Watershed Resilience Framework and Toolkit — A Guide to Accelerate Resiliency in California's Watersheds

DRAFT

April 2024

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Acronyms

DWR	California Department of Water Resources
CVFPP	Central Valley Flood Protection Plan
CRIDA	Climate Risk Informed Decision Analysis
GSA	Groundwater Sustainability Agency
HUC	Hydrologic Unit Code
IRWMP	Integrated Regional Water Management Plan
IWM	Integrated Water Management
NGO	non-governmental organization
RCC	Regional Climate Collaborative
RFMA	Regional Flood Management Agency
RFFC	Regional Forest and Fire Capacity
RMWG	Regional Water Management Group
RWS	Regional Water System
USGS	United States Geological Survey
WRP	Watershed Resilience Program
WRCC	Western Regional Climate Center

Introduction

This document presents a draft of the Watershed Resilience Framework (Framework) that is being developed by the California Department of Water Resources (DWR). The draft Framework is being provided as a planning guide and toolkit to support watershed managers in better understanding climate effects and vulnerabilities and how to plan for more resilient watersheds.

Background

Climate change is being experienced all over the globe. Water and environmental challenges associated with climate change have dominated the World Economic Forum's top ten list of "most severe global risks" for the past decade.

California is experiencing dramatic climate changes as temperatures are warming, sea levels are rising, upper watersheds are experiencing less snowpack, and extreme events such as floods, droughts, and wildfires are increasing and becoming more consequential.

Over the past five years, California has recorded the warmest temperatures since the beginning of the 20th century, has likely experienced the worst drought in over a century, and has experienced the largest wildfires in recorded history. Meanwhile, hundreds of miles of coastline are experiencing the effects of rising sea levels and more extreme flood regimes. It is now imperative to adapt to the effects of climate change.

Climate impacts vary widely across the state and are unique from watershed to watershed. Watershed-scale coordination and collaboration from headwater to groundwater to ocean offer new opportunities to integrate human and natural systems, leverage and build capacity, advance multi-sector and multi-benefit solutions, and accelerate climate change adaptation.

California Water Plan Update 2023 described a Watershed Resilience Program (WRP) to encourage all water-related sectors (water supply, flood management, groundwater, ecosystems, water quality, recreation, and hydropower) to collaborate on climate resilience planning and management at the watershed scale. The WRP supports the development of watershed-scale vulnerability assessments, supports the development of Watershed

Resilience Plans (Plans), and provides funding to increase regional climate resilience. The program will also advance the Governor's Water Supply Strategy, which recognized the need for assessments to identify and measure possible gaps in regional water supply.

This Framework seeks to help watershed managers develop more comprehensive assessments and robust resiliency strategies to ensure that California is prepared for future climate change.

Audience and Use of Framework

The Framework is intended to support resource managers (water agencies, flood agencies, regional planning groups, Groundwater Sustainability Agencies (GSAs), non-governmental organizations (NGOs), cities/counties, Tribes, conservancies, federal agencies, State agencies, etc.) with a set of key watershed planning and management principles and a flexible, but replicable, guide for conducting resilience planning at the watershed scale across multiple water resource sectors.

Watershed Resilience Principles

The State's vision for watershed resilience is inclusive cross-sector, cross-jurisdictional watershed networks across California for climate resilience planning and project implementation. Watershed networks provide all water-related sectors and communities a seat at the table to collaborate on understanding climate vulnerabilities and system function, formulating multi-benefit adaptation strategies, and tracking watershed outcomes for transparency and accountability. Watershed networks will be locally led, State supported, and centered in equity to ensure that underrepresented voices can engage as equals in a watershed-wide conversation. State investment in these watershed networks throughout California is also an investment in the social infrastructure of relationships and trust that are needed to effectively adapt to climate change throughout a watershed.

An approach focused on watershed resilience incorporates many of the fundamental principles of adaptive management and integrated water management. These principles encourage robust, iterative planning in the face of uncertainty and recognize that water supports, and is managed for, many interdependent resources. Key watershed resilience principles include:

1. Promote multi-sector, multi-benefit resilience strategies.

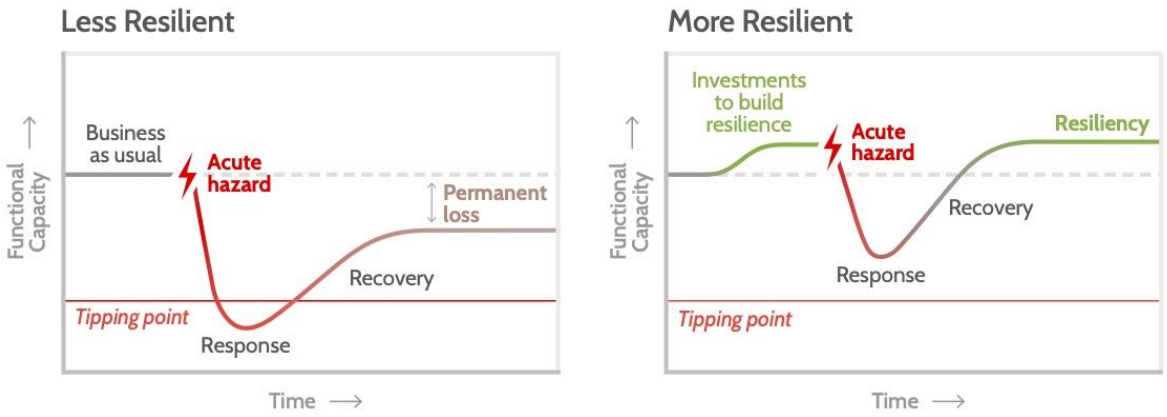
2. Integrate and prioritize equity and social justice as part of the planning and implementation process.
3. Focus on watersheds and interdependencies of water resource systems.
4. Build and strengthen diverse watershed networks through collaboration, relationships, and trust.
5. Apply best available science and promote best practices, approaches, and tools for climate resilience planning.
6. Build a robust understanding of climate risks and embrace uncertainty by considering a range of plausible future conditions.
7. Promote outcomes-based management with watershed performance indicators and a focus on implementation.

The principles of the watershed resilience approach support administration policies and priorities, including the *Governor's Water Supply Strategy* and *Water Resilience Portfolio*, focusing on climate urgency, and building regional resilience through multi-benefit projects, integrated resource management, and a strong focus on equity.

While many definitions of resilience exist, the following definition is commonly applied by State of California agencies and best reflects the goals of this water resilience framework. Resilience is the capacity of natural and built systems to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience.

One of the foundational goals of this framework is to improve the resilience of watersheds throughout the state of California such that they can continue to function and provide services for the human and natural environment. Improving resilience will require considerable investments in natural and built infrastructure as well as the social capital to recognize vulnerabilities and implement solutions. Figure 1 graphically depicts less resilient and more resilient systems, and how proactive investments will be required to ensure that functional capacity is recovered following an acute hazard. In the context of watershed climate resilience, the "functional capacity" represents the ability for the watershed to continue to support services (e.g., water supply, ecosystem, flood management) during and following climate-related hazards (e.g., drought, floods, seasonal changes in hydrology).

Figure 1 Graphical Depiction of Resilience Function



Watershed Resilience Planning Framework

Effective watershed resilience planning will require local and State agencies collaboratively working together with clear roles and a common process framework. The Framework is designed to serve as a robust but flexible roadmap for water managers to conduct watershed resilience planning, evaluate climate vulnerability and risk, support and prioritize adaptation strategies, and track progress toward climate change adaptation for water-related sectors.

Summary of Framework Planning Steps

The Framework draws from the best practices and innovations currently being implemented around the state to understand climate risk and develop resilient solutions. The Framework consists of five main steps (Figure 2):

1. **Set the Stage —** convene a diverse and inclusive watershed network, set vision and goals for this resilience planning effort, and identify the components, interdependencies, and bounds of the planning effort.
2. **Explore Hazards —** understand current state of the system, historical climate influences on the system, and future projections and uncertainty.
3. **Assess Vulnerabilities and Risks —** identify water resource and socio-economic indicators, assess the vulnerability of watershed systems to current — and a range of plausible future climate conditions — and use risk analysis to identify high-priority focus areas.
4. **Develop Adaptation Strategies —** identify and evaluate a wide spectrum of adaptation options for high priority focus areas, consider sustainability principles, and recommend no- or low-regret strategies considering uncertainty.
5. **Implement and Monitor —** develop the timeline and triggers for implementing selected strategies through on-the-ground actions; fund, implement, and monitor the performance of actions; and adapt strategies as needed.

