	The Pre-Disaster Mitigation (PDM) grant program makes federal funds available to state, local, tribal and territorial governments to plan for and implement sustainable cost-effective measures designed to reduce the risk to individuals and property from future natural hazards, while also reducing reliance on federal funding from future disasters. Projects would need to be submitted by local governments.	Grant	C, G
Homeland Security Preparedness Technical Assistance Program	FEMA/Dept. of Homeland Security	Build and sustain preparedness technical assistance activities in support of the four homeland security mission areas (i.e., prevention, protection, response, recovery) and homeland security program management.	Grant	C

Table I-1. Summary of Federal Funding Opportunities

Funding Program Name	Funding Entity	Description	Loan or Grant?	Relevant Adaptation Strategy (A-H)
Coastal Habitat Restoration and Resilience Grants for Underserved Communities	NOAA	$10 million in funding is available for habitat restoration and resilience awards for underserved communities in FY2022 under the Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act). Through this funding, NOAA will engage underserved communities in habitat restoration activities that promote resilient ecosystems and communities. It will provide capacity for these communities to more fully participate in developing future transformational habitat projects.	Grant	G
Transformational Habitat Restoration and Coastal Resilience Grants	NOAA	$85 million in funding is available for transformational habitat restoration and coastal resilience projects in FY2022 under the Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act). This funding will prioritize habitat restoration actions that rebuild productive and sustainable fisheries, contribute to the recovery and conservation of threatened and endangered species, use natural infrastructure to reduce damage from flooding and storms, promote resilient ecosystems and communities, and yield socioeconomic benefits. This funding opportunity will invest in projects that have the greatest potential to provide holistic benefits, through habitat-based approaches that strengthen both ecosystem and community resilience.	Grant	C, G
National Coastal Resilience Fund	NOAA/National Fish and Wildlife Foundation	Restores, increases and strengthens natural infrastructure to protect coastal communities while also enhancing habitats for fish and wildlife. Invests in conservation projects that restore or expand natural features such as coastal marshes and wetlands, dune and beach systems, oyster and coral reefs, forests, coastal rivers and floodplains, and barrier islands that minimize the impacts of storms and other naturally occurring events on nearby communities. Targeted at community planning initiatives and can be directed to improve recovery plans. Examples of projects that have been awarded this grant include coastal restoration projects, planning project in Oregon to prepare them for a future catastrophic tsunami, and flood risk reduction projects.	Grant	C, G
Flood Risk Management Program	USACE	The programs related to planning efforts for flood risk management include dam safety, levee safety, emergency operations, and responses to climate change. With the exception of limited research funding via the U.S. Army Engineer Research and Development Center (ERDC), the Corps does not administer grant programs for flood risk management. With specific congressional authorization, the Corps of Engineers can evaluate flood problems and solutions and recommend to Congress whether or not a flood risk reduction project should be authorized. This approach is generally used for larger projects. In addition, the Corps Continuing Authorities program allows the Corps of Engineers to plan, design, and construct smaller projects without specific authorization from Congress. The potential non-Federal sponsor must request the Corps of Engineers to investigate potential flood risk management issues that might fit the program. Once the Corps of Engineers determines that the project fits the program, the District will request funds to initiate a reconnaissance effort to determine potential Federal interest in proceeding to a feasibility study.	Grant	C, G (flood-related only)
WaterSMART Drought Response Program	USBR	Provides assistance to water managers to: develop and update comprehensive drought plans and implement projects that will build long-term resiliency to drought.	Grant	A, B, C, D, E, G

