Chapter 9
Climate Change Resiliency and Adaptation

9.1 Introduction

Climate is the average weather over many years, measured most often in terms of temperature, precipitation, and wind. For example, the climate of California's Central Valley is a Mediterranean climate, which is hot and dry during the summer and cool and damp in winter, with the majority of precipitation falling as rain in the winter months. Climate is unique to a particular location and changes on timescales of decades to centuries or millennia.

Climate change generally refers to "statistically significant variations of the mean state of the climate or of its variability, typically persisting for decades or longer" (Intergovernmental Panel on Climate Change 2021:2222). Although the climate can change, and has changed, in the past in response to natural drivers, recent climate change has been more rapid than previous episodes of climate change and has been unequivocally linked to increasing concentrations of greenhouse gases (GHGs) in Earth's lower atmosphere and the rapid timescale on which these gases have accumulated (Intergovernmental Panel on Climate Change 2021:SPM-5, TS-60). The major causes of this rapid loading of GHGs into the atmosphere include the burning of fossil fuels since the beginning of the Industrial Revolution, agricultural practices, increases in livestock grazing, and deforestation (Intergovernmental Panel on Climate Change 2021:150).

Higher concentrations of heat-trapping GHGs in the atmosphere result in increasing global surface temperatures, a phenomenon commonly referred to as *global warming* or *climate change*. Higher atmospheric GHG concentrations and global surface temperatures in turn result in changes to Earth's climate system, including rainfall patterns, extreme weather events, ocean temperature and acidity, the amount of spring snow cover in the Northern Hemisphere, atmospheric water content, and global sea-level rise (Intergovernmental Panel on Climate Change 2021:SPM-5, SPM-19, 2-5–7). Some of the above changes will result in specific impacts at the state and local levels.

9.1.1 Purpose

The objective for this chapter is to evaluate the Long-Term Operations of the State Water Project (SWP) facilities in the Sacramento–San Joaquin Delta (Delta), Suisun Marsh, and Suisun Bay (Proposed Project) and how climate change could influence the ability of the Project to fulfill its intended purpose. To understand this, this chapter analyzes three fundamental questions relating to climate change.

1. How is climate change projected to affect the study area?
2. How might the Proposed Project's operations and potential impacts on resources in the study area be exacerbated or mitigated by climate change?
3. How might the Proposed Project contribute to the study area's resiliency and ability to adapt to projected changes in climate, including extreme climate events?

This chapter is organized differently from the other resource chapters in this Draft Environmental Impact Report (EIR) because analyzing how climate change is projected to affect the study area, and how anticipated resource impacts resulting from the Proposed Project could be affected by climate change, are fundamentally different analyses than those presented in other chapters. One of the functions of this chapter is to analyze and disclose projected future conditions in the study area under climate change. The study area for this chapter includes the Sacramento River from the confluence with the Feather River to the Delta, the Delta, and the SWP facilities in Suisun Marsh and Suisun Bay. The Proposed Project does not affect areas upstream of the Delta region; however, the SWP water delivery system relies on runoff and reservoir releases in areas upstream of the Delta. The water delivery system may be affected by changes in hydrology and Delta salinity levels due to climate change, regardless of the proposed operational changes.

Section 9.2.3.1, "Climate Change Trends in the Study Area," addresses Question 1 by noting recent trends, climate change projections to midcentury, and expected climate impacts in the study area.

Question 2 is addressed in Section 9.4, "Potential Climate Change Impacts on Baseline Operations and the Proposed Project." Most resource chapters in this EIR evaluate how Proposed Project operations would affect the specific resources in question compared to existing operations at the time of the Notice of Preparation (June 2023); however, these chapters do not take into account the additional underlying effects of future climate change. This chapter compares the Proposed Project operations to existing operations, including reasonably foreseeable changes in existing conditions and changes that would be anticipated to occur in the foreseeable future (i.e., including climate change) to understand the impact of climate change and whether Proposed Project operations in the study area may exacerbate or mitigate effects to meet specified targets.

Section 9.5, "Climate Change Resiliency and Adaptation Benefits," discusses Question 3, the potential resiliency and adaptation benefits of the Proposed Project for the study area that may help address challenges posed by projected changes in climate and its associated impacts on resources in the study area.

This chapter contains an analysis of hydrologic modeling conducted to quantify the impact of climate change on Proposed Project operations. Modeling that considers climate change focuses on a future climate scenario that includes hydrologic conditions simulated using CalSim 3 and modeled using a 30-year climate period centered around year 2022 (2008–2037) with 15 centimeters (cm) of sea-level rise. The evaluation of model results on key locations shows the influence of climate change, and this analysis describes the impact of the Proposed Project to exacerbate or mitigate these effects. The Proposed Project is evaluated using a projection of future climate that includes changes in temperature, precipitation, and hydrology and sea-level rise. Assumptions and further detail on the modeling scenarios are found in Appendix 4A, "Model Assumptions," and Appendix 4D, "Climate Sensitivity."

Table 9-1 describes the differences between this chapter and the other resource chapters with respect to climate change discussion. The differences between these chapters allow readers to determine the incremental effects attributable to climate change as distinct from the impacts of the Proposed Project in key locations. Climate change and the Proposed Project operations both will influence flows and water availability at locations in the Delta, and it is important to understand the changes attributed to each influence.

Table 9-1. Comparison of Climate Change Chapter to Other Resource Chapters

Topic	Chapter 9, "Climate Change"	Other Resource Chapters
What is covered	Focuses on effects of climate change; also compares a climate-changed future with baseline operations to a climate-changed future with the Proposed Project. Evaluates how the Proposed Project would affect the resiliency of the study area or its resources to climate change. Discusses how the Proposed Project may support adaptation and resilience to climate change. Reference analyses of Project operations were performed for historical hydrology and current climate conditions and future climate and sea-level rise conditions with climate change scenarios and draw from Appendix 4A and Appendix 4D.	Focus on comparing Proposed Project operations current to Baseline Conditions (i.e., the environmental setting as it exists at the time of issuance of the NOP). This comparison excludes any impacts resulting from climate change. Includes a discussion of Proposed Project operations that describes expected conditions resulting from proposed policies and programs by federal, state, and local agencies in the absence of the climate changes that are anticipated to occur in the future. Select resources include appendices providing modeled quantitative comparisons for the Baseline against the Proposed Project current.
Limitations	Uses peer-reviewed literature and best available science to identify likely climate impacts in the study area and evaluate resiliency and adaptation. Uses CalSim 3 modeled output with current climate scenarios and future climate change scenarios centered around year 2022 with 15 cm of sea-level rise (see Appendix 4D).	Does not specifically contemplate the extent to which Proposed Project would contribute to meeting targets in the study area and the effects of climate change.

NOP = Notice of Preparation.

As noted in California Environmental Quality Act Guidelines Section 15064.4, the lead agency must determine: (1) whether GHGs may be generated by a proposed project and, if so, quantify or estimate the GHG emissions by type and source; and (2) whether the project's incremental contribution to climate change is cumulatively considerable. Because the Proposed Project will only result in operational changes and not involve any construction that may result in GHG emissions, this EIR does not contain a chapter discussing GHGs.

9.1.2 Organization

This chapter presents the following: (1) basic background on scientific efforts to evaluate the degree and impacts of future climate changes; (2) a discussion of observed climatological changes over the past several decades and expected future changes during the rest of this century globally, in California, and in the study area; and (3) an evaluation of how the Proposed Project's impacts on resources in the study area will be affected by climate change.

9.1.3 Climate Change Background

Scientific measurements have shown that changes in the global climate system are already occurring. These changes include rising global average surface temperatures, rising ocean temperatures, changes in precipitation patterns, changes in ocean salinity, ocean acidification, glacier shrinking, decreased Arctic sea-ice extent, rising global sea levels, and increased intensity and frequency of extreme events such as heat waves and heavy precipitation events (Intergovernmental Panel on Climate Change 2021:1-50–1-51, 2-7; California Natural Resources Agency et al. 2020:14–15).

Studies on climate change impacts conducted by the Intergovernmental Panel on Climate Change (IPCC), the U.S. Global Change Research Program (USGCRP), the Governor’s Office of Planning and Research (OPR), the California Energy Commission (CEC), the California Natural Resources Agency (CNRA), agencies in the State of California (e.g., the California Department of Water Resources [DWR]), the DWR Interagency Ecological Program, and the U.S. Bureau of Reclamation (Reclamation) are referenced throughout this chapter. Particularly relevant studies to the study area include the Delta Stewardship Council’s report, *Delta Adapts: Creating a Climate Resilient Future* (Delta Stewardship Council 2021) and DWR’s vulnerability assessment in the *Climate Action Plan Phase III: Climate Change Adaptation Plan* (California Department of Water Resources 2020).

IPCC was established by the United Nations Environment Programme and the World Meteorological Organization to provide the world with a clear scientific view of the current state of knowledge regarding climate change and its potential environmental and socioeconomic impacts (Intergovernmental Panel on Climate Change 2012:i). IPCC, an organization of more than 800 scientists from around the world, regularly publishes summary documents that analyze and consolidate all recent peer-reviewed scientific literature, providing a consensus of the state of the science. Thus, IPCC is viewed by governments, policymakers, and scientists as the leading international body on the science of climate change, and its summaries are considered the best available science. IPCC documents address changes at the global and super-regional scales. The *Sixth Assessment Report of the Intergovernmental Panel on Climate Change: Climate Change 2021: The Physical Science Basis* (AR6 Report) (Intergovernmental Panel on Climate Change 2021) is the most recent synthesis report and the one cited here, along with various special reports.

The USGCRP was established by a U.S. Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act of 1990 (15 U.S. Code, Section 2921 et seq.). It consists of 13 U.S. federal agencies that “conduct or use research on global change and its impacts to society.” USGCRP’s congressional mandate is to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.” As part of meeting this mandate, USGCRP develops National Climate Assessments that “analyze the impacts of global change in the United States,” and each assessment undergoes extensive external peer review to serve as an “authoritative” and “policy neutral” resource (U.S. Global Change Research Program 2023).

OPR, CEC, and CNRA coordinate development of statewide climate assessments, including *California’s Fourth Climate Change Assessment* (Fourth Assessment), published in 2018. The Fourth Assessment presents climate science and impact and adaptation analyses specific to the state, regional, or local levels and includes information and recommendations to inform vulnerability assessments and adaptation strategy development for sectors such as water resources and management in California (California Governor's Office of Planning and Research et al. 2018a). All research contributing to the Fourth Assessment was peer reviewed.

9.2 Affected Environment and Resources

The study area is in a region characterized by hot, dry summers and cool, rainy winters. From 1981 through 2010, average monthly temperatures in Sacramento ranged from 41.0 degrees Fahrenheit (°F) (5 degrees Celsius [°C]) in December and January to 94.1 °F (34.5 °C) in July, with average monthly rainfall ranging from a low of 0.02 inch (0.05 cm) in July to a high of 3.90 inches (9.9 cm) in February (Western Regional Climate Center 2021). Average air temperatures in the mountainous regions of the watershed are typically 5 to 10 °F (3 to 6 °C) lower than the temperature on the valley floor.

Although the snow lines vary by storm event, portions of the Sacramento, San Joaquin, Mokelumne, and Cosumnes River watersheds are above the snow line; consequently, much of their respective runoff into the Delta is from snowmelt. Snow in higher elevations serves as an effective type of natural storage because typically it melts gradually during the spring and summer, historically providing consistent flow into the Delta during these driest months of the year.

Precipitation at two geographic scales predominantly affect the Delta—local rainfall within the Delta, and precipitation in the broader Sacramento-San Joaquin watersheds, which is mostly received as snow in the Sierra Nevada. Most precipitation in the region occurs during cooler and wetter months from October through April, and occurs as storms or atmospheric river events (Delta Stewardship Council 2021:13-16). Precipitation that falls as rain can run off into the rivers (and eventually into the Delta), infiltrate into the soils (recharging the groundwater system), or evapotranspire. Factors such as spring temperatures and the nature of precipitation (i.e., rain/snow elevations in storms) during the October to April period play an important role in runoff timing.

Precipitation within the Delta and Delta watersheds is characterized by high interannual variability and considerable regional and geographic variability. From 1961 through 1990, the Suisun Marsh and north Delta regions experienced the highest annual average precipitation at 22 inches (56 cm), while the south Delta received 8 inches (20 cm) on average annually (Delta Stewardship Council 2021:3-15).

Sandy and peaty soils are found in the Delta region. These soils were developed by the formation of mineral soils near the channels during flood conditions and organic soils on marsh island interiors because plant residues accumulated faster than they could decompose. Prior to the mid-nineteenth century, the Delta was a vast marsh and floodplain, under which peat soils developed to a thickness of up to 65 feet (20 meters) in the central Delta (Whipple et al. 2012:125). In addition to peat, the Delta soils are composed of mineral sediments from rivers (U.S. Geological Survey 2013:3).

The study area historically has been affected by periodic extreme precipitation events. The majority of these historical events have likely been caused by atmospheric phenomena called *atmospheric rivers* (Dettinger 2011:518–519)—narrow corridors of water vapor transported in the lower atmosphere that traverse long swaths of Earth's surface (Ralph and Dettinger 2011:265). These storms can deliver large amounts of precipitation to California in a short period of time. In addition, these storms tend to be warm (originating in the tropics), which results in higher snow lines and larger portions of the watershed contributing to direct runoff.

Because this chapter discusses how the Proposed Project operational changes affect the study area with respect to climate change, this section also discusses expected changes to the affected environment. The following background sections provide brief descriptions of: (1) recent trends in key climate metrics, such as temperature, precipitation, and sea level; and (2) projections of how the climate will change in the future with a particular focus on changes by midcentury. Although the Proposed Project considers operational changes for a 10-year period, a midcentury time horizon (ranges centered around 2040 or 2050, depending on the data source) was chosen for discussion of climate change trends in this chapter because it represents the nearest available climate projections.

In the subsections that follow, this information is summarized at the global scale, at the state level, and for the study area. Projections of future climate change are based on: (1) the level of GHGs already in the atmosphere; (2) the current rate at which human activity releases GHGs to the atmosphere; and (3) the projected future rate of GHG emissions, which in turn relies on predictions of future population, global economic growth, future available energy sources, and regulations. Consequently, future projections of climate change typically are displayed as a range, with the lower end representing a lower expectation of the amount of change, and the higher end representing a higher expectation for the degree of change.

9.2.1 Global Climate Change Trends

9.2.1.1 Recent Trends in Climate

The IPCC has found observed changes to be unprecedented, "Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2,000 years" (Intergovernmental Panel on Climate Change 2021:SPM-8). Atmospheric and ocean warming, reduced snow and ice, and sea-level rise have been observed (Intergovernmental Panel on Climate Change 2021:1-50–1-51). Global average surface temperatures from 2011 to 2020 are 1.96 °F (1.09 °C) higher than those from 1850 to 1900 (Intergovernmental Panel on Climate Change 2021:SPM-5). Furthermore, the period from 1983 to 2012 was very likely the warmest 30-year period in the Northern Hemisphere over the last 800 years (Intergovernmental Panel on Climate Change 2021:2-34).[1]

Global mean sea levels rose by approximately 7.87 inches (0.2 meter) from 1901 to 2018 and have been rising at a higher rate since the mid-nineteenth century compared to the average rate in the two millennia prior, increasing to an average rate of 0.15 inch (3.7 millimeters) per year during 2006 to 2018 (Intergovernmental Panel on Climate Change 2021:SPM-6). Melting glaciers and ice sheets have been the main contributors to twenty-first-century global mean sea-level rise, as well as thermal expansion of oceans (Intergovernmental Panel on Climate Change 2021:SPM-11, 7-128).