The role of State and local agencies involved in each step of the watershed resilience framework is included below in Table 1.

Figure 2 Watershed Resilience Planning Framework

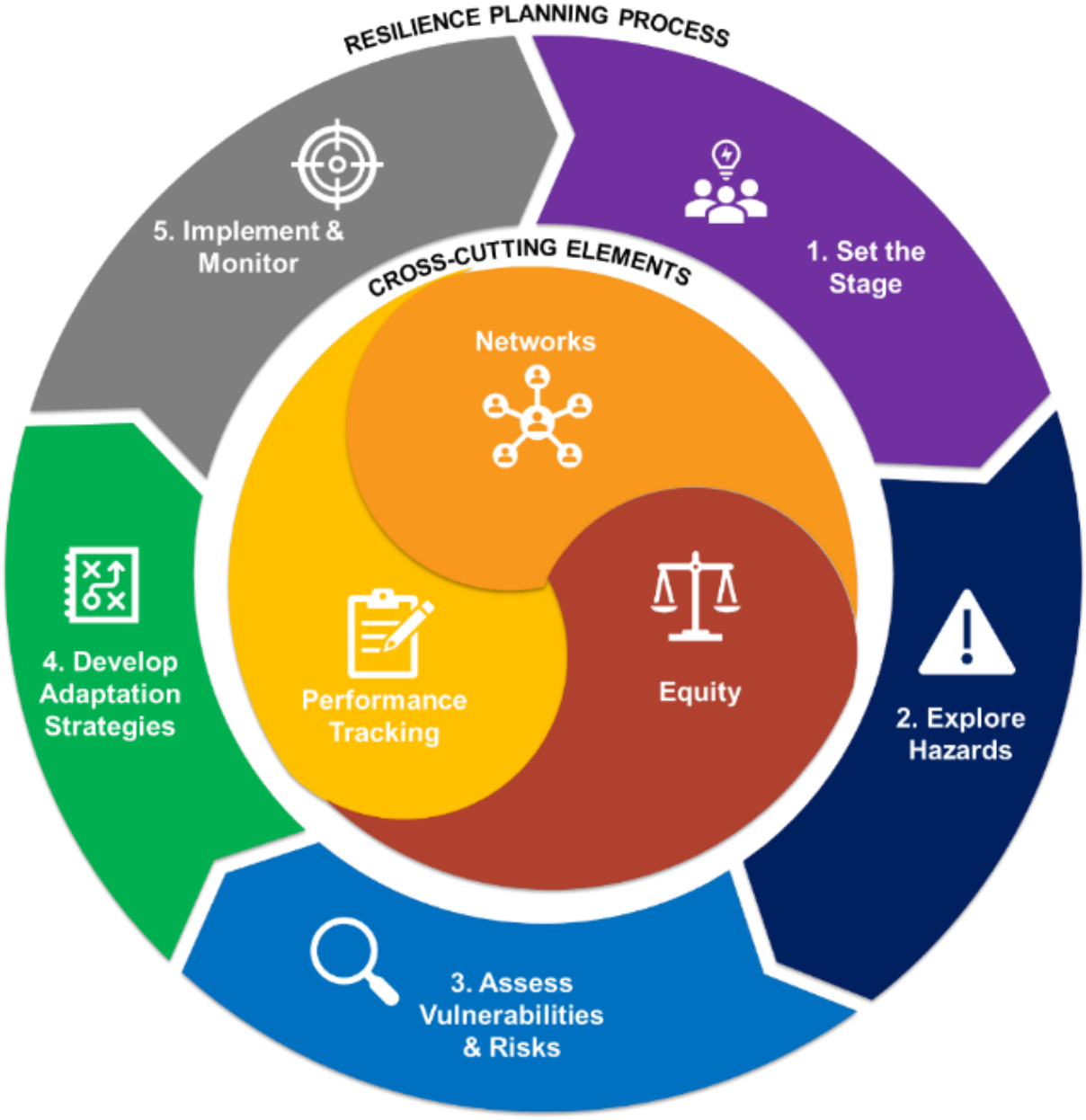


Table 1 State and Local Roles in Achieving Watershed Resilience

Watershed Resilience Step	State Support Role	Local/Regional Role
1. Set the Stage	Support for building watershed networks; provide guidance for outreach and engagement strategies	Build, foster and convene watershed networks; region-specific resilience problem statements; region-specific goals and indicators
2. Explore Hazards	Identify risk drivers and trends throughout the state; provide guidance for watershed water budgets; share common climate scenarios and data	Identify relevant local risk drivers and trends; state of watershed assessments; regionalize scenarios for use at watershed scale
3. Assess Vulnerabilities and Risks	Provide technical support, case studies, and funding for vulnerability and risk assessments; review regional vulnerabilities to inform future statewide policy and funding priorities	Conduct vulnerability and risk assessments; communicate risks to community interests; report findings to State
4. Develop Adaptation Strategies	Provide resilience toolkit and adaptation strategy database for use throughout the state; share decision support approaches and best practices	Identify unique and expanded watershed-specific adaptation strategies; determine priority and inter-jurisdictional needs; identify financial and technical support
5. Implement and Monitor	Inform opportunities for permitting and regulatory improvements; support cross jurisdictional partnering; promote sustainable funding for resilience planning and implementation; revise framework based on reported resilience performance	Leverage watershed network to support implementation; pursue implementation strategies; build support for action; identify local sources of funding for State and federal matching; regionalize metrics to report on resilience progress

Cross-Cutting Elements

Integral to this Framework are three elements that are cross-cutting: **watershed networks**, **equity**, and **performance tracking**. These three elements integrate across all steps of the framework and are considered foundational to the success of any watershed resilience planning effort.

These include the formation of watershed networks, ensuring equity is integrated in the planning process, and that resilience performance metrics are defined and tracked over time. The Framework has the flexibility to be customized and used in California's diverse watersheds. Specific considerations associated with each of the cross-cutting and process elements are shown in Table 2.

Table 2 Integration of Cross-Cutting Elements and Planning Framework Steps

	Setting the Stage	Explore Hazards	Assess Vulnerability & Risks	Develop Adaptation Strategies	Implement & Monitor
Watershed Networks	Establish diverse and inclusive network; set shared watershed vision and goals	Share and solicit input of historical hazards and key climate threats	Ensure vulnerabilities are broad-based, locally relevant, and cover resource sectors	Recommend and review strategies; identify intersections with other resilience efforts	Assist in identifying partners; implementation support for priority actions
Equity	Acknowledge past equity challenges, include vulnerable communities in network, and develop equitable network decision making structure	Share understanding of impacts to most vulnerable communities	Ensure vulnerabilities assessed are inclusive of critical equity challenges	Recommend and review strategies; ensure equity challenges are addressed	Community participation in design and implementation
Performance Tracking	Determine what is important to measure and develop corresponding metrics	How did past events affect key metrics? And how are future climate hazards expected to affect these?	Quantify as many metrics as possible; identify thresholds or reference values	Use metrics to quantitatively measure potential performance of strategies	Track progress on action implementation and performance indicators

This Framework document provides an overview of the watershed resilience planning process and includes guidance on key questions to consider in each process step, links to case studies and practical examples, links to tools and resources, and a workbook that can be used to track progress in preparing the plans. To accompany the Framework, DWR has compiled and developed

a set of guidance, resources, and tools, and best practices to support watershed managers to conduct resilience planning. The guidance and toolkit serve as a template for watershed networks to conduct resilience planning and develop and customize their own adaptation strategies. The guidance and toolkit are also aligned with best practices in State and national climate resiliency and equity efforts.

The current version of this Framework is provided as a document with hyperlinks to supporting materials. Subsequent versions will be developed as an interactive online resource that could be modified and appended as more supporting resources and tools become available, watershed resilience pilots initiate development of resilience plans, and refinements to the process are made.

