Common Response 4.2
Drought and Climate Change

Introduction

This introduction provides important context to this common response. A similar introduction is provided in each common response to ensure that the reader has the appropriate context when reviewing common responses. For ease of reference, a table of contents is included after this introduction to guide readers to specific subject areas.

Protecting the San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) watershed and its many beneficial uses of water is one of the State Water Resources Control Board's (State Water Board) primary responsibilities and top priorities. In response to declines of several native aquatic species since the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Watershed (Bay-Delta Plan or Plan) was last comprehensively updated, the State Water Board commenced a process to update the Bay-Delta Plan for the Sacramento River and its tributaries, Delta eastside tributaries (including the Calaveras, Cosumnes, and Mokelumne Rivers), and Delta for the reasonable protection of fish and wildlife beneficial uses, referred to as the Sacramento/Delta Update to the Bay-Delta Plan. The Bay-Delta Plan identifies beneficial uses of water to be protected in the Bay-Delta watershed, water quality objectives and program of implementation to achieve the reasonable protection of those beneficial uses, monitoring, evaluation, and special study provisions. The State Water Board's proposed action to update the Bay-Delta Plan is supported by a Staff Report/Substitute Environmental Document (Staff Report), which provides an evaluation of the environmental impacts and economic effects in support of consideration of different alternatives to update the Bay-Delta Plan to achieve reasonable protection of fish and wildlife beneficial uses in the Sacramento/Delta. The Staff Report is functionally equivalent to an Environmental Impact Report under the California Environmental Quality Act (CEQA) but also provides the additional analyses that support the State Water Board's consideration of the action under the Clean Water Act and Porter-Cologne Water Quality Control Act.

Development of the final Staff Report and final draft Bay-Delta Plan were informed by several opportunities for public comment over multiple years. This common response may address issues that were raised during any of those public comment periods. In September 2023, the State Water Board released the 2023 draft Staff Report evaluating different alternatives for the Sacramento/Delta Update to the Bay-Delta Plan for public review and comment. Following release of the 2023 draft Staff Report, the State Water Board released draft amendments to the Bay-Delta Plan in October 2024 (2024 draft Plan) for public review and comment that incorporated alternatives identified in the 2023 draft Staff Report with revisions based on public comments. The State Water Board released revised draft Plan updates in July 2025 (July 2025 revised draft Plan), but delayed public comment on that version of the Plan pending further updates, though some parties did submit public comments on the July 2025 draft that are part of the State Water Board's response to comments. In December 2025, the State Water Board released Chapter 13*, Revised Proposed Plan Amendments,* as a limited recirculation of the 2023 draft Staff Report (2025 partially recirculated draft Staff Report) together with the December 2025 revised draft Plan for public review and comment. These documents reflect the updated proposed project, referred to as the revised proposed Plan amendments, which brings together in the Bay-Delta Plan program of

implementation a voluntary agreement (VA) pathway that incorporates commitments identified in the Healthy Rivers and Landscapes (HRL) proposal and would apply to specified HRL water rights, and a regulatory pathway based on the revised proposed Plan amendments that would apply to other water rights and to any HRL water rights no longer covered under the VA pathway. In August 2026, the State Water Board released a final draft Bay-Delta Plan that included refinements to the revised proposed Plan amendments based on public comments received on the December 2025 revised draft Plan. At the same time, the State Water Board released this final Staff Report, including responses to comments previously received on the draft Staff Report. The final Staff Report informs the State Water Board's consideration of adoption of the Sacramento/Delta updates to the Bay-Delta Plan.

With respect to the CEQA impact conclusions, it is important that they be understood in the context of the overall nature of the proposed project, which is intended to be an environmental restoration action. CEQA only considers changes that could negatively impact the existing environment and does not recognize or offset negative changes with improvements that could result from an environmentally beneficial project. Here, the impacts that could potentially result from implementation of the restoration action occur in a system that has been highly altered, and the project would be expected to improve conditions for native fish and wildlife in the Sacramento/Delta watershed over time. However, the project will also result in changes in hydrology and changes in water supply that could result in some potentially significant adverse environmental impacts at certain times and locations that must be analyzed under CEQA. These potentially significant environmental impacts should be viewed in light of the overall purpose and goals of the Sacramento/Delta update to the Bay-Delta Plan.

The State Water Board reviewed and considered all comments and developed common responses to address recurring comments and common themes. Specifically, this common response addresses the following topics raised by commenters:

- Consideration of drought and climate change in analysis under CEQA and Porter-Cologne
- Inclusion of climate change considerations into the Sacramento Water Allocation Model (SacWAM)
- Consideration of climate change in the environmental impact conclusions
- Analysis of multi-year droughts and associated compounding impacts
- Development of drought response measures

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Background

Climate change is a systemwide stressor for the Bay-Delta ecosystem, affecting native fish and other estuarine species across all life stages and throughout the tributaries to the larger estuary. Across California, both maximum (daytime) and minimum (nighttime) temperatures are increasing as a result of increased greenhouse gas emissions, though the degree of this change varies depending on location, and minimum temperatures appear to be rising at a faster rate than maximum temperatures. Statewide annual average temperature has increased by about 2.5°F since 1895, with minimum temperatures rising at a rate of 2.9°F per century and maximum temperatures rising at a rate of 1.1°F per century (OEHHA 2022). These changes in temperature have environmental effects, such as impacts to the hydrologic cycle, sea level rise, or alterations to species distributions and ranges, all of which act and interact as intensifying stressors on the Bay-Delta ecosystem.

Many predicted environmental effects of climate change have already been observed and will continue to increase in severity, including physical changes to ocean, river, and stream environments along the western coast. Climate-driven effects such as warmer atmospheric temperatures, diminished snowpack resulting in altered streamflow volume and timing, lower late-summer flows, a continued rise in stream temperatures, and increased sea-surface temperature and ocean acidity all contribute to changes in the estuary, resulting in altered marine and freshwater food-chain dynamics (Herbold et al. 2022). Climatic "whiplash" has been especially felt across the Sacramento Valley, where drought years are expected to occur with greater frequency punctuated by increased heavy precipitation events and atmospheric-river storms (Swain et al. 2018). While median annual freshwater flow in the Bay-Delta system has not experienced significant change over the last 100 years, seasonal patterns have shifted and an increase in the variability of Delta outflow has been observed (Hutton et al. 2021). Additionally, over the last 50 years, spatially and seasonally variable warming water temperatures have also been reported for most months and areas modeled in the Bay-Delta system with an average water temperature increase of 0.03°F per year across the Delta (Bashevkin et al. 2022).

