MWDOC

2023 ORANGE COUNTY WATER RELIABILITY STUDY

Municipal Water District of Orange County

July 2023

CDM Smith

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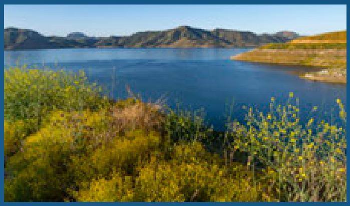

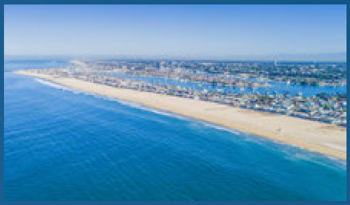

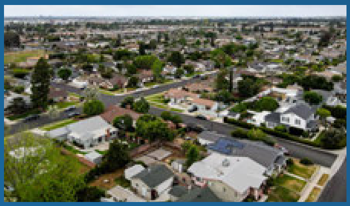

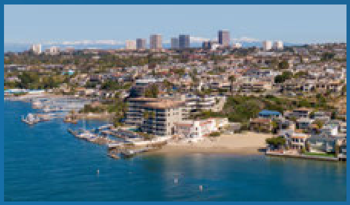

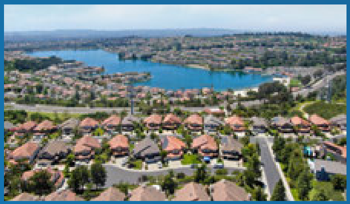

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Executive Summary

Background

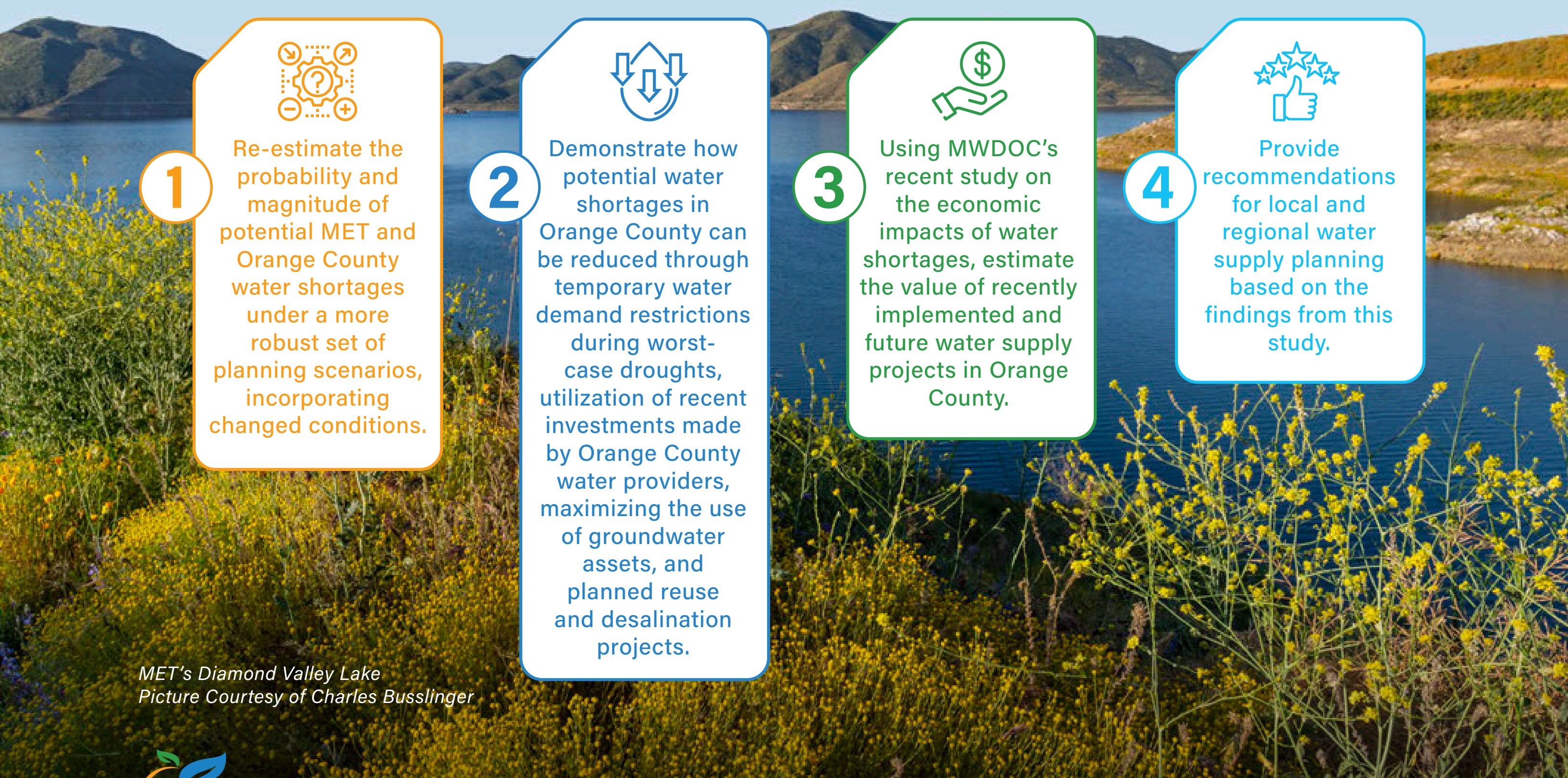
Ensuring a reliable water supply that is resilient to droughts and climate change is essential to supporting a vibrant economy and quality of life for residents in Orange County. To help guide planning for future water supply reliability for water providers in Orange County and provide input on regional water supply issues for the Metropolitan Water District of Southern California (MET), the Municipal Water District of Orange County (MWDOC) has prepared this 2023 Orange County Water Reliability Study (2023 OC Study) based on a number of changed conditions since the completion of its previous 2018 OC Study.

The changed conditions include:

- Improved understanding of climate change impacts to water supply reliability.
- Declining water availability from the State Water Project and the Colorado River.
- Changes in planned water supply projects, such as the California's withdrawal of permits for the two-tunnel California WaterFix project and its replacement with a one-tunnel Delta Conveyance Project, and the advancement of MET's Pure Water Southern California project.
- Reduced regional and Orange County water demands through successful water reuse and water use efficiency efforts.
- Completion of MET's 2020 Integrated Water Resources Plan (IRP) Needs Assessment, including higher assumptions of new local water supplies in the region than previously projected.

The objectives of the 2023 OC Study are:

1. Re-estimate the probability and magnitude of potential MET and Orange County water shortages under a more robust set of planning scenarios, incorporating changed conditions.
2. Demonstrate how potential water shortages in Orange County can be reduced through temporary water demand restrictions during worst-case droughts, utilization of recent investments made by Orange County water providers, maximizing the use of groundwater assets, and planned reuse and desalination projects.
3. Using MWDOC's recent study on the economic impacts of water shortages, estimate the value of recently implemented and future water supply projects in Orange County.
4. Provide recommendations for local and regional water supply planning based on the findings from this study.



MET's Diamond Valley Lake
Picture Courtesy of Charles Busslinger

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Water Reliability Assessment

The 2023 OC Study developed five plausible planning scenarios made up of combinations of uncertainties facing Southern California and Orange County, which are summarized as:

SCENARIO 1. Low Stress without Delta Conveyance

Warm/wet climate future, lower-level retail water demands, increased local water supplies in the MET region, moderate amounts of new MET water supplies, but without implementation of California's Delta Conveyance Project.

SCENARIO 2. Moderate Stress without Delta Conveyance

Warm/dry climate future, medium-level retail water demands, increased local water supplies in the MET region, moderate amounts of new MET water supplies, but without implementation of California's Delta Conveyance Project.

SCENARIO 3. Moderate Stress with Delta Conveyance

Warm/dry climate future, medium-level retail water demands, increased local water supplies in the MET region, moderate amounts of new MET water supplies, and implementation of California's Delta Conveyance Project.

SCENARIO 4. Significant Stress without Delta Conveyance

Hot/dry climate future, higher-level retail water demands (but offset with increased water use efficiency), increased local water supplies in the MET region, higher amounts of new MET water supplies, but without implementation of California's Delta Conveyance Project.

SCENARIO 5. Significant Stress with Delta Conveyance

Hot/dry climate future, higher-level retail water demands (but offset with increased water use efficiency), increased local water supplies in the MET region, higher amounts of new MET water supplies, and implementation of California's Delta Conveyance Project.

The results of the water demand and supply modeling for the 2023 OC Study were then used to estimate the probability and size of potential MET water shortages. MET water shortages were then allocated to Orange County using MET's water supply allocation formulas. Shortages were first estimated without mandatory water use restrictions, and then with assumed 15 percent water use restrictions. Under the more likely Scenarios of 2-5, the probabilities of any-sized water shortage occurring for the MET region and in Orange County range from 10 to 20 percent of the time (or between 1 in 10 years to 1 in five years). Maximum water shortages for Scenarios 2-5, assuming 15 percent mandatory water use restrictions by 2050, are estimated to range from 171,000 to 538,000 AFY for MET and range from 40,000 to 128,000 AFY for Orange County. These maximum shortages are projected to occur 3.5 percent of the time.

Key Findings and Recommendations

The key findings from the 2023 OC Study are summarized as:

Under a hot/dry climate future (which recent evidence seems to suggest might be the current path), coupled with 15 percent mandatory water demand restrictions and optimistic future water supply assumptions (i.e., maximum levels of local and regional reuse, increased water use efficiency, new water transfers and storage, and implementation of the Delta Conveyance Project), the analysis indicates that water shortages in the MET and Orange County service area can still occur. The maximum water shortage in 2050 under these future conditions (as represented in Scenario 5) is 171,000 AFY for MET and 40,000 AFY for all of Orange County. The probability of these maximum shortages occurring is 3.5 percent.

Within Orange County, these net water shortages can be reduced to near zero values utilizing recent investments made by local water agencies in reuse and water banking, temporarily maximizing local groundwater beyond overdraft targets, and with planned new water supply projects.

The maximum value of the Delta Conveyance Project, when coupled with 250,000 AF of new regional storage, is estimated to be 367,000 AFY for MET and 63,000 AFY for Orange County. The Delta Conveyance Project also reduces the probability that any shortage occurs by about 10 percent—meaning a doubling of the time between shortage conditions from once every 5 years to once every decade.

Based on MWDOC's 2022 report on the Economic Impacts of Water Shortages in Orange County, the value of water supply investments in Orange County is estimated to be approximately $2,500/AF in present value terms. In comparison, the present value unit costs of recently completed and planned water supply projects in Orange County range from $1,950-$2,350/AF. Therefore, it can be interpreted that these Orange County projects represent a net economic benefit to Orange County.

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The following represents the recommendations from the 2023 OC Study:

Recommendation 1

Orange County water agencies should continue to make investments in water reuse, water use efficiency, water transfers and banking, groundwater/surface water conjunctive use, and desalination.

Recommendation 2

Orange County officials should advocate for a balanced regional portfolio of water supplies for MET that includes: (a) implementation of MET's Pure Water Southern California program; (b) implementation of the Delta Conveyance Project; (c) new regional storage, which could include participation in the proposed Sites Reservoir Project; (d) continued financial support for water use efficiency and local projects, and (e) exploration of regional seawater desalination.

Recommendation 3

Orange County and MET should continue to study the evolving science of climate change and its impacts on water demands and supplies, as well as develop adaptive management strategies to mitigate these impacts.

In short, there is no one or two silver bullets that will provide full water reliability for MET and Orange County. The results from this comprehensive assessment justify an "all of the above strategy" to ensure a robust regional economy and quality of life for our residents for decades to come.

Section 1: Introduction

1.1 History of Orange County Water Reliability Study

Water reliability and resiliency is of key importance for the Southern California region and within Orange County. Droughts and unplanned system failures can significantly reduce water supplies needed for a robust economy and quality of life for residents. In 2014, the Municipal Water District of Orange County (MWDOC) completed its first Orange County Water Reliability Study (OC Study). This study examined water supply and system reliability[1] for three areas of the county: (1) Brea/La Habra; (2) Orange County Basin; and (3) South Orange County. These areas were defined based on the amount and sources of local water supply and vulnerability to imported water shortages caused by droughts and seismic events. To evaluate water reliability for this study, a systems model was developed by CDM Smith that simulates future water demands and supplies under multiple hydrologies and climate change.