The IPCC AR6 Report identifies observed changes in the climate system, causes of climate change, impacts of climate change, and changes in extreme events. In addition to warming surface temperatures and rising sea levels, the AR6 Report identified the following observed changes in the climate system: ocean warming; changes in precipitation, with trends varying by region; changes in ocean surface salinity; ocean acidification; mass loss in the Greenland and Antarctic ice sheets; global glacier shrinking; decreased extent of spring snow cover in the Northern Hemisphere;

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[1] The IPCC used the term *very likely* to indicate the assessed likelihood of the outcome or result, based on an evaluation of underlying evidence and agreement. *Very likely* probability indicates 90–100 percent likelihood of this outcome or result (Intergovernmental Panel on Climate Change 2021:SPM-4).

increased permafrost temperatures in most regions; and changes in sea-ice extent (e.g., decreased annual mean Arctic sea-ice extent and regional differences in extent of change in Antarctica) (Intergovernmental Panel on Climate Change 2021:SPM-5–SPM-6, SPM-11).

The AR6 Report also describes impacts of changes in climate on natural and human systems, including altering hydrological systems and shifting geographic range, migration patterns, seasonal patterns, abundances, and interaction of species. Some impacts on human systems have also been attributed to climate change, including the negative impacts of climate change on crop yields and fisheries (due to ocean acidification), which have adverse effects on food security (Intergovernmental Panel on Climate Change 2021:1-69–1-70, 5-56).

Furthermore, the AR6 Report states that since 1950, changes in extreme weather and climate events have been observed, including increases in the frequency of warm temperature extremes, extreme high sea levels, and the number of heavy precipitation events (Intergovernmental Panel on Climate Change 2021:SPM-8). Additionally, globally, the number of warm days and nights has increased, and heat waves have become more frequent, along with increased intense tropical cyclone activity (Intergovernmental Panel on Climate Change 2021:TS-67, TS-82).

The IPCC also found that measurements have shown a decline in the extent of mountain glaciers; increased atmospheric water vapor content; increased precipitation in most of North America, the southeastern portion of South America, northwestern Australia, and northern and central Eurasia; drying conditions in most of Africa, the Mediterranean, the Middle East, eastern Australia, central South America, and parts of East Asia and Canada; strengthening in mid-latitude westerly winds; more intense and frequent drought conditions in some regions; and decreased frost days and increased frequency and duration of extreme heat events (since the 1950s) (Intergovernmental Panel on Climate Change 2021:8-34, 12-31, 12-78, 12-96, 12-105, SPM-19).

9.2.1.2 Twenty-First Century Climate Change Projections

A variety of climate changes are projected to occur during the twenty-first century. The shared socioeconomic pathways (SSP) scenarios begin to affect the magnitude of projected changes in climate by midcentury, with increasing divergence among scenarios in 2100 and beyond. The SSP5-8.5 modeling trajectory represents a very high GHG concentration trajectory if no concerted policy efforts are undertaken to reduce GHGs; the SSP2-4.5 modeling scenario represents an intermediate GHG concentration trajectory. GHG concentration trajectories vary depending on socioeconomic assumptions and climate mitigation levels (Intergovernmental Panel on Climate Change 2021:SPM-14–SPM-15).

The IPCC finds that compared to 1850 to 1900 levels, global surface temperatures are likely to be higher by approximately 2.7 °F (1.5 °C) and 2.9 °F (1.6 °C) in the near term (2021–2040) and 3.6 °F (2 °C) and 4.3 °F (2.4 °C) in the mid-term (2041–2060), under the SSP2-4.5 and SSP5-8.5 scenarios, respectively (Intergovernmental Panel on Climate Change 2021:SPM-14). Warming will vary by region—more rapid warming will continue to occur in the high-latitude Arctic region compared to the global mean, warming over land will be greater than warming over oceans, and there will be global average warming for all modeling scenarios. Hot temperature extremes are projected to become more frequent and cold extremes less frequent over most land areas on seasonal and daily timescales for all modeling scenarios. Heat waves are projected to increase in frequency and duration, although cold winter extremes will continue to occur on occasion (Intergovernmental Panel on Climate Change 2021:TS-61, TS-66, TS-82).

Changes in precipitation, ocean temperatures and acidity, Arctic sea ice and near-surface permafrost extent, glacier volume, and sea levels are also likely to occur for all SSP modeling scenarios (Intergovernmental Panel on Climate Change 2021:SPM-22, TS-143). Changes in precipitation may vary by region, with many high-latitude regions, mid-latitude wet regions, and the equatorial Pacific likely to see increased mean precipitation and many subtropical regions likely to see decreased mean precipitation by end of century under all SSP modeling scenarios. Additionally, increased frequency and intensity of extreme precipitation events is likely, depending on regional conditions, such as monsoons and mid-latitude storms (Intergovernmental Panel on Climate Change 2021:SPM-9, SPM-18).

Ocean warming and global ocean acidification will continue over the century for all SSP scenarios. Surface ocean pH is projected to decrease for all SSP scenarios. Arctic sea ice is projected to decrease, as is the extent of permafrost and mountain and polar glaciers across scenarios (Intergovernmental Panel on Climate Change 2021:SPM-15, SPM-22).

Global average sea levels are projected to continue to rise through the twenty-first century and at a faster rate compared to historical rates. Compared to 1995 to 2014, midcentury (2050s) global mean sea-level rise is likely to be 0.55 to 0.85 foot (0.17 to 0.26 meter) under the intermediate SSP2-4.5 modeling scenario and 0.65 to 0.95 foot (0.20 to 0.29 meter) under the SSP5-8.5 scenario, although there will be variation by region.[2] By 2100, sea levels will very likely rise in more than approximately 95 percent of the ocean area,[3] and almost 70 percent of the global coastline is projected to see a change in sea level within ±20 percent of the global mean increase (Intergovernmental Panel on Climate Change 2021:SPM-21, SPM-25).

IPCC projected additional changes to the global climate system, including reduced global snow cover; increased thaw depth in permafrost regions; decreased sea ice with potential full disappearance in summer months; increased frequency of heat waves, droughts, and heavy precipitation events; increased intensity of tropical cyclone events; and northward movement of extra-tropical storm tracks (Intergovernmental Panel on Climate Change 2021:TS-67, TS-71, TS-76, TS-82, TS-134).

9.2.2 Climate Change Trends in California

This section reviews the current understanding of potential climate change in California as established by recent scientific and peer-reviewed publications, including the *California's Fourth Climate Change Assessment* and the *Fifth National Climate Assessment*. These assessments use projections from downscaled Coupled Model Intercomparison Project Phase 5 (CMIP5) Global Climate Models using Representative Concentration Pathway (RCP) GHG trajectories, rather than the SSPs. Downscaled projections for California using CMIP6 Global Climate Models and SSPs are in development and will be used in future state and federal climate assessments.

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[2] IPCC used the term *likely* to indicate the assessed likelihood of the outcome or result, based on an evaluation of underlying evidence and agreement. *Likely* probability indicates 66–100 percent likelihood of this outcome or result (Intergovernmental Panel on Climate Change 2021:SPM-4).

[3] IPCC used the term *very likely* to indicate the assessed likelihood of the outcome or result, based on an evaluation of underlying evidence and agreement. *Very likely* probability indicates 90–100 percent likelihood of this outcome or result (Intergovernmental Panel on Climate Change 2021:SPM-4).

California has experienced warming during the twentieth century, and annual maximum temperatures are projected to increase throughout the twenty-first century (California Governor's Office of Planning and Research et al. 2018a:23).

Overall precipitation is projected to continue to be variable, and annual precipitation may increase broadly in the north and decrease in the southernmost regions of California (California Governor's Office of Planning and Research et al. 2018a:25). These wetter conditions in the northern regions are expected to be more notable under the RCP 8.5 GHG concentration trajectory compared to the RCP 4.5 trajectory, particularly in the central California coast, due to the increased heavy precipitation extremes (Scripps Institution of Oceanography 2018:22). Some basins overall—and some areas within basins—are projected to become wetter, some are projected to become drier, and some have approximately equal chances of becoming drier or wetter (California Governor's Office of Planning and Research et al. 2018a:25). Projected changes in precipitation are less consistent across climate models and characterized by greater uncertainty compared to projected changes in temperature. Although changes in annual precipitation are projected to be small in many regions throughout California, extreme heavy precipitation events and dry spells are projected to increase significantly throughout the state (California Governor's Office of Planning and Research et al. 2018a:22, 26).

Warming trends appear to have led to a shift in cool season precipitation toward more rain and less snow, which has caused increased rainfall-runoff volume during the cool season accompanied by less snowpack and spring snow water accumulation in some western United States locations (Scripps Institution of Oceanography 2018:51; California Governor's Office of Planning and Research et al. 2018a:26). Climate projections suggest that warming and associated loss of snowpack will persist over much of the western United States throughout the end of the century (U.S. Global Change Research Program 2023). However, there are some geographic contrasts. Snowpack losses are projected to be greatest where the baseline climate is closer to freezing thresholds (e.g., lower-lying valley areas and lower-altitude mountain ranges). It also appears that in some high elevation regions there is a chance that snowpack actually could increase during the twenty-first century because winter precipitation increases are projected (U.S. Bureau of Reclamation 2021:ES-iii). This increase in snowpack in some areas may occur during rain–snow storms due to an increase in mixed precipitation types and increased precipitation (California Energy Commission 2018a:40).

One of the technical reports in California's Fourth Climate Change Assessment is *Mean and Extreme Climate Change Impacts on the State Water Project* (California Department of Water Resources 2018a). This report used the CalSim 3 water resources planning model to assess risks of midcentury impacts of shifting hydrology, warming temperatures, and rising sea levels on the SWP. It also presents key findings on impacts on the SWP system by midcentury under both the RCP 8.5 and RCP 4.5 modeling scenarios, indicating that both water quantity and quality in the Delta would be affected by climate change.

The technical report *Climate Change Risk Faced by the California Central Valley Water Resource System* is also included in the Fourth Assessment and was prepared by DWR (California Department of Water Resources 2018b). This report assesses water supply vulnerability to midcentury climate impacts of changing temperatures and precipitation, using a stress-test strategy and Global Climate Model-based probability estimates, under RCPs 4.5 and 8.5. It uses the 1,100-year record of Sacramento and San Joaquin River flows, assessing extreme droughts and floods and variability. The report presents key findings on changing temperatures and precipitation levels that could affect system performance, finding likely declines in system performance of supply, storage, and Delta outflow with increasing temperatures (California Department of Water Resources 2018b:iii).

9.2.2.1 Recent Trends in Climate

Over the last 100+ years, temperatures have been warming and sea levels have been rising. Observed changed in annual average temperature across the state show an increase of 1–2 °F from a historical baseline (1901–1960) to present day (1986–2016), with some areas exceeding 2 °F (California Governor's Office of Planning and Research et al. 2018a:22). Sea levels along the central and southern California coast have also rise by more than 5.9 inches over the twentieth century (California Governor's Office of Planning and Research et al. 2018a:31).

California experiences significant precipitation variability across seasons, between annual, monthly, and daily precipitation totals, and in multi-year dry and wet cycles; notably, extreme precipitation events significantly affect annual variability. This climate is exemplified by recent, unusually wet years (e.g., 2005, 2011, 2017) and droughts (e.g., 2012–2016) (California Governor's Office of Planning and Research et al. 2018a:24). Long-term observations have not shown significant trends of California being wetter or drier overall, but rather recent trends have observed general increases in annual, winter, and spring precipitation variability that indicate an increasing frequency of precipitation extremes—heavy precipitation and drought (He and Gautam 2016:11, 17).

Over the last 60+ years, snowpack has been declining, there have been some downward trends (mostly not significant) in marine layer clouds, and there have been no significant trends in frequency and intensity of Santa Ana winds (California Governor's Office of Planning and Research et al. 2018a:22). Winter storms caused by atmospheric river events—modeled by the U.S. Geological Survey (USGS) ARkStorm scenario (U.S. Geological Survey 2018) and often referred to as *ARkStorms*—can create heavy precipitation when they encounter mountain ranges along the coast and are capable of creating widespread, severe flooding. ARkStorms can also contribute to snowpack when occurring in the colder months. Many of California's water resources depend on snowpack from atmospheric rivers each year (California Governor's Office of Planning and Research et al. 2018a:24–26).

Over the last 30+ years, acres burned by wildfire have been increasing, for which both biophysical factors (e.g., temperature, moisture, wind, vegetation) and rapid population growth near wildland areas are attributed as causes (California Governor's Office of Planning and Research et al. 2018a:22).

9.2.2.2 Twenty-First-Century Climate Change Projections for California

In brief, projected trends of climate impacts anticipate future temperature warming, sea-level rise, snowpack decline, and increasing intensity of heavy precipitation events, frequency of drought, and acres burned by wildfire. The direction of future change in annual precipitation, frequency and intensity of Santa Ana winds, and marine layer clouds is unknown (California Governor's Office of Planning and Research et al. 2018a:22).

Trends and associated impacts will vary by region, and it will become increasingly critical for water managers to use climate science and projections to plan as historical hydrological information stops serving as a "trustworthy guide" (California Natural Resources Agency et al. 2020:14–15).

As described in the 2020 California Water Resilience Portfolio (California Natural Resources Agency et al. 2020:14–15), these trends may affect California water resources in various ways, including those listed below.

- Increased risk of intense storms and flooding, rising sea levels, and storm surges, making coastal communities vulnerable to coastal flooding and seawater intrusion. Water resources in the San Francisco Bay Area and Delta may be adversely affected, for example, by increased salinity.
- Decreased snowpack in areas such as the Cascade and Sierra Nevada ranges may lead to increased "flashy winter runoff and flood risks" and lower spring and summer stream flow (California Natural Resources Agency et al. 2020:14–15). Additionally, more intense drought may affect areas dependent on surface water flows and may affect water resources (e.g., degrading water quality in estuaries). Updated water infrastructure and management—for example, to capture water in high-flow periods to mitigate impacts in dry periods—will be key to managing increased variability of water bursts and prolonged periods of dry conditions.
- Increased wildfire risk in fire-prone areas heightens the risk of catastrophic fire impacts on water supply and quality.
- Decreased water quality in estuaries during droughts.
- Increased and more frequent saltwater intrusion in the San Francisco Bay Area and upstream of the Delta as sea levels rise.

Compared to 1960 through 2005 observations, annual average maximum daily temperatures across California are projected to increase by 4.4 °F (2.4 °C) for RCP 4.5 and 5.8 °F (3.2 °C) for RCP 8.5 by midcentury (2040–2069) (California Governor's Office of Planning and Research et al. 2018a:22–23). Warming will not be uniform across the state (California Natural Resources Agency et al. 2020:14–15).