Table I-1. Summary of Federal Funding Opportunities				
Funding Program Name	Funding Entity	Description	Loan or Grant?	Relevant Adaptation Strategy (A-H)
WaterSMART Basin Study Program	USBR	Basin studies evaluate water supply and demand and help ensure reliable water supplies by identifying strategies to address imbalances in water supply and demand. Each study includes four key elements: state-of-the-art projections of future supply and demand by river basin, an analysis of how the basin's existing water and power operations and infrastructure will perform in the face of changing water realities, the development of strategies to meet current and future water demands, and a trade-off analysis of strategies identified.	Grant	B, D, E, F
WaterSMART Cooperative Watershed Management Program	USBR	Provides funding to watershed groups to encourage diverse stakeholders to form local solutions to address water management needs. Funding is provided for watershed group development, restoration planning, and management project design (Phase I), and provides cost-shared financial assistance to watershed groups to implement watershed management projects (Phase II).	Grant	G
Water Infrastructure Finance and Infrastructure Act (WIFIA)	USEPA	A federal credit program administered by EPA for eligible water infrastructure projects, which include drought resilience, desalination, acquisition of property, or projects eligible for the Clean Water or Drinking Water State Revolving Fund.	Loan	B, C, D, E, F, G
Community Development Block Grants (CDBG) Programs	US Department of Housing and Urban Development	Focuses on transformative impact in the community, improving the lives of all residents, and especially those with low- and moderate-income levels. Many funding categories within the CDBG programs. Various programs focus on disaster recovery, neighborhood revitalization, economic development, and improved community facilities.	Grant	G
Emergency Management Performance Grant Program (EMPG)	CalOES	The purpose of the EMPG Program is to provide federal grants to states to assist state, local, territorial, and tribal governments in preparing for all hazards. Grants for the purpose of providing a system of emergency preparedness for the protection of life and property in the United States from hazards and to vest responsibility for emergency preparedness jointly in the federal government and the states and their political subdivisions.	Grant	C
Clean Water State Revolving Fund (CWSRF)	EPA, administered by SWRCB	The primary purpose of the CWSRF Program is to provide financing for eligible projects to restore and maintain water quality in the state. The SWRCB also seeks to reduce the effects of climate change and to promote sustainable water resources for future generations. Includes funding for energy efficiency, water reuse, water conservation, efficiency, and reuse, construction of publicly owned treatment works, nonpoint source, and stormwater.	Grant/Loan	A, E, G

Table I-1. Summary of Federal Funding Opportunities				
Funding Program Name	**Funding Entity**	**Description**	**Loan or Grant?**	**Relevant Adaptation Strategy (A-H)**
Drinking Water State Revolving Fund (DWSRF)	EPA, administered by SWRCB	Funds infrastructure improvements in drinking water systems. The DWSRF emphasizes funding to small and economically disadvantaged communities and other programs that encourage preventing pollution to drinking water. Publicly or privately owned community water systems and non-profit non-community water systems are eligible. Project types include: drinking water treatment, pipe installation/replacement, well construction/rehabilitation, source water protection, storage, and more.	Grant/Loan	C, D, E, G
Proposition 1	SWRCB	Prop 1 authorized $7.545B in general obligation bonds for water projects, including surface and groundwater storage, ecosystem and watershed protection and restoration, and drinking water protection. The State Water Board will administer Prop 1 funds for five programs. Of the $7.545B, Prop 1 provides $200M in grant funds for multi-benefit storm water management projects, which may include but not be limited to green infrastructure, rainwater and storm water capture projects, and storm water treatment facilities. Storm water resource plans or functionally equivalent plan(s) are required to obtain grant funds for storm water and dry weather capture projects.	Grant/Loan	B, C, D, E, G
California Energy Commission (CEC) grant program	CEC	See general available solicitations for funding opportunities that the California Energy Commission offers that advance the state's transition to clean energy and transportation through innovation, efficiency, and the development and deployment of advanced technologies.	Various	N/A (Depends on individual grants offered annually)
Caltrans Sustainable Transportation Planning Grant Program	Caltrans	The Sustainable Transportation Planning Grant Program was created to support the California Department of Transportation's (Caltrans) Mission: Provide a safe and reliable transportation network that serves all people and respects the environment. Note: Caltrans could potentially leverage the Biden Administration's commitment to climate adaptation to expand federal funding for the FHWA SP&R program to support regional coastal sea level rise planning.	Grant	G
Vegetation Management Program	CalFire	Cost-sharing program between Cal FIRE and private land owners, which focuses on the use of prescribed fire, mechanical, biological, and chemical means addressing wildland fire fuel hazards and other resource management issues on SRA and LRA lands.	Grant	C, G
Wildfire Emergency and Mitigation Funds	CalFire	Administers funding from the FEMA, Bureau of Land Management, and U.S. Forest Service for certain types of wildfire emergency and mitigation funding.	Grant	C, G
Community Economic Resilience Fund (CERF)	Employment Development Department	On September 23, 2021, Governor Gavin Newsom signed Senate Bill (SB) 162 (Chapter 259, Statutes of 2021)10, which established the Community Economic Resilience Fund (CERF). SB 162 supports regionally centered plans to respond to the diverse needs across our state and to build sustainable and resilient regional economies. The purpose of the CERF funding is to build an equitable and sustainable economy across California's diverse regions and foster long-term economic resilience in the overall transition to a carbon-neutral economy. Could support capital projects and partnerships.	Grant	C, G, H