In 2018, MWDOC updated the OC Study based on more advanced modeling of imported water from the Metropolitan Water District of Southern California (MET) and local groundwater in Orange County using planning scenarios. At the time of the 2018 OC Study, it was assumed that the California "WaterFix" two-tunnel project in the Sacramento–San Joaquin River Delta would be implemented by 2035 for all of the scenarios given that the project had cleared an extensive environmental review and approvals by the State and Federal governments. Based on the climate change modeling and information available, two climate scenarios were utilized that represented minimal and moderate climate impacts on imported and local water supplies. Finally, the 2018 OC Study examined several proposed Orange County water supply projects in terms of potential costs and benefits.

[1] Water supply reliability measures water shortages caused by hydrology (e.g., droughts and extended dry periods), whereas system reliability measures water shortages caused by unplanned outages (e.g., seismic events or major system failures).

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1.2 Changed Conditions for 2023 Study

As a result of significant changed conditions since the 2018 OC Study, MWDOC has prepared this updated 2023 OC Study. It should be noted that some of these changed conditions decreased the water reliability estimated in the 2018 OC Study, while others improved the estimated reliability.

Changed Condition 1 – Improved Understanding of Climate Change

The final installment of the Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report was released on March 20, 2023. This 8-year long undertaking from the world's most authoritative scientific body on climate change summarizes the findings from 234 scientists on the physical science of climate change; 270 scientists on impacts, adaptation and vulnerability to climate change; and 278 scientists on climate change mitigation. To date, this is the most comprehensive and best available scientific assessment of climate change. Some of more relevant findings from this IPCC report are as follows:

Climate change is already underway. The current 1.1 degrees C of global temperature rise (with the last decade being the warmest in over 125 years) has resulted in: glacial retreat and loss of summer artic ice that is greater than anytime during the last 2,000 years; sea level rise that has been faster than any prior century for 3,000 years; ocean acidification that is at its highest level in last 26,000 years; and observable shifts in the hydrologic cycle of fresh water systems.

Climate impacts are more widespread and severe than expected. Every degree increase beyond the current 1.1 degrees C increase will result in significantly more droughts, extreme heat events, flooding, and wildfires; and significant loss of food-producing agriculture and ecosystem biodiversity.

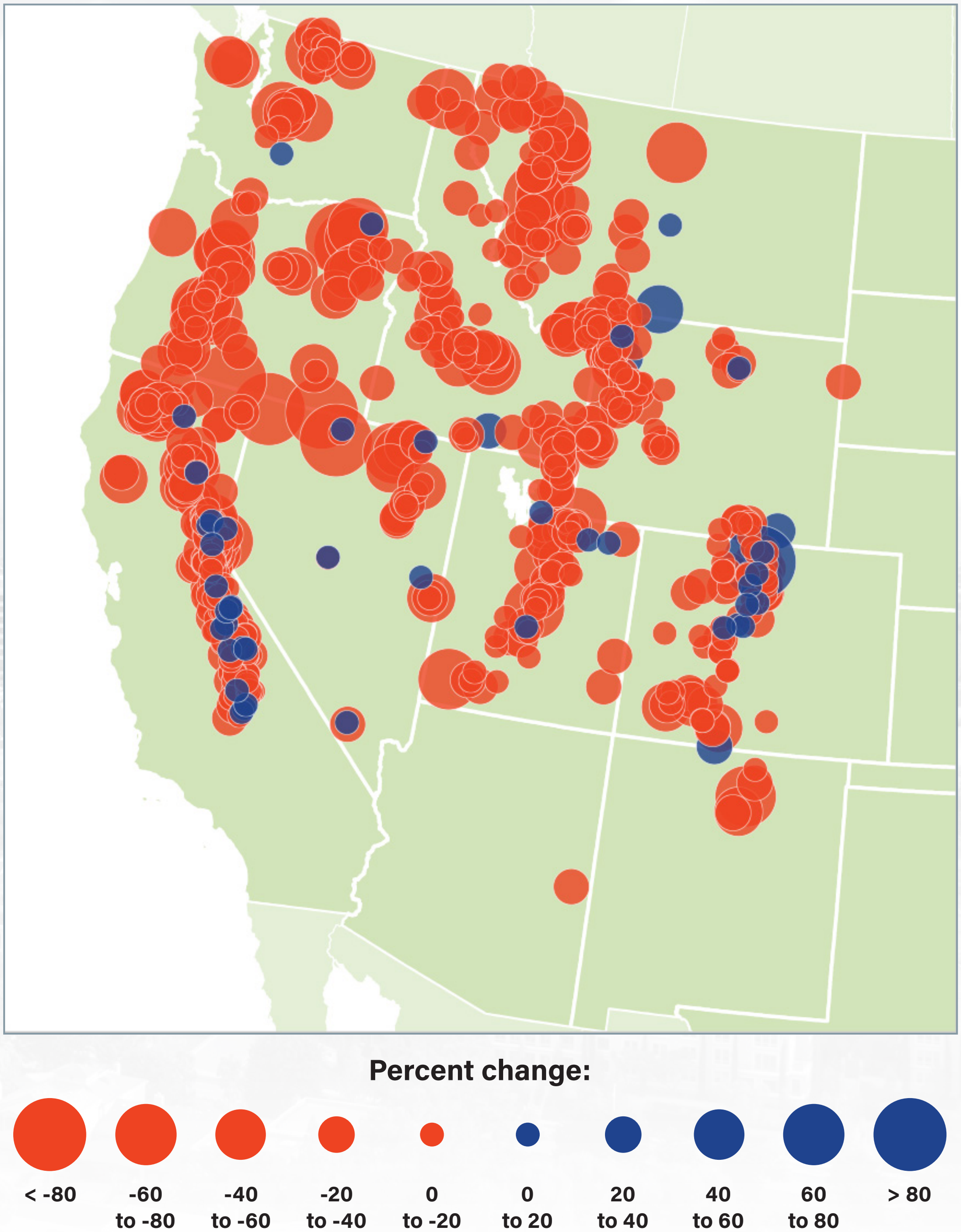
Some climate impacts are so severe that they can never be adapted. Some areas around the global have reached a point where climate adaptation can no longer be implemented, resulting in permanent losses and damages.

Global greenhouse gas emissions will continue to climb. Global emissions will continue to climb through 2030 before leveling off and then start to decrease if current world governments mitigation efforts are successful. As a result, between 2021 and 2050 there is a more than a 50 percent chance that global temperature rise will surpass 1.5 degrees C and a 25 percent chance that temperatures will rise past 3.5 degrees C.

Changes in precipitation and intensity will vary in North America. The findings indicate that there is a high confidence that total precipitation will increase for the northern half of North America, and medium confidence that it will decrease in parts of the western and south western United States. Further, a greater fraction of precipitation is expected to occur as "intense events" such as those caused by atmospheric rivers.

Regional evidence of climate change can be seen in decreased snowpack in the Western United States, as depicted in **Figure 1-1**. In California, snowpack has declined by 30-50 percent since 1955. Snowpack is essentially free storage and in an average year it represents about 30 percent of the fresh water supply in California and Colorado River basin.

Figure 1-1. Changes in April Snowpack from 1955-2022

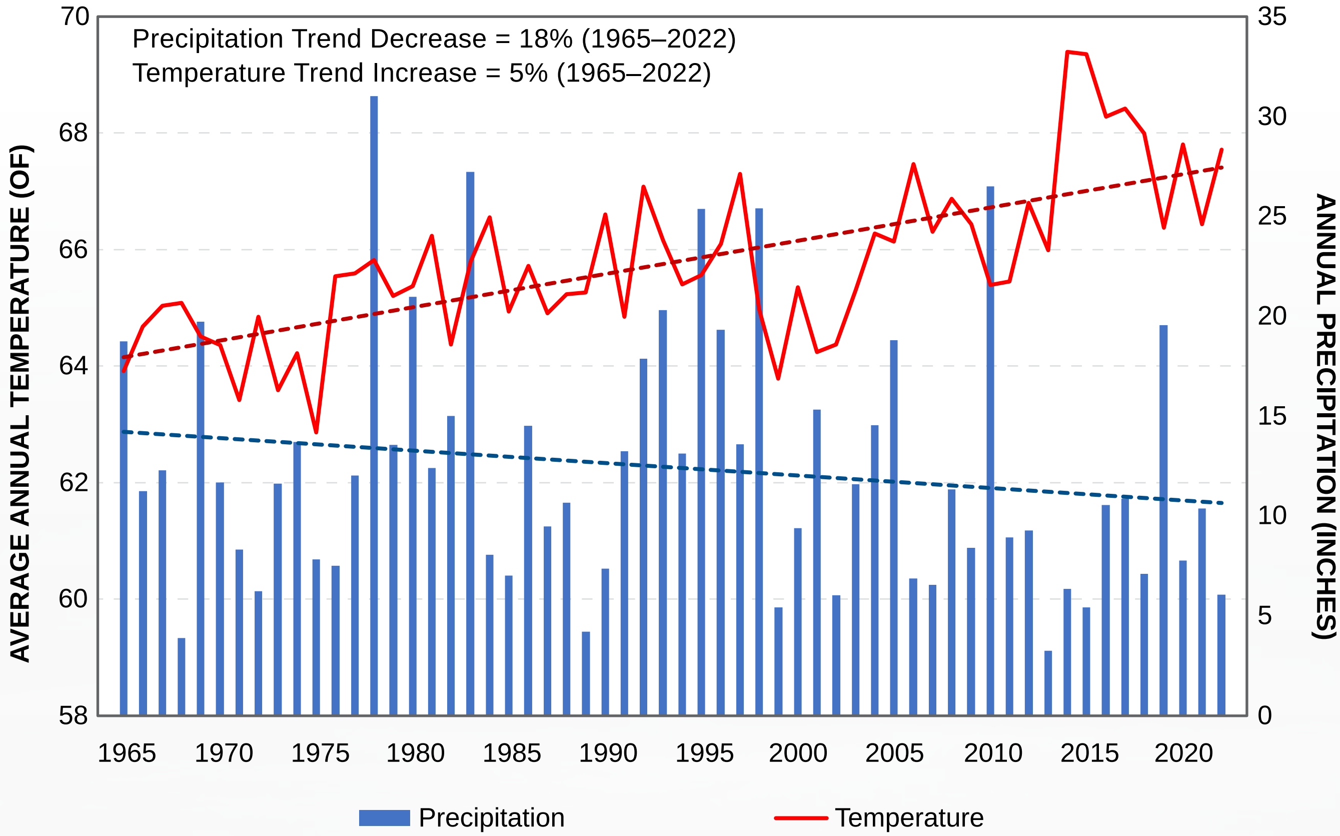


Graphic Source: Courtesy of https://www.epa.gov/climate-indicators/climate-change-indicators-snowpack

In addition, since 1945 there has been an 18 percent decline in snowmelt contribution to late spring inflows in the Sacramento River. The shifting of snowmelt from late spring to late winter occurring in California is important because less of it can be utilized as water supply.

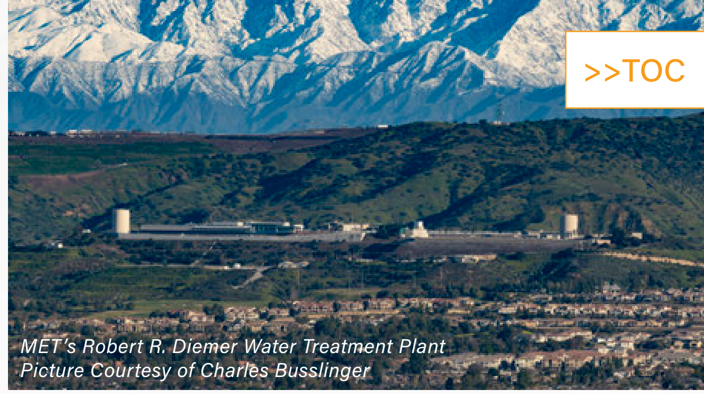
Within Orange County, evidence of climate change can be seen in **Figure 1-2**, with clear trends showing precipitation decreasing by 18 percent and temperature increasing by 5 percent since 1965.