How to Use this Guide

When you see …	Look for ….
	Key Questions to Consider
	Case Studies/Practical Examples
	Tools & Resources
	Workbook for Tracking Progress

Step 1 — Set the Stage

Watershed resilience planning requires an integrated and inclusive approach to assessing climate challenges and solutions. Setting the stage for such a broad, inclusive planning approach involves organizing a watershed network, developing collaboration and governance guidelines, framing watershed boundaries and challenges, and establishing a watershed resilience vision and goals. These steps are critical to the success of the resilience planning process and the outcomes of resilience actions.

Key elements of this step in the process include the following:

Identify and Assess Existing Regional Networks

In most watersheds of the state, some form of regional or local watershed network may already exist. These networks may include Regional Water Management Groups (RMWGs), Groundwater Sustainable Agencies (GSAs), Regional Climate Collaboratives (RCCs), Regional Flood Management Agencies (RFMAs), Regional Forest and Fire Capacity (RFFC) Program groups, environmental groups, and other water and resource management groups. The level of current activity of these groups, breadth of engagement and resources covered, and level of potential intersection with the watershed resilience planning effort should be assessed. The goal of identifying and assessing existing networks is not to critique these efforts but rather to ascertain potential interconnections with watershed resilience planning efforts.

In addition to existing water management program networks, watershed resilience requires engagement and participation by vulnerable communities and California Tribes. Additional key partners for broader multi-sector collaboration include water supply, groundwater, water quality, flood management, ecosystem, recreation, hydropower, and other interests within the watershed.

Vulnerable Communities corresponds to the Governor's Office of Planning and Research Integrated Climate Adaptation and Resiliency Program definition. Climate vulnerability describes the degree to which natural, built, and human systems are at risk of exposure to climate change impacts. Vulnerable communities experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts. These disproportionate effects are caused by physical (built and environmental), social, political, and/ or economic factor(s), which are exacerbated by climate impacts. These factors include, but are not limited to, race, class, sexual orientation and identification, national origin, and income inequality (OPR, 2018).

A detailed review of these existing networks, program groups, communities, and water management partners should be performed before embarking on other steps of this framework. This survey will provide a more complete understanding of the state of engagement in related efforts in the region, status and activity of programs, and intersections and gaps for a watershed resilience network.

? What existing water management networks exist? What intersections in objectives or function do they have with a potential watershed resilience network?

? Which California Tribes exist in the region? Are they engaged in other resilience planning efforts?

? Which vulnerable communities exist in the region? Are they engaged in other resilience planning efforts?

Define Watershed and Planning Boundary

The Watershed Resilience Program is designed to support water and resource managers as they develop watershed resilience plans. To this end, DWR has developed a draft set of 48 hydrologically consistent watershed boundaries in California as the basis for watershed resilience planning. Figure 3 shows the initial watershed boundaries proposed by DWR that are based on United States Geological Survey (USGS) Hydrologic Unit Code (HUC)-6 and HUC-8 watershed classifications. The use of combined HUC-6 and HUC-8 hydrologic units was necessary to attempt to create similar levels

of scale in the Sacramento and San Joaquin basins as in other parts of the state.

An explicit definition of the watershed boundary, systems, and components to be evaluated, and the bounds of the study are needed to frame and guide the resilience assessment. The plans should consider the initial watershed boundaries that DWR has provided. These watersheds are hydrologically consistent and consider the complete watershed lands from headwaters to groundwater and outlet. These watershed areas are not intended to be prescriptive but serve as a starting point for consideration. Regional partners are to consider the DWR-generated preliminary watersheds and can propose their own watershed planning area for approval by DWR.

Watershed areas proposed by regional partners should:

- Include upstream headwaters that provide sources of surface runoff and floodwaters in the watershed.
- Include geographic extent of water-related effects and impacts from within the watershed.
- Consider the geographic extent of water-related systems (water supply, flood management, groundwater basins, ecosystem functioning, etc.) in the watershed.
- Consider the geographic extent of potential systemwide adaptation opportunities.
- Consider critical influences from adjacent watersheds.
- Proposed changes to the DWR-generated watershed boundaries should be documented and fully justified for approval by DWR.

In California, most watersheds have some interconnection and critical influences from adjacent watersheds. These interconnections and influences may include water imports or exports, power diversions, groundwater underflows, governance, and other factors. These factors should be recognized and be given careful consideration when evaluating the management of, or impacts to, water resources within the watershed. However, interconnected infrastructure with adjacent watersheds does not necessitate an expansion of the watershed boundary.

The watershed area and boundaries should be explicitly defined and mapped, and major interconnections and critical influences should be identified.

Figure 3 Draft Watersheds and Boundaries for Use in Resilience Planning

⚒ Draft Watershed ArcGIS Map — exploration of watershed boundaries and other hydrological and planning area boundaries.

⚒ Water Management Boundary Tool — various hydrological, planning, and other jurisdictional boundaries.

Form the Watershed Network

Based on a careful survey of existing networks, watershed resources, and potential partners, a watershed network should be formed to help guide the planning effort and support resilience efforts throughout the watershed. Network participants should be selected based on a shared interest in furthering watershed resilience, a broad representation of resource areas, and inclusive participation by California Tribes and vulnerable communities. The watershed network should be viewed as a mechanism to increase voluntary participation in collaborative watershed resilience planning.

A DWR representative will engage in the network as a "Watershed Coordinator" to provide regular communication with DWR and offer guidance and DWR resources as needed.

Major considerations in the formation of a watershed network include:

- Identify key participants representing the areas important to the planning effort including vulnerable communities, Tribes, and water-related sector partners.
- Determine roles and expectations for watershed network participants.
- Develop outreach and engagement strategies for the watershed network and for informing the public on progress.
- Form a watershed network consisting of representative participants for the development of the watershed resilience plan.
- Develop an equitable and inclusive decision-making structure to guide the development of the watershed resilience plan.
- Charter a network team to ensure common understanding, vision, and objectives.

Network Story — Flood-MAR — provides a summary of recent water planning networks in California and best practices and considerations in forming a network.

Establish Watershed Resilience Vision and Goals

A key task of the watershed network is to establish an overarching vision and feasible goals for the watershed resilience planning effort. The network will convene, discuss, and establish watershed-specific problem statements,

resilience vision, and resilience goals. The problem statements, vision, and goals should be documented and should serve as a guide for development of the plan. The desired outcomes from the planning effort should be discussed from both technical and policy perspectives and be documented. In addition, it is advised that a list of potential pitfalls be discussed during this work element and initial strategies be developed to overcome these challenges.

❓ What are the expected outcomes to be achieved from this planning effort? How will the results and recommendations be used?

❓ What process goals are envisioned by the network? How will network participants help carry the resilience vision to their respective organizations?

❓ What are potential pitfalls to be avoided? What difficult conversations should be initiated early to avoid late changes to vision, goals, or overall planning effort?

Step 1 Work Products:

Watershed Resilience Plan chapters covering the work elements associated with Step 1, including:

- Assessment of existing regional networks and engagement efforts and identifies any gaps in engaging historically excluded communities.
- Watershed network development and partner engagement chapter.
- Written policies and procedures for watershed network.
- Watershed area map with boundaries and descriptions.
- Watershed-specific resilience problem statements.
- Watershed-specific resilience vision and goals.

📚 **WRP Tracking Workbook — Step 1**

Step 2 — Explore Hazards

A robust understanding of the current state of the watershed, historical climate influences on the system, and future climate projections is necessary before embarking on climate vulnerability and risk assessments. The objective of Step 2 is to explore the watershed's climate hazards, identify historical weather-related challenges or events, identify the climate risk drivers and trends, and to summarize the current state of watershed resilience and planning.

This effort is meant to develop a strong understanding of the water and climate within the watershed. Step 2 is envisioned as a focused compilation of historical weather-related events, historical impacts to water management and communities, and climate science and projections. No new modeling is anticipated within Step 2.

