STAFF REPORT

Delta Watershed
Water Availability Analysis Tool
Climate Scenario Analysis

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Division of Water Rights
Permitting Section
State Water Resources Control Board
California Environmental Protection Agency

1. Delta Watershed Water Availability Analysis Tool Background

The Delta Watershed Water Availability Analysis Tool (WAA Tool) is based on the framework of the State Water Board's Water Unavailability Methodology for the Delta Watershed[1] (Unavailability Methodology). In 2022, the Division developed the WAA Tool to assist in the processing of water right applications in the Delta watershed. The WAA Tool provides an estimate of the amount of water that may be available to supply a new appropriation by balancing modeled unimpaired runoff against diverter demand as well as adopted and reasonably foreseeable flow requirements under the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan).

The Division released a staff report in February 2021 that recommended leveraging existing climate change data in permitting water availability analysis (WAA). In order to adapt the WAA Tool to assess water availability under historical hydrology and climate change scenarios, Division staff identified available hydrology datasets for the Delta watershed which best represent current and future climate conditions. The current version of the WAA Tool (as of October 9, 2024), includes six unimpaired flow datasets which the user can choose between for a given analysis. The following sections of the report describe these datasets, the approach taken to integrate them into the WAA Tool framework, the recommended approach for performing WAAs which consider hydrology based on both current and future climate conditions, and the rationale for this approach.

2. Delta Watershed Hydrology Datasets

The WAA Tool divides the Delta watershed into 20 subwatersheds and requires monthly unimpaired flow data inputs for each. This section describes the various datasets that Division staff have identified as suitable for representing historical, current, and future hydrologic conditions for WAAs using the WAA Tool. With the exception of the streamflow change factors developed as part of the California Water Commission's Water Storage Investment Program (WSIP) climate change analysis, all of the datasets described in this section have been integrated into the WAA Tool.

2.1 Water Unavailability Methodology for the Delta Watershed Historical Hydrology Dataset

Initial applications of the WAA Tool made use of the historical hydrology dataset originally developed for use in the Unavailability Methodology based on monthly unimpaired flow data from the Estimates of Natural and Unimpaired Flows for the

[1] https://www.waterboards.ca.gov/drought/drought_tools_methods/delta_method.html

Central Valley of California[2] for October 1921 through September 2012 and daily unimpaired flow data (aggregated to monthly) from the California Nevada River Forecast Center (CNRFC)[3] for October 2012 through September 2023. This dataset is described in detail in the Unavailability Methodology summary report.[4]

2.2 WSIP Streamflow Change Factors

The California Department of Water Resources (DWR) has created resources related to climate change analysis to be used primarily to aid development of Groundwater Sustainability Plans (GSPs) by Groundwater Sustainability Agencies (GSAs).[5] These resources are based on the results of the California Water Commission's Water Storage Investment Program (WSIP) climate change analysis[6] and are intended to be used, among other things, for developing long-term water budgets, making them applicable for WAAs.

The available datasets were developed based on the WSIP analysis for projected climate conditions centered around 2030 and 2070. The climate projections include a 2030 central tendency, a 2070 central tendency, and 2070 extreme scenario that is drier with extreme warming, and a 2070 extreme scenario that is wetter with moderate warming.

Table 1 shows the projected temperature and precipitation changes associated with each of these scenarios, averaged across the entire Delta watershed. The climate scenario datasets preserve historical variability from January 1915 through December 2011 while increasing or decreasing the magnitude of events based on projected changes in precipitation and air temperature from downscaled global climate models (GCMs). The underlying datasets were derived as part of California's Fourth Climate Change Assessment and are described in Thomas et al., 2018.[7]

Available datasets include precipitation, reference evapotranspiration, hydrology data, and water operations data for the Central Valley as well as unimpaired streamflow change factors for all HUC 8 watersheds in California. These streamflow change factors are calculated as a future scenario divided by the historical detrended scenario. The resulting ratios can be used to perturb historical data to represent projected future

[2] https://data.ca.gov/dataset/estimates-of-natural-and-unimpaired-flows-for-the-central-valley-of-california-wy-1922-2014
[3] https://www.cnrfc.noaa.gov/
[4] https://www.waterboards.ca.gov/drought/drought_tools_methods/docs/2023/wua_report_011923.pdf
[5] https://data.cnra.ca.gov/dataset/sgma-climate-change-resources
[6] https://data.cnra.ca.gov/dataset/climate-change-projections-wsip-2030-2070
[7] Thomas, N., Mukhtyar, S., Galey, B., Kelly, M. (University of California Berkeley). 2018. *Cal Adapt: Linking Climate Science with Energy Sector Resilience and Practitioner Need. California's Fourth Climate Change Assessment, California Energy Commission*. Publication Number: CCCA4-CEC-2018-015

conditions to represent 2030 central tendency, 2070 central tendency, 2070 drier with extreme warming, and 2070 wetter with moderate warming climate scenarios for years 1915-2011.