Figure 1-2. Historical Orange County Climate



Data Source: NOAA, Santa Ana Fire Station Data.

Lake Mead



MET's Robert R. Diemer Water Treatment Plant
Picture Courtesy of Charles Busslinger

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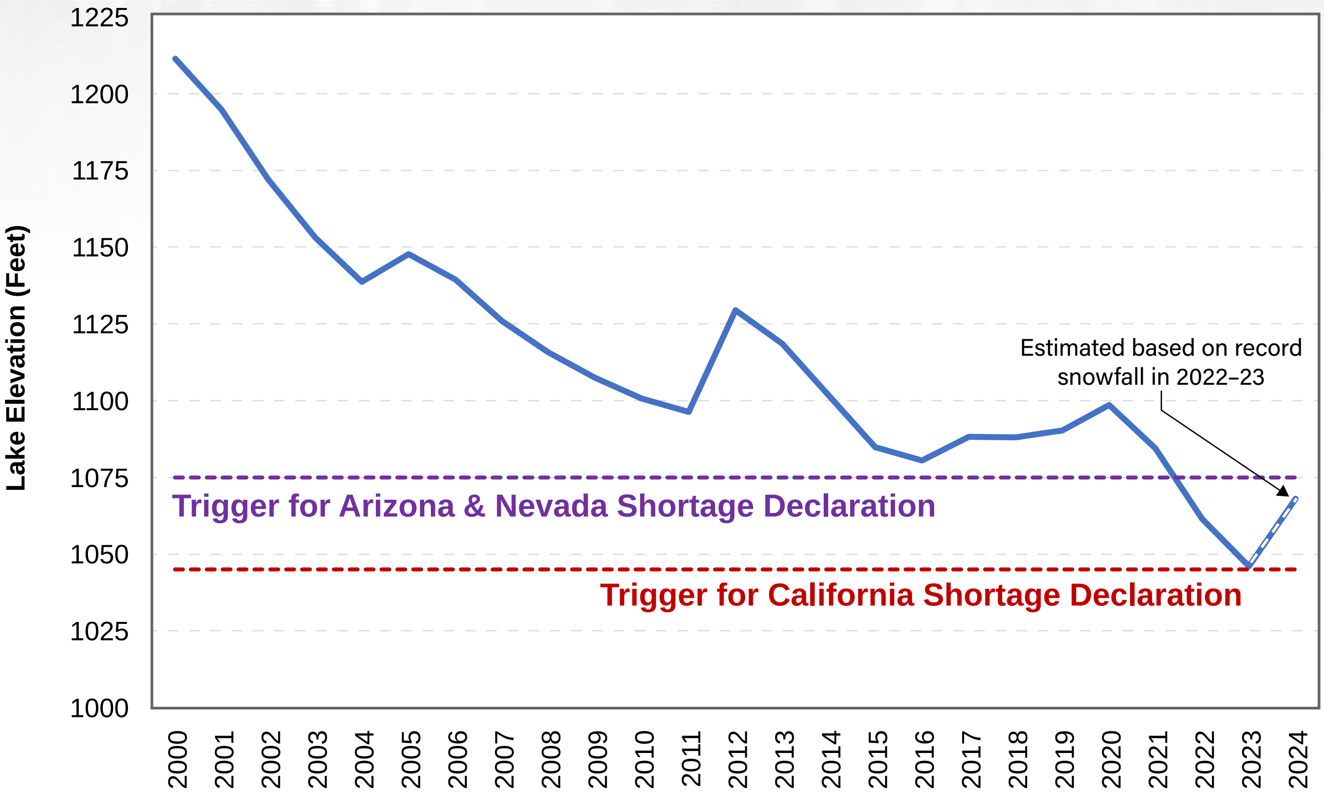
Changed Condition 2 – Declining Imported Water Availibility

Since the publication of the 2018 OC Study, imported water to MET's region from the Colorado River Aqueduct (CRA) and State Water Project (SWP) have declined in reliability. The current 23-year drought in the Colorado River Basin is considered the worst in 1,200 years[2]. Lake Mead elevation levels have been steadily declining since 2000 (see **Figure 1-3**), triggering official shortage declarations from the U.S. Bureau of Reclamation (BOR) for Arizona and Nevada in 2022 under the current Drought Continency Plan. California's shortage declaration under the current drought plan occurs when Lake Mead elevations are consistently below 1,045 feet. In July 2022, lake levels did drop to 1,040 feet but rebounded slightly to 1,046 feet due to recent record rainfall in late 2022 which spared California an official shortage declaration. Record snowpack in late 2022 and early 2023 is expected to increase Lake Mead elevation to 1,061 feet by the end of 2023.

Figure 1-3. Lake Mead Elevation Levels



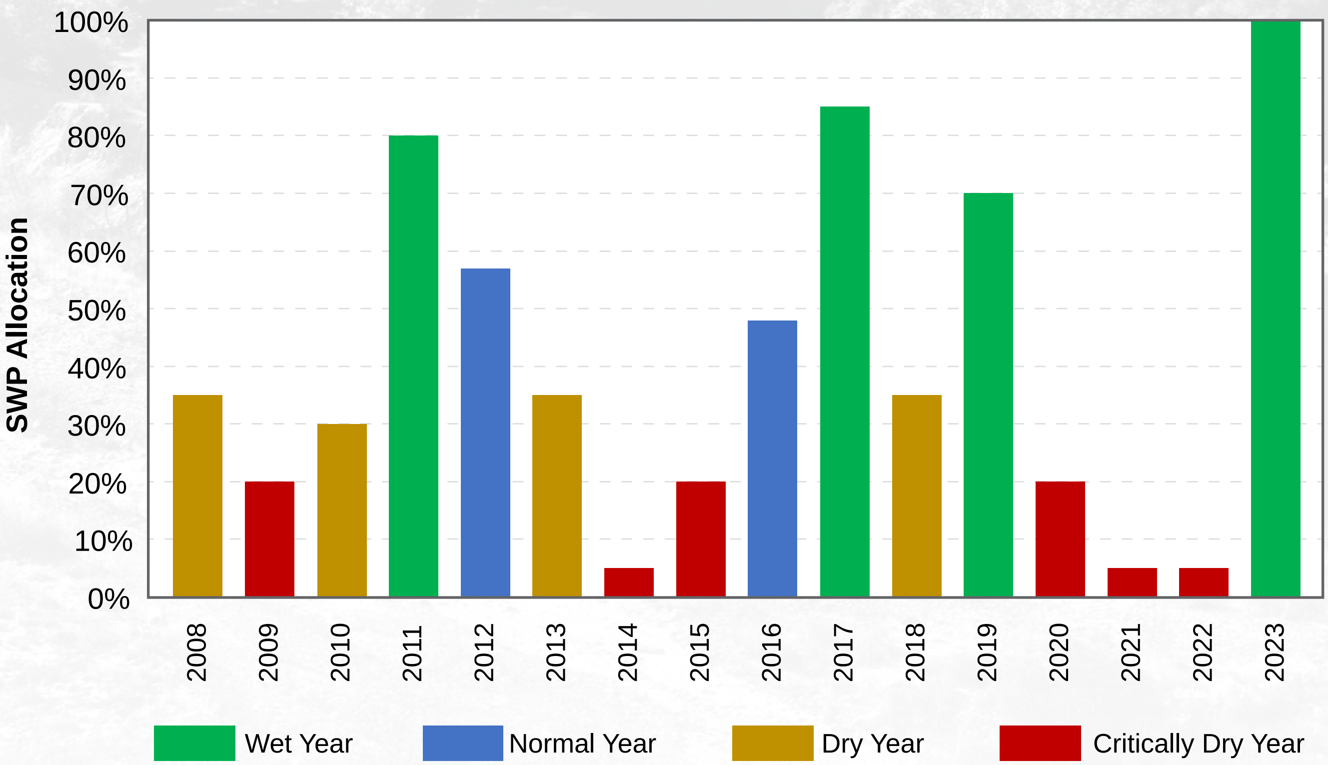
Data Source: https://www.usbr.gov/lc/region/g4000/hourly/mead-elv.html

[2] Based on: Williams, A.P., Cook, B.I. & Smerdon, J.E., Rapid Intensification of the Emerging Southwestern North American Megadrought in 2020–2021. Nature Climate Change Journal, Issue 12, February 12, 2022.

Despite the water supply cuts issued for Arizona and Nevada to date, and record precipitation occurring in late 2022 and early 2023, the Colorado River is still considered to be in peril. In May of 2023 a recent agreement between the BOR and all seven Basin states calls for cuts in river water use of 3 million acre-feet by 2026 between Arizona, California and Nevada. More cuts will likely be needed according to BOR and climate experts, as well as the development of an official long-term operating plan for the River.

The California Department of Water Resources (DWR) spring allocations of SWP Table A contract deliveries to MET are shown in **Figure 1-4**. Ten of the last 16 years (63 percent of the time) have been classified as dry or critically dry years. Three years during this same period had SWP allocations of 5 percent, which is unprecedented. Normal years only represented 13 percent (2 years) of this past 16-year period, while wet years represented 25 percent (4 years). As a comparison, from 1922-2000, wet, normal and dry years were fairly distributed, with wet and dry years occurring about 20 percent of the time and normal years occurring 60 percent. The more recent pattern of multiple dry years followed by a very wet year is indicative of climate change predictions for the western United States. Further

Figure 1-4. State Water Project Spring Allocations to MET



Data Source: https://water.ca.gov/Programs/State-Water-Project/Management/SWP-Water-Contractors

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Orange County Water District's Bond Basin.
Picture Courtesy of Charles Busslinger

demonstrating that climate change is already occurring is the recent extreme precipitation that occurred from 12 atmospheric rivers hitting northern California from December 2022 to March 2023—which led to the very rare 100 percent SWP allocation for contract deliveries in 2023. However, it should be noted that both the timing of precipitation (whether as rain or snow) and the intensity of storm events has significant implications in terms of usable water supply. High intensity storms of short durations, more precipitation falling as rain rather than snow, coupled with earlier snowmelt is not ideal for the SWP system which would struggle to handle extreme volumes of runoff in short amounts of time.

Changed Condition 3 – Update on California and MET Imported Water Projects

In May of 2019, DWR withdrew its permit for a two-tunnel WaterFix project in favor for a smaller one-tunnel project alternative. In July 2022, the draft Environmental Impact Report (EIR) for the recommended Delta Conveyance Project alternative was issued. With an estimated cost of $16 billion and strong opposition by environmental organizations and other interests in the Delta, the best-case scenario is that the project is operational by 2040. However, it is also possible that the project is not implemented within the planning horizon of the 2023 OC Study.

In light of worsening conditions for imported water, MET has launched its Pure Water Southern California project, which will use advanced purification technology to treat reclaimed water for indirect potable reuse and potentially direct potable reuse by 2035. Up to 168,000 acre-feet per year (AFY) is anticipated from this project.

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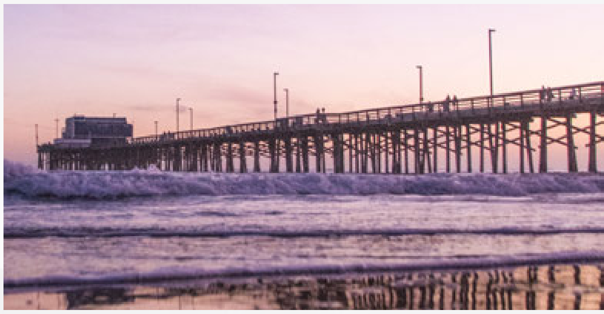

Changed Condition 4 – Lower Regional and Local Water Demands

Water demands for MET have been decreasing steadily since 2007 (from 2.4 MAF in 2007 to 1.4 MAF in 2017), as a result of greater levels of water use efficiency, increases in local water supply by MET's member agencies, and periodic mandatory water use restrictions during droughts. However, it appears that this downward trend may be reaching a plateau, with recent MET demands averaging around 1.5 MAF for several years now. Total Orange County water demands have decreased from 687,000 AFY in 2007 to 506,000 AFY in 2017 due to increased water use efficiency and mandatory water use restrictions during droughts. However, since 2015, water demands in Orange County have increased to about 550,000 AFY under average weather conditions.