Broadly, California is expected to experience a longer dry season and increased numbers of dry days and dry years and more frequent heavy precipitation and flood events, although future total precipitation projections remain uncertain (California Governor's Office of Planning and Research et al. 2018a:19). The climate change modeling for this EIR relies on an ensemble of climate projection scenarios to account for a range of climate change outcomes; however, it does not explicitly resolve or investigate precipitation extremes. More details are provided in Appendix 4D, "Climate Sensitivity." Precipitation projections in California show regional variation, with models indicating Northern California may become wetter and Southern California may become drier, although, compared to annual precipitation variability, these trends are relatively small. Atmospheric rivers are projected to become stronger and carry more moisture in a warmer climate, which may lead to increased extreme precipitation. Additionally, the likelihood of a "prolonged 'mega-drought'" occurring in the twenty-first century in the southwestern United States is increasing, as is the likelihood of a "mega-flood" occurring in California (California Governor's Office of Planning and Research et al. 2018a:24–27). Global changes, such as a decrease in Arctic sea ice, may affect future precipitation in California, as well; further research is needed to understand this potential link (California Governor's Office of Planning and Research et al. 2018a:24–27).

Snowpack in the Nevada and California mountains that serves as a natural reservoir and key source of surface water and groundwater may decline substantially under future climate conditions, in part because warmer temperatures may lead to a smaller percentage of precipitation falling as snow and a greater percentage of precipitation falling as rain (California Governor's Office of Planning and Research et al. 2018a:26–28).

Warmer air temperatures may increase soil moisture loss and lead to drier soils, affecting both drought events and seasonal dryness; seasonal impacts will vary (e.g., earlier soil drying in the spring may lead to prolonged summer dryness). Soil moisture is projected to show a 10 percent decline under the RCP 8.5 scenario by end of century (California Governor's Office of Planning and Research et al. 2018a:70).

Wildfire risks in California are already increasing due to changes in climate (e.g., warmer air temperatures) and other factors (e.g., changes in land use, such as development along the wildland–urban interface). Scientists are still working to determine how winds that often play a significant role in amplifying fire weather conditions in California—such as the Santa Ana, Sundowner, and Diablo winds—may respond to climate change. The complexity of wildfire drivers also leads to a range in results of future projections, from "modest changes" to "relatively large increases in wildfire regimes" compared to historical conditions. Projections by the CEC (2018b:19, 21), which do not incorporate potential changes in wind regimes, project an accelerating trend after midcentury and a significant increase in large fire events by end of century under the RCP 8.5 modeling scenario (California Governor's Office of Planning and Research et al. 2018a:28–30).

Substantial sea-level rise is projected to occur by the end of the century, although the rate and degree of increase remain uncertain. At the San Francisco Bay, the 50th percentile change in projected sea-level rise under the RCP 8.5 modeling scenario ranges from 0.4 foot in 2030 to 0.9 foot and 2.5 feet in 2050 and 2100, respectively (California Natural Resources Agency and California Ocean Protection Council 2018:57). Erosion caused by flooding from coastal wave events and sea-level rise may affect large areas and lead to substantial property damage. USGS's Coastal Storm Modeling System model simulations along the Southern California coastline estimated widespread beach erosion by end of century, assuming "limited human intervention" and sea-level rise scenarios from 3 to 6.6 feet (0.9 to 2 meters) (California Governor's Office of Planning and Research et al. 2018a:31–33).

9.2.3 Climate Change Trends and Associated Impacts on the Study Area

9.2.3.1 Climate Change Trends in the Study Area

Looking comparatively at existing conditions and projected midcentury conditions, scenarios were chosen to assess impacts of the operational changes, considering expected impacts of climate change and sea-level rise (Appendix 4A, "Model Assumptions," and Appendix 4D, "Climate Sensitivity"). Global model projections generated under RCPs 4.5 and 8.5 are used. These were selected because of their relevance to DWR's programs and planning and as representative of broader climate projections. Historical events and future climate projections with this basis support precipitation and temperature data used for the climate change modeling scenario. The most feasible models were chosen for historical data and projected outcomes based on changing factors, including temperature and precipitation changing hydrologic conditions, sea-level rise, water temperature and quality, and salmonid populations.

As shown in Table 9-2, average maximum temperatures, temperature extremes, flood risks, and wildfire risks are all expected to increase in the study area by 2100.

The character of precipitation in the Sacramento and San Joaquin River basins is projected to change under warming conditions, resulting in more frequent rainfall events and less frequent snowfall events (He et al. 2019:11). Increased warming is projected to diminish the accumulation of snow during the cool season (i.e., late autumn through early spring) and the availability of snowmelt to sustain runoff during the warm season (i.e., late spring through early autumn). Warming may lead to more rainfall runoff during the cool season, rather than snowpack accumulation. Consequently, this change in runoff pattern leads to increases in December through March runoff and decreases in April through July runoff.

Recent modeling indicates that sea level at the San Francisco (Golden Gate) tide gage may increase by as much as 1.8 feet (0.55 meter; H++ scenario, which is an extreme modeling scenario resulting from loss of the West Antarctic ice sheet) by 2040 and 10.2 feet (3.11 meters; H++ scenario) by 2100 (California Natural Resources Agency and California Ocean Protection Council 2018:18). It is expected that more land in the study area will be subject to inundation by 2100 compared to current conditions. Potential changes in inundation zones (i.e., tidal regime) may affect the salinity and suitable habitat for species in the Delta.

Table 9-2 reflects climate projections (for all variables except sea-level rise) provided in regional reports developed as part of the Fourth Assessment by OPR, CEC, and CNRA: Sacramento Valley (California Governor's Office of Planning and Research et al. 2018b:18–20), San Francisco Bay Area (California Governor's Office of Planning and Research et al. 2018c:14, 17, 31, 61), San Joaquin Valley (California Governor's Office of Planning and Research et al. 2018d:7–8), San Diego (California Governor's Office of Planning and Research et al. 2018e:10, 19, 21, 27–29, 39, 74), Sierra Nevada (California Governor's Office of Planning and Research et al. 2018f:5, 15, 18, 28, 46), and Inland Deserts (California Governor's Office of Planning and Research et al. 2018g:14, 18, 21, 23, 29). The Delta Stewardship Council's *Delta Adapts: Creating a Climate Resilient Future* (2021:3-13, 5-8) is used to supplement some information. Sea-level rise projections referenced are those developed for the 2018 update to the *State of California Sea-Level Rise Guidance*; data is provided for representative tide gages in each region (California Natural Resources Agency and California Ocean Protection Council 2018:18, 63, 72, 78). Regions for which sea-level rise data is not provided are indicated with a "–" symbol.

Table 9-2. Climate Change Projections for the Study Area [a]

Study Area Region	Average Max. Temperature [b]	Temperature Extremes [c]	Precipitation	Sea-Level Rise [d]	Flood Risk	Wildfire Risk	Other Impacts
Sacramento Valley Region	Average daily max. temperature likely [e] to increase by 10 °F (5.6 °C) by end of century (2100)*	Average number of extreme heat days (above 104 °F [40 °C]) increases from 4 to 40 per year by end of century (2100) in midtown Sacramento*	Dry and wet extremes increase	Sea-level rise in the Bay Area will increase flood potential and salinity of Delta waters	More flood potential in Delta	Increased summer and fall wildfire activity	Streamflow shifts from spring to winter, more runoff, and less groundwater recharge
San Francisco Bay Area Region	Annual average max. temperature likely to increase by 4.4 °F (2.4 °C) by midcentury (2040–2069) and 7.2 °F (4.0 °C) by end century (2070–2100)*	Average number of extreme heat days (over 85 °F [29.4 °C]) to increase by 15–40 by 2050 and potentially 90 by 2100*	Dry and wet extremes increase	San Francisco tide gage: 1.8 feet (0.5 meter; 2040) to 10.2 feet (3.1 meters; 2100)	More flood potential	Increased fire activity (more frequent or greater area burned)	Winter storms more intense; a once-in-20-year storm (extreme precipitation) will become a one-in-seven-year or more frequent storm by end of century*
San Joaquin Valley Region	Annual average max. temperature likely to increase 4–5 °F (2.2–2.7 °C) by midcentury (2035–2064) and 5–8 °F (2.7–4.4 °C) by end century (2070–2100)*	Average number of extreme heat days (above 101.6 °F [38.7 °C]) increases from 4–5 per year to 23–28 towards midcentury (2035–2064) and 45–68 days towards end century (2070–2099)*	Dry and wet extremes increase	–	More flood potential in Delta	Longer fire season, increase in wildfire frequency, expansion in fire-prone areas	Salinity intrudes deeper into Delta; stream flows shift from spring to winter; more runoff and less groundwater recharge
San Diego Region	Annual average max. temperature likely to increase by 7–9 °F (3.6–5 °C) by end century (2070–2100)*	Average hottest day per year increase by 10 °F (5.5 °C) by end century (2070–2100) at the coasts*	Dry and wet extremes increase	San Diego tide gage: 1.8 feet (0.5 meter; 2040) to 10.2 feet (3.1 meters; 2100)	More flood potential	Increase in wildfire frequency, expansion in fire-prone areas	Changes in Santa Ana winds; sediment/debris from wildfires intrudes flows
Sierra Nevada Region	Average temperature likely to increase by 6–9 °F (3.3–4.9 °C) by end century*	–	Dry and wet extremes increase	–	More flood potential	Increase in wildfire frequency and size, expansion in fire-prone areas	Higher rain-to-snow ratio, earlier snowmelt, less snowpack

Study Area Region	Average Max. Temperature [b]	Temperature Extremes [c]	Precipitation	Sea-Level Rise [d]	Flood Risk	Wildfire Risk	Other Impacts
Inland Deserts Region	Daily average max. temperature is likely to increase by 10 °F (5.5 °C) by midcentury (2040–2060) and 14 °F (7.8 °C) by end century (2070–2100)*	Average number of extreme hot days (over 95 °F [35 °C]) increases from 90–135 days to 141–179 days per year by end century*	Dry and wet extremes increase	–	More flood potential, particularly flash floods		More runoff, diminished inflows into and increased salinity of Salton Sea

Sources: California Governor's Office of Planning and Research et al. 2018b:18–20; 2018c:14, 17, 31, 61; 2018d:18–21, 2018e:10, 19, 21, 27–29, 39, 74; 2018f:5, 15–18, 21, 24, 28, 46; 2018g:14–15 18, 21, 23, 29; Delta Stewardship Council 2021:3-13, 5-8; California Natural Resources Agency and California Ocean Protection Council 2018:18, 63, 72, 78.

°C = degrees Celsius; °F = degrees Fahrenheit.

[a] * Indicates "under RCP8.5". Temperature data shown in the table are probabilistic projections developed for RCP 8.5 assuming an end-of-century (i.e., 2100) timeline (see second and third columns from left). Sea-level rise changes shown (see fifth column from left) are projections developed for the H++ scenario, which does not have an associated likelihood of occurrence.

[b] Information available in the Fourth Assessment region reports varies by region; projections for average maximum temperature is provided for all regions except the Sierra Nevada region, which has the projected change in average temperature (i.e., not average maximum).

[c] Information available in the Fourth Assessment region reports varies by region; average number of extreme heat days is provided for all regions except San Diego, which has average hottest day instead.

[d] Sea-level rise projections referenced are those developed for the *State of California Sea-Level Rise Guidance: 2018 Update* (California Natural Resources Agency and California Ocean Protection Council 2018). Projections provided are for the H++ scenario, a single scenario for extreme sea-level rise, not a probabilistic projection; it does not have an associated likelihood of occurrence but is recommended for consideration in significant, long-term decisions (California Natural Resources Agency and California Ocean Protection Council 2018:12). For example, sea-level rise at the San Diego tide gage for the H++ scenario is 1.8 feet in 2040 and 10.2 feet in 2100.

[e] The IPCC used this term to indicate the assessed likelihood of the outcome or result, based on an evaluation of underlying evidence and agreement. "Likely" probability indicates 66–100% likelihood of this outcome or result (Intergovernmental Panel on Climate Change 2021:SPM-4).

9.2.3.2 Climate Change Impacts in the Study Area

Water temperatures, precipitation, and runoff, sea-level rise, flooding, and drought climate change impacts are explored in more detail in the following subsections. These climate impacts are evaluated within the study area across additional resource areas covered in this DEIR including hydrology, water quality, and aquatic biological resources.

The hydrology of the Delta area is projected to be affected by climate change in the future. Based on climate trends on the study area, reduced runoff volume and changes in evapotranspiration in the warm season (April–July) due to climate change may decrease the amount of water in channels and associated infrastructure throughout the Delta. However, increases in rain-on-snow events, earlier snowmelt, and increased frequency and severity of flood events that are expected during the cool season (December–March) may exacerbate challenges related to channel and reservoir capacity limits or risks associated with runoff or flood flows. Higher water levels under sea-level rise and changes in erosion and sedimentation may compound these effects. Continuation of existing management and operations in the Delta will increasingly expose Delta water users, ecosystems, and those that depend on water exported from the Delta to risks of water supply interruption and diminishing water supply reliability over time.

Changing flooding trends, increasing water temperature, and seasonally reduced precipitation and drought could result in decreased species populations and quality of species habitat in the study area. In response to decreased species populations and habitat, additional restoration actions could be implemented to support populations of native species populations.

Water Temperatures

With projected future climate changes, warmer water temperatures are expected to decrease suitable summer habitat of Delta Smelt (*Hypomesus transpacificus*), a federally listed threatened species and state-listed endangered species, because water in the lower Delta may be too saline and lack enough food for the species, whereas fresh water in the upper Delta may be too warm (National Research Council 2012:167–168). Warming of streams and rivers also facilitates colonization by invasive species that may compete with native species for habitat (Garcia et al. 2018:10993). Growth of nonnative, invasive aquatic plants, such as the water hyacinth (*Eichhornia crassipes*) and Brazilian waterweed (*Egeria densa*), has reduced habitat quality and value for many native fishes and raises concerns about the plants' ability to clog waterways (described in further detail in Chapter 6, "Aquatic Biological Resources"). Given that these plants can clog diversion points and contribute to water quality issues, growth of invasive macrophytes presents maintenance and operational problems for water users. Growth of these invasive plants generally is facilitated by warmer temperatures and inhibited by colder conditions (U.S. Fish and Wildlife Service 2018:6–11), and climate change is projected to increase temperatures around the Delta. Interventions that could be taken to mitigate vulnerability of fish and wildlife to climate effects could include habitat restoration and water flow management to provide greater access to habitat (Delta Stewardship Council 2021:5-50). These actions would have corresponding tradeoffs because less water would remain in upstream reservoirs for other uses. Reduced instream water availability would result in difficulty meeting regulatory standards, given negative effects on upstream aquatic species, including coldwater pool resources, that are critical for salmonid rearing. Reduced water availability also could affect reliability for agricultural, municipal, and industrial water supplies and result in associated loss in productivity or other economic costs.

Increased water temperatures affect aquatic organisms and habitats biologically, physically, and chemically. These impacts may be seen in changing maximum dissolved oxygen saturation levels (i.e., the highest amount of oxygen water can dissolve) and primary productivity, nutrient and chemical cycling, and organism metabolism, growth, and reproductive and mortality rates (Interagency Ecological Program, Management, Analysis, and Synthesis Team 2015:32). Reduced dissolved oxygen levels may have adverse effects on fish spawning in the form of reduced egg survival and may reduce the habitat zone (i.e., reduce abundance) of fish that are sensitive to higher temperatures, such as Delta Smelt. Salmonid egg survival and population productivity also may be affected by higher temperature levels, which can limit sufficient oxygen levels, increase disease prevalence, and interfere with synchrony of natural systems like migration (National Oceanic and Atmospheric Administration 2018:4, 25, 31, 37).