Table 1 – Average projected changes in climate conditions in the Delta watershed used in WSIP analysis

	2030 Central Tendency	2070 Central Tendency	2070 Extreme – Hot, Dry	2070 Extreme – Cool, Wet
Precipitation Change	3.2%	5.3%	-8.6%	21.1%
Temperature Change	2.6° F	5.9° F	9.2° F	3.9° F

Ultimately, after discussions with DWR staff, it was decided that these datasets would not be integrated into the WAA Tool as the CMIP5 models used to develop them are not as sophisticated as the CMIP6 models used to develop the more-recent climate change datasets released as part of the 2023 State Water Project (SWP) Delivery Capability Report (DCR), described in the following section. However, for most areas of the state outside of the Central Valley, the WSIP streamflow change factors represent the best available representation of future hydrology under climate change scenarios.

2.3 2023 State Water Project Delivery Capability Report Hydrology Datasets

As part of the 2023 DCR, DWR developed five CalSim 3 hydrology datasets representative of distinct climate scenarios which can be applied in water supply analyses for the Delta watershed. These include historical hydrology for WY 1922 – WY 2021, an "adjusted historical" dataset which alters the historical hydrology to be representative of the WY 1992 – WY 2021 climate period (i.e. current conditions), and three risk-informed future climate scenarios which alter the historical hydrology to be representative of possible 2043 conditions.[8]

2.3.1 Historical Hydrology Dataset

The historical hydrology dataset represents WY 1922 – WY 2021 based on observed streamflow, land use, and meteorological data. In cases where historical data was not available, synthetic hydrologic data was created based on extrapolation from observed data. The methods used to develop synthetic hydrologic data for each CalSim 3 watershed are described in the CalSim 3 Hydrology Report – 2023.[9]

[8] https://data.cnra.ca.gov/dataset/finaldcr2023/resource/e41f531d-dace-4d37-b52e-35a6ddd2224e
[9] https://data.cnra.ca.gov/dataset/finaldcr2023/resource/6ba59600-d562-44da-a267-a6a50dff3f0d

2.3.2 Adjusted Historical Hydrology Dataset

The adjusted historical hydrology dataset was developed to capture the observed interannual variability for the entire WY 1922 – WY 2021 period while representing current hydrologic conditions. Precipitation and streamflow data from the historical hydrology dataset for the current climate period of WY 1992 – WY 2021 were used as the basis for modifying the data for WY 1922 – WY 1991 via a combination of statistical scaling methods. The resulting adjusted historical hydrology dataset is identical to the historical hydrology dataset for water years 1992 through 2021, with adjustments to the standard deviation and monthly distribution of historical streamflow for WY 1922 – WY 1991 (i.e. wetter wet years, drier dry years, and seasonal shifts in flows).

2.3.3 Risk-Informed Future Climate Hydrology Datasets

The 2023 DCR analyzes SWP system performance under three risk-informed future climate scenarios. DWR used a novel risk-based analysis to develop hydrology datasets for 2043 climate scenarios representing 50th, 75th, and 95th percentile levels-of-concern, each representative of a different magnitude of change to the Eight River Index April – July runoff (8RI_AJ). The risk-based analysis differs from approaches previously applied by DWR and others that use the average of projected climate conditions from an ensemble of GCMs. In the risk-based analysis approach, DWR applied a bottom-up stress test paired with a probability density function representative of likely climate conditions based on an ensemble of GCMs to develop scenarios representing climate-informed levels-of-concern. The three scenarios developed by DWR are summarized below.

2043 50th Percentile Level-of-Concern Scenario

The 50th Percentile Level-of-Concern Scenario is characterized by a 1.5 °C (2.7 °F) increase in average temperature, a 1.5-percent increase in average precipitation, and a 10.5-percent increase in the 99th percentile daily precipitation event. Based on the climate model simulations used in the risk-based analysis, there is an approximately equal chance of actual 2043 climate conditions being worse or better than the conditions represented in the 50th percentile level-of-concern scenario in terms of declines in the 8RI_AJ.

