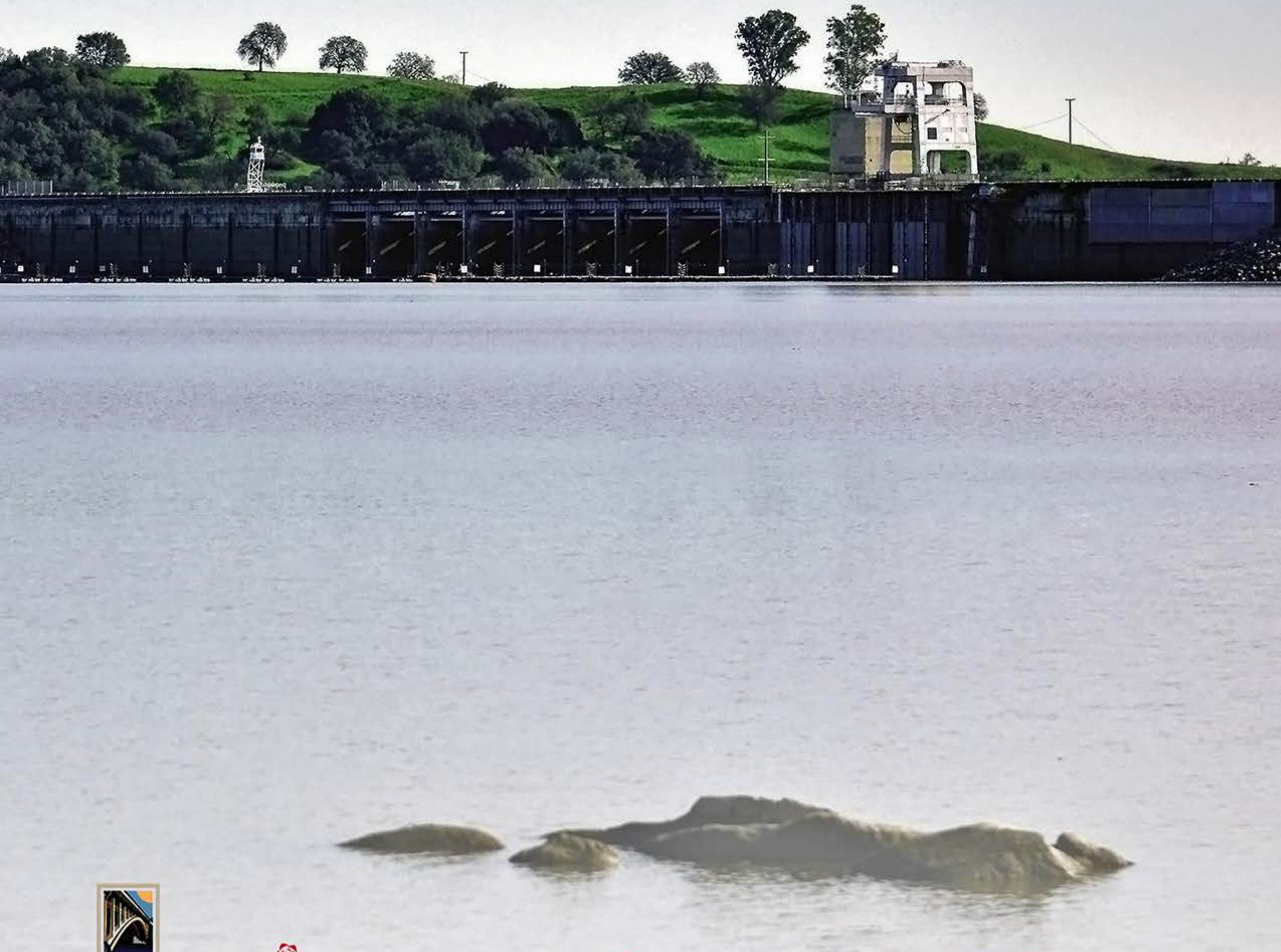
BUREAU OF RECLAMATION

American River Basin Study

Interior Region 10 – California-Great Basin



City of FOLSOM Distinctive by nature · City of ROSEVILLE California · City of SACRAMENTO · El Dorado Water Agency · PCWA · RWA Regional Water Authority · SAFCA Sacramento Area Flood Control Agency

U.S. Department of the Interior

August 2022

Mission Statements

The Department of the Interior (DOI) protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

American River Basin Study

Interior Region 10 – California-Great Basin

prepared by

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Abbreviations and Acronyms

°F	degrees Fahrenheit
ANN	artificial neural network
ARBS	American River Basin Study
ARIOps	American River Integrated Operations Model
ATSP	Automated Temperature Schedule Procedure
Basin	American River Basin
BO	Biological Opinion
CAL-AM	California-American Water Company
CCTAG	Climate Change Technical Advisory Group
cfs	cubic feet per second
Cl	chloride
cm	centimeters
CMIP3	Coupled Model Intercomparison Project Phase 3
CMIP5	Coupled Model Intercomparison Project Phase 5
CT	Central Tendency Climate Scenario
CTP-CTD	current trend growth in population and development density
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CWC	California Water Commission
D1641	Water Right Decision 1641 (State Water Resources Control Board, 2000)
Delta	Sacramento-San Joaquin Delta
DSM2	Delta hydrodynamic model
DWR	California Department of Water Resources
EDCWA	El Dorado County Water Agency
EID	El Dorado Irrigation District
EPA	Environmental Protection Agency
ESG	Executive Steering Group
FIRO	forecast-informed reservoir operations
FMS	Flow Management Standard
GCM	global climate model
GDPUD	Georgetown Divide Public Utility District
GPCD	gallons per capita per day
HD	Hot-Dry Climate Scenario
HDe	ensemble-informed hybrid delta (climate projection method)
HUC	hydrological unit code
HW	Hot-Wet Climate Scenario
IPCC	Intergovernmental Panel on Climate Change
km	kilometer
LLNL	Lawrence Livermore National Laboratory
LOCA	Localized Constructed Analog
M&I	municipal and industrial
MFP	Middle Fork Project
mg/L	milligrams per liter

MW	megawatt
MWh	megawatt hours
NMWC	Natomas Mutual Water Company
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
PCWA	Placer Counter Water Agency
PET	potential evapotranspiration
PG&E	Pacific Gas and Electric
P.L.	Public Law
PM	Project Manager
PMT	Project Management Team
RCP	representative concentration pathway
Reclamation	Department of the Interior, Bureau of Reclamation
RLECWD	Rio Linda/Elverta Community Water District
RWA	Regional Water Authority
RWS	reservoir water surface
SAFCA	Sacramento Area Flood Control Agency
SECURE Water Act	Science and Engineering to Comprehensively Understand and Responsibly Enhance Water Act; Subtitle F of Title IX of Public Law 111-11, Omnibus Public Lands Management Act of 2009
SGMA	Sustainable Groundwater Management Act
SMUD	Sacramento Municipal Utility District
SSJRBS	Sacramento-San Joaquin Rivers Basin Study
Study	American River Basin Study
SWE	snow water equivalent
SWP	State Water Project
TA	thousand acres
TAF	1,000 acre-feet
UIFR	unimpaired inflow to Folsom Reservoir
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
VIC	Variable Infiltration Capacity
WAPA	Western Area Power Administration
WaterSMART	Sustain and Manage America's Resources for Tomorrow
WIIN	Water Infrastructure Improvements for the Nation
WD	Warm-Dry Climate Scenario
WFA	Sacramento Water Forum Agreement
WSIP	Water Storage Investment Program
WW	Warm-Wet Climate Scenario
X2	distance of the 2 parts per thousand salinity isohalines (contours/lines of equal salinity) from the Golden Gate Bridge in kilometers

Executive Summary

Water managers in the American River Basin (Basin) continue to experience a growing imbalance between water demands and water supplies due to continued economic development, regulatory updates, and effects from climate change. The Bureau of Reclamation (Reclamation) previously evaluated potential impacts of projected climate change on water supply, water quality, and critical habitat within California's Central Valley in the Sacramento and San Joaquin Rivers Basin Study (SSJRBS) in 2016. The SSJRBS study results suggested that further basin-specific studies would be necessary for identifying adaptation strategies to effectively accommodate regional conditions.

Building on the SSJRBS, this American River Basin Study (ARBS) developed data, tools, analyses, and climate change adaptation strategies specific to the American River Basin. The ARBS examined strategies to integrate or better coordinate local and Federal water management practices to improve regional water supply reliability, while enhancing Reclamation's flexibility in operating Folsom Reservoir to meet flow and water quality standards in the Sacramento-San Joaquin Delta (Delta) and to protect endangered fishery species in the Lower American River.

AMERICAN RIVER BASIN STUDY SETTING

Counties and Major Cities: El Dorado County (Placerville), Placer County (Auburn, Lincoln, Roseville, Rocklin), Sacramento County (Sacramento, Folsom, Elk Grove)

Study Area: 3,600 square miles

Major Water Uses: municipal (516,000 acre-feet), agricultural (719,000 acre-feet), hydropower, recreation, flood control, and fish and wildlife

Surface Water Use: From the American River (primarily) and Sacramento River (884,000 acre-feet on average)

Groundwater Use: From North and South American groundwater basins (361,000 acre-feet on average)

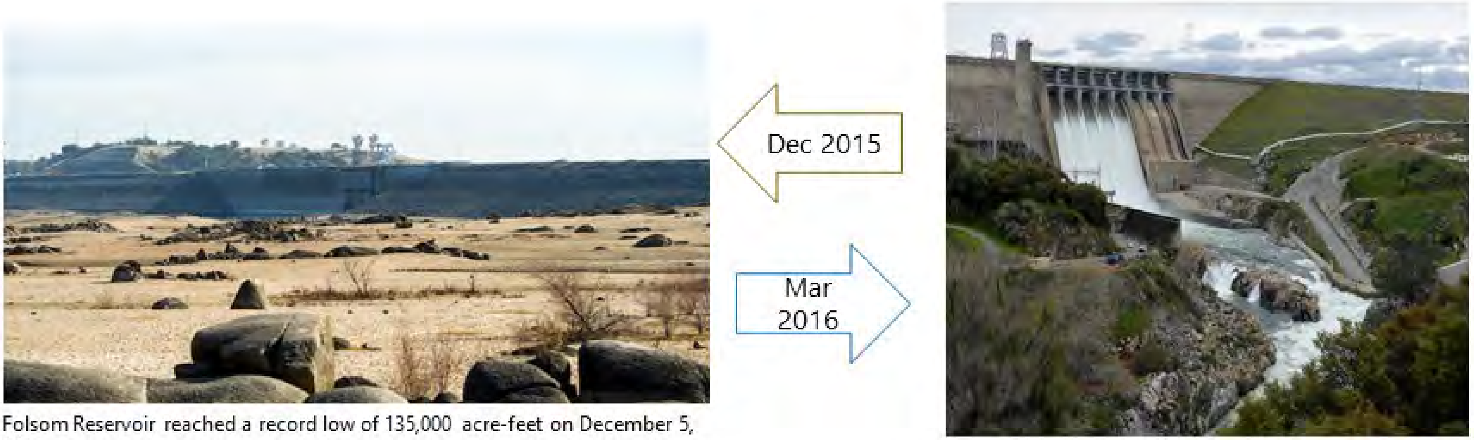
Key Reclamation Facilities: Folsom Dam, Nimbus Dam, Folsom South Canal

Key Regional Facilities: Middle Fork Project, Project 184, Sly Park Unit, and Upper American River Project

Study Background

Operations. Reclamation exercises an integral role on national, regional, and statewide levels in water management in the American River Basin by storing and conveying Central Valley Project (CVP) and local water right diversions and operating Folsom Reservoir for water supply, environmental needs and flood risk management. Reclamation's management of Folsom Dam and Reservoir as a part of the CVP and an important component of the water supply management for this region, along with locally owned and operated water projects and infrastructure. The Folsom Reservoir is relatively small compared to the annual runoff from the contributing American River watershed and compared with other major CVP/SWP reservoirs in the Sacramento River Basin. Its water operations rely on seasonal snowpack in upper watershed to provide a large portion of the storage necessary to regulate runoff for water supplies and environmental purposes. Changing climate conditions in the Sierra Nevada will reduce the size of the snowpack, impact the volume of water stored in the snowpack, and the timing for runoff entering Folsom Reservoir.

Changing climate conditions can also complicate Folsom Reservoir operations. In late 2015, severe drought conditions precipitated water right curtailments, greatly reducing contract allocations, mandatory extraordinary conservation measures, and relaxed regulatory flow and quality requirements systemwide. In addition, regulatory requirements (e.g., Delta flow and water quality requirements) further constrained Reclamation's flexibility in operating Folsom Dam to meet all authorized project purposes. Folsom Reservoir reached its lowest recorded level (135,000 acre-feet). Three months later in March 2016, after several moderate El Niño storms, Reclamation followed flood control release requirements. This rapid shift in hydrologic conditions (Figure ES-1) illustrates the need to re-examine the effectiveness of flood risk management strategies and Folsom Dam infrastructure. The current flood risk management regime was developed based on historical hydrology—and may not be effective under the "new normal" of changing climate.



Folsom Reservoir reached a record low of 135,000 acre-feet on December 5, 2015.

Although drought in California remained, Folsom Reservoir made releases in 2016 to maintain flood space. (March 28, 2016).

Figure ES-1. Varying hydrologic conditions at Folsom Reservoir within four months.

Fish and Wildlife Habitat. The American River is a major tributary to the Sacramento River. The Lower American River is the only urban waterway in the United States to be designated a "Wild and Scenic River" for recreation by Federal and State agencies.[1] The river is home to 43 fish species, including federally threatened steelhead and struggling fall-run Chinook salmon. Further, the superior water quality in the American River and Folsom Reservoir's proximity to the Delta gives Folsom Reservoir a critical role in CVP operations to satisfy Delta flow and quality standards and other requirements for protecting endangered fish species. This is further exacerbated during times when Shasta Dam is experiencing low storage conditions due to reduced inflow during droughts.

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[1] 46 Federal Register 7484 (January 23, 1981) (Federal designation); Public Resources Code Section 5093.54(3) (State designation). The Nimbus Dam to Sacramento River segment within the American River Parkway Plan is being administered under the California Wild and Scenic River System Act (2009 Assembly Bill No. 889).

Water Supply Reliability. The City of Sacramento and adjacent metropolitan areas comprise the largest growth area in northern California in the past two decades and in the near future. Water managers in the American River Basin continue to experience a growing imbalance between water demands and water supply due to a variety of factors, including population growth; increased regulatory requirements; changes in CVP and State Water Project (SWP) operations. Drought conditions threaten water supplies and ecosystems of the American River Basin.

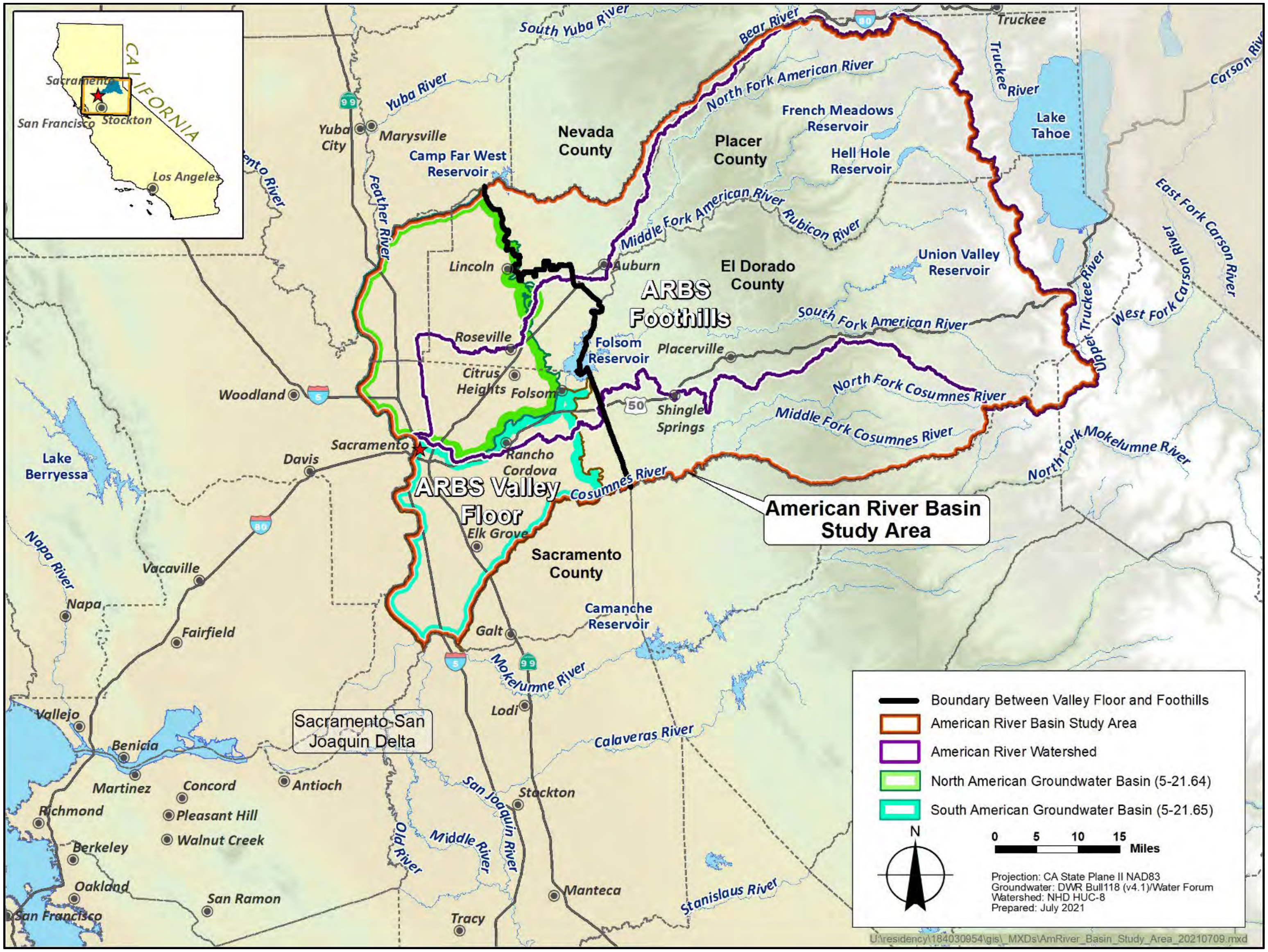
Moreover, in the American River Basin, the potential effects of a changing climate have introduced significant uncertainty in long-term water supply reliability. Interagency planning is needed more than ever to address emerging climate change conditions and increasingly intense and more frequent extreme events (e.g., droughts and floods). There is significant need to align the vision and climate adaptation strategies for sustainable basin-wide water management.

Regional Planning. Reclamation has a long history of collaborating with local water agencies and stakeholders to meet this important responsibility. Reclamation’s last watershed planning effort—the American River Water Resources Investigation of the late 1990s—recommended regional conjunctive use to leverage the region’s existing water rights and contract entitlements alongside its groundwater resources. After this, regional entities completed the Sacramento Water Forum Agreement in 2000, which presented a balanced approach for water supply reliability and environmental protection along the Lower American River. The 2006 American River Basin Integrated Regional Water Management Plan, subsequent 2013 and 2018 Updates, and 2019 Regional Water Reliability Plan continued the collaborative planning and implementation efforts in the region. These efforts serve as an innovative model to support planned economic development, enhanced protection for salmon and steelhead species in the Lower American River, and social and recreation values unique to the region.

Despite this history of successful collaboration in the basin, Federal and regional planning would benefit from additional integration, and regulatory changes and evolving climate conditions still need to be addressed. In addition, the previous studies focused more on the Valley Floor (lower basin) water management for conjunctive use without considering the changes in snowpack storage under climate change—which directly impact water supply reliability in the Foothills (upper basin) which lacks meaningful groundwater resource. The importance of connecting Valley Floor and Foothills management cannot be overstated because the management of headwaters will directly affect the amount and timing of runoff available to the lower basin. These issues must be resolved to meet the competing and more importantly, changing needs for regional self-reliance, CVP delivery reliability, and environmental protection.

Study Area

The study area is bounded by the ridge of the Sierra Nevada to the east, the Feather and Sacramento Rivers to the west, the Bear River to the north, and the Cosumnes River to the south (Figure ES-2). In addition to the American River Watershed, the study area encompasses the North and South American groundwater basins as well as non-Federal Partners’ service areas outside of the American River watershed. Figure ES-2 also shows the boundary between the ARBS Valley Floor and the ARBS Foothills.



Projection: CA State Plane II NAD83
Groundwater: DWR Bull118 (v4.1)/Water Forum
Watershed: NHD HUC-8
Prepared: July 2021

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Figure ES-2. study area boundary for the American River Basin Study.

The study area is a combination of three areas:

- **American River watershed**. This watershed covers 2,140 square miles from the Sacramento River to the peaks of the northern Sierra Nevada mountains west of Lake Tahoe.
- **ARBS Non-Federal Partners' Service Areas Outside of the American River Watershed**. This represents areas outside of the American River Watershed in adjacent watersheds of the Bear River and Cosumnes River that are served by the Non-Federal Partners with American River water.
- **North and South American Groundwater Basins**. The American River separated these two groundwater basins in the west side of the study area. Their eastern boundary represents the approximate edge of the alluvial basin, where little or no groundwater flows into or out of the groundwater basins from the Sierra Nevada basement rock.

Study Partners

The ARBS data and analyses help improve the resolution of regional climate change data and develop and analyze regional-specific adaptation strategies. These strategies build on those identified in the SSJRBS (Reclamation, 2016). The ARBS was developed by Reclamation in collaboration with six non-Federal Partners: Placer County Water Agency (PCWA), City of Roseville, City of Sacramento, El Dorado County Water Agency (EDCWA), City of Folsom, and Regional Water Authority (RWA). These Study Partners represent the major water purveyors in the American River Basin and include CVP water contractors. RWA is a Joint Powers Authority with the primary mission to facilitate integrated regional water management and surface and groundwater conjunctive use among its over 20 member agencies in the Sacramento-Placer-El Dorado region. To address flood risks associated with the projected future climate, the non-Federal Partners also coordinated the Study development with Sacramento Area Flood Control Agency (SAFCA).

Study Authority and Objectives

The ARBS is authorized under Section 9503(b)(2) of the SECURE Water Act.[1] This study is not a Federal decision document. Rather, it presents an opportunity to develop concepts of adaptative portfolios, with compatible measures to address identified basin-specific climate vulnerabilities, which Reclamation and regional partners would have interests to explore further through continued collaboration. It neither requests nor proposes any new feasibility study pursuant to Public Law (P.L.) 111-11 nor any new Federal construction authority.

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[1] SECURE Water Act = **S**cience and **E**ngineering to **C**omprehensively **U**nderstand and **R**esponsibly **E**nhance Water Act; Subtitle F of Title IX of Public Law 111-11, Omnibus Public Lands Management Act of 2009

ARBS objectives are to:

- Further refine water supply and demand assessments in the American River Basin
- Address regional demand-supply imbalances and infrastructure deficiencies under the existing and future climate change conditions
- Improve regional collaboration for sustainable water resources management
- Improve coordination of local and Federal water management to improve regional water supply reliability and to increase Reclamation's operational flexibility of Folsom Reservoir to meet CVP purposes
- Better align water management tools, strategies, and planning efforts of Reclamation and water agencies in the Basin

Study Approach

The ARBS is a holistic examination of water management practices in the Basin, including both the Foothills and Valley Floor, to address significant recent changes in water supply conditions and regulatory requirements, and improved understanding in the science of climate change. The ARBS provides a unique opportunity to better align the water management strategies and planning efforts within the region for benefits of Reclamation and regional partners alike. Reclamation, the CVP, and the Study Partners are dedicated to pursuing integrated water management solutions that benefit all parties. ARBS has incorporated significant local technical contributions, including:

- Development of projected future urban and agricultural demands through direct funding contribution and in-kind concurrent studies (Regional Water Reliability Plan [RWA, 2019], and El Dorado County Water Resources Development and Management Plan [EDCWA, 2019])
- Formulation and evaluation of adaptation portfolios through direct funding
- Temperature modeling of the Lower American River, including Folsom Reservoir, using locally funded state-of-the art temperature models
- Extensive outreach and engagement with stakeholders and interested persons in addition to ARBS planned engagement activities

Projected Future Conditions

Surface air **temperatures** are projected to increase steadily, with summer temperature increasing by approximately 7.2 degrees Fahrenheit (°F) by the end of the 21st century (Figure ES-3), and winter temperature increasing by 4.9°F. Projections of daily maximum and minimum temperatures suggest similar seasonal trends. Maximum temperatures are projected to increase more than minimum temperatures during all seasons, with the largest increase of 7.3°F during the summer months.

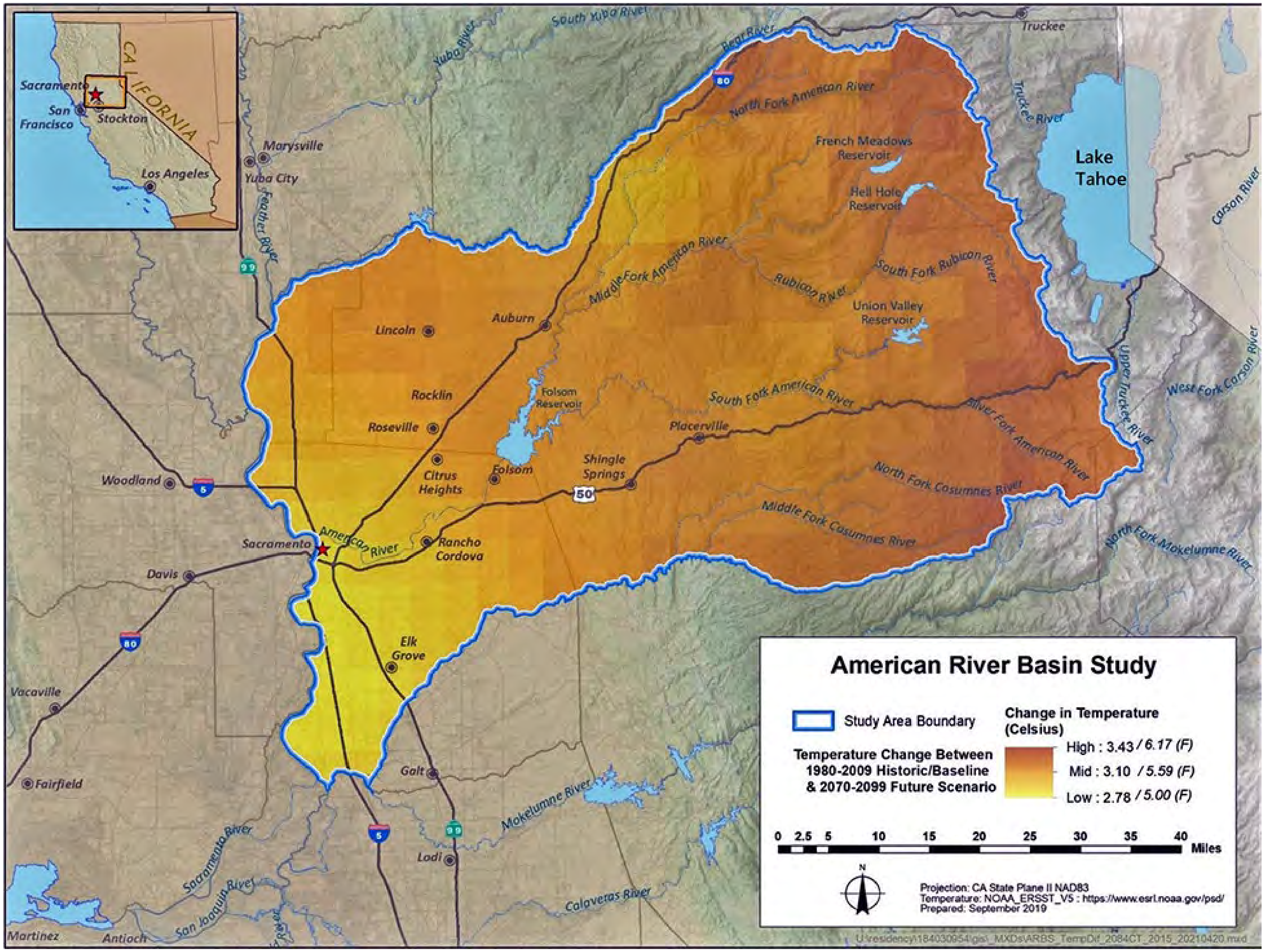
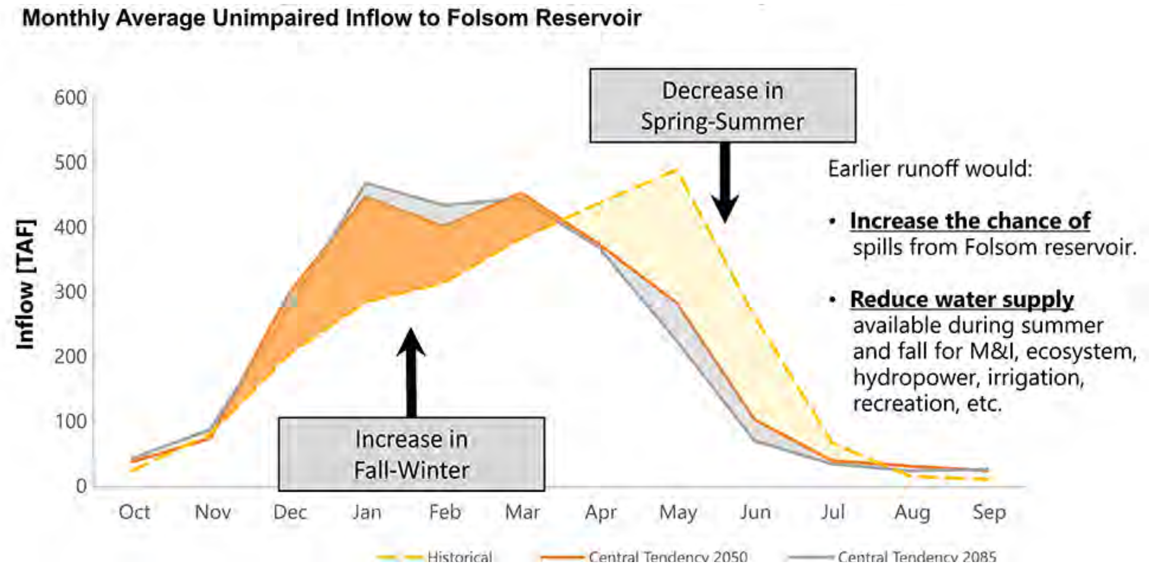


Figure ES-3. Projected changes in average July temperatures between historical (1980-2009) and end-of-century under the Central Tendency Climate Scenario.

Annual **precipitation** projections show no clear trend over the 21st century. Many of the available global climate model (GCM) projections show change in precipitation, but there is no consistency in the magnitude and direction of projected change between models. Approximately half of the projections indicate an increase in annual precipitation and half indicate a decrease—highlighting the large uncertainty in future precipitation over this region. Despite unclear trends in projected annual precipitation, by the end of the 21st century, average fall and spring precipitation are expected to decrease and winter and summer precipitation to increase. Increasing variability is also projected in winter and fall precipitation. **Snowpack** will likely decline due to warming.

Runoff is projected to increase during winter months. Projections indicate a pronounced shift in the distribution of runoff from May and June to earlier in the season (December to March)—implying a shift in precipitation from snow to rainfall and/or earlier snowmelt. Peak runoff may shift by more than a month earlier by mid- to late century (Figure ES-4). Spring runoff would decrease due to reduced winter snowpack.


Monthly Average Unimpaired Inflow to Folsom Reservoir

Decrease in Spring-Summer

Increase in Fall-Winter

Earlier runoff would:

- **Increase the chance of** spills from Folsom reservoir.
- **Reduce water supply** available during summer and fall for M&I, ecosystem, hydropower, irrigation, recreation, etc.

Figure ES-4. Projected timing of inflows to Folsom Reservoir under future climate change[1] conditions compared to historical conditions.

Water Management Challenges

Water management in the Basin is facing the combined climate pressures of warming temperatures, shrinking snowpack, shorter and more intense wet seasons, more volatile precipitation, and rising sea levels. Warming has complex and interrelated effects: it reduces the share of precipitation falling as snow, causes earlier snowpack melting and higher winter runoff, raises water temperatures. Warming also amplifies the severity of droughts and floods: warmer, more intense droughts increase pressure to draw down groundwater resources and warmer, more intense storms add stress to surface reservoirs—making it harder to meet often competing objectives.

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[1] This figure is based on projections for the Central Tendency Climate Scenario, which represents the median range of projected change in precipitation and temperature. See Section 2.3. *Future Climate Scenarios.*

These climate pressures will make it harder to simultaneously store water for droughts, manage flood risk, and protect freshwater ecosystems. Sea level rise threatens the Delta and puts more pressure on Folsom Dam to meet Delta water quality. Specific anticipated impacts include:

- **Water Supply Reliability—**Under the 2070 level of development, the supply-demand imbalance is projected to be 63 to 78 thousand acre-feet (TAF) per year in the Foothills, which means around 50 percent of total demands cannot be met. In the Valley Floor, groundwater extraction is expected to increase by 62 to 155 TAF/year to offset the imbalance, which would affect groundwater sustainability.
- **Fish and Wildlife Habitat—**The shift in runoff timing and potential lower Folsom Reservoir storage during summer and fall months would affect the reservoir's ability to manage flows and water temperatures in the Lower American River for fish and wildlife purposes.
- **Flood Risk Management—**Increased early season runoff would increase flood risks along the Lower American River where further setback levees are not possible in the heavily populated urban area.
- **Hydropower and Recreation—**Without reservoir operation changes, the shift in runoff timing would affect reservoir storage during summer and fall months—reducing hydropower generation and recreation opportunities.

Figures ES-5 and ES-6 compare the water budgets from the 1995 baseline to three climate scenarios in 2070 for the Valley Floor and Foothills areas. The zero X axis line shows no imbalance where supply equals demand. Negative bars show imbalances where demands are greater than supply (i.e., water shortages). See Section 2.3 *Future Climate Scenarios*.

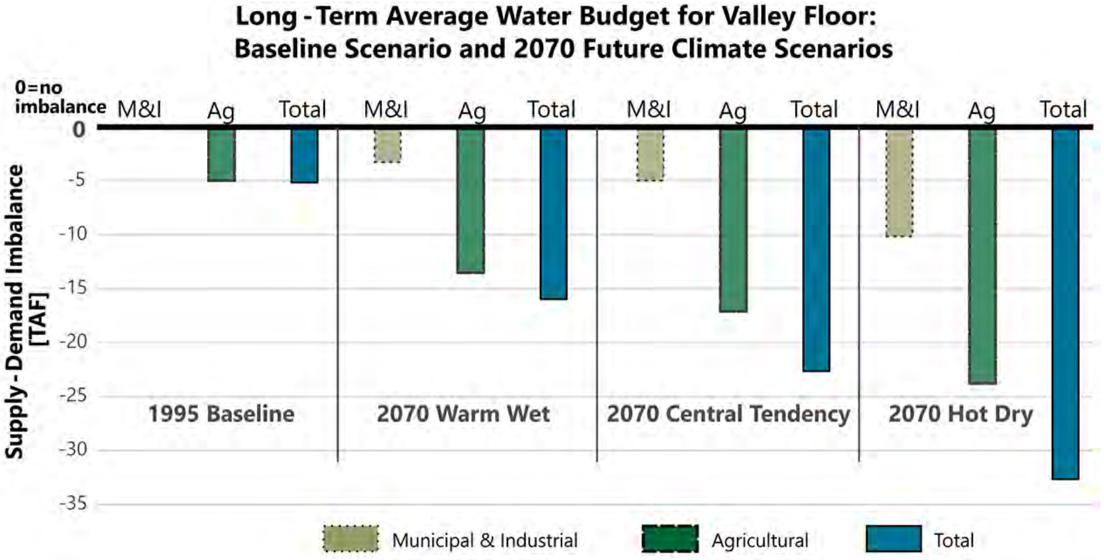

Figure ES-5. Long-term average[1] water budget for the Valley Floor: Baseline Scenario and 2070 future climate scenarios.

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[1] Long-term averages are averages over the full CalSim simulation period (1922-2015).

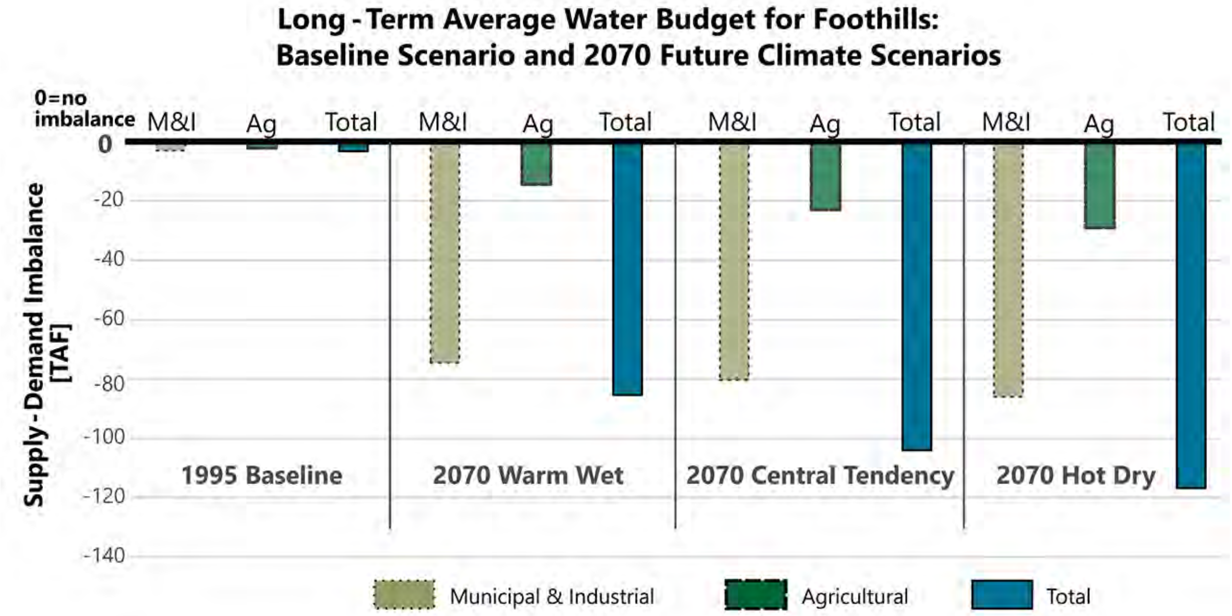

Figure ES-6. Long-term average water budget for the Foothills: Baseline Scenario and 2070 future climate scenarios.

Regional Vulnerabilities

Vulnerabilities are physical, operational, or institutional threats to a water system that could result in temporary, long-term, or even permanent loss of supplies necessary to meet water demands.

Anticipated challenges to water management are further aggravated by existing regional vulnerabilities throughout the study area. The key regional vulnerability pathways (how and why the vulnerabilities exist in the region) are:

- Folsom Reservoir's storage capacity is relatively small when compared with annual American River watershed runoff.
- Basin-wide water supply heavily depends on one river, especially in the North American Groundwater basin.
- Opportunities to set back levees in Sacramento urban areas to manage risks from increasing volume of floods in the future are limited.
- Individual water rights and contract entitlements could become less reliable or less protected under droughts with increased frequency and severity.
- Folsom Reservoir operations are challenging as inherent trade-offs between water demands, environmental protection, and flood risks involve coordinating between Reclamation for CVP purposes and the U.S. Army Corps of Engineers (USACE) for regional flood risk management.
- Groundwater in the Foothills only occurs in fractured rock aquifers. Thus, groundwater is not a meaningful and reliable supplemental water supply source for the Foothills.

- Forest management practices can significantly affect snowpack retention, major wildfire threats, and subsequently water quality.
- Regional conjunctive use potential is not fully developed. Conjunctive use's potentially high investment costs and need for an accepted governance framework could be further investigated.
- Varying levels of water use efficiency.

These key vulnerability pathways (mapped in Figure ES-7) are the focal target of adaptations to address or reduce their effects.

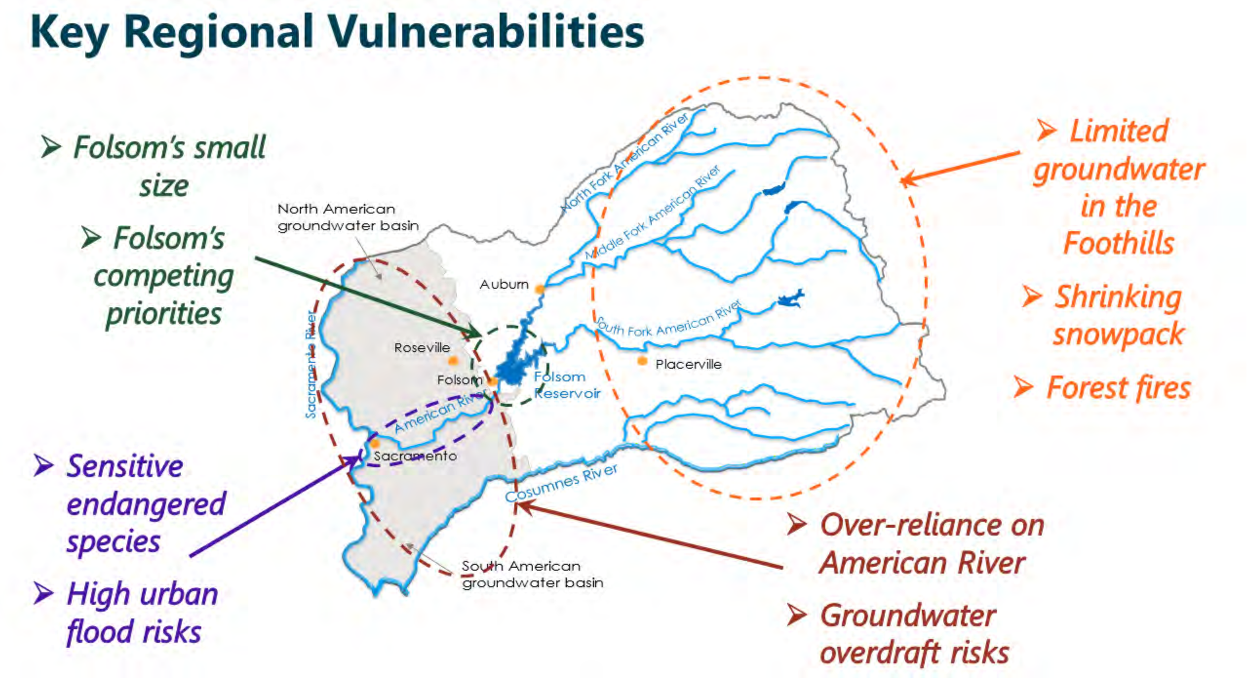

Figure ES-7. Regional map of vulnerabilities.

Updated Planning Data and Tools

The ARBS is one of the first large-scale applications of the updated CVP/SWP water resources planning model (CalSim 3), jointly developed by Reclamation and the California Department of Water Resources (DWR). The ARBS refined the model's representation of the upper watershed of the American River (North, Middle, and South Forks) by mapping existing upper watershed OASIS models (American River Integrated Operations Model [ARIOps]) into CalSim 3 with consistent spatial resolutions and operation rules to form a fully integrated model with both upstream facility operation and the broader CVP/SWP system operations. This integrated model alleviates the piecemealing modeling approach that requires iterations and prone to errors and inconsistency.

To support regional planning using CalSim 3, global climate model (GCM) downscaling from 2 degrees to $^{1}/_{16}$-degree grids (approximately 6 by 6 kilometers [km]) was used. ARBS climate scenarios used 32 GCMs under the RCP4.5[1] and RCP8.5 emissions scenarios for a total of 64 climate projections. Reclamation Technical Services Center developed a suite of future climate scenarios for three future periods: 2040-2069, 2055-2084, 2070-2099. For each future period, five climate scenarios were developed: Warm-Wet (WW), Warm-Dry (WD), Hot-Wet (HW), Hot-Dry (HD), and Central Tendency (CT) Climate Scenarios. These five ensembles cover the range of potential climate futures.

In addition, the Variable Infiltration Capacity (VIC) hydrology model was used to simulate hydrologic conditions under each climate scenario, including potential evapotranspiration, snow water equivalent, and total runoff. Reclamation's Technical Services Center developed corresponding inputs to CalSim 3 for each future climate scenario. The refined-scale climate and hydrological data was prepared for the entire CalSim 3 model domain covering the Sacramento and San Joaquin River Basins.

The climate change approach adopted for the ARBS was consistent with the approach recommended by the DWR Climate Change Technical Advisory Group (CCTAG) as being most appropriate for California water resource planning and analysis (DWR CCTAG, 2015). It was also consistent with the approach adopted by the California Water Commission for its climate change analysis of the Water Storage Investment Program.

Portfolio Planning

This ARBS helps identify vulnerabilities to the Basin's water resources under a range of future conditions and evaluates the ability of different actions to address these vulnerabilities and maintain balance between supplies and demands. To achieve this, we adopted a portfolio planning approach to allow considerations of the full range of possible future conditions. Portfolio planning is an effective framework for development of flexible, long-term plans and making decisions where future conditions are uncertain. This framework relies upon the construction and comparison of a broad range of conditions to understand stressors, vulnerabilities, and vulnerability pathways (causality), as well as for the evaluation of options to address those vulnerabilities.

Adaptation Measures/ Management Actions are specific strategies, actions, or tactics that contribute to addressing vulnerabilities or alleviating climate change impacts.

Adaptation Portfolios are theme-based and represent project/action concepts that are locally supported and provide both regional and Federal benefits.

Key features of this approach are:

- Portfolio planning is focused on addressing the key regional vulnerability pathways and thus, address identified basin-specific vulnerabilities.

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[1] RCP is the representative concentration pathway that represents a greenhouse gas concentration (not emissions) trajectory adopted by the Intergovernmental Panel on Climate Change for climate modeling and research use.

- Each portfolio addresses one or more vulnerabilities. While no one portfolio can address all of the vulnerabilities examined in the ARBS, the formulated portfolios will collectively address these vulnerabilities.
- Each portfolio is built on an existing Federal authority and identified local support from sponsor(s) to create mutually acceptable and implementable solutions.

The portfolio planning approach used for the ARBS followed these steps (Figure ES-8):

1. Identify stressors
2. Identify vulnerabilities (how and why the basin is vulnerable)
3. Identify adaptation measures or actions
4. Define screening and formulation approach
5. Formulate and evaluate adaptation portfolios

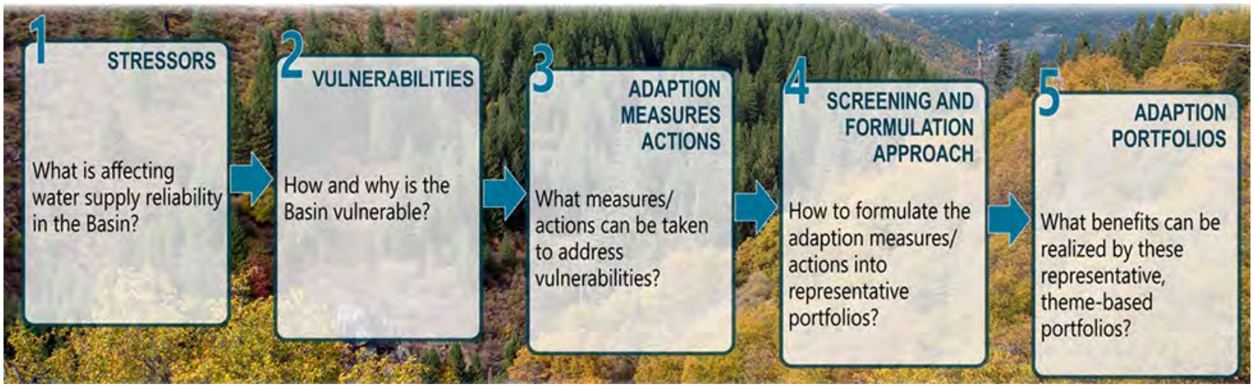

Figure ES-8. Steps to develop adaptation portfolios.

Portfolios are formulated explicitly to create mutually beneficial conditions to the region and to Reclamation's operation of Folsom Reservoir by increasing storage or reducing demand. Folsom Reservoir is the major water management facility in the region for water supply, managing flood risks, fisheries management, and recreation.

Table ES-1 documents the identification of water management stressors, the resulting vulnerabilities and their pathways, adaptation measures identified by the stakeholders. Table ES-2 documents the screening criteria and the portfolio formulation approach, and the formulated portfolios.

Several adaptation measures are already ongoing or are committed to in the near future. Therefore, these foundational adaptation measures of water demand management, institutional actions, and forest management are included in each of the formulated adaptation portfolios.

Other actions could be compared to these portfolio actions in future studies. For example, although Auburn Dam remains an authorized project in the Basin, the ARBS did not consider it due to potential issues and concerns. In 2008, Reclamation restored the river channel and completed PCWA's water diversion facility. California's State Water Resources Control Board has revoked Reclamation's water rights for the Auburn Dam project.

Table ES-1. Identification of Water Management Stressors, Vulnerabilities, and Adaptation Measures

Stressors	Vulnerability Pathways	Vulnerabilities (Consequences)	Adaptation Measures/Actions
What is affecting water supply reliability in the basin? • Population growth • Climate change • Ecosystem degradation • Regulatory intervention for environmental protection • Change in social values and preferences	Why is the basin vulnerable? 1. Folsom Reservoir size is relatively small when compared with annual American River watershed runoff due to historical dependency on snowpack storage. 2. Basin-wide water supply heavily depends on one river, especially in the North American Groundwater basin. 3. Opportunities to set back levees in Sacramento urban areas to manage increasing volume of floods in the future are limited. 4. Individual water rights and contract entitlements become less reliable or less protected under droughts with increased frequency and severity. 5. Folsom Reservoir operations are challenging as inherent trade-offs between water demands, environmental protection, and flood risk management involve coordinating between Reclamation and USACE. 6. Groundwater is not a meaningful and reliable supplemental water supply source for the Foothills. 7. Forest management can significantly affect snowpack retention, major wildfires threats, and subsequently water quality 8. Regional conjunctive use potential is not fully developed. 9. Varying levels of water use efficiency.	How is the basin vulnerable? (Pathway # causing the vulnerability) • Water supply-demand imbalance varies geographically (4, 6, 8, 9) • Loss of environmental protection in Lower American River (1, 2, 7) • Increased water supply shortage during intensified droughts (1, 2, 4, 5, 6, 7, 8, 9) • Lack of water security for small water systems and rural communities in the foothills without alternative sources of water (6, 9) • Intensified flood conditions lower flood protection levels in Sacramento area during (1, 3) • Decreased surface water availability for direct use or in-lieu groundwater recharge that contributed to reducing regional groundwater overdraft condition since 1990s (1, 4, 5, 8) • Increased long-term water quality risks from wildfires due to intensified weather conditions and infestation (7)	**What type of measures/actions can be taken to address the identified vulnerabilities?** • Improve demand management o Increase agricultural water use efficiency o Increase urban water use efficiency • Diversify water supplies o Increase regional water reuse o Stormwater capture o Develop additional points of delivery and/or water rights o Expand portfolio diversification for all agencies • Improve operational flexibility o Structure flexible exchange o Expand flexible conjunctive use to reduce reliance and diversions of surface water in dry and critical years. o Increase water storage and associated integrated operations • Improve resource stewardship o Improve headwaters and forest health o Improve Lower American River ecosystem • Secure institutional agreements to enable flexibility o Reclamation and CVP contractors continue to coordinate on contracts o Regional framework for transparency and collaboration

Table ES-2. Adaptation Measures Screening and Adaptation Portfolios Formulation

Adaptation Measures Screening	Adaption Portfolios Formulation	Formulated Adaption Portfolios
How to assess and screen the identified adaptation measures/actions? • Relevancy to vulnerability pathways. • Technical feasibility • Measurable and quantifiable benefits (e.g., increase in supply or reduction in demand). • Long-term viability • Nexus to Reclamation/Federal interest • Local support for implementation	**How to formulate the adaptation measures/actions into representative theme-based portfolios?** • Portfolios are theme-based and reflect locally supported project/action concepts • Each portfolio represents a unique central theme or concept, to the extent possible. • Each portfolio's central theme was led by an existing Federal authority or nexus to benefit to Reclamation, where possible. • Each unique theme is combined with other complementary projects/actions that further advance its central concept. However, included projects/actions are not intended to be exhaustive of all possibilities. • Every portfolio provides mutual benefits for the region and for Reclamation. • Collectively, portfolios cover all identified pathways of vulnerabilities in the region.	• Importance of Long-Term CVP Contracts • Alder Creek Storage and Conservation Project • Sacramento River Diversion Project • Federally Recognized Groundwater Bank (North and South American Groundwater Basins) • Folsom Dam Raise with Groundwater Banking (South American Groundwater basin) • 2019 BO Flow Management Standard Project

Notes: [1.] All portfolios include the common foundational measures as basic building blocks.