These changes in hydrology and water temperature will have negative effects on future Chinook salmon populations (^NMFS 2014a; ^Lindley et al. 2009), Delta smelt populations (^Brown et al. 2016; Halverson et al. 2022), and many other native California fishes (Moyle et al. 2013). Because of both decadal-scale climate variations and the loss of complex freshwater and estuarine habitats, salmon populations have declined. Though resilient to historic flood and drought sequences in the climate record, present-day salmon now encounter more stressful conditions than those in which they evolved (Herbold et al. 2018). Pelagic fishes, which live in open water, have already seen drastic declines in abundance and will likely be most impacted by recurring drought and drought-managed flows, as these fish do not recover from dry water years in subsequent wet or normal years. By contrast, littoral fish, which live closer to shore, are more resistant to conditions resulting from flow management during droughts (^Mahardja et al. 2021). While many of California's native species have survived past drought and floods characteristic of California's Mediterranean hydroclimate, native species now confront the effects of climate change in a drastically altered landscape, where centuries of post-colonial land conversion and water system engineering have left drying floodplains, low river baseflows, and opportunities for the proliferation of invasive, predatory species (Power et al. 2024). Warming temperatures are particularly impactful in the central and south Delta, where temperature thresholds for listed species such as juvenile salmonids are frequently exceeded during summer and early fall, translating into longer periods and higher levels of thermal stress (Pien et al. 2024). In this same region, *Microcystis*, a cyanobacteria known to

cause harmful algal blooms (HABs), experiences the lowest average number of thermal stress days (Pien et al. 2024), potentially allowing it to thrive. Climate change acts as a primary factor contributing to the increase in the frequency and severity of HABs in the Delta (^Kudela et al. 2023), further creating harmful conditions for fish.

As climate patterns change, California is poised to experience an increasing number of more severe and lengthy droughts. Anthropogenic warming contributes to drought anomaly, causing previously improbable prolonged and mega-drought scenarios to become substantially more likely in North America, with California's Central Valley being especially vulnerable (Williams et al. 2015; Williams et al. 2020). As climate change brings enhanced year-to-year variation in precipitation, increasingly prevalent multi-year droughts will likely result in large changes to aquatic communities and increase the need to more effectively balance between human and environmental uses of water.

The influence of intensive and multi-year droughts has already been observed in the Delta, affecting both water quality and ecosystems. Multi-year drought periods in the Delta are characterized by altered water quality parameters including high water temperatures, increased salinity, clearer waters, and elevated nutrient levels, all of which contribute to patchy phytoplankton blooms, varying by region and season (Bosworth et al. 2024). Drought periods also heavily influence flow in the Delta, predicting higher residence times, particularly along the Sacramento and San Joaquin Rivers, and heavily reduced net Delta outflow (Hartman et al. 2024). These drought-induced changes may cause changes at higher trophic levels, such as shifts in zooplankton species composition and distribution, an increase in the incidence of HABs, and changes in the larger phytoplankton community composition of the Delta (Hartman et al. 2024). Changes in water quality conditions can also impact larger fish and aquatic organisms, potentially leading species to experience temperatures, flows, and salinities for which they are not historically suited.

Climate change contributes to the overall decline of the Bay-Delta ecosystem and negatively impacts many native fish species, as described in Staff Report Section 4.6, *Climate Change*. The purpose of the Bay-Delta Plan updates is to provide for the reasonable protection of fish and wildlife beneficial uses through establishment of water quality objectives, a program of implementation, and monitoring and special study measures (see Section 7.1.3, *Purpose and Goals of the Sacramento/Delta Update to the Bay-Delta Plan*). The flow scenarios and alternatives were evaluated in the Staff Report for their ability to meet the purposes and goals of updating the Bay-Delta Plan, feasibility, and ability to avoid significant impacts on the environment. This planning process includes actions to directly address the reasonable protection of fish and wildlife beneficial uses. To the extent that climate change acts as a stressor on these beneficial uses, these same protective actions contribute to addressing the impacts of climate change.

The revised proposed Plan amendments include provisions for annual and periodic review, pursuant to the requirements of the Porter-Cologne Act. As a result, the planning process continually accounts for changing conditions related to water quality and water planning, such as climate change. Because climate change would occur relatively slowly over many years, these mechanisms of adaptation would permit responses to climate change to occur sufficiently rapidly to protect resources to the extent possible.

The unimpaired flow metric that is the basis for the numeric inflow requirements in the regulatory pathway of the revised proposed Plan amendments is a strategy that addresses impacts of climate change. As described in Staff Report Section 2.1.1, *Natural and Unimpaired Flow*, unimpaired flow is the flow that would occur without water diversions within existing channel configurations and is an

indication of the amount of water available within a stream system to support all the uses for water within that system. As precipitation patterns shift and climate conditions change, the total amount of water available within a stream system may also change. By requiring a percentage, rather than a defined volume, of total unimpaired flow to be left within streams and contribute to Delta outflow, flexibility is built into the system, thereby preserving a natural range of conditions. In addition, adaptive management of unimpaired flows can help to address changes to the landscape over time, including changes due to climate. The precise future climate conditions in the Bay-Delta are unknown and the flexibility provided by a percent unimpaired flow approach can help buffer against this uncertainty.

The flexibility of the Plan amendments, the ability of the Plan amendments to allow adjustments, and the continuing water quality control planning process allow for responses to changing circumstances like climate change. The adaptive implementation methods described in the revised proposed Plan amendments would provide the State Water Board with the ability to respond to changing flow and water quality conditions that may arise due to climate change.

The analysis of the flow scenarios in the Staff Report includes a range of potential instream flow changes in increments of ten, from 35 percent up to 75 percent unimpaired flow in order to fully capture the potential impacts associated with the revised proposed Plan amendments and the Low and High Flow Alternatives. As required by CEQA, this analysis examines the project's impact on the existing environment. These conditions include effects of climate change that are already being experienced globally and those specific to the Bay-Delta watershed. As the Bay-Delta Plan is updated in the future, including in the periodic review process, additional modeling or analyses may be completed to account for changing conditions, including those brought about by climate change. These reviews will also consider any changes in science that may affect relationships between the protection of beneficial uses and flow thresholds, including new climate science. Based on periodic reviews, the Bay-Delta Plan may be updated to reflect these changes.

Climate Change

The following section addresses comments specific to climate change. Comments on climate change generally fell into three subtopics, focusing on: 1) climate change analysis as it relates to CEQA requirements, State Water Board resolutions, and other state policies, 2) the inclusion of climate change effects into SacWAM for the Staff Report, and 3) the analysis of climate change effects within the environmental impact conclusions detailed in the Staff Report.

Consistency with Regulatory Requirements and Other Policies

Some commenters asserted that there was a lack of climate change analysis included in the Staff Report and that this purported lack amounted to a CEQA violation. Commenters stated that the regular reviews of water quality control plans do not preclude the need for climate change analysis since these reviews do not include a new balancing of beneficial use protection, do not result in new CEQA documents prior to continuation of the plans, and do not include updated modeling of the system with respect to changes in climate. Additionally, some commenters maintained that not conducting climate change modeling is improper for informed decision making and public disclosure surrounding the environmental effects of the revised proposed Plan amendments under CEQA. Other commenters asserted that the purported lack of climate change analysis was in direct contradiction to the State Water Board's own climate resolution (Resolution No. 2017-0012).