2043 75th Percentile Level-of-Concern Scenario

The 75th Percentile Level-of-Concern Scenario is characterized by a 1.7 °C (3.0 °F) increase in average temperature, a 0.1-percent increase in average precipitation, and a 12.0-percent increase in the 99th percentile daily precipitation event. Based on the climate model simulations used in the risk-based analysis, there is an approximately 25-percent chance of actual 2043 climate conditions being worse than the conditions represented in the 75th percentile level-of-concern scenario in terms of declines in the 8RI_AJ.

2043 95th Percentile Level-of-Concern Scenario

The 95th Percentile Level-of-Concern Scenario is characterized by a 1.8 °C (3.2 °F) increase in average temperature, a 1.8-percent increase in average precipitation, and a 12.6-percent increase in the 99th percentile daily precipitation event. Based on the climate model simulations used in the risk-based analysis, there is an approximately 5-percent chance of actual 2043 climate conditions being worse than the conditions represented in the 95th percentile level-of-concern scenario in terms of declines in the 8RI_AJ.

3. Methods for Integrating 2023 DCR Hydrology Datasets into the Delta WAA Tool Framework

The 2023 DCR hydrology datasets described above were developed for use with CalSim 3, a SWP and Central Valley Project (CVP) operations model. CalSim 3 hydrology is based on unimpaired flow input from 206 rim watersheds which encompass the mountainous areas that line the perimeter of California's Central Valley, as well as precipitation-surface runoff modeling for an additional 42 "water budget areas" (WBAs) which encompass the valley watershed areas. The WAA Tool is not an operations model and only makes use of the rim watershed unimpaired flow inputs and modeled water budget area (WBA) precipitation-surface runoff estimates for each climate scenario. The WAA Tool separates the Delta Watershed into 20 subwatersheds, including 17 "headwater" subwatersheds and 3 "valley floor" subwatersheds. In order to input CalSim 3 hydrologic data into the WAA Tool, it was necessary to "crosswalk" the 248 CalSim 3 watershed areas into the 20 subwatershed areas used in the WAA Tool.

ArcGIS was used to overlay CalSim 3 and WAA Tool watershed boundaries. Inflows from each CalSim 3 rim watershed were allocated to a single WAA Tool subwatershed. In many cases small portions of CalSim 3 watersheds fell within the boundaries of a WAA Tool subwatershed as a result of misalignment of geospatial datasets. These slivers have been excluded and inflows from each CalSim 3 rim watershed have been assigned to the WAA Tool subwatershed which encompasses the largest percentage of that rim watershed. Background knowledge was also used to ensure that inflows from each CalSim 3 watershed were routed to the appropriate WAA Tool subwatershed. Surface runoff from CalSim 3 WBAs was allocated to WAA Tool subwatersheds based on the percentage of each WBA that falls within each WAA Tool subwatershed. No weighted average calculations were applied to account for precipitation distributions or land use/land cover data.

Of note, the Unavailability Methodology hydrology dataset only assigns flows from upstream of the rim dams (e.g. New Melones, New Don Pedro, etc.) to the headwater subwatersheds, with flows originating downstream of the rim dams but still within the tributary watershed (e.g. inflows to the Tuolumne River below New Don Pedro) assigned to the relevant valley floor subwatershed (San Joaquin Valley Floor, Upper

Sacramento Valley, Sacramento Valley Floor). Conversely, when adapting the 2023 DCR hydrology datasets for use in the WAA Tool, all flows originating within a given headwater subwatershed, even in areas downstream of the rim dams, were assigned to that subwatershed. For example, inflows to the Tuolumne River downstream of New Don Pedro are assigned to the Tuolumne River subwatershed, not the San Joaquin Valley Floor subwatershed as with the Unavailability Methodology hydrology dataset. This adjustment was made in order to align supply and demand representations in the WAA Tool. The CalSim 3 datasets facilitate this approach, as discussed below.

4. Climate Scenario Analysis Approach

While the WAA Tool provides the ability to perform a WAA based on the Unavailability Methodology historical hydrology dataset, Division staff have migrated to basing WAAs off of the 2023 DCR CalSim 3 datasets. This section describes the rationale for:

- basing WAAs on these new datasets rather than the Unavailability Methodology historical hydrology dataset that was used previously;
- using the 2023 DCR adjusted historical hydrology dataset in place of the historical hydrology dataset; and
- using the 2043 50th percentile level-of-concern scenario to represent future climate conditions in WAAs.