Compile Existing Climate Vulnerability Information

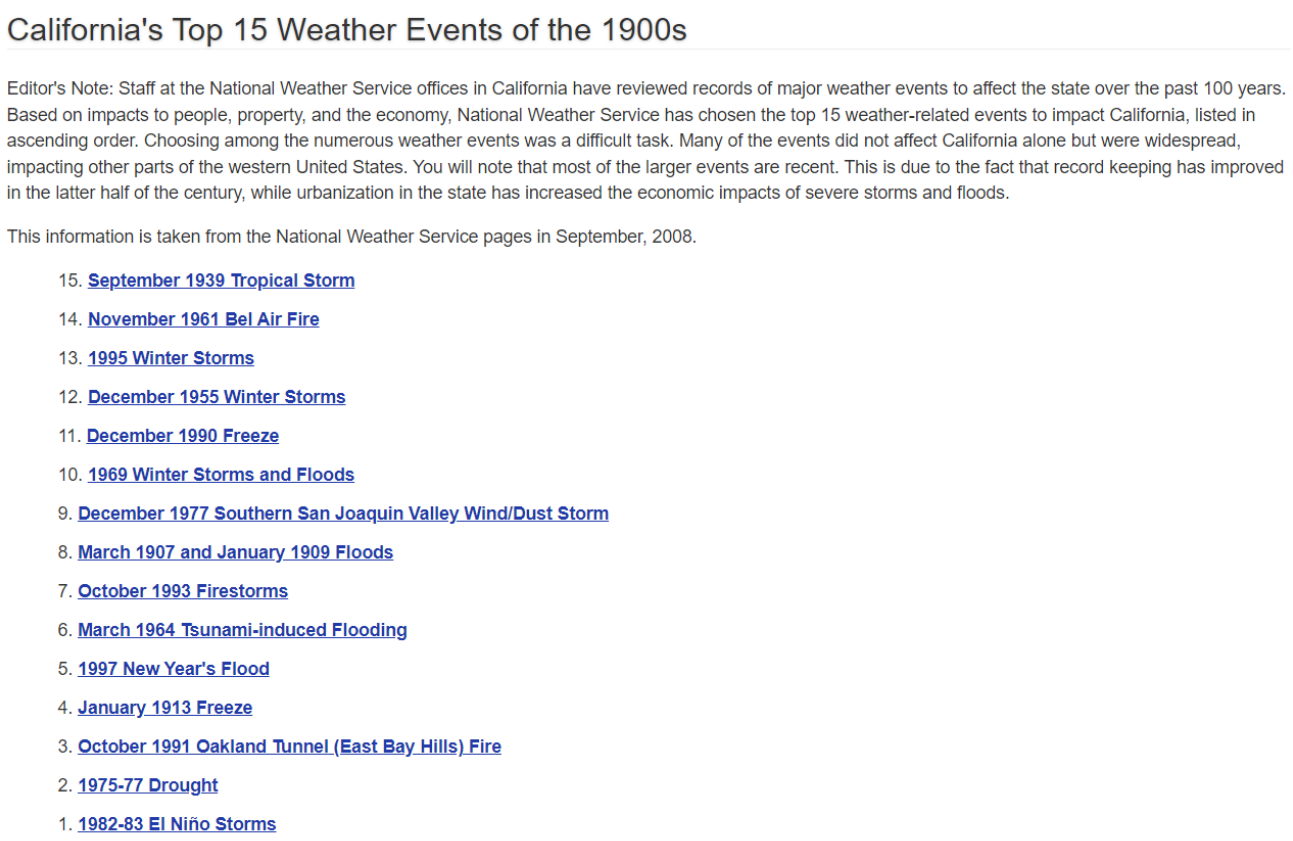
The watershed network participants shall compile existing climate vulnerability assessment information for all water-related sectors (water supply, groundwater, flood management, water quality, ecosystems, recreation, hydropower, etc.). This information may include climate assessments prepared for Integrated Regional Water Management Plans (IRWMPs), climate adaptation plans, Local Hazard Mitigation Plans, basin studies, or other planning efforts. A summary of the available information should be compiled, including a study description and the water resource sectors evaluated. Previous technical analysis and assessments that can be leveraged in the watershed resilience planning effort should be identified, along with data gaps that will need to be filled.

What are the most useful climate resilience planning studies for the watershed? Was a vulnerability assessment prepared? Were adaptation strategies developed and evaluated?

Identify Critical Historical Weather-Related Events

As part of the process of improving understanding of climate, network participants will identify critical historical weather-related events and describe the impacts of these events on watershed resources and communities. For example, the Western Regional Climate Center (WRCC) has compiled a list of the top 15 weather events of the 1900s for California. These historical events are described based on the causal mechanisms and impacts. A similar listing should be prepared for weather-related events for the specific watershed. The top 10 to 15 historical events and impacts should be documented to provide context and demonstrate real, observed, and experienced conditions. Often these historical events (especially if recent), support communication of climate risks and development of a narrative to share with non-technical audiences.

Figure 4 WRCC's Top 15 Weather Events of the 1900s for California



California's Top 15 Weather Events of the 1900s

Editor's Note: Staff at the National Weather Service offices in California have reviewed records of major weather events to affect the state over the past 100 years. Based on impacts to people, property, and the economy, National Weather Service has chosen the top 15 weather-related events to impact California, listed in ascending order. Choosing among the numerous weather events was a difficult task. Many of the events did not affect California alone but were widespread, impacting other parts of the western United States. You will note that most of the larger events are recent. This is due to the fact that record keeping has improved in the latter half of the century, while urbanization in the state has increased the economic impacts of severe storms and floods.

This information is taken from the National Weather Service pages in September, 2008.

15. September 1939 Tropical Storm
14. November 1961 Bel Air Fire
13. 1995 Winter Storms
12. December 1955 Winter Storms
11. December 1990 Freeze
10. 1969 Winter Storms and Floods
9. December 1977 Southern San Joaquin Valley Wind/Dust Storm
8. March 1907 and January 1909 Floods
7. October 1993 Firestorms
6. March 1964 Tsunami-induced Flooding
5. 1997 New Year's Flood
4. January 1913 Freeze
3. October 1991 Oakland Tunnel (East Bay Hills) Fire
2. 1975-77 Drought
1. 1982-83 El Niño Storms

What are the most significant historical weather-related events within your jurisdiction or watershed? What impacts did they have

on water resources and communities? Were any cascading impacts observed?

⚒ Tools to Support Assessment of Historical Weather-Related Events

FEMA National Risk Index
WRCC Top 15 Weather Events
California Water Watch
Historical Climate Tracker tool
Historical Drought Stripes
USGS Basin Characterization Model
USGS StreamStats Tool
California Ocean Observing Systems Data Portal
NOAA Relative Sea Level Trends
National Flood Hazard Layer
NOAA Atlas 14
California Fire Hazard Severity Zones (FHSZ)
CAL FIRE State Responsibility Area (SRA)
USGS Post Wildfire Debris Flow Hazard Assessment Viewer

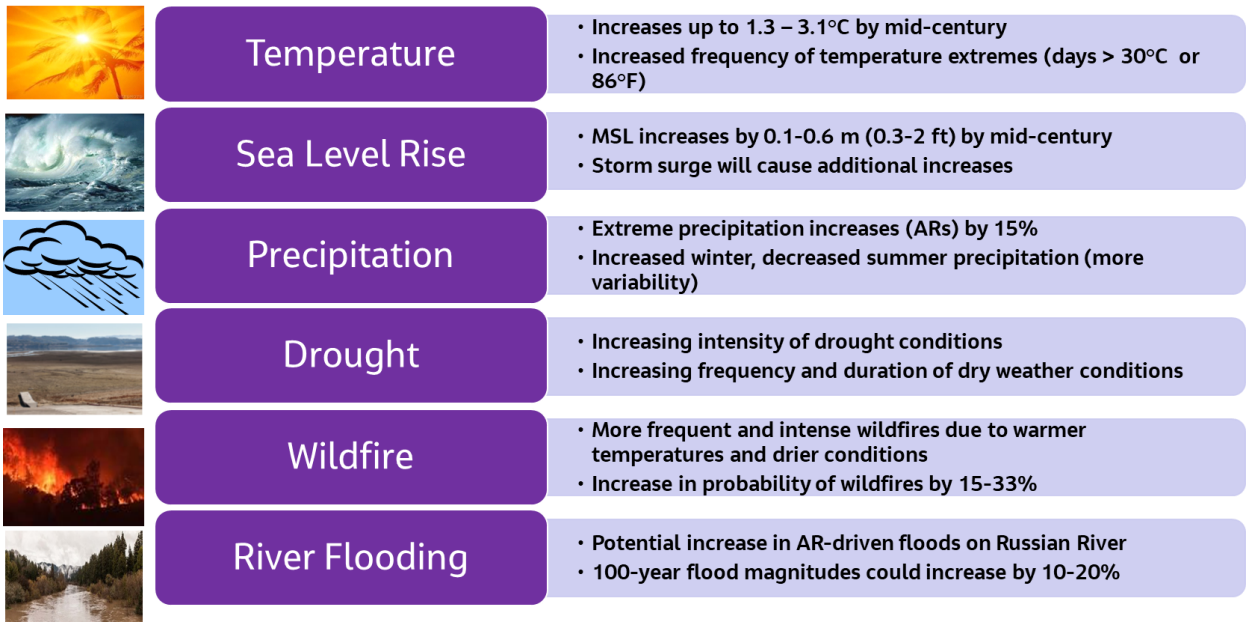
Identify the Most Relevant Regional Climate Drivers and Trends

Climate impacts each watershed in a slightly different way. As part of the resilience planning process, major climate drivers and trends for the watershed should be documented. The documented climate drivers should include descriptions of historical trends and projected changes in temperature, precipitation, sea level, floods, drought, wildfire, and other climate-driven processes that are relevant to the watershed. Based on the understanding gained from identifying historical weather-related events and major regional climate drivers and trends, the most relevant drivers for each of the water resource sectors within the watershed will be identified.