Contrary to these commenters' assertions, the Staff Report assesses the effects of climate change and describes the potential impacts of climate change in many different sections throughout the report, including:

- Section 2.6, *Climate Change and Drought*
- Section 4.6, *Climate Change*
- Section 5.6.2.3, *Climate Change, Drought, and Public Safety*
- Section 6.2.3, *Climate Change*
- Section 7.10.2.2, *Climate Change Effects*
- Section 2.4.4, *Climate Change, in Appendix G2, Final Scientific Basis Report Supplement in Support of Proposed Voluntary Agreements for the Sacramento River, Delta, and Tributaries Update to the San Francisco Bay/Sacramento-San Joaquin Delta Water Quality Control Plan*
- Section 6.2.3, *Limitations to Benefits with Climate Change, in Appendix G2, Final Scientific Basis Report Supplement in Support of Proposed Voluntary Agreements for the Sacramento River, Delta, and Tributaries Update to the San Francisco Bay/Sacramento-San Joaquin Delta Water Quality Control Plan*

Section 2.6, *Climate Change and Drought*, identifies that climate change has increased the probability of temperature and precipitation conditions that historically have led to drought in California. This section also includes a description of droughts that have occurred during the hydrologic period of record (1923-2015) that was used for SacWAM in the 2023 draft Staff Report. This modeled time period captures many intense droughts, both in severity and duration, similar to those that are expected as a consequence of climate change. Section 4.6, *Climate Change*, discusses how climate change can exacerbate ecosystem stressors, particularly through increased water temperatures, changing patterns of runoff, and salinity intrusion, all of which already occur in the Bay-Delta system, and have been analyzed. This section also describes changes in precipitation, snowmelt runoff, and sea level rise as well as potential actions to prepare and mitigate the effects of climate change. Section 5.6.2.3, *Climate Change, Drought, and Public Safety* discusses the need to address drought circumstances within the context of climate change, particularly the planning needed to maintain minimum health and safety water supplies. Section 6.2.3, *Climate Change,* discusses the level of uncertainty surrounding climate change, including uncertainty in model inputs for SacWAM. Finally, the Staff Report discusses climate change effects at the global scale and for California in Section 7.10.2.2, *Climate Change Effects*.

Appendix G2, *Final Scientific Basis Report Supplement in Support of Proposed Voluntary Agreements for the Sacramento River, Delta, and Tributaries Update to the San Francisco Bay/Sacramento-San Joaquin Delta Water Quality Control Plan*, contains descriptions and assessments of the effects of climate change on the Bay-Delta ecosystem. Section 2.4.4, *Climate Change*, of Appendix G2, describes how climate change in and of itself will act as a systemwide stressor on the Bay-Delta, but may also act to exacerbate other systemwide stressors in a variety of ways. Section 6.3.2, *Limitations to Benefits with Climate Change*, of Appendix G2, includes specific details on how VA benefits may be reduced by climate change, as well as more general climate change effects that would apply regardless of the implementation pathway. This section details potential impacts to floodplains due to climate change-induced shifts in hydrology, impacts on restored habitat availability from sea level rise, and consequences for suitable habitat restoration in light of elevated water temperatures.

Quantitatively, the Staff Report analysis considers climate change through the hydrologic record used in the SacWAM period of simulation. This period included water years 1923-2015 in the 2023 draft Staff Report. The model simulation period was extended to include water years 2016-2021 in the final Staff Report. This expanded record captures a wide range of hydrologic conditions, including large winter and spring floods and multi-year droughts, and thus reflects the extreme conditions that will likely be experienced in future climate scenarios. This variable climate is carried forward into the analysis presented throughout Chapters 6, *Changes in Hydrology and Water Supply*, 8, *Economic Analysis and Other Considerations*, 9, *Proposed Voluntary Agreements*, and 13, *Revised Proposed Plan Amendments*, modeling changes in hydrology, surface water supply, groundwater supply, and other water management actions as they would occur under the various flow scenarios over the SacWAM period of simulation that encompasses the more extreme variability of a changing climate.

The analysis of changes in hydrology and water supply described in Chapters 6, *Proposed Voluntary Agreements*, 9, *Proposed Voluntary Agreements*, and 13, *Revised Proposed Plan Amendments*, encompasses potential climate change effects through the wide range of variability captured within the hydrologic record used for SacWAM simulations and through the large range of potential instream flow changes from 35 percent up to 75 percent unimpaired flow. These modeled changes in hydrology and water supply serve as the basis for the environmental and economic analyses included in Chapters 7, *Environmental Analysis*, 8, *Economic Analysis and Other Considerations*, 9, *Proposed Voluntary Agreements*, and 13, *Revised Proposed Plan Amendments*. The environmental and economic analyses that are found within these chapters thus inherently consider conditions that could be seen in potential climate change scenarios, and therefore fully disclose a wide range of responses and associated environmental impacts and economic effects that could occur as a result of the proposed project and its alternatives.

The various qualitative and quantitative considerations of climate change that are included in the Staff Report will help inform decision-making and provide a comprehensive description of the Bay-Delta system under potential changes included within the revised proposed Plan amendments. This approach includes consideration of how climate change may add or contribute to the revised proposed Plan amendments' potential impacts on water supply and associated resources. The Staff Report fulfills the requirements of CEQA and the State Water Board's CEQA regulations (Cal. Code Regs., tit. 23, § 3775 et seq.) to analyze the environmental effects of the proposed regulatory activity (i.e., updating the Bay-Delta Plan), as well as requirements of the Porter-Cologne Water Quality Control Act.

Recognizing the importance of climate change, in 2017, the State Water Board adopted Resolution No. 2017-0012 Comprehensive Response to Climate Change. As stated in Section 5.6.2.3, *Climate Change, Drought, and Public Safety*, Resolution No. 2017-0012 calls for a proactive climate change approach in all State Water Board actions and details actions to be taken within Water Board efforts in order to prepare for, adapt, and respond to the impacts of climate change, including informed decision making through climate change analysis. The proposed program of implementation includes actions that address effects of climate change in accordance with Resolution 2017-0012, including required planning for drought and minimum health and safety supplies, a significant degree of flexibility and adaptive management, and other actions to encourage and support water use efficiency and diversifications of water supplies. The various climate change discussions included throughout the Staff Report inform these actions and therefore comply with Resolution 2017-0012. In accordance with the resolution, and as described above, the Staff Report includes analyses that consider and discuss climate change in many different sections throughout the report

Additionally, Resolution 2017-0012 specifically directs the Division of Water Rights to focus on identifying data needs to make recommendations for policy changes regarding modeling when conducting water availability analyses and shortage analyses related to water right permitting activities. This specific directive is satisfied within the Recommendations for an Effective Water Rights Response to Climate Change report (SWRCB 2021), which also contains further information on the Division's responses to climate change.

The Board is required to review the Bay-Delta Plan every 3 years. As described further in Common Response 1.3, *Revised Proposed Plan Amendments*, periodic reviews would include discussion of implementation progress, effectiveness at providing for the reasonable protection of beneficial uses, and possible needed changes to the Bay-Delta Plan and its implementation. Though not required to include a new balancing of beneficial use protection, the periodic review may focus on the effectiveness of the water quality objectives and implementation measures at protecting beneficial uses of water which may result in changes to the objectives or implementation measures to provide for the reasonable protection of beneficial uses. The Board will also hold annual public meetings and reviews to provide updates on relevant compliance activities, ecological monitoring and assessment, and implementation activities. During annual and periodic reviews, the State Water Board will continue to assess current science as it relates to climate change in the Bay-Delta watershed including: changes in hydrology resulting from changes to snowmelt, runoff, and stream losses; seawater intrusion issues; frequency and severity of droughts; changes in air and water temperatures and other water quality conditions; changes in ecological conditions driven by climate change; and other appropriate issues. Based on these assessments, the State Water Board will consider the need for updates to the plan or its implementation based on the latest scientific information. Given the frequency of the annual and periodic reviews, it is more appropriate to analyze current climate conditions in this Staff Report, although, as described above, the Staff Report does include analysis and discussion of climate change. As the Bay-Delta Plan is updated in the future, additional modeling or analyses may be completed to account for changing conditions related to climate change.