Each portfolio illustrates the benefits for specific central concepts or theme. Each portfolio is formulated around an existing Federal authority or nexus to benefit to Reclamation that also has strong local support:

- **Importance of Long-Term CVP Water Contracts.** This portfolio illustrates the importance of CVP water contracts for the regional water reliability. During ARBS process, Reclamation worked with American River Division contractors with Interim Renewal Contracts to convert their contracts into repayment contracts and finalized the water supply contract with EDCWA. These actions were significant steps to assist local agencies in long-term water-supply planning and an early success for the engagement between Reclamation and local agencies in the ARBS that was critical to support the other climate adaptation portfolios.
- **Alder Creek Reservoir and Conservation Project**: This portfolio evaluates an example of using high-elevation, off-stream storage to replace lost storage from reduced snowpack and earlier snowmelt to improve water supply reliability in the Foothills and CVP water supply from Folsom Reservoir. The effects of modeled inflows from the North and South Fork of the American River as well as Alder Creek would need to be further investigated in a feasibility study. Reclamation's participation in future Alder Creek project has not yet been determined.
- **Sacramento River Diversion Project:** This portfolio evaluates the use of existing diversion facilities on the Sacramento River and exchange of water supply to reduce reliance of regional water supply on Folsom Reservoir and the American River.
- **Federally Recognized Groundwater Bank (North and South American Groundwater Basins):** This portfolio evaluates the expanding conjunctive use operations through leveraging market mechanisms and the resulting contribution to climate change adaptations to augment the regulatory capacity of Folsom Reservoir.
- **Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin)**: While Reclamation is not a beneficiary of the Folsom Dam raise for water supplies, this portfolio evaluates a multi-benefit forecast-informed reservoir operations (FIRO) concept that integrates the increase in flood control surcharge spaces through raising Folsom Dam and additional upstream flood control surcharge space via facility modifications. This portfolio investigates facilitating early flood releases for groundwater recharge to create additional regional water supply and ecosystem benefits where feasible.
- **2019 BO Flow Management Standard Project:** This portfolio evaluates effectiveness of the flow management standard for the Lower American River in the 2015 update of the Sacramento Water Forum Agreement to reduce adverse effects on Lower American River ecosystem and fisheries from climate change. Note that elements included in this portfolio are currently being implemented as part of the 2019 National Oceanic and Atmospheric Administration (NOAA) Fisheries and U.S. Fish and Wildlife Service (USFWS) Biological Opinions (BO) on Long-term Operation of the CVP and SWP (USFWS 2019 and NOAA Fisheries 2019).

Table ES-3 show how each portfolio can address vulnerability pathways, areas of Federal Interest, and provide benefits to Reclamation. The table also lists each portfolio's primary area(s) of focus (P) for the Federal Interest, which are the areas that the portfolio is specifically formulated to address and each portfolio's secondary area(s) of focus for the Federal Interest, which are areas that receive incidental benefits from the portfolio.

Table ES-3. Adaptation Portfolios Contribution to Addressing Vulnerability Pathways, Benefits to Reclamation, and Areas of Federal Interest

	Vulnerability Pathways Addressed									**Benefit to Reclamation**			**Areas of Federal Interest Addressed**							
Baseline and Adaptation Portfolios	1. Size of Folsom Dam	2. Reliance on one river	3. Setback levees not possible	4. Reliability of water rights and contracts	5. Folsom operations	6. Foothills limited groundwater	7. Forest management	8. Conjunctive use not fully implemented	9. Inefficient water use	A. Increase flexibility	B. Reduce direct demands on Folsom	C. Increase Folsom regulating capacity	1. Water supply	2. Hydroelectric	3. Recreation	4. Fish and wildlife habitat	5. Listed species protection	6. Water quality	7. Ecological resiliency	8. Flood risk management
Future Operations Baseline				✓			✓		✓	■			P							
Importance of Long-term CVP Water Contracts							✓		✓											
Alder Creek Storage and Conservation Project	✓			✓	✓	✓	✓		✓	■	■	■	P	P	S					P
Sacramento River Diversion Project	✓	✓		✓	✓		✓		✓	■	■		P		S	P	P	P	P	
Federally Recognized Groundwater Bank (North and South American Groundwater Basins)	✓			✓	✓		✓	✓	✓	■	■	■	P			S	S	S	S	
Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin)	✓		✓	✓	✓		✓	✓	✓	■		■	P	S	S	S	S		S	P
2019 BO Flow Management Standard Project	✓			✓	✓		✓		✓	■	■		P		S	P	P	P	P	

Key: P = Federal interest is primary focus of the portfolio

✓= portfolio addresses a vulnerability pathway

S = Federal interest is secondary focus of the portfolio

■ = portfolio contributes to a Reclamation's benefits

Portfolio Evaluation

Each of the adaptation portfolios addresses certain vulnerability pathways. Note that these evaluations were not intended to identify the "best" portfolio or combination of portfolios. Rather, they were intended to demonstrate the likely range of benefits that could be provided by each portfolio, emphasizing potential mutual benefits to the region and Reclamation. Some pathways are addressed in multiple portfolios due to their large influence. Some pathways are only addressed by a single portfolio. None of the portfolios will address all the vulnerability pathways. However, the portfolios collectively address all the vulnerability pathways. Table ES-1 shows how each of the adaption portfolios address the vulnerability pathways.

Findings from the adaptation portfolio evaluation are summarized in Figure ES-9.

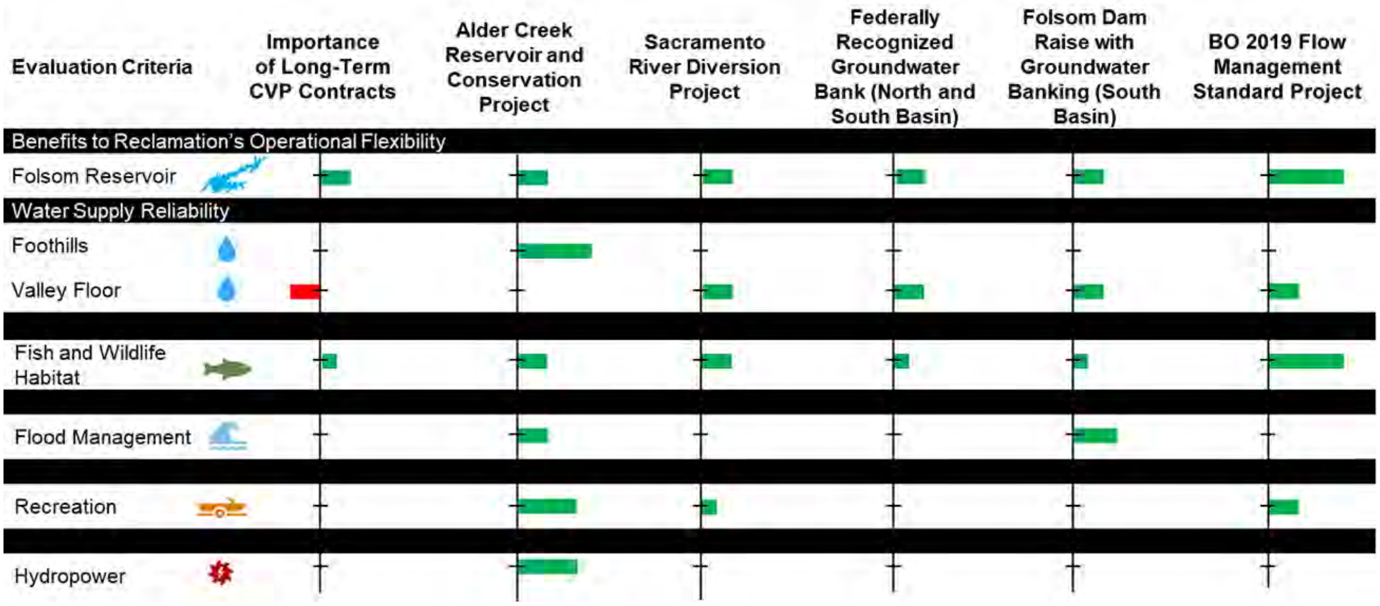

Figure ES-9. Summary of adaptation portfolio performance relative to 2070 future baselines.

Key findings include:

- **Benefits to Reclamation's Operational Flexibility.** All the adaption portfolios provide benefits to Reclamation's Folsom Reservoir operations by increasing the accessible combined storage for operational flexibility and/or by reducing demands from the reservoir.
- **Water Supply Reliability.** All the adaption portfolios provide benefits to regional water supply reliability. Most of the portfolios improve groundwater sustainability through enhanced recharge opportunities. The Sacramento River Diversion Project Portfolio also increases available surface water supplies during dry periods. The Alder Creek Reservoir and Conservation Project Portfolio is the only portfolio that could address the water supply reliability and rural community sustainability in the Foothills.

- **Fish and Wildlife Habitat.** All the adaption portfolios provide benefits to the ecosystem of the Lower American River by creating opportunities to increase Folsom Reservoir storage and its cold-water pool, and/or increase flows on the Lower American River. The 2019 BO Flow Management Standard Project Portfolio provides the largest ecosystem benefits. Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio has a unique potential to provide ecosystem benefits to the Cosumnes River through improved hydraulic connectivity of the underlying groundwater basin.
- **Flood Risk Management.** The Folsom Dam Raise with Groundwater Banking and the Alder Creek Reservoir and Conservation Project portfolios enhance the flood risk management function of Folsom Reservoir by creating new flood control surcharge space at Folsom Reservoir and facilities in the Foothills. The FIRO under the Folsom Dam Raise with Groundwater Banking portfolio will further improve the precision of flood operations to accommodate water supply benefits at Folsom Reservoir with or without groundwater banking.
- **Recreation and Hydropower.** The Alder Creek Reservoir and Conservation Project Portfolio operations would prioritize releasing water during months of peak demand—resulting in increased flows during summer months.

Conclusions

The ARBS is an integrated watershed study that holistically examines water management practices in the American River Basin under evolving climate conditions and identifies adaptation portfolios with specific measures and actions to reduce the gap of projected water supply and demand in the region. The ARBS has identified critical risks to water management in the region driven by future shifts in hydrology, where peak runoff is forecasted to shift from March through May to earlier in the season to January through March. This shift can upend the existing paradigm of water management and results in significant changes in water supply reliability and drought resiliency for the entire basin, and flood risk to the urban region surrounding the Lower American River. These risks are exacerbated by existing regional vulnerabilities, most prominently the relatively small size of Folsom Reservoir compared to annual watershed runoff, coupled with the high reliance on the single river, American River, and its major facility, Folsom Reservoir, for regional and systemwide water supplies, flood risk management, and ecosystem protection.

The ARBS portfolio planning approach helped address these vulnerabilities, focusing on developing implementable adaptations that create mutual benefits to Reclamation and the region with local support. Ultimately, the successful strategy for addressing future climate changes will require a combination of some, or all, adaptation portfolios to comprehensively address the key regional vulnerabilities. The precise composition, scale, operations, partnerships, funding, and governance to advance these adaptions will require further evaluations and coordination among American River Basin interests, including Reclamation, local water agencies, interest groups and stakeholders.

Overall, the ARBS achieved many of the objectives it set out to accomplish, including:

- Further refined the future water supplies and demands in the American River Basin.
- Evaluated regional demand-supply imbalance and infrastructure challenges under the existing and future climate change conditions. Formulated adaptations portfolios provide a road map of potential strategies to address these identified imbalances.
- Contributed towards improving regional collaboration for sustainable water resources management.
- Contributed towards better aligning water management tools, strategies, and planning efforts of Reclamation and water agencies in the Basin. The ARBS developed a fine-scale region specific future climate and hydrology dataset that will be available for Federal, state, and local planning studies in the region. Integrating regional and CVP/SWP operations in CalSim 3 creates a common planning platform for future studies with a consistent set of data and underlying assumptions. In addition, this study used water temperature modeling tools for Folsom Reservoir and the Lower American River that PCWA developed and Reclamation reviewed for technical sufficiency. This establishes another common planning platform for assessing the effects on water and temperature management actions and fisheries in the region.
- Contributed towards improving coordination of local and Federal water management to improve regional water supply reliability and to increase Reclamation's operational flexibility of Folsom Reservoir to meet all purposes of the CVP. The adaption portfolios were explicitly formulated around existing Federal authority and have identified local support to ensure mutually beneficial and implementable solutions. With input from Reclamation, the non-Federal Partners, and stakeholders, these adaptations portfolios are blueprints for coordinated Federal and local actions.

Next Steps

Anticipated next steps to advance the adaptation portfolios are summarized in Table ES-4.

Table ES-4. Anticipated Next Steps for Adaptation Portfolios Development

Adaptation Portfolios	Anticipated Next Steps
Importance of Long-Term CVP Water Contracts	• American River Division agencies with Interim Renewal Contracts have successfully worked with Reclamation to convert their contracts into repayment contracts to ensure long-term supplies. Reclamation executed congressionally mandated contract conversions on February 28, 2020 pursuant to the Water Infrastructure Improvements for the Nation (WIIN) Act for City of Folsom, City of Roseville, PCWA, Sacramento County Water Agency, San Juan Water District, and Sacramento Municipal Utility District (SMUD), and finalized the water supply contract with EDCWA.
Alder Creek Reservoir and Conservation Project	• Reclamation and EDCWA are working to initiate a Federal Feasibility Study (authorized by Public Law [P.L.]108-361, Section 202).
Sacramento River Diversion Project	• Reclamation, PCWA, and RiverArc project partners are working to advance planning for a Sacramento Groundwater Bank through the 2019 Basin Study Program—Water Management Options Pilots.

Adaptation Portfolios	Anticipated Next Steps
Federally Recognized Groundwater Bank (North and South American Groundwater Basins)	• Reclamation and RWA are working to advance planning for a Sacramento Groundwater Bank through the 2019 Basin Study Program—Water Management Options Pilots.
Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin)	• USACE is initiating construction of the Folsom Dam Raise for flood risk management (authorized by PL 106-53 Section 101(a)(6); P.L. 108-137, Section 28; P.L. 110-114, Section 3029(b)). • PCWA, SMUD, and SAFCA are cooperating on facility improvements upstream of Folsom Dam to provide additional flood control surcharge space and facilitate FIRO. • In collaboration with regional partners, SAFCA is investigating the potential for flood-managed aquifer recharge in Sacramento County.
2019 BO Flow Management Standard Project	• The 2019 BO Flow Management Standards has been included in the NOAA Fisheries and USFWS 2019 Biological Opinions on Long-term Operation of the Central Valley Project and State Water Project.

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Chapter 1. Introduction

This Chapter provides the American River Basin Study (ARBS) study authorization, purpose, objectives, and background.

1.1. Report Organization

This report summarizes the range of planning, technical, and engagement activities conducted during the ARBS. The appendices provide additional detail regarding methods and results for the assessments included in the Basin Study, and document processes such as stakeholder outreach and engagement. The report is organized in chapters:

Chapter 1. Introduction—Provides the authorization, purpose, and context for the ARBS.

Chapter 2. Technical Approach and Supporting Information—Describes ARBS planning approach and supporting sources of information.

Chapter 3. Water Supply and Demand Imbalance—Presents the water demand and water supply conditions developed for use in the ARBS, including representations of existing and projected demands and supplies under future climate change.

Chapter 4. Risk and Vulnerability Assessment—Characterizes water management stressors, regional water supply vulnerabilities, and vulnerability pathways.

Chapter 5. Adaption Measures and Portfolios—Describes management actions, or adaptation measures, suggested by stakeholders for addressing water supply vulnerabilities and the formulation of representative adaptation portfolios using the screened adaptation measures for quantitative analysis.

Chapter 6. Performance of Adaption Portfolios—Presents the performance evaluation of formulated adaptation portfolio, and their contribution to addressing vulnerabilities.

Chapter 7. Conclusions and Suggested Next Steps—Reviews key findings from the portfolio evaluation and discusses opportunities for developing local or regional responses to future conditions.

Chapter 8. References—Lists the references cited in this report.

Appendices. Note that these appendices are records of analysis for the ongoing study. The main report may have updated information that is not reflected in the appendices.

- **Appendix A. Communication and Outreach Activities—**Documents communication and outreach activities conducted in support of the ARBS development.
- **Appendix B. Development of Future Climate and Hydrology Scenario**s—Describes the observed historical climate conditions, and projected future climate conditions and hydrology scenarios developed for ARBS.
- **Appendix C. CalSim 3 American River Module—**Documents the development and validation of CalSim's American River module.

- **Appendix D. Development of Urban and Agricultural Demands—**Describes the methods and data sources used to develop the urban and agricultural water demands to support modeling of four planning horizons: existing demands (2015), 2050, 2070, and 2085 levels of development.
- **Appendix E. Adaptation Measure Preliminary Screening Results—**Documents the evaluation and screening of adaptation measures generated through stakeholder input.
- **Appendix F. Draft Description of Adaptation Portfolios—**Describes the facilities, operations, and key modeling assumptions for the formulated adaptation portfolios.
- **Appendix G. Adaptation Portfolio Evaluation Results—**Provides detailed evaluation metrics results for each of the adaptation portfolios.
- **Appendix H. Lower American River Water Temperature Modeling Documentation and Results—**Documents the data and modeling tools used to simulate water temperature in Folsom Reservoir and along the Lower American River. It also documents the evaluation results of existing conditions and under future climate change scenario.

1.2. WaterSMART: Authorization and Program

The Basin Study Program, as part of the U.S. Department of the Interior's WaterSMART (Sustain and Manage America's Resources for Tomorrow) Program, addresses twenty-first century water supply challenges such as increased competition for limited water supplies and climate change. The SECURE Water Act of 2009[1] and Secretarial Order 3297 established the WaterSMART Program, which authorizes Federal water and science agencies to work with state and local water managers to pursue and protect sustainable water supplies and plan for future climate change by providing leadership and technical assistance on the efficient use of water. Through the Basin Study Program, the Bureau of Reclamation (Reclamation) works with States, Tribes, non-governmental organizations, other Federal agencies, and local partners to identify strategies to adapt to and mitigate current or future water supply and demand imbalances, including the impacts of climate change and other stressors on water and power facilities.

1.3. Study Background

Reclamation completed the Sacramento and San Joaquin Rivers Basin Study (SSJRBS) in 2016. The SSJRBS evaluated potential impacts of projected climate change on water supply, water quality, and critical habitat within California's Central Valley. The 60,000 square-mile study area for the SSJRBS encompassed all main tributaries in the Central Valley as well as the Sacramento-San Joaquin Delta (Delta), the largest estuary on the west coast of North America. The SSJRBS outlined potential impacts over a range of possible future climate conditions on various natural resources and presents portfolios of broad adaptive strategies for consideration by water agencies and other interests.

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[1] SECURE Water Act = **S**cience and **E**ngineering to **C**omprehensively **U**nderstand and **R**esponsibly **E**nhance Water Act; Subtitle F of Title IX of Public Law 111-11, Omnibus Public Lands Management Act of 2009.

ARBS is focused on a portion of the SSRJBS planning area, the American River Basin. The American River is a major tributary to the Sacramento River. Reclamation plays an integral role in water management in the American River Basin by storing and conveying Central Valley Project (CVP) and other contract supplies and operating Folsom Reservoir for regional and statewide natural resource protection and flood risk management.

The Lower American River is the only urban waterway in the United States to be designated a "Wild and Scenic River" for recreation by Federal and State agencies.[1,2] The river is home to 43 fish species, including federally threatened steelhead and struggling fall-run Chinook salmon. Further, the superior quality of water in the American River and its proximity to the Delta give Folsom Reservoir a critical role as the "first responder" in CVP operations to satisfy Delta flow and quality standards and other requirements for protecting endangered fishery species. The ability for Folsom Reservoir to act in this capacity may be eroded by regulatory requirements.

The City of Sacramento, and adjacent metropolitan areas have comprised the largest growth area in northern California in the past two decades and this trend is expected to continue in the near future. This growth demonstrates a significant need to align the vision and climate adaptation strategies for sustainable basin-wide water management.

Water managers in the American River Basin (Basin) continue to experience a growing imbalance between water demands and water supplies due to a variety of factors. These include population growth, increased regulatory requirements, changes in CVP operations, and inadequate infrastructure. More closely coordinated interagency planning is also needed to realize the potential of regional water reliability as well as to adequately address the potential shift in precipitation patterns (from snow to rainfall and in seasonal distribution) and the increasingly intense and more frequent extreme events (e.g., droughts and floods).

1.4. Study Purpose

The basin study is authorized under Section 9503(b)(2) of the SECURE Water Act.[3] This study is not a Federal decision document. Rather, it presents an opportunity to develop concepts of adaptative portfolios with compatible measures to address identified basin-specific climate vulnerabilities, which Reclamation and regional partners would have interests to explore further through continued collaboration. It neither requests nor proposes any new feasibility study pursuant to Public Law (P.L.) 111-11 nor any new Federal construction authority.

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[1] 46 Federal Register 7484 (January 23, 1981) (Federal designation); Public Resources Code Section 5093.54(3) (state designation).

[2] 46 Federal Register 7484 (January 23, 1981) (Federal designation); Public Resources Code Section 5093.54(3) (State designation). The Nimbus Dam to Sacramento River segment within the American River Parkway Plan is being administered under the California Wild and Scenic River System Act (2009 Assembly Bill No. 889).

[3] SECURE Water Act = Science and Engineering to Comprehensively Understand and Responsibly Enhance Water Act; Subtitle F of Title IX of Public Law 111-11, Omnibus Public Lands Management Act of 2009.

The ARBS's purpose is to develop the data, tools, analyses, and adaptation strategies specific to the American River Basin within the broad context of the SSJRBS. The ARBS evaluated applying adaptation strategies to improve regional water supply reliability—while enhancing Reclamation's flexibility in operating Folsom Reservoir to meet flow and water quality standards in the Delta and protect endangered fishery species in the Lower American River.

The ARBS examined ways to better integrate and coordinate local and Federal water management practices, incorporated new scientific information on climate change specifically for the American River Basin, and addressed significant recent changes in conditions and regulatory requirements related to the CVP and regional water management, including the Biological Opinions (BO) for endangered fishery species protection and protection of the Sacramento-San Joaquin Delta,[1] and the State of California's (State) Sustainable Groundwater Management Act and water rights administration in drought conditions.

1.5. Study Objectives

The ARBS objectives are to:

- Further refine the assessment of water supplies and demands for the American River Basin developed under the SSJRBS and regional planning efforts.
- Address regional demand-supply imbalance and infrastructure deficiencies under the existing and future climate change conditions.
- Improve regional collaboration for sustainable water resources management.
- Improve coordination of local and Federal water management to improve regional water supply reliability and to increase Reclamation's operational flexibility of Folsom Reservoir to meet all purposes of the CVP.
- Align water management tools, strategies, and planning efforts of Reclamation and water agencies in the Basin.

The ARBS objectives address all the required Basin Study elements:

- Develop projections of future water supply and demand in the Basin, including an assessment of risk to the water supply relating to potential changes in climate as defined in Section 9503(b)(2) of the SECURE Water Act.
- Analyze how existing water and power infrastructure and operations will perform in the face of changing water realities and other impacts identified in Section 9503(b)(3) of the SECURE Water Act, including the ability to deliver water; hydroelectric power generation; recreation; fish and wildlife habitat; applicable species listed as endangered, threatened, or candidate species and/or designated critical habitat under the Endangered Species Act of 1973, as Amended; water quality issues (including salinity levels); flow and water dependent ecological resiliency; and flood risk management.

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[1] National Oceanic and Atmospheric Administration (NOAA) Fisheries and U.S. Fish and Wildlife Service (USFWS) 2019 Biological Opinions on Long-term Operation of the CVP and SWP (NOAA Fisheries, 2019 and USFWS, 2019).

- Develop adaptation and mitigation strategies specific to the Basin within the broad context of the SSJRBS to address imbalances between current and future supplies and demands identified through the Study analysis.
- Complete a trade-off analysis of the identified options, including an analysis of all options in terms of their relative cost, environmental impact, risk, stakeholder response, and other common attributes.

1.6. Study Partners

The ARBS data and analyses help improve the resolution of regional climate change data and develop and analyze regional-specific adaptation strategies. These strategies build on those identified in the SSJRBS (Reclamation, 2016). The ARBS was developed by Reclamation in collaboration with six non-Federal Partners: Placer County Water Agency (PCWA), City of Roseville, City of Sacramento, El Dorado County Water Agency (EDCWA), City of Folsom, and Regional Water Authority (RWA). These Study Partners represent the major water purveyors in the American River Basin and include CVP water contractors. RWA is a Joint Powers Authority with the primary mission to facilitate integrated regional water management and surface and groundwater conjunctive use among its over 20 member agencies in the Sacramento-Placer-El Dorado region.

To address flood risk associated with the projected future climate, the non-Federal Partners also coordinated the Study development with Sacramento Area Flood Control Agency (SAFCA).

1.7. Study Area Boundaries

Figure 1-1 shows the study area, which is bounded by the Bear River to the north, the Cosumnes River to the south, the ridge of Sierra Nevada to the east, and the Feather and Sacramento Rivers to the west. The study area is a combination of three areas:

- **American River watershed**. This watershed covers 2,140 square miles from the Sacramento River to the peaks of the northern Sierra Nevada mountains west of Lake Tahoe. It includes the sub-basins of the American River: Lower American River Sub-basin (U.S. Geological Survey [USGS] hydrological unit code [HUC] 18020111), North Fork American River Sub-basin (HUC 18020128), and South Fork American River Sub-basin (HUC 18020129).
- **ARBS Non-Federal Partners’ Service Areas Outside of the American River Watershed**. This represents areas outside of the American River Watershed in adjacent watersheds of the Bear River and Cosumnes River that are served by the Non-Federal Partners with American River water.
- **North and South American Groundwater Basin.** These two groundwater basins in the west side of the study area are separated by the American River. Their eastern boundary represents the approximate edge of the alluvial basin, where little or no groundwater flows into or out of the groundwater basins from the Sierra Nevada basement rock.

Figure 1-1 also shows the boundary between the Valley Floor and the Foothills. The boundary line between the Valley Floor and Foothills follows the El Dorado County line, the bifurcation between upper and lower PCWA Zone 6, City of Lincoln sphere of influence, and the North American groundwater subbasin.

Figure 1-2 shows the water purveyors in the study area. Water purveyors in the Foothills do not have access to groundwater as part of their normal supplies because there are no recognized groundwater resources in Foothills (fractured-rock aquifers only) to provide meaningful and reliable supplemental water supply. These entities include: El Dorado Irrigation District (EID), PCWA Upper Zone 6, Georgetown Divide Public Utility District (GDPUD), and Nevada Irrigation District.

Note that City of Folsom, located at the transition of the Valley Floor to the Foothills, does not have access to groundwater either.

Folsom Reservoir is on the American River in the Sierra Nevada foothills of California and lies within Placer, El Dorado, and Sacramento Counties. It is about 25 miles (40 kilometers [km]) northeast of the City of Sacramento. The lake has a surface area of 11,500 acres (46.54 square km), with an elevation of 466 feet (142 meters) and 75 miles (121 km) of inundated shoreline. The reservoir has a normal full-pool storage capacity of 975 thousand acre-feet (TAF) with a seasonally designated flood control surcharge space that varies between 400 to 600 TAF based on forecast inflow conditions and is operated to release up to 115,000 cubic feet per second (cfs). The reservoir provides flood protection for the Sacramento area; water supplies for irrigation, domestic, municipal, and industrial uses; and hydropower. It also provides extensive water-related recreational opportunities; water quality control in the Delta; and helps maintain the flows needed to balance anadromous and resident fisheries, wildlife, and recreational considerations in and along the Lower American River.

Folsom Dam and Reservoir is a major water management facility within a large metropolitan area and provide key flood control structures to protect the Sacramento metropolitan area.

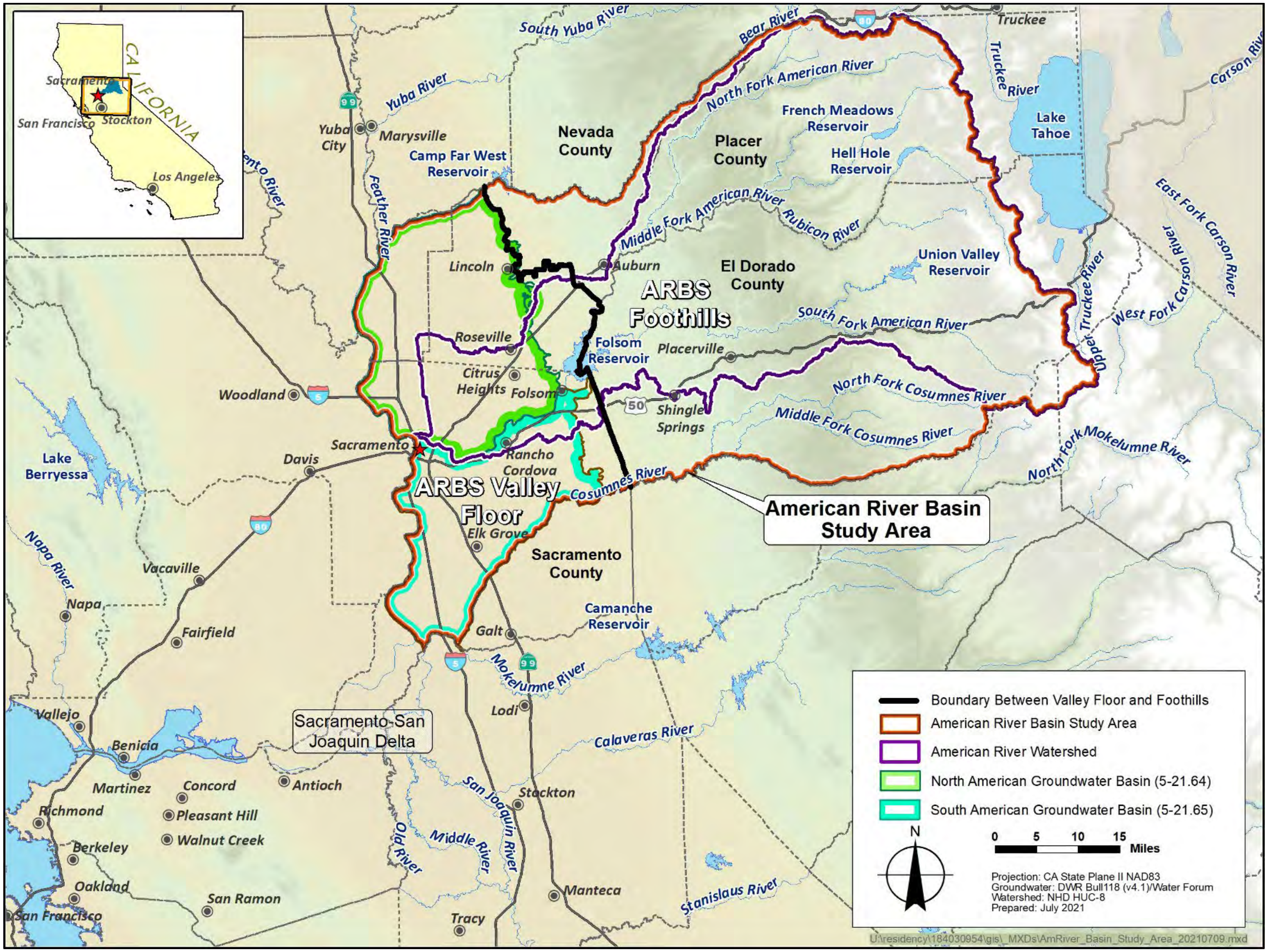


Figure 1-1. study area boundary for the American River Basin Study.

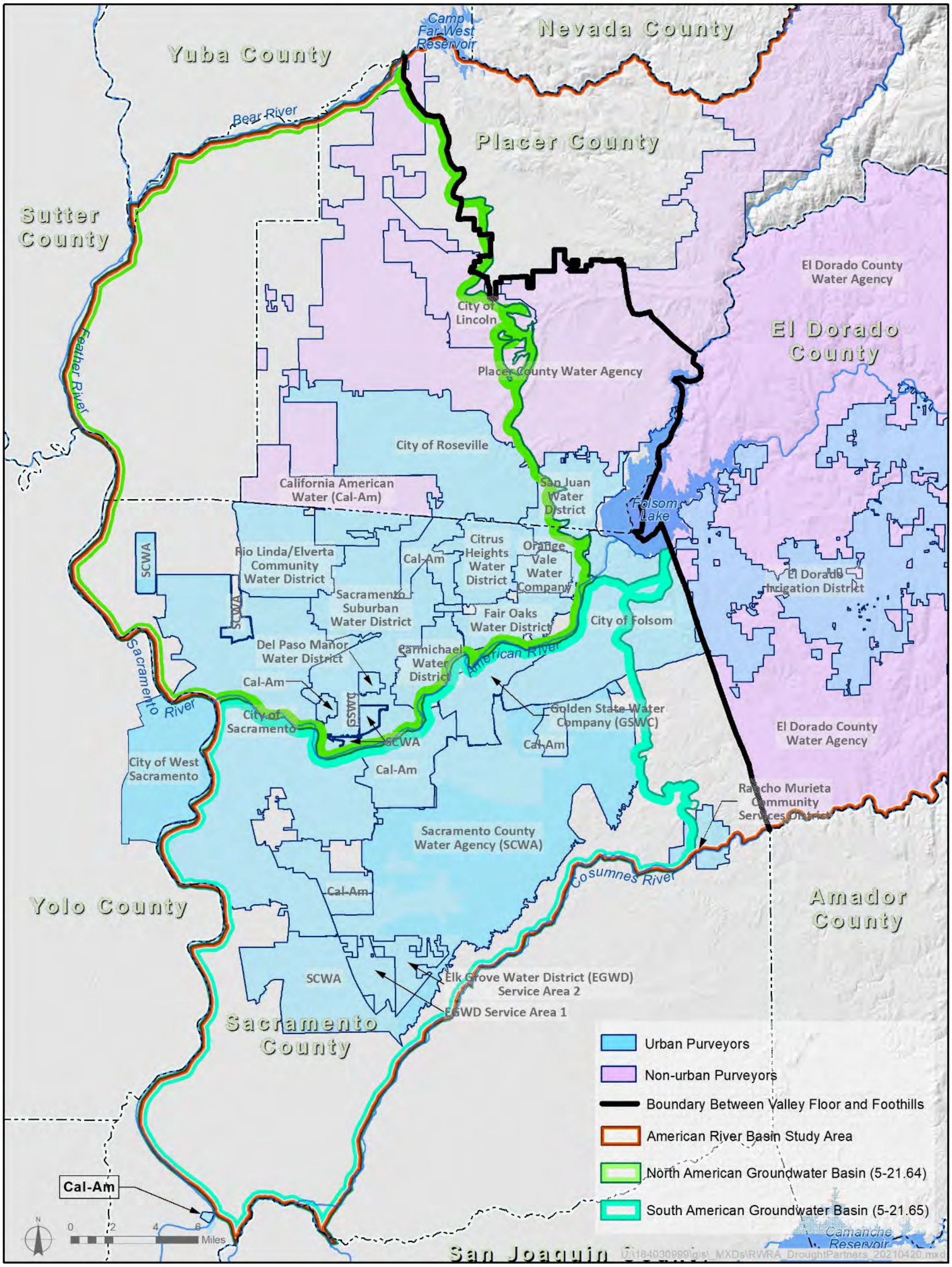


Figure 1-2. Water purveyors in the study area.

1.8. Previous Studies

The SSJRBS (Reclamation, 2016) outlined major impacts from projected climate change on water supply, fish and wildlife protection, and flood risk management due to reductions in snowpack and changes in seasonal runoff. In the American River Basin, the potential effects of a changing climate have introduced significant uncertainty in long-term water supply reliability. Folsom Reservoir has a limited capacity relative to the watershed it serves, partially because seasonal snowpack has historically provided a large portion of the storage necessary to regulate runoff for water supply. Warming conditions and changes in precipitation patterns in the Sierra Nevada mountains threaten the volume of water that will be stored as snowpack later in the season and runoff will enter the reservoir earlier in the year.

To build on this history of successful collaboration in the Basin, integrating Federal and regional planning, addressing regulatory changes, and adapting to evolving climate conditions is still needed. These issues must be resolved if the competing needs for regional water supply reliability, CVP systemwide delivery reliability, and endangered species protection in the Lower American River and beyond are to be met in a balanced way under an aligned vision for water management.

Reclamation's watershed planning effort, the American River Water Resources Investigation (1998), recommended regional conjunctive use to leverage the region's rich water rights and contract entitlements alongside its groundwater resources. Consistent with that premise, regional entities completed the Sacramento Water Forum Agreement (WFA) in 2000, which presented a balanced approach for water supply reliability and environmental protection along the Lower American River. The 2006 American River Basin Integrated Regional Water Management Plan and subsequent 2013 and 2018 Updates, the North American Basin Regional Drought Contingency Plan (Regional Water Authority, 2018), and Regional Water Reliability Plan (Regional Water Authority [RWA], 2019) continued the collaborative planning and implementation efforts in the region to support planned economic development, enhanced protection for salmon and steelhead species in the Lower American River, and social and recreation values unique to the region.

1.9. Study Management Structure

Reclamation and the Non-Federal Partners implemented a management structure that is fully integrated and allowed partnership at all levels (Figure 1-3).

1.9.1. Executive Steering Group

The Executive Steering Group (ESG) is a group of management-level representatives from Federal and non-Federal partners. The ESG's primary purpose is to provide:

- ARBS oversight
- Guidance on issues presented by the Project Management Team (PMT) and technical staff to ensure continued forward progress and timely completion of the Study
- Guidance and direction as appropriate on any or all aspects of study formulation, performance, funding, and management.

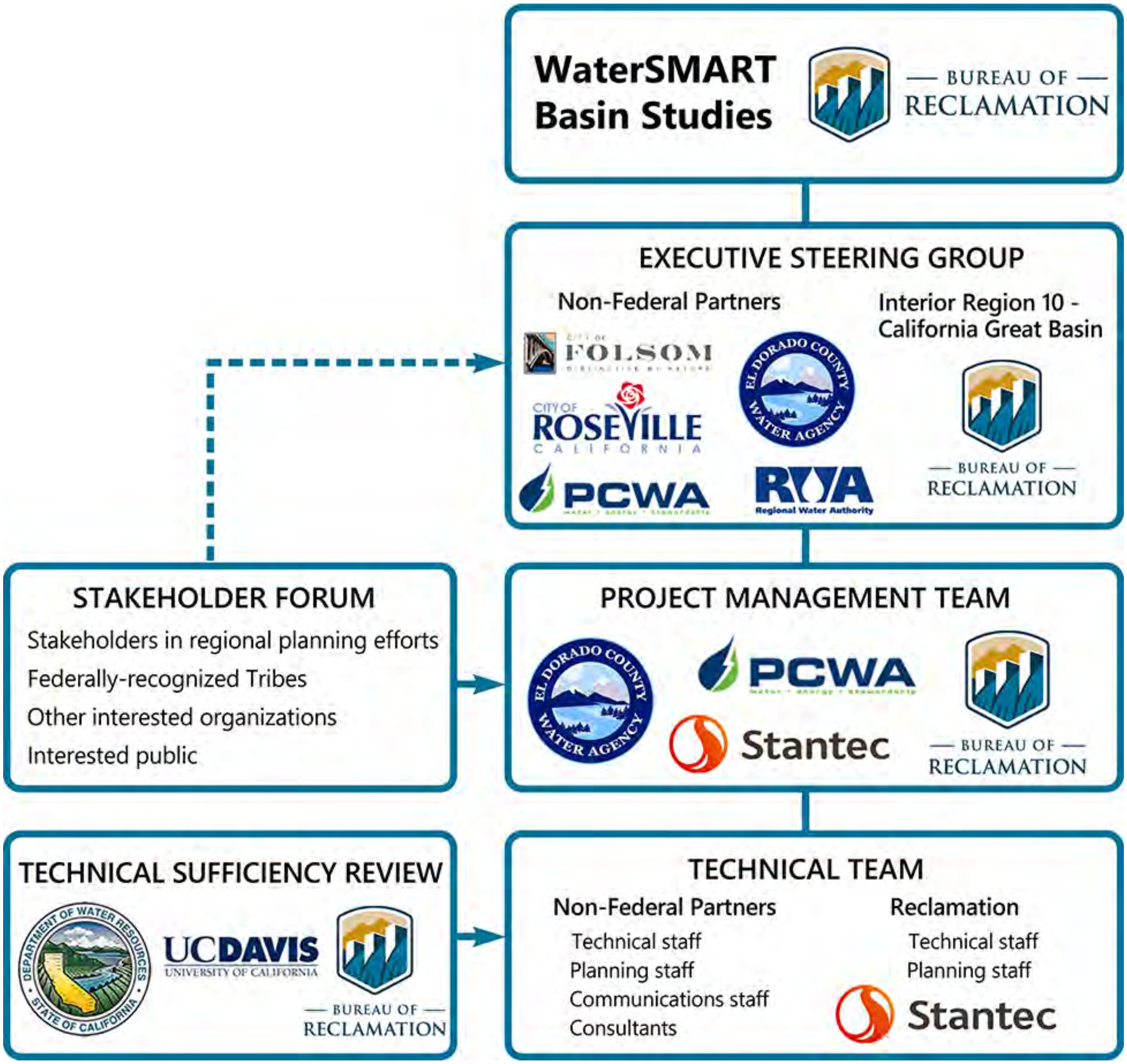


Figure 1-3. American River Basin Study management structure.

1.9.2. Project Management Team

The Project Management Team's (PMT) purpose is to ensure completion of all study phases and tasks according to the approved critical path schedule and within the approved project budget. This includes guidance and direction to contractor and agency staff members of the Technical Team who will be completing the project work. The PMT included the ARBS Project Manager (PM), Reclamation's Basin Study Coordinator, and administrative support staff.

The ARBS PM is provided by PCWA but works for and reports to the Executive Steering Group. The Reclamation Basin Study Coordinator is responsible together with the PM for management and completion of all ARBS milestones and tasks according to the approved schedule and approved study budget. EDCWA provided administrative support for the Executive Steering Group and the Project Management Team.

1.9.3. Technical Team

The Technical Team is responsible for completing technical, planning, and communications and outreach activities, as directed by the PMT. The Technical Team included non-Federal Partners' technical, planning, and communications staff and consultants, and Reclamation's technical and planning staff, and contractor, Stantec Consulting Services Inc.

1.9.4. Stakeholder Forum

The Stakeholder Forum provides regular opportunities for stakeholders—interested parties, non-governmental organizations, and other organizations/individuals—to be kept informed of ARBS progress and to provide input. The PMT developed a contact list from current and past stakeholders in regional planning efforts, and a website for Study information and instructions for participating in the Stakeholder Forum. Reclamation's Native American Affairs Office, solicitor, and other offices (as needed) coordinated to contact federally recognized Tribes in the study area to determine their desired levels of engagement.

1.9.5. Technical Sufficiency Review

The Technical Sufficiency Review is a required component of Reclamation's Basin Study Program as detailed in Paragraph 11 of Directives and Standards WTR 13-01 of the Reclamation Manual. The approach for this review was developed in consultation with the Executive Steering Group. The Technical Sufficiency Review team included individuals with specialized expertise in climate change studies from Reclamation, DWR, and University of California, Davis. The TSR team reviewed the draft Study Report, and their feedback informed updates to the Draft Report.

1.10. Stakeholder Coordination and Outreach

Communication and outreach for the ARBS leveraged existing regional collaboration venues and built on a long history of coordinated planning in the region. Study managers provided regular briefings on the Study and its progress at various regional planning forums, public board meetings, and noticed public webinars. In addition, publicly noticed workshops were held to solicit stakeholders and interested public input. A comprehensive list of communication and outreach activities is provided in Appendix A.

In addition, PCWA created a project website on its website to keep stakeholders and the public, informed about the ARBS (https://www.pcwa.net/planning/arbs). The project website was updated regularly to include content on ARBS development, upcoming meetings and workshops, meeting materials, and other public ARBS documents.

Chapter 2. Technical Approach and Supporting Information

This Chapter describes ARBS planning approach and supporting sources of information.

2.1. Technical Approach Overview

Figure 2-1 illustrates the analytical process and tools used to assess the effects of climate change in the study area. To assess the effects of future climate change on water system operations and deliveries (dashed boxes in Figure 2-1), two key sets of inputs are developed:

- Future water urban and agricultural water demands based on the current trend socioeconomic growth scenario (orange boxes)
- Future climate and hydrology projections (blue boxes)

These inputs and tools to simulate water system operations are discussed in this chapter.

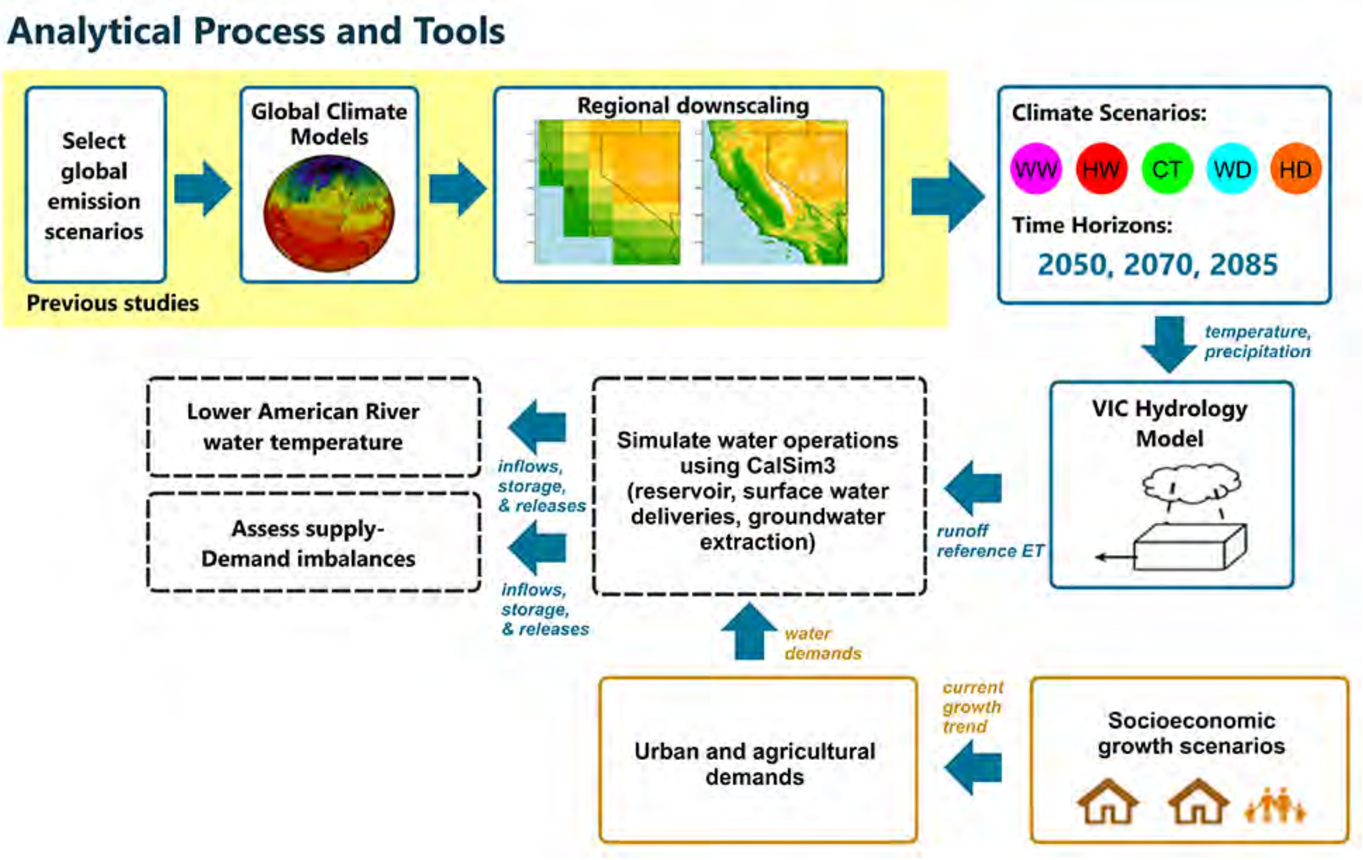


Figure 2-1. Analytical process and tools to assess effects of climate change in the study area.

2.2. Future Socioeconomic Scenarios

ARBS future socioeconomic conditions are based on socioeconomic scenarios from the SSJRBS (Reclamation, 2016). The SSJRBS developed three scenarios representing the range of projected future socioeconomic conditions in the study area with alternative views of how the future population and urban density might unfold. These socioeconomic scenarios are presented in Table 2-1. The scenario representing current trend growth in population and development density (CTP-CTD) was selected to project future demands, as this scenario best avoids over- or under-estimation of future demands.

Table 2-1. Growth Scenarios for the Sacramento River Hydrologic Region Average

Population Growth Scenario	**Development Density Scenario**	**Combined Growth Scenario**	**Change in Population (2006-2050)**	**Change in Urban Density (2006-2050)**	**Change in Irrigated Crop Area (2006-2050)**
Lower than Current Trends (LOP)	Higher than Current Trends (HID)	LOP-HID	+35%	+16%	-0.3%
	Current Trends (CTD)	LOP-CTD	+35%	+18%	-0.5%
	Lower than Current Trends (LOD)	LOP-LOD	+35%	+20%	-0.7%
Current Trends (CTP)	Higher than Current Trends (HID)	CTP-HID	+56%	+27%	-1.4%
	Current Trends (CTD)	CTP-CTD*	+56%	+30%	-1.7%
	Lower than Current Trends (LOD)	CTP-LOD	+56%	+33%	-2.0%
Higher than Current Trends (HIP)	Higher than Current Trends (HID)	HIP-HID	+104%	+44%	-3.2%
	Current Trends (CTD)	HIP-CTD	+104%	+51%	-3.8%
	Lower than Current Trends (LOD)	HIP-LOD	+104%	+57%	-4.5%

Source: Tables SR-21, SR-22, and SR-23 California Water Plan Update 2013 (DWR).