❓ What water resource sectors have been impacted the most by recent climate change? What new impacts are expected based on the climate projections?

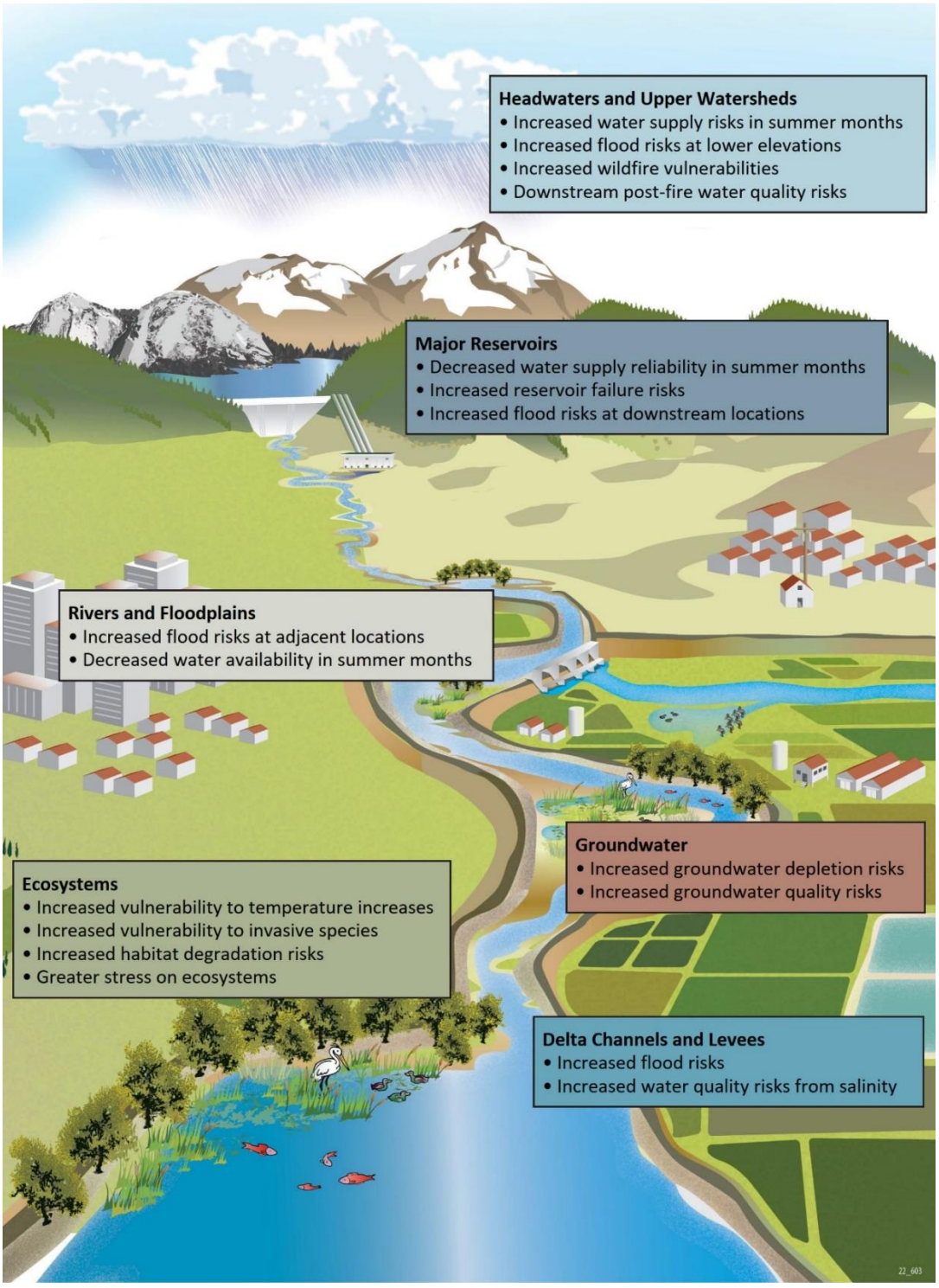
How much are the resource systems impacted by expanding climate variability versus directional change? Annual changes or seasonal shifts?

Figure 5 Depiction of Climate Drivers and Projections for the Russian River



Source: Sonoma Water 2021.

Figure 6 Example Qualitative Description of Impacts to Various Watershed Components in the Central Valley



Source: Central Valley Flood Protection Plan (California Department of Water Resources 2022).

Resources for Future Climate Projections

Cal-Adapt
Gridded Weather Generator Perturbations of Historical Detrended and Stochastically Generated Temperature and Precipitation for the State of CA and HUC8s
Climate Toolbox
Risk Factor
USGS Basin Characterization Model
USGCP Climate Explorer
Our Coast, Our Future Hazard Map
USGS Hazard Exposure and Reporting Analytics (HERA)
NOAA Sea Level Rise Viewer
Interagency Sea Level Rise Scenario Tool
IPCC Projection Tool

DWR recommends using Cal-Adapt, Gridded Weather Generator data, and Our Coast Our Future as sources of future down-scaled climate projections. These sources are being used in other WRP efforts led by DWR, such as the Statewide Watershed Resilience Assessment. DWR can assist in providing an initial climate projection set for each watershed in the WRP if requested.

Conduct State-of-Watershed Assessment

The watershed network should conduct a state-of-watershed assessment, including summaries of climate and hydrology in the watershed, relevant prior assessments, key challenges influencing resilience, and opportunities for increasing future resilience. It is expected that this task will uncover a number of vulnerabilities through a robust discussion and assessment of historical conditions, current reports, and recent observations of climate changes. The assessment should not involve any new quantitative assessments or modeling at this time and should primarily rely on a synthesis of the preceding tasks in Step 2.

Step 2 Work Products:

A Watershed Resilience Plan chapter covering the work elements associated with Step 2, including:

- Historical weather-related challenges, events, trends, and impacts.
- Summaries of climate and hydrology in the watershed.
- Projected changes in temperature, precipitation, sea level, floods, drought, wildfire, and other climate-driven processes relevant to the watershed.
- Relevant prior assessments.
- Key challenges influencing resilience.
- Opportunities for increase future resilience.

WRP Tracking Workbook — Step 2

Step 3 — Assess Vulnerabilities and Risks

A major goal of the WRP is to support robust and consistent climate vulnerability and risk assessments throughout the state's watersheds. The objective of Step 3 is to ensure that a robust assessment of climate vulnerabilities and risks is conducted using the robust and consistent approaches recommended by DWR. The task includes identification of quantitative modeling tools, technical approaches for climate assessments, climate data, robust vulnerability and risk assessments, and eventual identification and prioritization of critical risks.

Conducting a Climate Change Vulnerability Assessment

A climate change vulnerability assessment involves determining a system's exposure to climate hazards, its sensitivity to changing climate conditions, and its inherent capacity to respond to and recover from climate change impacts. The vulnerability assessment in Step 3 is performed both qualitatively and quantitatively and should highlight areas of the system — i.e., specific system components, sectors, and service areas — which have the greatest vulnerability to climate change.