Staff Report Modeling

Commenters raised concerns based on the premise that the Staff Report's modeling does not account for climate change. Such comments generally assert that without consideration of climate change, SacWAM's analysis has limited ability to support the Staff Report's conclusions. Commenters also suggested that the hydrologic period used in the 2023 draft Staff Report SacWAM (1923-2015) is limited in predicting future hydrologic conditions and is not representative of what may be seen in the future with regard to shifting snowpack and streamflow peak patterns. To address these identified issues, commenters called for the latest climate change science to be incorporated into SacWAM.

SacWAM is the hydrologic and system operations model developed for the evaluation of alternatives for the Bay-Delta Plan Update. It was first publicly released in 2016 and has since been reviewed and improved based on input from independent panel reviewers and stakeholders. While other models and approaches to modeling may be utilized within other environmental efforts, SacWAM was developed specific to the Bay-Delta watershed and designed to satisfy needs of the State Water Board as it develops an updated Bay-Delta Plan. SacWAM is the best available tool for performing a good faith investigation into the proposed project's potential environmental impacts and remains the best available model for the purposes of this project. As described in Section 2.1.2, *Watershed*

Overview, SacWAM is currently one of the most advanced representations of the Sacramento watershed; the model includes more than 60 reservoirs, over 150 demand nodes, complex operations of the State Water Project (SWP) and Central Valley Project (CVP), and can be used to estimate Delta salinity. With these features and specificity to the Bay-Delta watershed, SacWAM can be used to model both the hydrology and the water supply effects of variable hydrology that are a component of climate change. Please see Common Response 6.1, *Sacramento Water Allocation Model and Changes in Hydrology and Water Supply*, for more information on SacWAM and its use in the Staff Report.

Staff Report Section 6.2.3, *Climate Change*, discusses the uncertainty surrounding the ways in which global climate change may locally impact the Bay-Delta system. Sea level rise, wind conditions, changing temperature, and variable precipitation all may have large effects on the hydrology of the Bay-Delta system and associated water supply, creating large levels of uncertainty in SacWAM parameters. Due to this uncertainty and the lack of detailed climate change information required to generate inputs for SacWAM, climate change is instead considered both qualitatively and quantitatively in various sections of the Staff Report as described in the sections above. Despite uncertainty surrounding climate change, SacWAM remains the most accurate tool for describing hydrology and water supply changes in the Bay-Delta watershed. The wide range of flow scenarios considered coupled with the large amount of variability inherent in the hydrologic record used for SacWAM simulations ensures that the analysis provided by the model captures and accurately describes all potential environmental effects associated with the revised proposed Plan amendments.

As described in Section 4.6, *Climate Change*, climate change is expected to result in warmer temperatures and reduced snowpack. However, effects of climate change on future precipitation are uncertain and cannot be modeled accurately. This is exemplified by two articles from *Nature*, one of which predicts more precipitation in California (Allen and Luptowitz 2017) and the other of which predicts less precipitation in California (Cvijanovic et al. 2017). Other research shows that precipitation intensity is increasing, largely driven by atmospheric rivers, while precipitation frequency is decreasing, resulting in greater year-to-year precipitation volatility overall (Gershunov et al. 2019). For the Bay-Delta system, changes in precipitation can translate into changes in flow and while median annual freshwater inflow to the Bay-Delta estuary has not changed significantly over the last 100 years, seasonal patterns have shifted and the overall variability of Delta outflow has increased, adding to uncertainty (Hutton et al. 2021).

It is expected that climate change could result in increased year-to-year variations in precipitation, but it is unclear how much volatility in the recent hydrologic record is attributable to climate change or is characteristic of highly variable California hydrologic conditions. The 2023 draft Staff Report analysis used 93 years of hydrologic conditions that provide a robust representation of the wide variability observed in California, including the effects of climate change on hydrologic inputs through 2015. Although extension of the hydrologic record would not alter conclusions from the Staff Report due to the high year-to-year variability which is already captured in the 93-year hydrologic record, the years 2016-2021 were added to SacWAM for the release of the 2025 partially recirculated draft Staff Report, further extending the hydrologic record to include a total of 99 years of variable conditions, which again inherently include the past effects of climate change. These additional years capture a water year type sequence of below normal, wet, below normal, wet, dry, and critical years, with the last two years capturing the start of the most recent drought. SacWAM results that include this extended hydrologic record can be found in Appendix H1, *Modeling for the Revised Proposed Plan Amendments*.

Variability in runoff over time is shown in Section 2.6, *Climate Change and Drought*, Table 2.6-1. An essential part of SacWAM is the inclusion of multiple wet and dry year sequences within the 99-year modeling period, which is long enough to capture the year-to-year variability that characterizes California hydrology. This variability, modeled under the 35 to 75 flow scenario range, covers a wide range of potentially very dry and very wet future conditions as well as a wide range of available water supply, thereby covering a range of potential impacts similar to what could be seen with shifting precipitation, snowpack, and streamflow patterns from climate change.

Prior to release of the final Staff Report, technical challenges encountered during the incorporation of climate change hydrology precluded development of operational scenarios based on climate change hydrology. However, evaluation of these operational scenarios and extension of the hydrologic record to even more recent years (beyond 2021) would be unlikely to affect the conclusions of the Staff Report because the 99 years of hydrology that were evaluated already include substantial variability that encompasses the increased variability observed in recent years. A key feature of hydrologic conditions in California is high year-to-year variability, which makes it difficult to discern changes in the hydrologic record over time. Although commenters suggest some evidence of changes in variability or trends, inclusion of additional years beyond 2021 would not change the analysis enough to alter the conclusions. Additionally, as described in Section 7.1.5.2, *Baseline, Evaluation Approach, and Modeling Tools*, the full analysis of environmental impacts provided by the Staff Report is based on qualitative information in addition to the quantitative information provided by SacWAM results. The model results serve to supplement the analysis with information on simulated changes in hydrology and water supply but are not the sole source of information supporting the analysis and conclusions. Despite the challenges surrounding the incorporation of climate change hydrology in SacWAM, SacWAM remains the best possible modeling tool for the purposes of the Bay-Delta Plan Update.