Table I-1. Summary of Federal Funding Opportunities				
Funding Program Name	Funding Entity	Description	Loan or Grant?	Relevant Adaptation Strategy (A-H)
Regional Climate Collaboratives (RCC) Grant	Strategic Growth Council	This new capacity building grant program funds community-rooted and cross-sectoral partners to develop the processes, plans, and projects that will drive and sustain climate action in their communities. In this first round, SGC has $8.35 million available for grant awards and applicants have flexibility in requesting their funding amount with the range of $500,000–$1750,000.	Grant	C, G, H
Prop 68	State Coastal Conservancy	Proposition 68 authorized $4 billion in general obligation bonds for state and local parks, environmental protection and restoration projects, water infrastructure projects, and flood protection projects. The priority issue area for this round of Proposition 68 funding is the nexus between marine protected areas and climate resiliency for species, habitats, and people.	Grant	C, G
CalConserve Water Use Efficiency Loan Program	DWR	Sustainable funding source for water use efficiency projects that establishes a loan program to local agencies for specific types of water conservation and water use efficiency projects and programs to achieve urban water use targets, specifically water use efficiency upgrades and fixing expensive and difficult-to-repair customer leaks. Projects include but are not limited to dish/clothes washer upgrades; water-saving plumbing fixtures; hot-water recirculating pumps; leak detection and repair; landscape irrigation upgrades; and commercial, institutional, and industrial water efficiency.	Loan	A
Sustainable Groundwater Planning (SGWP) Grant Program	DWR	Provides a minimum of $103M in Prop 68 funds for competitive grants, in two rounds of grant solicitations, to fund implementation projects that address drought and groundwater challenges to achieve regional sustainability for investments in groundwater recharge projects with surface water, stormwater, recycled water, and other conjunctive use projects; prevent or clean up contamination of groundwater that serves as a source of drinking water; support water supply reliability, water conservation, and water use efficiency; and support water banking, exchange, and reclamation	Grant	A, B, D, E, G
Water Desalination Grant Program	DWR	DWR provides grants to local agencies for planning, design, and construction of desalination facilities (including pilot, demonstration, and research projects) for both brackish and ocean water. DWR has conducted three funding rounds since 2005 using Prop 50 funds. The rules and procedures for funding vary depending on funding source/availability and DWR priorities at the time of funding. A fourth funding round is planned and will use primarily Prop 1 funds.	Grant	B, C, D, E
SF Bay Water Quality Improvement Fund	USEPA	In 2022, it focused on inequities in the access to Federal funding and implementation of projects and climate resilience in underserved communities. Selected projects focus on water quality results, such as restoration of impaired waters and enhancement of wetland habitat.	Grant	E, G
Bay Area Integrated Regional Water Management Plan	DWR, Proposition 1	The Bay Area Integrated Regional Water Management Plan is a nine-county effort to coordinate and improve water supply reliability, protect water quality, manage flood protection, maintain public health standards, protect habitat and watershed resources, and enhance the overall health of the San Francisco Bay.	Grant	C, G, H

Table I-1. Summary of Federal Funding Opportunities				
Funding Program Name	Funding Entity	Description	Loan or Grant?	Relevant Adaptation Strategy (A-H)
General Fund; General obligation bonds; Lease Revenue Bonds	Alameda County Board of Supervisors	Variable funding may be available through the County Board of Supervisors for public safety projects or program operations	Loan	All
Defensible Space Fuel Reduction Program	Diablo Fire Safe Council	Sponsorship program for defensible space fuel reduction projects. Cost-share assistance of up to $5,000 per project in 2020-2021 is available to groups or groups of individuals to hire contractors to reduce fuel loads and create defensible space.	Grant	C, G
Measure AA	San Francisco Bay Restoration Authority	Measure AA, or the San Francisco Bay Clean Water, Pollution Prevention and Habitat Restoration Measure, was a revenue generating measure placed on the June 2016 ballots of the nine-county San Francisco Bay Area by the Restoration Authority. The measure proposed a 20-year, $12 parcel tax to raise approximately $25 million annually, or $500 million over twenty years, to fund restoration projects in the Bay. The Board may fund projects to protect, restore and enhance the San Francisco Bay, including: habitat restoration projects; flood protection projects that are part of a habitat restoration project; and shoreline access and recreational amenity projects that are part of a habitat restoration project.	Grant	C, G, H