Developing Vulnerability Metrics and Thresholds

To perform a climate change vulnerability assessment, metrics and thresholds for each major water sector are needed. Metrics should be included for water supply, groundwater, flood management, ecosystems, water quality, recreation, and hydropower — as applicable for each watershed. Metrics should also be included for equity considerations. During the quantitative assessment, measurable thresholds that describe when performance of the system or resource is challenged should be established. These thresholds can be based on system performance that provides a target level of service or can be based on a historical reference condition.

❓ At what level of change is system performance severely challenged? Can these levels be quantified? What historical range in performance has been observed?

📍 DWR Merced River Watershed Flood-MAR Reconnaissance Study — study of climate change vulnerability and Flood-MAR adaptation in the Merced River Watershed that includes metrics for water supply, flood, and ecosystem sectors.

📍 Colorado River Basin Study — study of the future of Colorado River management includes detailed metrics and thresholds to measure vulnerability.

📍 Central Valley Future Scenarios Analysis — analysis of climate impacts to Central Valley water resources.

Prepare Updated Watershed Water Budget

Supportive of the vulnerability assessments is an understanding of the water budget for the watershed. An updated historical watershed water budget should be prepared using the appropriate methods, as indicated in DWR's *Handbook for Water Budget Development*. This water budget will provide additional information on the historical water supply and uses within the watershed and may influence approaches and methods for conducting vulnerability assessments.

⚒️DWR Water Budget Handbook — a guidance handbook for developing water budgets with or without models.

📍 Merced Basin Pilot Study — water budget prepared consistent with DWR Water Budget Handbook.

Assess, Organize, and Prepare Modeling Tools

To assess various vulnerabilities, analytical tools may be required to better quantify the range of system response to climate stressors. The availability and adequacy of existing modeling tools to support the measurement of vulnerabilities for water resources in the watershed should be assessed. These modeling tools may include watershed hydrological, groundwater, river basin management, river hydraulic, water quality, ecological, economic, and other models. Any updates to existing models or development of new models for use in assessing climate vulnerabilities should be identified. Model adjustments may be made in order to prepare the models for use in quantitative vulnerability assessments.

❓ How robust are the analytical tools to be used in the assessment? What level of investment in new or modified tools should be considered? How will decision-makers respond to various approaches and presentations of information?

Qualitative Vulnerability Assessment

A comprehensive qualitative assessment should be developed before embarking on the more detailed quantitative assessment. Qualitative assessments help to improve understanding of local climate and variables of interest, engage those who manage, operate, and maintain the system, and identify the areas that required further investment of resources to improve the assessment.

Qualitative assessments often include the following elements:

- Review of existing information related to the watershed system.
- Field visits to major facilities or resource areas of interest.
- Identification of hazard mapping, photos, and critical levels (e.g., flooding elevation or storage levels).
- Preparation of initial qualitative vulnerability assessment ratings.
- Workshops with subject matter experts to confirm and modify findings of vulnerability at each of the major system components or facilities.
- Identification of areas of critical focus for quantitative assessments.

An initial qualitative vulnerability assessment can be prepared using the sensitivity and inherent capacity of the system to adapt to climate hazards and the vulnerability rating tables provided in the WRP Tracking Workbook. These rating scales and descriptions can/should be modified to reflect specific watershed conditions.

📚 **WRP Tracking Workbook — Step 3**

Table 3 shows an example of a vulnerability rating table including sensitivity and adaptative capacity.

Table 3 Qualitative Vulnerability Assessment Rating Table of Sensitivity and Inherent Adaptative Capacity

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

Sensitivity and Inherent Adaptive Capacity

In the qualitative vulnerability assessment, the *sensitivity* of the system to current climate and climate changes is assessed through a standard five-point rating scale ranging from low to high. The sensitivity rating is based on a qualitative understanding of the degree to which system performance is dependent on climate. Likewise, *inherent adaptive capacity* is based on a qualitative understanding of the ability of the system, operations, or management to respond to, *with little or no changes in the current system function or operational/management structure*, climate hazards and climate change while continuing to provide an acceptable level of performance. As with the sensitivity rating, a standard five-point rating scale is also used for inherent adaptive capacity. The combined rating of sensitivity and inherent adaptive capacity results in a qualitative assessment of *vulnerability*. A system component that is highly sensitive (high) to climate and has little inherent adaptive capacity (low) represents a high vulnerability. But not all system components that show high sensitivity to climate are considered highly vulnerable. If substantial operational flexibility exists to adapt to such

changes, then the component may be considered to have only low to moderate vulnerability.

The WRP Tracking Workbook contains vulnerability rating scales for sensitivity and adaptive capacity that can be used or modified for specific applications.

WRP Tracking Workbook — Step 3

Qualitative Vulnerability Results and Presentation

An example of the resulting qualitative vulnerability assessment table is shown in Table 4. The table organizes the overall watershed resources into systems, planning areas, and components. In this table, "system" is related to water resource sector (e.g., water supply, flood management, ecosystem, etc.), "planning area" is related to the sub-organization of the system (e.g., reservoirs or groundwater basins), and "component" is related to the specific facility or asset (e.g., Reservoir X or Groundwater Basin Y).

Table 4 Example Summary Vulnerability Rating Table

System	Planning Area	System Component	Vulnerability Rating (1=Low, 3=Moderate, 5=High)
Water Supply System	Upper Watershed	Source Water Protection Lands	4
		Federal/State Forest	5
	River Operations	Reservoir	3
		River Operations	3
	Conveyance System	Canals	4
		Pump Stations	4
	Groundwater System	Recharge Basins	3
		Groundwater Wells	2
		Natural Recharge Areas	4
	Water Treatment	Water Treatment Plant	5
		Disinfection Facilities	3
Flood Management System	Flood Planning Area 1	Engineered Levees	3
	Flood Planning Area 2	Detention Basins	3
	Flood Planning Area 3	Flood Control Reservoir	5
		Flood Operations	5

System	Planning Area	System Component	Vulnerability Rating (1=Low, 3=Moderate, 5=High)
	Flood Planning Area 4	Flood Diversion and Bypass	4
	Flood Planning Area 5	Coastal Tide Gates	5

It is important that moderate and high vulnerabilities are mapped back to the specific climate threats or stressors that are causing the vulnerability. An example of a resulting vulnerability assessment table mapped to climate stressor is shown in Table 5.

Table 5 Example Summary Vulnerability Rating Table by Climate Stressor

System Component	Temp	Sea Level Rise	Extreme Precip	River Flooding	Drought	Wildfire
System Component 1	M				H	M
System Component 2	M				M	M
System Component 3				H	M	H
System Component 4				H	M	H
System Component 5			M/H	M/H		M/H
System Component 6			L	L		L
System Component 7			M/ H	H		
System Component 8			H			
System Component 9			M			

Sonoma Water Climate Adaptation Plan — robust climate adaptation plan for Sonoma Water's water supply, flood management, and sanitation systems.

Quantitative Vulnerability Assessment

Following completion of the qualitative assessment, a quantitative assessment should be performed for the areas indicating high potential vulnerability. DWR is encouraging the use of two approaches for conducting quantitative vulnerability assessments for watershed resilience planning:

- Scenario-based approach.

- Decision-scaling approach.

Scenario-based approach

The scenario-based approach uses a set of distinct scenarios to describe the range of future climate conditions and other factors. Typically, these scenarios include a subset of the available downscaled climate projections and may be combined with uncertainties related to land use, growth projections, and other factors. Models and other analytical tools are then used to assess the system performance under these future scenarios. Comparison of model performance to historical conditions, other reference conditions, and vulnerability thresholds is performed to describe possible system performance without adaptation strategies. Then, following the development of adaptation strategies, these same models and tools are applied with inclusion of the strategy to measure reductions in vulnerability. Scenario-based approaches have been widely used in characterizing climate impacts to water and other resources in California.

Sacramento-San Joaquin Basin Study — scenario approaches used in the Bureau of Reclamation's (Reclamation) Basin Studies program.

Sonoma Water Climate Adaptation Plan — robust climate adaptation plan for Sonoma Water's water supply, flood management, and sanitation systems.

American River Basin Study — scenario approaches used in Reclamation's Basin Studies program.