Some commenters asserted that because the Staff Report does not account for the effects of climate change, it therefore ignores climate change effects on increasing the formation and extent of HABs. Existing flows and temperatures are often already unsuitable for fish under baseline conditions described in the Staff Report, and climate change would increase the difficulty in maintaining temperatures and flow conditions suitable for fish under all possible scenarios. Similarly, climate change is expected to worsen HABs. Climate change will stress conditions generally for the Bay-Delta system, affecting all scenarios described in the Staff Report, including baseline conditions. The Staff Report considers climate change effects on HABs in Section 4.3.2, *Harmful Algal Blooms*, Section 4.6, *Climate Change*, and Section 7.12.1, *Surface Water*. The Staff Report describes how climate change, through increased temperatures, is expected to increase the frequency and severity of HABs, including extending the duration of the bloom season. As detailed in this common response, climate change considerations are built into the Staff Report analyses through the inclusion of the extensive hydrologic record which was further extended after release of the 2023 draft Staff Report. The environmental analyses, including the analyses of the effects of changes in hydrology on HABs included in Sections 7.12.1 and 13.7.12.1, each titled *Surface Water,* are based upon SacWAM results that utilize the 93 and 99-year hydrologic record, respectively. The analyses of HABs included in the Staff Report therefore include considerations of the extreme temperature and hydrologic events anticipated with climate change. As identified under Impact SW-f within Sections 7.12.1 and 13.7.12.1, HABs may increase in some reservoirs at certain times, and changes in Delta inflow and exports could result in an increase in the production of HABs in certain Delta channels at certain times. Mitigation measures for these impacts are identified in Sections 7.12.1 and 13.7.12.1.

Some commenters claimed that a failure to account for climate change in the water temperature modeling leads to underestimated water temperatures and a failure to accurately assess suitable water temperatures. Similar to the analysis of HABs, the water temperature modeling in the Staff Report relies upon SacWAM results that capture a range of hydrologic conditions. The effects of climate change on water temperature and associated effects on fish and the ecosystem are considered in Section 4.6, *Climate Change*, and Section 7.6.2, *Aquatic Biological Resources,* and the corresponding sections of Chapters 9, *Proposed Voluntary Agreements,* and 13, *Revised Proposed Plan Amendments*. These sections describe how climate change acts to increase water temperatures across the Bay-Delta system, reducing cold water habitat for native fishes and decreasing the effectiveness of water temperature management for fish populations below reservoirs.

Commenters asserted that the uncertainty around climate change described in the Staff Report is not an acceptable reason for the asserted lack of climate change modeling. Some commenters referred to global climate projections that may be available for incorporation to SacWAM input files or suggested that technical approaches utilized by the California Department of Water Resources (DWR) and the Bureau of Reclamation that allow for the incorporation of uncertainty around future climate change into project analyses are available for use. As previously discussed, the uncertainty around future climate conditions prevented incorporating climate change effects directly into SacWAM. To account for climate change, the Staff Report includes qualitative and quantitative assessments as well as the SacWAM results, which incorporate variability by using the historic record. SacWAM remains the best available tool for performing the hydrological and water supply analyses necessary for the Bay-Delta Plan Update, and the modeling included in the Staff Report represents a good faith effort to analyze and disclose environmental impacts associated with the revised proposed Plan amendments. While some commenters referenced technical approaches for conducting climate change analyses utilized by other agencies, they did not indicate what these specific approaches were or provide any additional information on these approaches.

The inherent uncertainty of the exact nature, magnitude, and timing of future climate change conditions necessitates that the Bay-Delta Plan have the ability to maneuver and adapt based on up-to-date monitoring data, special studies, and investigations. To address and incorporate the effects of climate change, the revised proposed Plan amendments include provisions that require annual and periodic reviews of all Bay-Delta Plan implementation activities, including monitoring and reporting. As additional climate and environmental data is gathered through the implementation activities of the Bay-Delta Plan, these data can be used to inform potential future climate change modeling within the system, filling data gaps and helping to create a more complete picture of how the Bay-Delta watershed may respond to climate change. With the intent to revisit, continually re-evaluate, and potentially update the Bay-Delta Plan in the future, the Board ensures that the Bay-Delta Plan remains responsive to the then-current climate conditions and avoids potential missteps in implementation due to speculation on future climate scenarios.

Impact Analyses

Some commenters asserted that climate change effects were excluded from the Staff Report's impact analyses and, because these effects were allegedly not analyzed, the impacts of the revised proposed Plan amendments are underestimated. Commenters also asserted that climate change impacts should have been analyzed in combination with the impacts of the revised proposed Plan amendments since these impacts are similar in nature (e.g., shifting peak reservoir storage) and may compound upon one another.

As described in further detail above, climate change effects are part of the current condition of the Bay-Delta watershed and the Sacramento/Delta water supply and are therefore included in the Staff Report's description of the existing environment and the baseline for environmental analysis. Moreover, climate change effects are expressly described within the Staff Report in Section 7.10.2.2, *Climate Change Effects*, are included in several other sections of the Staff Report, and are incorporated through the natural variability in the hydrological inputs for SacWAM.

The climate change impacts included through SacWAM hydrology are part of the impact analyses forming the basis for the impact conclusions. Staff Report Section 7.1.5, *Environmental Analysis*, further describes the approach to the environmental analysis and includes an overview of the potential changes in hydrology and changes in water supply, such as shifting peak reservoir storage, that are evaluated in further detail throughout Sections 7.3 through 7.20, Chapter 8, *Economic Analysis and Other Considerations*, and Sections 9.7, *Environmental Analysis*, and 9.8, *Economic Analysis and Other Considerations*. These potential changes are again evaluated for the revised proposed Plan amendments in Section 13.4, *Changes in Hydrology and Water Supply*, Section 13.7, *Environmental Analysis*, and Section 13.8, *Economic Analysis and Other Considerations*.

Some commenters provided shifting peak reservoir storage as an example of the combined potential impacts of climate change and the revised proposed Plan amendments. Shifting peak reservoir storage is broadly described in Section 7.1.5.3, *Reasonably Foreseeable Methods of Compliance and Response Actions*. This description includes an explanation of the mechanism by which water supply impacts may result from changes in reservoir levels that may occur due to new instream flow and cold water pool requirements. Because the environmental analysis of these potential changes included results produced through SacWAM, the analysis of these changes already includes potential impacts associated with climate change as discussed above. Moreover, the discussion recognizes that the actual level of a given reservoir could differ from a modeled level as operations are refined with increased understanding of actions needed to protect cold water habitat, and that modeling scenarios represent only one possible operation of the reservoirs. Operational scenarios may be developed that could reduce reservoir drawdown effects currently reflected in the modeling scenarios, provided the narrative objectives are met. Nevertheless, modeling results indicate that Sacramento/Delta supplies to other regions would be reduced under the revised proposed Plan amendments. The resulting impact conclusions in the Staff Report's environmental resource sections consider the potential environmental effects of the revised proposed Plan amendments under a wide and variable range of climatic conditions, encompassing the current effects of climate change, as shown and described through SacWAM.

Under State CEQA Guidelines section 15126.2(a) and the California Supreme Court's decision in *California Building Industry Association v. Bay Area Air Quality Management District* [2015] 62 Cal.4th 369, CEQA review generally does not consider the environment's impact on the project under review, except to the extent that the project could exacerbate the effects of existing environmental hazards. The Staff Report examines the proposed project's potential impact on the existing environment and therefore satisfies CEQA requirements. The Staff Report is not required to include an analysis of the impacts of climate change itself on the environment or the economy; climate change is nevertheless considered within the Staff Report through the qualitative and quantitative analyses. The Staff Report's analysis and disclosure of the revised proposed Plan amendment's environmental effects thus take into account the ways that future climate change could influence those impacts in the ways described above.