Changed Condition 5 – MET 2020 Integrated Resources Plan Needs Assessment

On April 12, 2022 the MET Board of Directors approved the needs assessment phase for the update of MET's regional Integrated Resources Plan (IRP). This needs assessment looked at four future scenarios made up of low and high service area demographic growth, increases in local water supplies for the region, and impacts of climate change. For this 2020 MET IRP, projections of local water supplies in the region were made by MET's member agencies without adjustment. These unadjusted projections therefore greatly increase the forecast of local water supplies in the MET region verses what was assumed for the 2018 OC Study. The maximum water shortage under MET's IRP high growth/signifcant climate change scenario was projected to be about 1 MAF by 2045 without any assumed future MET water supply projects. It should be noted that MET used different planning scenarios and climate change assumptions for its 2020 IRP than those used for this 2023 OC Study.

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California Aqueduct

Summary of Changed Conditions

Table 1-1 summarizes how the changed conditions for the 2023 OC Study impacted the water supply reliability estimated vs the 2018 OC Study.

Table 1-1. Changed Conditions and Impacts to Estimated Supply Reliability

Changed Condition for 2023 OC Study	Impact
1. Improved Understanding of Climate Change	Reduced Supply Reliability
2. Declining Imported Water Availability	Reduced Supply Reliability
3. Update on California and MET Water Projects	Little Net Impact
4. Lower Regional and Orange County Water Demands	Increased Supply Reliability
5. MET 2020 IRP Needs Assessment (Higher Local Supplies)	Increased Supply Reliability

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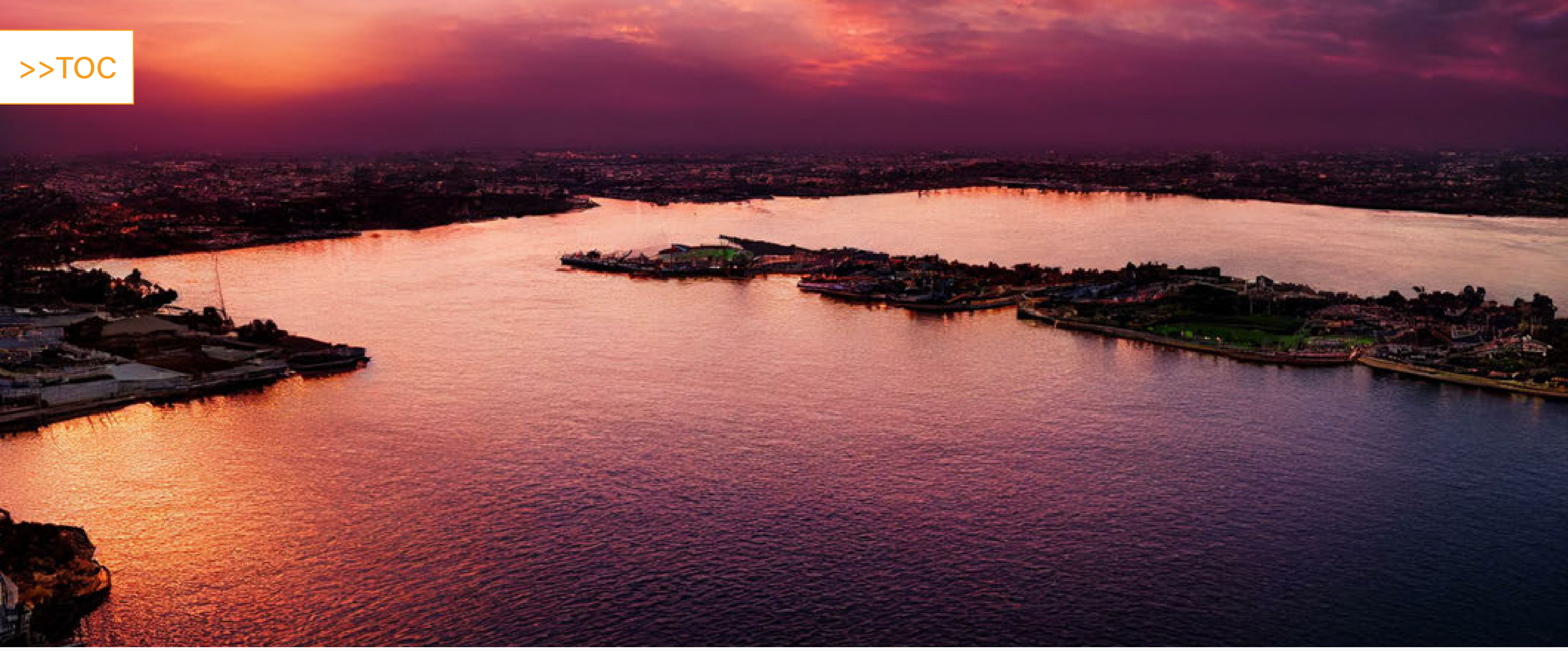

1.3 Objectives for 2023 Orange County Water Reliability Study

The key objectives for the 2023 OC Study are as follows:

1. Re-estimate the probability and magnitude of potential MET and Orange County water shortages under a more robust set of planning scenarios, incorporating changed conditions.
2. Demonstrate how potential water shortages in Orange County can be reduced through temporary water demand restrictions during worst-case droughts, utilization of recent investments made by Orange County water providers, maximizing the use of groundwater assets, and planned reuse and desalination projects.
3. Using MWDOC's recent study on the economic impacts of water shortages, estimate the value of recently implemented and future water supply projects in Orange County.
4. Provide recommendations for local and regional water supply planning based on the findings from this study.

It should be noted that the 'system reliability' analyzed in the 2018 OC Study under potential seismic events were not re-estimated for the 2023 OC Study as they are still considered to be valid—meaning no material change in water demands or emergency water supplies occurred between the two studies.

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Section 2: Planning Scenarios

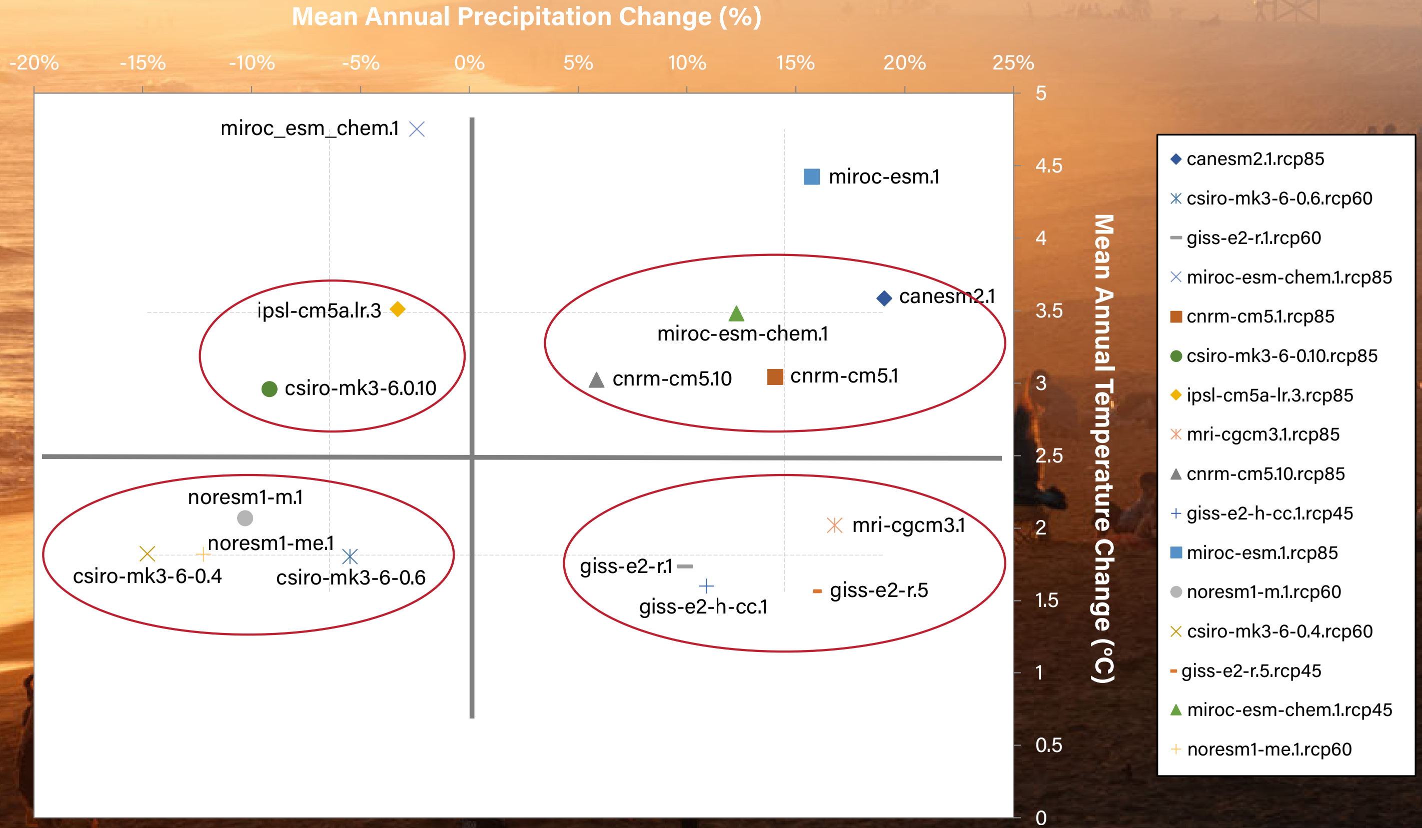
The 2023 OC Study developed plausible planning scenarios made up of combinations of the following uncertainties: climate change, water demands and efficiency levels, Orange County Groundwater Basin assumptions, local water supplies in the MET service area, success of new MET water supply programs, and success of the Delta Conveyance Project.

2.1 Uncertainties

Climate Change

The 2023 OC Study utilized the Coupled Model Intercomparison Project Phase 5 (CMIP5) global climate models (GCMs), which utilize Representative Concentration Pathways (RCP's) to show a range in climate projections. CDM Smith selected a sub-set of 16 GCM/RCP combinations to represent four distinct climate futures: (1) hot/dry, (2) hot/wet, (3) warm/dry, and (4) warm/wet. **Figure 2-1** presents these GCMs plotted for the Colorado River system, showing departures between 2050 temperature and precipitation from historical conditions. The GCMs that are circled in the figure were ensembled to represent the climate futures. It should be noted that the study team decided not to use any GCM showing greater than 4 degrees C change in temperature by 2050, as most climate scientists now indicate this is very unlikely[3].

Figure 2-1. Downscaled GCMs Selected to Represent Four Climate Scenarios for Colorado River



[3] "Emissions – the 'business as usual' story is misleading". Hausfather & Peters, Nature Vol 577, Jan 30, 2020, page 620. And World Energy Outlook 2022 - International Energy Agency, Temperature Rise Scenarios page 127.