Higher water temperatures can affect fish habitat, and there are some existing management strategies to maintain the desired water temperature; however, projected Critically Dry years resulting from climate change would make it more difficult to meet water temperature requirements for suitable aquatic habitat for sensitive species. Atmospheric forcing, amount, and temperature of inflows influence Delta temperatures, while ocean temperature has a negligible effect in the saline areas. The specific impact of upstream river temperature and discharge, as well as rainfall and other atmospheric forcings, affect water temperature differently across the Delta, depending on dispersion and residence times (Vroom et al. 2017).

Precipitation and Runoff

The geographic variation and unpredictability in precipitation that California receives make it challenging to manage the available runoff that can be diverted or captured in storage to meet urban and agricultural water needs. In California, winter precipitation and spring snowmelt are captured in surface water reservoirs to provide flood protection and water supply. In general, peak runoff times are projected to be earlier for watersheds in the study area according to climate projections. The peak is projected to shift one month earlier from March to February by the late twenty-first century for the Sacramento River and its tributaries (the Feather, Yuba, and American rivers) under both RCP 4.5 and RCP 8.5 modeling scenarios. Sacramento Valley watersheds are expected to peak earlier (except for Sacramento River above Bend Bridge), by midcentury (He et al. 2019:9). The San Joaquin River and its tributaries (the Stanislaus, Tuolumne, and Merced rivers) and San Joaquin Valley watersheds are projected to remain unchanged in May in both future periods under both RCP 4.5 and RCP 8.5 modeling scenarios; however, the Stanislaus River is projected to have an earlier peak during late century under the RCP 8.5 modeling scenario (He et al. 2019:11).

Snowmelt is an important part of water systems in the study area. Due to elevation differences Sacramento Valley watersheds generally have higher temperatures and are more rain-dominated with the peak runoff timing occurring earlier in the season than San Joaquin Valley watersheds, which are snow-dominated and experience later season peak flows as snowpack melts. In these watersheds, runoff peak timing is projected to remain largely unchanged (He et al. 2019:13).

Sea-Level Rise

When considering potential sea-level rise impacts, special consideration must be given to the following three interrelated elements.

Inundation. Changes in sea levels and Delta inflows have the potential to cause more temporary or permanent inundation (e.g., permanent inundation due to higher sea levels, temporary inundation due to higher inflows associated with higher sea levels and increased precipitation variability) (Delta Stewardship Council 2021:5-52–5-55).

Salinity Gradient. The location of the gradient between saline, brackish, and fresh water in the San Francisco Bay and Delta will be affected by sea-level rise. As sea levels rise, the salinity gradient will shift farther upriver. The position of the daily average salinity gradient in the San Francisco Estuary is called "X2," which is the distance in kilometers (km) upstream of the Golden Gate Bridge of the 2 parts per thousand isohaline (State Water Resources Control Board 1995). The X2 position is highly variable due to daily tidal movement and upstream flow. Outflow objectives identified in the Bay-Delta Water Quality Control Plan (State Water Resources Control Board 1995) manage X2 to control salinity intrusion into the Delta. The daily average X2 provides an index of the upstream extent of saltwater intrusion as a consequence of sea-level rise. Under State Water Resources Control Board D-1641, SWP and Central Valley Project (CVP) operators are responsible for maintaining the X2 location, as specified in the 1995 Water Quality Control Plan (State Water Resources Control Board 1995).

Tidal Variations. Changes in sea level will influence natural tidal variations along the California coast and within the San Francisco Bay and Delta. Edge species that rely on existing variations between wet and dry conditions may become permanently inundated or otherwise experience inhospitable environmental changes. Sea-level rise and heightened coastal storms have a combined effect on storm surges, particularly for coastal regions (California Governor's Office of Planning and Research et al. 2018a:54).

Inland Flooding

Historical patterns of precipitation have been used by the U.S. Army Corps of Engineers and DWR to develop reservoir storage criteria to reduce flood potential in watersheds. Assumptions for snowfall and rainfall patterns have been made for the Proposed Project to reflect climate change that is anticipated to increase surface water runoff from rainfall in the winter and early spring and decrease runoff from snowmelt in the late spring and early summer, as described in Chapter 4, "Hydrology and Water Supply."

Flooding from increased precipitation, sea-level rise, and more intense storm events threatens California's critical infrastructure and populations. The increasing proportion of precipitation falling as rain rather than snow throughout California regions will exacerbate winter floods (California Department of Water Resources 2018b:3). Sea-level rise will increase the potential for flooding in the Delta, particularly during high-tide events (California Governor's Office of Planning and Research et al. 2018b:33). North-of-Delta reservoirs will not have the capacity to hold runoff from early snow melting and increased precipitation and instead will be released as flood water and become Delta outflow (California Department of Water Resources 2018a:40–41). Throughout the Sacramento Valley region, growing storm intensity will create conditions that increase the likelihood of and shorten the timeline before inland mega-floods—such as one like the 1862 "Great Flood" (California Governor's Office of Planning and Research et al. 2018b:19, 34).

Drought

The study area experiences periodic droughts. The Sacramento and San Joaquin 8 Rivers Index, the Sacramento 4 Rivers Index, and the San Joaquin 4 Rivers Index were included in a study evaluating drought using streamflow-based indices, looking for "deficits" (i.e., any negative difference between the annual flow and the long-term mean annual flow) from 1906 to 2012, which included six significant deficit spells: 1928 (an eight-year deficit), 1944 (a seven-year deficit), 1976 (a two-year deficit), 1987 (a six-year deficit), 2007 (a four-year deficit), and 2012 (a four-year deficit) (U.S. Bureau of Reclamation 2014:25, 28). The majority of these six drought periods had runoff levels that were classified as "dry" or "critical" under the Sacramento and San Joaquin Valley Water Year Indices, which had important agricultural consequences given the level of agricultural production in the Central Valley (California Department of Water Resources 2018a:12; U.S. Geological Survey 2021). By 2050, extreme Delta drought conditions are projected to occur five to seven times more frequently (Delta Stewardship Council 2021:5-62). During midcentury droughts, Delta exports are projected to reduce to half of the quantity compared to historical droughts exports (California Department of Water Resources 2018a:41). Over the next several decades, dry years will become drier (California Governor's Office of Planning and Research et al. 2018a:19). Meanwhile, in southwest California, the likelihood of a long-lasting "mega-drought" is becoming greater (California Governor's Office of Planning and Research et al. 2018a:24).

9.2.4 Application of California Climate Projections to Proposed Long-Term Operations Changes

As identified in Chapter 2, Section 2.1.1, "Project Objectives," the purpose of the Proposed Project is to obtain incidental take authorization from the California Department of Fish and Wildlife pursuant to the California Endangered Species Act to allow DWR to continue the long-term operation of the SWP consistent with applicable laws, contractual obligations, and agreements. Consistent with this underlying purpose, DWR's Project objectives are to store, divert, and convey water in accordance with DWR's existing water rights to deliver water pursuant to water contracts and agreements up to full contract quantities and to optimize water supply and improve operational flexibility while protecting fish and wildlife based on the best available scientific information.

The Proposed Project consists of multiple elements that characterize future operations of SWP facilities including Banks Pumping Plant, John E. Skinner Fish Protective Facility, Clifton Court Forebay, Barker Slough Pumping Plant, and Suisun Marsh facilities; modify ongoing programs being implemented as part of SWP operations; improve specific activities that would enhance protection of special-status fish species; or support ongoing studies and research on these special-status species to improve the basis of knowledge and management of these species. These elements are intended to continue operation of the SWP and deliver up to their "Table A" entitlement, the maximum amount of water SWP delivers on an annual basis, while minimizing and fully mitigating the take of listed species consistent with California Endangered Species Act requirements.

A future climate change scenario was developed for CalSim 3 (Appendix 4D, "Climate Sensitivity") for use in the Proposed Project's integrated operational analysis. This simulation was used to understand the impact of climate change on flows and water availability at key nodes in the SWP system (e.g., X2, Freeport Flow, exports). As noted in Appendix 4A, "Model Assumptions," and Appendix 4D, the simulation baseline conditions were used to represent SWP operations to comply with the current regulatory environment, including existing facilities and ongoing programs that existed as of June 16, 2023 when the Notice of Preparation of the EIR was issued. The Proposed Project conditions consider proposed operational changes based on the details in Chapter 2, "Project Description."

For this analysis, the CalSim 3 model was run for both Baseline Conditions and Proposed Project operations with two sets of climate inputs: current climate and future climate change. The Baseline Conditions and Proposed Project scenarios with current climate assumptions are based on historical hydrology and the climate change scenarios are centered around 2022 with 15 cm of sea-level rise, as described in Appendix 4D. Ten CMIP5 global climate models and two GHG concentration scenarios (RCP 4.5 and RCP 8.5) were used to develop 20 climate model projections. These projections were then downscaled using the Localized Constructed Analogs method to develop the future climate change scenario, based on temperature and precipitation projections from the 20-model ensemble used in the CalSim 3 simulation. Generally consistent with the Bay Delta Conservation Plan/California WaterFix/Delta Conveyance Project analysis, Water Storage Investment Program Application, Sustainable Groundwater Management Act, Reinitiation of Consultation on the Long-Term Operations of SWP and CVP, and the SWP incidental take permit, a quantile mapping approach was used to adjust historical daily temperature and precipitation time series based on the climate projections.

As described in Appendix 4D, under the climate change scenario average temperature is projected to increase by at least 1.5 °C (2.7 °F) in all major watersheds in the Sacramento and San Joaquin River basins compared to the reference period (1981–2010). The highest temperature increases in the Sacramento and San Joaquin River basins are projected to occur in the Yuba River (1.6 °C [2.9 °F]) and Feather River (1.7 °C [3.0 °F]) watersheds. All major San Joaquin River Basin watersheds are expected to increase by 1.7 °C (3.0 °F). Overall, all major watersheds are projected to be wetter, with average precipitation increases from 2.4 to 4.4 percent. Sacramento River Basin is projected to experience a higher increase in long-term average precipitation than the San Joaquin River Basin. See Appendix 4D for more information.

9.3 Applicable Laws, Regulations, and Programs

DWR requires that all EIRs for which DWR acts as the lead agency contain additional information and analysis of climate change. This chapter evaluates the impacts of climate change on the Proposed Project in accordance with the guidance provided in DWR's *Climate Action Plan Phase 2: Climate Change Analysis Guidance*. Although the California Environmental Quality Act does not require an agency to analyze how climate change will affect a project, DWR has established a policy of including climate change impacts in all EIRs in which DWR acts as the lead agency (California Department of Water Resources 2018c).

9.4 Potential Climate Change Impacts on Baseline Operations and the Proposed Project

The Proposed Project would modify SWP operations, which would alter surface water flows and exports at SWP facilities. More details are provided in Chapter 2, "Project Description." Descriptions of estimated changes in hydrology are presented in Chapter 4, "Surface Water Hydrology," and Appendix 4B, "Model Results," to provide a basis for understanding potential impacts on designated beneficial uses under Baseline Conditions (i.e., current climate conditions). Although a variety of changes in climate described in this chapter, including changes in temperature, hydrology, and wildfire risk, may affect the Delta region, the future climate scenarios developed for this assessment focuses on projected sea-level rise and hydrologic changes (e.g., temperature and precipitation-driven shifts in surface water, groundwater, runoff) because they present the most pressing threats to SWP operations.

The Proposed Project could have impacts on special-status fish habitat and special-status species. Climate change presents challenges to water quality including elevated water temperatures and increased water temperature variability. Climate change is predicted to increase large flow events and sediment loading into the Delta, increasing turbidity. Affected water clarity may affect some fish species (for more information see Chapter 6, "Aquatic Biological Resources"). This results in the potential for impacts on special-status species resulting from the Proposed Project to compound with those driven by climate change. Because riverine habitat is anticipated to continue to be stressed and vulnerable under climate change (California Natural Resources Agency et al. 2020:12), water resources operations that affect flows to tidal and Delta channel habitat could have both exacerbating and mitigating effects, given changes to flow and wetted areas from climate change, depending on timing and volume of those flows. However, the impacts on habitat in the Delta associated with the Proposed Project would be reduced with the ongoing restoration of tidal and channel habitat.

Climate change analysis was performed using the CalSim 3 model to estimate the changes in flow at various locations in the Project area. Simulations were run by DWR and two scenarios were run for both existing climate and future climate conditions: Baseline Conditions and Proposed Project conditions. More information on the CalSim 3 model simulations and results are provided in Section 9.2.4, "Application of California Climate Projections to Proposed Long-Term Operations Changes," and Chapter 4. To represent the broad range of potential future climate and sea-level rise conditions, the Proposed Project and Baseline Conditions were analyzed under future climate change and sea-level rise projections. More details are provided in Appendix 4D, "Climate Sensitivity."

Table 9-3. CalSim 3 Model Simulations used to Analyze Climate Change Impact on Operations

	Scenario	Climate change considered?	Proposed Project LTO considered?
1	Baseline Conditions Current Climate	No	No
2	Baseline Conditions Future Climate	Yes	No
3	Proposed Project Conditions Current Climate	No	Yes
4	Proposed Project Conditions Future Climate	Yes	Yes

Table 9-3 shows the CalSim 3 scenarios used to understand the impact of the Proposed Project and climate change to meet specific conditions. To understand the impact of climate change, this chapter analyzes various locations in the Project area to understand the changes in hydrologic variables: the location of X2, flows in the Old and Middle rivers (OMR), flow in the San Joaquin River at Vernalis, flow in the Sacramento River at Freeport, SWP exports, and Delta outflow. Model results are used at six locations to quantify the impact of climate change on Baseline Conditions and Proposed Project operations, relative to Baseline Conditions and current climate conditions. Monthly results were analyzed and categorized based on water year type. Five water year types were considered, from driest to wettest: Critical Water Year, Dry Water Year, Below Normal Water Year, Above Normal Water Year, and Wet Water Year.[4]

9.4.1 X2

Sea-level-rise-driven saltwater intrusion in the Delta may have a variety of effects on soil, groundwater, or infrastructure, particularly affecting water quality for diversions and Delta tidal wetland habitat. Managing water quality and saltwater intrusion in the Delta has been accomplished by releasing water from upstream storage to minimize saltwater intrusion; however, rising sea levels and more extreme drought events projected in the future will limit available storage, which in turn limits the ability to push back saltwater from the Delta. Water releases are coordinated between the CVP and the SWP. Climate change and sea-level rise are expected to reduce the amount of water that can be released, diminishing Delta water quality and outflow. Regulations such as State Water Resources Control Board D-1641, agricultural water quality requirements, and controlling standards are concerned with water quality and outflow.

X2 is the modeled location of the gradient between saline, brackish, and fresh water in the San Francisco Bay and Delta. The location of this salt front, measured in km from the Golden Gate Bridge, is affected by sea-level rise and downstream flow from natural hydrology and water released from reservoirs. The location of this interaction between saline water and fresh water is critical for Delta Smelt summer and fall habitat. Under the Proposed Project, DWR and Reclamation will maintain a 30-day average location of X2 of less than or equal to 80 km from September 1 through October 31 in Wet and Above Normal water year types. Additional information on X2 is found in Section 2.2.4, "Project Description—Delta Smelt Summer-Fall Habitat." With the Proposed Project, for both the current and future climate scenarios, CalSim 3 model results show that during Wet and Above Normal water years in September, this objective is met as intended.

Climate change and sea-level rise are expected to reduce the amount of water that can be released, diminishing Delta water quality and outflow. This is projected to move the location of X2 but this will not greatly affect the ability of the system to meet the Delta Smelt Summer-Fall habitat target.