4.1 Benefits of 2023 DCR Hydrology Datasets

This section describes the three major reasons for basing WAAs off of the 2023 DCR CalSim 3 hydrology datasets rather than the Unavailability Methodology historical hydrology dataset.

4.1.1 Increased Granularity in Unimpaired Flow Accounting

The CalSim 3 datasets include estimates of unimpaired streamflows and surface runoff from 248 individual watershed areas, as opposed to the 20 subwatersheds used in the Unavailability Methodology. The Unavailability Methodology historical hydrology dataset lumps inflows to major tributary streams (e.g. Tuolumne River, Feather River, etc.) below the rim dams together with inflows to the San Joaquin and Sacramento Rivers, even though diverter demands in these areas are assigned to the relevant headwater subwatershed and not the downstream valley floor subwatershed. This misalignment of supply and demand representation can lead to accuracy issues in quantifying water availability in headwater subwatersheds (which also impacts availability findings in downstream valley floor subwatersheds). The CalSim 3 datasets represent unimpaired flow inputs below the rim dams on a finer spatial scale, allowing for inflows to major tributary streams below the rim dams to be assigned to the relevant headwater subwatershed and improving the accuracy of water availability findings.

4.1.2 Accounting for Surface Runoff in Valley Floor Areas

The CalSim 3 datasets account for surface runoff in valley floor areas while the Unavailability Methodology historical hydrology dataset only accounts for inflows from major tributaries to the Sacramento and San Joaquin Rivers. This represents a substantial amount of inflow to the Sacramento and San Joaquin Rivers and can have a significant impact on water availability findings, also affecting availability findings in headwater subwatersheds.

4.1.3 Ability to Compare Water Availability under Different Climate Scenarios

It is a priority to include representations of both future climate and current climate in WAAs using the WAA Tool, and to be able to compare water availability findings under different climate scenarios. The CalSim 3 future climate hydrology datasets represent the best-available climate change scenario data available for use in the WAA Tool, and a direct comparison between historical and future conditions would not be possible using the Unavailability Methodology historical hydrology dataset because of underlying methodological differences in the creation of the datasets (e.g. omission of surface runoff from valley floor areas in the Unavailability Methodology).

4.2 Selecting Between the 2023 DCR Hydrology Datasets

As described above, five distinct CalSim 3 hydrology datasets were developed as part of the 2023 DCR effort. While the WAA scenario analysis could include a comparison of water availability findings under all five of these datasets, Division staff recommend basing findings off of the adjusted historical and 50^{th} percentile level-of-concern scenario datasets.

4.2.1 Adjusted Historical Hydrology vs. Historical Hydrology

In climate science, the concept of stationarity suggests that weather for a given region fluctuates within a well-bounded envelope of variability. Weather patterns might vary from one year or one decade to the next, but they basically fall within a space described by a probability density function that relates to the observed record. Climate stationarity was declared “dead” in 2008[10], and since then numerous other studies have suggested that climate stationarity no longer exists.

In developing the 2023 DCR, DWR orchestrated an analysis to determine whether current hydrologic conditions in the Central Valley have shifted sufficiently from historical conditions to warrant replacing the use of historical hydrology in planning models with a dataset more representative of the current hydrologic regime. The effort

[10]Milly, P. C. D., et al. (2008), Stationarity is dead: Whither water management?, Science, 319, 573–574. https://www.science.org/doi/full/10.1126/science.1151915

resulted in a finding that interannual variability of unimpaired runoff has increased and that seasonal shifts in runoff timing have occurred over the past century to such an extent that historical hydrologic data are no longer representative of the current hydrologic regime. This ultimately led to the creation of the adjusted historical hydrology dataset described above.

The purpose of a water availability analysis is to use available data to determine how much water might currently be available for a new appropriation. With the availability of the adjusted historical CalSim 3 hydrology dataset, it is possible to assess current hydrologic conditions while also capturing the interannual variability that occurred over a 100-year period of record.

Climate-Period Analysis vs. Transient Analysis

Broadly speaking, there are two common approaches for performing climate change analyses for water resource planning: transient analysis, in which climate change and associated impacts progress over the modeled period, and climate-period analysis, in which weather patterns vary annually while the underlying climate remains stationary over the entire modeled period. An analysis based on the historical hydrology dataset would represent a transient analysis, while use of the adjusted historical or future climate hydrology datasets would represent a climate-period analysis. In the context of WAAs, a transient analysis might provide a better understanding of how water availability has changed over time under a shifting hydrologic baseline, while a climate-period analysis would provide results that are more relevant to understanding current and future conditions.