Decision-scaling approach

The decision-scaling approach is DWR's primary recommended approach for climate change vulnerability, risk, and adaptation strategy analysis. Decision-scaling uses models and other analytical tools to understand the specific conditions that lead to system vulnerability, otherwise known as a "stress test." This requires modeling several combinations of temperature, precipitation, or other factors that are systematically perturbed relative to historical conditions. In addition, weather generators can be used to develop plausible storm patterns and multi-year periods of wet and dry conditions that have not been observed in the relatively limited observational record but are reflective of the inherent natural variability of California's climate.

System performance is assessed under all of these conditions which enables mapping system vulnerability onto a "decision-space." For example, comparison of modeled system performance to specific performance thresholds quantifies the robustness of the system to climate change stressors, both individually and when they interact. These same models and tools are then applied with an adaptation strategy to measure reductions in vulnerability and increases in system robustness.

The decision-scaling approach typically has a higher analytical burden than scenario-based approaches because of the additional number of model evaluations that need to be assessed. If the capacity and resources are available, there are several key benefits of the approach:

1. Uses the most credible information available from a much larger set of climate projections than is typically feasible in the scenario-based approach.
2. Provides a more comprehensive understanding of system sensitivity and leads to identification of robust adaptation strategies (i.e., strategies which perform well under many possible futures).
3. Accommodates multiple beliefs about the future, which makes the approach flexible in public decision-making processes.
4. Incorporates probabilistic quantification of projected climate changes that supports a risk-based decision-making framework.
5. System modeling results are not conditional on specific climate projections and can therefore more easily be re-purposed when new climate projection information becomes available.

📍 DWR Merced River Watershed Flood-MAR Reconnaissance Study — decision-scaling approach and its application to multi-sector climate change vulnerability and Flood-MAR adaptation in the Merced River Watershed.

📍 Climate Risk Informed Decision Analysis | CRIDA — CRIDA provides stepwise planning guidance for water resources planners, managers, and engineers to perform bottom-up climate-risk-based analysis.

San Francisco PUC Long-Term Vulnerability Assessment — decision-scaling approach and its application to the SFPUC Regional Water System (RWS).

Step 3 Work Products:

A technical memorandum covering the work elements associated with Task 3, including:

- Watershed water budget.
- Vulnerability and risk assessment report.

WRP Tracking Workbook — Step 3

Step 4 — Develop Adaptation Strategies

Step 4 includes the work elements necessary to develop and evaluate watershed-specific climate adaptation strategies, including identification of priority risk areas, and developing, evaluating, and recommending adaptation strategies.

Identify Priority Risk Areas

Based on the understanding gained from review of the vulnerability assessment findings and through discussions with network partners, the priority risk areas should be identified. Priority areas should be based on the level of vulnerability and risk and impacts to multiple resources. These priority areas should be documented along with the drivers of climate risks and resources impacted.

Develop and Evaluate Watershed-Specific Adaptation Strategies

Based on the priority risk areas, watershed-specific adaptation strategies that address the identified risks should be developed. Adaptation strategies may consist of infrastructure and operations strategies, land and water management strategies, regional strategies, and regulatory and policy decisions. Grantees may use the adaptation strategy database included in DWR's *Watershed Resilience Framework and Toolkit* or other resources to generate initial concepts.

Each adaptation strategy should be evaluated for a range of considerations, including ability to reduce risk, technical complexity, cost, regulatory complexity, environmental impacts, and social effects. Specific evaluation criteria should be developed for these and other categories which the adaptation strategies will be evaluated against. For primary strategies, ones that are likely to have large positive improvements for priority areas, the evaluation should also demonstrate through quantitative methods the risk reduction that could be achieved. ***Quantitative evaluation of risk reduction should utilize the same technical tools and approaches used in the vulnerability assessment analysis.***

The climate change adaptation principles outlined in this Framework are the basis for identifying and developing a broad set of climate change adaptation types. Example climate adaptation strategy change types are presented below:

- **Water Management Infrastructure:** Physical, engineered solutions and approaches aimed at improving water management.
- **Reservoir and River System Operations:** Operational adjustments and modifications for reservoirs and other water management infrastructure.
- **Operations, Maintenance, Repair, Rehabilitation, and Replacement:** Approaches focused on improving and enhancing both routine and non-routine upkeep of water management facilities.
- **Watershed and Floodplain Management:** Efforts related to improving the assessment and mitigation of flood risk under climate change at both the watershed and floodplain scale.
- **Ecosystem Management:** Nature-based solutions and approaches aimed at improving ecological processes, restoring and reconnecting habitats, and reducing stressors.
- **Science and Technology:** Actions focused on the monitoring, prediction, and measurement of climate-related information under climate change.
- **Emergency Management:** Measures related to improving emergency preparedness and response under potential future risks associated with climate change.
- **Programmatic, or Project-Specific Permitting:** Programmatic or project-specific mitigation and permitting-related approaches or modifications aimed at promoting multi-benefit or climate-resilient actions.
- **Policy and Regulations:** Regulatory or policy changes focused on addressing or incorporating climate change into new or existing guidance.
- **Funding and Finance:** Actions focused on improving climate preparedness and resiliency through funding or financing options.

- **Land Management:** Solutions and approaches aimed at improving natural, urban, public, and agricultural land management under climate change.
- **Groundwater Management:** Approaches related to improving groundwater recharge, use, and quality.
- **Delta and Estuaries:** Measures focused on enhancing climate resiliency and preparedness in the Delta and estuaries.
- **Coastal Management:** Efforts aimed at improving the management of coasts and adjacent areas, with particular emphasis on sea-level-rise adaptation and erosion.
- **Water Quality Management:** Actions related to improving water quality and water supply under climate change.

Within each of the climate change adaptation types, individual sub-categories or specific actions can be used to further classify potential adaptation measures and strategies. DWR has developed an "Adaptation Strategy Toolbox" that can be used for initial adaptation strategy ideas. The toolbox includes over 200 water resource climate adaptation actions with application for various climate stressors, by water resource sector and hydrologic region. References are provided for each adaptation action.

⚒**WRP Adaptation Strategy Toolbox** — searchable database of water management adaptation strategies based on climate threat, resource, and hydrologic region.

⚒**EPA Climate Resilient Strategies** — EPA climate resilient strategies as part of EPA's Climate Ready Water Utilities program.

Based on an understanding of the baseline system vulnerability, strategies that reflect a wide range of infrastructure, operational, and policy options should be identified. Evaluation criteria should be developed and applied for each option to capture economic, environmental, and social attributes. As part of the Central Valley Flood Protection Plan (CVFPP) 2022 Update, DWR prepared a suite of water management adaptation strategies and an approach for applying evaluation criteria. Included in this approach are criteria related to:

- Improvement in performance.

- Resilience benefits.
- Cost to implement.
- Time to implement.
- Environmental impacts.
- Feasibility.
- Energy impacts.
- Permitting and legal complexity.
- Social impacts.
- Jurisdictional complexity.

Evaluation of each adaptation strategy with respect to these criteria should be performed to allow for a more complete understanding of strategy benefits and impacts.

Recommend Adaptation Strategies

Based on the identification and evaluation of adaptation strategies, a set of recommended strategies to improve the resilience of the watershed resources should be recommended. The recommended strategies should address prioritized water resource sectors and also demonstrate how equity considerations were included. Recommended strategies should be developed through robust discussions with network partners. The benefits and costs associated with each recommended strategy should be documented.

Step 4 Work Products

A Watershed Resilience Plan chapter covering the work elements associated with Step 4, including:

- Identification and description of priority areas.
- Adaptation strategy development and evaluation.
- Recommended strategies.