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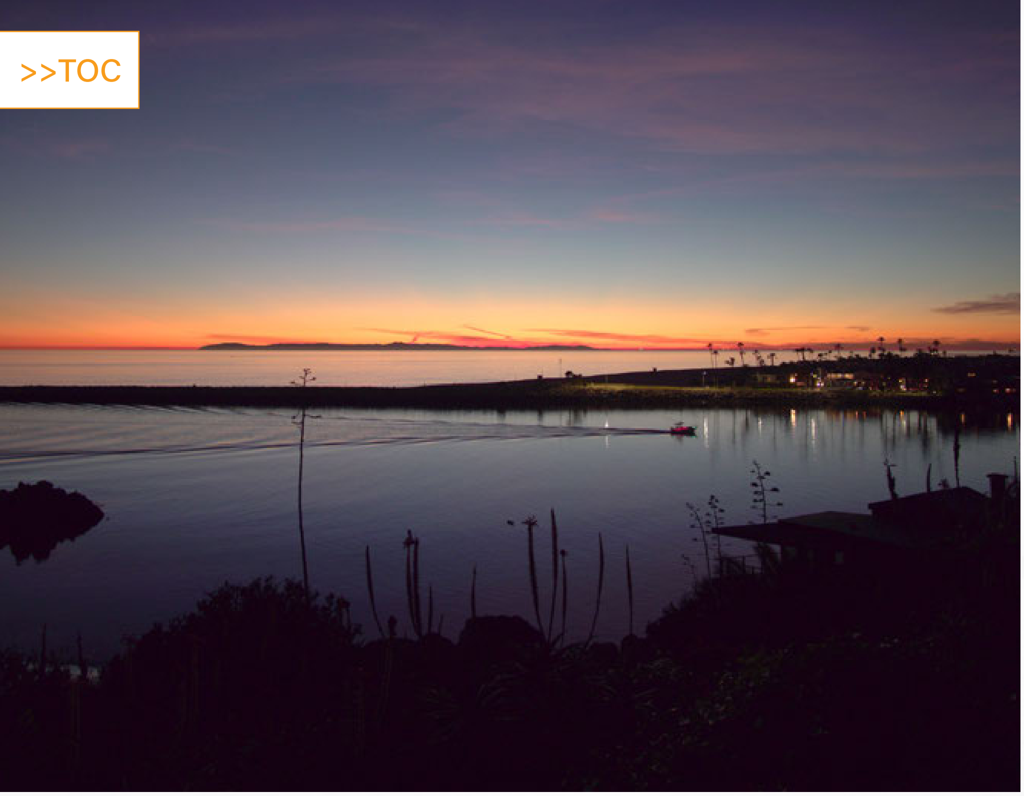

The same GCMs shown in Figure 2-1 for the Colorado River were also used for the Delta region and Orange County Basin. In the end, three climate change futures were selected for the 2023 OC Study, as shown in **Table 2-1**, to model impacts on water supplies and demands. The hot/wet climate future was omitted as the water supply modeling results were very similar to the warm/dry future.

Table 2-1. Selected Climate Futures for 2023 OC Study

2023 OC Study Climate Futures	Change in Temperature (°C) by 2050	Change in Precipitation (%) by 2050
Warm/Wet	1.0 – 1.8 increase	10 – 12% increase
Warm/Dry	1.2 – 1.8 increase	5 – 9% decrease
Hot/Dry	2.0 – 3.1 increase	5 – 8% decrease

The lower range in temperature increase shown in Table 2-1 for the climate futures represented Northern California, while the higher range represented the Colorado River Basin. The more optimistic changes in preciptation for the climate futures represented Northern California, while the less optimistic changes represented the Colorado River Basin.

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Water Demands

MET's 2020 IRP included low and high retail water demand forecasts, based on a range of demographic projections. For the 2023 OC Study, a mid-range of the low and high retail water demand forecasts was used for both the MET region and Orange County. Uncertainties around these mid-range water demand forecasts included climate change impacts and future water use efficiency levels. Climate change impacts on retail-level water demands were estimated statistically based on historical variability of water use, historical precipitation and historical temperature. Factors such as the economy, development density, and levels of historical water conservation were also accounted for in this statistical analysis, ensuring that weather impacts were isolated. This analysis indicated that future climate could increase retail water demands in 2050 between 5 and 7 percent, above normal historical weather conditions.

Two levels of future water use efficiency were tested, baseline and increased levels. Baseline efficiency assumed continuation of current targets for indoor residential water use, plus assumed increases in outdoor water use efficiency and commercial/institutional/industrial efficiency. Assumptions for increased levels of water use efficiency included reduced indoor residential per capita water use to 42 gallons per person per day, and additional reductions to outdoor water use. Based on proposed California DWR water use targets to achieve the 2018 California legislation goals on making "Water Conservation a Way of Life", the projected water savings from the baseline water use efficiency used in the 2023 OC Study are just shy of these targets, while the water savings projections in this analysis from the increased efficiency levels will likely exceed the DWR proposed targets. The estimated additional water savings from the increased efficiency levels assumed for the 2023 OC Study are 211,000 AFY for the MET region and 40,000 AFY for Orange County.

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Orange County Groundwater Replenishment System. Courtesy of CDM Smith

Baker Water Treatment Plant. Courtesy of IRWD

Yorba Linda Water District PFAS Treatment Plant. Courtesy of YLWD

Orange County Groundwater Basin

The Orange County Groundwater Basin is managed by the Orange County Water District (OCWD) and operated based on an annual calculation of accumulated overdraft (AOD). OCWD sets its Basin Production Percentage (BPP[4]) for water providers operating wells in the OC Groundwater Basin (i.e., basin pumpers) to drive the AOD to a desired volume each year. Generally, a long-term target for the basin is not to allow the AOD to be greater than 500,000 acre-feet (AF). OCWD policy calls for consideration to lower the BPP once the AOD exceeds 400,000 AF. Since 1980, the annual AOD has been greater than 400,000 AF two times (5 percent of the time). In the last few years, the AOD has been between 200,000 to 250,000 AF. Due to the wet winter experienced in FY 2022-23, OCWD expects the June 30, 2023, AOD to decline to approximately 185,000 AF.

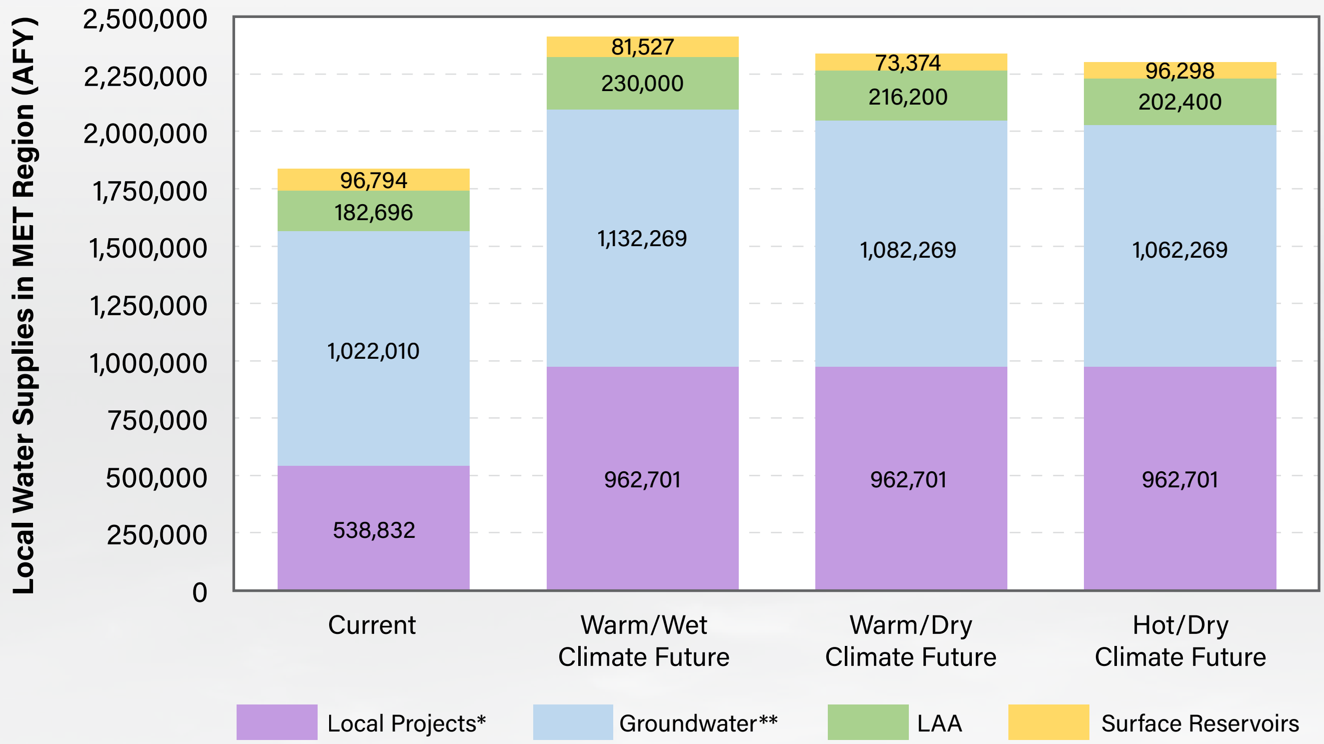
OCWD recently increased the BPP from 82 to 85 percent in FY2022-23 and has maintained it at the same level for FY2023-24. OCWD has also projected the BPP to remain at 85 percent for the next five years. Maintaining this BPP in the future is contingent on projected stormflows in the Santa Ana River, incidental recharge overlaying the basin from rainfall, and baseflows of upstream diverted wastewater in the Santa Ana River. Given the uncertainties in these inflows to the basin, the 2023 OC Study assumed long-term BPP target of 82 percent. Stormflows and incidental recharge were estimated by CDM Smith for each climate future, based on statistical analysis of historical conditions. For the 2023 OC Study, two levels of Santa Ana River baseflows were assumed: (1) the first level reduces current baseflows, estimated to be around 70,000 AFY, to approximately 52,000 AFY by 2040; and (2) the second level reduces current baseflows to 36,000 AFY, reflecting greater upstream water recycling. The recharge of the basin from the Orange County Groundwater Replenishment System is assumed to be constant at 130,000 AFY. When basin recharge capacity and MET water is available, recharge of imported water is modeled to occur. Based on all projections of inflows and basin AOD targets, it is projected that the BPP of 82 percent can be maintained 61 to 77 percent of the time in 2030, and 33 to 73 percent of the time in 2050.

[4] The allowable percentage of a water provider's demands that can be pumped from the basin in any one year.

Increases in Local Water Supplies for MET Region

The projections of local water supplies for the MET region were based on MET's projections of local groundwater, Los Angeles Aqueduct supplies, surface water supplies, recycled water and groundwater recovery used for its 2020 IRP Regional Needs Assessment. The largest assumed increase under these projections is from assumed increases in local water reuse of about 420,000 AFY. Based on CDM Smith's climate modeling of groundwater, surface water, and Los Angeles Aqueducts, MET's projections of these sources were altered to reflect the climate scenarios used for the 2023 OC Study. Regarding MET's projections of new seawater desalination, the supply yield anticipated from the Huntington Beach project was removed as it was not approved by the California Coastal Commission; and the yield for the Doheny project for South Coast Water District was removed as the purpose of the 2023 OC Study is meant to first estimate reliability without new Orange County water supply projects. **Figure 2-2** presents the range of local water supplies in the MET region used for the 2023 OC Study.

Figure 2-2. Local Water Supplies in MET Region used for 2023 OC Study



* Recycled water, groundwater recovery and Carlsbad seawater desalination, based on MET IRP Scenarios.
** Net of replenishment by MET.

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Success of MET Water Supply Programs

For the 2023 OC Study it was assumed that MET would implement its Pure Water Southern California program for all of the scenarios, but with two different supply yields (102,000 AFY for solely groundwater replenishment, and 168,000 AFY for groundwater replenishment and direct potable reuse). In addition, a new water transfer program for the CRA of 100,000 AFY was assumed for all scenarios, based on conversations with MET staff. For scenarios that included the Delta Conveyance Project, it was also assumed that MET would invest in new surface water storage of 250,000 AF based on conversations with MET staff. This new storage to maximize the benefits of the DCP could represent a new reservoir (likely in MET's SWP-exclusive area of Ventura County) or MET's participation in the proposed Sites Reservoir Project north of the Delta.

Success of Delta Conveyance Project

For the 2023 OC Study, some scenarios had the Delta Conveyance Project being implemented by 2040, while other scenarios did not have the project implemented within the planning horizon of this study. This allowed the value of this project to MET and Orange County to be determined.

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2.2 Planning Scenarios

Based on the uncertainties discussed in Section 2.1, five scenarios were developed for the 2023 OC Study. These scenarios were assembled to be internally consistent—meaning that for stressed conditions, it was assumed that MET and its member agencies would respond by taking additional actions. Therefore, it is the belief of the OC Study team that all of these scenarios are plausible, but none of them represent a "Black Swan" event. Black Swan events represent rare, worst-case conditions across the board—meaning highest levels of projected water demands coupled with extreme climate change impacts, and no or few new projects being implemented.