With the Proposed Project, for both the current and future climate projections, during Wet and Above Normal water years in September, X2 meets the objective of remaining less than or equal to 80 km.

For both the Proposed Project and Baseline Conditions scenarios under current and future climate current in Below Normal, Dry, and Critically Dry years in September, as well as all water year types in October, the location of X2 is above 80 km, averaging 91 km in September and 86 km in October.

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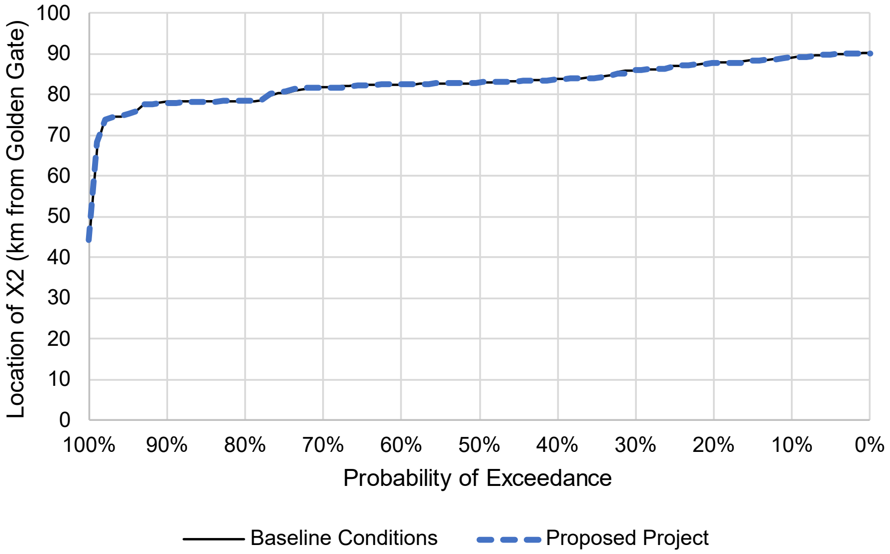
[4] Water year type designations are based on the Sacramento River 40-30-30 index under existing climate conditions.

Overall the location of X2 does not change substantially under the Proposed Project when compared to Baseline Conditions.

Climate change is projected to move the location of X2 1 km inland during Below Normal and Dry water years in September, and during Wet water years in October; however, this will not greatly affect the ability of the system to meet the Delta Smelt Summer-Fall habitat target.

(a)



(b)

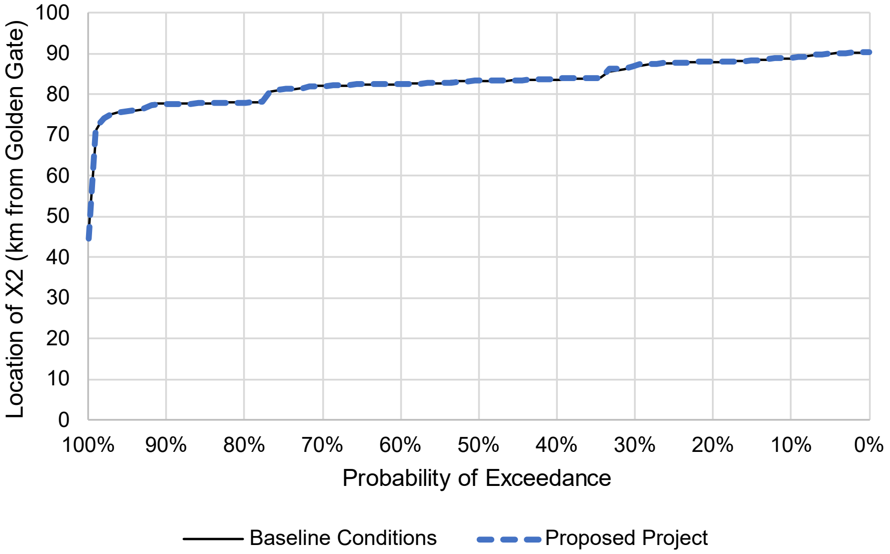


Figure 9-1. Exceedance Probability Showing the Location of the X2 for September and October in Current Climate (a) and Projected Climate (b) Scenarios Relative to Existing Operations and Climate Conditions

Table 9-4. Exceedance Probability of X2 during September and October under Baseline Conditions and the Proposed Project under Current and Future Climate Assumptions

Probability of Exceedance	Baseline Conditions; Current Climate	Proposed Project Conditions; Current Climate	Baseline Conditions; Future Climate	Proposed Project Conditions; Future Climate
1%	93.67 km	93.69 km	93.90 km	93.81 km
5%	93.15 km	93.15 km	93.67 km	93.68 km
50%	85.21 km	85.53 km	85.99 km	86.18 km
95%	79.07 km	79.79 km	77.79 km	77.75 km
99%	72.74 km	72.79 km	73.01 km	73.04 km

Figure 9-1 and Table 9-4 show the exceedance probabilities for the location of X2 during the months of September and October. Figure 9-1(a) shows current climate conditions and Figure 9-1(b) shows projected future climate. The location of X2 during the September through October period under current and future climate scenarios would be similar. Approximately 77 percent of the time during these months, the location of X2 is more than 80 km from the Golden Gate Bridge. Climate change is not likely to be a significant factor in meeting this target.

The conditions when the location of X2 is greater than 80 km occur when there is insufficient fresh water flowing through the Delta to push back saltwater coming in from the Bay. In addition, rising sea levels will affect the ability of the same freshwater flows to hold back saltwater in the future. Modeled climate change conditions account for 15 cm of sea-level rise. See more information on how sea level was modeled in Appendix 4D, “Climate Sensitivity.” Under these future sea levels, additional flow from the Delta will be required to push back the saline water and keep X2 stable.

9.4.2 State Water Project Exports

SWP facilities are operated to meet Delta flow requirements, salinity requirements, export water to SWP contractors, and facilitate out-of-basin water transfers between contracting entities. Generally, SWP exports would be slightly lower under a climate change scenario than under a current climate scenario. This is true for both Baseline Conditions and the Proposed Project. Under a future climate scenario, SWP exports under the Proposed Project would be slightly higher than Baseline Conditions for all water year types other than Dry and Critically Dry, where exports would be marginally lower (Table 9-5).

Table 9-5. Long-Term Average SWP Exports under Baseline Conditions and the Proposed Project under Current and Future Climate

Water Year Type	Baseline Conditions (current climate)	Proposed Project (current climate)	Baseline Conditions (future climate)	Proposed Project (future climate)
Wet	4,916	5,144 (5%)	4,671	4,925 (5%)
Above Normal	3,661	3,816 (4%)	3,343	3,502 (5%)
Below Normal	3,528	3,541 (0%)	3,006	3,019 (0%)
Dry	2,457	2,419 (-2%)	2,017	1,969 (-2%)
Critically Dry	1,342	1,334 (-1%)	1,139	1,130 (-1%)

In addition:

Climate change will cause a decrease in water availability and a decrease in SWP exports for all water years from June to November. The largest declines in exports in Dry, Critically Dry, and Below Normal water years start in July, while the largest declines start in September for Above Normal and Wet water years. From July onwards, there is less than 3 percent difference in SWP exports for Proposed Project versus Baseline operations for all water year types.

The Proposed Project will generally limit the largest export reductions due to climate change, although the impact is dependent on the water year type. Decreases in SWP exports reach up to 63, 38, and 24 percent during late summer months for Dry, Above Normal, and Wet water year types, respectively. The Proposed Project would limit the maximum decreases to 55, 31, and 20 percent, respectively. In Critically Dry and Below Normal water years, export decreases reach up to 44 and 48 percent, respectively, in late summer, and decreases are slightly greater under the Proposed Project than Baseline operations.

For all water year types under the climate change scenario, SWP exports are expected to be higher with the Proposed Project than under Baseline operations by an average of 26 percent in April and 68 percent in May. The Proposed Project takes advantage of earlier spring snowmelt to increase exports during this period.

SWP exports in Critically Dry water years are expected to decrease below present-day export levels by an average of 20 percent for all months. Exports under the Proposed Project are an average of 7 percent lower than Baseline operations for January, February, March, and June, and an average of 26 percent higher than Baseline operations in April and May.

Changes in exports under the future climate scenario simulated in CalSim 3 are more due to climate change than to Project operations, but the Proposed Project enables system flexibility such that, during Below Normal, Dry, and Critically Dry water years the reductions in exports under the Proposed Project are smaller under future climate conditions than under current climate conditions (Table 9-6). Further, averaged across all water year types, the Proposed Project enables 2.3 percent higher SWP exports annually than Baseline Conditions. Figure 9-2 and Figure 9-3 show the impact of climate change on SWP exports.

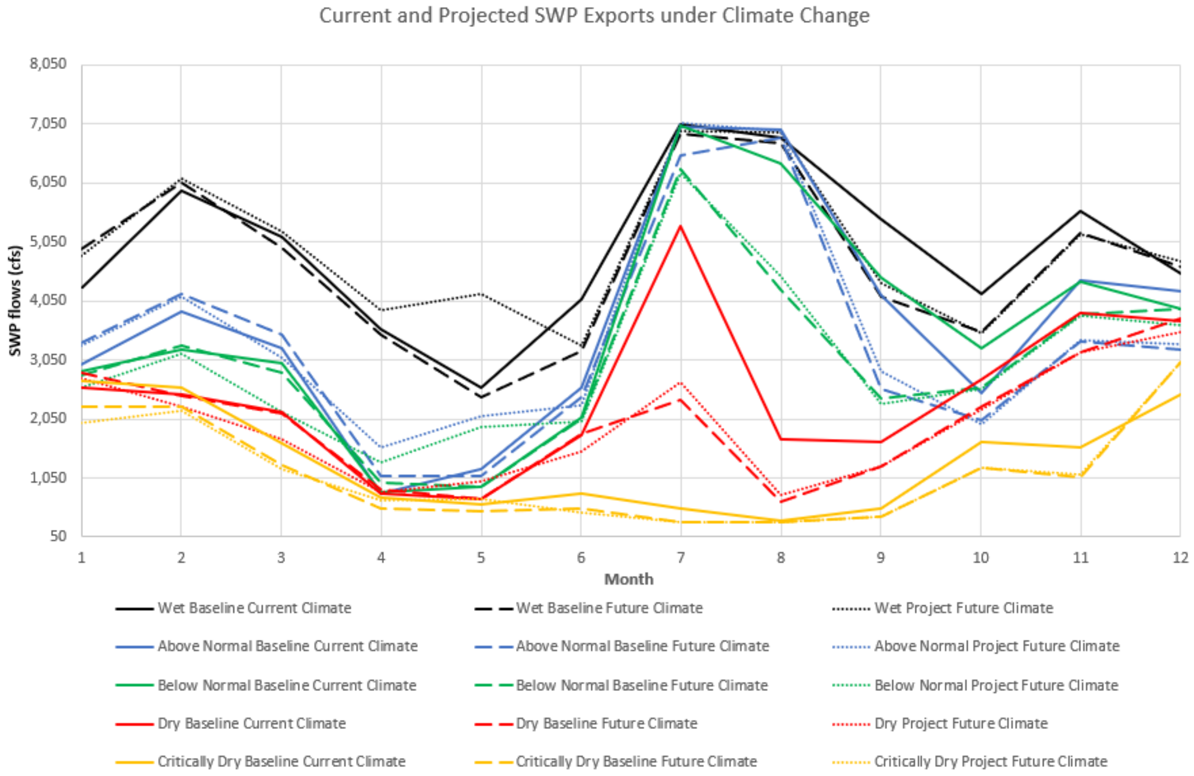


Figure 9-2. State Water Project Exports under Current Conditions and Future Climate Change Conditions. Flows under climate change are shown as flows with operational changes described under the Proposed Project (Project) and with no operational changes (Baseline).

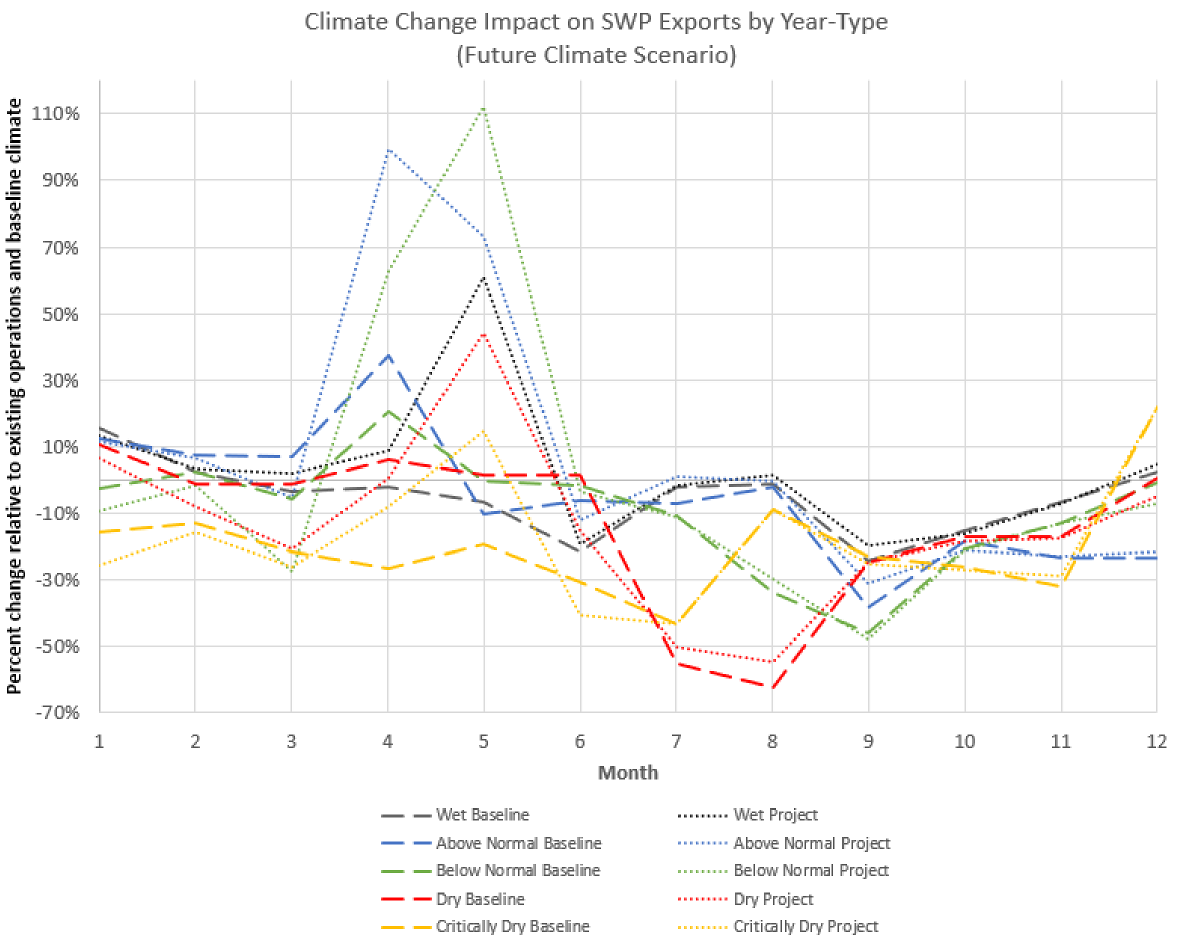


Figure 9-3. Climate Change Impact on State Water Project Exports are shown for the Future Climate Scenario for both Baseline and Proposed Project Operations, Relative to Existing Operations and Climate Conditions

9.4.3 Old and Middle River Flows

The Old and Middle Rivers are a key part of the Delta's functional ecology, and flow levels are key to the goals of the Proposed Project as these flows have the ability to affect entrainment of special-status species into the export facilities. The Proposed Project would implement a set of new operations throughout the OMR management season to decrease the risk of entrainment. These operations include maintaining a multi-day average OMR index at no more negative than -5,000 cubic feet per second (cfs) or -3,500 cfs under certain conditions to protect adult Delta Smelt, larval and juvenile Delta Smelt, larval and juvenile Longfin Smelt, winter-run Chinook Salmon juveniles, and spring-run Chinook Salmon juveniles (see Chapter 2, "Project Description," for more details). The OMR index is used as a suitable proxy measure for USGS OMR flows and flows likewise correlate to index values (California Department of Water Resources 2017). Generally, under a future climate scenario, long-term average OMR flows would be slightly less negative than under a current climate scenario for both the Proposed Project and Baseline Conditions. Under a future climate scenario, the Proposed Project would generally be slightly less negative than Baseline Conditions (Table 9-6).