Moreover, the revised proposed Plan amendments are intended to improve conditions in the Delta, which are presently declining in part due to climate change. Chapter 3, *Scientific Knowledge to Inform Fish and Wildlife Flow Recommendations;* Section 13.5, *Beneficial Environmental Effects;* Appendix B, *Scientific Basis Report in Support of New and Modified Requirements for Inflows from the Sacramento River and its Tributaries and Eastside Tributaries to the Delta, Delta Outflows, Cold Water Habitat, and Interior Delta Flows (2017)*; and Appendix G2, *Final Scientific Basis Report Supplement in Support of Proposed Voluntary Agreements for the Sacramento River, Delta, and Tributaries Update to the San Francisco Bay/Sacramento-San Joaquin Delta Water Quality Control Plan*, describe those conditions, including the contribution of climate change, and the Plan amendments' benefits. Though the environmental analysis contained within the Staff Report cannot precisely describe effects of the project and its alternatives under future climatic conditions, the analysis nevertheless adequately describes potential impacts and benefits of the revised proposed Plan amendments for informed decision-making.

Drought

The following section addresses comments regarding drought conditions. Comments on drought generally fell into two subtopics, focusing on: 1) the inclusion of a multi-year drought analysis within the Staff Report, and 2) drought response measures in the project or its alternatives.

Multi-Year Drought Analysis

Many commenters raised concerns about multi-year drought impacts, claiming that impacts to water supply, reservoir storage, and carryover targets under the proposed flow scenarios were not analyzed under multi-year drought conditions. Commenters also expressed that multi-year drought periods are when the potential impacts of the proposed objectives would be most severe, and this should be considered in the Staff Report. Although the Staff Report includes an analysis of impacts during critical water years, commenters asserted that this analysis was not a sufficient substitute for a multi-year drought analysis because it allegedly does not capture compounding impacts of consecutive dry years. Commenters expressed concerns about the ability of water users to cope with multi-year drought sequences under the proposed flow requirements.

The Staff Report accounts for multi-year droughts in the 99-year hydrologic period modeled using SacWAM. The 1923 to 2021 hydrologic period captures extensive year-to-year variability that is characteristic of California's climate, including multi-year droughts. As discussed in Section 2.6, *Climate Change and Drought*, the 2012 to 2016 drought was one of the most severe in California within the past century. From water year 2012 through 2016, runoff into the Delta was below normal, with 3 very dry years in a row (2013–2015). Other droughts also have occurred within the SacWAM period of simulation, including in 1929–1934, 1976–1977, 1987–1992, and 2020-2021. By including these periods in the hydrologic record used for SacWAM to assess impacts, the Staff Report considers associated impacts from multi-year droughts within its analysis. This modeling also captures compounding effects from multi-year droughts by simulating continuous hydrology over 99 years, allowing cumulative stress on water supply to build across consecutive dryer year types and revealing impacts that single-year models cannot. SacWAM results for water supply are presented in Appendix A1, *Sacramento Water Allocation Model Methods and Results*, Appendix G3a, *Sacramento Water Allocation Model Methods and Results for the Proposed Voluntary Agreements*. and Appendix H1a3, *Sacramento Water Allocation Model Results for Updated Unimpaired Flow Scenarios*,

as annual exceedance plots and tables for each water budget area and south of Delta contractor type. The exceedance plots show the distribution of annual water supply displaying the magnitude of supply and the frequency in which the magnitudes were delivered. These results show annual deliveries for all years of the simulation including years with the lowest water supply which tend to occur in years at the end of multi-year droughts shown at the tail end of the exceedance plots. The annual exceedance plots and tables show that the reductions in deliveries in drought years, as shown by the values at the tail ends of the exceedance plots, are similar to the reduction in deliveries shown in critical years presented in the corresponding tables in analyses throughout the Staff Report. Furthermore, Tables 6.4-2 through 6.4-26 and Tables 13.4-105 through 13.4-152 show that water supply reductions are most severe in dry/critical years and that the frequency of shortfalls increases with higher unimpaired flow requirements. By preserving hydrologic sequences, the model also reflects delayed recovery in surface supply after drought, demonstrating that storage and allocations do not immediately rebound even when hydrologic conditions improve. As a result, the framework captures both the severity of individual drought years and the accumulated hydrologic and operational stresses from persistent drought conditions. Therefore, the Staff Report's analysis of water supply impacts during critical years sufficiently covers impacts that may be felt during multi-year drought sequences.

SacWAM results regarding impacts to surface water supply, utilizing the described hydrologic period of record, can be found in Section 6.4, *Changes in Surface Water Supply*. This section details how Sacramento/Delta water supply deliveries may be impacted across different service regions, by water year type, and by water use type as compared to baseline. Given the hydrologic record used for SacWAM includes multi-year droughts, drought impacts to surface water deliveries are inherently captured within the surface water supply analysis.

Within the Staff Report, distributions of annual water supply changes across the various flow scenarios and average water supply changes across water year types are both included to help convey the effects of the revised proposed Plan amendments as they function over multiple years and to provide a sense of impacts in more specific scenarios (e.g., extremely dry conditions). For the purposes of the Staff Report, these analyses represent the best available method for estimating impacts at the scale of the project. Changes seen at smaller scales, such as at monthly time steps or year-to-year deficit accumulations have been aggregated to the appropriate scale and analyzed as part of the full effect of the revised proposed Plan amendments.

Municipal water supply impacts from multi-year droughts are acknowledged, discussed, and analyzed in Sections 7.20.3, *Impact Analysis*, and 13.7.20*, Utilities and Service Systems*, of the Staff Report under Impact UT-d. The impact analysis provides a regional-level assessment of how a reduction in Sacramento/Delta water supplies could affect municipal deliveries, whether additional water supplies may be needed, and whether impacts could be avoided by relying on existing supplies from other sources or more intensive use of demand management measures. The analysis concludes that, although some communities appear to have reserve supply from other sources that could replace Sacramento/Delta supply reductions, other communities do not have enough reserve supplies. Associated mitigation measures can be found in Sections 7.20.4, *Mitigation Measures*, and 13.7.20, *Utilities and Service Systems*.

Similarly, water supply impacts from multi-year droughts specific to agriculture are acknowledged, discussed, and analyzed in Sections 7.4.3, *Impact Analysis,* and 13.7.4, *Agriculture and Forest Resources*, under Impact AG-a and AG-e. This impact analysis considers how and to what extent actions under the revised proposed Plan amendments could lead to reductions in irrigated acreage

that could result in conversions of important farmland to non-agricultural uses or could affect parcels under existing contracts protecting agricultural land. This evaluation focuses on the potential conversion of irrigated farmland to non-agricultural uses as a result of changes in hydrology and changes in water supply. Associated mitigation measures can be found in Sections 7.4.4*, Mitigation Measures,* and 13.7.4. Additional analyses investigating "critically dry" water years and multi-year droughts using the Statewide Agricultural Production (SWAP) model were performed in the interest of transparency and are presented in Common Response 7.4, *Agricultural Resources*.

Staff Report Section 6.3.2, *Reservoir Storage and Elevation*, includes exceedance curves and tables that show how reservoir storage might be impacted under a range of very wet to very dry conditions. Because this analysis is based on the extended hydrologic record used for SacWAM, this analysis includes multiple multi-year drought sequences, and the associated impacts are summarized within the exceedance curves and tables. Similarly, multi-year drought impacts to reservoir storage and carryover targets under the VA proposals can be found within the exceedance curves and tables presented in Section 9.5.3, *Changes in Hydrology*, of the Staff Report. As the proposed Plan amendments were updated for water supply adjustments and new carryover storage target refinements, updated multi-year drought impacts to reservoir storage and carryover targets are captured and reflected in Section 13.4.3.2, *Reservoir Storage and Elevation*.