The planning scenarios for the 2023 OC Study are summarized as:

SCENARIO 1. Low Stress without Delta Conveyance

Warm/wet climate future, lower-level retail water demands, increased local water supplies in the MET region, moderate amounts of new MET water supplies, but without implementation of California's Delta Conveyance Project.

SCENARIO 2. Moderate Stress without Delta Conveyance

Warm/dry climate future, medium-level retail water demands, increased local water supplies in the MET region, moderate amounts of new MET water supplies, but without implementation of California's Delta Conveyance Project.

SCENARIO 3. Moderate Stress with Delta Conveyance

Warm/dry climate future, medium-level retail water demands, increased local water supplies in the MET region, moderate amounts of new MET water supplies, and implementation of California's Delta Conveyance Project.

SCENARIO 4. Significant Stress without Delta Conveyance

Hot/dry climate future, higher-level retail water demands (but offset with increased water use efficiency), increased local water supplies in the MET region, higher amounts of new MET water supplies, but without implementation of California's Delta Conveyance Project.

SCENARIO 5. Significant Stress with Delta Conveyance

Hot/dry climate future, higher-level retail water demands (but offset with increased water use efficiency), increased local water supplies in the MET region, higher amounts of new MET water supplies, and implementation of California's Delta Conveyance Project.

The five scenarios are presented in more detail in Table 2-2 on the following page.

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Table 2-2. Planning Scenarios for the 2023 OC Study

	Uncertainties						
Scenario Name	**Climate Change Future**	**Water Demands**	**Water Use Efficiency Levels**	**OC Basin Groundwater Assumptions**	**Increased Local Water Supplies in MET Region**	**Assumed New MET Water Supply Programs/ Projects**	**Delta Conveyance Project**
1. Low Stress without Delta Conveyance	Warm/Wet	Lower Levels	Baseline	▪ BPP of 82% achieved 77% of time in 2030 ▪ Med SAR baseflows	▪ 110 TAF GW ▪ 420 TAF Reuse	▪ 102 TAF Pure Water SoCal (2030) ▪ 100 TAF CRA Transfers (2030)	Not Implemented
2. Moderate Stress without Delta Conveyance	Warm/Dry	Medium Levels	Baseline	▪ BPP of 82% achieved 74% of time in 2030 ▪ Med SAR baseflows	▪ 60 TAF GW ▪ 420 TAF Reuse	▪ 102 TAF Pure Water SoCal (2030) ▪ 100 TAF CRA Transfers (2030)	Not Implemented
3. Moderate Stress with Delta Conveyance	Warm/Dry	Medium Levels	Baseline	▪ BPP of 82% achieved 74% of time in 2030 ▪ Med SAR baseflows	▪ 60 TAF GW ▪ 420 TAF Reuse	▪ 102 TAF Pure Water SoCal (2030) ▪ 100 TAF CRA Transfers (2030) ▪ 250 TAF Storage (2035)	Implemented (2040)
4. Significant Stress without Delta Conveyance	Hot/Dry	Higher Levels	Increased: ▪ 211 TAF MET ▪ 40 TAF OC	▪ BPP of 82% achieved 61% of time in 2030 ▪ Low SAR baseflows	▪ 40 TAF GW ▪ 420 TAF Reuse	▪ 168 TAF Pure Water SoCal (2035) ▪ 100 TAF CRA Transfers (2030)	Not Implemented
5. Significant Stress with Delta Conveyance	Hot/Dry	Higher Levels	Increased: ▪ 211 TAF MET ▪ 40 TAF OC	▪ BPP of 82% achieved 61% of time in 2030 ▪ Low SAR baseflows	▪ 40 TAF GW ▪ 420 TAF Reuse	▪ 168 TAF Pure Water SoCal (2035) ▪ 100 TAF CRA Transfers (2030) ▪ 250 TAF Storage (2035)	Implemented (2040)

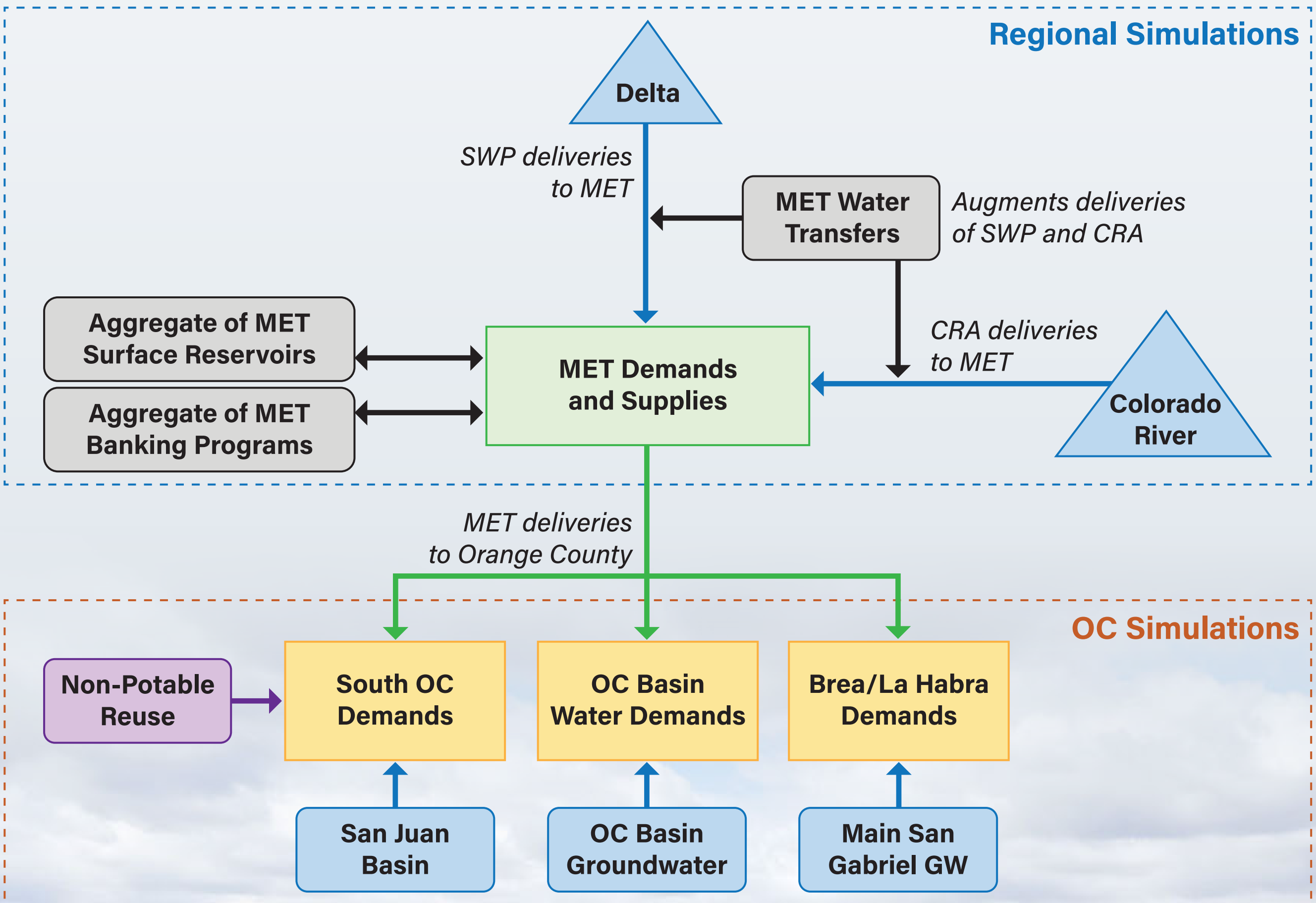
Notes: MET = Metropolitan Water District of Southern California, TAF = Thousand Acre-Feet, BPP = OCWD Basin Pumping Percentage, SAR = Santa Ana River, GW = Groundwater, CRA = Colorado River Aqueduct, Numbers in ( ) indicate online operations

Section 3: Water Supply Modeling

3.1 Orange County Water Supply Systems Model

To estimate water supply reliability at the MET regional and Orange County levels under a wide range of planning scenarios, CDM Smith developed the OC Water Supply Simulation Tool (OCSIM) using the systems model WEAP (Water Evaluation And Planning). WEAP is maintained by the Stockholm Environment Institute[5] and used by water agencies around the world. **Figure 3-1** presents the modeling schematic for OCSIM used for the 2023 OC Study.

Figure 3-1. CDM Smith's OCSIM Model Schematic



[5] http://weap21.org

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First, OCSIM performs regional simulations of MET's water demands (representing MET retail demands minus local supplies in the region), MET's imported water sources (SWP and CRA), MET's water transfers, and MET's storage and banking programs. Using indexed-sequential simulation, historical traces of hydrologic patterns of imported water supply from 1965-2022 are mapped onto projected water demands through the year 2050. The 2023 OC Study used a truncated historical hydrology pattern to account for observed climate change that has already occurred, as discussed in **Section 1.2** of this report. Mass-balance equations are then used to simulate storage and banking operations under surplus and dry year conditions. Reduced inflows into the SWP and Colorado River systems for different climate change futures are based on hydrologic watershed evaluations conducted by Dr. David Yates under contract to CDM Smith[6]. These hydrologic models account for changes in temperature, precipitation, snowpack, and monthly patterns that alter naturalized flows of major river systems in Northern California and Colorado River Basin. The results of these climate change impacts are then used to adjust the historical hydrologic periods for SWP and CRA deliveries to MET using the BOR hybrid-delta method. The OCSIM mimics many of the simulations found in MET's water supply planning tool IRPSIM. The OCSIM also utilizes direct outputs from DWR's CALSIM and BOR's CRSS modeling for calibration. The output from this regional simulation is the probability and size of potential MET water shortages.

Second, OCSIM performs water demand and supply simulations for three study areas of Orange County (Orange County Basin, South Orange County, Brea/La Habra). When regional water shortages occur, MET's water shortage allocation formulas from MET's Water Supply Allocation Plan (WSAP) are used to determine cutbacks in deliveries to Orange County. Local water supplies, which impact MET's water shortage allocations, are also simulated (see **Section 3.3** for discussion on Orange County groundwater simulations). The output from this second round of simulations is the estimated probability and size of water shortages for Orange County through the year 2050. Initially, no mandatory water demand restrictions are assumed for these potential water shortages.

[6] Dr. Yates utilized a Southwestern WEAP model to estimate inflow changes to the SWP and Colorado River systems based on 16 GCMs that represent bookends of potential climate futures.

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3.2 Water Demand Forecast

MET Regional Demand Forecast

To estimate MET's future water demands for the 2023 OC Study, data from the MET 2020 IRP were utilized. While MET used a low and a high projection of retail water demands for its scenarios, the 2023 OC Study used an average of these two MET projections for all of its scenarios. Using CDM Smith's previous statistical analyses of water demand and weather variables, projected average-year retail water demands were adjusted to account for future climate change. Projections of recycled water and groundwater recovery in the MET region were based on MET's 2020 IRP. As noted in **Section 2.1** of this report, the 2023 OC Study did not use MET's projected increases in seawater desalination. MET's projection of local groundwater, surface water supplies, and Los Angeles Aqueduct supplies were also adjusted for future climate change based on CDM Smith's statistical models of water supply and weather variables.

Average-year MET water demands under warm/wet future climate are summarized in **Table 3-1**, while **Table 3-2** and **Table 3-3** summarize MET demands under warm/dry and hot/dry climate, respectively. Note that for 2023 OC Study Scenarios 4 and 5, MET demands under hot/dry climate were reduced to account for additional water use efficiency, which is also shown in **Table 3-3**. For supply reliability simulation, average-year water demands are adjusted in the OCSIM for year-to-year variability matched to hydrologic conditions from 1965-2022. In a dry hydrologic year, MET water demands can be as much as 15 percent greater than an average-year demand; while in a wet hydrologic year, MET demands can be as much as 15 percent lower than an average-year demand. This high variability is due to MET being a supplemental supply for some MET member agencies, as well as the extreme hydrologic variability throughout Southern California, and accounts for variability in both retail water demands and local water supplies.