Table 9-6. Old and Middle River Flows under Baseline Conditions and the Proposed Project under Current and Future Climate

Water Year Type	Baseline Conditions (current climate)	Proposed Project (current climate)	Baseline Conditions (future climate)	Proposed Project (future climate)
Wet	-5,209	-5,420 (-4%)	-4,766	-5,009 (-5%)
Above Normal	-5,452	-5,603 (-3%)	-5,020	-5,167 (-3%)
Below Normal	-5,653	-5,644 (0%)	-5,073	-5,074 (0%)
Dry	-5,005	-4,910 (2%)	-4,447	-4,356 (2%)
Critically Dry	-3,104	-3,079 (1%)	-2,839	-2,817 (1%)

This subsection uses projected OMR flows to determine whether requirements during the OMR management season are met. The OMR management season is triggered anytime between December 1 and January 1 and is concluded on June 30 or when the water temperature exceeds prescribed thresholds for fish populations, whichever comes first. Figure 9-4 and Figure 9-5 show the absolute and relative impact of climate change on Baseline Conditions and Proposed Project operations in the Delta.

For most months and water year types, there is a less than 3 percent difference in flows under Baseline Conditions compared to the Proposed Project scenario.

With or without the Proposed Project, OMR flows would be an average of 15 percent less negative in July to November of Above Normal, Below Normal, Dry, and Critically Dry water year types under a climate change scenario. Similarly, OMR flows for Wet water years would be less negative by an average of 10 percent in July through November under a climate change scenario.

January and February OMR flows would be 13 percent less negative in Wet, Critically Dry, and Above Normal water year types under a climate change scenario.

The largest decrease in OMR flows would occur under the Proposed Project in April and May of Wet, Above Normal, and Below Normal water year types under a climate change scenario. OMR flows under the Proposed Project flows would be lower than current operations and climate conditions by 81 percent in April and by 102 percent in May. Under a climate change scenario, Proposed Project OMR flows are also lower than flows under Baseline Conditions by 320 to 430 cfs in April and by 920 to 1,660 cfs in May.

CalSim model results indicate that climate change will be the largest factor in future OMR flow changes. Only in the months and water year types with large increases or decreases in OMR flows relative to Baseline Conditions under the current climate scenario are there larger differences in flows due to SWP operations (see Figure 9-5 and Figure 9-3).

In April and May of Wet, Above Normal, and Below Normal water year types, the Proposed Project enhances system flexibility by maximizing SWP exports while still maintaining compliance to the -3,500 cfs OMR index threshold to protect fish. While the Proposed Project has more negative flows than Baseline Conditions during this period, the absolute impact of this relative decrease is reduced because the more negative flows occur in months and water year types where more water is available in the system. The relative decrease does not translate into an absolute decrease in flows significant enough to violate Project objectives and cause OMR flows to decrease below -3,500 cfs in this period (Figure 9-4).

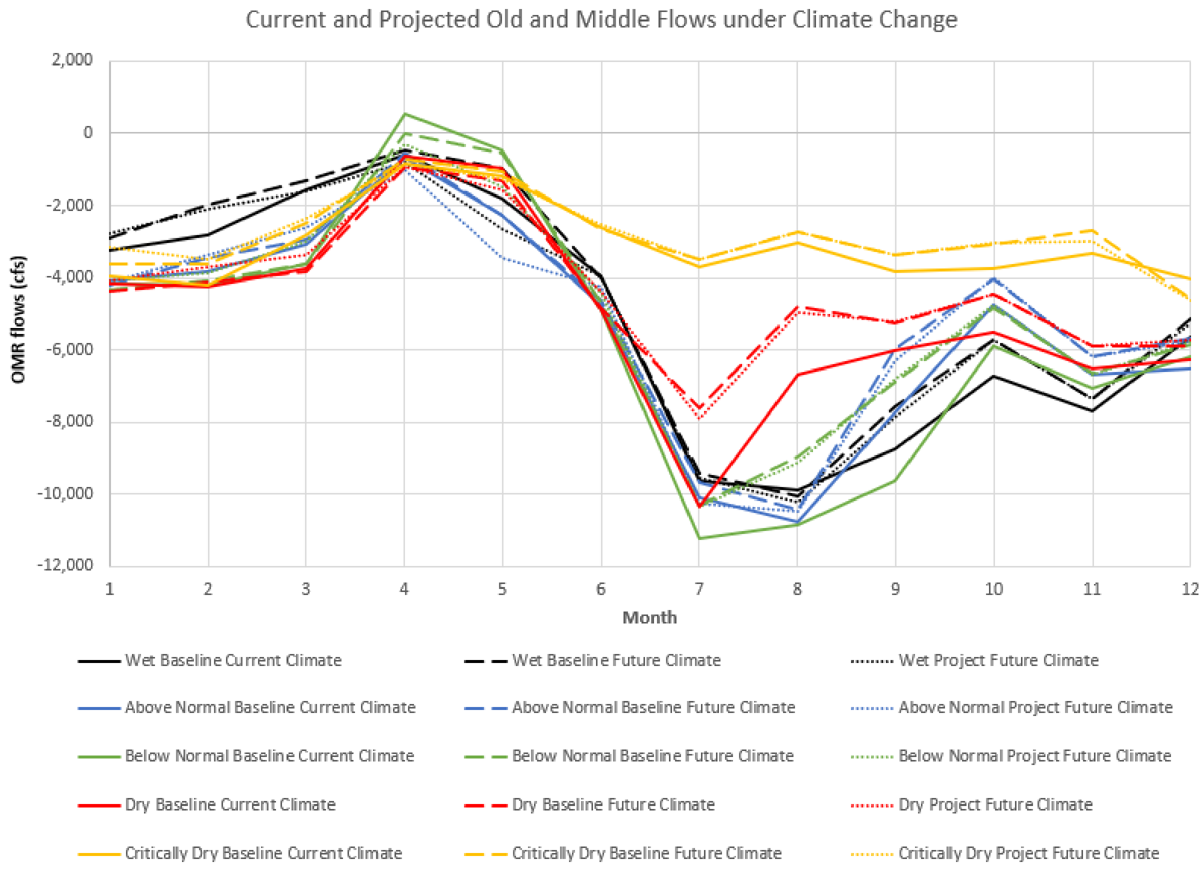


Figure 9-4. Old and Middle River Flows under Current Conditions and under Future Climate Change Conditions. Flows under climate change are shown as flows with operational changes described in the Project (Project) and with no operational changes (Baseline).

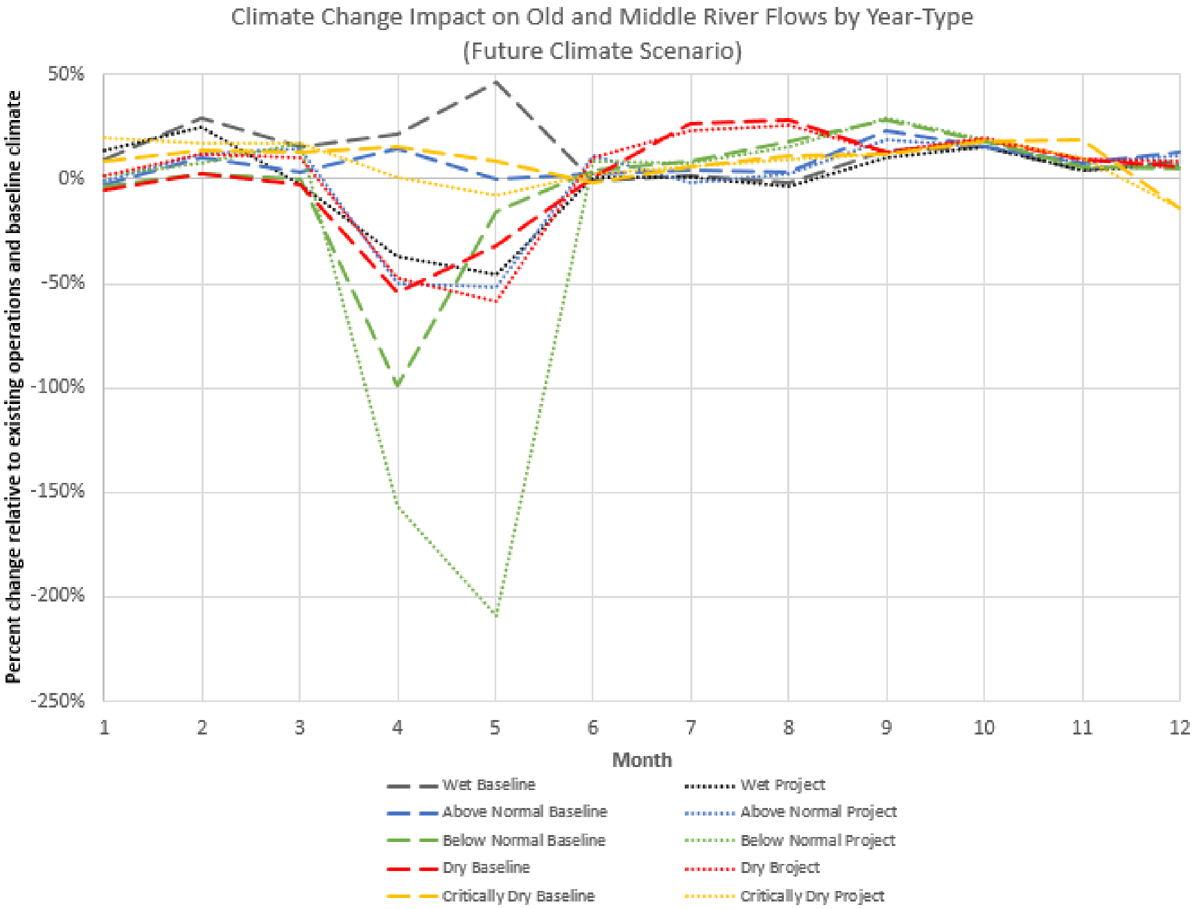


Figure 9-5. Old and Middle River Flows are Shown for the Future Climate Scenario for both Baseline and Proposed Project Operations Relative to Existing Operations and Climate Conditions

9.4.4 Delta Outflow

The Proposed Project includes Voluntary Agreement flows to increase Delta outflow through SWP export reductions and collection of diversion fees from SWP contractors to purchase water for Delta outflow per the terms of the Voluntary Agreements. More detail is available in Section 2.3.3, "Spring Delta Outflow." Proposed operational actions in the system, including DWR actions or agricultural fallowing, may divert water to be used as Delta outflows for the benefit of native fish populations. Climate change has the potential to disrupt the ability for the SWP to maintain Delta outflow requirements under Baseline Conditions; however, Proposed Project operations have a more limited impact on Delta outflow. Generally, Delta outflow under a future climate scenario would be slightly higher under the Proposed Project and Baseline Conditions than under a current climate scenario. Under a future climate scenario, Delta outflow under the Proposed Project would be similar to Baseline Conditions (Table 9-7).

Table 9-7. Delta Outflow under Baseline Conditions and the Proposed Project under Current and Future Climate

Water Year Type	Baseline Conditions (current climate)	Proposed Project (current climate)	Baseline Conditions (future climate)	Proposed Project (future climate)
Wet	40,059	39,897 (0%)	41,557	41,337 (-1%)
Above Normal	23,883	23,850 (0%)	24,579	24,566 (0%)
Below Normal	14,506	14,495 (0%)	14,575	14,596 (0%)
Dry	10,144	10,221 (1%)	10,217	10,300 (1%)
Critically Dry	7,223	7,286 (1%)	7,578	7,623 (1%)

Figure 9-6 and Figure 9-7 show the impact of climate change on Delta outflow by year type for both Baseline and Proposed Project operations relative to current operations and climate.

During Wet and Above Normal water years, climate change is projected to increase Delta Outflow during December, January, and February, averaging +15 percent with or without the Proposed Project, relative to current operations and climate conditions.

During all water year types, except Critically Dry water years, Delta outflow during December, January, and February is projected to increase under a future climate scenario compared to current climate, due to more precipitation falling as rain instead of snow upstream of the Project site.

Under a climate change scenario, Delta outflow is anticipated to decrease by an average of 22 percent under Baseline Conditions and 26 percent under the Proposed Project, relative to current operations and climate conditions during May and June of Wet and Above Normal year types.

During all water year types, except Critically Dry water years, in May and June climate change is projected to decrease flows on average 20 percent with or without the Proposed Project, relative to current operations and climate conditions. This is due to climate change's impact on precipitation falling as rain instead of snow.

Climate change has the potential to disrupt the ability for the SWP to maintain Delta outflow requirements under Baseline Conditions, which may be limited by Proposed Project operations.

The Proposed Project has a more limited impact on Delta outflow relative to the impacts of climate change. Climate change is expected to increase Delta outflow in the winter and spring of all but the Critically Dry and Dry water year types. Climate change is also expected to decrease Delta outflow in May and June of Wet and Above Normal water year types. The largest decrease in Delta outflow occurs during Wet years where Baseline Conditions would result in about a 47 percent decrease in June and the Proposed Project would decrease Delta outflow by about 46 percent, relative to Baseline Conditions operations and current climate conditions. Overall, under a future climate scenario Delta Outflow is anticipated to decrease on average 1 to 4 percent.