Appendix J: Equity Snapshot

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Appendix J

Equity Snapshot

While the impacts of climate change could affect all local populations in the Bay Area, not all communities may experience the effects to the same degree. From prolonged droughts, more frequent wildfires, rising sea levels, and increased storm intensities, not all communities are equipped with the same resources to mitigate, respond to, recover, and adapt to chronic and worsening conditions due to climate change. These disparities leave vulnerable communities, such as communities of color and low-income communities, to disproportionately bear the brunt of climate change impacts if local governments and agencies do not include equity and climate justice within their resiliency planning framework in how they address climate change.

Climate change could exacerbate existing inequities because communities that already lack the means to handle these impacts would be further strained by the financial implications and health effects that would limit their ability to find adequate housing, jobs opportunities, and access to affordable and safe necessities. For instance, a study conducted by the Pacific Institute on drought and equity in California found that “low-income households, people of color, and communities already burdened with environmental pollution suffered the most severe impacts” as a result of the enduring California drought (Feinstein et al., 2017). Many of the drought-impacted public water systems were small water districts (defined as serving less than 1,000 connections or fewer), which typically have fewer capabilities to overcome ongoing drought challenges, as a large proportion of those systems were in disadvantaged communities (median household income of less than 80 percent of the state median). Climate change is not just an environmental issue, but one that is intimately interconnected with public health, social justice, and equity. Table J-1 highlights some of the other potential health impacts from climate change.

Table J-1. Climate Change Health Impacts		
Hazard	**Climate Impact**	**Health Impact**
Heat	Average yearly temperature to increase between 4.1 and 6.2 ° F by 2100 Extreme Heat Days (over 85 ° F) to increase by 15-40 days by 2050, potentially 90 days by 2100 Increase in heatwave length and frequency	• Heat-Related Illness • Dehydration • Heat Stroke • Heat-Related Mortality • Heart Disease • Air Quality Effects • Respiratory Illness • Asthma • Allergies • Mental and Behavioral Health
Sea Level Rise	Sea levels projected to rise between 7-15 inches by 2050, 25-46 inches by 2100	• Fatal and Nonfatal Injury • Water-borne Disease • Mental and Behavioral Stressors • Income Loss
Extreme Storms	As precipitation levels fluctuate year-to-year, in rainy years, the frequency and severity of extreme storms is predicted to increase	• Fatal and Nonfatal Injury • Water-Borne Disease • Mental and Behavioral Stressors • Strain on Public Health Infrastructure • Income Loss
Drought	As precipitation levels fluctuate year-to-year, in dry years where the high-pressure system off the coast does not dissipate, the frequency and severity of droughts will increase	• Food Insecurity • Malnutrition • Air Quality/Allergens • Respiratory Illness • Asthma • Allergies • Mental and Behavioral Health • Income Loss

Source: California's Fourth Climate Change Assessment – San Francisco Bay Area Region Report

In evaluating which communities in the District's service area may be most susceptible to certain climate change impacts, a social vulnerability ranking can be used. Social vulnerability can be defined as "the ways individuals, households and neighborhoods may be disproportionately harmed by a hazard" (Nutters, 2012, p. 5). Figure J-1 shows the social vulnerability ranking for the District service area, using social vulnerability indicators for climate change developed by San Francisco Bay Conservation and Development Commission (BCDC) Adapting to Rising Tides (ART) program.
Table J-2 shows the count by block group of the individual social vulnerability indicators in the 70th and 90th percentiles for the District service area. These social vulnerability indicators include income level, English proficiency, race, age, education level, vehicle ownership, home ownership, citizenship, and disability at the census block group level, which are then ranked relative to the other block groups within the nine counties in the Bay Area region to determine the social vulnerability rank as low, moderate, high, or highest. This approach considers the cumulative effects of multiple social vulnerability indicators to provide a more holistic view of social vulnerability as vulnerabilities do not occur in isolation from one another.