* CTP-CTD represents the current trend for population grown and pattern of development density. CTP-CTD current socioeconomic trend is selected to forecast future demands for the ARBS.

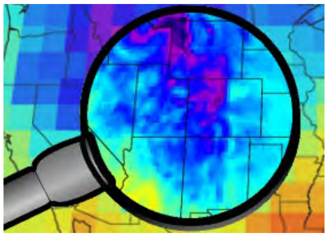
2.3. Future Climate Scenarios

Projecting the ways in which the climate may change in the future involves attempting to capture a large range of highly variable potential future conditions. A wide array of types and sources for greenhouse gas emissions may drive climate changes into the future. Greenhouse gas emission rates throughout the globe are uncertain as they are a product of global and local economies, population, regulatory requirements, and available technologies—all of which may change in the future in a variety of ways. The Intergovernmental Panel on Climate Change (IPCC) develops a range of global emissions scenarios to bracket the uncertainty surrounding the future global patterns of greenhouse gas emissions for use in climate models (IPCC, 2017).

Global Projections using Emission Scenarios and Global Climate Models. Global greenhouse gas emissions are used to derive global climate models or general circulation models (GCM) that simulate future climate conditions. Each model has its own emphasis, strengths, and weaknesses. Due to these differences, GCMs often forecast varying future climate system conditions. Therefore, typically, multiple GCMs are used (Reclamation, 2011). The different greenhouse gas emission scenarios are simulated through an assemblage of different GCM models. These different models and varying initial condition assumptions result in multiple projections for global climatic conditions.

Regional Projections. These global climatic projections are next translated, or "downscaled," to regional scales at higher resolution using different statistical methods.

Represent a Range. Because of the large number of climatic projections, an "ensemble" approach is used to develop a simplified, meaningful set of climate change projections that also preserves uncertainty about temperature and precipitation in the future. The ensemble approach simplifies the process of using climate projections in climate change studies by bundling projections from a variety of different climate models into a handful of distinct climate change ensembles. The ensembles represent the range of temperature and precipitation changes.



Downscaling is the general name for a procedure to take data for large scales to predict local scales.

2.3.1. Global Emission Scenarios

Climate projections are typically developed using GCMs to simulate changes in the earth's energy balance—and corresponding changes in weather and climate conditions—in response to projected changes in atmospheric composition. Future climate change projections are made primarily based on coupled atmosphere-ocean general circulation model simulations under a range of future emission scenarios, called representative concentration pathways (RCP). These RCP emission scenarios do not represent forecasts or projections of future atmospheric composition; rather RCPs represent plausible future trajectories of atmospheric greenhouse gas concentration under various assumption of population growth, economic growth, technology development, and governmental policies regarding greenhouse gas emissions.

The two emission scenarios used were:

- **RCP 8.5,** which represents a "business as usual" future emissions trajectory where greenhouse gas concentrations continue to rise unchecked.
- **RCP 4.5**, which represents a "reduced emissions" future emissions trajectory where greenhouse gas emissions would peak around 2040 and decline thereafter.

2.3.2. Climate Projections

Analyses of projected future climate conditions in the American River Basin and development of climate scenarios for the ARBS were based on an ensemble of bias-corrected and spatially downscaled climate projections. Global climate projections from the Coupled Model Intercomparison Project Phase 5 (CMIP5) (Tayler et al., 2009 and 2012) were bias corrected and downscaled over the continental United States, southern Canada, and northern Mexico using the Localized Constructed Analogs (LOCA) method (Pierce et al., 2014). Bias-corrected and downscaled projections over the Sacramento and San Joaquin River Basins were obtained from the Downscaled Coupled Model Intercomparison Project Phase 3 (CMIP3) and CMIP5 Climate and Hydrology Projections archive (Reclamation et al., 2013) hosted on the Lawrence Livermore National Laboratory (LLNL) Green Data Oasis REF (LLNL, 2020).

2.3.3. Climate Projections Downscaling

Using 16 GMs, two RCPs (4.5 and 8.5), and two initial state conditions for each GCM, results in 64 climate projections. These 64 projections were then statistically downscaled to provide adequate resolution for regional planning (see Figure 2-1). The spatial grid resolutions of GCM-based climate projections from the CMIP5 multi-model dataset are typically on the order of 1 to 2 degrees latitude by 1 to 2 degrees longitude, or roughly 110 to 220 km by 110 to 220 km over mid-latitudes. Local weather and climate conditions vary significantly across a degree of latitude or longitude as variations in topography, land cover, and many other factors affect local climate. In addition, GCM-based projections generally exhibit biases in simulated climate conditions that stem largely from the coarse spatial resolution of GCMs and the use of simplified parameterizations to represent physical processes that cannot be explicitly represented at the GCM grid scale. Coarse spatial resolution and biases limit the direct application of GCM-based climate projections to local and basin-scale analyses.

A broad range of methods have been developed to bias-correct and downscale GCM-based climate projections to support local and basin-scale analyses, planning, and decision making. Climate projections selected for the ARBS were downscaled using the Localized Constructed Analog (LOCA) downscaling procedure. The LOCA procedure uses an observational dataset to develop relationships between large-scale and local-scale weather and climate conditions. These relationships are then used to “downscale” coarse-resolution GCM projections onto a finer resolution grid—i.e., observed relationships between large-scale and local-scale weather and climate are used to estimate projected climate conditions on a finer-resolution grid from coarser-resolution GCM projections (Pierce et al., 2014). The LOCA procedure has been shown to preserve regional patterns of projected changes in precipitation and temperature more accurately than other downscaling methods. In addition, the LOCA procedure better preserves extreme hot days and heavy precipitation events, which are often dampened by other downscaling methods.

An ensemble of LOCA projections is available from Dr. David Pierce at the Scripps Institution of Oceanography. The LOCA ensemble includes bias-corrected and downscaled projections of daily precipitation, daily minimum temperature, and daily maximum temperature for the period 1950-2099. Projections are provided at a spatial resolution of $\frac{1}{16}$ th degree latitude by $\frac{1}{16}$ th degree longitude (approximately 6 km by 6 km) and cover the continental United States and portions of Mexico and Canada. The LOCA ensemble includes climate projections from 32 GCMs under the RCP4.5 and RCP8.5 emissions scenarios for a total of 64 climate projections. The LOCA ensemble has been used by the California Water Commission (CWC) and DWR as the primary source of climate projection information in several recent studies, including the Water Storage Investment Program (WSIP) and California’s Fourth Climate Change Assessment (Pierce et.al., 2018).

2.3.4. Development of ARBSE Climate Scenarios

To simplify the use of the 64 LOCA climate projections, a Hybrid Delta ensemble approach (Tohver et al. 2014 and Hamlet et al. 2013) was used to develop a simplified, meaningful set of climate change projections that also preserves uncertainty about temperature and precipitation in the future. The ensemble approach simplifies the process of using climate projections in climate change studies by bundling projections from a variety of different climate models into five distinct climate change ensembles. The ensembles represent the outer-bound ranges of temperature and precipitation changes, as well as a central tendency of all the projections. These five ensembles cover the range of potential future climate scenarios.

The climate change approach adopted for the ARBS is consistent with the approach recommended by the DWR's Climate Change Technical Advisory Group (CCTAG) as being most appropriate for California water resource planning and analysis (DWR, 2015). It is also consistent with the CWC approach to its climate change analysis for the WSIP (CWC, 2016).

Development of the ARBS climate ensembles required three discrete steps, described in the sections that follow and the appendices to this Report:

- Select a set of GCM climate projections
- Group GCM climate projections into five ensembles
- Translate, or "downscale," GCM outputs for use in the selected hydrology models

The first step to develop an ensemble is to categorize the 64 LOCA climate projections based on whether they are above or below the median change in temperature and precipitation relative to the historical conditions for the period 1980-2009 (Figure 2-2). The Central Tendency ensemble consists of projections within the 25th and 75th percentiles. A nearest-neighbor statistical method was used to build the four other ensembles using select projections around the 10th and 90th percentile changes in temperature and precipitation. If all projections in each quadrant are used to produce a full ensemble, it results in a smaller range of climate variability because some of the central tending projections may be included. The nearest neighbor statistical approach represents seasonal trends of larger ensembles but retains the variability range of smaller ensembles.

Once the projections have been categorized into an ensemble, adjustment factors (also known as change factors or "deltas") are calculated and applied to the baseline climate scenario (de-trended historical climate) using a quantile mapping approach to produce a single climate change time series for each ensemble. See Appendix B for further information. Percent changes for precipitation and incremental changes for temperature were used as adjustment factors in this Basin Study. This mapping approach maintains the historical sequencing of droughts and flood in the climate change time series while perturbing precipitation and temperature magnitudes according to each ensemble.

The resulting five subsets of the 64 LOCA projections are: Warm-Wet (WW), Warm-Dry (WD), Hot-Wet (HW), Hot-Dry (HD), and Central Tendency (CT) Scenarios. The five future climate scenarios include a temperature increase from moderate (Warm) to more severe (Hot), and a precipitation increase (Wet) or decrease (Dry). The Central Tendency Scenario represents the center (median) of the range of projected change in precipitation and temperature. These subsets are shown on Figure 2-2 by colored polygons and projection points as well as their position relative to the change in precipitation and change in temperature axis.

These five climate scenarios represent the range of projected changes in temperature (less warming to more warming) and precipitation (from decreases to increases) for three future time horizons, (2050, 2070, and 2085). This resulted in a subset of 15 climate scenarios.

The ARBS Partners selected three future periods for analysis of the supply-demand imbalance: 2050, 2070, and 2085. These three periods correspond to important milestones in the buildout conditions in the Valley Floor and Foothills. To account to uncertainty in climate forecasts, climate conditions for each of these three periods were represented by the average of a 30-year window around the targeted year. 2050 climate conditions were based on 2040-2069, 2070 conditions were based on 2055-2084, and 2085 conditions were based on 2070-2099. A suite of five future climate scenarios was developed to reflect the uncertainty in projected climate change across the ensemble of the 64 LOCA projections as depicted in Figure 2-2.

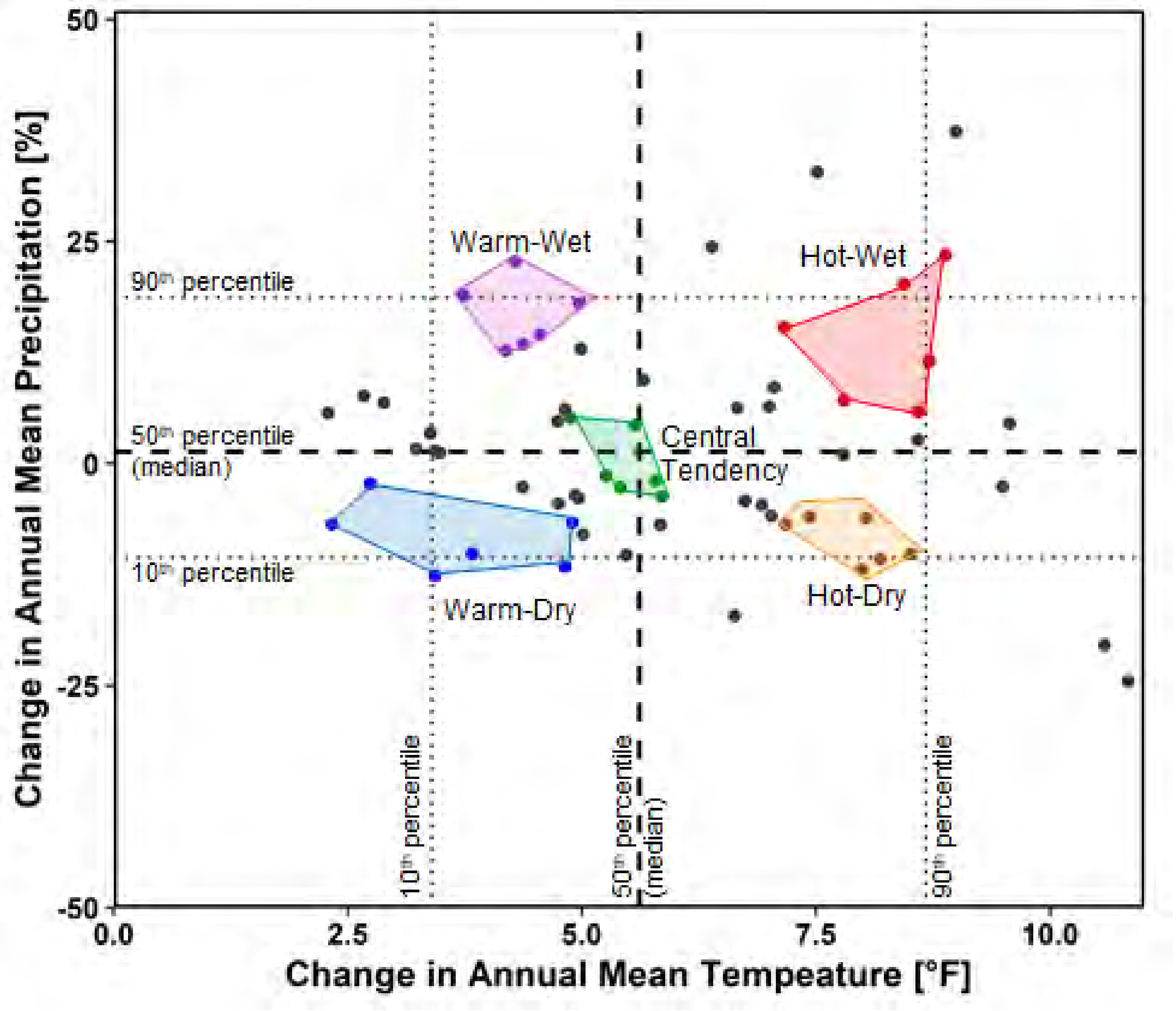


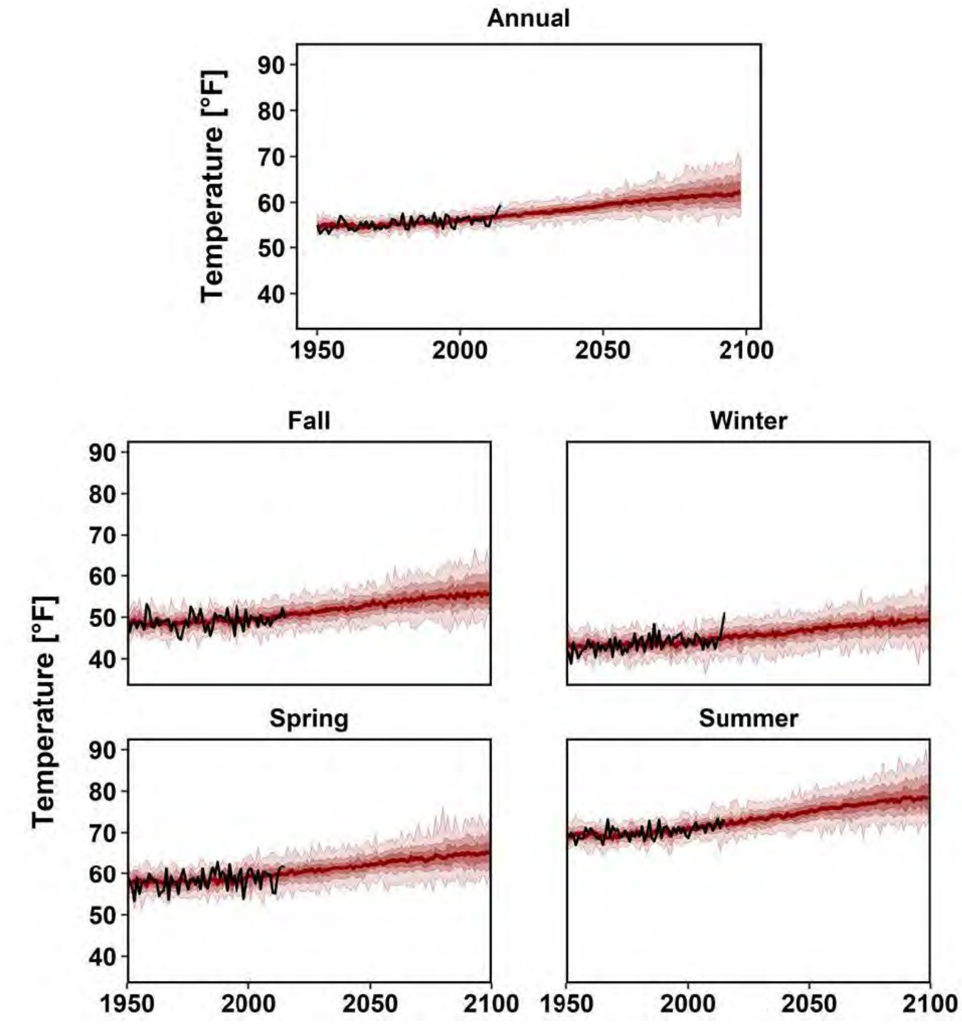
Figure 2-2. Five climate scenarios developed from the 64 LOCA ensembles.

2.3.5. Projected Future Temperature

Projected future climate conditions were evaluated and characterized based on the LOCA ensemble of downscaled climate projections. Projected future climate conditions were evaluated on a $\frac{1}{16}$th degree grid and averaged over the study area.

All LOCA projections indicate a significant increase in annual and seasonal average temperatures over the study area by the end of the 21st century.

The range of projected basin-averaged seasonal and annual average temperature are shown in Figure 2-3. The median of 64 LOCA projections suggest that increases in temperature over the study area would be greatest during the summer months, with summer temperatures increasing by approximately 7.2 degrees Fahrenheit (°F) by the end of the 21st century. Projected warming would be least for winter months, with an ensemble median projected increase of 4.9°F by the end of the century. Projections of daily maximum and minimum temperatures suggest similar seasonal trends, with the most increase in temperature occurring during summer and the least increase during winter. The maximum daily temperatures across the 64 projections are projected to increase more than daily minimum temperatures during all seasons, with the largest projected increase of 7.3°F during the summer months.



Notes: The dark red line shows the ensemble median; dark red shading indicates the range between ensemble 25th and 75th percentile values; medium red shading indicates the range between ensemble 10th and 90th percentile values; light red shading indicates the ensemble maximum and minimum values; and the black line shows observed historical values.

Figure 2-3. Timeseries of averaged annual and seasonal average temperature [°F] over the study area, 1950-2099.

While all 64 projections indicate generally uniform warming over the region, the magnitude of projected warming varies considerable among individual projections (Figure 2-4). Projected warming by the end of the 21st century ranges from approximately 2°F to 10°F. The range of projected warming reflects uncertainties in future atmospheric composition (i.e., differences between RCP4.5 and RCP8.5) as well as uncertainties how global, regional, and local climates will respond to future changes in atmospheric composition. It should also be noted that historical extreme temperatures are projected to be exceeded in almost all years for all the future projection periods across the 64 LOCA projections. This highlights the relative extent of future warming (refer to Appendix B for more details).

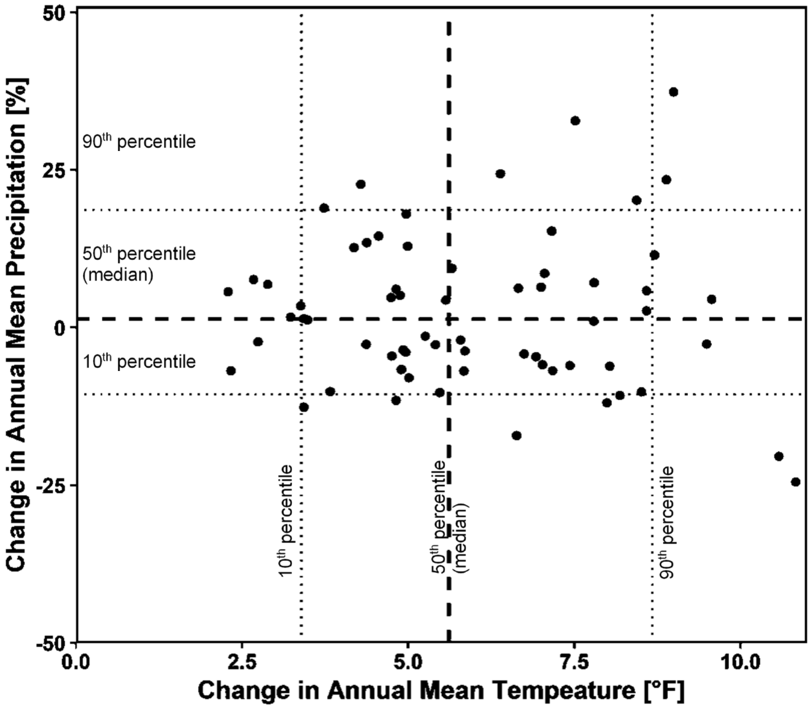
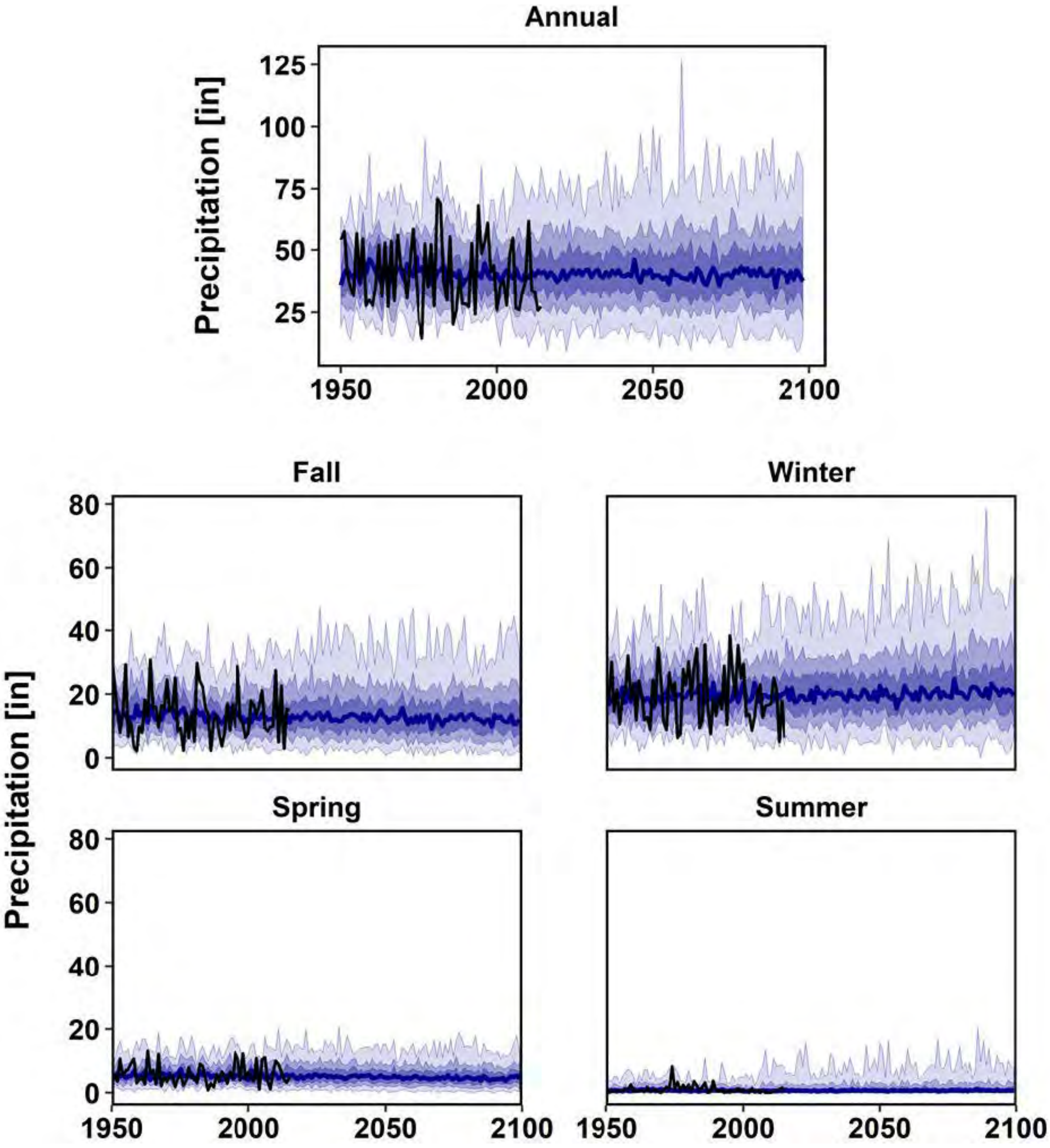


Figure 2-4. Projected changes in period-mean basin-averaged temperature and precipitation (%) from 64 LOCA projections (historical compared to 2070 to 2099 average).

2.3.6. Projected Future Precipitation

In contrast to projected temperature, there is no clear trend in projected precipitation over the study area or the broader Sacramento and San Joaquin River Basins. Projections of basin-averaged annual and seasonal precipitation over the study area are shown in Figure 2-5. Approximately half of the LOCA projections indicate an increase in annual precipitation, and half indicate a decrease. The lack of consistency in projected annual precipitation highlights the large uncertainty in future precipitation over this region. The large uncertainty in projected annual precipitation is further illustrated in Figure 2-5, which shows distribution of projected change in annual precipitation over the 21st century in each of the 64 LOCA projections. The large uncertainty in projected precipitation changes suggests that multiple climate projections or scenarios are needed to represent the potential impacts of climate change on water supplies in the study area.

Climate change is forecasted to intensify storms, result in more precipitation falling as rain, and cause early runoff.



Notes: Dark blue lines show the ensemble median; dark blue shading indicates the range between ensemble 25th and 75th percentile values; medium blue shading indicates the range between ensemble 10th and 90th percentile values; light blue shading indicates the maximum and minimum ensemble values; and black line shows observed historical values.

Figure 2-5. Timeseries of basin-averaged annual and seasonal average precipitation [inches] over the American River Basin study area, 1950-2099.

While there are no clear trends in projected annual precipitation (Figure 2-5 top), trends in the timing of projected seasonal precipitation are more apparent (Figure 2-5 bottom panels and Table 2-2). By the end of the 21st century, the ensemble median projections show that wetter season precipitation will occur later in the year. They also show a decrease in average fall precipitation by approximately 6 percent and an increase in average winter precipitation by approximately 5 percent. Changes in the drier season show an even larger change in the amount of precipitation that will occur later in the year as projected spring precipitation decreases by approximately 12 percent and projected summer precipitation increases by approximately 10 percent. Thus, while timing changes, these opposing seasonal projected trends do not change the overall amount of annual precipitation in the study area.

Table 2-2. Mean Projected Change in Precipitation and Temperature Over the Study Area Between 1980-2009 and 2070-2099 (averaged across the 64 LOCA projections)

	Percent Change in Average Annual Mean Precipitation (%)	**Change in Average Annual Mean Daily Air Temperature (°F)**	**Change in Annual Mean of Daily Maximum Air Temperature (°F)**	**Change in Annual Mean of Daily Minimum Air Temperature (°F)**
Fall	-6.0	+5.8	+6.1	+5.5
Winter	+4.7	+4.9	+5.0	+4.8
Spring	-11.9	+5.8	+6.3	+5.1
Summer	+10.4	+7.2	+7.3	+7.0

2.3.7. Projected Sea Level Rise

Sea-level rise will affect the Delta's hydrodynamics—increasing the salinity in the Delta. This increasing salinity will have significant impacts on water management throughout the State. For this analysis, a sea-level rise projection of 45 centimeters was selected to represent future sea-level rise conditions beyond 2050, consistent with the National Research Council (NRC) findings (California Natural Resources Agency and California Ocean Protection Council, 2018 and NRC, 2012).

2.4. Development of Future Hydrology

2.4.1. Hydrology Scenarios

A suite of hydrology scenarios was developed to evaluate the effects of climate change on water supplies and demands in the study area. We used the Variable Infiltration Capacity (VIC) hydrology model to simulate hydrologic conditions under each of the five climate scenarios and future time periods considered in the ARBS (2040-2069, 2055-2084, and 2070-2099). The VIC hydrology model is a large-scale, semi-distributed hydrologic model that simulates the surface water balance at each grid cell, including infiltration and soil moisture storage, evaporation and transpiration, and surface runoff and baseflow.

The key indicators for the hydrology evaluation are potential evapotranspiration (PET), annual average snow water equivalent (SWE), and total runoff. PET serves as a key indicator of landscape water demands, including consumptive use by evaporation and transpiration from bare soil, water surfaces, native vegetation, and crops. SWE is a key indicator of water supplies in the region, where runoff from many watersheds is dominated by snowmelt. Lastly, runoff is a direct indicator of the water supply available to the CVP-SWP system.

Hydrology scenarios were used to develop streamflow inputs to the water operation model, which was then used to evaluate changes in water supplies, demands, and management throughout the CVP-SWP, including the study area. The hydrology scenarios were developed using the VIC model version 4.2.b. The VIC model was configured using the same $\frac{1}{16}$ th-degree (approximately 6-km) grid as the observed historical climate dataset and the 64 LOCA bias corrected and downscaled climate projections. Static model inputs were obtained from an existing VIC model for the State that the CWC developed to support WSIP (CWC, 2016). Static model inputs were previously calibrated to closely match historical streamflow over 1970-2003 for twelve major stream gages throughout the Sacramento and San Joaquin River Basins.

2.4.2. Projected Hydrological Changes

Table 2-3 lists the annual change in key climatic and hydrologic indicators between historical observations (1915-2015) and projected future conditions for the study area: average, maximum, and minimum temperatures, PET, precipitation, and average and maximum SWE. Table 2-4 lists the percentage change for the same climatic and hydrologic indicator.

Evaporation is expected to increase with temperature rises. Snow is expected to decrease, and there is a range of projected runoff amounts.

Average annual PET is expected to increase by 6.2 to 1.2 inches across all climate scenarios and future time periods (Table 2-2). PET is strongly correlated with air temperature. PET is thus expected to increase more under the hot scenarios (HD and HW) than under the warm scenarios (WD and WW). Average SWE is projected to decrease by 0.7 to 1.3 inches across all climate scenarios and future time periods (Table 2-3). These values include areas that do not receive snow and therefore have a change of zero inches. Areas that accumulate snow are projected to have up to a 12-inch decrease in average annual SWE. Similar to the precipitation scenarios, there is wide range in projected runoff where the ‘wet’ scenarios suggest an increase in annual runoff and the ‘dry’ scenarios suggest a decrease in annual runoff. The projected changes in runoff range from an increase of 486 TAF during the HW scenario to a decrease of 273 TAF during the WD scenario by the end of the century.

Table 2-3. Change in Annual Climatic and Hydrologic Indicators Between Historical Conditions and Projected Future Conditions for the Study Area

Climate Scenario	Precip (in)	T_{avg} (in)	T_{max} (in)	T_{min} (in)	PET (in)	SWE_{avg} (in)	SWE^{max} (in)	Runoff (TAF)
Historical Conditions	**38.2**	**54.8**	**67.8**	**35.6**	**42.8**	**1.5**	**5.7**	**1,458**
2050 WW	+1.9	+4.0	+6.2	+1.6	+1.6	-0.7	-2.3	+701
2050 WD	-2.4	+3.9	+6.3	+1.4	+2.2	-0.7	-2.2	-185
2050 CT	+0.1	+5.0	+8.1	+2.1	+2.7	-0.90	-2.8	-2.0
2050 HW	+2.1	+6.2	+10.4	+2.7	+3.4	-1.0	-3.3	+143
2050 HD	-2.8	+6.2	+10.4	+2.7	+3.7	-1.1	-3.4	-206
2070 WW	+3.8	+4.7	+7.4	+2.0	+2.0	-0.8	-2.5	+199
2070 WD	-2.9	+4.4	+7.5	+1.6	+2.8	-0.8	-2.6	-212
2070 CT	-1.1	+6.3	+11.1	+2.6	+4.1	-1.08	-3.5	-93
2070 HW	+2.1	+7.6	+12.9	+3.5	+4.2	-1.2	-4.0	+177
2070 HD	-3.4	+7.9	+13.3	+3.7	+5.0	-1.2	-3.8	-185
2085 WW	+7.0	+5.4	+8.3	+2.5	+1.8	-0.9	-2.9	+486
2085 WD	-4.2	+4.7	+8.0	+1.8	+3.2	-0.9	-2.7	-273
2085 CT	-0.6	+6.5	+11.0	+2.8	+3.9	-1.0	-3.3	-54
2085 HW	+5.3	+9.3	+15.5	+4.6	+4.5	-1.3	-4.1	+366
2085 HD	-4.6	+8.9	+15.7	+4.1	+6.2	-1.3	-4.3	-203

avg = average max = maximum), and min = average temperature Max SWE is April SWE.

Table 2-4. Percent Change in Annual Climatic and Hydrologic Indicators Between Historical Conditions and Projected Future Conditions for the Study Area

Climate Scenario	Precip (in)	T_{avg} (in)	T_{max} (in)	T_{min} (in)	PET (in)	SWE_{avg} (in)	SWE^{max} (in)	Runoff (TAF)
Historical Conditions	**38.2**	**54.8**	**67.8**	**35.6**	**42.8**	**1.5**	**5.7**	**1,458**
2050 WW	+5%	+7%	+9%	+4%	+4%	-49%	-39%	+5%
2050 WD	-6%	+7%	+9%	+4%	+5%	-48%	-38%	-13%
2050 CT	+0.2%	+9%	+12%	+6%	+6%	-60%	-49%	-0.1%
2050 HW	+5%	+11%	+15%	+7%	+8%	-68%	-57%	+10%
2050 HD	-7%	+11%	+15%	+8%	+9%	-72%	-59%	-14%
2070 WW	+10%	+9%	+11%	+6%	+5%	-53%	-43%	+14%
2070 WD	-8%	+8%	+11%	+5%	+6%	-55%	-46%	-15%
2070 CT	-3%	+11%	+16%	+7%	+10%	-72%	-60%	-6%
2070 HW	+6%	+14%	+19%	+10%	+10%	-80%	-69%	+12%
2070 HD	-9%	+14%	+20%	+10%	+12%	-78%	-66%	-13%
2085 WW	+18%	+10%	+12%	+7%	+4%	-61%	-50%	+33%
2085 WD	-11%	+9%	+12%	+5%	+7%	-59%	-47%	-19%
2085 CT	-2%	+12%	+16%	+8%	+9%	-69%	-58%	-4%
2085 HW	+14%	+17%	+23%	+13%	+10%	-84%	-72%	+25%
2085 HD	-12%	+16%	+23%	+12%	+14%	-85%	-75%	-14%

2.5. Modeling Tools

This section describes the models used to assess the effects of climate change on water supply, demand, and operations in the study area.

2.5.1. CalSim 3 Model and Updates

Many water agencies in the study area divert water from the Lower American River and the lower Sacramento River, based on a mix of water rights, CVP contracts, and wholesale agreements. Surface water supplies are used conjunctively with groundwater. A system operation model is needed for planning to:

- determine the availability of surface water and groundwater to meet demands,
- analyze regional water management actions in the context of broader CVP/SWP operations, and
- coordinate CVP/SWP operations so that the two projects can meet both contractual obligations and in-basin needs, as prescribed in their water right permits.

The ARBS used CalSim 3 (DWR, 2019) to analyze integrated surface water and groundwater uses, and regional and CVP-SWP system operations. CalSim 3 is a new and improved water resources planning model, jointly developed by Reclamation and DWR, to simulate operations of the SWP and the CVP and much of the water resources infrastructure in the Central Valley of California and the Delta region. It is the next generation of the CalSim-II model which was released in 2002 and has been used in various Central Valley water resources planning studies since then. CalSim 3's improvements and enhancements include:

- Improved geographical resolution, allowing improved representation of water supplies from mountain and foothill watersheds and more refined water budget calculations for the Valley Floor
- Land use-based and production-based, demand-driven operations for surface water and groundwater management
- Embedded linkage to a finite-element based groundwater module to simulate groundwater responses to streamflows and boundary stresses (e.g., boundary flows)
- Enhanced simulation of local water agency operations based on local and regional planning documents and input from local agencies
- Improved model transparency and documentation

Non-Federal Partners and other American River interests have conducted extensive, state-of-the-art modeling in the upper American River watershed, including flows and temperatures in the North and South Forks and tributary streams; alternatives for improving cold water pool management in Folsom Reservoir; and flow regimes and temperature plans for the Lower American River that optimize water supply reliability and resource protection. The ARIOps, a detailed operations model of the Middle and South Forks, was built on an OASIS model platform (Western Hydrologics, 2021) to support relicensing of PCWA's hydroelectric facilities and EDCWA's Alder Reservoir feasibility study and county-wide water management strategy development.

Under the ARBS, CalSim 3 representation of the upper watershed of the American River (North, Middle, and South Forks) was refined by mapping existing upper watershed ARIOps model into CalSim 3 (Figure 2-6). This included water management facilities owned and operated by Nevada Irrigation District, Pacific Gas and Electric (PG&E), PCWA, Sacramento Municipal Utility District (SMUD), and EID. ARIOps model domain is within the Foothills boundary. The ARIOps model was mapped into CalSim 3 to have a fully integrated model with upstream and the broader CVP/SWP system operations.

Figure 2-6 also shows the boundaries of the Water Budget Areas used in CalSim3. The Water Budget Areas are aggregates of several demand units that describe large regions with similar characteristics (e.g., climatic conditions). Key Water Budget Areas included within the study area include:

- WBA 22 - Natomas, Pleasant Grove
- WBA 23 - Camp Far West, Sutter
- WBA 24 - Lincoln, West Placer
- WBA 26N - Sacramento, North
- WBA 26S - Sacramento, South

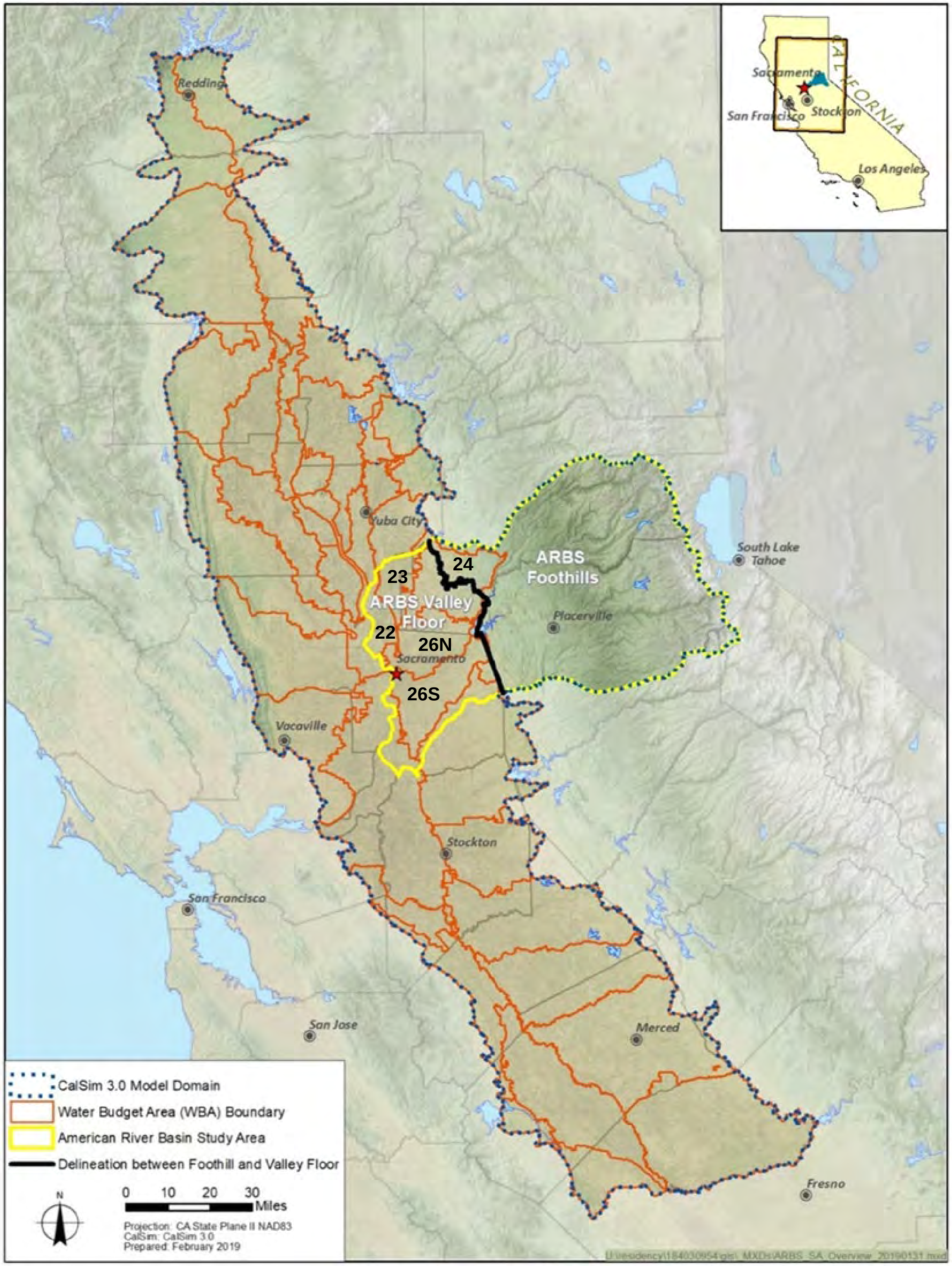


Figure 2-6. CalSim 3 model domain and its extension to represent reservoir operations and water deliveries in the Foothills and the Valley Floor.

2.5.2. Incorporating Effects of Sea Level Rise in CalSim 3

Determining flow-salinity relationships in the Delta is critical to both water project operations and ecosystem management. Operating the CVP and SWP facilities and management of Delta flows often depends on Delta flow needs for salinity standards. Salinity in the Delta cannot be simulated accurately by the simple mass balance routing at the monthly time step used in CalSim 3. CalSim 3 uses a built-in artificial neural network (ANN) to confirm that the operations of the upstream reservoirs and the Delta export pumps' operation satisfy specific salinity requirements in the Delta (Wilbur and Munévar, 2001). The ANN is trained to mimic the flow-salinity relationships as simulated in the detailed Delta hydrodynamic model (DSM2) to provide a rapid transformation of this information into a form usable by CalSim 3. The ANN implemented in for this analysis that reflects 45 centimeters (cm) of sea level rise was provided by DWR. This allows incorporation of the effect of sea level rise on the operations of CVP/SWP system to meet Delta water quality standards.

2.5.3. Water Temperature Models

To analyze water temperatures under future conditions and the effects of each adaptation portfolio, we used two models: the CE-QUAL-W2 Folsom Reservoir model and the Lower American River regression model.

2.5.3.1. Folsom Reservoir Temperature Model

ARBS used the CE-QUAL-W2 hydrodynamic and temperature model for Folsom Reservoir in conjunction with several regression models for the Lower American River that calculate daily average (and daily maximum) temperature. Water temperatures were modeled at representative locations along the Lower American River at Hazel Avenue, William B Pond Recreation Area, and Watt Avenue (Figure 2-7).

Figure 2-7. Location map for the Lower American River downstream of Folsom Dam.

The CE-QUAL-W2 code was modified to iteratively solve for the best down-river temperature schedule (Automated Temperature Schedule Procedure [ATSP]) that can be achieved by modifying the position of individual penstock shutters and the proportion of water going through each penstock of Folsom Dam under each year's hydrologic and meteorological conditions. The ATSP attempts to balance the seasonal use of Folsom Reservoir's cold-water availability and provides the best attainable temperature in the lower American to protect juvenile steelhead over-summer rearing while balancing the needs of fall-run Chinook salmon spawning. The code was also modified to iteratively set the elevation of the municipal intake on Folsom Dam to track a user-supplied water temperature in the reservoir and to operate the low-level outlets within a user supplied range of dates and maximum daily volumes. The low-level outlet operations allow access to cold water below the power penstock intake elevations similar to the low-level outlets' current operations.

2.5.3.2. Lower American River Water Temperature Regressions

To predict daily average water temperatures at specific locations, we developed a multiple regression equation for each location that related daily average water temperature at that location to daily average flow releases into the Lower American River, daily average water temperature of Folsom Dam releases, and daily local average air temperatures.

To predict daily average water temperature at any river mile on the Lower American River, the river mile water temperature regression included the river mile of each water temperature station (Hazel Avenue, William B. Pond, and Watt Avenue) in the dataset as an additional parameter. These regressions were used to calculate water temperatures in the Lower American River given outflow temperatures from Folsom Reservoir (CE-QUAL-W2 model) and each scenario's meteorological conditions.

2.5.3.3. Meteorological Data

Hourly historical meteorological data from the vicinity of Folsom Reservoir for the 1922-2015 model period were compiled from various nearby stations and, where appropriate, adjusted to match the Folsom Reservoir and American River local conditions. This historical meteorological dataset was then adjusted to reflect expected changes in air temperature and dew point temperature under future climate scenario.

2.5.3.4. Model Inflow Temperature Regressions

A multiple regression was developed to estimate North Fork American River inflow temperatures using daily air temperature, daily North Fork American River flow (above confluence with the Middle Fork), and daily Middle Fork American River flow.

Another multiple regression was developed to estimate South Fork American River inflow temperatures using daily air temperature and daily South Fork American River flow. These regressions were used in conjunction with the CalSim 3 hydrology and meteorological data to estimate daily average inflow temperatures to Folsom Reservoir.

2.6. Modeling the Existing Baseline and Future Climate Scenarios

ARBS analysis of climate change effects uses a fixed-period (or fixed level of development) approach. This approach evaluates the effects of future climate changes at pre-set point(s) in the future: 2050, 2070, and 2085. These three periods correspond to important milestones in the buildout conditions in the Valley Floor and Foothills. Note that the level of demands for 2050, 2070, and 2085 conditions are based on the socioeconomic scenario of current trend growth in population and development density (CTP-CTD) described in Section 2.2. *Future Socioeconomic Scenarios* (Table 2-1). Unlike the climate scenarios, which represent average conditions over a 30-year window around the targeted date, the level of development are projected demands for the specific targeted year.

To assess the effect of climate change on supply-demand imbalance in the study area, the following modeling scenarios were used (Figure 2-8):

- **Baseline climate scenario (historical conditions):** reflects the existing level of development (2015 demands) and historical climate and hydrological conditions. The ensemble-informed hybrid delta (HDe) methodology involves adjusting a dataset of observed historical precipitation and temperature to remove historical trends, then adjusting this de-trended dataset to reflect projected climate changes between a historical reference period and a selected future period. The de-trended observed historical dataset is referred to as the "baseline climate scenario" or "historical conditions." Future climate scenarios are based on this de-trended baseline climate scenario. While the HDe method does not reflect projected changes in the frequency, intensity, and duration of weather and climate extremes, it ensures that characteristics of weather and climate variability on daily to inter-decadal timescales is realistic and is not affected by limitations of GCMs.
    - **2050 future climate scenarios:** these five climate scenarios (WW, WD, CT, HW, and HD) reflect the projected level of development in 2050 from the CTP-CTD socioeconomic scenario and climate based on average forecasted conditions over the period 2035-2069.
    - **2070 future climate scenarios:** these five climate scenarios (WW, WD, CT, HW, and HD) reflect the projected level of development in 2070 from the CTP-CTD socioeconomic scenario and climate based on average forecasted conditions over the period 2055-2084.
    - **2085 future climate scenarios:** these five climate scenarios (WW, WD, CT, HW, and HD) reflect the projected level of development in 2085 from the CTP-CTD socioeconomic scenario and climate based on average forecasted conditions over the period 2070-2099.

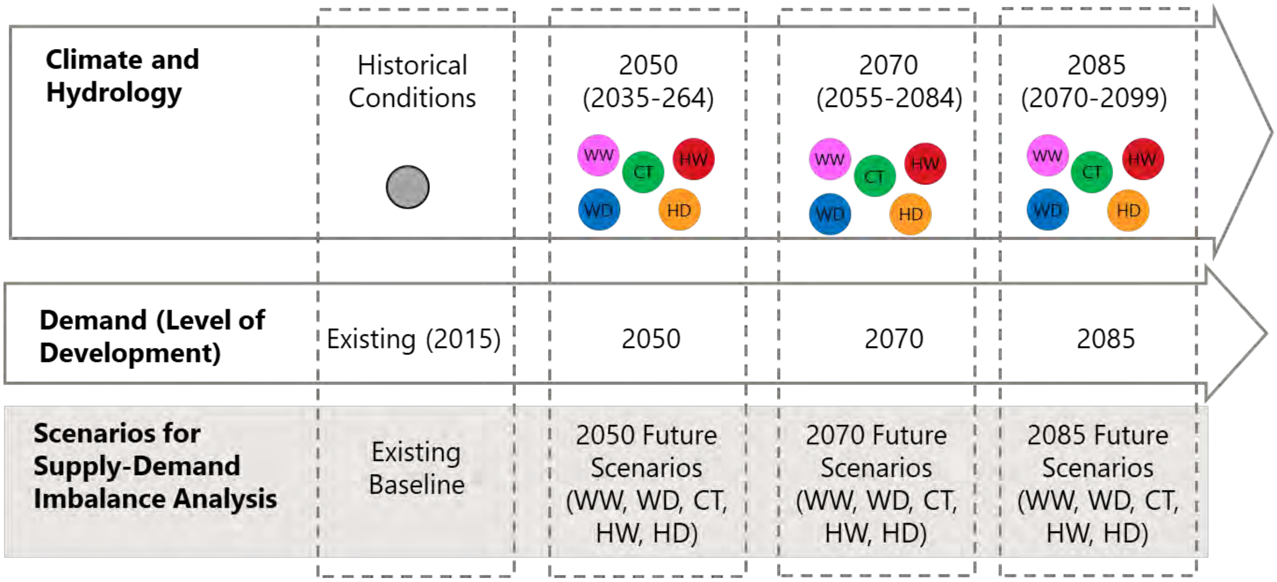


Figure 2-8. The developed 15 future climate scenarios for supply-demand imbalance analysis.

To assess how the formulated adaptation portfolios can address the effect of climate change, we selected a representative subset of three future climate scenarios (WW, CT, and HD) reflecting the projected level of development and the range of 2070 climate scenarios (based on average forecasted conditions over the period 2055-2084) to present in in this report (see Figure 2-9). See Appendix B. *Development of Future Climate and Hydrology Scenarios* for more detail. The 2070 climate scenarios were selected because 2070 represents an important milestone for build-out conditions in the study area, where most of Valley Floor and good portion of the Foothills are anticipated to reach build-out conditions. The WW and HD scenarios were selected as bookend conditions to represent the outer range of potential climate conditions. The WW scenario represent the lower end of warming conditions and high end of wet conditions. The HD scenario represent the high end of warming conditions and lower end of wet conditions (i.e., most dry conditions). The CT scenario represents the median conditions for warming and wet conditions.