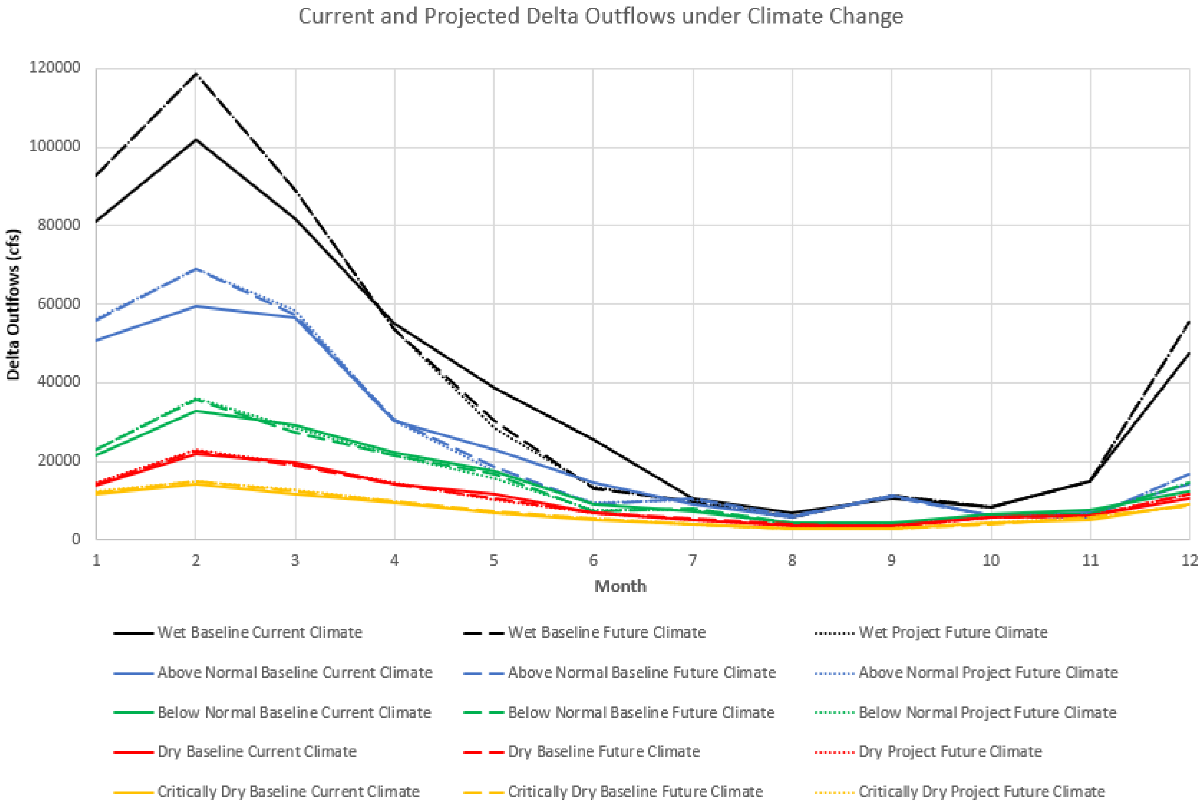


Figure 9-6. Delta Flows under Current Conditions and under Future Climate Change Conditions. Flows under climate change are shown as flows with operational changes described in the Project (Project) and with no operational changes (Baseline).

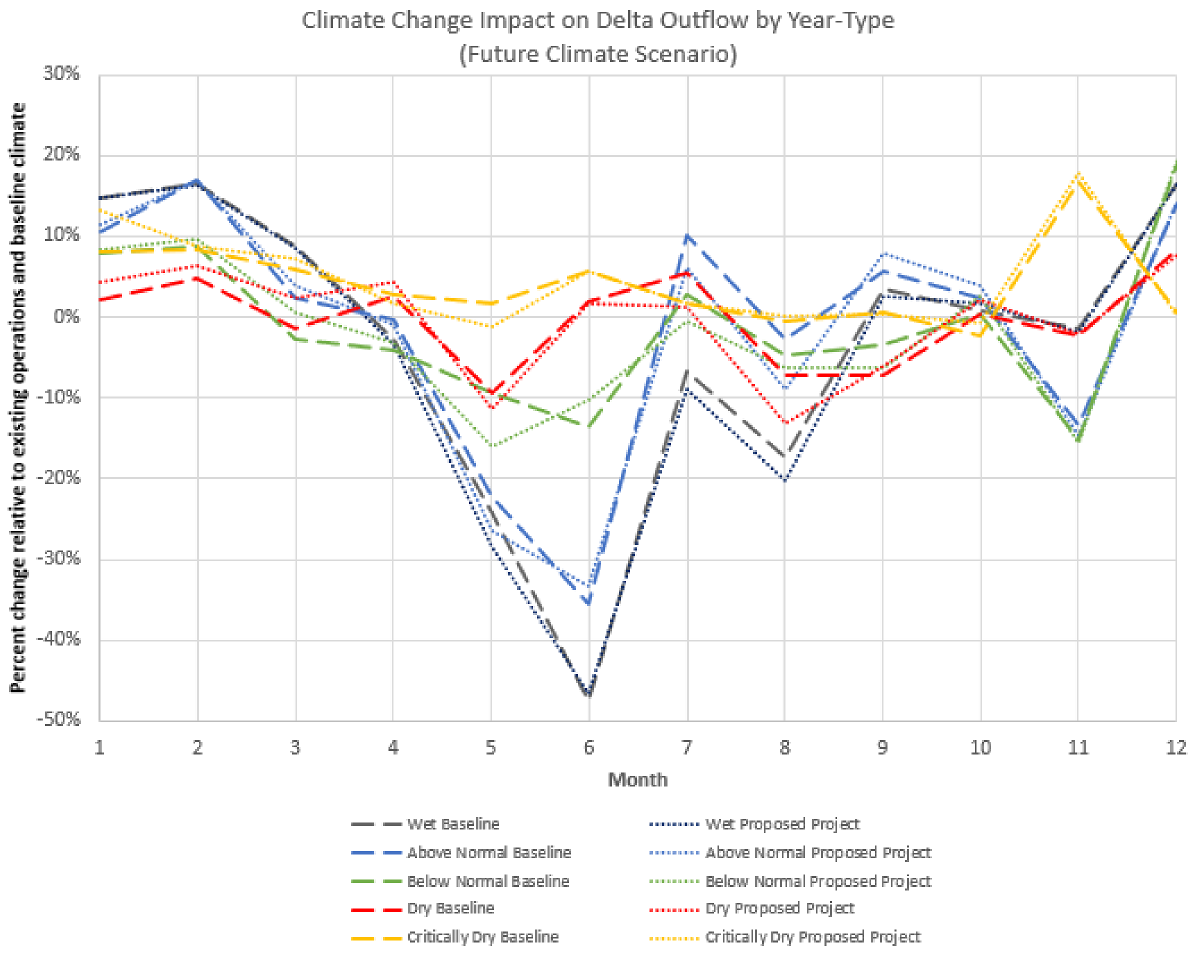


Figure 9-7. Climate Change Impact on Delta Outflows are Shown for the Future Climate Scenario for both Baseline and Proposed Project Operations relative to Existing Operations and Climate Conditions

9.4.5 San Joaquin River at Vernalis

The Vernalis streamflow gage is located along the San Joaquin River south of Stockton, California and is a measure of flow entering the Delta from the San Joaquin River. The Vernalis flow station measures water flowing into the Delta from one of the major tributaries, the San Joaquin River. In all water years and during all months, flow into the Delta from the San Joaquin River under a future climate scenario would be reduced by an average of 6 percent, reducing the water available to meet Delta outflow, SWP exports, and other targets in the Project area. Generally, San Joaquin River flows at Vernalis under a future climate scenario would be slightly higher under the Proposed Project and Baseline Conditions in Wet and Above Normal water years and slightly lower in Below Normal, Dry, and Critically Dry water years than under a current climate scenario. Under a future climate scenario, San Joaquin River flow at Vernalis under the Proposed Project would be similar to Baseline Conditions (Table 9-8).

Table 9-8. Flows in the San Joaquin River at Vernalis under Baseline Conditions and the Proposed Project under Current and Future Climate

Water Year Type	Baseline Conditions (current climate)	Proposed Project (current climate)	Baseline Conditions (future climate)	Proposed Project (future climate)
Wet	6,762	6,757 (0%)	6,843	6,839 (0%)
Above Normal	3,600	3,598 (0%)	3,616	3,613 (0%)
Below Normal	2,839	2,835 (0%)	2,738	2,734 (0%)
Dry	1,882	1,873 (0%)	1,684	1,680 (0%)
Critically Dry	1,536	1,533 (0%)	1,463	1,453 (-1%)

The impact of climate change varies throughout the year with some water year types experiencing increases in wintertime flows and decreases in summertime flows (see Figure 9-8 and Figure 9-9). The Proposed Project has limited impact on flows relative to the impacts of climate change.

Flows under the Proposed Project differ by a maximum of 2 percent relative to Baseline Conditions for all months in all water year types. The Proposed Project is anticipated to differ by less than a 0.3 percent on average from Baseline Conditions.

In Above Normal and Below Normal water years, flows under future Baseline Conditions are projected to increase in January, February, and March and decrease from April through December, relative to current climate Baseline Conditions. For Dry and Critically Dry water years, flows are generally expected to decrease in all months.

For all water year types except Above Normal water years, the largest decreases in flow occur in July and August under future climate conditions as a result of changing precipitation patterns and increased evapotranspiration in the San Joaquin River watershed.

The largest changes in San Joaquin River flow at Vernalis due to climate change occur in Wet water years. For Wet water years, climate change is projected to increase flows in December through May with the largest increase in January at 27 percent. Flows are projected to decrease from June through November, with the largest decrease in August at 36 percent. Flows under a future climate scenario are anticipated to be approximately the same for Wet water years under the Proposed Project and Baseline Conditions (less than 0.1 percent difference).

The impact of the Proposed Project is substantially smaller than the total impact of climate change on flow in the San Joaquin River.

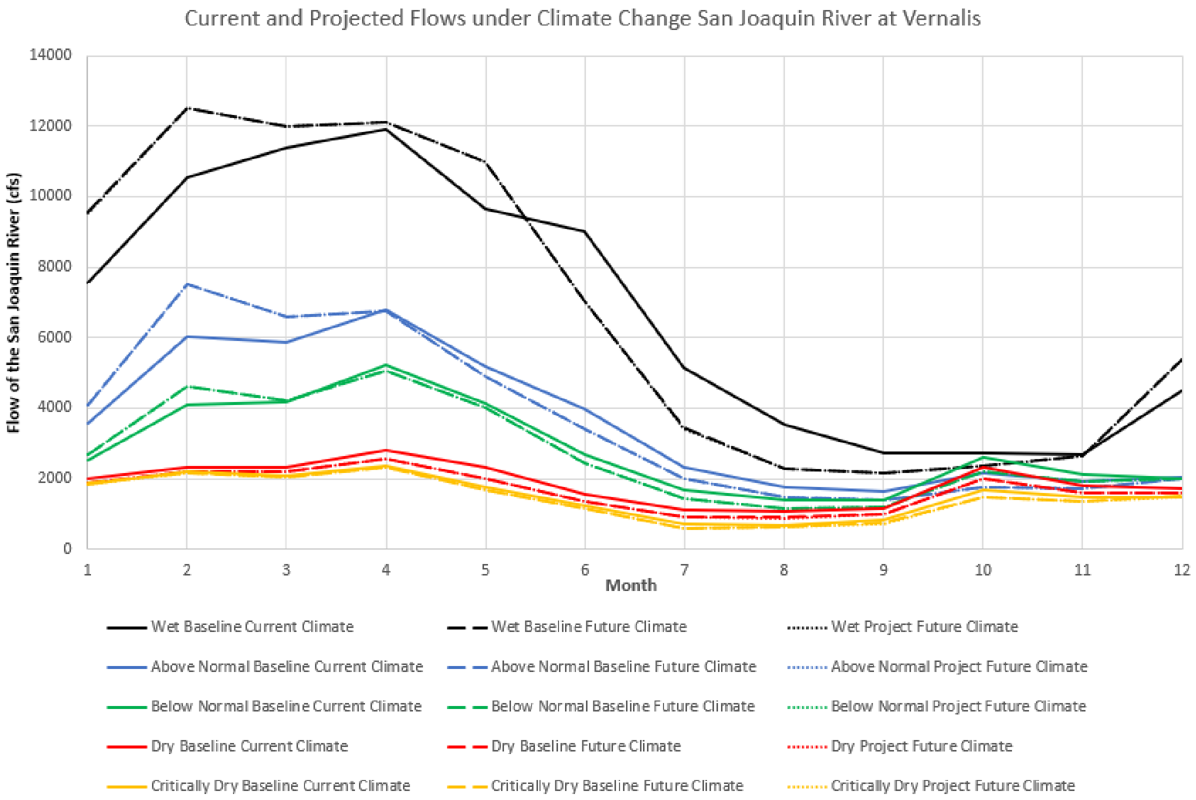


Figure 9-8. San Joaquin River flows at Vernalis under Current Conditions and Future Climate Change Conditions. Flows under climate change are shown as flows with operational changes described in the Project (Project) and with no operational changes (Baseline).

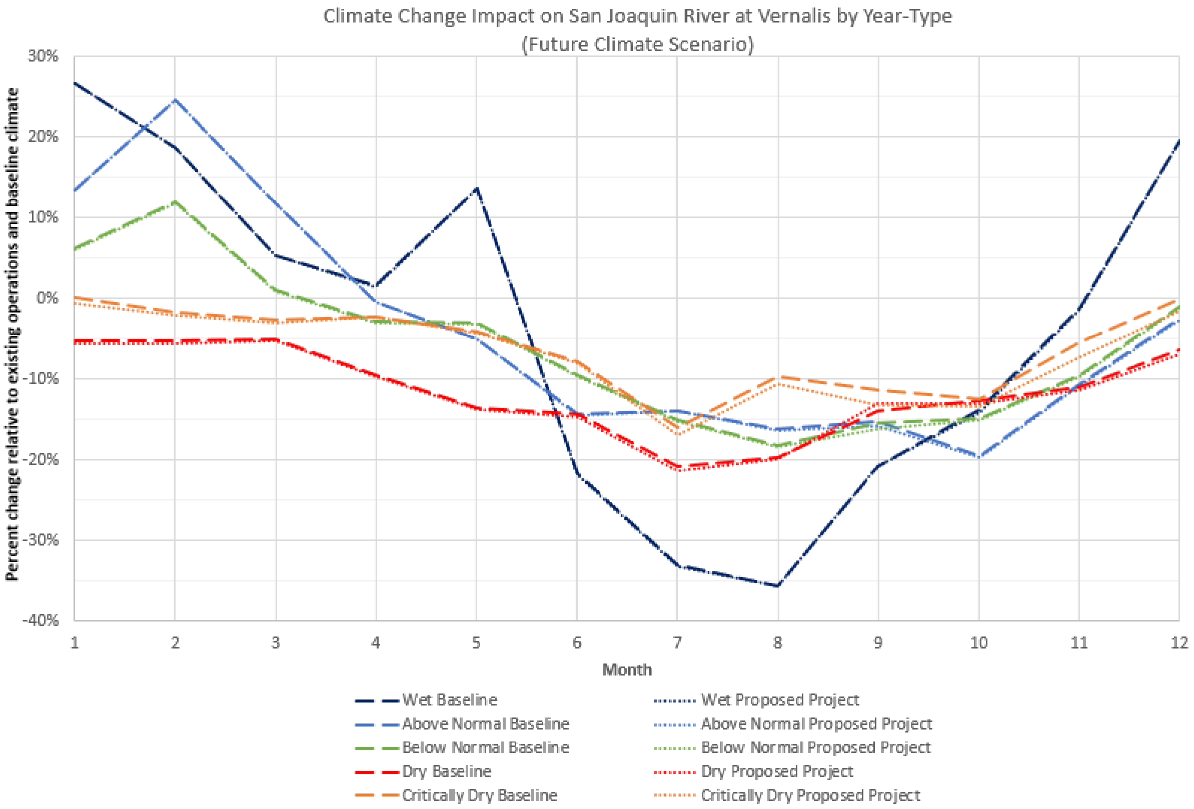


Figure 9-9. Climate Change Impact on San Joaquin River flows at Vernalis for the Future Climate Scenario for both Baseline and Proposed Project Operations Relative to Existing Operations and Climate Conditions

9.4.6 Sacramento River at Freeport

The Freeport streamflow gage on the Sacramento River measures flow into the Delta south of the city of Sacramento. Climate change has the potential to alter the flows into the Delta for all water year types, shown in Figure 9-10, Figure 9-11, and Table 9-9. Generally, Sacramento River flow at Freeport under a future climate scenario would be slightly lower under the Proposed Project and Baseline Conditions than under a current climate scenario. Under a future climate scenario, Sacramento River flow at Vernalis under the Proposed Project would be similar to Baseline Conditions (Table 9-9).