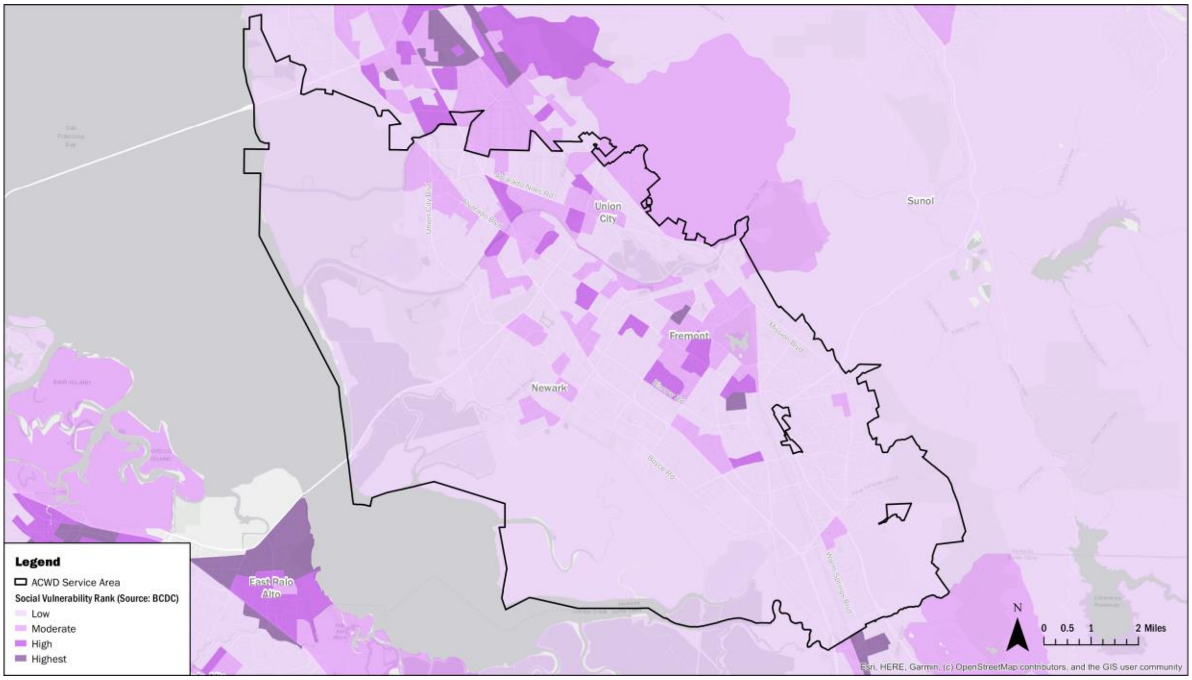

Figure J-1. Social vulnerability rank

Source: Bay Conservation and Development Commission (BCDC) Adapting to Rising Tides (ART) program

For the District, most of the service area is identified as low social vulnerability ranking with some areas in the middle northeast region having moderate, high, and highest social vulnerability ranks. These block groups (moderate, high, and highest) have at least four indicators in the 70th percentile or three indicators in the 90th percentile. Understanding where these socially vulnerable communities are allows for more focused, informed, and effective strategies for adaptation and mitigation efforts as well as opportunities to better engage with those communities on such efforts.

Table J-2. Individual Indicators by Block Groups in 70th and 90th Percentile within the District's Service Area

Social Indicator	70th Percentile		90th Percentile	
	Number of Block Groups	Percentage of Total Block Groups in District's Service Area[a]	Number of Block Groups	Percentage of Total Block Groups in District's Service Area[a]
Renter	31	17%	7	4%
Under 5	59	32%	14	8%
Without a Vehicle	27	15%	2	1%
Disabled	32	18%	9	5%
Single Parent Families	20	11%	0	0%
Communities of Color	135	74%	23	13%
Over 65 and Living Alone	22	12%	7	4%
No High School Degree	25	14%	1	1%
Limited English Proficiency	61	34%	8	4%
Not U.S. Citizen	105	58%	26	14%
Severe Housing Cost Burden	5	3%	0	0%
Very Low Income	24	13%	2	1%

a. *Estimated approximately 182 block groups within the District's service area.*