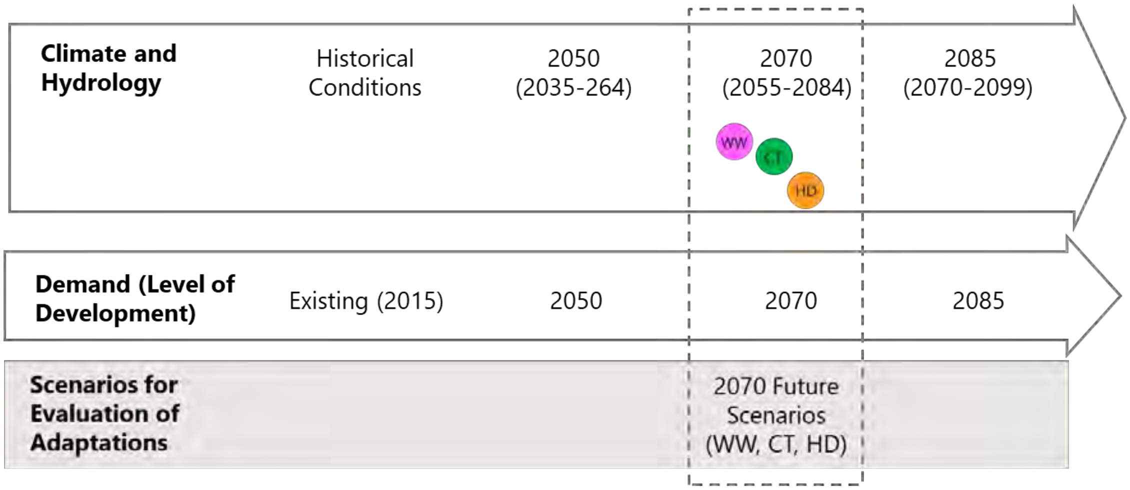


Figure 2-9. The selected three future climate scenarios for evaluation of adaptation portfolios.

Simulating the existing baseline and future climate scenarios using CalSim 3 requires two sets of model inputs:

- Urban and agricultural demand datasets
- Inflow dataset for rivers and streams

Development of the urban and agricultural demands is described in Chapter 3 and Appendix D. *Development of Urban and Agricultural Demands*.

The CalSim 3 inflow dataset is a monthly time series for 1922-2015. This dataset reflects historical conditions and capture the range of observed hydrologic variability. To capture the effects of future climate change, the VIC model was used to generate inflow timeseries for each of the 15 future climate scenarios: 2050 climate scenarios (WW, WD, CT, HW, and HD), 2070 climate scenarios (WW, WD, CT, HW, and HD), 2085 climate scenarios (WW, WD, CT, HW, and HD). Each future inflow time series reflects the 1922 to 2015 observed hydrologic variability and the effects of the corresponding climate change scenario (see Figure 2-10).

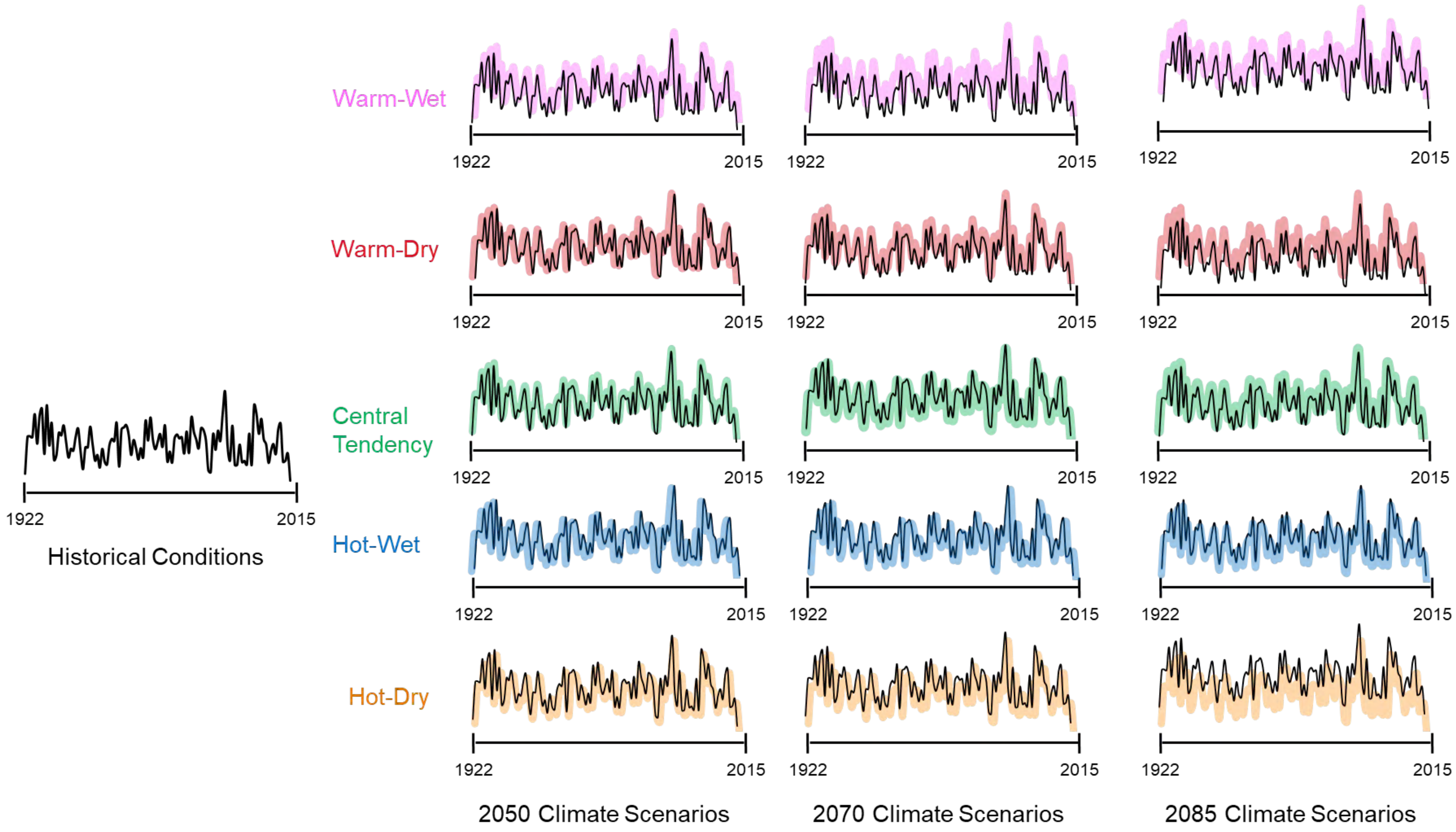


Figure 2-10. CalSim 3 inflow datasets used to model existing baseline (historical flows) and future climate scenarios (historical flows that have been pattern-adjusted for climate change effects).

Chapter 3. Water Supply and Demand Imbalances

To analyze present and future water supply vulnerabilities and then identify and evaluate adaptation measures and portfolios to address these vulnerabilities, first we must understand the water supply and demand imbalances throughout the study area. This chapter provides projected future demands, projected future water supplies, and the resulting supply and demand imbalances.

Imbalances occur when water demands cannot be met using available water supplies.

3.1. Projected Future Demands

The ARBS developed urban and agricultural demands to support evaluation of four planning horizons: existing (2015), 2050, 2070, and 2085 levels of development. Demand for the future horizons (2050, 2070, and 2085) reflect the socioeconomic scenario of current trend growth in population and development density (CTP-CTD). As described in Section 2.2. *Future Socioeconomic Scenarios,* this scenario best avoids over- or under-estimating future demands.

3.1.1. Water Demand Management

Water demand management improves water use efficiency for essential uses and curbing waste. This tactic reduces the identified water supply-demand imbalance. Regulatory actions and social awareness focus on managing water demands. However, it is important to recognize that implementing water conservation measures and managing demand does not always reduce total water use—which is also influenced by population growth and economic development. Water agencies in the American River Basin voluntarily took extraordinary conservation measures during dry conditions. The required drought resiliency for urban water users and additional new requirements for small water suppliers and rural communities can also affect the future water supply needs and required levels of service.

The ARBS incorporated the most updated information and actions for water demand management into all portfolios to evaluate.

As water demand management is ongoing in California, this tactic is incorporated into future projections and embedded in all formulated adaptation portfolios. See Section 5.2.2.1. *Common Foundational Measures.*

3.1.2. Projected Urban and Agricultural Demands

Projected future demands were based on agency-specific planning documents, SSJRBS (Reclamation, 2016), and the California Water Plan (DWR, 2018). These projections account for the effects of climate change on outdoor irrigation. Appendix D. *Development of Urban and Agricultural Demands* documents the methods and data sources used to develop the urban and agricultural water demands for the ARBS. It presents the estimated urban and agricultural water demands for each demand unit in the study area, including the Valley Floor and Foothills. While demands were developed for four planning horizons, supply-demand imbalance information is only presented for the existing baseline and three 2070 future climate scenarios (2070 WW, 2070 CT, and 2070 HD). These three future climate scenarios thus correspond to the 2070 build-out conditions for the Valley Floor.

Figure 3-1 presents urban water demands projections in the study area for each of the four planning horizons (existing [2015], 2050, 2070, and 2085). Modeling conducted under the ARBS assumes that in the Valley Floor, urban demands increase over time but level off by 2070, representing build-out conditions in the area. Urban demands in the Foothills increase under each sequential planning horizon.

Figure 3-2 shows the agricultural water demands projections in the study area for each of the four planning horizons (existing [2015], 2050, 2070, and 2085). In the Valley Floor, agricultural demands are projected to decrease over time but level off by 2070, representing the ongoing agricultural to urban land use conversion in the area. Agricultural demands in the Foothills increase under each sequential planning horizon, representing expansion of vineyards and other crops in previously undeveloped areas.

Figure 3-3 and Figure 3-4 show the decreasing trend of irrigated crop areas and agricultural water demands in the Valley Floor. Applied water for each irrigated acre increases with future climate change with increases in temperature and related evaporation. The magnitude of this applied water increase varies across the different future climate change scenarios.

Figure 3-5 compares existing and future urban and agricultural demands in the study area. Overall, urban demands increase—and agricultural demands decrease—as land use shifts from agricultural to urban uses. Urban demands increase from 42 percent of total water use in the study area to over 55 percent by 2085, with a corresponding reduction in agricultural water use (from 58 to 45 percent).

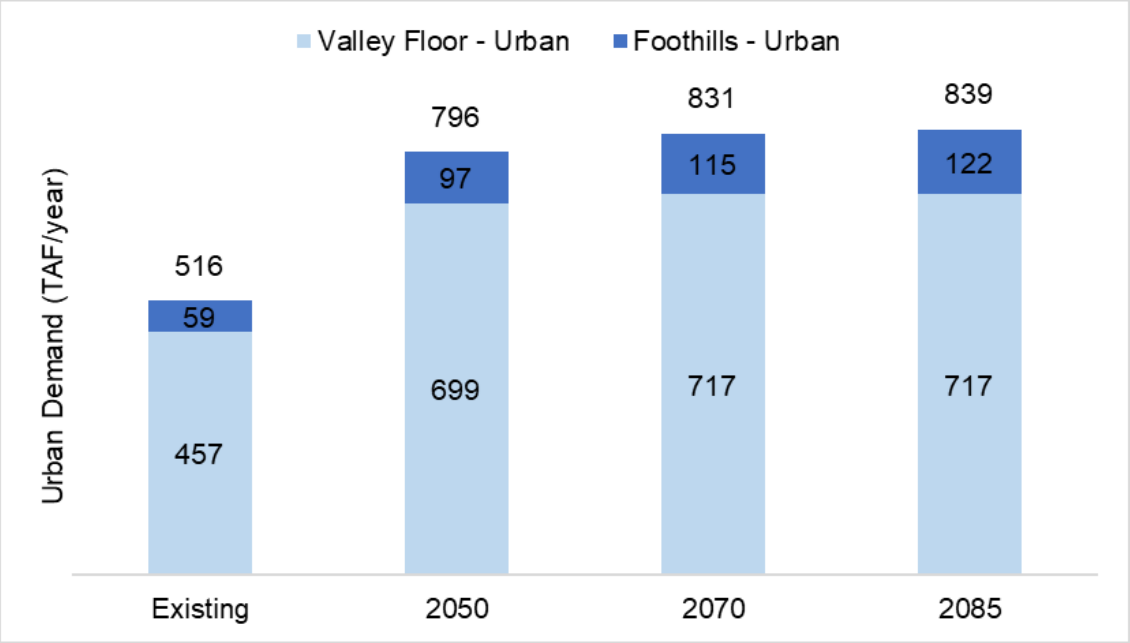


Figure 3-1. Urban water demand estimates (TAF/year) in the study area for existing (2015), 2050, 2070, and 2085 planning horizons.

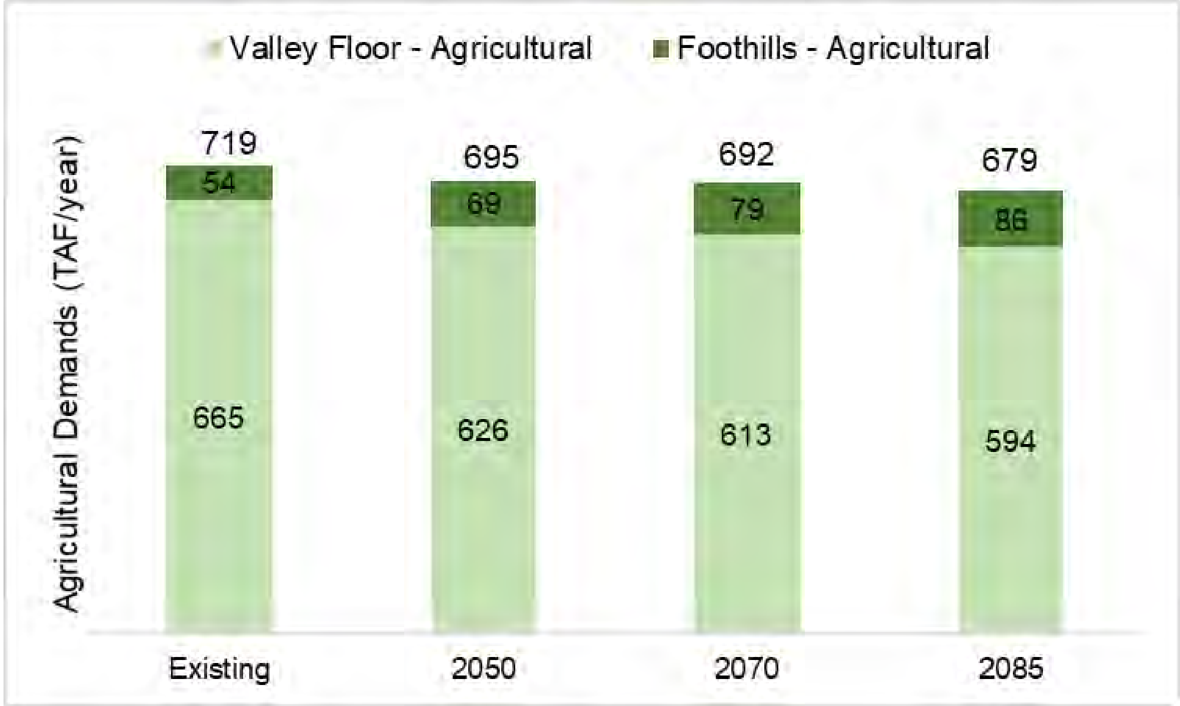


Figure 3-2. Agricultural water demand estimates (TAF/year) in the study area for the existing (2015), 2050, 2070, and 2085 planning horizons.

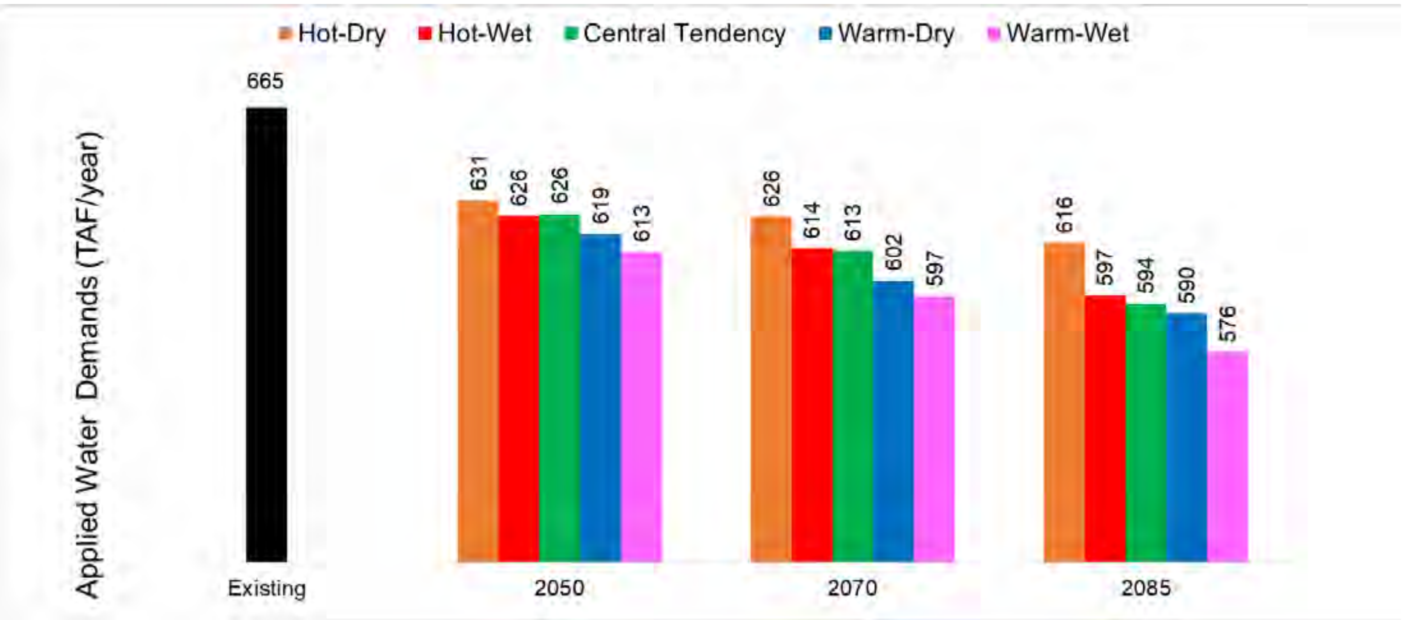


Figure 3-3. Agricultural applied water demand (TAF/year) in the Valley Floor for the existing baseline and future climate scenarios.

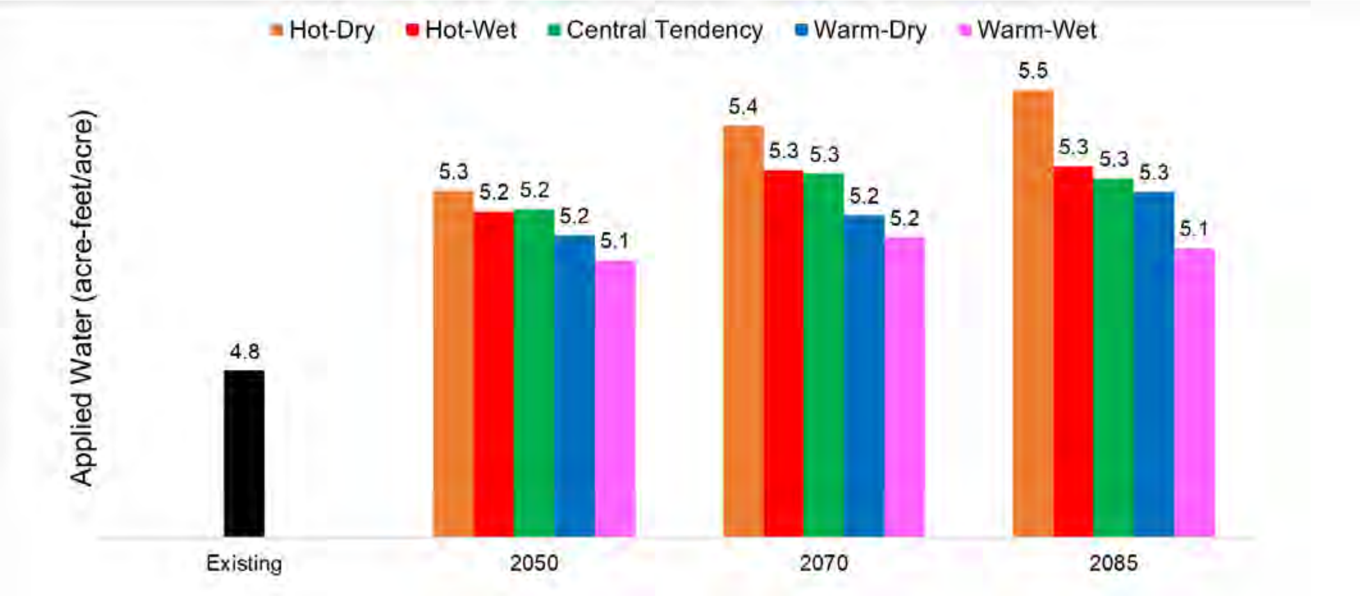


Figure 3-4. Agricultural applied water per irrigated acre (acre-feet/acre) in the Valley Floor for the existing baseline and future climate scenarios.

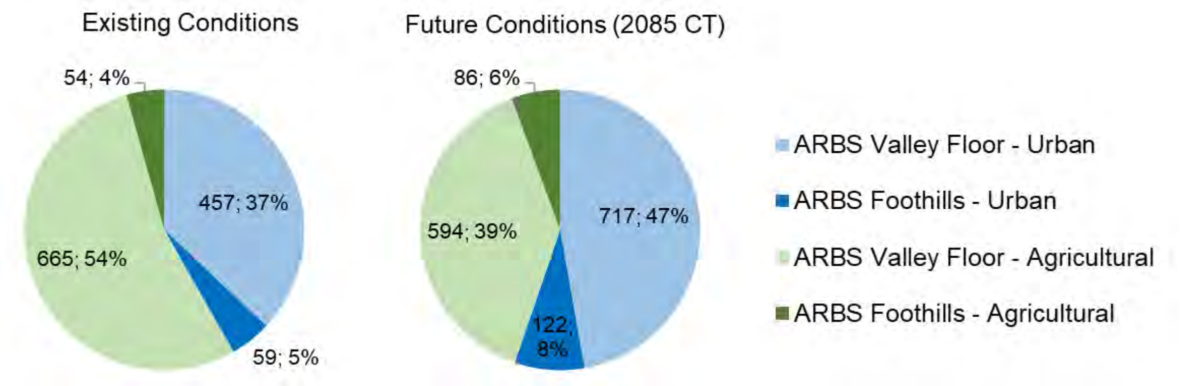


Figure 3-5. Comparison of existing and 2085 future urban and agricultural water demands in the study area (TAF/year and percentage of the whole).

3.2. Projected Future Water Supplies

This section provides a summary of recent historical and projected future water supplies in the study area for:

- Historical climate conditions
- Three 2070 climate scenarios (WW, CT, and HD).

Urban and agricultural water users in the study area relies on a mix of surface water and groundwater supplies, and some recycled water. However, recycled water is not covered in this analysis.

3.2.1. Total Unimpaired Runoff in the Study Area

Total unimpaired runoff in study area is defined as the full natural flow, or the volume of water that would run off into the basin if there were no water development projects. It encompasses inflow to the American, Bear, and Cosumnes Rivers, which are part of the study area (refer to Figure 1-1). Figure 3-6, Figure 3-7, and Figure 3-8 compare the annual volume of unimpaired runoff in the study area under the 2070 climate scenarios (WW, CT, and HD) to the historical conditions. Under both the 2070 CT and 2070 HD climate scenarios, the annual unimpaired runoff is projected to be lower than that under historical conditions. In the 2070 WW climate scenario, annual unimpaired runoff is projected to be higher than that under historical conditions.

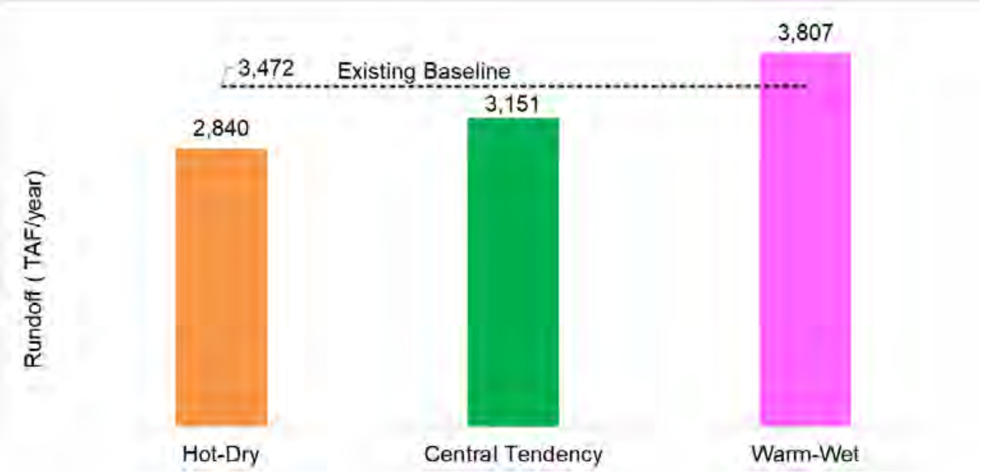
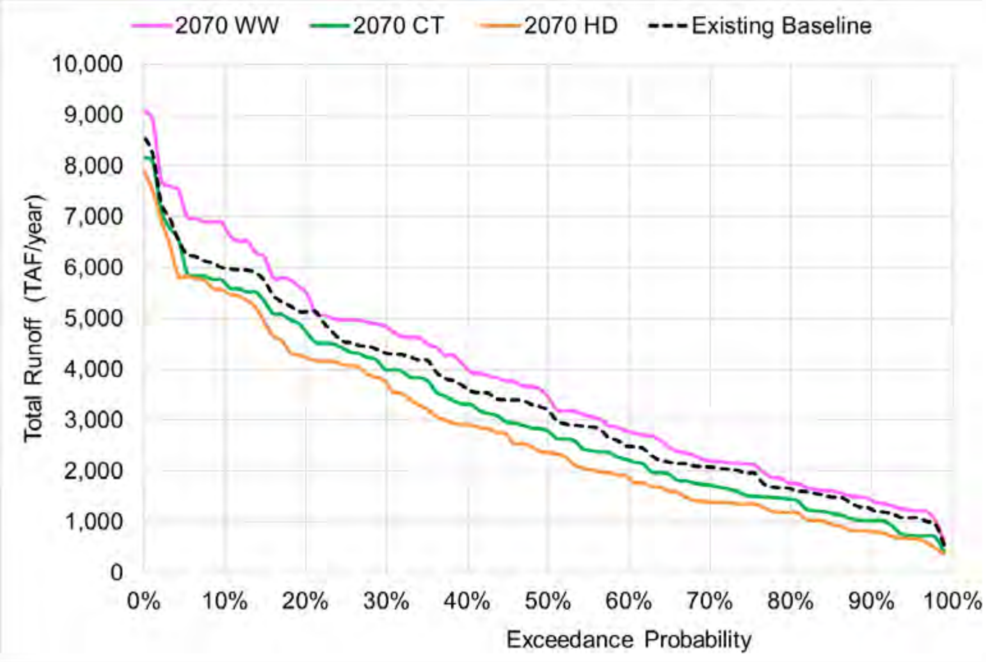


Figure 3-6. Annual average total unimpaired runoff in the study area under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.



The exceedance probability curve gives the probability (on the x-axis) that a value shown on the vertical axis (y axis) will be equaled or exceeded.

Figure 3-7. Exceedance plot of total unimpaired runoff in study area under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

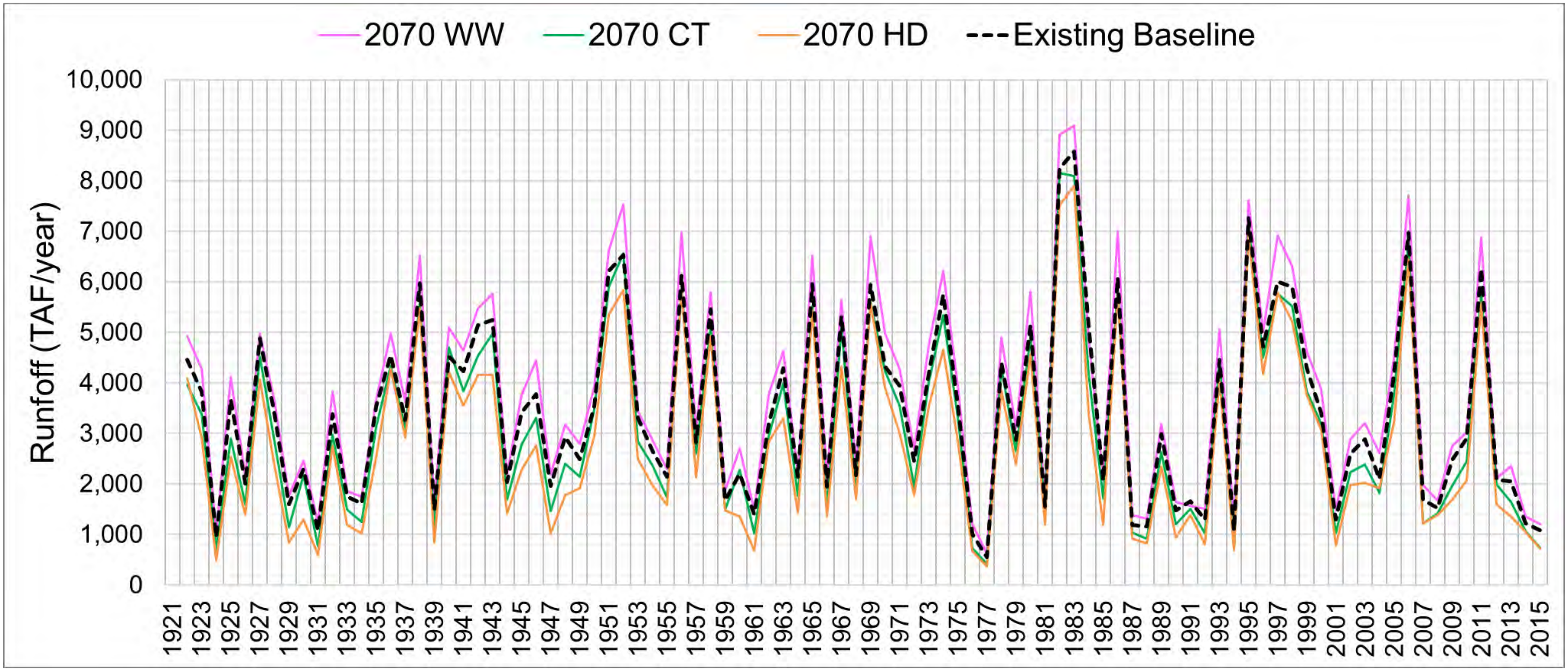


Figure 3-8. Timeseries of total unimpaired runoff in the study area under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

3.2.2. Pattern and Timing of Runoff

Figure 3-9 shows monthly runoff patterns in the study area under the 2070 climate scenarios (WW, CT, and HD) compared to the historical conditions. There is a pronounced shift in the distribution of runoff from March to May to earlier in the season (December to March)—implying a shift in precipitation from snow to rainfall and/or earlier snowmelt.

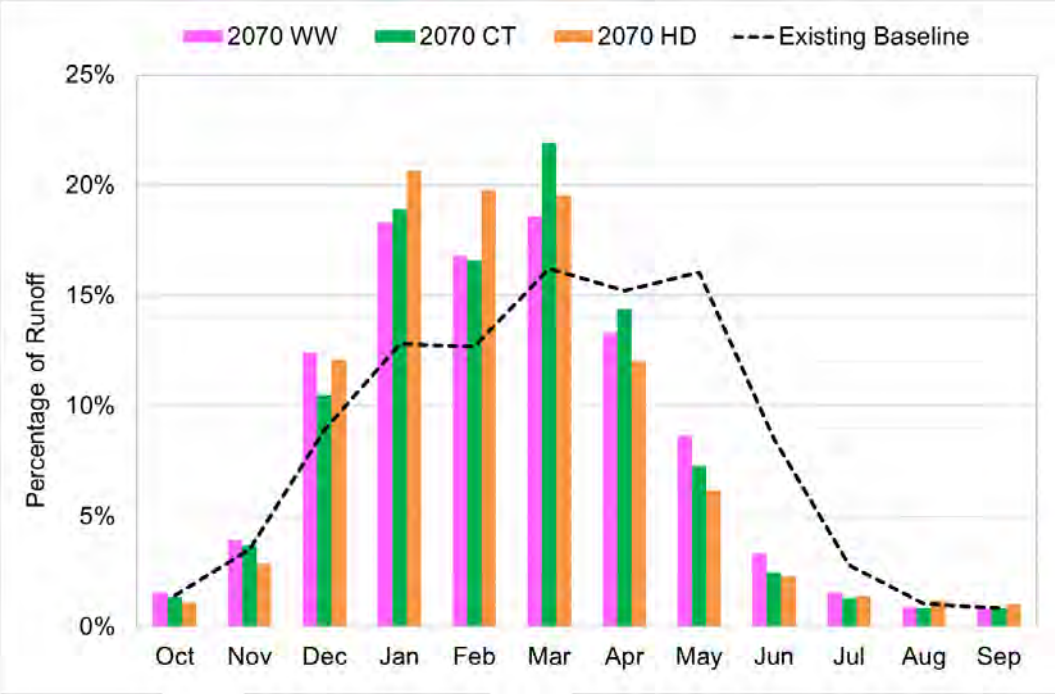


Figure 3-9. Monthly distribution of total unimpaired runoff in the study area for all elevations under the 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

Figure 3-10 shows the projected earlier timing of runoff into Folsom Reservoir and consequences of that earlier runoff in 2050. Figure 3-11 through Figure 3-13 show the pattern of monthly unimpaired runoff for the 2070 climate scenarios (WW, CT, and HD) compared to the historical conditions. These figures show the pattern of runoff in the study area at lower elevations (below 3,000 feet), intermediate elevations (3,000 to 5,000 feet), and higher elevations (above 5,000 feet), respectively. Shifts in the timing of peak runoff vary with elevation:

- **Lower elevations** (below 3,000 feet) are dominated by rainfall and generally exhibit a less pronounced shift than in higher elevations, where the runoff pattern is historically more sensitive to snowpack accumulation. The shift in runoff patterns for lower elevations is shown on Figure 3-11.
- In **intermediate elevations** (3,000 to 5,000 feet) and **higher elevations** (above 5,000 feet), runoff is dominated by snowpack and, therefore, shows a more pronounced shift in the timing than runoff in lower elevations. The peak runoff generally shifts from spring to winter—and this shift becomes more prominent with increasing climate temperatures. Figure 3-12 and Figure 3-13 show the shift in runoff pattern for intermediate and higher elevations, respectively.

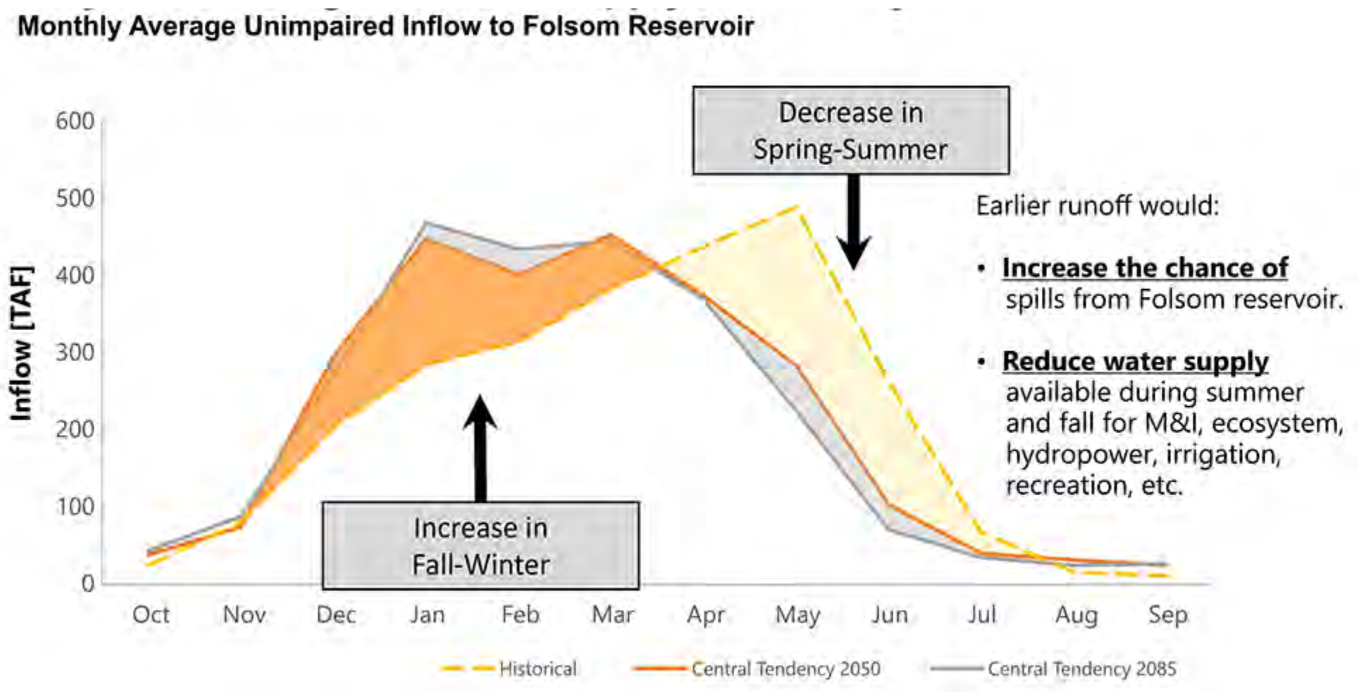


Figure 3-10. Changes and consequences from earlier runoff.

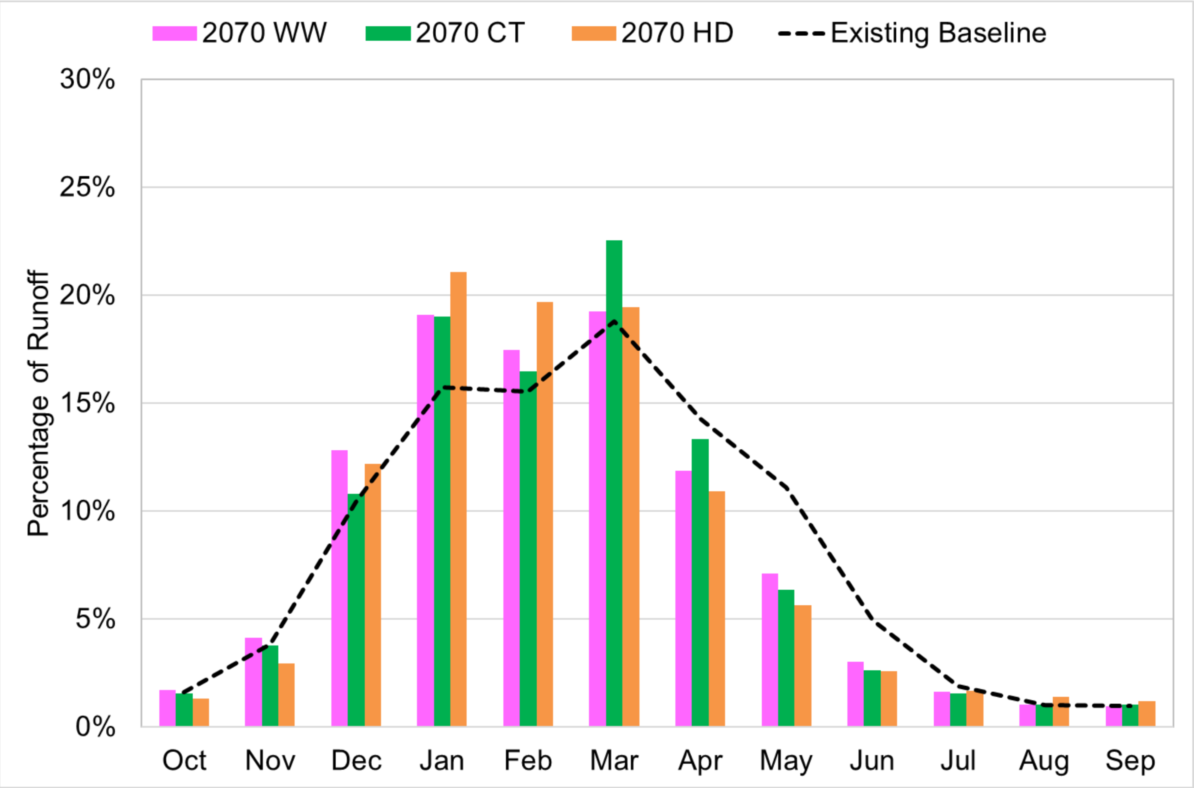


Figure 3-11. Monthly distribution of total unimpaired runoff in the study area for elevations less than 3,000 feet under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

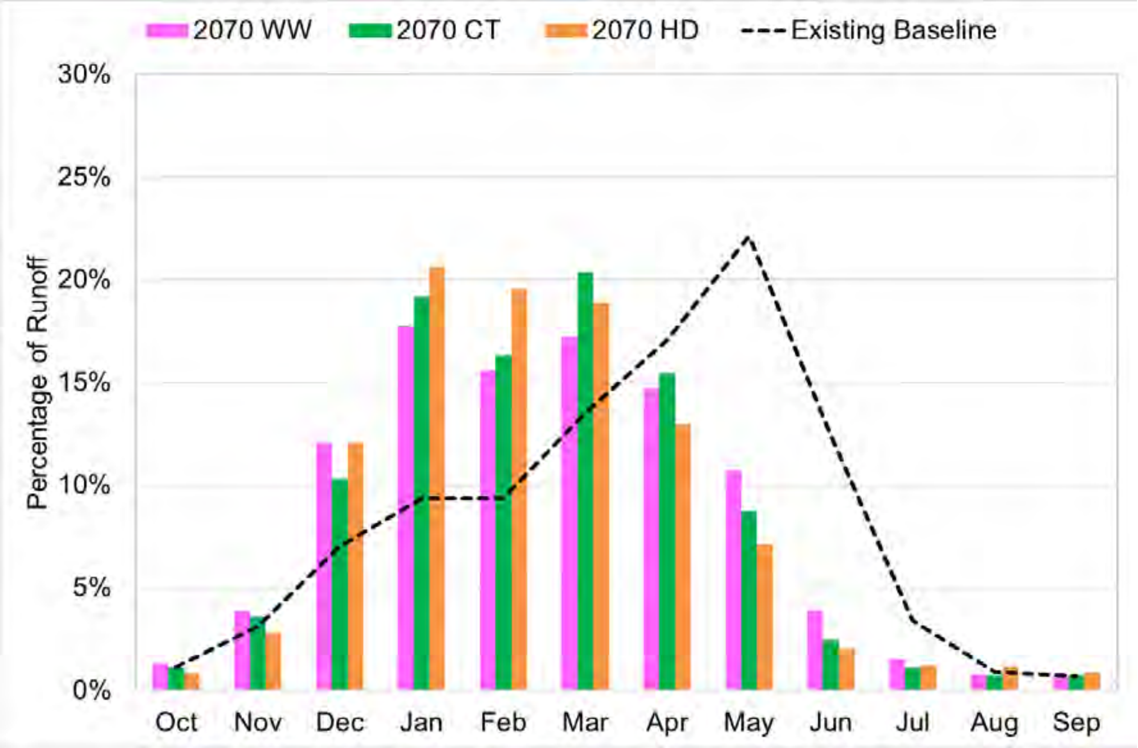


Figure 3-12. Monthly distribution of total unimpaired runoff in the study area for elevations between 3,000 and 5,000 feet under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

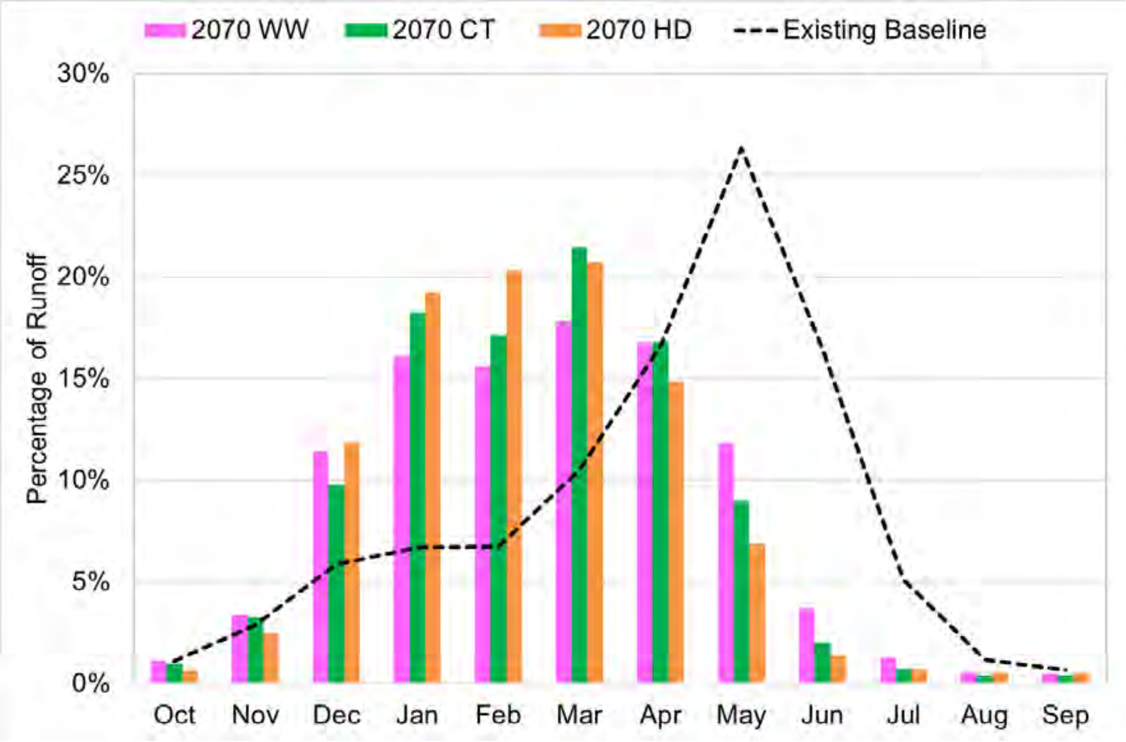


Figure 3-13. Monthly distribution of total unimpaired runoff in study area for elevations greater than 5,000 feet under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

3.2.3. Unimpaired Inflow to Folsom Reservoir

Annual unimpaired inflow to Folsom Reservoir is a portion of the total unimpaired runoff in the study area occurring between October 1st to September 30th (see Figure 3-14). Figure 3-15 and Figure 3-16 show that unimpaired inflow to Folsom Reservoir is lower than historical conditions under the 2070 CT and 2070 HD future climate scenarios. Unimpaired inflow to Folsom Reservoir is projected to be higher than historical conditions. under the 2070 WW future climate scenario. This change in unimpaired inflow to Folsom Reservoir is consistent with the observed pattern for total unimpaired runoff in the study area (Figure 3-6 and Figure 3-7).

Unimpaired runoff/inflow is the full natural flow, or the volume of water that would be observed if no water development projects had been constructed.

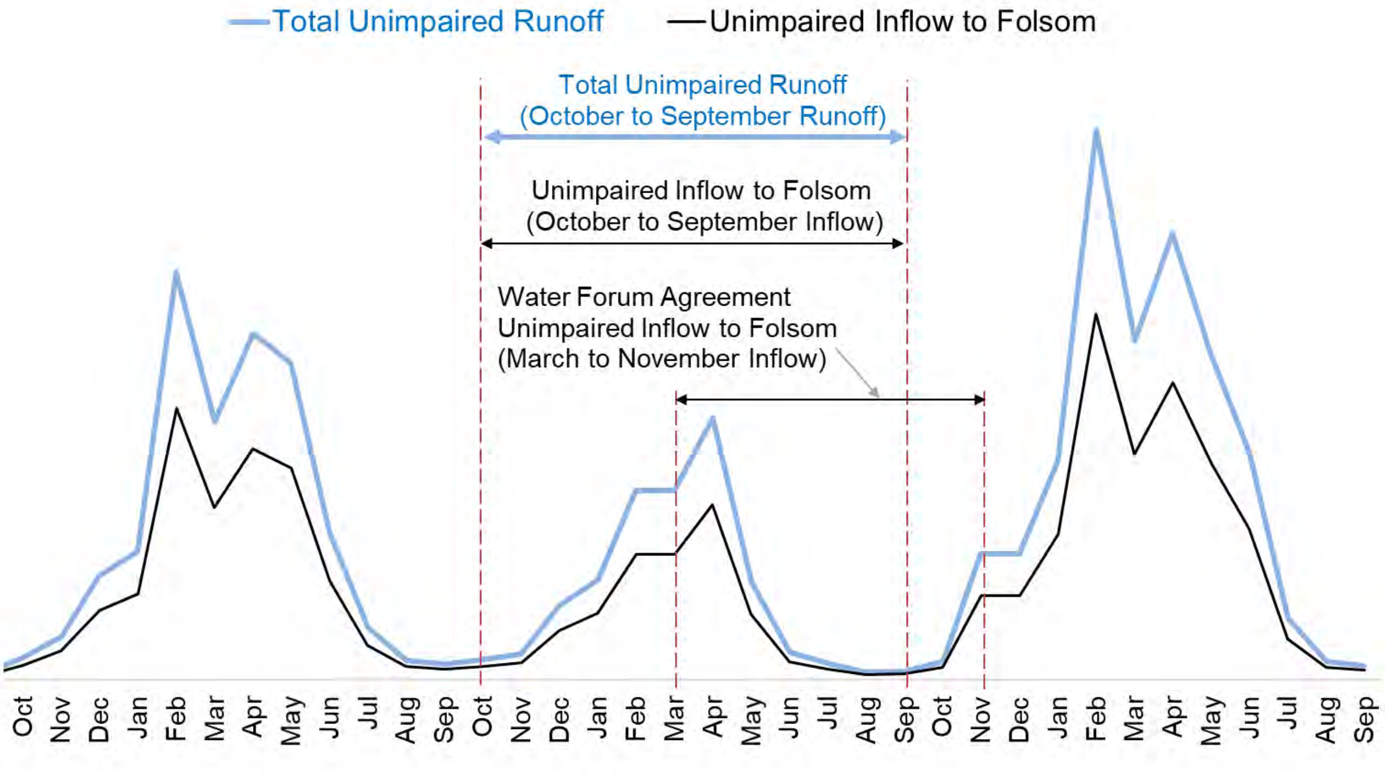


Figure 3-14. Comparison of total unimpaired runoff, unimpaired inflow to Folsom Reservoir, and Water Forum Agreement unimpaired inflow to Folsom Reservoir.