Table 9-9. Flows in the Sacramento River at Freeport under Baseline Conditions and the Proposed Project under current and future climate.

Water Year Type	Baseline Conditions (current climate)	Proposed Project (current climate)	Baseline Conditions (future climate)	Proposed Project (future climate)
Wet	32,449	32,524 (0%)	31,492	31,530 (0%)
Above Normal	24,905	25,047 (1%)	24,653	24,771 (0%)
Below Normal	18,494	18,483 (0%)	17,872	17,893 (0%)
Dry	14,801	14,784 (0%)	14,348	14,339 (0%)
Critically Dry	10,585	10,613 (0%)	10,575	10,600 (0%)

The Proposed Project has limited impact on flows relative to the impacts of climate change. On average, under a future climate scenario, there is a 0.8 percent difference between flows under the Proposed Project and Baseline Conditions. Averaged across all months and water year types, the Proposed Project provides 0.2 percent higher flows than Baseline Conditions.

Under a future climate scenario, the largest difference in flows under the Proposed Project compared to Baseline Conditions occurs during June in Dry water years. Baseline Conditions would result in a 1.9 percent increase in flows under a future climate scenario compared to current climate Baseline Conditions.

For all water year types, climate change is projected to increase flows from December through February by approximately 5 percent with or without the Proposed Project, relative to current operations and climate conditions.

For all water year types from May through October, flow is projected to decrease by approximately 9 percent with or without the Proposed Project, relative to current operations and climate conditions.

Sacramento River flow at Freeport during Wet and Above Normal water years is projected to decrease substantially during May and June under a future climate scenarios with or without the Proposed Project, relative to a current climate scenario.

Sacramento River flow at Freeport during Dry, Below Normal, and Critically Dry water years is projected to decrease by an average of 9 percent under a future climate scenario with or without the Proposed Project from August through November, relative to a current climate scenario.

Freeport flow is an indicator of water flowing into the Delta from one of the major tributaries, the Sacramento River. Across all water years and during all months, climate change is projected to decrease the flow into the Delta by an average of 3 percent, reducing the water available to meet Delta outflow, SWP export, and other targets in the Project area.

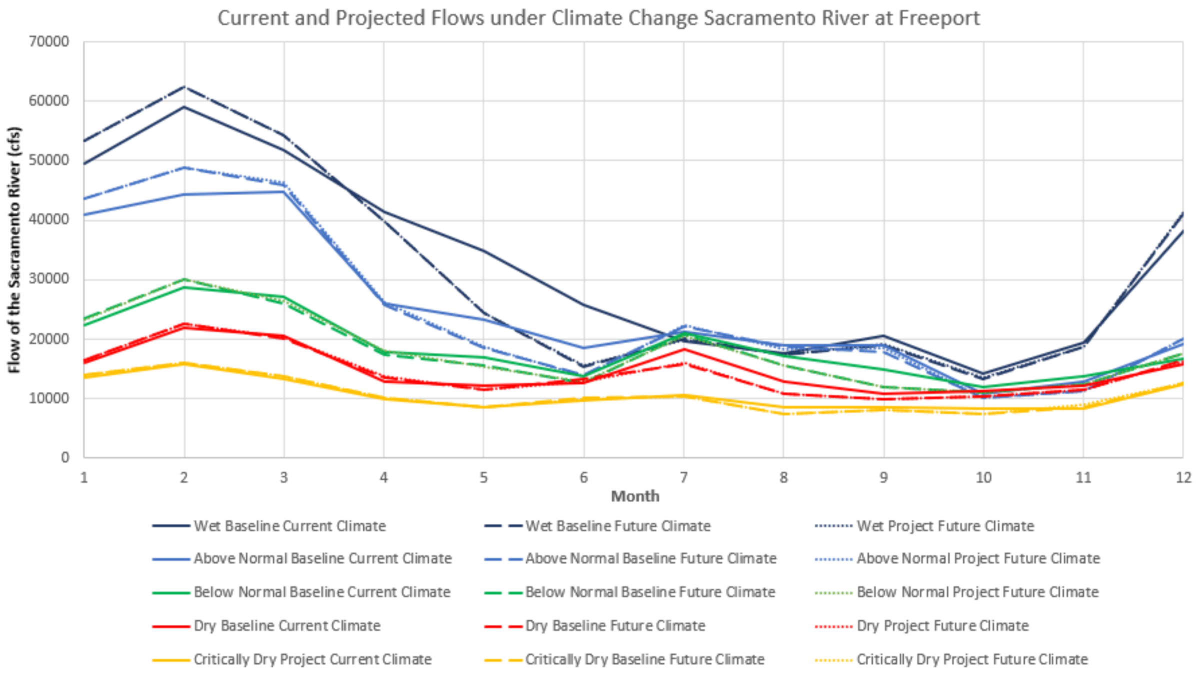


Figure 9-10. Sacramento River flows at Freeport under Current Conditions and Future Climate Change Conditions. Flows under climate change are shown as flows with operational changes described in the Project (Project) and with no operational changes (Baseline).

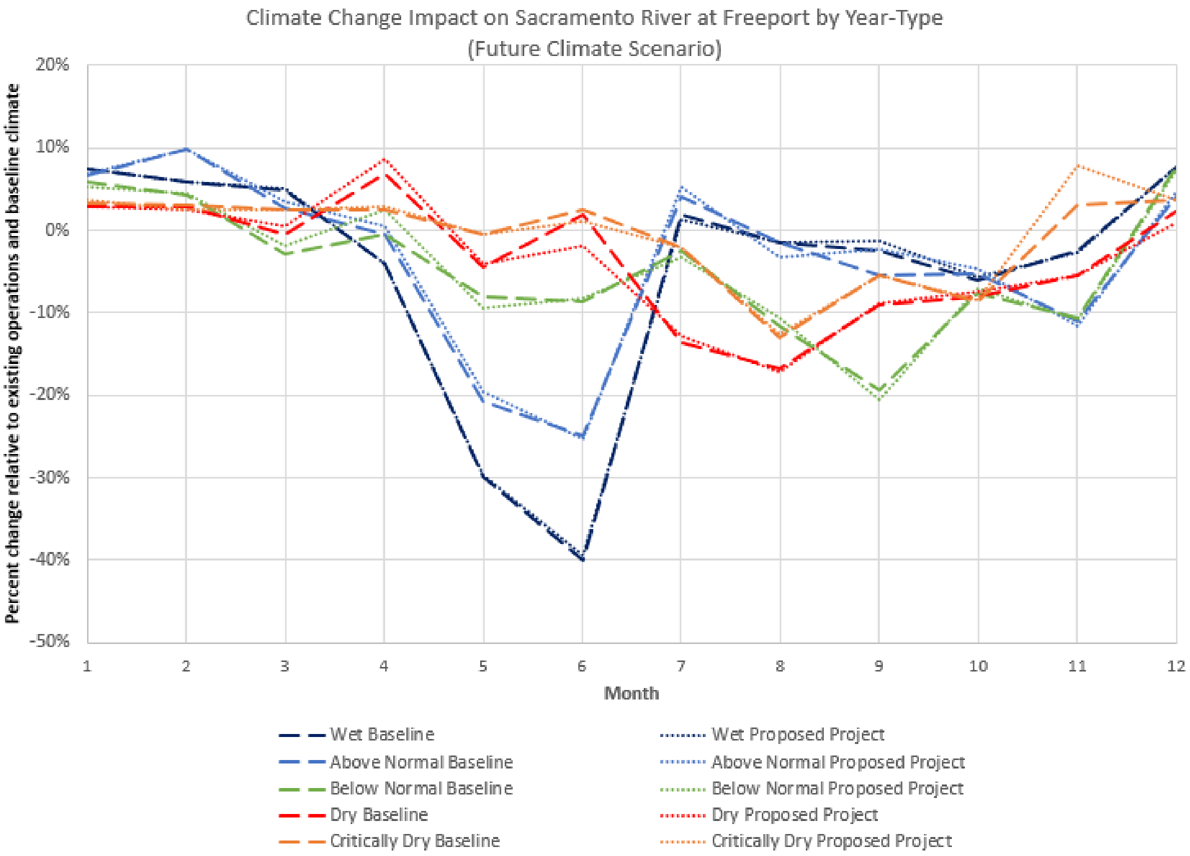


Figure 9-11. Climate Change Impact on Sacramento River flows at Freeport for the Future Climate Scenario for both Baseline and Proposed Project Operations Relative to Existing Operations and Climate Conditions

9.5 Climate Change Resiliency and Adaptation Benefits

California will face increased challenges in water management as the effects of climate change are projected to intensify in the future. Future projected changes in temperature and precipitation will affect the hydrologic cycle in the Project area. Climate resilience and adaptation are often discussed together and when used effectively can mitigate the impacts of climate change. *Adaptation* is an action or set of actions that reduce physical climate risk, whereas *resilience* describes a state of readiness to face climate risks. These two concepts are complementary when analyzing how the Proposed Project can limit the impact of projected future climate change, with specific adaptation actions or strategies used to build resilience to respond to future changes. Preparing for the identified climate risks is adaptation, while a series of adaptive steps contribute to overall resilience (California Natural Resources Agency 2022).

The Proposed Project allows DWR operators to adapt to future conditions and build resilience by enhancing flexibility and the ability to manage extreme events. These operations align with California's statewide Safeguarding California Plan (California Natural Resources Agency 2018), specifically by including adaptive management provisions to address and respond to scientific advances, changing environmental conditions including climate change (W-4.1). The Proposed Project also provides an opportunity for California to better prepare for hotter and drier conditions while improving water storage capacity (W-5) in conjunction with DWR's work with other state, federal, and local agencies to evaluate the effects of reoperating flood management and water supply systems in the context of climate change (W-5.6). The Proposed Project also supports statewide adaptation needs articulated in the Water Resilience Portfolio 2020 that highlights the importance of preparing for future environmental conditions, including changes in extreme events like droughts and floods (California Natural Resources Agency 2020).

Based on the analyses included in this chapter, the effects of climate change will influence future projected stream flows as water enters and exits the Delta. As climate change alters water availability during certain months and water year types, the ability to meet targets can be affected without substantial export reductions or supplemental flow purchases. Climate change will affect the timing of precipitation and river flows in the Project area, and operators can use this opportunity to manage water flexibly to meet targets in the face of these changing conditions. Increased temperatures are projected to decrease precipitation stored as snowpack in the Sierra Nevada, increasing runoff and river flows in the winter and spring as less snow is available to melt later in the year, while reducing the summer and fall flows (see Section 9.2.2.2, "Twenty-First-Century Climate Change Projections for California"). Adaptive management techniques include analyzing water availability at regular intervals to determine water year type and available water to meet operational targets in the near future. Changes in interannual variability indicate that water availability in certain years will be constrained. Operators can use this information combined with flexible targets, including the Voluntary Agreement flows, to adapt operations to future climate conditions as they occur.

The Proposed Project will allow operators to adapt to future events, such as increased winter precipitation or extreme drought or high flow events, by allowing DWR to operate the Banks Pumping Plant to capture peak flows from storm-related events over the course of OMR management season, which may extend from December to February (see Section 2.4.2.4, "Storm Flex"). The Proposed Project's increased monitoring of drought conditions supports DWR's capacity to adapt to increased temperature and drought. DWR's Drought Relief Year (DRY) team will convene monthly adaptive management meetings, beginning in October of each year, to determine whether DWR should pursue actions appropriate for current or anticipated drought and Dry year conditions, and the evaluation will be included in an annual Drought Report (see Section 2.4.16, "Drought"). This adaptive management will use near-term (less than one year) water availability forecasting to best manage operations for different future climate conditions.

With the Proposed Project, DWR retains the flexibility to adapt to the possibility of more frequent drought conditions by making operational decisions based on anticipated water availability (i.e., depending on the water year type). Each year, DWR will manage appropriate Spring Delta outflows based on water year type (see Section 2.4.3, "Spring Delta Outflow"). DWR will continue to support water transfers across the Delta without alteration from SWP operations other than the specific timing of these flows (see Section 2.4.8, "Water Transfers"). These water transfers assist urban and agricultural water users in meeting their water needs, and over 70 percent of water transfers facilitated by DWR are contracts to the San Joaquin Valley and Southern California water users. By operating the SWP based on water availability (i.e., using water year type designations), operators can manage outflow and export volumes based on actual water availability as the climate changes. This type of adaptive management will be increasingly important in the future with increased interannual variability affecting water availability each year.

The Proposed Project also increases climate adaptation benefits for vulnerable fish populations during Dry and Critically Dry years. Because entrainment in the north Delta is more likely to occur during Dry and Critically Dry water years, DWR will adjust Barker Slough Pumping Plant operations in these years to support fish populations. This also supports DWR's ability to adapt to climate change induced alterations in the timing of flows.

In certain instances, Project operations will mitigate extreme climate impacts by bringing future flow extremes closer to present-day conditions. For example, in the Sacramento River at Freeport, during May of Dry water years, the Proposed Project is anticipated to increase flows by 1 percent, while under Baseline Conditions flows would decrease by 4.5 percent due to climate change. Proposed Project operations would also limit projected Sacramento River flow decreases due to climate change by 2 to 5 percent for Above Normal and Below Normal water years in May (see Section 9.4.6, "Sacramento River at Freeport"), making more water available in the Delta during this time. Similarly, OMR flows would experience less extreme flow changes. For example, between February and May the Proposed Project would reduce a 40 percent decrease in flows in Wet water years to a 14 percent decrease (see Section 9.4.3, "Old and Middle River Flows"). These changes indicate that the Proposed Project operations are better adapted to the projected future conditions where more precipitation falls as rain, affecting the timing of peak flows in the system. These adaptive operations account for future conditions where water availability is expected to increase in the spring and decrease in the summer.

The Proposed Project changes may also allow the operators to evaluate the effect of their response to climate events such as drought. Climate change may increase the frequency and severity of drought events, and the Proposed Project will allow operators to evaluate the risk of drought and act in response to demands on the hydrological, facility, and biological conditions in the SWP system. Operators will also have the ability to evaluate the effectiveness of actions taken in response to projected drought events, increasing the capacity of operators to make informed decisions about drought response.

OMR flows are considered an indicator for Delta Smelt and Longfin Smelt entrainment risk with more negative flows increasing entrainment risk (Grimaldo et al. 2009). In Wet water years the Proposed Project would significantly limit climate change–induced flow decreases in the OMR corridor over the main period of adult entrainment risk (December–March; U.S. Fish and Wildlife Service 2019:140), providing adaptation benefits for smelt populations. Decreased precipitation during Dry years, reduced flows, and sea-level rise together indicate saltwater intrusion into freshwater resources and habitat within the Project area. According to analyses presented in this chapter, climate change will be the dominant factor in determining the extent of saltwater intrusion into the Delta. The influence of climate change will not be severe enough to warrant major concern in the short term. Model results show that the Proposed Project operations will neither exacerbate the effects of climate change nor reduce the minimal changes expected from sea-level rise.