Commenters expressed concern regarding the compounding impacts of a multi-year drought sequence under the revised proposed Plan amendments and flow scenarios, with some commenters calling for a more detailed level of analysis and modeling to understand how the flow scenarios and drought may affect water user operations. Reductions in water supply, however, are not by themselves environmental impacts requiring analysis under CEQA. The Staff Report does analyze impacts that may follow from changes in water supply, such as impacts to municipal uses and the conversion of agricultural land. As discussed above, these analyses account for multi-year drought conditions. Moreover, the Staff Report's environmental analyses of the Staff Report are necessarily broad; due to the scope and complexity of Sacramento/Delta water use; specific and detailed discussion for every water district or diverter would require inappropriate speculation and therefore is neither feasible nor required. The required degree of specificity in an environmental document corresponds to the degree of specificity involved in the underlying activity being analyzed. (Cal. Code Regs., tit. 14, § 15146.)

Similarly, while modeling results can convey information regarding changes in deliveries, they are not intended to represent detailed and specific operational outcomes, such as the exact manner in which a reservoir would be managed during a particular year or a particular drought sequence. This reflects the nature of the revised proposed Plan amendments, which do not prescribe specific operations or dictate management of individual reservoirs. Instead, the model uses generalized operational rules designed to respond to hydrologic variability. Please see Common Response 6.1, *Sacramento Water Allocation Model and Changes in Hydrology and Water Supply*, regarding SacWAM scope, scale and application and for further discussion about the modeled operations of a reservoir for a single year of simulation.

As discussed in Section 7.4.4, *Mitigation Measures,* agricultural suppliers that provide water to 10,000 acres or more are required to develop and implement Agricultural Water Management Plans (AWMPs) that describe efficient agricultural water management practices that should result in reduced water supply demands. The AWMPs also have specific requirements for sections that discuss drought and water shortage contingency plans, including assessing vulnerability and

resilience. Similarly, Section 7.20.4, *Mitigation Measures*, discusses Urban Water Management Plans (UWMPs), which also include detailed information on drought and water supply reliability for urban water suppliers. The revised proposed Plan amendments do not direct local agencies in how they may respond to multi-year drought scenarios. AWMPs and UWMPs are tailored and unique to individual agricultural and urban water suppliers and their service areas and can be used as a resource for learning about potential responses by individual suppliers, which is beyond the scope of the Staff Report's analysis.

Commenters asserted that increasingly frequent and severe drought years would result in the proliferation of HABs in the Delta and this was not accounted for in the Staff Report modeling and analyses. The Staff Report considers drought and flow effects on HABs in Section 4.3.2, *Harmful Algal Blooms* and Section 7.12.1, *Surface Water,* and the corresponding sections of Chapters 9, *Proposed Voluntary Agreements*, and 13, *Revised Proposed Plan Amendments*. The Staff Report describes how increased residence time, associated with low flows, contributes to the extent and severity of HABs across the Bay-Delta system and notes that the recent increase in HABs may be partly attributable to more frequent drought years. As detailed above, multi-year drought considerations are built into the Staff Report analyses through the inclusion of the extensive hydrologic record that captures a wide range of climatic variability. The environmental analyses, including the analyses of the effects of changes in hydrology on HABs included in Sections 7.12.1 and 13.7.12.1, each titled *Surface Water*, are based upon the SacWAM hydrologic record and therefore, the analyses of HABs included in the Staff Report necessarily include considerations for drought and climate change. As identified under Impact SW-f within Sections 7.12.1 and 13.7.12.1, HABs may increase in some reservoirs at certain times, and changes in Delta inflow and exports could result in an increase in the production of HABs in certain Delta channels at certain times. Mitigation measures for these impacts are identified in Sections 7.12.1 and 13.7.12.1.

Commenters also raised the concern that a lack of climate change analysis compounds upon the purported lack of a drought analysis. As described in the *Climate Change* section above, the Staff Report includes various qualitative and quantitative assessments of climate change and analysis of potential impacts. The Staff Report also includes analysis of multi-year droughts and further discussion of the analysis of associated impacts is detailed within this common response. Both climate change and drought are included, considered, and presented as part of the full disclosure of potential environmental impacts and economic effects of the proposed project at the necessary scale of the project.

Drought Response Measures

Commenters expressed concerns surrounding drought response measures and the need for more clear measures to be included in the Staff Report, stating that measures such as the approval of Temporary Urgency Change Petitions (TUCPs) must be halted and the unimpaired flow standard by itself is not an adequate drought response measure during consecutive dry years. For information and responses to comments on TUCPs, please see Common Response 1.3, *Revised Proposed Plan Amendments.*

Commenters further asserted that the Staff Report needs to better describe how it will protect sensitive beneficial uses during drought periods. Drought response measures that are incorporated into the revised proposed Plan amendments include provisions within the regulatory pathway implementation of the Sacramento/Delta cold water habitat objective. These provisions consist of carryover storage targets that are presented as ranges for both drought and non-drought years

where drought is defined as two or more consecutive dry or critically dry water years or years in which there is a watershed drought proclamation. These ranges are designed to prevent reservoir depletion for multiple purposes (health and safety, meeting other minimum flows, etc.) and protect cold water habitat in the fall. Under the most extreme drought circumstances, lower carryover storage levels could also apply on a temporary one-year basis as approved by the Executive Director.

These provisions are in addition to the unimpaired flow requirement, which is in itself a drought response measure. As future conditions may become more wet or more dry, as in the case of multi-year droughts, the total amount of water available within a stream system may change accordingly. By requiring a percentage, rather than a defined volume, of total unimpaired flow to be left within streams and contribute to Delta outflow, flexibility is built into the system, thereby preserving a natural range of conditions.

The revised proposed Plan amendments also include provisions for adaptive implementation of the inflow objective, which can be used to respond to droughts. These provisions allow for adjustment to the unimpaired flow requirement between 45 and 65 percent provided that certain conditions are met. In addition, flow shaping may be used to manage the numeric inflow requirement as a total volume of water on a water year basis and released on an adaptive schedule. Adaptive implementation of the inflow requirement is intended to assist in providing for the reasonable protection of fish and wildlife thereby protecting sensitive beneficial uses during drought sequences.

Finally, the revised proposed Plan amendments also include specific provisions for human health and safety that provide protection when critical water supply needs may be necessarily prioritized, such as during multi-year droughts. These provisions would allow for short-term and long-term exceptions to curtailments for human health and safety, other emergency circumstances such as emergency firefighting, and certain non-consumptive diversions. One function of these provisions is to allow for continued water diversions for minimum human health and safety water supplies where alternate supplies are not available. For municipalities or areas that are highly dependent on Sacramento/Delta water supply, this provision is intended to safeguard against potential water supply impacts that may be exacerbated under drought conditions. The drought response measures in the revised proposed Plan amendments have been informed by the analysis of drought conditions that are included in the Staff Report and described in the *Multi-year Drought Analysis* section of this response.