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Table 3-1. Average-Year MET Water Demands Forecasts under Warm/Wet Climate Future (AFY)

MET Region Water Demands (AFY)	2020*	2025	2030	2035	2040	2045	2050
Retail M&I Demands	2,974,558	3,075,000	3,173,000	3,276,250	3,379,500	3,482,750	3,586,000
Retail Agricultural Demands	143,905	144,377	134,418	130,494	122,986	123,301	123,300
Regional Seawater Barrier Needs	62,780	68,517	70,253	71,990	72,000	72,000	72,000
Regional Replenishment Needs	197,620	331,534	363,327	383,043	395,555	400,863	400,863
Total Regional Demand	**3,378,863**	**3,619,429**	**3,740,998**	**3,861,778**	**3,970,041**	**4,078,914**	**4,182,163**
MET Region Local Water Supplies (AFY)	**2020***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Groundwater Production	1,101,757	1,235,671	1,267,465	1,287,180	1,299,692	1,305,000	1,305,000
Surface Production	96,794	81,527	81,527	81,527	81,527	81,527	81,527
Los Angeles Aqueduct	182,696	190,000	190,000	215,000	230,000	230,000	230,000
Seawater Desalination	50,500	50,500	50,500	50,500	50,500	50,500	50,500
Groundwater Recovery	114,707	152,788	185,680	205,770	215,233	222,295	222,295
Recycled Water	373,625	489,093	570,666	622,433	678,447	689,906	689,906
Total Local Supplies	**1,920,079**	**2,199,579**	**2,345,837**	**2,462,410**	**2,555,399**	**2,579,228**	**2,579,228**
Water Demands on MET (AFY)	**2020***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Consumptive Use	1,379,037	1,270,851	1,243,254	1,235,245	1,246,927	1,326,956	1,430,204
Seawater Barrier	21,444	10,489	5,915	5,590	5,334	5,077	5,077
Replenishment	58,303	138,509	145,992	158,532	162,381	167,654	167,654
Total Demands on MET	**1,458,784**	**1,419,849**	**1,395,161**	**1,399,367**	**1,414,642**	**1,499,687**	**1,602,935**

*Actual values

Table 3-2. Average-Year MET Water Demands Forecasts under Warm/Dry Climate Future (AFY)

MET Region Water Demands (AFY)	2020*	2025	2030	2035	2040	2045	2050
Retail M&I Demands	2,974,558	3,075,000	3,204,730	3,341,775	3,480,885	3,622,060	3,765,300
Retail Agricultural Demands	143,905	144,377	134,418	130,494	122,986	123,301	123,300
Regional Seawater Barrier Needs	62,780	68,517	70,253	71,990	72,000	72,000	72,000
Regional Replenishment Needs	197,620	205,954	218,333	226,667	236,000	244,333	247,620
Total Regional Demand	**3,378,863**	**3,493,848**	**3,627,734**	**3,770,926**	**3,911,871**	**4,061,695**	**4,208,220**

MET Region Local Water Supplies (AFY)	2020*	2025	2030	2035	2040	2045	2050
Groundwater Production	1,101,757	1,101,757	1,101,757	1,101,757	1,101,757	1,101,757	1,101,757
Surface Production	96,794	81,527	79,896	78,266	76,635	75,005	73,374
Los Angeles Aqueduct	182,696	182,000	188,840	195,680	202,520	209,360	216,200
Seawater Desalination	50,500	50,500	50,500	50,500	50,500	50,500	50,500
Groundwater Recovery	114,707	152,788	185,680	205,770	215,233	222,295	222,295
Recycled Water	373,625	489,093	570,666	622,433	678,447	689,906	689,906
Total Local Supplies	**1,920,079**	**2,057,665**	**2,177,340**	**2,254,406**	**2,325,093**	**2,348,823**	**2,354,033**

Water Demands on MET (AFY)	2020*	2025	2030	2035	2040	2045	2050
Consumptive Use	1,379,037	1,412,765	1,443,481	1,508,774	1,578,619	1,696,670	1,834,699
Seawater Barrier	21,444	10,489	5,915	5,590	5,334	5,077	5,077
Replenishment	58,303	12,929	998	2,156	2,826	11,124	14,411
Total Demands on MET	**1,458,784**	**1,436,183**	**1,450,395**	**1,516,520**	**1,586,779**	**1,712,872**	**1,854,188**

*Actual values

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Table 3-3. Average-Year MET Water Demands Forecasts under Hot/Dry Climate Future (AFY)

MET Region Water Demands (AFY)	2020*	2025	2030	2035	2040	2045	2050
Retail M&I Demands	2,974,558	3,075,000	3,217,422	3,367,985	3,521,439	3,677,784	3,837,020
Retail Agricultural Demands	143,905	144,377	134,418	130,494	122,986	123,301	123,300
Regional Seawater Barrier Needs	62,780	68,517	70,253	71,990	72,000	72,000	72,000
Regional Replenishment Needs	197,620	212,620	227,620	242,620	257,620	272,620	287,620
Total Regional Demand	**3,378,863**	**3,500,515**	**3,649,713**	**3,813,090**	**3,974,046**	**4,145,706**	**4,319,940**
MET Region Local Water Supplies (AFY)	**2020***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Groundwater Production	1,101,757	1,101,757	1,101,757	1,101,757	1,101,757	1,101,757	1,101,757
Surface Production	96,794	81,527	79,081	76,635	74,189	71,744	69,298
Los Angeles Aqueduct	182,696	182,000	186,080	190,160	194,240	198,320	202,400
Seawater Desalination	50,500	50,500	50,500	50,500	50,500	50,500	50,500
Groundwater Recovery	114,707	152,788	185,680	200,066	200,066	200,066	200,066
Recycled Water	373,625	489,093	570,666	622,433	678,447	689,906	689,906
Total Local Supplies	**1,920,079**	**2,057,665**	**2,173,764**	**2,241,551**	**2,299,199**	**2,312,293**	**2,313,927**
Water Demands on MET (AFY)	**2020***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Consumptive Use	1,379,037	1,412,765	1,459,749	1,547,839	1,645,066	1,788,925	1,946,525
Seawater Barrier	21,444	10,489	5,915	5,590	5,334	5,077	5,077
Replenishment	58,303	19,595	10,285	18,109	24,446	39,411	54,411
Total Demands on MET	**1,458,784**	**1,442,849**	**1,475,949**	**1,571,539**	**1,674,846**	**1,833,413**	**2,006,014**
With Additional Water Use Efficiency	–	(28,857)	(90,320)	(117,776)	(147,148)	(178,489)	(211,851)
Net Demands on MET	**1,458,784**	**1,413,992**	**1,385,629**	**1,453,763**	**1,527,698**	**1,654,924**	**1,794,163**

*Actual values

Orange County Water Demand Forecast

For MWDOC's 2020 Urban Water Management Plan, CDM Smith prepared water demand forecasts for each of the 2023 OC Study areas. **Table 3-4** presents the average year Orange County demand forecast for the three climate change futures. Note that for 2023 OC Study Scenarios 4 and 5, total Orange County demands under hot/dry climate were reduced to account for additional water use efficiency, which is also shown in **Table 3-4**. For supply reliability simulation, average year water demands are adjusted in the OCSIM for year-to-year variability matched to hydrologic conditions from 1965-2022.

Table 3-4. Average-Year Orange County Demand Forecasts for Analyzed Climate Futures (AFY)

Water Demands with Warm/Wet Climate Future (AFY)	2022	2030	2040	2050
South Orange County	124,754	128,774	132,551	135,000
Orange County Basin	389,722	407,882	421,563	423,565
Brea/La Habra	18,508	18,953	19,504	19,531
Total Orange County	**535,006**	**557,639**	**575,658**	**580,146**
Water Demands with Warm/Dry Climate Future (AFY)	**2022**	**2030**	**2040**	**2050**
South Orange County	124,754	130,614	136,812	139,048
Orange County Basin	389,722	412,543	432,403	440,507
Brea/La Habra	18,508	19,224	20,131	20,508
Total Orange County	**535,006**	**564,411**	**591,386**	**602,113**
Water Demands with Hot/Dry Climate Future (AFY)	**2022**	**2030**	**2040**	**2050**
South Orange County	124,754	131,350	138,516	141,697
Orange County Basin	389,722	414,874	437,823	448,979
Brea/La Habra	18,508	19,332	20,382	20,898
Total Orange County	**535,006**	**567,586**	**598,761**	**613,623**
With Additional Water Use Efficiency	-	(22,703)	(35,926)	(39,886)
Net Total Orange County Demands	**535,006**	**544,882**	**562,835**	**573,738**

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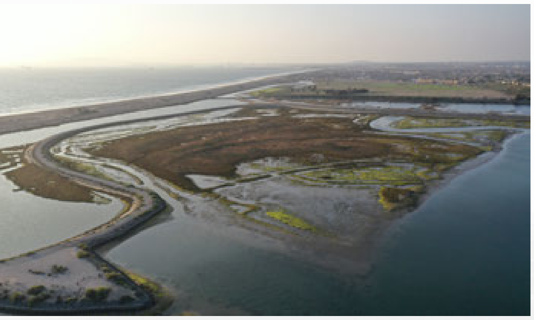


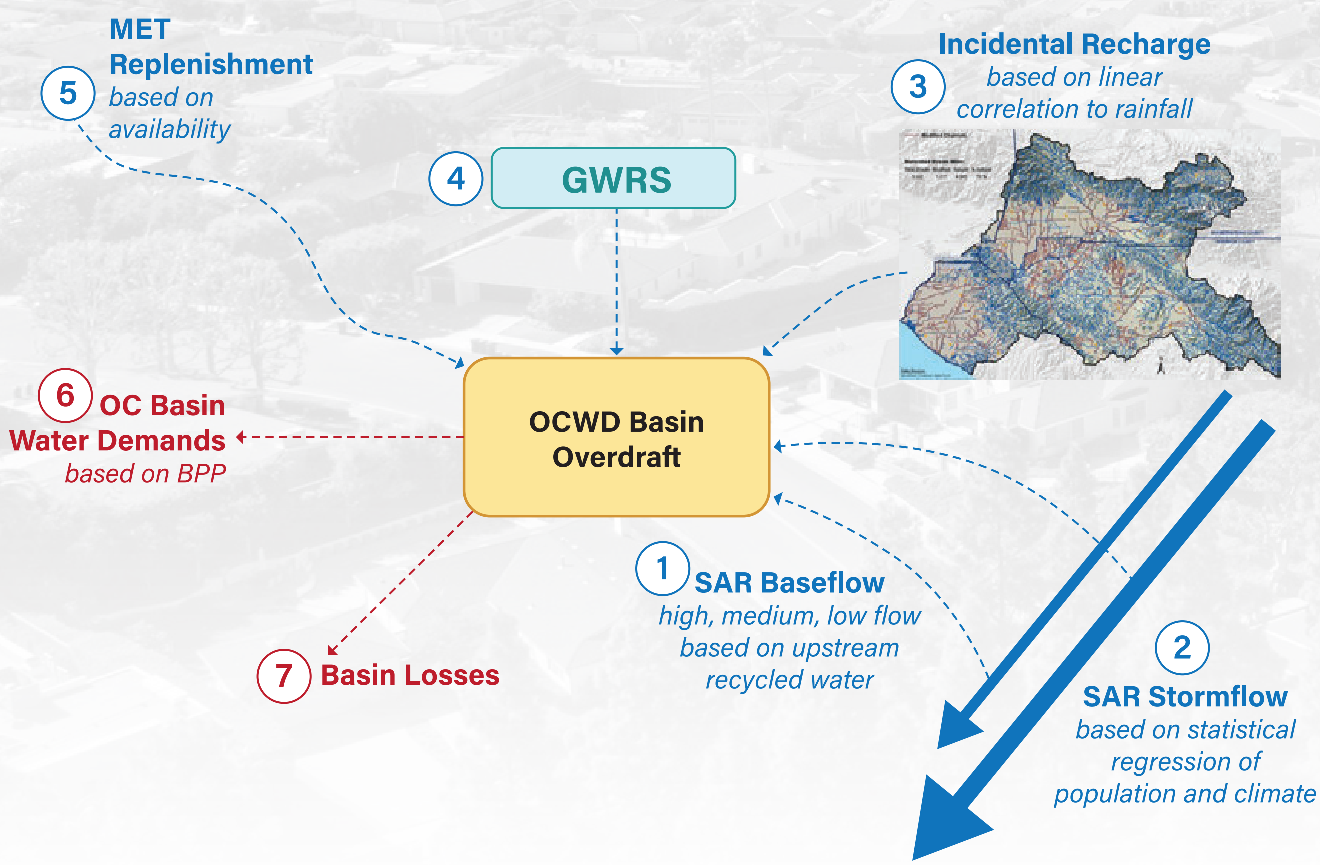
Rattlesnake Reservoir. Courtesy of IRWD

3.3 Orange County Groundwater Assumptions

Orange County Basin

For the Orange County Basin, CDM Smith developed a simple mass-balance model to estimate basin AOD, which is illustrated in **Figure 3-2**.