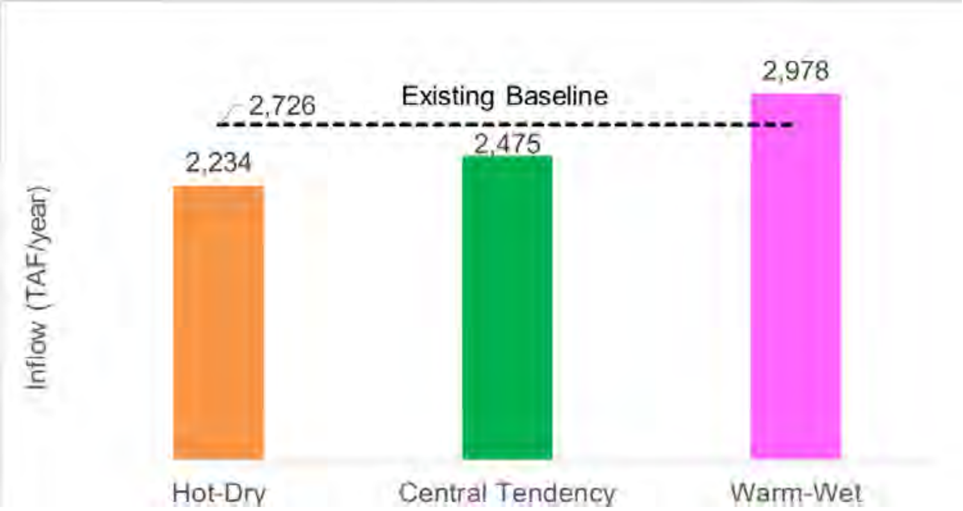


Figure 3-15. Average annual unimpaired inflow to Folsom Reservoir (October to September) under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

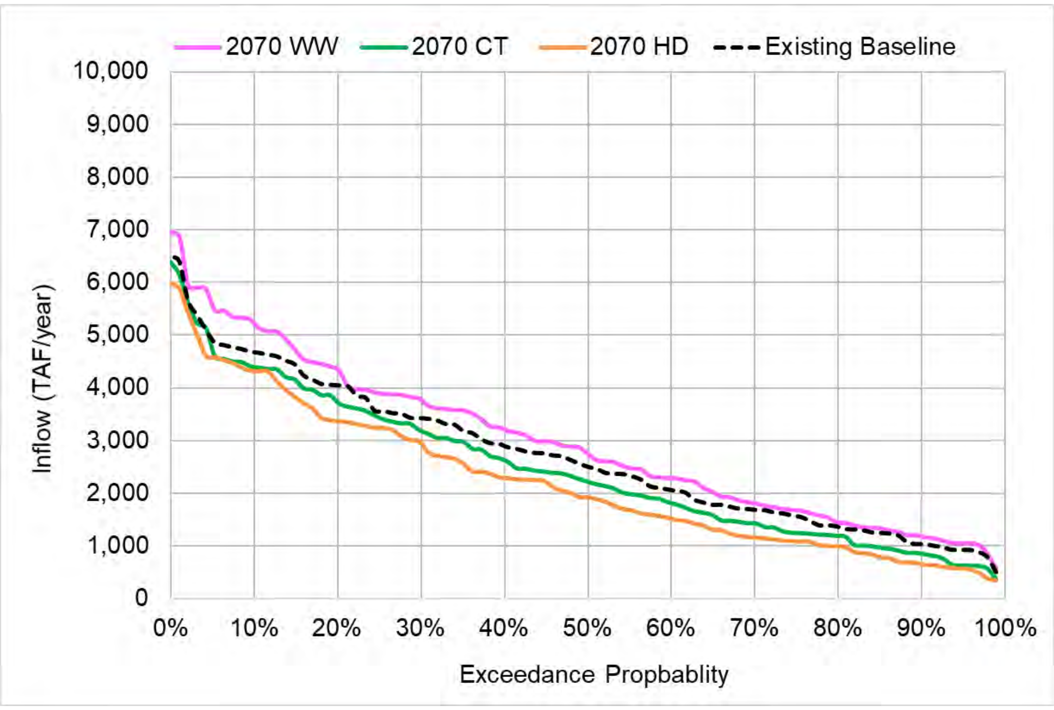


Figure 3-16. Exceedance plot of unimpaired inflow to Folsom Reservoir (October to September) under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

3.2.4. Frequency of Water Forum Agreement Water Year Types

The Water Forum Agreement (WFA) uses an index that represents water availability over a broad range of hydrologic conditions based on the March through November unimpaired inflow to Folsom Reservoir (UIFR) (see Figure 3-14). Each year’s hydrologic condition is classified a WFA year types using this index (Sacramento Water Forum, 2015a). This classification system is an important factor in determining surface water availability for water agencies in the American River Basin. The water year types include:

- **Driest (Conference) Years**: years when March-November UIFR is less than 400 TAF, and water supplies are inadequate to achieve baseline amounts for all purveyors
- **Dry (Wedge) Years**: years when March-November UIFR is greater than 400 TAF and less than 950 TAF
- **Average (Hodge) Years**: years when March-November UIFR is greater than 950 TAF and less than 1,600 TAF
- **Wet Years**: years when March-November UIFR is greater than 1,600 TAF

Figure 3-17 shows that the March-November UIFR decreases under the 2070 climate scenarios compared to the Baseline historical conditions. Unlike the October-September UIFR (Figure 3-15), the March-November UIFR under the 2070 WW Climate Scenario is projected to be less than under historical conditions. This can be attributed to the shift in spring runoff from the March-May period to the December-March period (Figure 3-9). A similar trend is also seen in Figure 3-18 and Figure 3-18.

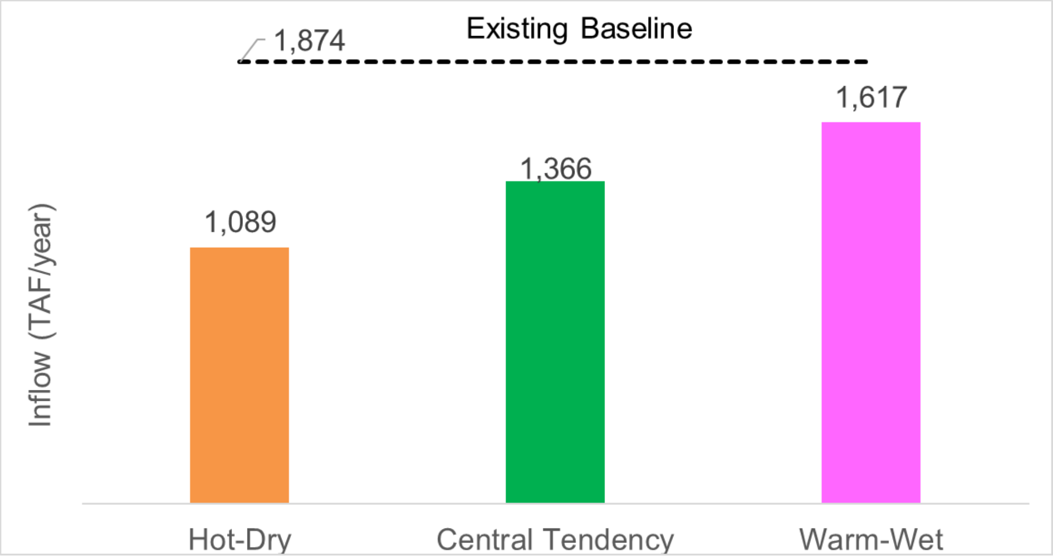


Figure 3-17. March to November unimpaired inflow to Folsom Reservoir under the 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

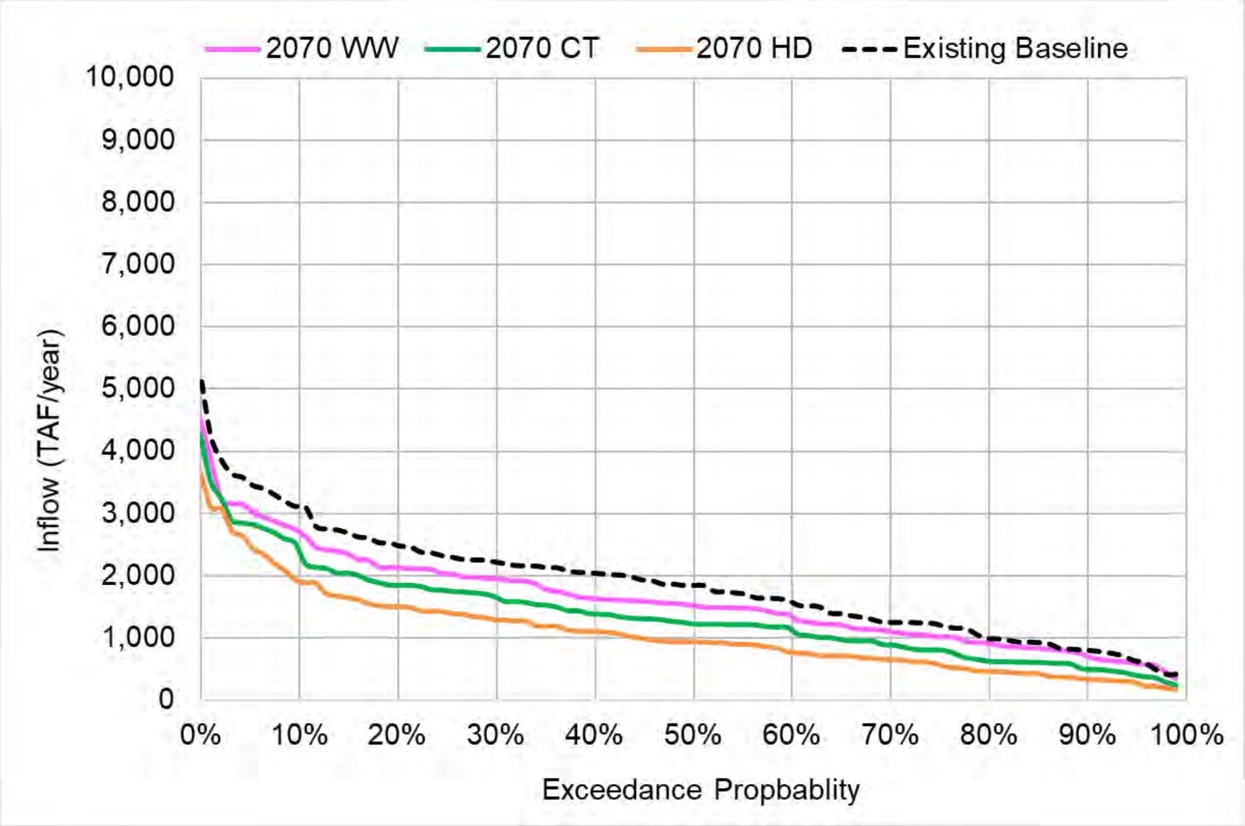


Figure 3-18. Exceedance plot of March to November unimpaired inflow to Folsom Reservoir under the 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

Table 3-1. Distribution of Water Forum Agreement Water Year Types Under 2070 Future Climate Scenarios (WW, CT, and HD) Compared to the Existing Baseline

WFA Water Year Type	Description	Existing Baseline	2070 Warm-Wet	2070 Central Tendency	2070 Hot-Dry
Driest (Conference Year)	Less than 400 TAF	2%	2%	5%	17%
Drier (Wedge Year)	Greater than 400 TAF and less than 950 TAF	19%	19%	33%	41%
Average (Hodge Year)	Greater than 950 TAF and less than 1,600 TAF	27%	32%	36%	30%
Wet (No Restrictions)	Greater than 1,600 TAF	52%	47%	26%	12%

3.3. Current and Future Water Budget Analysis

This section provides a quantitative evaluation of the water budget and supply-demand imbalance in the study area for the existing baseline, and 2070 future climate scenarios (WW, CT, and HD).

3.3.1. Analysis Approach

CalSim 3 demand units and associated water demands are classified as agricultural, urban, or managed wetlands. All agricultural water demands are land-use based; thus land-use data must be developed for each agricultural demand unit. Urban water demands are either population-based or derived from recent historical production data. Demands for managed wetlands are land-use based, although some demands are subsequently adjusted to match contract amounts.

Surface runoff varies with precipitation, land cover, and soil type. Surface runoff is calculated for each demand unit and aggregated to the spatial scale of the Water Budget Area (Figure 2-7). Water users in the study area rely on the seasonal melting of substantial mountain snow to augment groundwater stores. Some of this runoff is stored in Folsom Reservoir and released in summer when demands are highest, while balancing flood control operations and conservation storage management. Under drought conditions, runoff volumes are significantly reduced and demands far exceed runoff and storage—resulting in supply-demand imbalances. These imbalances may result in tradeoffs between competing demands. For example, in Driest (Conference) years, the WFA may ask diverters to reduce diversions to keep water instream for recreation and fishery benefits.

In CalSim 3, if demands cannot be met by surface water, groundwater is used to meet demands, and the model assumes that unlimited groundwater pumping is available to meet most demand units in the Valley Floor. Historically, groundwater has been used as backup supply in the Valley Floor. However, this can lead to groundwater overdraft conditions. Therefore, supply-demand imbalances in the Valley Floor may be higher than forecasted. Other factors that need to be considered are the purveyor-specific contracts, overdraft conditions, and groundwater regulations that may limit the capacity of a water purveyor to use groundwater as a reliable source of supply to bridge supply-demand imbalances. Note that there is limited groundwater in the Foothills that could be used as a supplemental water supply source.

3.3.2. Water Budget Analysis for the Valley Floor

Table 3-2 shows the long-term average[1] water budget analysis for the Valley Floor for the existing baselines and 2070 future climate scenarios (WW, CT, and HD). See Section 2.3. *Future Climate Scenarios* for the evaluation of future climate scenarios.

Imbalances (i.e., demands that cannot be met by surface water or groundwater) are highlighted by red negative numbers. Both surface water and groundwater use are projected to increase to satisfy increased future demands to the extent possible.

Under all the climate scenarios, both the urban and agriculture sectors show imbalances—with a greater supply demand imbalance in the 2070 HD baseline than in the 2070 CT and 2070 WW baselines.

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[1] [1] Long-term averages are averages over the full CalSim 3 simulation period (1922-2015).

There is no imbalance under existing conditions for the urban sector, and the agricultural sector imbalance is small compared to overall demands. Note that this small imbalance represents a long-term average, as some years may have higher or lower water shortages, depending on hydrologic conditions.

Figure 3-19 summarizes the long-term average water budget from the baseline scenario and future climate scenarios in 2070. This graph shows the X axis line at zero, where there is no imbalance and supply equals demand. Negative bars show imbalances where demands are greater than supply. See Section 2.3 for the evaluation of future climate scenarios.

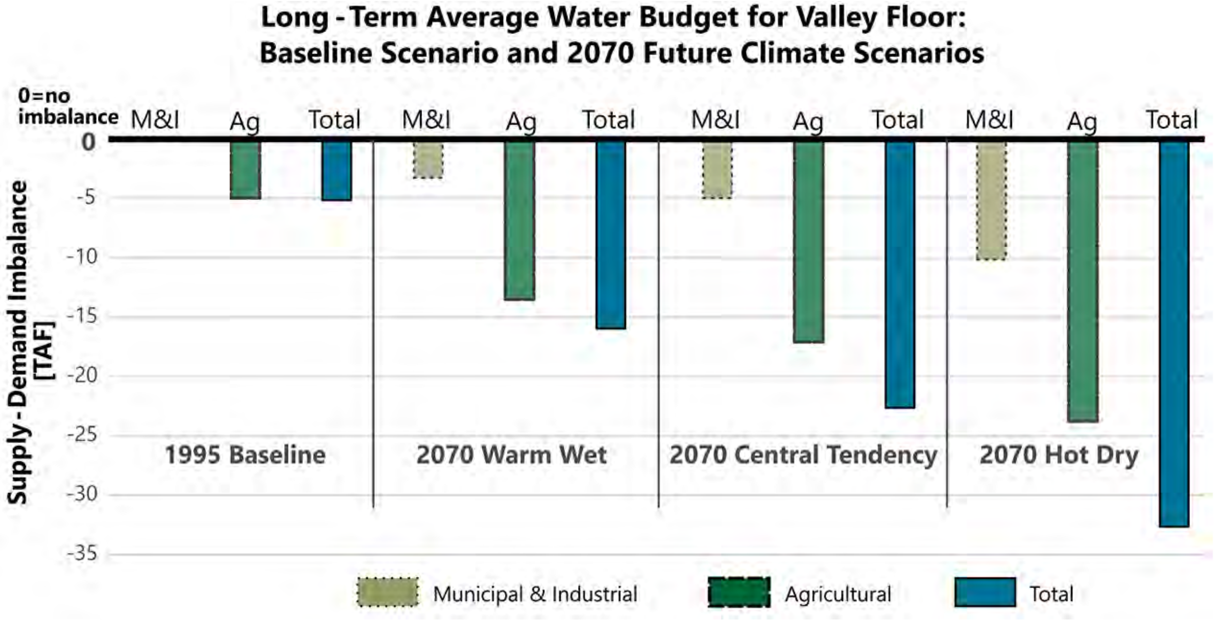


Figure 3-19. Long-term average water budget for the Valley Floor: Baseline Scenario and 2070 future climate scenarios.

Table 3-2 through Table 3-4 show urban and agricultural demands that can be met by available surface water and groundwater supplies. Table 3-3 shows the water budget under dry conditions (represented by the hydrologic patterns from the 1976-1977, corresponding to WFA's Driest [Conference] year conditions). During dry periods, surface water supply is limited by hydrology, water storage infrastructure, and CVP water service contract shortage policies. These limitations often result in using more groundwater. For regions with limited or no access to groundwater, such limitations can result in a supply-demand imbalance.

Table 3-4 shows the water budget under wet conditions (represented by the hydrologic patterns from the 1978-1983, corresponding to WFA's Wet [No Restrictions] year conditions). During the wettest periods, surface water supplies are generally not hydrologically limited. Compared to dry periods, more surface water supplies are used to satisfy demands, resulting in less reliance on groundwater.

Table 3-2. Long-Term Average Water Budget (TAF/year) for the Valley Floor for the Existing Baseline and 2070 Future Climate Scenarios

Baseline/Scenario	Type	Total Demand	Demand Met by Surface Water	Demand Met by Groundwater	Imbalance
Existing	Urban	484	329	155	0
	Agriculture	583	300	279	-5
	Total	**1,067**	**629**	**434**	**-5**
2070 WW	Urban	742	491	249	-3
	Agriculture	538	265	261	-13
	Total	**1,280**	**756**	**510**	**-16**
2070 CT	Urban	759	532	222	-5
	Agriculture	521	263	242	-17
	Total	**1,280**	**795**	**464**	**-22**
2070 HD	Urban	784	505	270	-10
	Agriculture	551	255	274	-23
	Total	**1,335**	**760**	**544**	**-33**

Table 3-3. Dry Period[1] Average Water Budget (TAF/year) for the Valley Floor for the Existing Baseline and 2070 Future Climate Scenarios

Baseline/Scenario	Type	Total Demand	Demand Met by Surface Water	Demand Met by Groundwater	Imbalance
Existing	Urban	484	307	177	-1
	Agriculture	598	275	317	-6
	Total	**1,082**	**582**	**494**	**-7**
2070 WW	Urban	759	494	246	-19
	Agriculture	525	242	261	-22
	Total	**1,284**	**736**	**507**	**-41**
2070 CT	Urban	742	385	337	-21
	Agriculture	552	216	316	-21
	Total	**1,294**	**601**	**653**	**-42**
2070 HD	Urban	784	345	395	-45
	Agriculture	560	201	339	-22
	Total	**1,344**	**546**	**734**	**-67**

[1]. Represented by the hydrologic patterns from the 1976-1977, corresponding to WFA’s driest/Conference year.

Table 3-4. Wet Period[1] Average Water Budget (TAF/year) for the Valley Floor for the Existing Baseline and 2070 Future Climate Scenarios

Baseline/Scenario	Type	Total Demand	Demand Met by Surface Water	Demand Met by Groundwater	Imbalance
Existing	Urban	487	360	127	0
	Agriculture	572	348	220	-4
	Total	**1,059**	**708**	**347**	**-4**
2070 WW	Urban	760	569	189	-2
	Agriculture	509	289	217	-3
	Total	**1,269**	**858**	**406**	**-5**
2070 CT	Urban	743	534	201	-8
	Agriculture	525	300	222	-3
	Total	**1,268**	**834**	**423**	**-11**
2070 HD	Urban	788	562	219	-7
	Agriculture	536	274	259	-3
	Total	**1,324**	**836**	**478**	**-10**

[1]. Represented by the hydrologic patterns from the 1978-1983, corresponding to WFA's Wet year.

3.3.3. Water Budget Analysis for Foothills

This section describes the budget analysis for the Foothills under the existing baseline and 2070 future climate scenarios (HD, CT, and WW). See Section 2.3. *Future Climate Scenarios* for the evaluation of future climate scenarios. Demands in the Foothills are projected to rapidly increase and outpace the availability of surface water supplies in the region, without new infrastructure to develop additional surface water supplies. Along with increased urban populations, agricultural demands in the Foothills (predominantly in El Dorado County) are expected to increase as additional lands are brought into cultivation, consistent with the current trend of expanding vineyards and orchards.

Table 3-5 through Table 3-7 show urban and agricultural demands that can be met by available surface water and groundwater supplies. These show average, dry, and wet periods as described in Section 3.2.2. *Water Budget Analysis for Valley Floor*. As shown in Table 3-5, the Foothills is projected to have higher supply-demand imbalances than the Valley Floor. The more pronounced imbalances in the Foothills can be attributed to:

- lack of regional groundwater resources due to topography and subsurface geology,
- limited storage infrastructure, and
- limited contractual water assets.

Figure 3-20 summarizes the long-term average water budget. This graph shows the X axis line at zero, where there is no imbalance and supply equals demand. Negative bars show imbalances where demands are greater than supply. See Section 2.3 for the evaluation of future climate scenarios.

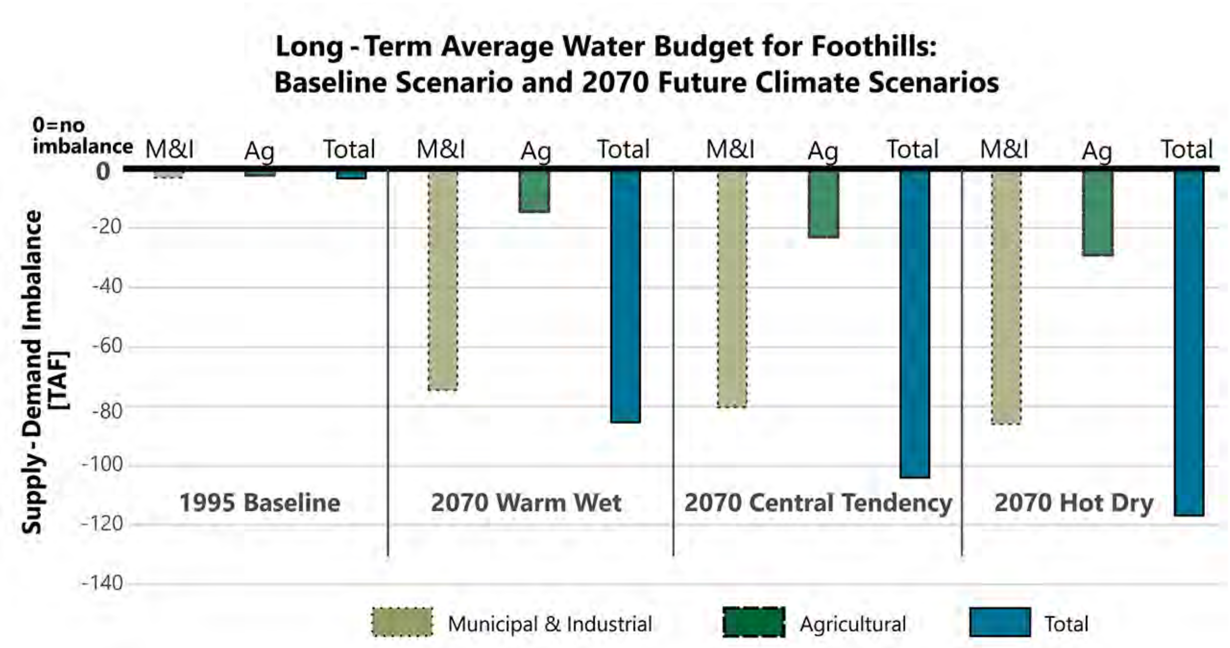


Figure 3-20. Long-term average water budget for Foothills: Baseline Scenario and 2070 future climate scenarios.

In the Foothills, increased demands would be met with corresponding (and insufficient) increases in surface water uses, as no groundwater is available (Table 3-5). There are relatively few imbalances under the existing baseline, and considerably more pronounced supply-demand imbalances under all 2070 future climate scenarios, where only around 50 percent of total demands can be met. These imbalances are a result of demand increases, consistent with the build-out plan in the El Dorado County general plan, and limited infrastructure to capture and develop additional water supplies.

Table 3-6 shows the water budget under dry conditions (represented by the hydrologic patterns from the 1976-1977, corresponding to WFA's Driest Conference year conditions) would have demands exceeding supplies by around 64 percent.

Table 3-5. Long-Term Average Water Budget for the Foothills Floor (TAF/year) for the Existing Baseline and 2070 Future Climate Scenarios

Baseline/Scenario	Type	Total Demand	Demand Met by Surface Water	Demand Met by Groundwater	Imbalance
Existing	Urban	57	55	0	-2
	Agriculture	46	44	1	-1
	Total	**103**	**99**	**1**	**-3**
2070 WW	Urban	136	64	0	-72
	Agriculture	66	51	1	-14
	Total	**202**	**115**	**1**	**-86**
2070 CT	Urban	141	61	0	-80
	Agriculture	71	47	1	-23
	Total	**212**	**108**	**1**	**-103**
2070 HD	Urban	147	59	0	-88
	Agriculture	76	46	1	-29
	Total	**223**	**105**	**1**	**-117**

Table 3-6. Dry Period[1] Average Water Budget for the Foothills (TAF/year) for the Existing Baseline and 2070 Future Climate Scenarios

Baseline/Scenario	Type	Total Demand	Demand Met by Surface Water	Demand Met by Groundwater	Imbalance
Existing	Urban	57	53	0	-4
	Agriculture	47	32	1	-14
	Total	**104**	**85**	**1**	**-18**
2070 WW	Urban	136	59	0	-77
	Agriculture	65	33	1	-31
	Total	**201**	**92**	**1**	**-108**
2070 CT	Urban	141	51	0	-90
	Agriculture	74	30	1	-43
	Total	**215**	**81**	**1**	**-133**
2070 HD	Urban	147	49	0	-98
	Agriculture	78	33	1	-44
	Total	**225**	**82**	**1**	**-142**

[1]. Represented by the hydrologic patterns from the 1976-1977, corresponding to WFA’s driest/Conference year.

Table 3-7. Wet Period[1] Average Water Budget for the Foothills (TAF/year) for the Existing Baseline and 2070 Future Climate Scenarios

Baseline/Scenario	Type	Total Demand	Demand Met by Surface Water	Demand Met by Groundwater	Imbalance
Existing	Urban	57	56	0	-1
	Agriculture	43	43	1	-1
	Total	**100**	**99**	**1**	**-2**
2070 WW	Urban	136	70	0	-66
	Agriculture	63	53	1	-10
	Total	**199**	**123**	**1**	**-76**
2070 CT	Urban	141	64	0	-77
	Agriculture	67	50	1	-16
	Total	**220**	**114**	**1**	**-93**
2070 HD	Urban	147	61	0	-86
	Agriculture	73	50	1	-22
	Total	**220**	**114**	**1**	**-108**

[1] Represented by the hydrologic patterns from the 1978-1983, corresponding to WFA's Wet year.

Chapter 4. Risk and Vulnerability Assessment

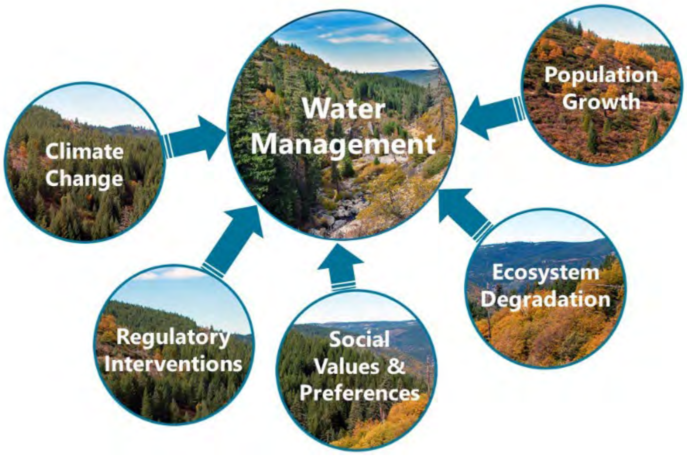
This chapter describes the regional water management stressors that affect the water supply-demand imbalance and identifies key regional water management vulnerabilities.

The region's water supply reliability is vulnerable to projected changes in climate and increases in demands.

4.1. Regional Water Management Stressors

Water managers in the American River Basin continue to experience a growing imbalance between water demands and supply due to a variety of factors (stressors). Major stressors are:

- Climate change
- Population growth
- Regulatory interventions
- Ecosystem degradation
- Changes in social values and preferences



4.1.1. Climate Change

The SSJRBS concluded that the potential effects of projected climate change have introduced significant uncertainty in the Basin's long-term water supply reliability. Folsom Reservoir has a limited capacity and cannot store all the watershed's precipitation. The water system relies on seasonal snowpack for a large portion of the storage needed to regulate runoff. Changing climate conditions in the Sierra Nevada Mountains threaten to reduce the volume of water stored in the snowpack and to shift the timing of runoff entering Folsom Reservoir. Consequently, future climate conditions can also affect the critical role of Folsom Reservoir in CVP operations to satisfy Delta flow, quality standards, and other requirements such as protecting endangered fishery species. This reliance on Folsom Reservoir is expected to increase as sea level rises increase the salinity in the Delta. Modeling these factors has illustrated that, without operational adjustments, Folsom Reservoir is projected to have lower average storage levels that would approach the level where there is no access to the municipal water intake[1] more often under 2070 CT and HD future climate scenarios (see Figure 4-1 and Figure 4-2).

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[1] Full pumping capacity at Folsom Dam is at reservoir water surface (RWS) elevation 340 feet (111 TAF) and above; reduced pumping is possible between elevations 340 feet and 310 feet (55 TAF). Below 310 feet, no pumping or deliveries can be made, although releases to the river could continue until Folsom Lake levels approach 1 TAF.

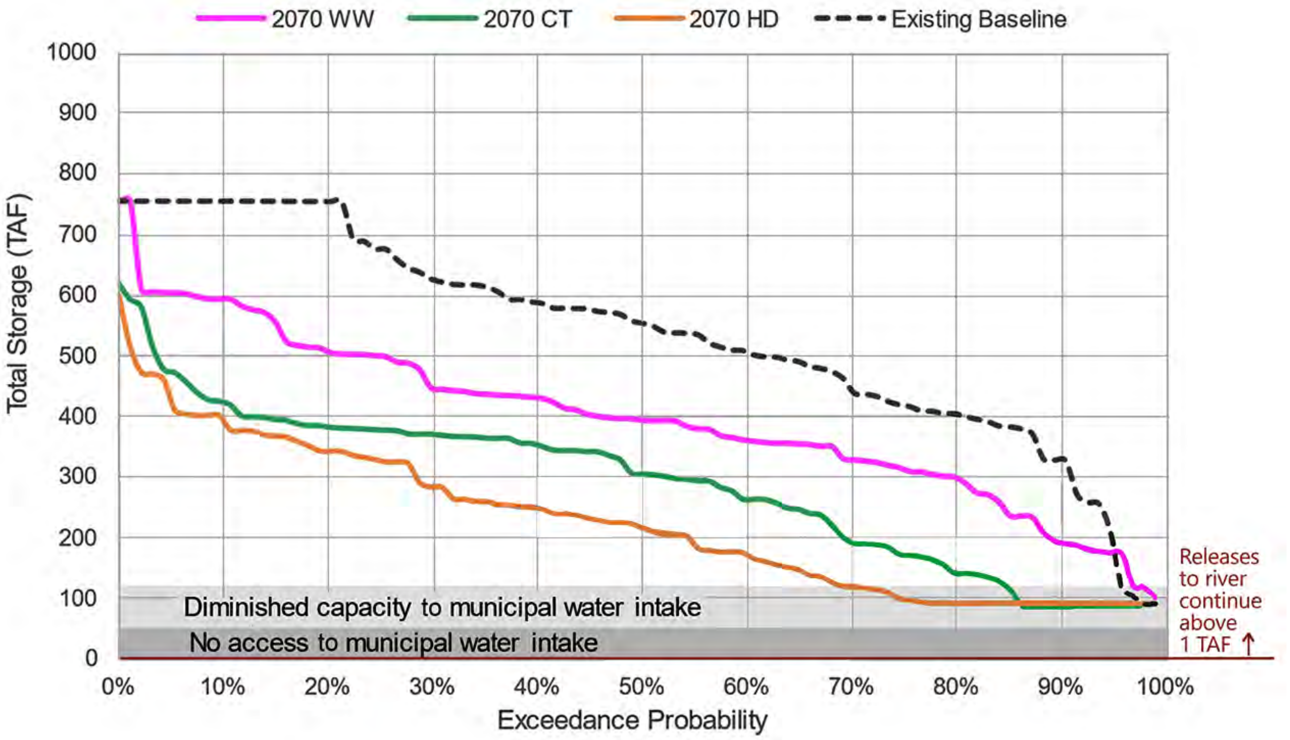

Figure 4-1. Exceedance plot of Folsom Reservoir end-of-September storage under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

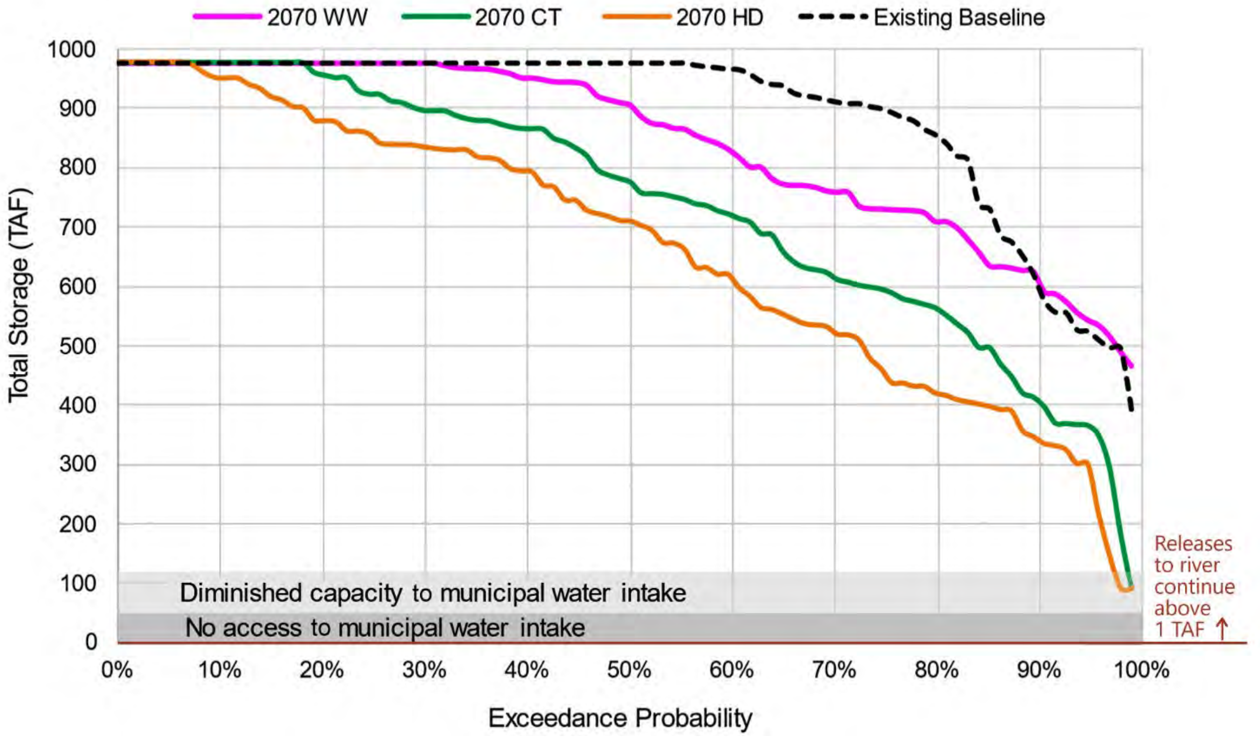

Figure 4-2. Exceedance plot of Folsom Reservoir end-of-May storage under 2070 future climate scenarios (WW, CT, and HD) compared to the existing baseline.

4.1.2. Population Growth

The Sacramento region (Sacramento, Yolo, El Dorado, and Placer Counties) is expected to grow by one million people, or nearly 50 percent, over the next 20 years (Sacramento Area Council of Governments, 2016). This is consistent with the socioeconomic scenario of current trend growth in population and development density (CTP-CTD) (as described in Section 2.2. *Future Socioeconomic Scenarios* and Table 2-1). Currently, a large portion of the region's water demand is from the residential sector (single family and multifamily households). While the average amount of water used per person (expressed as gallons per capita per day [GPCD]) has steadily declined (from 280 to 180 GPCD) over the last decade and half, the sheer number of new residents has the potential to increase water use in this sector overall (Figure 4-3).
Per-person water use includes both residential indoor and outdoor water use. Between 50 to 65 percent of residential water use is outdoor use (U.S. Environmental Protection Agency [EPA], 2013).

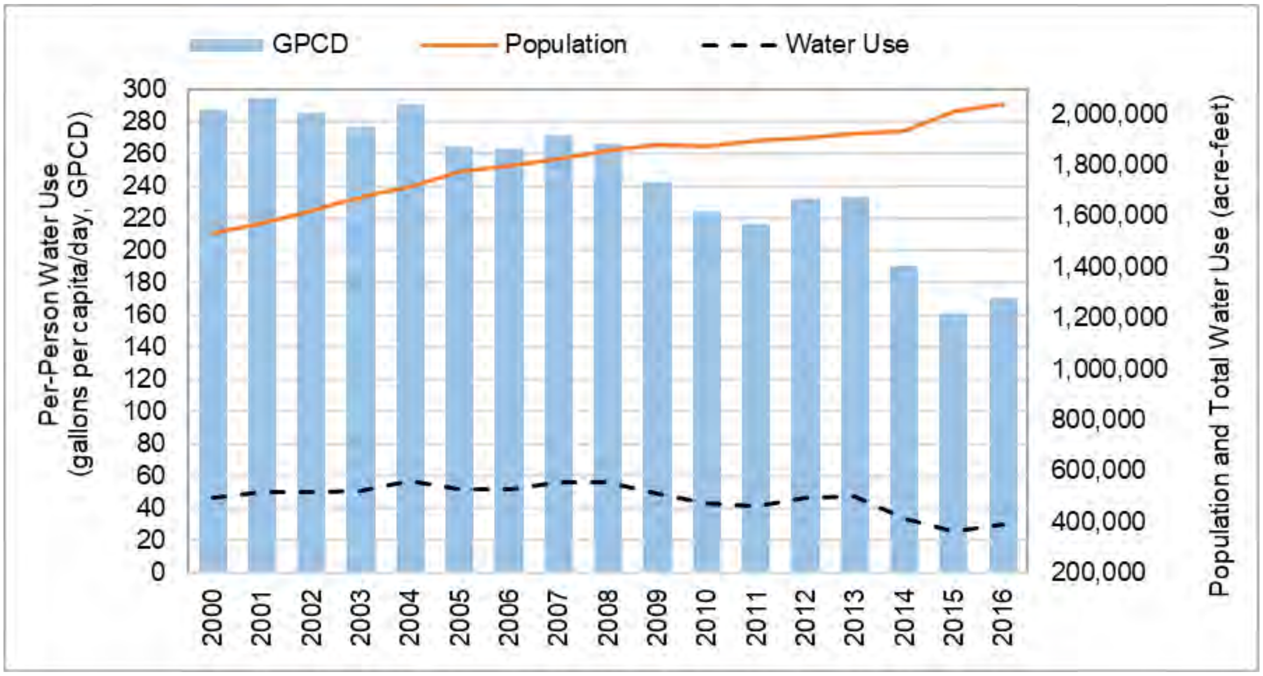

Figure 4-3. Population, total water use, and per-person water use in the Sacramento Region.

The impact on water demand and reliability will largely depend on how and where these future residents settle into the region. For example, if the region grows with more compact, denser development patterns (transit-oriented, multifamily units), there will be fewer, smaller individual household landscape areas—which would lower GPCD demands. However, if most of the future residents choose to settle in more traditional, larger single-family lots, outdoor water uses and, therefore, GPCD demands could remain the same or increase. Most likely, future residential development will be a mixture of more compact, denser development as well as traditional and larger lot households. As for residential indoor use, recent past and current efficiency gains from fixtures such as toilets and showerheads will wane over time (unless new more efficient fixture standards are adopted) as older fixtures have been exchanged for efficient fixtures. In addition to residential water use, new residents will also need schools, government services, and commercial services such as restaurants and grocery stores—which will also impact future water demand and, therefore, future water reliability.

4.1.3. Ecosystem Degradation

Ecosystem degradation of the American River is another stressor on water management in the region. To develop a balanced approach for water supply reliability and environmental protection along the Lower American River, regional entities joined together as the Water Forum to guide development of a regional solution and negotiated the WFA. This diverse group; including business and agricultural leaders, environmentalists, citizen groups, water managers, and local government; found that without acting, the region was looking at a future of water shortages, environmental degradation, contamination, threats to groundwater reliability and limits to economic prosperity. Through this landmark agreement signed in 2000, the Water Forum implements projects aimed at protecting the Lower American River and the region's water supply. The Water Forum's two coequal objectives are to:

- Provide a reliable and safe water supply for the region's economic health and planned development through to the year 2030[1]
- Preserve the fishery, wildlife, recreational, and aesthetic values of the Lower American River.

Despite these efforts, the Lower American River ecosystem remains vulnerable, and its fisheries are stressed. The Lower American River is home to two anadromous salmonid species: Central Valley steelhead and fall-run Chinook salmon. Only a few hundred steelhead spawn annually in the Lower American River, and in 1998, the Federal government listed steelhead as a threatened species. Fall-run Chinook salmon populations have been at historical lows in the past decade (California Department of Fish and Wildlife, 2015). Conditions in the Lower American River are often unhealthy for these anadromous fish due to high water temperatures.

In addition, groundwater overdraft conditions in the Consumes and South American groundwater basins have severed hydraulic connectivity between the groundwater aquifer and the Consumes River. This has resulted in the Cosumnes River, an important tributary to the Delta, going dry during the summer months.

4.1.4. Social Values and Preferences

Social values are the most important aspects of a social system and play a predominant role in establishing the norms and expectations in the society. As a society, this region values water highly for a range of economic, environmental, social, recreational, and cultural benefits—which at times conflict with each other.

While efforts such as the WAF have helped to balance social values and preferences, balancing values will continue to be a stressor—especially when extreme hydrologic conditions occur. For example, during the recent drought, environmental flows statewide were drastically cut to ensure sufficient water for human use and consumption. Adequate emergency response preparations for each of these social values is important as future hydrological extremes arise.

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[1] The Water Forum Agreement signatories are currently negotiating the extension of the agreement.

4.1.5. Regulatory Interventions

The State and Federal governments have issued regulations throughout California's history to manage the often conflicting and limited uses of water. For example, the 2014 Sustainable Groundwater Management Act (SGMA) requires governments and water agencies of high and medium priority basins to halt overdraft and bring groundwater basins into balanced levels of pumping and recharge. The study area includes two primary, high priority groundwater basins: North American groundwater basin and South American groundwater basin. This affects how groundwater will be used and managed in the region.

Curtailments are another example of regulatory interventions under emergency conditions. When there is insufficient water available to meet all the demand in a watershed, water right holders, starting with the most junior, are ordered to cease diverting surface water to protect the rights of more senior right holders. The State Water Resources Control Board uses these curtailments as a tool to help with the overall administration of the State's water rights system. Upon notice of curtailment, the water rights holder must immediately reduce or stop taking water according to the terms of the curtailment. Curtailment notices are generally rare in the region as water rights here are mostly senior. However, during the recent drought, curtailments were issued on rights with seniority dating back to the early 1900s, the first time these senior rights were curtailed. Notably, Carmichael Water District, which has a 1915 date on its water right, was curtailed in both 2014 and 2015. The City of Sacramento also experienced a curtailment of its Sacramento River water right, which is dated 1920 (Permit 992 (A1743, March 30, 1920) for diversion of up to 225 cfs, up to 81,800 AF per year, from the Sacramento River for service within the city limits).[1]

4.2. Regional Water Management Vulnerabilities

The abovementioned stressors affect water supply reliability and lead to various vulnerabilities throughout the study area. Vulnerabilities are associated with features of a water system that are susceptible to droughts, climate change, and other factors—resulting in the inability to meet intended uses of water. Vulnerabilities could be influenced by external factors or internal factors. They could also be physical (structural deficiencies or improvement needs), operational, or institutional (contractual, policy, and/or administrative issues) in nature. Vulnerabilities that are affected by external factors are those that individual agencies and the region have less control over, such as the climate, State-mandated water supply curtailments, or changing Federal and State regulations and policies. Agencies have more control or influence on local factors.

4.2.1. Vulnerability Pathways

Vulnerability pathways are how and why the vulnerabilities exist in a region. Key ARBS vulnerability pathways are shown in Figure 4-4 and discussed in this section.

Vulnerabilities are physical, operational, or institutional threats to a water system that could result in temporary, long-term, or even permanent loss of supplies necessary to meet water demands.

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[1] Note that City of Sacramento has other rights to use water from both the American and Sacramento Rivers, including a permanent water rights settlement contract with Reclamation (signed June 28, 1957) that governs the availability of its American River water rights.

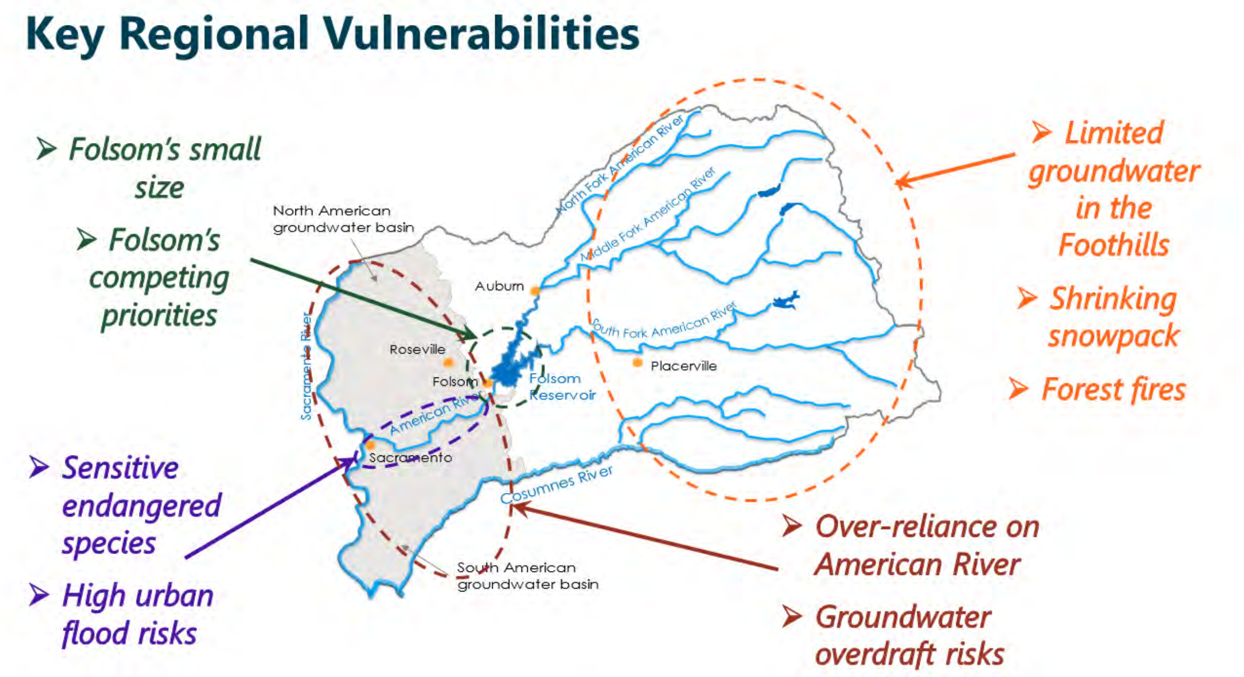

Figure 4-4. Map of key vulnerabilities.

4.2.1.1. Folsom Reservoir Storage Capacity

Folsom Reservoir's storage capacity is relatively small when compared with annual American River watershed runoff. After a severe drought, Folsom Reservoir reached record low levels in December 2015. Three months later in March 2016, after several moderate El Niño storms, Reclamation followed flood control release requirements. This operational inflexibility creates an inability to store runoff due to the reservoir's small size limits the region's ability to store surface water. This pathway is particularly important under climate change, where runoff is projected to occur earlier—and snowpack will not be a storage option. Earlier runoff further reduces the amount of water that can be stored following the flood risk management operations season. Earlier runoff may be compensated for in part by shifting the operational curves governing Folsom operations. Nevertheless, more precipitation in the form of rain rather than snow would increase the frequency of spills from Folsom Reservoir—affecting available storage for water supply.

4.2.1.2. Heavy Dependance on the American River

Basin-wide water supply heavily depends on one river, especially in the North American Groundwater basin. While the American River is part of the Sacramento River watershed, hydrological conditions for flow on the American River are not necessary the same for flows on the Sacramento River. Therefore, dry conditions on the American River do not necessarily coincide with dry conditions on the Sacramento River. This region heavily relies on supplies from Folsom Reservoir and the American River for various uses:

- *Ecosystem protection in the Lower American River.* Folsom Reservoir releases manage flows and temperatures to help protect river and riparian ecosystems. The Water Forum works to balance environmental protections with water supply needs in this region, but the mostly singular reliance on Folsom Reservoir makes the ability to protect the ecosystem vulnerable.

- *Increasing water demands for Delta water quality.* The projected sea level rise would affect Delta salinity, which in turn would trigger requirements for freshwater releases from Folsom Reservoir and other CVP storage to maintain water quality standards in the Delta—thereby exacerbating the pressures on Folsom Reservoir.
- *Regional water supply demands.* Many agencies in the region rely in all or in part on the Folsom Reservoir to meet water demands. Regional water suppliers are very concerned when storage in Folsom Reservoir drops below 200 TAF. In the ten-year period from 2007 through 2016, Folsom Reservoir dropped below 200 TAF three times, with its lowest-ever recorded storage of under 135 TAF in December 2015. This low storage prompted the City of Folsom to be the first agency to call for mandatory customer conservation of 20 percent. Full pumping capacity at Folsom Dam is at reservoir water surface (RWS) elevation 340 feet (111 TAF) and above; reduced pumping is possible between elevations 340 feet and 310 feet (55 TAF). While emergency floating pumps provide water at lower storage volumes, when storage volumes fall below 110 TAF, water supply diversions are substantially impacted. While these storage levels have never occurred, low storage levels at Folsom Reservoir appear to be increasing in frequency. This increased occurrence of low storage and the region's current predominant reliance on Folsom Reservoir is a vulnerability.
- *Groundwater management and overdraft correction.* Until the 1990s, the region experienced decades of groundwater level decline. As part of WAF implementation to correct this decline, agencies in the region invested significant capital funds to construct facilities and take the required contracting actions to access and use surface water in wetter years. Since the late 1990s, the region estimates more than 300 TAF of surface water was delivered to offset groundwater demand in the underlying basin and provide in-lieu recharge. While groundwater conditions have been and continue to be improved, this is only possible due to the availability of surface water from Folsom Reservoir to offset groundwater use, whose supply, as discussed above, is itself vulnerable.