References Cited

Allen, R. J., and R. Luptowitz. 2017. El Niño-like teleconnection increases California precipitation in response to warming. *Nature Communications*, *8*(1). Available: https://doi.org/10.1038/ncomms16055.

Bashevkin, S. M., Mahardja, B., and Brown, L. R. 2022. Warming in the upper San Francisco Estuary: Patterns of water temperature change from five decades of data. *Limnology and Oceanography*, 67(5):1065–1080. Available: https://doi.org/10.1002/lno.12057.

Bosworth, D., Bashevkin, S., Bouma-Gregson, K., Hartman, R., and E. Stumpner. 2024. The Anatomy of a Drought in the Upper San Francisco Estuary: Water Quality and Lower-Trophic Responses to Multi-Year Droughts Over a Long-Term Record (1975-2021). *San Francisco Estuary and Watershed Science*, *22*(1). Available: https://doi.org/10.15447/sfews.2024v22iss1art1.

^Brown, L. R., L. M. Komoroske, R. W. Wagner, T. Morgan-King, J. T. May, R. E. Connon, and N. A. Fangue. 2016. *Coupled downscaled climate models and ecophysiological metrics forecast habitat compression for an endangered estuarine fish*. PloS ONE 11(1), e0146724.

California Office of Environmental Health Hazard Assessment (OEHHA). 2022. *Indicators of Climate Change in California (2022).* Fourth edition. Prepared by the Office of Environmental Health Hazard Assessment. Available: https://oehha.ca.gov/sites/default/files/media/epic/downloads/02airtemp.pdf. Accessed: July 22, 2026.

California State Water Resources Control Board (SWRCB). 2021. *Recommendations for an Effective Water Rights Response to Climate Change.* Prepared by the State Water Resources Control Board. Available: https://www.waterboards.ca.gov/waterrights/water_issues/programs/climate_change/docs/water_rights_climate_change_report_feb2021.pdf. Accessed: July 22, 2026.

Cvijanovic, I., Santer, B. D., Bonfils, C., Lucas, D. D., Chiang, J. C. H., and S. Zimmerman. 2017. Future loss of Arctic sea-ice cover could drive a substantial decrease in California's rainfall. *Nature Communications*, *8*(1). Available: https://doi.org/10.1038/s41467-017-01907-4.

Gershunov, A., Shulgina, T., Clemesha, R. E. S., Guirguis, K., Pierce, D. W., Dettinger, M. D., Lavers, D. A., Cayan, D. R., Polade, S. D., Kalansky, J., and F. M. Ralph. 2019. Precipitation regime change in Western North America: The role of Atmospheric Rivers. *Scientific Reports*, *9*(1). Available: https://doi.org/10.1038/s41598-019-46169-w.

Halverson, G. H., Lee, C. M., Hestir, E. L., Hulley, G. C., Cawse-Nicholson, K., Hook, S. J., Bergamaschi, B. A., Acuña, S., Tufillaro, N. B., Radocinski, R. G., Rivera, G., and T. R. Sommer. 2022. Decline in Thermal Habitat Conditions for the Endangered Delta Smelt as Seen from Landsat Satellites (1985–2019). *Environmental Science and Technology* 56(1):185–193. Available: https://doi.org/10.1021/ acs.est.1c02837.

Hartman, R., Burdi, C., Maguire, A., Bosworth, D., and E. Stumpner. 2024. Dry Me a River: Ecological Effects of Drought in the Upper San Francisco Estuary. *San Francisco Estuary and Watershed Science*, *22*(1). Available: https://doi.org/10.15447/sfews.2024v22iss1art5.

Herbold, B., Carlson, S. M., and R. Henery. 2018. Managing for Salmon Resilience in California's Variable and Changing Climate. *San Francisco Estuary and Watershed Science*, *16*(2). Available: https://doi.org/10.15447/sfews.2018v16iss2art3.

Herbold, B., Bush, E., Castillo, G., Colombano, D., Hartman, R., Lehman, P., Mahardja, B., and T. Sommer. 2022. Climate Change Impacts on San Francisco Estuary Aquatic Ecosystems: A Review. *San Francisco Estuary and Watershed Science*, 20(2). Available: https://doi.org/10.15447/sfews.2022v20iss2art1.

Hutton, P. H., Meko, D. M., and S. B. Roy. 2021. Supporting Restoration Decisions through Integration of Tree-Ring and Modeling Data: Reconstructing Flow and Salinity in the San Francisco Estuary over the Past Millennium. *Water*, 13(15). Available: https://doi.org/10.3390/w13152139.

^Kudela, R. M., M. D. A. Howard, S. Monismith, and H. W. Paerl. 2023. Status, Trends, and Drivers of Harmful Algal Blooms along the Freshwater-to-Marine Gradient in the San Francisco Bay–Delta System. *San Francisco Estuary and Watershed Science* 20(4):6.

^Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L. W. Botsford, D. L. Buttom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy, R. Webb, B. K. Wells, and T. H. Williams. 2009. *What Caused the Sacramento River Fall Chinook Stock Collapse?* Pacific Fishery Management Council. March 18.

^Mahardja, B., V. Tobias, S. Khanna, L. Mitchell, P. Lehman, T. Sommer, L. Brown, S. Culberson, and J. L. Conrad. 2021. Resistance and Resilience of Pelagic and Littoral Fishes to Drought in the San Francisco Estuary. *Ecological Applications*. 31(2):e02243.

Moyle, P. B., Kiernan, J. D., Crain, P. K. and R. M. Quinones. 2013. Climate change vulnerability of native and alien freshwater fishes of California: a systematic assessment approach. *PLOS ONE* 8(5). Available: https://doi.org/10.1371/journal.pone.0063883.

^National Marine Fisheries Service (NMFS). 2014a. *Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead*. West Coast Region, Sacramento, CA.

Pien, C., Hartman, R., Bush, E., Lehman, P., and B. Davis. 2024. Thermal Stress and Suitability for Aquatic Species in the San Francisco Estuary. *Biology and Life Sciences*. Available: https://doi.org/10.20944/preprints202409.1890.v1.

Power, M. E., Chandra, S., Gleick, P., and W. E. Dietrich. 2024. Anticipating responses to climate change and planning for resilience in California's freshwater ecosystems. *Proceedings of the National Academy of Sciences*, 121(32). Available: https://doi.org/10.1073/pnas.2310075121.

Swain, D. L., Langenbrunner, B., Neelin, J. D., and Hall, A. 2018. Increasing precipitation volatility in twenty-first-century California. *Nature Climate Change*, 8(5):427–433. Available: https://doi.org/10.1038/s41558-018-0140-y.

Williams, A. P., Seager, R., Abatzoglou, J. T., Cook, B. I., Smerdon, J. E., and E. R. Cook. 2015. Contribution of anthropogenic warming to California drought during 2012–2014. *Geophysical Research Letters*, 42(16):6819–6828. Available: https://doi.org/10.1002/2015GL064924.

Williams, A. P., Cook, E. R., Smerdon, J. E., Cook, B. I., Abatzoglou, J. T., Bolles, K., Baek, S. H., Badger, A. M., and B. Livneh. 2020. Large contribution from anthropogenic warming to an emerging North American megadrought. *Science*, 368(6488):314–318. Available: https://doi.org/10.1126/science.aaz9600.