Step 5 — Implement and Monitor

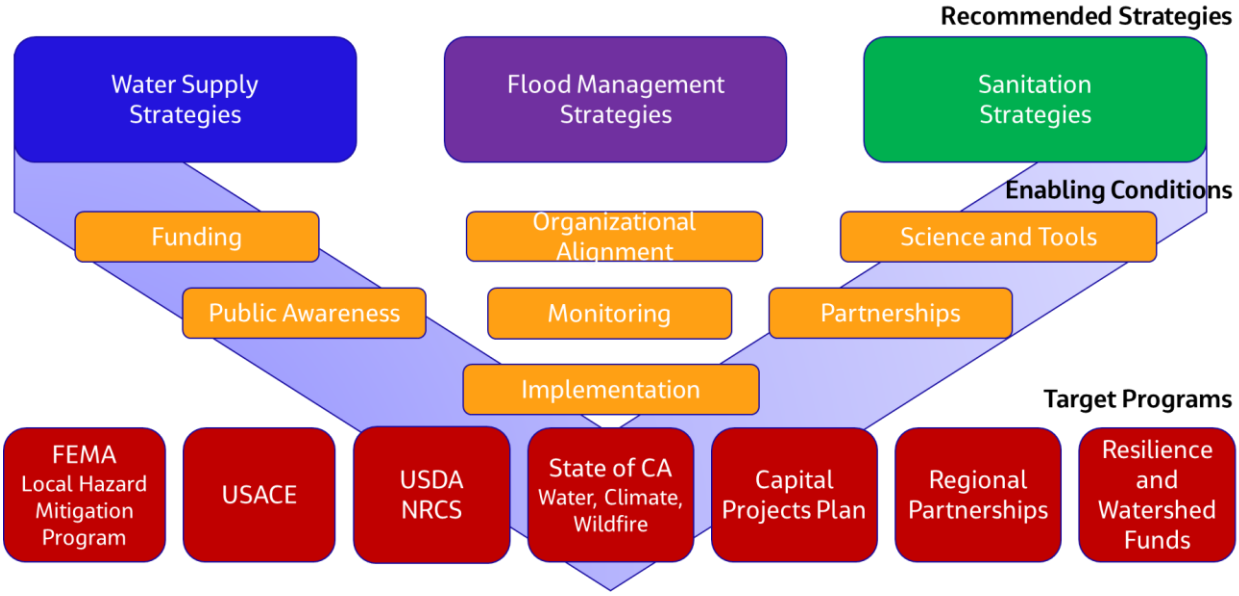
Once recommended adaptation strategies are developed, a plan for implementation, monitoring, and adjustment is needed. Consideration for how the recommended strategies will be implemented are included here.

Identify and Develop Implementation Strategies

Some infrastructure strategies may be incorporated into capital plans, while others may need to be implemented into programs, policies, or operational plans. Still others may require substantial partnerships throughout and beyond the watershed (e.g., for forest management) for successful implementation. Implementation strategies for each associated action, the parties responsible for implementation, the potential funding sources, and potential partnerships should be developed.

Implementation strategies should also consider enabling conditions such as funding opportunities, partnerships, science and tools, organizational alignment, public awareness, and other factors. These enabling conditions can provide support and guide implementation. An example mapping the recommended strategies to particular target implementation programs is shown in Figure 7. Each watershed, organizational structure, and watershed-specific strategy may have unique implementation pathways.

Figure 7 Example of Possible Implementation Strategies



Build Support for Strategies

The watershed network partners should work to build public support for the recommended strategies. Efforts to build support should include concise, publicly available information for the recommendations, outreach to specific impacted groups, and public messaging on the role of adaptation to achieve watershed resilience.

Develop Implementation Plan

An implementation plan and schedule for each recommended adaptation strategy should be developed. The implementation plan should indicate the adaptation strategy, specific actions, responsible lead and supportive parties, and schedule. The cost of implementation should also be included. The implementation plan should be used as the guide for strategy implementation and should be tracked over time.

Considerations for Implementation Under Future Uncertainty

Climate change inherently introduces several sources of uncertainty and risk that directly influence planning processes and the implementation of adaptive and resilient actions. Uncertainty arises primarily from imperfect knowledge of what conditions are changing, the magnitude of changes, how change can be addressed through implementation, and what the potential responses may be.

To address these uncertainties, adaptive planning efforts can be used to support the implementation of the recommended adaptation measures through ongoing monitoring, evaluation, and adjustment of interventions that contribute to the achievement of objectives and focuses on the risks posed by climate change. Some principles of adaptation implementation are as follows:

- **Keep options open** — consider a range of options for future long-term responses to climate change. Highlighting the uncertain factors to be monitored can help to avoid inadequate adaptation.
- **Reduce decision risk** — enable options to be implemented at the proper times to achieve ongoing resilience. Additional or future interventions can be guided through observed impacts or better understanding of impacts through improved data, modeling, and analysis.
- **Invest efficiently** — implementation of capital investments with other related efforts, programs, or partners can enable a more efficient financial approach.
- **Build relationships** — adaptation planning requires input from many different groups, often requiring active collaboration with local communities and partners. This approach should prioritize engagement with vulnerable communities for more equitable outcomes.
- **Realize multiple benefits** — adaptation approaches can be applied to a range of climate risk management strategies that deliver wider environmental benefits. Long-term thinking enables early consideration of wider benefits and environmental enhancements, prioritizing nature-based solutions and leveraging natural processes.

Given the future uncertainty associated with climate change, identifying and evaluating alternative adaptation pathways rather than a singular, fixed long-term plan provides the flexibility to shift from one pathway to another, presenting opportunities for plans to evolve as environments and conditions change over time. Adaptation pathways can help to deploy a robust portfolio of adaptation measures that reflect the best available information and current understanding of environmental, social, and economic conditions. Adaptation pathways can promote a variety of benefits during planning and implementation processes.

Monitor and Track Performance

DWR is making performance tracking of watershed resilience a priority. Plans should identify and begin tracking the most relevant metrics for resilience within the watershed and support DWR with the identification of these metrics and methods for continual monitoring.

DWR is preparing a set of indicators and metrics for measuring the performance of watershed resilience throughout the state. These draft indicators and metrics should be reviewed, and additional watershed-specific performance tracking indicators that can serve as "vital signs" for current watershed resilience should be recommended by the watershed network. The data sources and methods associated with each metric should be documented, and watershed-specific metrics should complement the statewide metrics.

Step 5 Work Products:

Watershed Resilience Plan chapters covering the work elements associated with Step 5, including:

- Development, review, and approval of implementation strategies, plans, associated budgets, and schedules in open and public forums.
- Documentation of identified indicators and metrics, supporting data, and availability.

Next Steps

The Framework described in this document is intended to serve as a working guide to support watershed resilience planning. An online version of this Framework and toolkit will be developed to support a more interactive experience for watershed managers to explore resources, case studies, and tools. This will allow for frequent updates to support watersheds in conducting resilience planning through guidance, tools, and best practices through each step of the process framework.

Through application of the Framework for initial watershed resilience pilots, it is expected that DWR will learn and update this Framework based on findings, suggestions, and lessons learned. In addition, it is envisioned that additional resources, tools, and case studies may be added to the online version. An interactive, online product similar to the one included in the US Resilience Toolkit is envisioned.

Glossary

Adaptation Strategy: Making changes in response to current or future conditions, usually to reduce harm, take advantage of new opportunities, and increase resilience. Includes investments, actions, policies, and statutes intended to reduce vulnerabilities.

Equity: Just and fair inclusion into a society in which all can participate, prosper, and reach their full potential (California Adaptation Planning Guide).

Integrated Water Management (IWM): A collaborative effort to identify and implement water management solutions that increase self-reliance, reduce conflict, and manage water to concurrently achieve social, environmental, and economic objectives.

Vulnerability: The degree to which systems are susceptible to harm from exposure to stresses and from the absence of capacity to adapt. A system's vulnerability is defined by exposure to stressors, sensitivity to stressors, and adaptive capacity to cope with threats.

Water Management Strategy: Investments, actions, policies, and statutes intended to enable, enhance, or advance a water sector or water resource jurisdiction's missions/goals.

Water Resource Resilience: The capacity of natural and built water resource systems to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience.

Water Resource Jurisdictions: Governmental and other entities that have a role or authority within a water sector and/or geographic area.

Water Resource Sustainability: Meeting Californians' current needs pertaining to public health and safety, a healthy economy, vital ecosystems, and opportunities for enriching experiences without compromising the needs of future generations.

Water Sectors: Categories of assets, services, and practices that together comprise the full scope of IWM. Example water sectors include water supply, flood management, ecosystem restoration, water quality, and groundwater sustainability.

Watershed: The land area from which water drains into a stream, river, or reservoir. A watershed includes all natural and artificial (human-made) features, including its surface and subsurface features, climate and weather patterns, geologic and topographic history, soils and vegetation characteristics, and land use. The watershed for a major river may encompass a number of smaller watersheds that ultimately combine at a common point.

Watershed Network: Locally developed and locally led collaboratives comprised of existing water resource jurisdictions with a mission of enhancing the resilience and sustainably of shared hydrologic and hydrogeologic systems.

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