4.2.1.3. Flood Control Opportunities

Lack of opportunities to set back levees in Sacramento urban areas for flood risk management to address increasing volume of floods in the future. Local, State, and Federal investments in flood protection for the urban areas along the Lower American River have achieved a 200-year level of improved flood risk management (see the Water Resources Development Act of 2007). However, climate change is forecasted to intensify storms, result in more precipitation falling as rain, and cause early runoff—thereby reducing the effective levee protection for the urban areas. Moreover, the lands surrounding the Lower American River are already built-out and highly urbanized. This limits the ability to set back levees to accommodate projected future increases in flood volumes. Instead, other measures will need to be taken to reduce this vulnerability.

4.2.1.4. Water Rights and Contracts

Regulatory uncertainty has contributed to less reliable/protected individual water right and contract entitlements. Once considered most senior and secured, water rights senior to those of CVP/SWP (including some pre-1914 water rights) were subject to curtailment under emergency orders in recent droughts. Individual water rights and contract entitlements become less reliable or less protected under droughts with increased frequency and intensity, leading to potential water right curtailments under emergency orders.

4.2.1.5. Folsom River Operations

Reclamation's operation of Folsom Reservoir is challenging as it attempts to coordinate the needs for CVP purposes and regional protection and other needs. Reclamation operates Folsom Reservoir as a CVP facility for systemwide needs. For example, Reclamation relies on Folsom Reservoir as the "first responder" in CVP operations to satisfy Delta flow and quality standards and other requirements for protecting endangered fishery species. When Folsom Reservoir supplies are limited, these operations may compete with regional water supply and environmental needs (e.g., during the 2014-2016 drought).

4.2.1.6. Lack of Groundwater in the Foothills

There is no recognized groundwater resource (fractured-rock aquifers only) in the Foothills to be a meaningful and reliable supplemental water supply source: The limited volume of groundwater in the Foothills forces the suppliers in those areas to rely predominately/solely on surface water. Reliance on any one source of water supply presents a vulnerability.

Additionally, in light of future climate change, the timing and volume of surface water is predicted to change and possibly decrease, especially with reduced snowpack for regulation—thus further exacerbating this vulnerability.

4.2.1.7. Forest Management

Forest management can significantly affect snowpack retention, major wildfire threats, and subsequently water quality. Snowmelt runoff from headwaters in the Sierra Nevada contributes significantly to the region's (and California's) water quality and water supply reliability. But decades of ineffective forest management and fire abatement practices (e.g., aggressive fire suppression contributing to denser forests and buildup of fuel) have had adverse effects on snowpack retention and fuel management. As snowpack decreases under climate change, improved forest management is even more imperative.

4.2.1.8. Conjunctive Use

Regional conjunctive use potential is not fully developed due to high investment costs and lack of an accepted governance framework: Conjunctive use practices have been used to reverse the region's past groundwater overdraft conditions. Conjunctive use using spreading basins is considered viable in the Study area south of the American River in gravel mining areas and along the Consumnes River. Stockton East Water District has implemented extensive conjunctive use include CVP supply near Farmington Reservoir. Similar conditions and geology occur in the American River study area. Using both surface and groundwater has also been identified in other regional studies (e.g., RWA 2019) as an opportunity to further enhance regional reliability while maintaining basin sustainability consistent with SGMA requirements. Conjunctive use's potentially high investment costs and need for an accepted governance framework could be further investigated.

4.2.1.9. Water Use Efficiency

Varying levels of water use efficiency provide opportunities for improvement. Efficient water use is critical to ensure that there is sufficient supply to meet increasing urban, agriculture, and environmental demands. This is especially true in light of climate change and other future uncertainties.

4.2.2. Consequences of Vulnerability Pathways

These vulnerability pathways have major consequences to water supply reliability in this region, including:

- Potential for loss of environmental protection in the Lower American River.
- Increased water supply shortages during intensified droughts.
- Lack of water security for small water systems and rural communities in the Foothills without alternative sources of water.
- Geographically variable water supply-demand imbalances (e.g., Valley Floor has access to backup groundwater supplies as compared to the Foothills with limited access to groundwater).
- Intensified flood conditions may reduce levels of flood protection in the Sacramento area during.
- Decreased surface water availability for direct use or in-lieu groundwater recharge that has been critical in correcting the regional groundwater overdraft condition since the1990s.
- Increased long-term water quality risks from wildfires due to intensified weather conditions and tree mortality resulting from stressed conditions and infestations.

Chapter 5. Adaptation Measures and Portfolios

This chapter describes identifying and screening adaptation measures (or actions) to address the identified vulnerability pathways in Chapter 4. The chapter also describes combining the retained adaption measures into adaptation portfolios to address that were further evaluated to assess their effect in addressing the projected impacts of climate change.

5.1. Adaptation Measures Development

To develop the portfolios, a planning approach (shown in Figure 5-1) was taken:

- Determine the stressors (what affects water supply reliabilities) as noted in Section 4.1.
- Examine the vulnerabilities as discussed in Section 4.2.
- Identify and screen measures to address these vulnerabilities as discussed in this section
- Group specific measures into theme-based portfolios to evaluate potential basin approaches as shown in Chapter 6.

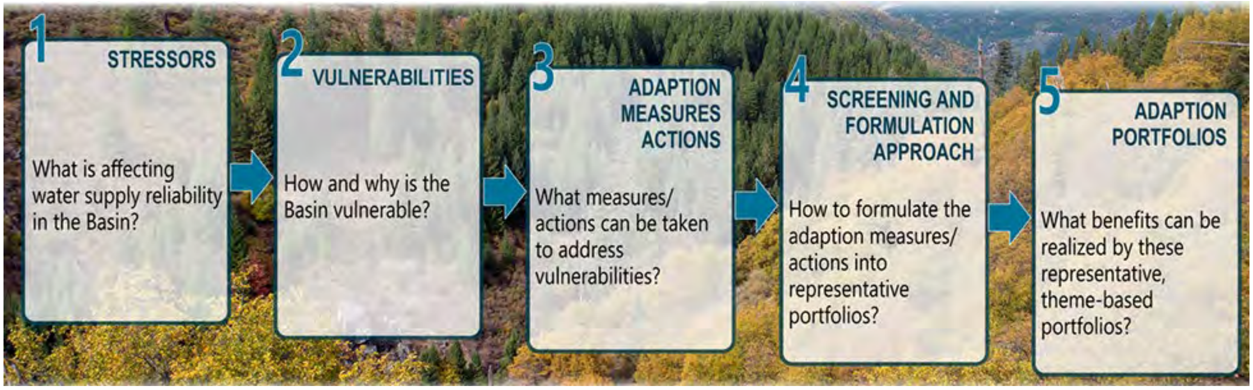

Figure 5-1. Steps to develop adaptation portfolios.

5.1.1. Identifying Adaptation Measures

During the October 15, 2019, public workshop,[1] stakeholders, other interested agencies, and members of the public proposed various adaptation measures to address the identified vulnerabilities. Adaptation measures were identified to mitigate identified vulnerabilities and imbalances on regional, sub-regional, and agency levels. Adaptation measures were grouped into five themes based on the range of measures identified.

An **adaptation measure:**

- May range from nonstructural policies or institutional changes to operational or structural projects
- May address one or more vulnerabilities
- May be location specific and vary in level of detail
- May be combined to form broader sets of portfolios

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[1] Communication and outreach activities are listed in Appendix A.

The identified adaptation measures were grouped under the following categories:

1. Improve demand management
    a. Increase agricultural water use efficiency
    b. Increase urban water use efficiency
2. Diversify water supplies
    a. Increase regional water reuse
    b. Increase stormwater capture
    c. Develop additional points of delivery and/or water rights
    d. Expand water supply portfolio diversification for all agencies
3. Improve operational flexibility
    a. Structure flexible exchanges
    b. Expand flexible conjunctive use to reduce reliance and diversions of surface water in dry and critical years
    c. Increase water storage and associated integrated operations
4. Improve resource stewardship
    a. Improve headwaters and forest health
    b. Improve the Lower American River ecosystem
5. Secure institutional agreements to enable flexibility
    a. Reclamation and CVP contractors continue to coordinate on contracts
    b. Implement a regional water accounting framework for transparency and collaboration

5.1.2. Screening Adaptation Measures

The identified adaptation measures were screened to determine whether they could improve the region’s resiliency in the face of climate change and could effectively address the identified vulnerability pathways. This preliminary screening was based on six criteria, which were used to determine whether a proposed measure would meet the criteria, would not meet the criteria, or would marginally meet the criteria. The screening criteria were:

- **Relevancy to Vulnerability Pathways**: The proposed measure could demonstrably address/mitigate one (or more) of the pathways of vulnerabilities.
- **Technical Feasibility**: The proposed measure was based on available, proven technology or practices underlie the proposed measure.
- **Measurable Benefit**: The proposed measure could generate a measurable quantity of water supply on a regional scale (either by increasing supplies or reducing demand).
- **Long-Term Viability**: The proposed measure could sustain its potential water supply improvement over the long-term. Incidental benefits are not considered reliable long-term.

- **Nexus to Reclamation/Federal Interest**: The proposed measure has a clear connection to a Federal interest per the WaterSMART authorization for Basin Studies, and provide benefit to Reclamation's (specific to operation of Folsom Reservoir), including:
    - Increase flexibility to meet all CVP authorized purposes
    - Reduce direct demands on Folsom Reservoir operations (needs to be satisfied via alternative means) on a long-term basis or an as-needed basis
    - Increase Folsom Reservoir's regulating capacity for flow and storage
- **Local Support for Implementation**: Proposed adaptation measure is locally led, and/or has local financial investment and political support.

A summary of the screening results can be found in *Appendix E. Adaptation Measure Preliminary Screening Results*. In general, the highest-ranking adaptation measures have long-term measurable benefits that have local implementation support and address multiple vulnerabilities. They also have at least one nexus to a Federal interest.

5.2. Adaptation Portfolio Development

This section describes the formulation of adaptation portfolios from the screened adaptation measures.

An **adaptation portfolio** is a collection of adaptation measures that jointly contributes towards an overall goal, or a strategy.

5.2.1. Formulation Approach

Through the study development and with input from stakeholders, these principles for formulation of the adaptation portfolios were adopted:

- Portfolios are theme-based and reflect project/action concepts that are locally supported.
- Each portfolio represents a unique central theme or concept to the extent possible.
- Each unique theme is combined with other complementary projects/actions that further advance its central concept. However, included projects/actions are not intended to be an exhaustive list of all possibilities.
- Each portfolio's central theme reflects an existing Federal authority or nexus to benefit to Reclamation, where possible.
- Every portfolio provides mutual benefits for the region and for Reclamation. Reclamation's benefits specifically relate to Folsom Reservoir operations to meet CVP's authorized purposes (e.g., reduce direct water demands on Folsom Reservoir operations and increase Folsom Reservoir's flow and storage regulating capacity).
- Collectively, the portfolios should cover all identified pathways of vulnerabilities in the region.

Choosing a preferred alternative was not the goal of this Study. Instead, the portfolios formulated in this Study are designed to work together to address the full range of vulnerabilities. ARBS formulation of adaptation portfolios did not attempt to optimize the scale or operations of proposed project concepts; rather, it focused on illustrating the potential range of benefits of each portfolio.

In addition, synergies among adaption portfolios were not explicitly assessed to identify optimal combinations. Analysis of these synergies were not part of the scope of the Study but could be pursued in subsequent studies building on the findings of the Study.

5.2.2. Formulated Adaptation Portfolios

5.2.2.1. Common Foundational Measures

Several adaptation measures are already ongoing or are committed to in the near future. Therefore, these foundational adaptation measures of water demand management, institutional actions, and forest management are included in each of the formulated adaptation portfolios:

- **Increase agricultural and urban water use efficiency.** Water demand management to increase urban and agricultural water use efficiency has been incorporated into future projections consistent with the approach used by the SSJRBS (Reclamation, 2016). It assumes urban demands are reduced by 20%. For the Valley Floor and throughout the Central Valley, it assumes that the agricultural applied water demand is reduced by 10% in 2020 and 20% by 2050.
- **Structure flexible water transfers and exchanges among water agencies in the study area**
- **Improve headwaters and forest health**

5.2.2.2. Future Operations Baseline

The Future Operations Baseline represents the current water management and operation practices as well as the foundational measures described in Section 5.2.21. This Future Operations Baseline is the building blocks to the adaptation portfolios. All its elements are included in each of the adaptation portfolios, except as noted otherwise. It is used to compare the relative performance of these portfolios.

To assess how the formulated adaptation portfolios can address the effect of climate change, the Future Operations Baseline is formulated to reflect 2070 conditions, as described in Section 2.3. *Future Climate Scenarios*. The Future Operations Baseline key elements are:

Urban and agricultural demands in the study area and the Central Valley reflect the projected 2070 level of development and incorporate demand management adaptations.

To represent the full range of potential future climates, three future climate scenarios (WW, CT, and HD) reflecting range of 2070 climate scenarios (based on average forecasted conditions over the period 2055-2084) are used (see Figure 2-9).

Climate and hydrology are based on the historical 1922-2015 datasets, which have been pattern-adjusted for 2070 (WW, CT, and HD) climate scenarios (see Figure 2-10).

Note that the Future Operations Baseline includes three subscenarios: 2070 WW, 2070 CT, and 2070 HD. Each of the formulated adaptation portfolios are evaluated against each of these three future operation baselines.

5.2.2.3. Importance of Long-term CVP Water Contracts

This portfolio illustrates the importance of CVP water contracts for regional water reliability and groundwater sustainability. It reflects the current water management and operation practices and the foundational measures—except for the assurances for long-term CVP water contracts for water agencies in the study area with Interim Renewal Contracts.

During ARBS development, Reclamation has worked with American River Division agencies with Interim Renewal Contracts to convert their contracts into repayment contracts to ensure long-term water supplies.

5.2.2.4. Alder Creek Reservoir and Conservation Project Portfolio

The Alder Creek Reservoir and Conservation Project Portfolio represents an example of more effectively capturing runoff upstream of Folsom Reservoir.

This portfolio includes the current water management and operation practices and the foundational measures. In addition, it includes upper watershed high-elevation, off-stream storage to replace lost storage from reduced snowpack and earlier snowmelt. Alder Creek Reservoir was selected to conceptually represent this theme because of the existing Federal authorization for the Alder Creek Storage and Conservation Feasibility Study.[1] Alder Creek is a tributary of the South Fork American River. The proposed Alder Creek Dam is 175,000 acre-feet off-stream reservoir. Water would be diverted from, and released back, to the South Fork American River (Figure 5-1). Other key adaptation measures included in this portfolio are:

- Provide water supply reliability and drought protection for the Foothills using created storage in Alder Creek Reservoir.
- Establish storage capacity exchange and other operational agreements to ease demands on Folsom Reservoir, including storage of CVP water to increase CVP yield in dry and critical years.
- Institute exchanges and operational agreements to augment water supply reliability needs for water purveyors in the Foothills.
- Build flexibility to participate in occasional water market participation (with primary focus of supporting Reclamation’s transfer programs). Note that feasibility, rules, and amounts of such transfers will need to account for water rights, Folsom and CVP operations, and environmental approvals and permits.

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[1] P.L. 108-361, Title II, Section 202, dated October 2004 authorized the Secretary of the Interior, through Reclamation, to conduct a feasibility study on the Alder Creek water Storage and Conservation Project.

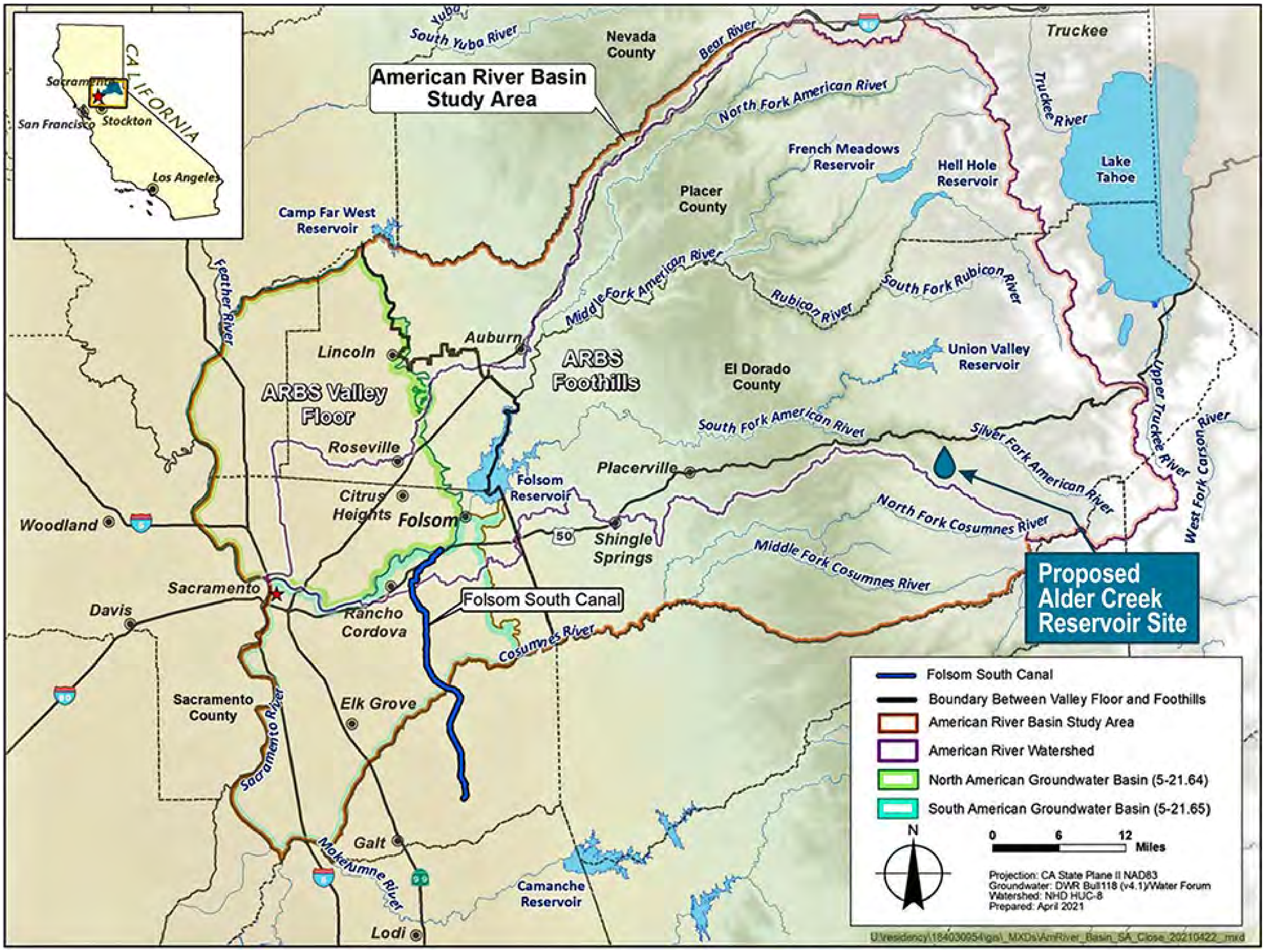

Figure 5-2. Location of the proposed Alder Creek Reservoir.

5.2.2.5. Sacramento River Diversion Project Portfolio

This portfolio uses existing infrastructure to exchange American River diversions for Sacramento River diversions and keep flows below the American River confluence with the Sacramento River unchanged while increasing regional water reliability and reducing demands on Folsom Reservoir.

This portfolio leverages the different hydrologic conditions in the American River Basin relative to the rest of the Sacramento River Basin to increase regional and system flexibilities. This portfolio includes the current water management and operation practices and the foundational measures. In addition, it includes using existing diversion facilities on the Sacramento River to reduce reliance on Folsom Reservoir and the American River. The Sacramento River Diversion Project Portfolio would shift diversions from the American River and Folsom Reservoir to existing Natomas Mutual Water Company's (NMWC) intakes on the Sacramento River (Figure 5-2).

This portfolio builds on existing Federal authority.[1] A variation of this concept is currently being developed in separate efforts by multiple local agencies as the RiverArc Project, as well as the potential expansion of Sacramento River water treatment plant and intake. Note that any further development of this portfolio would require analyses for water rights for potential alternative diversions.

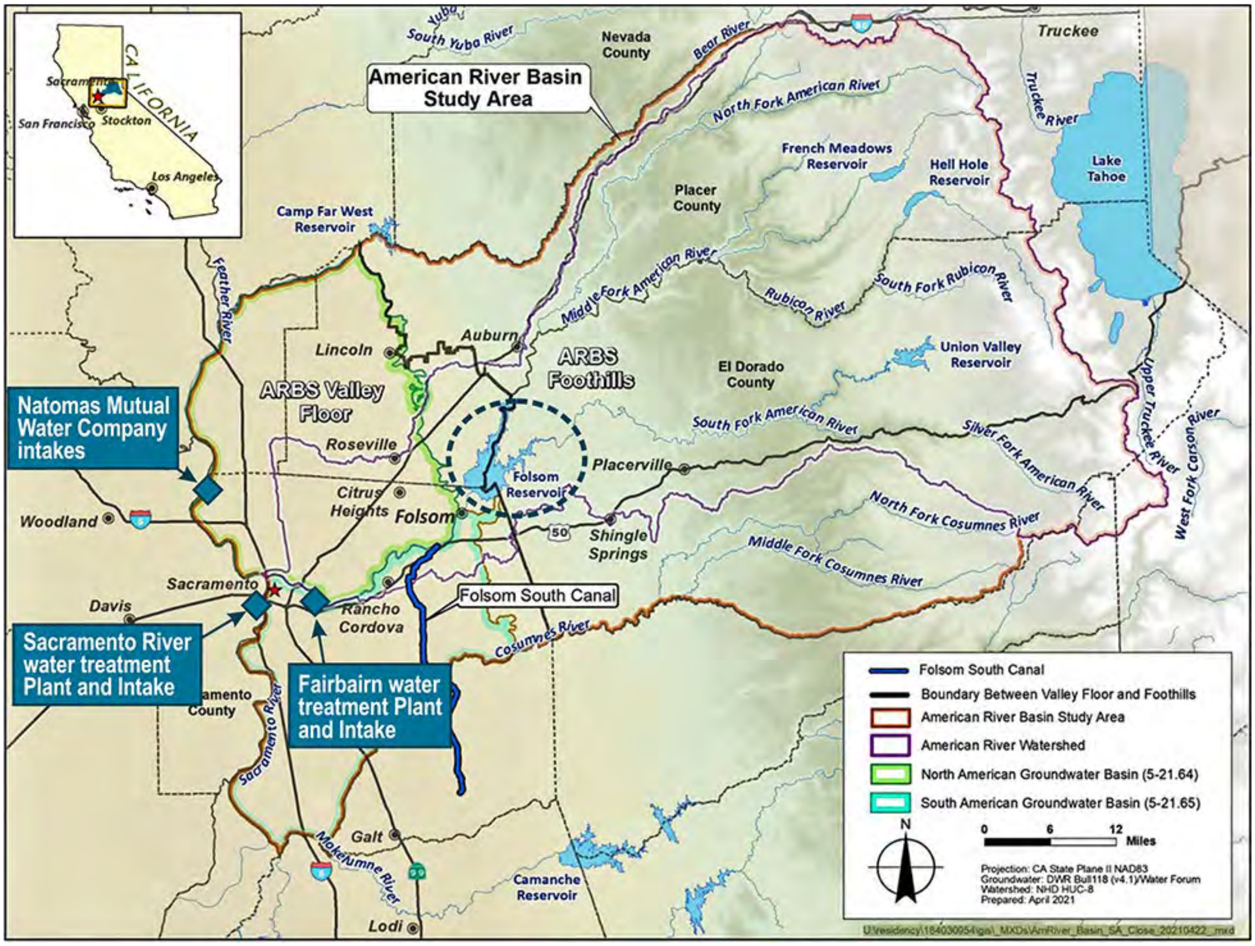

Figure 5-3. Location of facilities associated with the Sacramento River Diversion Project Portfolio.

In addition to foundational measures, other key adaptation measures included in this portfolio are:

- Add alternative point of delivery for existing water rights and CVP contract entitlements through exchanges to leverage different hydrologic conditions in the Sacramento River Basin relative to those specific to the American River Basin.
- Reduce the impact of the WFA voluntary diversion reductions in certain hydrologic conditions by shifting diversions to Sacramento River to maintain protection for the Lower American River.

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[1] P.L. 105-554, Appendix D, Division B, Section 103, dated April 24, 2000 directs the Secretary of the Interior to conduct a feasibility study for a Sacramento River diversion project, consistent with the WFA.

The goal of these adaption measures is to exchange American River diversions with Sacramento River ones and keep flows below the American River confluence with the Sacramento River unchanged while increasing regional water reliability and reducing demands on Folsom Reservoir. During drier conditions, some of the American River diversions would be shifted to Sacramento River at NMWC intakes, while American River flows would increase in similar proportions. Sacramento River flows would remain unchanged downstream from the confluence with the American River. This would benefit the American River during drier conditions—while not impacting the Delta inflow or conditions. Diversion timing could be further coordinated with Delta inflow requirements to benefit Reclamation by increasing CVP storage in Folsom Reservoir during drier conditions.

Table 5-1 lists the expected Sacramento River Diversion Project Portfolio diversions for each of the project partners (Crowley Water, 2018). Potential supply sources for these diversions are:

- **PCWA and California-American Water Company (CAL-AM):** Middle Fork Project (MFP) or CVP water supplies. CVP water would require administrative approval by Reclamation for changing the point of diversion. Relocating MFP water supplies to the Sacramento River would require an exchange agreement with Reclamation.
- **City of Roseville:** PCWA's MFP water supplies.
- **City of Sacramento:** Water rights on the Sacramento River for the City of Sacramento's service area north of the American River. Note that a portion of this supplies would be diverted at NMWC's intakes with the remaining portion diverted at the expanded Sacramento River Intake.
- **Rio Linda/Elverta Community Water District (RLECWD):** Potential Conversion of NMWC Settlement Contract with Reclamation for irrigation to a municipal and industrial (M&I) schedule.
- **Sacramento County Water Agency Service Area North of the American River:** Potential conversion of NMWC Settlement Contract with Reclamation for irrigation to M&I schedule.

Table 5-1. Expected Diversions for RiverArc Partners (TAF/year)

Water Purveyor	Phase 1	Phase 2	Build-out
Sacramento County			
Rio Linda/Elverta Community Water District	2.0	2.0	17.5
Sacramento County Water Agency	2.1	6.4	12.0
City of Sacramento	-	22.4	81.1
Placer County			
City of Roseville	-	7.1	7.1
California-American Water Company	-	10.0	10.0
Placer County Water Agency	-	-	26.0
Total	**4.1**	**47.9**	**153.7**

Source: Crowley Water, 2018.

5.2.2.6. Federally Recognized Groundwater Bank (North and South American Groundwater Basins) Portfolio

This portfolio leverages groundwater storage to increase the resiliency of water supplies in the Valley Floor.

This portfolio builds on Reclamation’s existing authority to approve federally recognized groundwater banks under the Central Valley Project Improvement Act (CVPIA).[1] This portfolio includes the current water management and operation practices and the foundational measures. In addition, it includes the expansion of conjunctive use operations to support climate change adaptation. It includes a market-oriented mechanism to incentivize the practice and fund infrastructure.

Other key adaptation measures included in this portfolio are:

- Enhanced regional conjunctive use using existing infrastructure and levering in-lieu operations in the urban core of the North and South American groundwater basins
- Build flexibility to participate in occasional water market participation (with primary focus of supporting Reclamation’s transfer programs)

The groundwater banking operations would rely primarily on in-lieu groundwater recharge. Urban groundwater users would be shifted to surface water supplies during wetter periods to allow the groundwater basin to naturally recharge; thereby creating banked water credits. Additional groundwater recharge would also be possible through injection using aquifer storage and recovery wells. The banked water would be pumped during drier periods for use by urban surface water users. The foregone surface water diversions would be stored in Folsom Reservoir for use by Reclamation and/or other CVP partners. Key assumptions for banking operations included:

- Up to 56 TAF/year available recharge capacity
- Up to 58 TAF/year available extraction capacity
- Banked water would be subject to one time 5 percent loss factor
- Banked water volume would be subject to an annual 1 percent loss factor

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[1] CVP water banking is authorized by the Central Valley Project Improvement Act, Title XXXIV, P.L. 102-575Sections 3408 (c), (d), and (e), October 1992.

5.2.2.7. Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio

While Reclamation is not a beneficiary of the USACE Folsom Dam raise for water supplies, the captured early flood releases could be used for groundwater recharge to create water supply and ecosystem benefits, consistent with water rights and Reclamation policies.

This portfolio builds on the existing Federal authority for the U.S. Army Corps of Engineers (USACE) ongoing actions to raise Folsom Dam for additional flood control surcharge space.[1] This portfolio includes the current water management and operation practices and the foundational measures. In addition, it includes a multi-benefit forecast-informed reservoir operations (FIRO) concept that integrates raising Folsom Dam and acquiring flood control surcharge space in existing reservoirs in the upper watershed (Figure 5-3).

Key adaptation measures included in this portfolio are:

- Consider modifications of upstream reservoirs (Hell Hole, French Meadows, and Union Valley) to provide additional flood control storage by pre-releasing ahead of forecasted storms for implementing FIRO.
- Implement FIRO at Folsom Reservoir in conjunction with upstream reservoirs operations for accommodating Reclamation’s water supply needs or where feasible, implementing flood-managed aquifer recharge.
- Informed by forecast, could coordinate with USACE to potentially provide for limited allowable conditional storage (30 to 60 days) of flood water in Folsom Reservoir with the dam raise without increasing flood risk and infrastructure risk.
- Implement flood-managed aquifer recharge by using Folsom South Canal to convey flood pre-releases and short-term stored flood water for groundwater recharge.
- Implement groundwater banking in the South American groundwater basin through rural area spreading basins to improve the hydraulic connectivity between the groundwater basin and the Cosumnes River to benefit river ecosystems. The banked water may also be used for water market opportunities; however, further formulation is required.

Key assumptions for banking operations include:

- Recharge capacity of 10 TAF/year (limited by recharge basins’ capacity)
- Up to 50 TAF/year extraction/recovery capacity
- Maximum allowable groundwater banking storage limited to 300 TAF
- Banked water would be subject to a one-time 5 percent loss factor for each recharge volume
- Banked water volume would be subject to an annual 1 percent loss factor

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[1] Folsom Dam Raise project was authorized under Section 101(a)(6) of the Water Resources Development Act of 1999 (P.L.106-53), Section 128 of the Energy and Water Development Appropriations Act of 2004 (P.L. 108-137), and Section 3029(b) of the Water Resources Development Act of 2007 (P.L. 110-114).

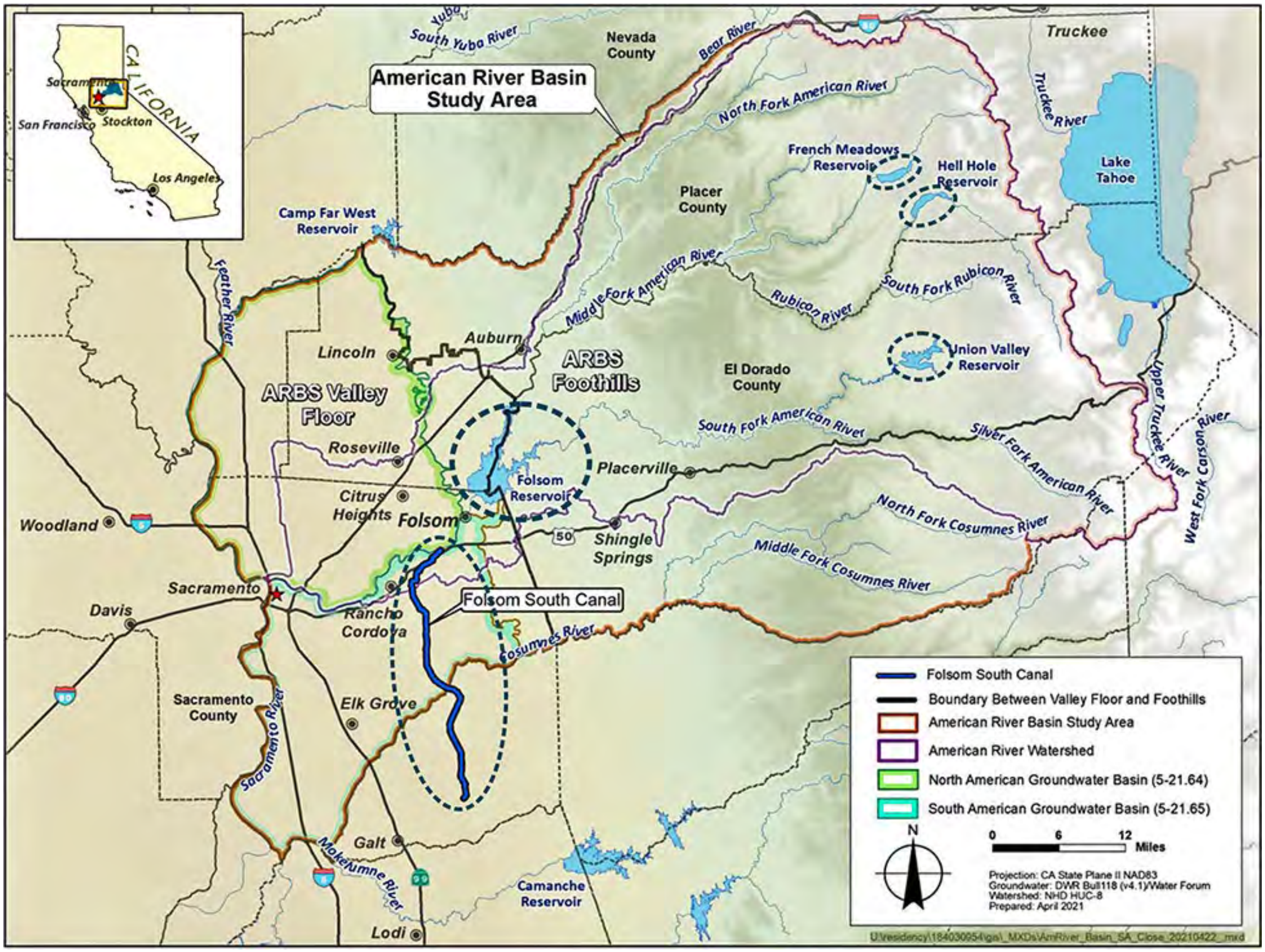


Figure 5-4. Location of facilities associated with the Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio.

5.2.2.8. 2019 BO Flow Management Standard Portfolio

This portfolio evaluates effectiveness of a flow management standard (FMS) for the Lower American River to reduce adverse effects on Lower American River ecosystem and fisheries from climate change. Note that elements included in this portfolio are currently being implemented as part of the National Oceanic and Atmospheric Administration (NOAA) Fisheries and USFWS 2019 Biological Opinions on Long-term Operation of the CVP and SWP (NOAA Fisheries, 2019 and USFWS, 2019).

This portfolio examines the effects of the Modified Flow Management Standard currently being implemented as part of the 2019 Biological Opinions.

This portfolio includes the current water management and operation practices. In addition, it includes the Modified FMS (minimum flows, end of May and December targets, and spring pulse flows) (Sacramento Water Forum, 2015b), along with a temperature control device on Folsom Dam to reduce climate change effects on Lower American River ecosystem and fisheries.

This portfolio builds on existing Federal authority for construction of automated temperature control shutters at Folsom Dam (Public-Law 105–295 of 1998) and ongoing consultations on the Coordinated Long-term Operations for CVP and SWP (Reclamation, 2019).

The 2019 BO FMS relies on minimum release requirements from Folsom Reservoir that are based on indices of water availability. Implementation curves specify higher releases during wet years and lower releases during dry conditions to ensure adequate flows later in the season. Flows in the Lower American River of 800 cfs provide 80 percent of the available spawning habitat. Flows of 500 cfs provide about 40 percent of the maximum amount of spawning habitat (i.e., increasing flows from 500 to 800 cfs doubles the amount of spawning habitat). Flows below 500 cfs create adverse conditions for spawning and rearing. The 2019 BO FMS objectives are to:

- Adjust the curves for determining minimum release requirements, using the Sacramento Valley Index and American River Index as indicators of water availability
- Add end-of-May and end-of-December storage targets, which can be used to adjust the minimum release requirement
- Add protective adjustments relating to Chinook salmon and steelhead redd dewatering
- Provide spring pulse flows
- Remove the adjustments to the release requirement and the WFA conference year and off-ramp conditions contained in the 2006 FMS (Sacramento Water Forum, 2006).

5.2.2.9. Other Considered But Not Included Concepts

Other actions could be compared to these portfolio actions in future studies. For example, although Auburn Dam remains an authorized project in the Basin, the ARBS did not consider it due to potential issues and concerns. In 2008, Reclamation restored the river channel and completed PCWA's water diversion facility. California's State Water Resources Control Board has revoked Reclamation's water rights for the Auburn Dam project.

5.3. Comparison of Adaptation Portfolios Formulation

Table 5-2 summarizes the vulnerability pathways addressed, benefits to Reclamation, and areas of Federal interest addressed by each portfolio. Note that the table does not reflect the extent to which a vulnerability is addressed, or the magnitude of benefits generated. It provides an overview of how the formulated portfolios can collectively help address all the identified vulnerabilities and areas of Federal Interest. It also highlights how each portfolio can provide benefits to Reclamation.

Additional details on facilities, operations, potential benefits, and formulation of each portfolio are provided in Appendix F. *Description of Adaptation Portfolios*.

Table 5-2. Adaptation Portfolios Contribution to Addressing Vulnerability Pathways, Benefits to Reclamation, and Areas of Federal Interest

	Vulnerability Pathways Addressed									**Benefit to Reclamation**			**Areas of Federal Interest Addressed**							
Adaptation Portfolio	1. Size of Folsom Dam	2. Reliance on one river	3. Setback levees not possible	4. Reliability of water rights and contracts	5. Folsom Operations	6. Foothills limited groundwater	7. Forest management	8. Conjunctive use not fully implemented	9. Inefficient water use	A. Increase flexibility	B. Reduce direct demands on Folsom	C. Increase Folsom regulating capacity	1. Water supply	2. Hydroelectric	3. Recreation	4. Fish and wildlife habitat	5. Listed species protection	6. Water quality	7. Ecological resiliency	8. Flood management,
Future Operations Baseline				✓			✓		✓	■			P							
Importance of Long-term CVP Water Contracts							✓		✓											
Alder Creek Storage and Conservation Project	✓			✓	✓	✓	✓		✓	■	■	■	P	P	S					P
Sacramento River Diversion Project	✓	✓		✓	✓		✓		✓	■	■		P		S	P	P	P	P	
Federally Recognized Groundwater Bank (North and South American Basins)	✓			✓	✓		✓	✓	✓	■	■	■	P			S	S	S	S	
Folsom Dam Raise with Groundwater Banking (South American Basin)	✓		✓	✓	✓		✓	✓	✓	■		■	P	S	S	S	S		S	P
2019 BO Flow Management Standard Project	✓			✓	✓		✓		✓	■	■		P		S	P	P	P	P	

Key: P = Federal interest is primary focus of the portfolio

S = Federal interest is secondary focus of the portfolio

✓= portfolio addresses a vulnerability pathway

■ = portfolio contributes to a Reclamation’s benefits

Chapter 6. Evaluation of Adaptation Portfolios

This chapter presents a summary of key results from using CalSim 3 to quantitively evaluate the adaptation portfolios.

6.1. Evaluation Criteria and Metrics

The criteria used to evaluate the adaptation portfolios relative to the Future Operations Baseline were:

- **Water supply reliability (system-wide and study area) and Reclamation's operation of Folsom Reservoir:** Assesses change in CVP storage and CVP/SWP exports under each portfolio relative to the Future Operations Baseline. For the study area, assesses changes in supply-demand imbalance in the Valley Floor and Foothills. Assesses changes in surface water and groundwater use. Evaluates relative changes in Folsom Reservoir storage.
- **Water quality (system-wide, Delta):** Assesses relative changes in Delta outflow and key salinity indicators.
- **Fish and wildlife habitat protection (system-wide and study area):** Assesses relative changes in CVP/SWP storage, which serve as indicator for cold water availability. For the study area, this criteria measures relative changes in Folsom Reservoir storage and Lower American River flow at key periods consistent with the metrics used by the Sacramento Water Forum.
- **Flood risk management (study area):** Evaluates relative changes in Folsom Reservoir spills.
- **Recreation (system-wide and study area):** Evaluates relative changes in CVP/SWP storge (system-wide) and Folsom Reservoir storage (study area) to assess the relative changes in reservoir surface area available for recreation. It also considers additional recreation opportunities created by portfolios.
- **Hydropower (study area):** Considers additional hydropower generation opportunities created by portfolios.

Table 6-1 presents the evaluation metrics associated with each of the above categories. The evaluation metrics are reported as change relative to future baselines.

Table 6-1. Evaluation Metrics for Adaptation Portfolio Performance Evaluation and Comparison Relative to the Future Baseline

Evaluation Metrics		Units	Description / Purpose
Water Supply Reliability and Folsom Dam Operations			
System-Wide	Change in CVP End-of-September Storage (Folsom, Shasta, and Trinity Reservoirs)	TAF	Indicator of storage available for CVP water reliability
	Change in Delta CVP Exports – Jones Pumping Plant	TAF	Indicator of CVP ability to meet urban, agricultural, and environmental demands
	Change in Delta SWP Exports - Banks Pumping Plant	TAF	Indicator of SWP ability to meet urban and agricultural demands
American River Basin	Foothills – Change in Total End-of-September Storage	TAF	Indicator of water reliability for the Foothills
	Foothills - Change in Total Demand	TAF	Long-term average urban and agricultural demands at 2070 level of development and climate
	Foothills - Change in Demand Met by Surface Water	TAF	Long-term average demand met with available surface water
	Foothills - Change in Unmet Demand	TAF	Indicator of long-term average supply-demand imbalance in the Foothills.
	Valley Floor - Change in Folsom End-of-September Storage	TAF	Indicator of water reliability for the Valley Floor
	Valley Floor - Change in Total Demand	TAF	Long-term average urban and agricultural demands at 2070 level of development and climate
	Valley Floor - Change in Demand Met by Surface Water	TAF	Long-term average demand met with available surface water and groundwater; conjunctive use operations indicated by the shift between the two sources to meet demands
	Valley Floor - Change in Demand Met by Groundwater	TAF	
	Net Change in Annual Groundwater Basin Storage	TAF	Indicator of the groundwater basin sustainability
Water Quality			
System-Wide	Change in Total Delta Outflow	TAF	Indicator of Bay-Delta water quality and ecosystem health
	Change in % Months when Salinity at Rock Slough > 150 milligrams per liter (mg/l) chloride (Cl)	%	Indicator of municipal and industrial (M&I) water quality specific to Contra Costa Canal
	Change in % Months when Salinity at Rock Slough > 250 mg/l Cl	%	Indicator of M&I water quality for all Delta export locations

Table 6-1. Evaluation Metrics for Adaptation Portfolio Performance Evaluation and Comparison (contd.)

Evaluation Metrics		Units	Description / Purpose
Fish and Wildlife Habitat			
System-Wide	Change in System End-of-April Storage (Folsom/Shasta/Trinity/Oroville)	TAF	Indicator of available cold-water storage in the system
	Change in Feb-Jun Delta Outflow (Spring X2)	TAF	Indicator of Delta spring salinity per D1641 requirements for spring X2
	Change in Sep-Nov Delta Outflow (Fall X2)	TAF	Indicator of Delta fall salinity per 2009 Biological Opinion requirements for fall X2
American River Basin	Change in Mar-May Folsom Reservoir Storage	TAF	Indicator of flow stressor period for steelhead and fall-run Chinook salmon
	Change in Jun-Nov Folsom Reservoir Storage	TAF	Indicator of temperature stressor period for steelhead and fall-run Chinook salmon
	Change in Mar-May Lower American River Flow	TAF	Indicator of flow stressor period for steelhead and fall-run Chinook salmon
	Change in un-Nov Lower American River Flow	TAF	Indicator of temperature stressor period for steelhead and fall-run Chinook salmon
	Change in % Months when Lower American River Flow < 500 cubic feet per second (cfs)	%	Indicator of flow level that creates adverse conditions for spawning and rearing
	Change in % Months when Lower American River Flow < 800 cfs	%	Indicator of flow level that provides 80% of available spawning habitat
	Change in American River Flow at Sacramento River Confluence	TAF	Outflow of the American River watershed
Flood Risk Management - American River Basin			
	Change in Annual Folsom Reservoir Spills	TAF	Indicator of flood releases
Recreation - American River Basin			
System	Change in May-Sep Surface Area (Folsom/Shasta/Trinity/Oroville)	TA	Indicator of recreation suitability in major Sacramento Valley reservoirs
ARB	Change in May-Sep Folsom Reservoir Surface Area	TA	Indicator of recreation suitability in Folsom Reservoir

Notes:

[1] D1641 = Water Right Decision 1641 (State Water Resources Control Board, 2000)

[2] Sacramento Water Forum (2015)

Key:
N/A = Not Applicable
TA = thousand acres
X2 = Distance of the 2 parts per thousand salinity isohalines (contours/lines of equal salinity) from the Golden Gate Bridge in kilometers

6.2. Future Operations Baseline

The Future Operations Baseline represents the "Without Adaptation Portfolio". It is used to highlight the relative effect of the adaptation portfolios on addressing the projected future climate conditions.

The Future Operations Baseline represents the current water management and operation practices, and the foundational measures described in Section 5.2.2.1.:

- Increase urban and agricultural water use efficiency
- Structure flexible water exchanges among water agencies in the study area
- Improve headwaters and forest health

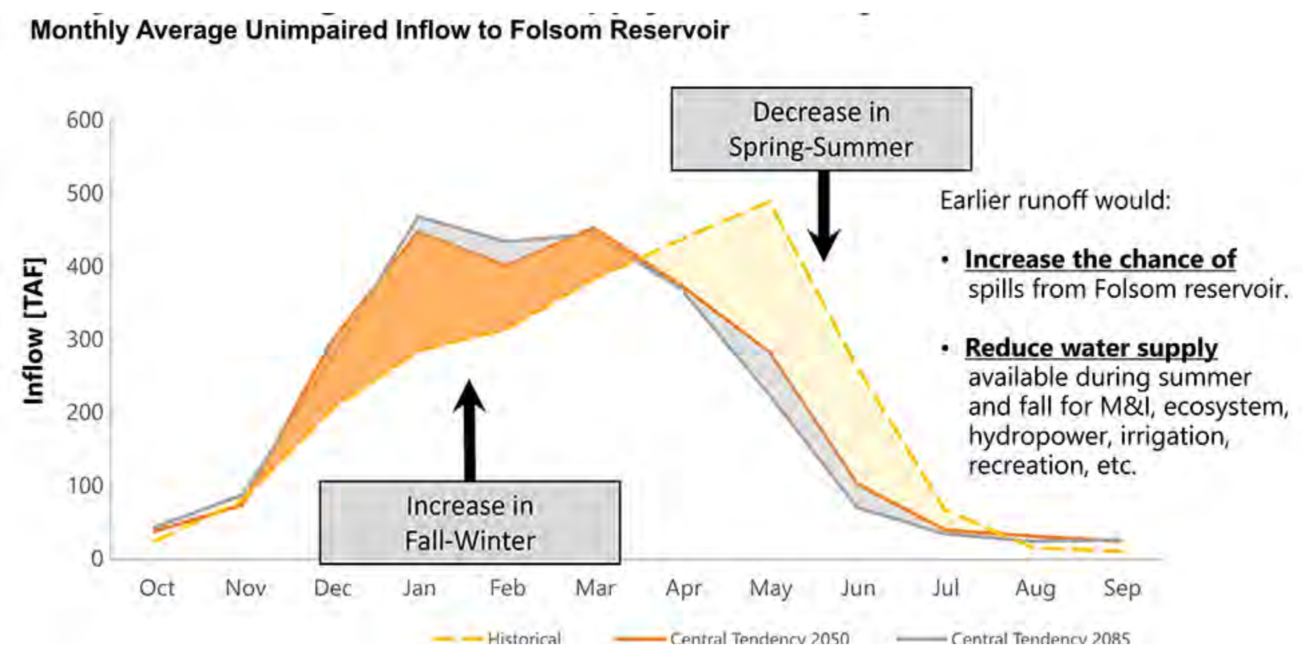
The Future Operations Baseline is used to compare the relative performance of these portfolios. It includes three subscenarios: 2070 WW, 2070 CT, and 2070 HD. Each of the formulated adaptation portfolios are evaluated against each of these three future operation baselines.

As described in Chapter 3, climate change is expected to alter the timing of runoff in the study area. Runoff in May has been historically relied on to fill surface water storage reservoirs for summer use. End-of-century projections indicate that the runoff midpoint could be 35 days earlier than the historical average—resulting in flashier runoff (Figure 6-1). By the end of the 21st century, the majority of runoff is anticipated to occur in February through March as flood flows that are currently not captured. May runoff could decrease by about 250 TAF—making the American River Basin and CVP/SWP more vulnerable to demand-supply imbalances without any modifications to reservoir operation rules.

Figure 6 -2 shows the projected increase in water temperature in the Lower American River under 2070 future baselines (WW, CT, and HD) compared to the existing baseline. The water temperature increase would range from an average of 2 to 5 degrees Fahrenheit.

In addition, sea level rise of 45 centimeters is also assumed to occur in 2070 and is reflected in the Future Operations Baseline. Sea level rise affects Delta salinity, which in turn triggers requirements for freshwater releases from Folsom Reservoir and other CVP storage to maintain water quality standards in the Delta. Modeling the effect of sea level rise uses the artificial neural networks embedded in CalSim 3 (as discussed in Section 2.5. *Modeling Tools*).

For Reclamation, these consequences would make it more difficult to balance Folsom Reservoir operations to meet all its authorized purposes, including local diversions and regional environmental and CVP-wide needs and obligations.


Monthly Average Unimpaired Inflow to Folsom Reservoir

Decrease in Spring-Summer

Earlier runoff would:

- **Increase the chance of** spills from Folsom reservoir.
- **Reduce water supply** available during summer and fall for M&I, ecosystem, hydropower, irrigation, recreation, etc.

Increase in Fall-Winter

Figure 6-1. Projected timing of inflow to Folsom Reservoir under future climate change conditions (2050 CT and 2085 CT) compared to historical conditions.