As discussed in Section 5.1, flooding and rising groundwater levels due to increasing sea level could mobilize contaminants, e.g., from hazardous waste sites into aquifers and other water bodies (although further study is needed to understand extent of ongoing coordination for risk mitigation). Therefore, another important consideration in discussing climate change equity is contamination vulnerability. BCDC ART data also includes a contamination vulnerability ranking of lower, moderate, high, and highest for the severity of contamination in each census block group, determined using data compiled by the CalEPA Office of Environmental Health Hazard Assessment. These rankings were developed using five specific types of contamination: hazardous cleanup activities, groundwater threats, hazardous waste facilities, impaired water bodies, and solid waste facilities. Figure J-2 shows a map for the contamination vulnerability rank for the District's service area. For the areas identified as moderate, high, or highest, which are predominately along the eastern shore of the District's service area, these block groups have at least 4 indicators in the 70th percentile and/or a total contamination score between 70th and 80th percentile.

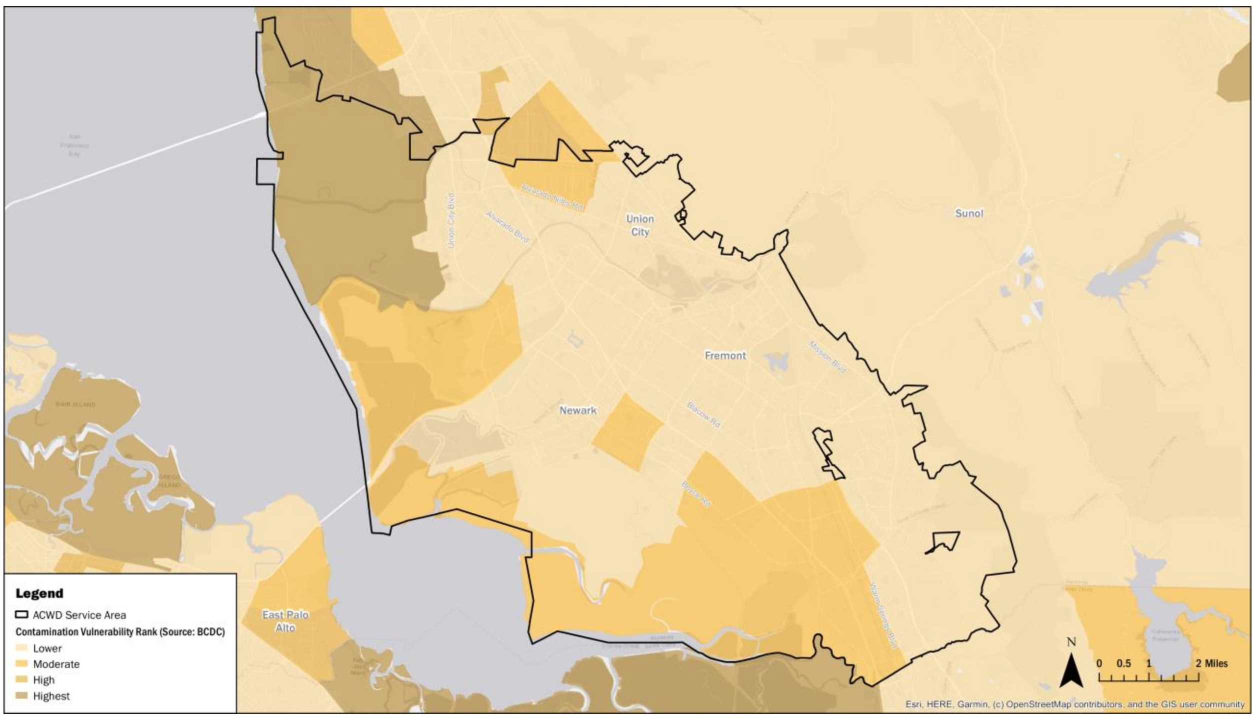

Figure J-2. Contamination vulnerability rank

Source: Bay Conservation and Development Commission (BCDC) Adapting to Rising Tides (ART) program

Within the District's service area alone, there are numerous hazardous waste sites, underground storage tanks, landfills, and contamination sites that could be at risk of nuisance flooding since they may not be designed to undergo permanent inundation. According to Heberger et al (2009), "The mobilization of these contaminants, particularly in densely populated communities, creates direct health risk due to exposure to metals and petrochemicals." Identifying where the areas that have higher risk and impact present opportunities for prioritizing remediation and restoration of those sites to lessen the social, economic, and environmental consequences that would occur from the pollutants if left unchecked.