The Division's climate scenario analysis approach for permitting WAAs builds off of the analyses and data products developed by DWR as part of the 2023 DCR. DWR transitioned from using transient analyses for SWP planning efforts to using a climate-period analysis in the 2023 DCR. Similarly, the Division's approach with the WAA Tool is to use a climate-period analysis for WAAs in the Delta watershed, basing water availability findings off of hydrology datasets which represent current conditions and 2043 future climate conditions rather than historical conditions.

4.2.2 Selecting a 2043 Future Condition Scenario for WAAs

The risk-based future climate scenarios developed by DWR for the 2023 DCR represent three possible climate futures for the year 2043. DWR selected these three specific climate futures based on the level of risk that each poses to SWP system-functionality, as defined by a single performance metric: 8RI_AJ. For example, the 75th percentile level of concern represents a 2043 climate condition where only 25-percent of the potential climate conditions evaluated lead to a greater reduction in 8RI_AJ. The logic of the risk-based approach is that if DWR plans around the 75th percentile level-of-concern scenario there is only a 25 percent chance that they will be "under-planned" for dealing with reductions in 8RI_AJ. Similarly, if DWR plans around the 50th or 95th percentile level-of-concern scenarios, there is a 50 percent or 5 percent chance that they will be under-planned, respectively.

The “level-of-concern” and “risk-based” framing used by DWR makes sense in the context of planning exercises for existing infrastructure. An agency can select their preferred future climate scenario based on their risk-tolerance and make planning decisions to ensure system functionality under those conditions. However, this framing does not align with water availability analyses for new water rights.

Reductions in the 8RI_AJ might pose a threat to existing water right holders who have come to rely on the ability to divert at a certain level from April through July, but likely do not impact water availability for new water rights which often seek to divert in the winter. While the 8RI_AJ may be a preferred metric for quantifying shifting hydrologic conditions in the Delta Watershed, it does not capture shifts in winter hydrology which are likely to increase as 8RI_AJ decreases. DWR provided Division Staff with data comparing the level-of-concern of various future climate scenarios based on the 8 River Index December – March Runoff (8RI_DM) against the level-of-concern based on 8RI_AJ. Levels of concern based on these two metrics have a nearly inverse relationship. Indeed, as 8RI_AJ level-of-concern increases, there is increased water availability for new water right applicants in the peak diversion season of December – March.

In a broader sense, the “risk-based” framing captures the difficulty in reoperating existing infrastructure to function under a novel hydrologic regime. While previously-submitted water right applications are constrained to the diversion season, face-value, and diversion rate that they have indicated on their application, there is no risk, per se, to these theoretical systems because nothing yet depends on them achieving a certain level of performance.

Though the “level-of-concern” framing that DWR has attached to the three risk-based future climate scenarios does not fit neatly into the context of water availability analysis for new water right applications, the scenarios themselves and the associated hydrologic data that was generated for each scenario can still be applied for our purposes. While the 75th and 95th percentile level-of-concern scenarios only have meaning in the context of projected reductions in the 8RI_AJ metric, the 50th percentile level-of-concern scenario simply represents the central tendency, or median outcome, of all evaluated GCM-predicted future climates. The 1.5 °C (2.7 °F) increase in average temperature, 1.5-percent increase in average precipitation, and 10.5-percent increase in the 99th percentile daily precipitation event that characterizes the 50th percentile level-of-concern scenario is the most likely 2043 climate future based on DWR’s analysis. Dispensing with the “risk-based” framing while still making use of the hydrologic data generated for this scenario allows Division Staff to assess water availability under probable 2043 conditions.

5. Conclusion

The WAA Tool was developed to perform WAAs to assist in the processing of water right applications in the Delta watershed. In order to account for the impacts of climate change on water availability, Division staff have integrated six distinct hydrology datasets into the WAA Tool which collectively represent Central Valley hydrology under historical, current, and future climate conditions. Of these six datasets, Division staff recommend basing water availability findings off of the 2023 DCR adjusted historical and 2043 50^{th} percentile level-of-concern scenario hydrology datasets. These datasets offer the best available representation of current and future hydrologic conditions in the Delta watershed and align the Division’s analytical approach with that used by DWR in its most recent analysis of SWP operations.