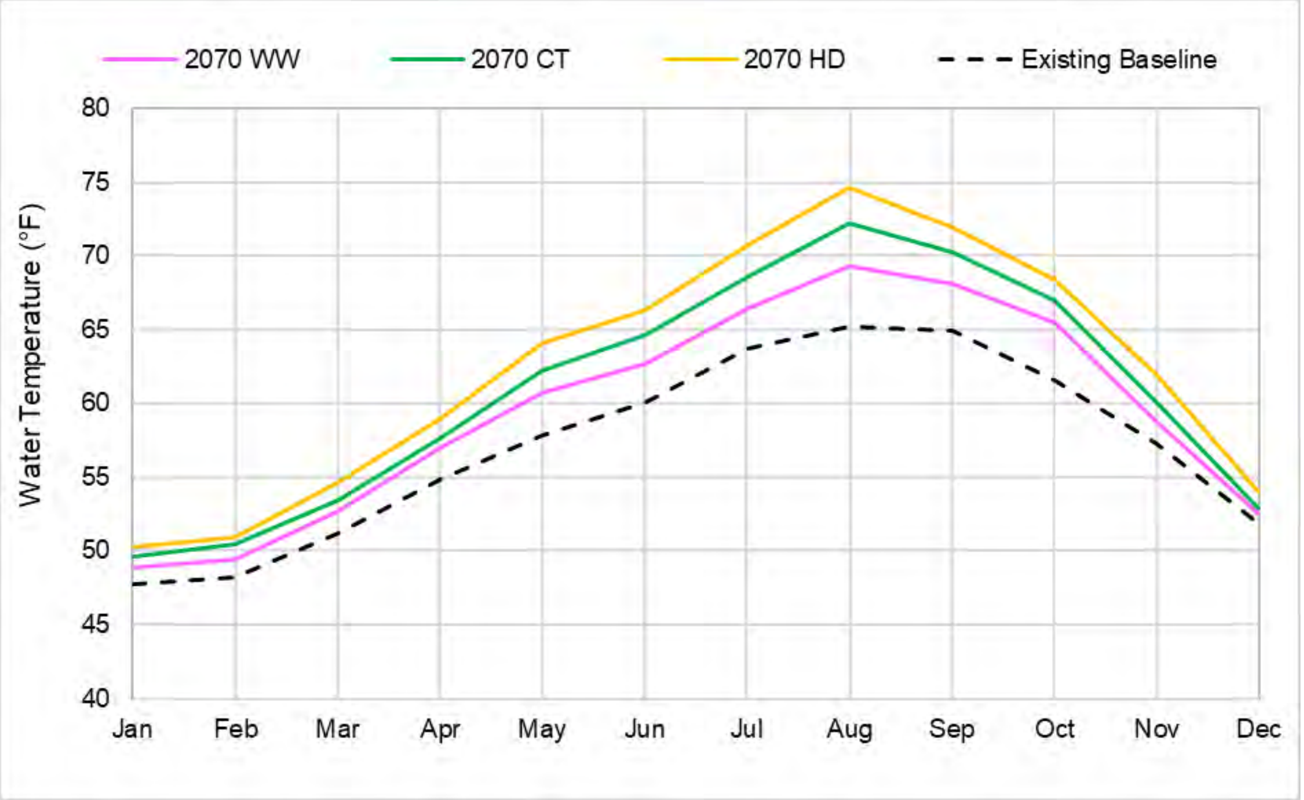


Figure 6-2. Projected Lower American River water temperature (at Watt Avenue Bridge) under the Existing Baseline compared to Future Operations Baseline under 2070 future climate scenarios (WW, CT, and HD).

Demands in the region are expected to increase more than 20 percent by 2085 as described in Section 3.1. *Projected Future Demands* and Figure 3-5. An increase in demands in combination with hydrologic changes would exacerbate the supply-demand imbalance.

The potential consequences of these imbalances, if not addressed, could include:

- Lost economic development
- Increased risk of groundwater overdraft
- Reduced hydroelectric power generation
- Shorter water-based recreation season
- Less water available for release to help meet downstream water quality standards
- Greater impacts on endangered fishery species in the Lower American River.

Table 6-2 shows the supply-demand balance for the Valley Floor and Foothills. To meet demand in the Valley Floor, groundwater extraction would need to increase by 62 to 155 TAF/year to supplement available surface water. This can affect long-term groundwater sustainability and increase the risk of overdraft conditions. Because groundwater resources are not available in the Foothills, the imbalance is projected to be 63 to 78 TAF/year under the 2070 future baselines.

Table 6-2. Water Supply-Demand Balances in the Study Area (TAF /year) Under the Existing Baseline and Future Operations Baseline Under 2070 Climate Scenarios (WW, CT, and HD)

Item	Existing Baseline	2070 Central Tendency	2070 Hot-Dry	2070 Warm-Wet
Valley Floor				
Total Annual Demand	**1,083**	**1,278**	**1,332**	**1,278**
a. Demand Met by Surface Water	701	803	789	835
b. Demand Met by Groundwater	378	466	533	440
Total Water Supply (a+b)	**1,079**	**1,269**	**1,322**	**1,275**
Supply-Demand Imbalance (Supply – Demand)	-4	-9	-10	-3
Groundwater Extraction Compared to Existing Baseline [1]	0	+88	+155	+62
Foothills				
Total Annual Demand	**104**	**211**	**222**	**202**
a. Demand Met by Surface Water	100	134	135	137
b. Demand Met by Groundwater	1	1	1	1
Total Water Supply (a+b)	**101**	**135**	**135**	**138**
Supply-Demand Imbalance (Supply – Demand)	-3	-76	-87	-63
Groundwater Extraction Compared to Existing Baseline [2]	0	0	0	0

[1] Demand in the Valley Floor is assumed to be met by increased groundwater extraction if surface water supplies are insufficient. This increase in groundwater extraction may not be sustainable.

[2] There are limited groundwater resources in the Foothills.

6.3. Importance of Long-Term CVP Water Contracts

A loss of CVP water service contracts under the WW scenario would create a greater deficit in surface water supplies and therefore would require more groundwater extraction to make up the shortage.

To illustrate the importance of CVP water contracts for the regional water reliability, ARBS developed the **Importance of Long-Term CVP Water Contracts** portfolio. During ARBS process, Reclamation worked with American River Division contractors with Interim Renewal Contracts to convert their contracts into repayment contracts and finalized the water supply contract with EDCWA. Reclamation executed congressionally mandated contract conversions on February 28, 2020, pursuant to the Water Infrastructure Improvements for the Nation (WIIN) Act for City of Folsom, City of Roseville, PCWA, Sacramento County Water Agency, San Juan Water District, and SMUD. These contracts remain active so long as the contractor continues to make the required annual payments. These actions were significant steps to assist local agencies in long-term water-supply planning and an early success for the engagement between Reclamation and local agencies in the ARBS that were critical to support the other climate adaptation portfolios. These actions addressed the forest management and inefficient water use vulnerability pathways.

This portfolio evaluates the effect of the loss of CVP water contracts on regional water reliability. Table 6-3 show that the loss of CVP water supplies subject to interim renewal contracts could increase groundwater extractions by 57 to 62 TAF/year under 2070 level of development. Under 2070 level of demands, City of Roseville and PCWA continue to rely on their CVP water service contracts to meet demands, and a loss of those contracts would require a large portion of the surface water deficit to be made up by increased groundwater extraction (23 and 31 TAF/year respectively, under the 2070 CT Climate Scenario). Sacramento County Water Agency and SMUD would be similarly impacted, resulting in potential increases in groundwater use of 5 and 3 TAF/year respectively, under the 2070 CT future baseline.

Table 6-3. Increases in Groundwater Extraction Resulting from Non-Renewal of CVP Water Service Contracts (Interim Renewal Contracts) (TAF/year) Under 2070 Climate Scenarios (WW, CT, and HD)

Agency	Reduced CVP Contract Amount	Increased Groundwater Extraction Compared to the Respective Future Operations Baselines		
		2070 HD	2070 CT	2070 WW
City of Roseville	32	22	23	24
PCWA	35	30	31	34
SMUD	60	5	8	4
Total	**127**	**57**	**62**	**62**

The potential increased reliance on groundwater by 57 to 62 TAF/year could contribute to groundwater overdraft conditions in the region. Declining groundwater levels in the North and South American groundwater basins were a concern for local water resource managers until the mid-1990s, with elevations dropping on a long-term average of more than a foot per year since the 1950s. Since the mid-1990s, overdraft conditions recovered by over 20 feet, largely because of implementing local conjunctive use operations (Sacramento Groundwater Authority, 2014). A loss of CVP water contracts would risk reversing the decades-long effort to stabilize and protect groundwater resources. It could also impede the region's ability to remain in compliance with the Sustainable Groundwater Management Act requirements.

Compared to the 2070 HD future baseline, groundwater extraction would increase in the 2070 WW baseline because CVP allocations would be subject to fewer reductions under the WW scenario. Figure 6-3 and Figure 6-4 show the simulated change in groundwater storage under this portfolio compared to the 2070 CT future baseline for the North and South American groundwater basins, respectively. Groundwater storage declines significantly under the future baseline and underscores the need for adaptions to address this impact.

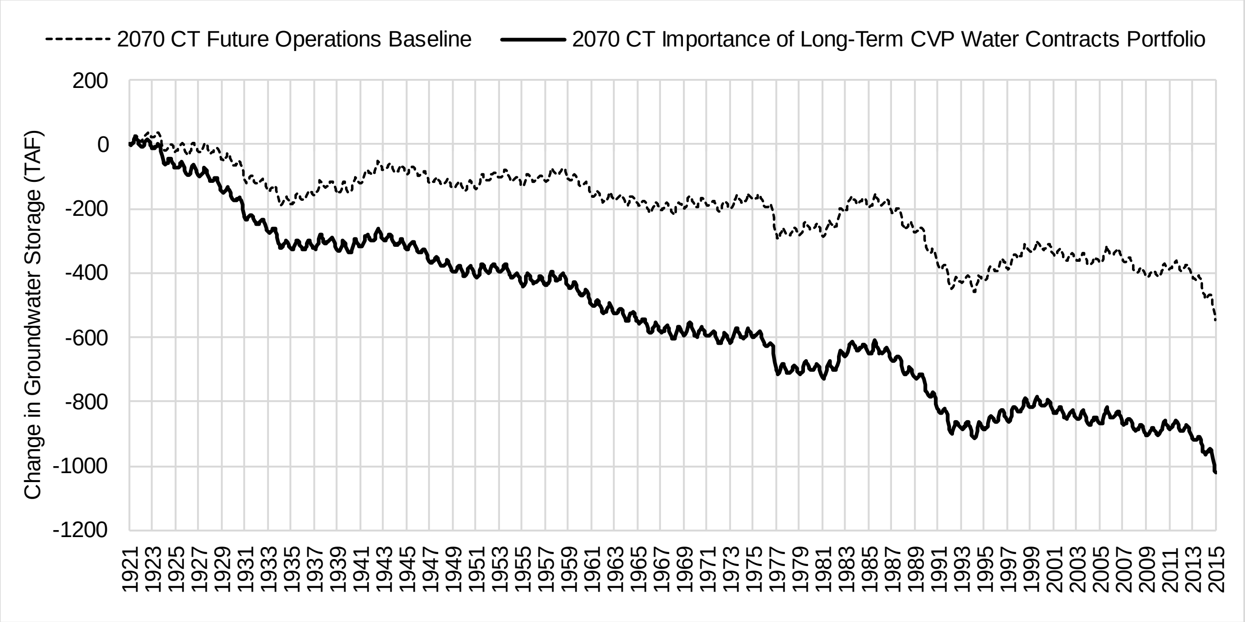


Figure 6-3. Cumulative change in North American groundwater basin storage under the Importance of Long-Term CVP Water Contracts Portfolio and the 2070 CT Future Operations Baseline.

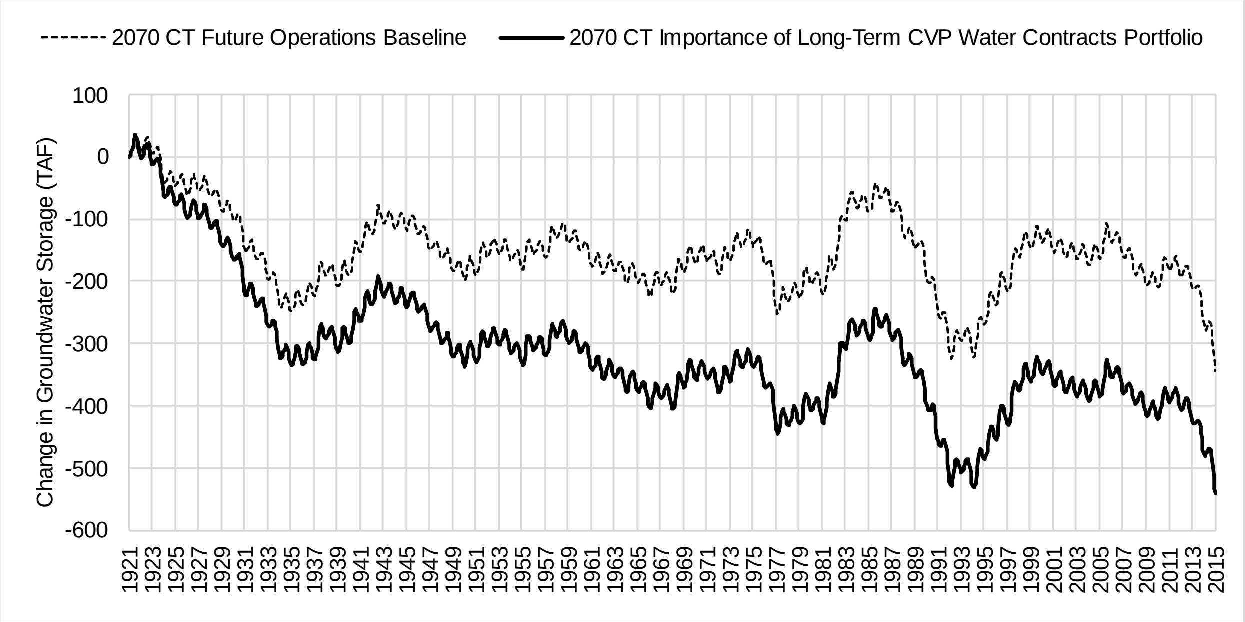


Figure 6-4. Cumulative change in South American groundwater basin storage under the Importance of Long-Term CVP Water Contracts Portfolio compared to the 2070 CT Future Operations Baseline.

6.4. Alder Creek Reservoir and Conservation Project Portfolio

This portfolio addresses the loss of snowpack using upstream storage. Alder Creek Reservoir is selected as an example to represent the concept of replacing lost snowpack storage with a high-elevation, off-stream storage reservoir.

Upstream reservoir storage could be an important feature to diversify water supply composition for the Foothills, while the proposed reservoir's carryover storage could also provide drought protection.

6.4.1. Water Supply Reliability

In El Dorado County, future demands are anticipated to exceed available supplies by about 63 to 83 TAF/year (see Table 6-2). The proposed 175 TAF Alder Creek Reservoir would greatly improve surface water availability in the Foothills and would significantly help address the supply-demand imbalance. Over the long-term, Alder Creek Reservoir would provide an additional 68 TAF/year of reliable surface water supply and 58 TAF/year of additional surface water carryover storage for drought protection. As presented in Figure 6-5, El Dorado County's 2070 demands would be fully met in 85 percent of all years under 2070 CT.

Additional yield from Alder Creek Reservoir and future SMUD supplies may decrease El Dorado County's reliance on existing facilities and Folsom Reservoir. This includes up to 40 TAF of SMUD storage, including up to 15 TAF of carryover storage without interfering with SMUD energy generation. Under the 2070 Central Tendency climate scenario, reliance on Folsom Reservoir could decrease by up to 9 TAF/year (Table 6-4). In addition, Alder Creek Reservoir could reduce the City of Folsom's reliance on Folsom Reservoir by 4 TAF/year (Table 6-5). Therefore, Alder Creek Reservoir could be an important feature to diversify water supply composition for the Foothills, while the proposed reservoir's carryover storage could also provide drought protection.

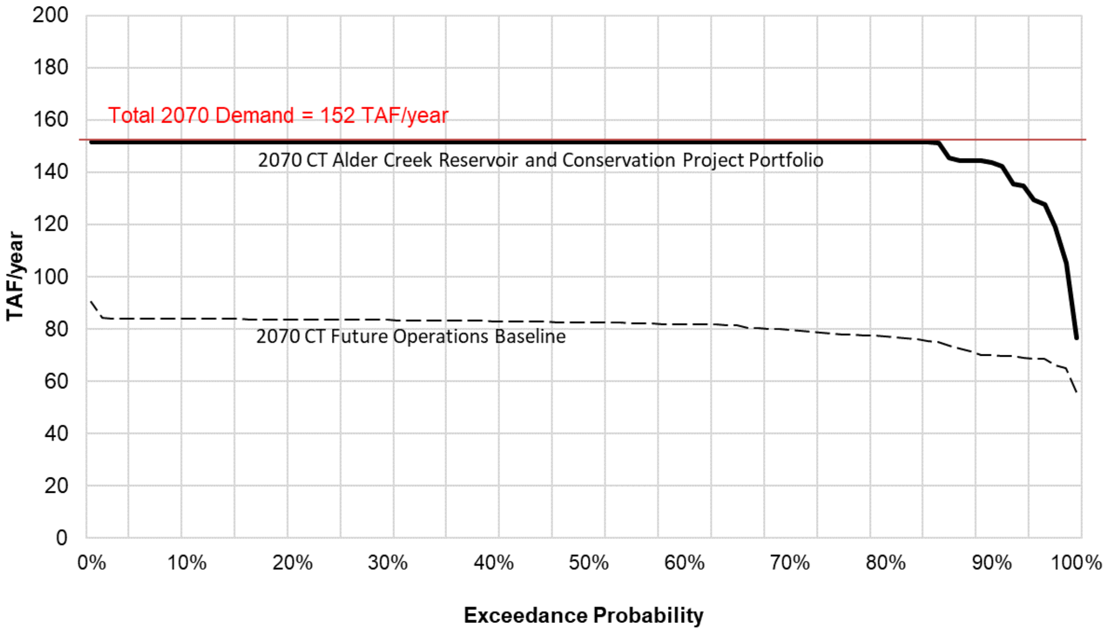


Figure 6-5. Annual water deliveries in El Dorado County to meet 2070 demands under the 2070 CT Alder Creek Reservoir and Conservation Project Portfolio Compared to the 2070 CT Future Operations Baseline.

Table 6-4. El Dorado County Water Supply Composition (TAF/year) Under 2070 CT Alder Creek Reservoir and Conservation Project Portfolio Compared to 2070 CT Future Operations Baseline

Item	2070 CT Future Operations Baseline	2070 CT Alder Creek Reservoir and Conservation Project Portfolio
Total Demands	**152**	**152**
Water Supplies	**81**	**149**
Folsom Reservoir Water Supplies	24	16
License 11835 and 11836 (Jenkinson Lake)	29	24
Project 184 (Forebay Diversions)	15	15
Permit 12827 (Stumpy Meadows)	12	11
Alder Creek Reservoir	0	43
Pending water right petition for EDCWA (White Rock Diversion) [1]	0	39
Groundwater	1	1
Supply Demand Imbalance	**-72**	**-4**

Note that this table lays out the complete water budget for El Dorado County. Project 184 (Forebay Diversions) are included for completeness, and this inclusion does not imply new transfers or other operational changes.

[1] EDCWA's water right petition and Alder Creek Reservoir are to meet projected demands based on County General Plan as described in the Water Resources Development and Management Plan (EDCWA, 2019).

Table 6-5. City of Folsom Water Supply Composition (TAF/year) Under 2070 CT Alder Creek Reservoir and Conservation Project Portfolio Compared to 2070 CT Future Operations Baseline

Item	2070 CT Future Operations Baseline	2070 CT Alder Creek Reservoir and Conservation Project Portfolio
Total Demands	**34**	**34**
Water Supplies	**34**	**34**
Folsom Reservoir Water Supplies	31	27
Upstream water supplies (Alder Creek)	0	4
Groundwater	3	3
Supply Demand Imbalance	**0**	**0**

6.4.2. Reclamation's Operation of Folsom Reservoir

As described in Section 4.1.1. *Regional Management Stressors: Climate Change*, climate change will likely result in increased runoff during winter months and reduced snowmelt in the spring months. Existing facilities, which are designed and operated based on current and past hydrology, will be overwhelmed and unable to provide adequate flood risk management or reliable water supply to meet all intended beneficial uses.

Upper watershed storage (for example, the proposed Alder Creek Reservoir) could replace some snowpack storage. During wet conditions, Alder Creek Reservoir could capture flows that would otherwise spill from Folsom Reservoir and shift releases to the summer for use during periods of higher demand. Attenuating unimpaired inflow into Folsom Reservoir during winter months could store up to 30 TAF/year of flood flows for use by Reclamation in summer months, thereby effectively increasing Folsom Reservoir’s water storage capabilities by increasing end-of-September carryover storage and reducing spills during the flood season.

Alder Creek Reservoir would capture winter flows that would otherwise have spilled from Folsom Reservoir. Therefore, reducing inflow and spills at Folsom Reservoir without affecting its spring storage.

Alder Creek Reservoir summer releases would increase Folsom Reservoir storge in the summer and the fall.

As displayed in Figure 6-6, snowpack replacement from Alder Creek Reservoir could improve Folsom Reservoir carryover storage in wet years. Because Alder Creek Reservoir would only capture flows that would have otherwise spilled from Folsom Reservoir, there would be no reduction in Folsom Reservoir storage during winter months. In subsequent summer months (July-September), Folsom Reservoir storage would increase as result of this increased carryover storage. In the following dry year, Folsom Reservoir would start with a higher carry-over storage. Because of the importance of the cold-water storage in Folsom Reservoir, summer releases from upstream reservoirs into Folsom Reservoir would need to be analyzed and constrained to avoid negative impacts to the cold-water pool due to stratification.

As presented in Figure 6-7, portion of Alder Creek Reservoir yield (May-September drawdown) is dedicated to local consumptive use (up to 40 TAF/year), and the remaining portion can be allocated to increasing Reclamation’s operational flexibility (up to 60 TAF/year).

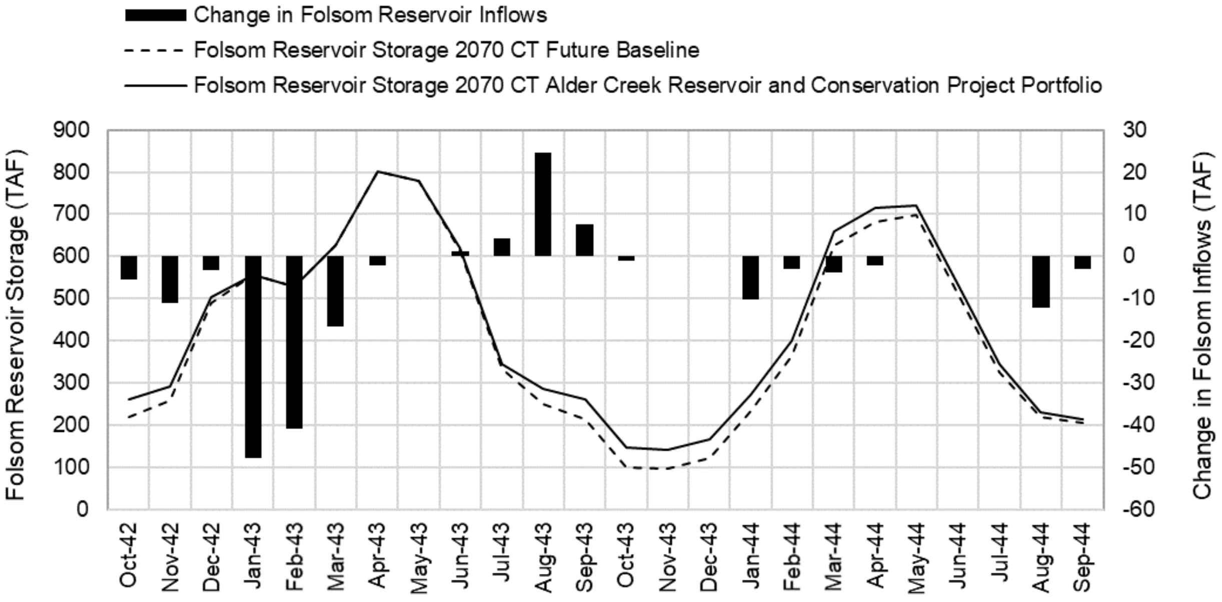


Figure 6-6. Folsom Reservoir storage in a representative wet year followed by a dry year (1943 and 1944), under 2070 CT Alder Creek Reservoir and Conservation Project Portfolio compared to 2070 CT Future Operations Baseline.

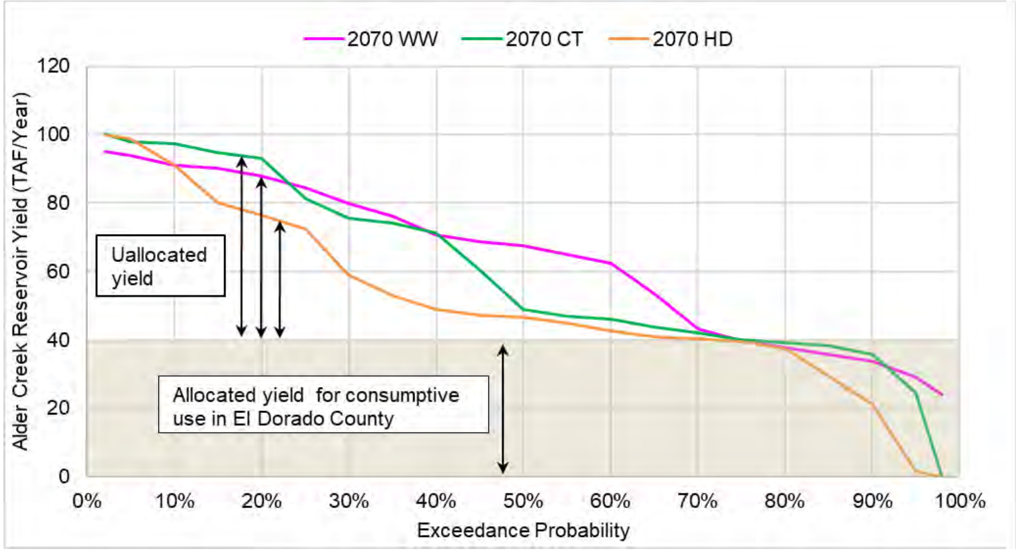


Figure 6-7. Alder Creek Reservoir projected annual yield under Alder Creek Reservoir and Conservation Project Portfolio under 2070 climate scenarios (WW, CT, and HD).

Alder Creek Reservoir unallocated yield (yield greater than 40 TAF/year) could be released downstream to Folsom Reservoir to increase Reclamation's operational flexibility to meet all authorized purposes.

6.4.3. Water Quality

This portfolio is anticipated to have limited impact to system-wide or Delta water quality because it would not have an appreciable effect on Delta inflows.

6.4.4. Flood Risk Management

Although this evaluation of the 175 TAF Alder Creek Reservoir did not include dedicated flood control surcharge space, Alder Creek Reservoir would reduce spills from Folsom Reservoir by up to 9 percent on average. It would intercept flood flows that otherwise would have reached Folsom Dam—thereby reducing peak flows in the Lower American River in average and wetter years. The timing of diversions into Alder Creek Reservoir would be intended to coincide with flood risk management operations at Folsom Reservoir to reduce spillage and, therefore, would not impact Reclamation's operations downstream.

Note that it would also be possible to establish conditional flood control storage tied to Folsom Dam FIRO in cooperation with SAFCA, or otherwise integrated with the Folsom Dam Raise with Groundwater Recharge Portfolio to further enhance water supply and flood risk management benefits. Under this arrangement, pre-releases from Alder Creek Reservoir would take place when large storms are forecasted 7 to 10 days in advance. The evacuated storage space would store some of the storm runoff—thereby reducing pressure on Folsom Reservoir and reducing the risks of high emergency releases down the Lower American River.

6.4.5. Fish and Wildlife Habitat Protection

June through October are often stressful on fisheries due to excessively warm water temperatures in the Lower American River. Increased storage in the Foothills would provide greater flexibility to manage the cold-water pool and improve flow and temperature conditions in the Lower American River but would be subject to Folsom Reservoir operations and hydrology. As formulated, the Alder Creek Reservoir and Conservation Project Portfolio operations would prioritize releasing water during months of peak demand—resulting in increased flows during summer months (Figure 6-6). The additional upstream storage would afford Reclamation additional flexibility to shift the timing of releases for fish and wildlife habitat needs or for water supply needs. To fully realize the cold-water benefits at Folsom Reservoir, some structural improvements to the temperature control device may be required. In addition, timing of upstream releases need to be further evaluated to avoid negative impacts to the cold-water pool due to stratification. Note that in this analysis, environmental effects from construction of Alder Creek Dam and associated facilities are assumed to be addressed through separate project-specific environmental reviews in consultation with resource agencies.

6.4.6. Recreation

Alder Creek Reservoir would provide additional recreation opportunities around the new reservoir and downstream areas through release.

6.4.7. Hydropower Benefits

Alder Creek Reservoir as proposed would be equipped with three powerhouses (total capacity of 110 megawatts [MW]). The proposed 175,000-acre-foot Alder Reservoir would divert approximately 180 TAF/year of water from the South Fork of the American River in addition to 23.4 TAF/year of local Alder Creek runoff. The resulting annual power generation would be up to 470,000 megawatt hours per year) (MWh/year (Mead and Hunt, 2004).

6.5. Sacramento River Diversion Project Portfolio

This portfolio evaluates the potential regional and system-wide benefits of using existing diversion facilities on the Sacramento River to reduce reliance on Folsom Reservoir and the American River project. During wetter conditions, diversions from the American River would continue in operations similar to the Baseline. Under drier conditions, some of the American River diversions would be shifted to Sacramento River at Natomas Mutual Water Company intakes. Sacramento River flows would remain unchanged downstream from the confluence with the American River.

Shifting diversions from the American River and Folsom Reservoir to the Sacramento River would enhance regional water supply reliability—especially during dry conditions—and increase the resiliency of regional groundwater supplies.

6.5.1. Water Supply Reliability

Available surface water supplies would be an average of 23 TAF more per year, and 49 TAF more per year during drought periods than under the 2070 CT future operations baseline. The increase in surface water supply reliability—especially during droughts—would reduce the region’s reliance on groundwater by 17 TAF/year. In addition, the new infrastructure would also help meet the buildout urban demand in Placer and Sacramento Counties. Key water supply reliability benefits for local agencies are summarized in Table 6-6. Simulated diversion volumes from the Sacramento River by local agencies are presented in Table 6-7.

Table 6-6. Regional Water Supply Reliability Benefits of the Sacramento River Diversion Project Portfolio Compared to 2070 CT Future Operations Baseline

Agency	Anticipated Water Supply Reliability Benefits
City of Sacramento—North American Groundwater Basin	• 5 TAF/year less reliance on groundwater • 57 TAF/year less reliance on the American River
City of Sacramento—South American Groundwater Basin	• Improved water supply reliability during dry periods as American River diversions is freed up for use in the South American Basin
Placer County Water Agency & California-American Water Company	• 30 TAF/year less reliance on American River supplies • Reliable supply for West Placer area
City of Roseville	• 6 TAF/year less reliance on Folsom Reservoir water supplies • Relief from WFA dry year restrictions
Rio Linda/Elverta Community Water District & Sacramento County Water Agency	• 12 TAF/year less reliance on groundwater

Table 6-7. Annual Sacramento River Diversions (TAF/year) Under the Sacramento River Diversion Project Portfolio

Agency	2070 Warm-Wet	2070 Central Tendency	2070 Hot-Dry
City of Sacramento[1]	59.7	57.4	56.9
Placer County Water Agency & California-American Water Company [2]	34.4	31.1	30.1
City of Roseville[3]	5.9	6.1	6.1
Rio Linda/Elverta Community Water District & Sacramento County Water Agency [4]	11.8	10.4	9.7
Total Sacramento River Diversion	**111.8**	**105.0**	**102.8**

[1] Shifts from Fairbairn Water Treatment Plant to Natomas Mutual Water Company's intakes and expanded Sacramento River Intake, using up to 81.1 TAF/year of the City of Sacramento's water rights on the Sacramento River.

[2] Shifts from Placer County Water Agency's assumed diversion of its 35 TAF/year CVP water service contract diverted from Folsom Reservoir

[3] Shifts from the City of Roseville's 7.1 TAF/year of Middle Fork Project supplies diverted from Folsom Reservoir.

[4] Offsets groundwater use in drier years by up to 29 TAF/year using Middle Fork Project water supplies

6.5.1.1. City of Roseville

The Sacramento River Diversion Project Portfolio would increase the City of Roseville's surface water reliability across all hydrologic conditions, with largest improvement during WFA dry year restrictions when Mar-Nov UIFRs are below 950 TAF (Table 6-8). The Sacramento River Diversion Project Portfolio would increase available surface water supplies to the City of Roseville by up to 5 TAF/year under 2070 CT climate scenario dry conditions.

Table 6-8. City of Roseville 2070 Annual Surface Water Diversions (TAF/year) Under 2070 CT Sacramento River Diversion Project Portfolio compared to the 2070 CT Future Operations Baseline

WFA Water Year Type	Description	2070 CT Year Type Frequency	2070 CT Future Baseline Diversions	2070 CT Sacramento River Diversion Project Portfolio Diversions	Increase in Diversions
Driest (Conference Year)	Less than 400 TAF	5%	22.3	24.8	+2.4
Drier (Wedge Year)	Greater than 400 TAF and less than 950 TAF	33%	44.9	45.7	+0.7
Average (Hodge Year)	Greater than 950 TAF and less than 1,600 TAF	36%	55.1	55.5	+0.4
Wet (No Restrictions)	Greater than 1,600 TAF	26%	57.2	57.3	+0.1
Long-term Average		**100%**	52.0	52.4	+0.4

6.5.1.2. City of Sacramento

The Sacramento River Diversion Project Portfolio would allow the City of Sacramento to receive surface water supplies from the Sacramento River when the Hodge flow criteria[1] limits the City of Sacramento's diversions on the American River. Under 2070 future baselines, Hodge flow criteria would limit diversions for up to six months each year on average. Table 6-9 shows that this portfolio would allow the City of Sacramento to increase its surface water diversions by 11 TAF/year on average. Under the most restrictive conditions (WFA Driest [Conference Year]), this portfolio would provide up to 65 TAF/year of additional water supply reliability for the City of Sacramento. This portfolio would increase water supply reliability for the City of Sacramento south of the American River as well as reduce reliance on groundwater in the City of Sacramento north of the American River by 15 TAF/year during the most restrictive conditions.

Table 6-9. City of Sacramento Surface Water Diversions (TAF/year) Under the 2070 CT Sacramento River Diversion Project Portfolio Compared to 2070 CT Future Operations Baseline.

WFA Water Year Type	Description	2070 CT Year Type Frequency	# of Months with Flows below Hodge Flow Criteria	2070 CT Future Operations Baseline Diversions	2070 CT Sacramento River Diversion Project Portfolio Diversions	Increase in Diversions
Driest (Conference Year)	Less than 400 TAF	5%	11	125.7	191.4	+65.8
Drier (Wedge Year)	Greater than 400 TAF and less than 950 TAF	33%	9	187.2	206.9	+19.7
Average (Hodge Year)	Greater than 950 TAF and less than 1,600 TAF	36%	5	208.4	214.7	+6.3
Wet (No Restrictions)	Greater than 1,600 TAF	26%	3	210.2	215.6	+5.4
Long-term Average		**100%**	6	201.1	212.1	+11.0

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[1] The Hodge flow criteria is a flow requirement that governs surface water diversions from the Lower American River. If the river flow rate is less than a specified minimum rate, diversions are not allowed unless an agency has no other supply source. Hodge flow criteria: 2,000 cfs between October 15 and February; 3,000 cfs between March and June; 1,750 cfs between July and October 14.

6.5.1.3. Placer County Water Agency and Cal-AM

Figure 6-8 shows the water supply sources for PCWA to meet 2070 demands. Supply sources include American River water supplies (CVP and Middle Fork Project), PG&E's Bear River water supplies, and groundwater. Under the Sacramento River Diversion Project Portfolio, up to 30 TAF/year of PCWA's American River diversions would be shifted to the Sacramento River (Figure 6-8). Although no net change in PCWA's total diversions would occur, this portfolio would help further diversify PCWA's water supply sources.

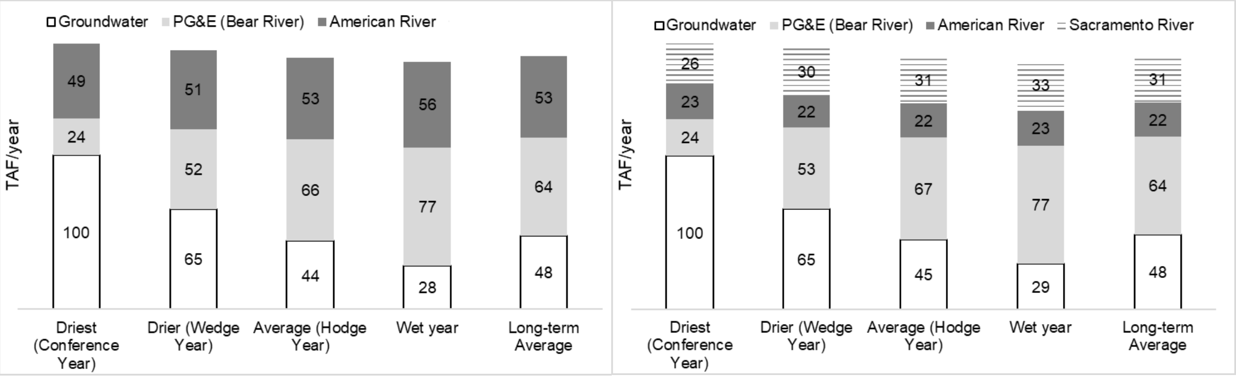

Figure 6-8. PCWA water supply sources to meet 2070 demands under the 2070 CT Sacramento River Diversion Project Portfolio (right) compared to the 2070 CT Future Operations Baseline (left).

6.5.1.4. Other Sacramento County Areas

The Sacramento River Diversion Project Portfolio would improve water supply reliability for the Sacramento County area north of the American River (including Sacramento County Water Agency service area and RLECWD) by diversifying its supply sources and reducing reliance on groundwater by 10 to 12 TAF/year (Table 6-7). This would improve groundwater sustainability.

6.5.2. Reclamation's Operation of Folsom Reservoir

Shifting diversions from the American River and Folsom Reservoir to the Sacramento River would increase water storage in Folsom Reservoir, providing Reclamation with the operational flexibility to:

- increase South of Delta exports when export capacity is available and
- meet environmental requirements on the American River, Sacramento River, and the Delta.

End-of-September storage in Folsom Reservoir would increase by up to 23 TAF (Figure 6-9), providing Reclamation with the flexibility to increase CVP water supply reliability, enhance Lower American River flows for fish habitat and spawning, and improve temperature management on both the American and Sacramento Rivers.

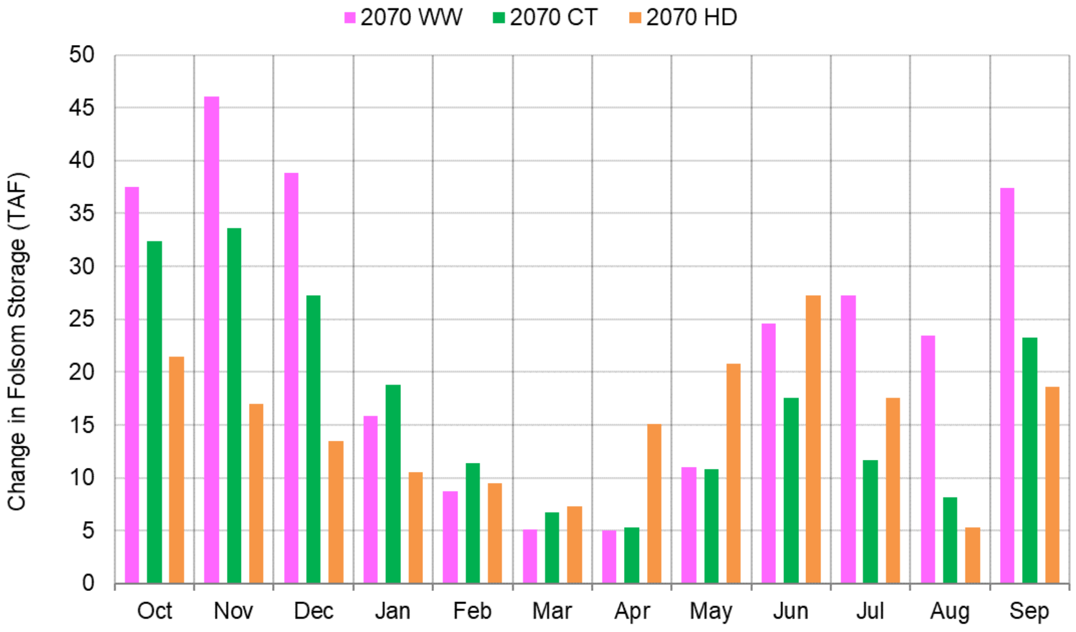

Figure 6-9. Change in Folsom Reservoir storage under the Sacramento River Diversion Project Portfolio relative to the Future Operations Baseline under 2070 climate scenarios (WW, CT, and HD).

6.5.3. Water Quality

This portfolio is anticipated to have limited impact to system-wide or Delta water quality because it would not have appreciable effect on Delta inflows.

6.5.4. Fish and Wildlife Habitat Protection

In the Sacramento River Diversion Project Portfolio, flows currently diverted from the American River and Folsom Reservoir would be held in Folsom Reservoir by diverting from the Sacramento River instead whenever possible, thereby enhancing cold water conditions both in Folsom Reservoir and downstream in the American and Sacramento Rivers.[1] June-November storage in Folsom Reservoir could increase by up to 10 percent (Figure 6-9), providing operational flexibility to maintain colder water and flows in the Lower American River. Stored supplies could also be released to maximize fall temperature benefits in the American and Sacramento Rivers for fish habitat and spawning.

The Sacramento River Diversion Project Portfolio would increase Lower American River flows throughout the spring and most of the summer (Figure 6-10). The decrease in September flows (Figure 6-10) corresponds to the increase in end-of-September carryover storage at Folsom Reservoir (Figure 6-9). Both Folsom Reservoir increased storage and American River flows would be at Reclamation’s discretion, within applicable laws and contractual constraints.

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[1] These flow changes would benefit the American River during drier conditions, while not impacting the Delta inflows or conditions. Timing of diversions can be further coordinated with Delta inflow requirements to benefit Reclamation by increasing CVP storage in Folsom Reservoir during drier conditions. An FY 2021 Reclamation Water Management Operations Pilot, Implementing FIRO at Folsom Reservoir, is conducting further detailed evaluations.

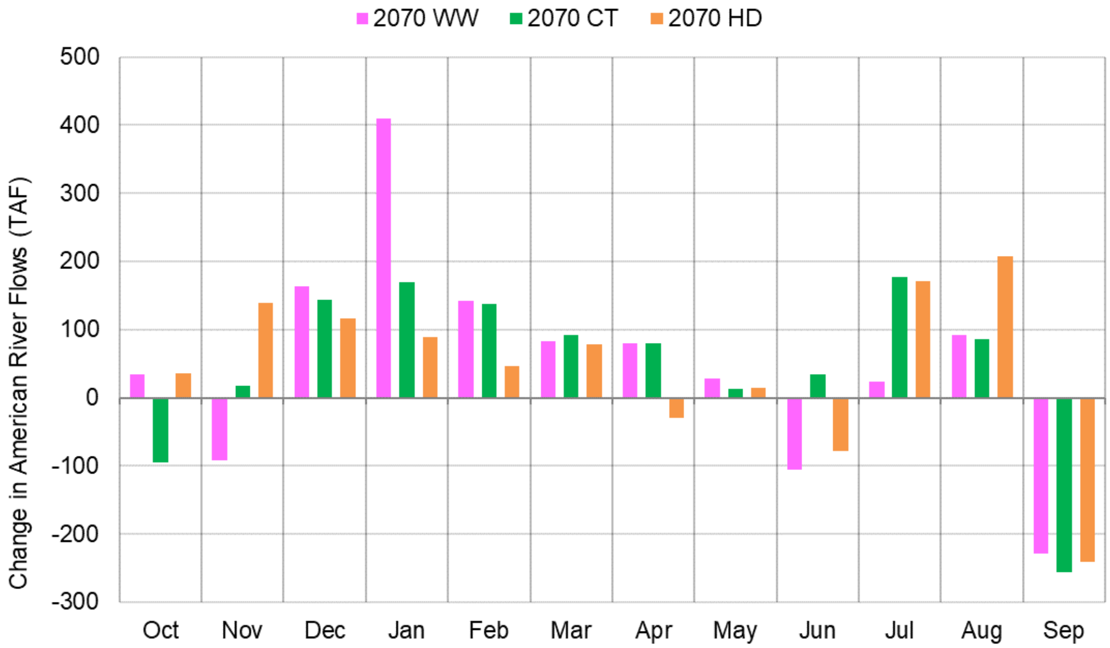

Figure 6-10. Change in American River flows at Sacramento River confluence under Sacramento River Diversion Project Portfolio relative to the Future Operations Baseline under 2070 climate scenarios (WW, CT, and HD).

6.5.5. Flood Risk Management

This portfolio is anticipated to have no impact on flood risk management in the study area.

6.5.6. Recreation

Relocating some Folsom Reservoir diversions to the Sacramento River would increase Folsom Reservoir carryover storage. This would contribute to increased surface area of the Folsom Reservoir and enhance recreation opportunities.

6.5.7. Hydropower

This portfolio is anticipated to have no impact on hydropower generation at Folsom Dam.

6.6. Federally Recognized Groundwater Bank (North and South American Groundwater Basins) Portfolio

This portfolio evaluates the regional and system-wide benefits for expanding conjunctive use operations via a federally recognized groundwater bank in the North and South American groundwater basins.

The Federally Recognized Groundwater Bank would enhance water supply reliability through enhancing groundwater sustainability.

6.6.1. Water Supply Reliability

Figure 6-11 illustrates the operations of the Federally Recognized Groundwater Bank Portfolio under the 2070 Central Tendency climate scenario. It shows groundwater recharge during wet periods and groundwater extraction during drier periods. It also shows the cumulative volume of accessible banked water and the cumulative volume of unrecoverable water (leave-behind). The leave-behind banked water (5 percent of recharged amount) would increase groundwater storage by 0.5 to 4.4 TAF/year (Table 6-10).

The **accessible storage** is the total recharged (banked) water, less the losses, that is available for withdrawal (recovery).

The **leave-behind (unrecoverable) storage** is the losses portion of recharged water. It includes:
(1) a one-time 5 percent loss factor of each recharged volume and
(2) a 1 percent annual loss factor of the total accessible storage volume.

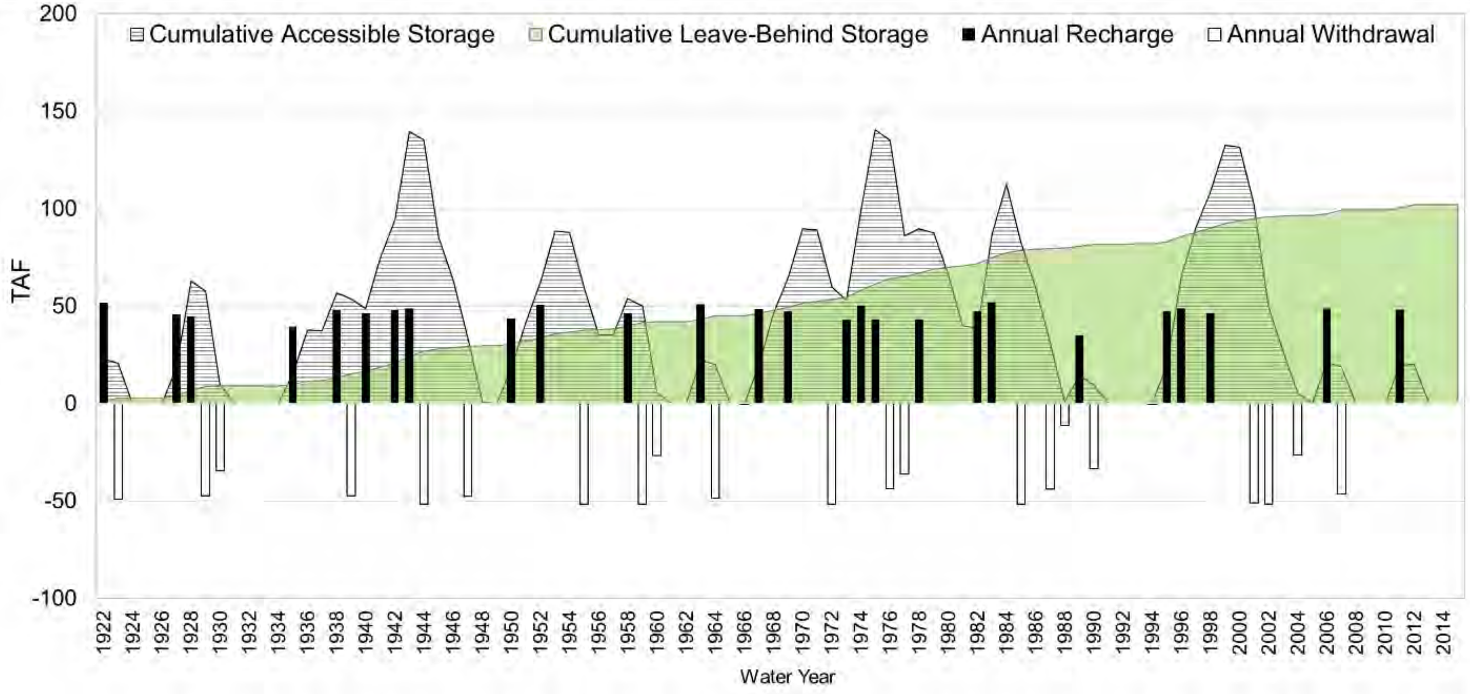

Figure 6-11. Simulated operations of the Federally Recognized Groundwater Bank Portfolio under 2070 CT climate scenario.

Table 6-10. Summary Results of the Federally Recognized Groundwater Bank Portfolio Analysis

Metric	**2070 Warm-Wet**	**2070 Central Tendency**	**2070 Hot-Dry**
Long-term Average Groundwater Recharge (TAF/year)	17.9	12.9	6.0
Long-term Average Groundwater Extraction (TAF/year)	11.2	9.6	5.5
Long-term Average Leave-Behind and Loss (TAF/year)	4.4	1.1	0.5
Cumulative Leave-Behind Groundwater Storage at End of Simulation Period (TAF)	650.6	102.1	44.6

6.6.2. Reclamation's Operation of Folsom Reservoir

The Federally Recognized Groundwater Bank Portfolio would provide Reclamation with operational flexibility, as foregone surface water deliveries during drier periods would be available to Reclamation in Folsom Reservoir. By using banked groundwater during drier years, Folsom Reservoir could be reoperated to increase May to September storage by about 10 TAF (Table 6-11). Figure 6-12 shows the increase in Folsom Reservoir storage, especially during periods of low storage. This portfolio would prioritize Folsom Reservoir storage support by minimizing surface water diversion on the American River in dry and critical years before consideration of potential transfers.