Existing inequities will continue to compound as the impacts of climate change become more severe. Not all communities are exposed to the same level of climate risk, as marginalized populations will experience disparate negative effects, which will create inequalities in future resilience solutions. As such, deliberate intention is needed to engage and involve vulnerable communities in the planning process for the path forward, as discussed in Section 9.3Recommendations for Future Community Engagement.

In moving toward and strengthening more equitable and resilient solutions, the District can also consider examples such as the steps identified in the City of Portland Bureau of Environmental Services Resiliency Master Plan Project Draft process for incorporating equity into capital planning for future phases of work (see Figure J-3 below, highlights provided in Section 9.3).

Figure J-3. Draft potential process for incorporating equity into capital planning

Source: Bureau of Environmental Services Resiliency Master Plan Project (2019)

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Appendix K: Further Resources

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Appendix K

Further Resources

- **California resources for wide range of resilience and adaptation efforts:** ResilientCA- Adaptation Clearinghouse
- **Cal-Adapt data and maps:** https://cal-adapt.org/
- **California Heat Assessment Tool:** http://www.cal-heat.org/
- **Adaptation Capability Advancement Toolkit:** http://arccacalifornia.org/adapt-ca/
- **DWR general resource page** (includes multiple direct climate risk and vulnerability assessment resources and links): Resources for Water Managers, DWR
- **SWRCB climate change landing page** (includes direct links to interagency adaptation and resilience resources): SWRCB Climate Change website
- **San Francisco Bay Regional Water Board climate change landing page** (includes link to Adaptation Atlas and Board activities): SF Regional Board Climate website
- **DWR and EPA Previously developed handbook:** DWR/EPA: Climate Change Handbook for Regional Water Planning
- **Framework for decision analysis:** Climate Risk Informed Decision Analysis (CRIDA)
- **Sea level rise viewers:**
    - The Bay Area has multiple sea level rise viewers to look at the geographical extents of various combinations of sea level rise and storm scenarios. These four viewers include the San Francisco Bay Conservation and Development Commission's Adapting to Rising Tides Shoreline Flood Explorer, National Oceanic and Atmospheric Administration's (NOAA) Sea Level Rise Viewer, United States Geologic Survey's (USGS) Our Coast, Our Future Flood Map, and USGS's Hazard Exposure Reporting and Analytics (HERA) tool. To view various SLR scenarios and their geographical extent, visit the web viewers for further information. The SLR maps within this study use the Adapting to Rising Tides flood data because they contain more locally relevant data than the national studies, such as USGS or NOAA's.
        - USGS - HERA (includes groundwater modeling)
        - Hazard Map – Our Coast, Our Future (ourcoastourfuture.org)
        - https://explorer.adaptingtorisingtides.org/explorer
        - https://coast.noaa.gov/digitalcoast/tools/slr.html

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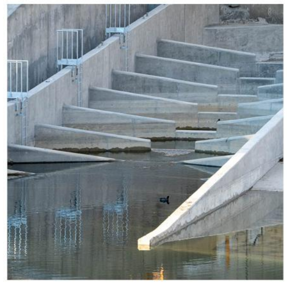

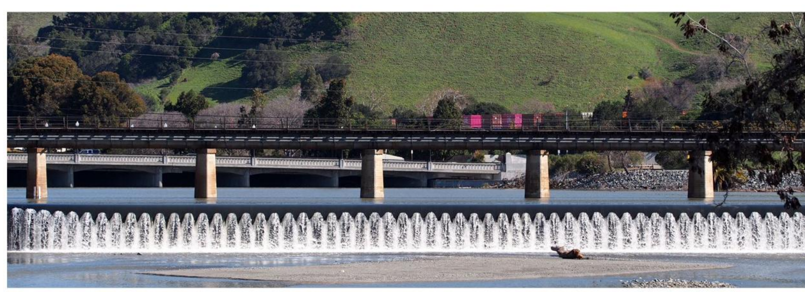

Brown AND Caldwell