Table 6-11. Summary of Groundwater Recharge and Extraction Under the Federally Recognized Groundwater Bank (North and South American Groundwater Basins) Portfolio Under the 2070 CT Climate Scenario

WFA Water Year Type	**Description**	**2070 CT Year Type Frequency**	**Groundwater Recharge**	**Groundwater Extraction**
Driest (Conference Year)	Less than 400 TAF	5%	0	-11.4
Drier (Wedge Year)	Greater than 400 TAF and less than 950 TAF	33%	0	-25.3
Average (Hodge Year)	Greater than 950 TAF and less than 1,600 TAF	36%	0	-4.5
Wet (No Restrictions)	Greater than 1,600 TAF	26%	+46.6	0
Long-term Average		**100%**	+12.9	-9.6

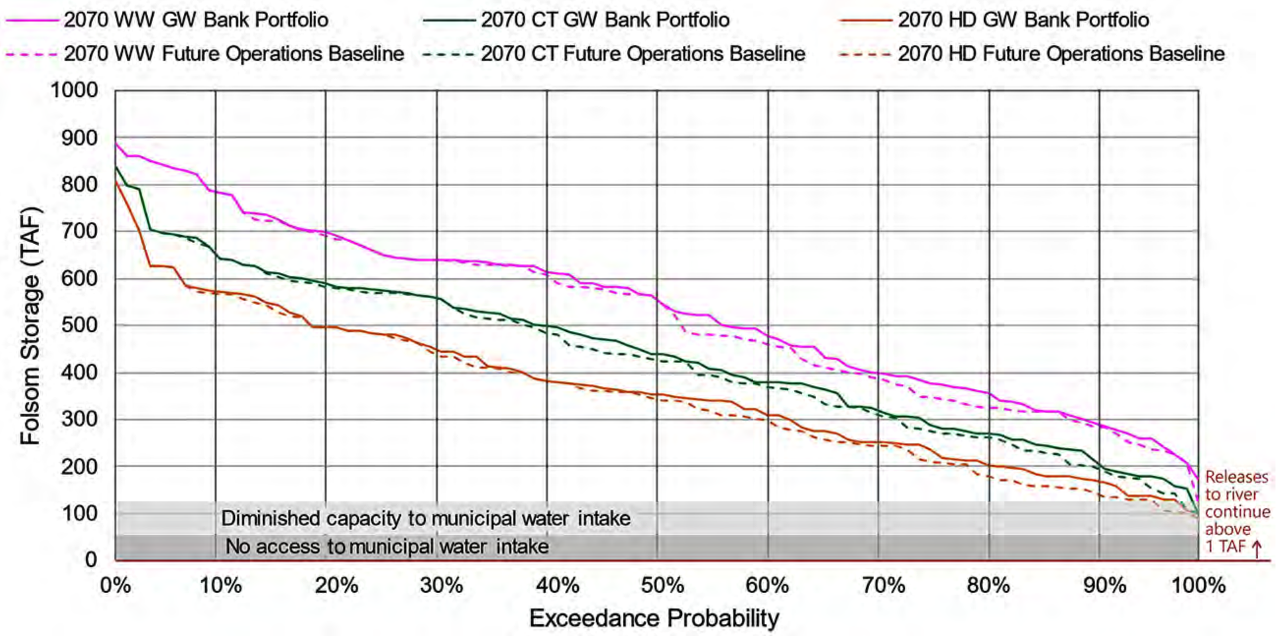

Figure 6-12. Folsom Reservoir storage during peak demand months (May-September) under the Federally Recognized Groundwater Bank Portfolio compared to Future Operations Baseline under 2070 climate scenarios (WW, CT, and HD).

6.6.3. Water Quality

This portfolio is anticipated to have limited impact to system-wide or Delta water quality because it would not have appreciable effect on Delta inflows.

6.6.4. Fish and Wildlife Habitat Protection

Banking partners may coordinate with Reclamation to switch from surface water diversions to banked groundwater to enhance cold-water conditions in Folsom Reservoir and downstream in the American and Sacramento Rivers. Foregone deliveries stored in Folsom Reservoir could be released to maximize fall temperature benefits in the Lower American River.

6.6.5. Flood Risk Management

This portfolio is anticipated to have limited effects on flood risk management in the study area. Note that the in-lieu groundwater recharge during wet years would not noticeably reduce flood releases from Folsom Reservoir. Figure 6-12 shows no change in Folsom Reservoir storage at high storage levels under this portfolio compared to the 2070 Future Operations Baseline under future climate scenarios (WW, CT, and HD).

6.6.6. Recreation

This portfolio is anticipated to have limited effects on recreation in the study area.

6.6.7. Hydropower

This portfolio is anticipated to have limited effects on hydropower generation at Folsom Dam.

6.7. Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio

This portfolio evaluates potential regional and system-wide benefits of an authorized Folsom Dam raise focused on increasing flood risk management by using FIRO at Folsom Reservoir with conjunction with new flood control surcharge space at upstream reservoirs.

Opportunities for pre-delivery of the flood releases for groundwater recharge in the South Basin, consistent with applicable water rights and permits, may be considered to create regional water supply and ecosystem benefits.

6.7.1. Water Supply Reliability

The Folsom Dam raise, authorized for flood risk management, in conjunction with allowable conditional storage operated under FIRO rules, would store some flood water that could be used for groundwater recharge. If no large storms are forecasted, some flood releases could be held in the conditional storage and diverted into Folsom South Canal to recharge planned spreading basins along the canal and the Cosumnes River. The amount of water diverted into the Folsom South Canal is limited to recharge capacity of spreading, which is assumed to 10 TAF per month (April to June) in this analysis. If large storms are forecasted, then the conditional storage would be rescinded, and reservoir evacuated to protect against flood risks.

Figure 6-13 shows the simulated recharge and withdrawals of the banking operations under the 2070 Central Tendency climate scenario. The banked water under this portfolio would contribute to improving groundwater overdraft conditions in the South American groundwater basin by up to 300 TAF—thereby enhancing sustainability and drought resiliency. Note that within the first 15 years of operations, the recharge amount of 10 TAF per month (April to June) results in the banked volume (accessible storage) reaching the 300 TAF banking cap assumed for this analysis. Subsequent years show limited groundwater recharge to fill evacuated storage through groundwater withdrawals. Figure 6-13 also shows the amount of cumulative leave-behind storage that would contribute to groundwater overdraft recovery in the South American groundwater basin.

6.7.2. Reclamation's Operation of Folsom Reservoir

Regional groundwater banking would provide CVP water supply benefits and operation flexibility. Banked CVP water supplies during wetter periods could be used in dry periods by project partners, and an equal amount of surface water would be made available at Folsom Reservoir for Reclamation to meet its authorized purposes. Table 6-12 shows that recharged surface water would average 32 to 19 TAF/year. Recovered banked water would average 13 to 27 TAF/year.

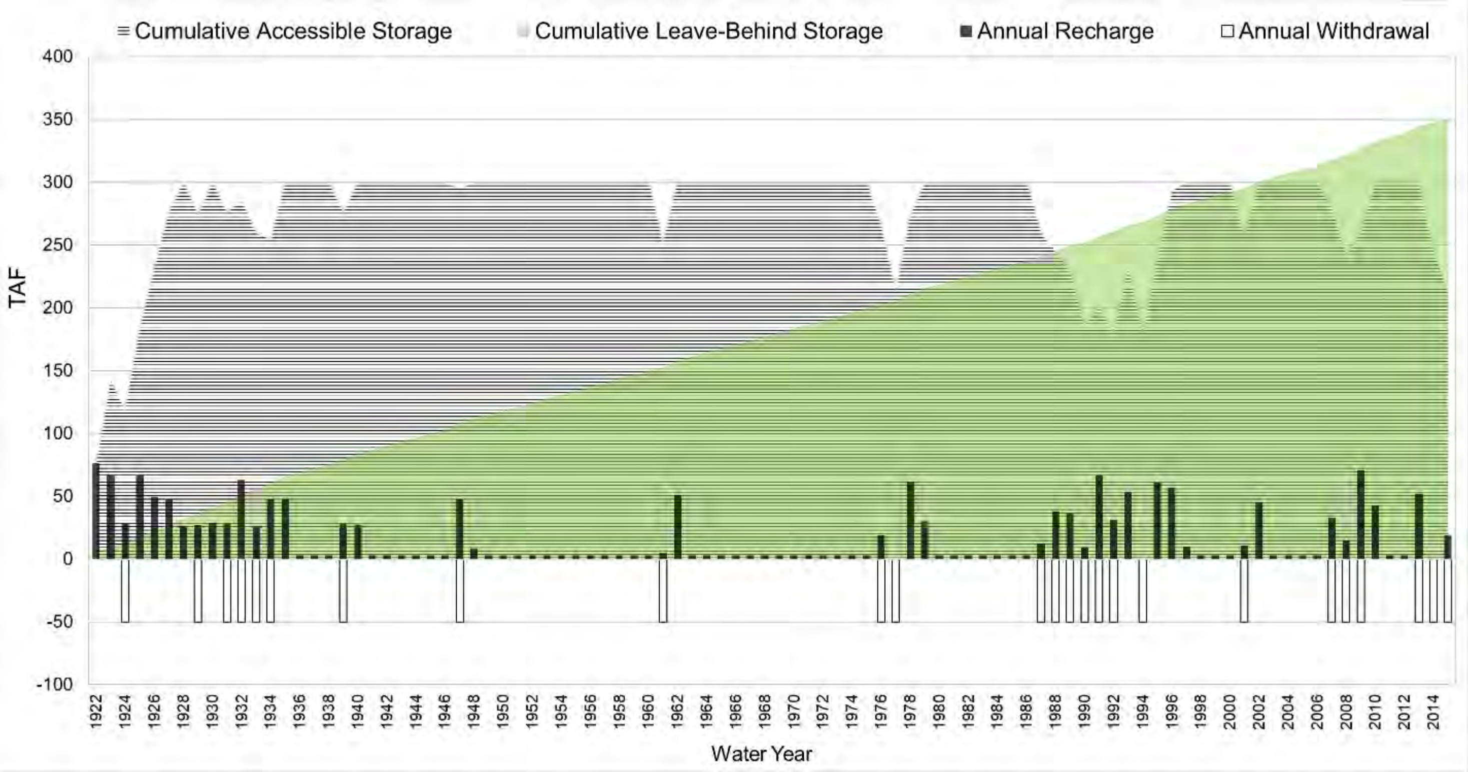

Figure 6-13. Simulated operations of the Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) portfolio under the 2070 CT climate scenario.

Table 6-12. Summary Results of the Folsom Dam Raise with Groundwater Banking Portfolio Analysis

Item	**2070 Wet-Warm**	**2070 Central Tendency**	**2070 Hot-Dry**
Long-term Average Recharge (TAF/year)	19.3	32.3	32.2
Long-term Average Recovery (TAF/year)	13.3	26.1	27.3
Long-term Average Leave-Behind and Loss (TAF/year)	3.7	4.0	3.7
Groundwater Bank Storage at End of Simulation Period (TAF)	276.5	237.2	205.7

6.7.3. Water Quality

This portfolio is anticipated to have limited impacts to system-wide or Delta water quality because it would not have appreciable effect on Delta inflows.

6.7.4. Fish and Wildlife Habitat Protection

Table 6-12 shows that this portfolio would contribute 205 to 276 TAF of banked water to increase groundwater storage in the South American River groundwater basin over the simulation period. This banked water would contribute to reversing groundwater overdraft conditions by reestablishing the hydraulic connectivity between the groundwater aquifer and the Consumes River. This hydraulic connectivity is key in supporting efforts for ecosystem restoration along the Consumes River, which is also an important tributary to the Delta.

In addition, project partners may coordinate with Reclamation to switch from surface diversions (including their CVP deliveries) to banked groundwater to enhance cold-water conditions in Folsom Reservoir and downstream in the American and Sacramento Rivers. Foregone deliveries stored in Folsom Reservoir would be released to maximize fall temperature benefits in the American River.

6.7.5. Flood Risk Management

By coordinating pre-releases and limited storage releases upstream of Folsom Reservoir together with Folsom Reservoir operations, this portfolio would lead to increased flood risk management downstream throughout the Lower American River. Up to 300 TAF of additional flood control surcharge space could be made available at the upper reservoirs (French Meadows, Hell Hole, and Union Valley Reservoirs). This additional flood control surcharge space would require agreements with reservoir owners and operators (PCWA and SMUD) and modifications to reservoir outlets to increase release capacity. According to modeled CalSim 3 results, Folsom Revoir has a normal full-pool storage capacity of 975 TAF with a seasonally designated flood control surcharge space that varies between 400 to 600 TAF based on forecast inflow conditions. Under this portfolio, Reclamation could coordinate with USACE and other entities. CalSim 3 modeling showed that coordinated operational changes could effectively increase the existing available flood management storage space on the American River from 400 to 600 TAF up to 700 to 900 TAF. In addition to the direct flood benefits from raising the dam, pre-delivery of flood flows for groundwater recharge could reduce Folsom Dam spills by 32 TAF/year on average. As CVP water supplies would not be increased with the Folsom Dam raise, this portfolio shows the potential opportunity for further study.

6.7.6. Recreation

This portfolio is anticipated to have limited effects on recreation in the study area because the dam raise is authorized for flood risk management and no long-term increase in reservoir level is anticipated.

6.7.7. Hydropower

This portfolio is anticipated to have limited effects on hydropower generation at Folsom Dam because the dam raise is authorized for flood risk management and no long-term increase in storage is anticipated.

6.8. 2019 BO Flow Management Standard Project Portfolio

This portfolio evaluates the effectiveness of the Flow Management Standard (FMS) implemented as part of the NOAA Fisheries and USFWS 2019 Biological Opinions on Long-term Operation of the CVP and SWP for the Lower American River (minimum flows, end of May and December targets, and spring pulse flows) (Sacramento Water Forum, 2015) along with construction of automated temperature control shutters at Folsom Dam, in reducing climate change effects on Lower American River ecosystem and fisheries. As the 2019 FMS is being implemented, this portfolio does not propose additional actions.

This portfolio evaluates the benefit of this water management strategy for climate change adaptation so that further coordination can determine future flow management standards. Thus, FMSs could change based on climate conditions and other variables.

6.8.1. Water Supply Reliability

Figure 6-14 shows that the proposed lower minimum release requirements during dry years and higher requirements during wet years in the 2019 BO FMS on the Lower American River would increase storage in Folsom Reservoir. The 2019 BO FMS would increase end-of-September carryover storage by 188 TAF, which would enhance water supply reliability in the American River Basin. The additional water available during wet periods could also be used to further expand conjunctive use operations in the region.

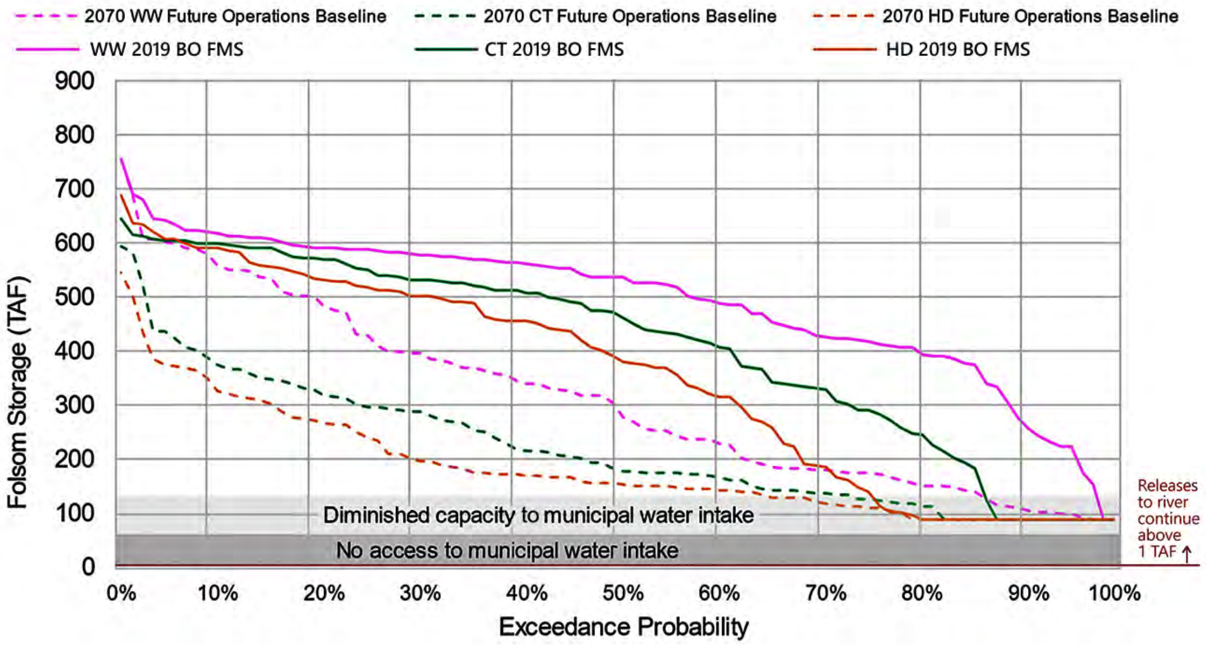

Figure 6-14. Exceedance plot of Folsom Reservoir end-of-September storage under the 2019 BO Flow Management Standard Project portfolio compared to the Future Operations Baseline under 2070 climate scenarios (WW, CT, and HD).

6.8.2. Reclamation's Operation of Folsom Reservoir

End-of-September carryover storage would increase by 188 TAF. This increased storage in Folsom Reservoir would provide Reclamation with additional flexibility, increasing CVP water supplies and helping to manage flow and temperature on the Lower American River. The required higher storage targets in Folsom Reservoir may affect other CVP storage (Shasta and Trinity Reservoirs), which may need to increase releases to offset Folsom reduced releases.

Figure 6-15 shows higher Folsom Reservoir storage during the June-October temperature stressor period under the Modified FMS compared to the 2070 future baselines. This is the result of the end-of-December targets. In addition to providing flexibility to Reclamation for cold-water management in the Lower American River, this portfolio would also improve water supply reliability with the increased carryover storage.

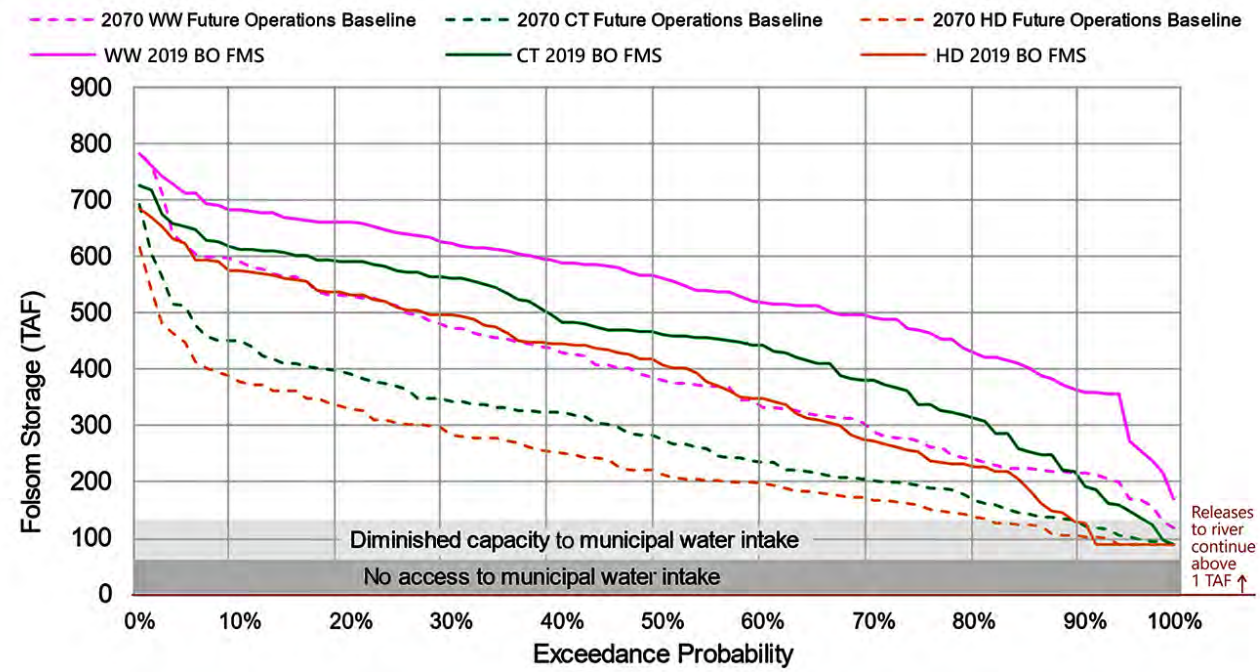

Figure 6-15. Exceedance plot of June to November Folsom Reservoir storage under the 2019 BO Flow Management Standard compared to Future Operations Baseline under 2070 climate scenarios (WW, CT, and HD).

6.8.3. Water Quality

This portfolio would not have an appreciable effect on Delta inflows and is anticipated to have limited impacts to system-wide water quality.

6.8.4. Fish and Wildlife Habitat Protection

Table 6-13 shows the amount of time that the Lower American River flows would be below 500 cfs and 800 cfs. Under the 2019 BO FMS portfolio, flows in the Lower American River would drop below 500 cfs in only 2 percent of all months compared to 11 percent of months under the 2070 CT future baseline. Flows between 500 cfs and 800 cfs would occur in 10 percent of all months compared to 13 percent under 2070 CT future operations baseline. Flows over 800 cfs would occur in 87 percent of the months compared to 76 percent under the 2070 CT future baseline. This improving trend holds the same for 2070 WW and 2070 HD future climate scenarios.

Figure 6-16 shows that the 2019 BO FMS addresses both the flow stressor period (March through May) and the temperature stressor period (June through November). It shows higher flows during the flow stress period. It also shows higher Folsom Reservoir storage during temperature stressor period, which will allow for better temperature management (Figure 6-17).

Table 6-13. Percent of Time that the Lower American River Flows Would Be below 800 and 500 cfs.

Lower American River Flow	2070 WW Future Operations Baseline	2070 WW 2019 BO FMS	2070 CT Future Operations Baseline	2070 CT 2019 BO FMS	2070 HD Future Operations Baseline	2070 HD 2019 BO FMS
Greater than 800 cfs	87%	96%	76%	87%	68%	80%
500 to 800 cfs	6%	3%	13%	10%	17%	12%
Less than 500 cfs	6%	1%	11%	2%	15%	7%

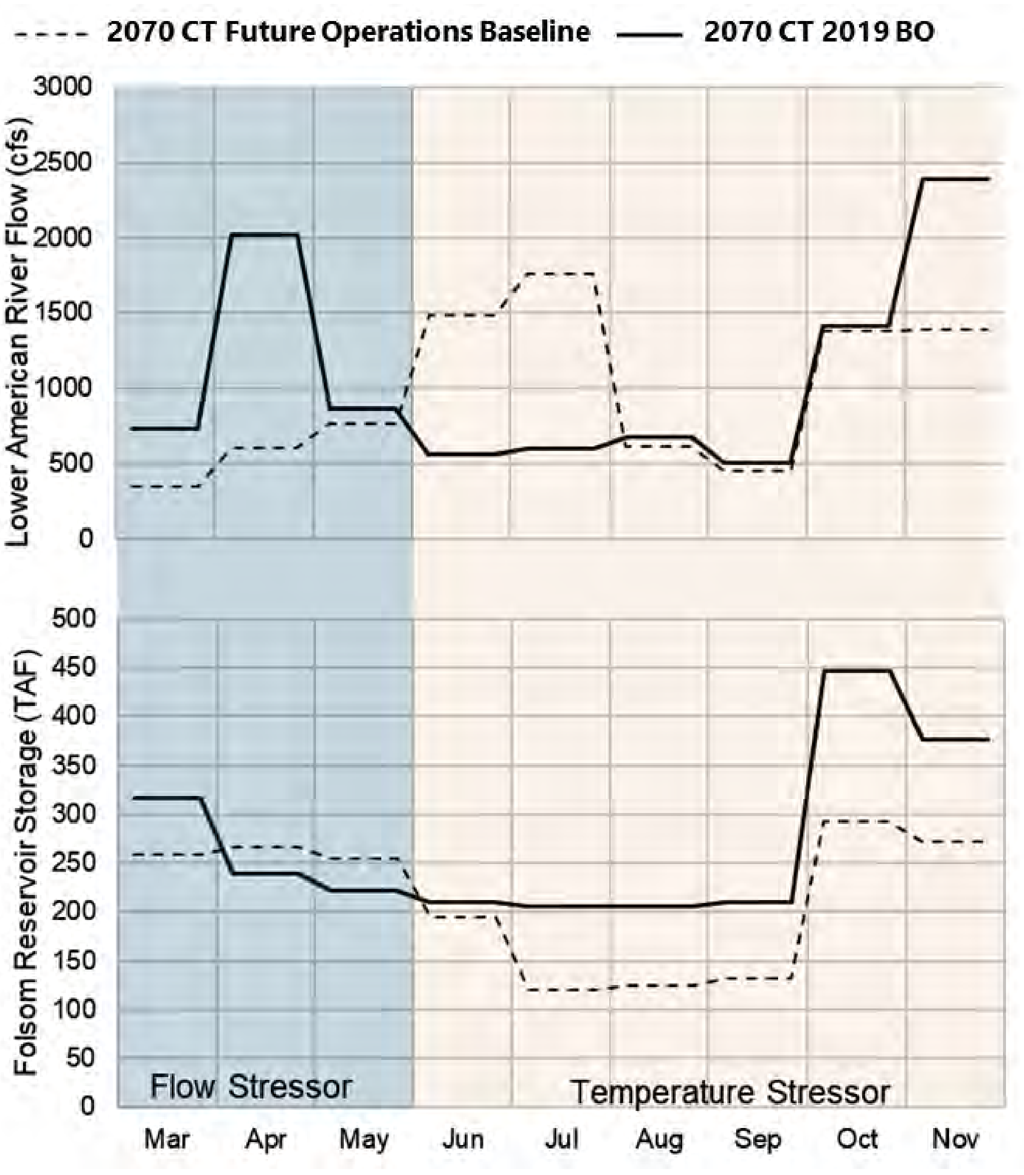

Figure 6-16. Lower American River flows and Folsom Reservoir storage during flow and temperature stressor periods with and without the 2019 BO FMS under the 2070 CT Future Operations Baseline.

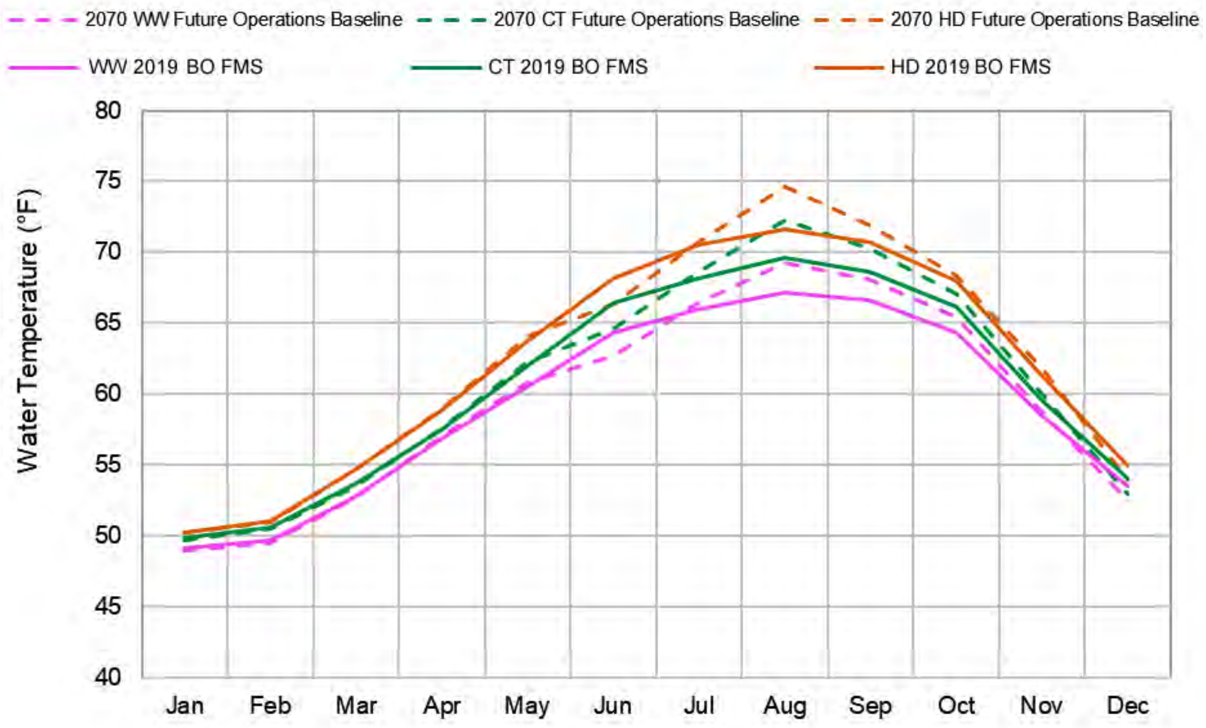

Figure 6-17. Average monthly water temperature in the Lower American River (at Watt Avenue) under the 2019 BO FMS compared to the Future Operations Baseline under 2070 climate scenarios (WW, CT, and HD).

6.8.5. Flood Risk Management

This portfolio is anticipated to have no effect on flood risk management in the study area.

6.8.6. Recreation

Revised storage and flow criteria would increase Folsom Reservoir carryover storage. This could contribute to increased surface areas for the Folsom Reservoir and enhance recreation opportunities.

6.8.7. Hydropower

This portfolio is anticipated to have no effect on hydropower generation at Folsom Dam.

6.9. Summary of Portfolios Evaluation

Figure 6-18 depicts the overall relative performance of the adaptation portfolios under future climate scenario projections. For each of the evaluation criteria, the green bars (to the right of the vertical axis) indicate positive effects; the red bars (to the left of the vertical axis) indicate negative effects; and no bars indicate no change or minimal change (less than 2 percent change in the metric). The relative length of the bar indicates the relative size of the effects. Detailed quantitative results of portfolio evaluation are provided in Appendix G. The following sections also provide in depth analysis of each portfolio and its unique adaptation features and benefits.

Figure 6-18 and Table 6-14 show that, relative to the Future Operations Baseline:

- All adaptation portfolios would provide benefits to Reclamation by increasing carryover storage in Folsom Reservoir or reducing demand on Folsom.
- All adaptation portfolios will provide fish and wildlife habitat benefits to varying degrees (mostly in the Lower American River). The 2019 BO Flow Management Standard Project Portfolio would provide the highest benefit.

For regional water supply reliability:

- The Importance of Long-Term CVP Water Contracts Portfolio shows that not providing contracts may contribute to overdraft conditions in the North and South American groundwater basins. This could result in an increase in groundwater extraction to meet demands.
- The Alder Creek Reservoir and Conservation Project Portfolio is the only portfolio that would help to address supply-demand imbalance in the Foothills.
- The other four portfolios would contribute positively to water supply reliability in the Valley Floor, including reducing the demand-supply imbalance and improving groundwater sustainability in both the North and South American groundwater basins.
- The Alder Creek Reservoir and Conservation Project and Folsom Dam Raise with Groundwater Banking Portfolios would contribute to flood risk management in Lower American River, as they both create flood control surcharge space in Folsom Reservoir or in upstream reservoirs (e.g., Alder Creek).
- The Alder Creek Reservoir and Conservation Project Portfolio would provide recreation benefits. The 2019 BO Flow Management Standard Project and the Sacramento River Diversion Project portfolios would also provide measurable recreation benefits by maintaining higher storage in Folsom Reservoir. The Folsom Dam raise, authorized for flood risk management, would not increase recreation benefits because increased storage is only used to manage large storms during flood season and not to increase carryover storage.
- The Alder Creek Reservoir and Conservation Project Portfolio would provide hydropower generation benefits. The Folsom Dam raise, authorized for flood risk management, would not increase hydropower generation because increased storage is only used to manage large storms during flood season and not to increase carryover storage.

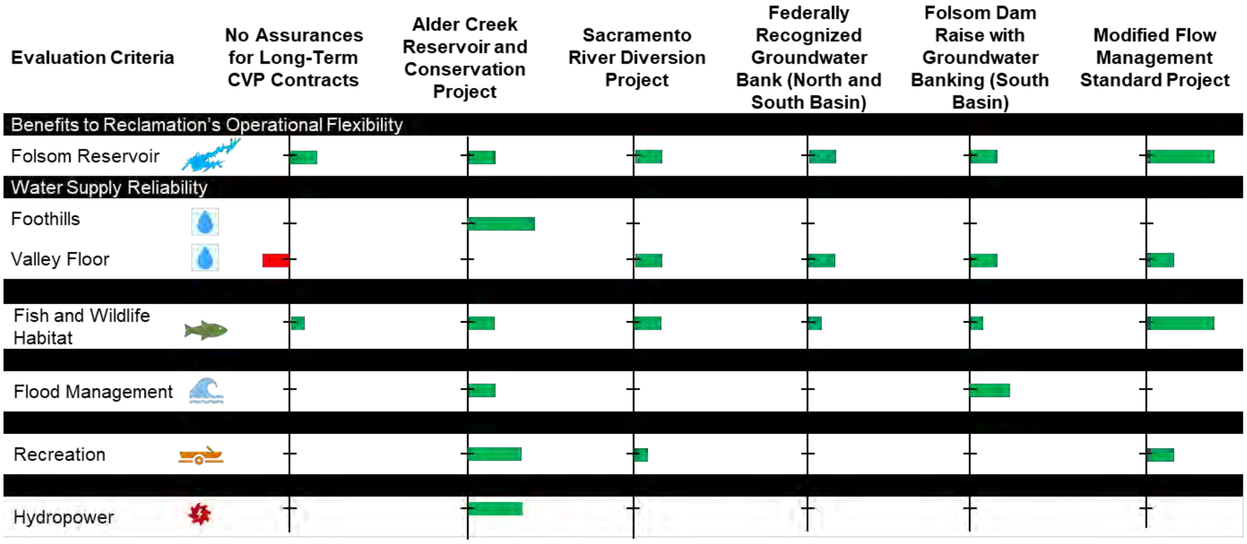

Figure 6-18. Summary of adaptation portfolio performance relative to the future operations baseline.

Table 6-14. Description of Adaptation Portfolio Performance Relative to Future Operations Baseline (green indicates positive effects, red indicates negative effects, and white indicates no or small changes (less than 2 percent change in metric).

Evaluation Criteria	Importance of Long-Term CVP Water Contracts	Alder Creek Reservoir and Conservation Project	Sacramento River Diversion Project	Federally Recognized Groundwater Bank (North and South Basins)	Folsom Dam Raise with Groundwater Banking (South Basin)	2019 BO Flow Management Standard Project
Benefits to Reclamation's Operation of Folsom Reservoir						
Folsom Storage	• Increase Folsom Reservoir carryover storage	• Increase Folsom Reservoir carryover storage • Reduce demands on Folsom Reservoir • Allow shifting some flood flows to summer months	• Increase Folsom Reservoir carryover storage by relocating diversions to Sacramento River. • Reduce demands on Folsom Reservoir during dry years	• Reduce demand on Folsom Reservoir during dry and critical years by using banked groundwater in dry periods	• Reduce demands on Folsom Reservoir by shifting use banked groundwater in dry periods	• Increase Folsom Reservoir carryover storage
Water Supply Reliability						
System-wide	Limited effect	Limited effect	Limited effect	Limited effect	Limited effect	Limited effect • May shift a small amount of storage from other CVP reservoirs due to carryover requirements in Folsom Reservoir
study area - Foothills	Limited effect	• Address supply-demand imbalance • Increase Foothills drought protection	Limited effect	Limited effect	Limited effect	Limited effect
study area – Valley Floor	• Increases groundwater use • Contribute to groundwater basin overdraft	Limited effect	• Increase available surface water supplies during drier periods • Increase groundwater basin recharge	• Increase groundwater basin recharge and contribute to groundwater sustainability	• Increase groundwater basin recharge and contribute to groundwater sustainability	• Improve reliability by increasing Folsom Reservoir carryover storage
Water Quality						
System-wide	Limited effect	Limited effect	Limited effect	Limited effect	Limited effect	Limited effect

Table 7-1. Adaptation Portfolio Performance Relative to 2070 Future Baselines (contd.)

Evaluation Criteria	**Importance of Long-Term CVP Water Contracts**	**Alder Creek Reservoir and Conservation Project**	**Sacramento River Diversion Project**	**Federally Recognized Groundwater Bank (North and South Basins)**	**Folsom Dam Raise with Groundwater Banking (South Basin)**	**2019 BO Flow Management Standard Project**
Fish and Wildlife Habitat						
System-wide	Limited effect	Limited effect	Limited effect	Limited effect	Limited effect	Limited effect
study area	• Increase in the Lower American River flows during temperature stress period (June-Nov)	• Potential to coordinate Foothills storage with flow and temperature management on the Lower American River	• Provide flexibility to increase cold water storage, and/or increase Lower American River flows • Increased river flows during temperature stress period (Jun-Nov)	• Provide flexibility to increase cold water storage, and/or increase river flows	• Contribute to restoration of Consumes River through Groundwater recharge • Use banked groundwater to improve flow and temperature management on LAR	• Increase in river flows during flow and temperature stress periods (Mar-May and June-Nov, respectively)
Flood Risk Management						
study area	Limited effect	• Reduce Folsom Dam spills and Lower American River peak flows • Potential for conditional flood control storage to support Folsom Dam forecast-based operations	Limited effect	Limited effect	• Improve flood risk management through Folsom Dam raise and forecast-based operations • Reduce spills through groundwater recharge	Limited effect
Recreation						
System-wide	Limited effect	Limited effect	Limited effect	Limited effect	Limited effect	Limited effect
study area	Limited effect	• Provide new recreation opportunities around Alder Reservoir and the downstream areas.	• Increase surface area of Folsom Reservoir	Limited effect	Limited effect	• Increase surface area of Folsom Reservoir
Hydropower						
study area	Limited effect	• Generate up to 470,000 MWh/year	Limited effect	Limited effect	Limited effect	Limited effect

Chapter 7. Findings and Next Steps

This section describes key ARBS findings and next steps.

7.1. Projected Future Conditions

Temperatures are projected to increase steadily, with summer temperatures increasing by approximately 7.2°F by the end of the 21st century and winter temperatures increasing by 4.9°F. Projections of daily maximum and minimum temperatures suggest similar seasonal trends. Maximum temperatures are projected to increase more than minimum temperatures during all seasons, with the largest increase of 7.3°F during summer months.

Approximately half of the projections indicate an increase in annual **precipitation** and half indicate a decrease, highlighting the large uncertainty in future precipitation over this region. Although there is not a clear trend in projected annual precipitation, by the end of the 21st century, average fall and spring precipitation is expected to decrease, with winter and summer precipitation increasing. Increasing variability is also projected in winter and fall precipitation. **Snowpack** will likely decline due to warming.

Runoff is expected to increase during winter months. Projections indicate a pronounced shift in the distribution of runoff from May and June to earlier in the season (December to March)—implying a shift in precipitation from snow to rainfall and/or earlier snowmelt. Peak runoff may shift to more than a month earlier by the mid- to late 21st century. Spring runoff will likely decrease due to reduced winter snowpack.

7.2. Projected Resource Impacts

Key anticipated impacts of the future climate projections on resources include:

- **Water supply reliability**: Under the 2070 level of development, the supply-demand imbalance is projected to be 63 to 78 TAF/year in the Foothills. However, because of groundwater availability in the Valley Floor, groundwater extraction is expected to increase by 62 to 155 TAF/year to offset the imbalance. Although no imbalance is projected, the increase in groundwater extraction would affect groundwater sustainability and result in overdraft conditions.
- **Flood risk management**: Increased early season runoff would increase flood risks along the Lower American River.
- **Hydropower and recreation**: Without changes to reservoir operations, the shift in runoff timing would affect reservoir storage during summer and fall months—reducing hydropower generation and recreation opportunities.
- **Fish and wildlife habitat**: The shift in runoff timing and potential lower Folsom Reservoir levels during summer and fall months would affect the reservoir's ability to manage flows and temperatures in the Lower American River for fish and wildlife habitat.

7.3. Overall Challenges to Water Management

Water management in the region is facing the combined climate pressures of warming temperatures, shrinking snowpack, shorter and more intense wet seasons, more volatile precipitation, and rising sea levels. Warmer, more intense storms add stress to surface reservoirs—making it harder to meet sometimes competing objectives. These climate pressures will make it harder to simultaneously store water for droughts, manage flood risk, and protect freshwater ecosystems. Warming has complex and interrelated effects: it reduces the share of precipitation falling as snow, causes earlier snowpack melting and higher winter runoff, raises water temperatures. Warming also amplifies the severity of droughts and floods: warmer, more intense droughts increase pressure to draw down groundwater resources and warmer, more intense storms add stress to surface reservoirs—making it harder to meet often competing objectives. Sea level rise threatens the Delta and puts more pressure on Folsom Dam to meet Delta water quality.

7.4. Adaptation Portfolios

Key findings from the adaptation portfolios evaluation are grouped by evaluation criteria category. Note that these evaluations were not intended to identify the “best” portfolio or combination of portfolios. Rather, they were intended to demonstrate the likely range of benefits that could be provided by each portfolio, emphasizing potential mutual benefits to the region and Reclamation.

7.4.1. Water Supply Reliability

The **Importance of Long-term CVP Water Contracts Portfolio** illustrates the role that CVP water contracts play for regional water reliability and groundwater sustainability. Without these supplies, groundwater extraction would increase by 57 to 62 TAF/year compared to the Future Operations Baseline. This would contribute to groundwater overdraft conditions in the North and South American groundwater basins.

Water reliability benefits to each region associated with the other portfolios are described below:

- Foothills:
  - **Alder Creek Reservoir and Conservation Project Portfolio**: Upstream storage would help address the supply-demand imbalance by meeting build out demands in most years. Storage would also provide drought protection.
- Valley Floor:
  - **Sacramento River Diversion Project Portfolio**: Relocating some diversions from Folsom Reservoir to the Sacramento River would increase available surface water supplies during drier periods and allow more opportunities for increasing in-lieu groundwater recharge.

  - **Federally Recognized Groundwater Bank (North and South American Groundwater Basins) Portfolio**: Expanding groundwater banking and conjunctive use practices would increase in-lieu groundwater recharge and contribute to long-term groundwater sustainability.
  - **Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio**: Expanding direct groundwater recharge in the South American Groundwater Basin would contribute to long-term groundwater sustainability.
  - **2019 BO Flow Management Standard Project Portfolio**: Updating the storage and flow criteria would increase Folsom Reservoir carryover storage; thereby reducing the risk of water levels below the municipal water intakes at Folsom Dam.

7.4.2. Reclamation's Operation of Folsom Reservoir

Each portfolio's central theme was formulated around an existing Federal authority or benefit nexus to Reclamation. Contribution to Reclamation's operational flexibility would be provided through the following two mechanisms:

- Increase Folsom Reservoir carryover storage:
  - **Alder Creek Reservoir and Conservation Project Portfolio**: Creating upstream storage to replace lost snowpack would capture flood flows that would otherwise be spilled from Folsom Reservoir and make some of these supplies available to Reclamation during summer months.
  - **Sacramento River Diversion Project Portfolio**: Relocating some diversions from Folsom Reservoir to the Sacramento River would increase Folsom Reservoir carryover storage.
  - **2019 BO Flow Management Standard Project Portfolio**: Revising storage and flow criteria would increase Folsom Reservoir carryover storage.
- Reduce demands on Folsom Reservoir:
  - **Alder Creek Reservoir and Conservation Project Portfolio**: Replacing Folsom Reservoir storage with upstream storage to meet portions of El Dorado County and City of Folsom demands would reduce demands on Folsom Reservoir.
  - **Sacramento River Diversion Project Portfolio**: Relocating some diversions from Folsom Reservoir to the Sacramento River would increase Folsom Reservoir carryover storage.
  - **Federally Recognized Groundwater Bank (North and South American Groundwater Basins) Portfolio**: Replacing surface water with banked groundwater water in dry and critical years would reduce demands on Folsom Reservoir.

  - **Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio**: Using banked groundwater water in dry and critical years rather than surface water and/or recycled water in South Sacramento County could reduce demands on Folsom Reservoir.

7.4.3. Water Quality

The formulated portfolios are anticipated to have limited impact to system-wide or Delta water quality because they would not have any appreciable effect on Delta inflows.

7.4.4. Fish and Wildlife Habitat Protection

Ecosystem protection of sensitive species and their habitats is an important Federal and local interest. Adaptation portfolios could contribute to ecosystem benefits in the following areas:

- Lower American River:
  - **Alder Creek Reservoir and Conservation Project Portfolio**: Upstream storage would provide opportunities to improve flow and temperature management in the Lower American River in coordination with Reclamation’s operations of Folsom Reservoir.
  - **Sacramento River Diversion Project Portfolio**: Relocating some diversions from Folsom Reservoir to the Sacramento River would increase Lower American River flows during the flow stress period (June-November). This portfolio would also provide opportunities to improve flow and temperature management in the Lower American River in coordination with Reclamation’s operations of Folsom Reservoir.
  - **Federally Recognized Groundwater Bank (North and South American Groundwater Basins) Portfolio**: Banked groundwater water would be used in dry and critical years rather than surface water, thereby providing opportunities to improve flow and temperature management in the Lower American River in coordination with Reclamation’s operations of Folsom Reservoir.
  - **Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio**: Banked groundwater water could be used in dry and critical years instead of surface water. Foregone surface water could reduce demands on Folsom Reservoir; thereby providing opportunities to improve flow and temperature management in the Lower American River in coordination with Reclamation’s operations of Folsom Reservoir.
  - **2019 BO Flow Management Standard Project Portfolio**: The storage and flow criteria would increase Lower American River flows during flow and temperature stress periods (March-May and June-November, respectively).
- Consumes River:
  - **Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio**: Expanding direct groundwater recharge in the South American groundwater basin would help recover groundwater overdrafts, which in combination

with other initiatives, would help reestablish hydraulic connectivity between the groundwater aquifer and the Consumes River. Reestablishing baseflow would contribute to ecosystem restoration along the Consumes River.

7.4.5. Flood Risk Management

Flood risk management is an important authorized purpose of Folsom Reservoir that would be affected under forecasted future climate conditions. There is a forecasted shift in the distribution of runoff from March to May to earlier in the season (December to March)—implying a shift in precipitation from snow to rainfall and/or earlier snowmelt. This would put additional stress on the flood risk management function of Folsom Reservoir. Adaptation portfolios could contribute to flood risk management benefits in the following areas:

- Expand Folsom Reservoir flood control surcharge space:
  - **Alder Creek Reservoir and Conservation Project Portfolio**: Upstream storage would provide opportunities to establish conditional flood control surcharge space facilitated by Folsom Dam FIRO in cooperation with SAFCA.
  - **Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio**: Raising Folsom Dam would provide additional storage that, coupled with FIRO, could enhance flood risk management for urban areas along the Lower American River.
- Reduce Folsom Dam Spills and Peak Flows on the Lower American River:
  - **Alder Creek Reservoir and Conservation Project Portfolio**: Upstream storage would intercept some flood flows, thereby reducing Folsom Dam spills and attenuating peak flows in the Lower American River.
  - **Federally Recognized Groundwater Bank (North and South American Groundwater Basins) Portfolio**: Increasing groundwater recharge when Folsom is spilling could contribute to reducing the spill volume.
  - **Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio**: Coordinating flood pre-releases from Folsom Dam through the South Folsom Canal would contribute to reducing Folsom Dam spills and attenuating peak flows in the Lower American River.

7.4.6. Recreation

Recreation is an important Federal and local interest. Adaptation portfolios could contribute to recreation benefits:

- Foothills:
  - **Alder Creek Reservoir and Conservation Project Portfolio**: Alder Creek Reservoir would provide recreation opportunities around the new reservoir and downstream areas on Alder Creek and the South Fork American River.

- Valley Floor:
  - **Sacramento River Diversion Project Portfolio**: Relocating some diversions from Folsom Reservoir to the Sacramento River would increase Folsom Reservoir carryover storage. This could increase water surface areas at Folsom Reservoir and enhance recreation opportunities.
  - **2019 BO Flow Management Standard Project Portfolio**: Revised storage and flow criteria would increase Folsom Reservoir carryover storage. This could increase water surface area at Folsom Reservoir and enhance recreation opportunities.

7.4.7. Hydropower Benefits

The Alder Creek Reservoir and Conservation Project Portfolio is anticipated to be equipped with 3 powerhouses (total capacity of 110 MW) and could generate up to 470,000 MWh annually.

7.5. Next Steps

The ARBS assessed several adaptation portfolios for addressing the range of vulnerabilities and future supply-demand imbalances in the study area. No singular adaptation portfolio was identified as the “best” option—each of the portfolios addresses some aspects of the effects of future changes in climate. Additionally, none of the adaptation portfolios analyses fully evaluated current Reclamation policy, Central Valley Project operational impacts, Western Area Power Administration’s (WAPA) integration or “green power” schemes, or applicable State and Federal laws and water rights. If any of these portfolios are evaluated further, analyses will be needed to ensure that they address these areas and Federal laws and policies are complied with.

Ultimately, the successful strategy for addressing future climate changes will require a combination of adaptation portfolios. The precise composition, scale, operations, partnerships, funding, and governance to advance these project concepts will require further evaluation and coordination among American River Basin interests, including Reclamation. Note that this Study did not attempt to optimize the scale or operations of proposed project concepts. In addition, synergies among adaption portfolios were not explicitly assessed to identify optimal combinations.

Planned next steps to advance the adaptation portfolios are summarized below:

- **Importance of Long-Term CVP Water Contracts Portfolio**: American River Division agencies with Interim Renewal Contracts have successfully worked with Reclamation to convert their contracts into repayment contracts to ensure long-term supplies. Reclamation executed congressionally mandated contract conversions on February 28, 2020 pursuant to the WIIN Act for City of Folsom, City of Roseville, PCWA, Sacramento County Water Agency, San Juan Water District, and SMUD, and finalized the water supply contract with EDCWA. These actions were significant steps to assist local agencies in long-term planning and an early success for the engagement between Reclamation and local agencies in the ARBS that were critical to support the other climate adaptation portfolios. This portfolio is thus retained in the Study to illustrate the importance of CVP water for the region. Reclamation and CVP contractors to continue to coordinate on contracts.

- **Alder Creek Reservoir and Conservation Project Portfolio**: Reclamation and EDCWA are working to initiate a Federal Feasibility Study (authorized by PL 108-361, Section 202). The effects of modeled inflows from the North and South Fork of the American River as well as Alder Creek would need to be further investigated in a feasibility study. Reclamation's participation in future Alder Creek project has not yet been determined.
- **Sacramento River Diversion Project Portfolio**: Reclamation, PCWA, and RiverArc project partners are working to advance planning for a Sacramento Groundwater Bank through the Basin Study Program—Water Management Options Pilots. More information on RiverArc is available on: https://riverarcproject.com/.
- **Federally Recognized Groundwater Bank (North and South American Groundwater Basins) Portfolio**: Reclamation and RWA are working to advance planning for a Sacramento Groundwater Bank through the Basin Study Program—Water Management Options Pilots. More information on RWA development of the bank is available at: https://rwah2o.org/sacramento-regional-water-bank/.
- **Folsom Dam Raise with Groundwater Banking (South American Groundwater Basin) Portfolio:**
    - USACE is initiating construction of the Folsom Dam Raise (authorized by PL 106-53 Section 101(a)(6); PL 108-137, Section 28; PL 110-114, Section 3029(b))
    - PCWA, SAFCA, and SMUD are cooperating on facility improvements upstream of Folsom Dam on Hell Hole Reservoir and Union Valley Reservoir to facilitate FIRO for improve downstream flood risk management.
    - In collaboration with regional partners, SAFCA is investigating the potential for flood-managed aquifer recharge in Sacramento County where feasible.
- **2019 BO Flow Management Standard Project Portfolio**: The 2019 BO FMS has been included in the NOAA Fisheries and USFWS 2019 Biological Opinions on Long-term Operation of the CVP and SWP. This analysis will be used in ongoing coordination to formulate the next FMS. More information on the 2019 BO FMS is available at: https://www.waterforum.org/the-river/flow-management-standard/.

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