Figure 3-2. CDM Smith's Mass-Balance Model Schematic of the Orange County Basin



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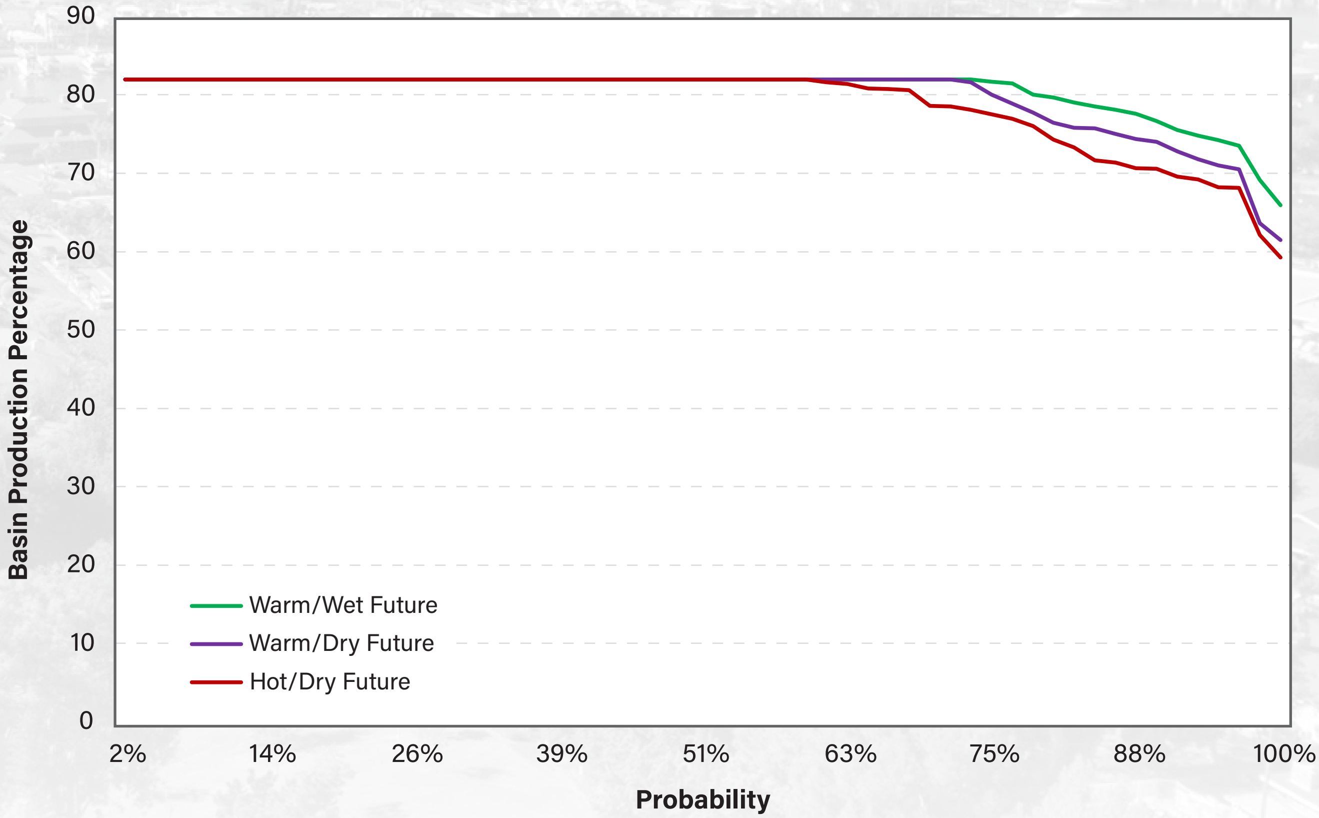
For each hydrologic year from 1965-2022, the mass-balance estimates of Santa Ana River (SAR) stormflows and incidental recharge into the basin are based on statistical regression formulas. Future precipitation for the warm/wet, warm/dry and hot/dry climate futures were estimated by CDM Smith and input into the statistical regression to alter stormflows and incidental recharge. SAR baseflows are assumed to ramp down from the current average of 70,000 AFY to 53,000 AFY in 2040 for Scenarios 1-3, and ramp down to 36,000 AFY for Scenarios 4-5. The lower baseflows assume more upstream water recycling in San Bernardino and Riverside Counties. A constant flow into the basin from the Groundwater Replenishment System of 130,000 AFY is also assumed. When spreading capacity in the basin and MET water supply is available, replenishment of imported water is assumed up to approximately 50,000 AFY. Water pumping from the basin to meet water demands is initially set at a BPP of 82 percent[7]. The AOD is tracked annually, and if it is greater than 450,000 AF for multiple years in a row, the BPP is reduced, and more imported water is required to meet water demands. If imported water is not fully available to meet the demands, water shortages to basin pumpers occurs. The simulated BPP under different climate change futures is shown in **Figure 3-3** for the year 2030.

Figure 3-3. Simulated Orange County Basin BPP Under Different Climate Change Futures in Year 2030



[7] While the current weighted average BPP for FY 2022-23 is 85 percent (meaning water providers in the basin can pump groundwater equal to 85 percent of their water demands), the 2023 OC Study used a long-term BPP target of 82 percent to reflect uncertainty regarding climate change.

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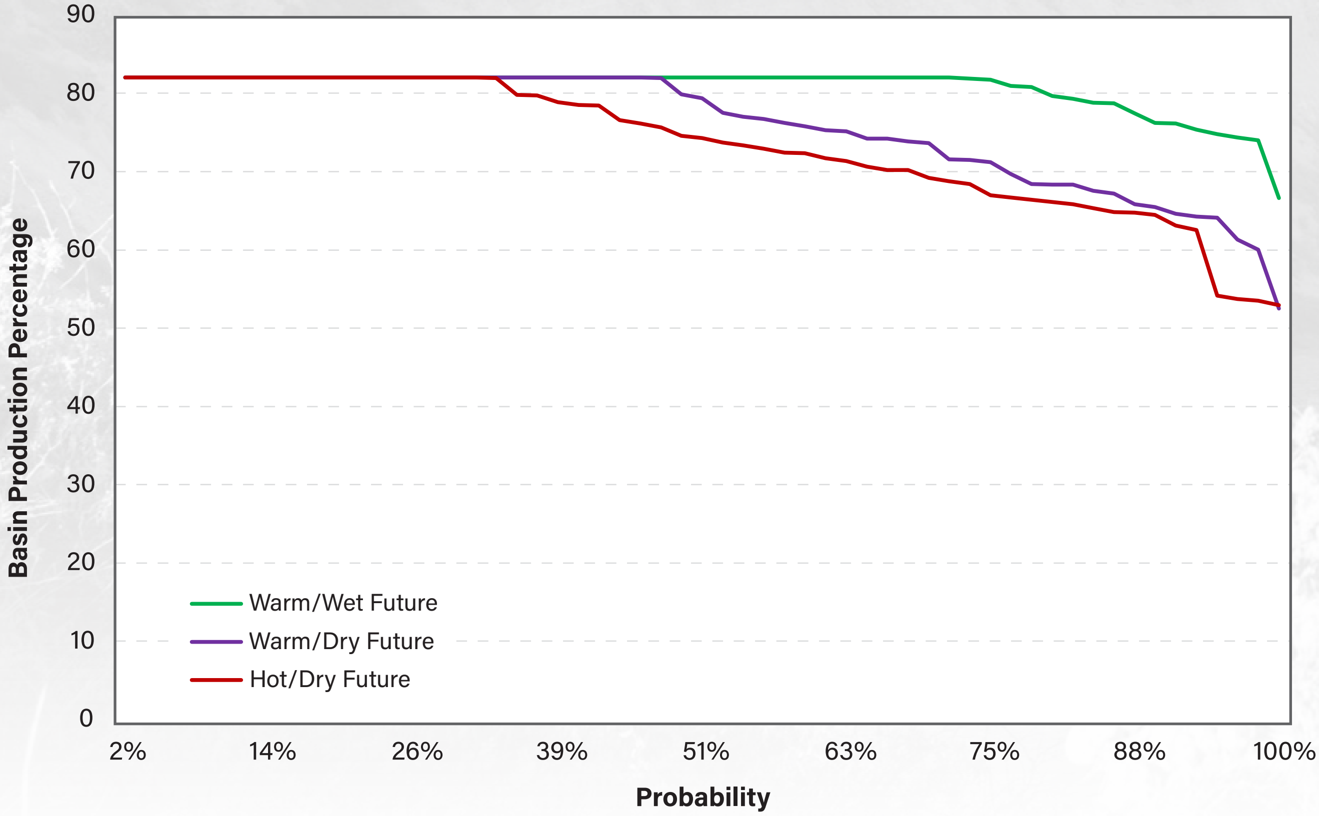
Based on the simulated hydrology of 1965-2022 and under the warm/wet future, the BPP target of 82 percent is achieved 77 percent of the time and never falls below 67 percent in the year 2030. Under the warm/dry future, the BPP target of 82 percent is achieved 74 percent of the time and never falls below 62 percent. Under the hot/dry future, the BPP target of 82 percent is achieved 61 percent of the time and never falls below 59 percent. The simulated BPP under different climate change futures is shown in **Figure 3-4** for the year 2050.

Based on the simulated hydrology of 1965-2022 and under the warm/wet future, the BPP target of 82 percent is achieved 75 percent of the time and never falls below 65 percent in the year 2050. Under the warm/dry future, the BPP target of 82 percent is achieved 48 percent of the time and never falls below 53 percent. Under the hot/dry future, the BPP target of 82 percent is achieved 33 percent of the time and never falls below 53 percent.

Figure 3-4. Simulated Orange County Basin BPP Under Different Climate Change Futures in Year 2050



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San Juan Basin

Within the South Orange County area, groundwater is pumped from the San Juan Basin[8]. A similar mass-balance of this basin was developed based on CDM Smith's statistical regression analysis of historical pumping, precipitation, creek evaporation, and outflows to the ocean. When storage in this basin falls below 36,000 AF only minimal groundwater pumping is allowed per the San Juan Basin Authority (SJBA) Adaptive Pumping Management (APM) Plan. **Table 3-5** presents the probability that full groundwater pumping can occur based on simulated San Juan Basin storage conditions for the three climate change futures.

Table 3-5. Probability of Full Groundwater Pumping in San Juan Basin

Climate Future	Probability of Full Groundwater Pumping in 2030	Probability of Full Groundwater Pumping in 2050
Warm/Wet	82%	70%
Warm/Dry	80%	55%
Hot/Dry	79%	41%

3.4 Imported Water Modeling

For the 2023 OC Study, extensive modeling of MET's imported water availability was conducted for baseline conditions using CALSIM output results from DWR's 2019 Delivery Capability Report for the SWP, and CDM Smith's own runs of the BOR's CRRS model. For both the SWP and Colorado River systems, the historical hydrology period of 1965-2021 was used. CDM Smith chose to use a more truncated historical hydrology, but with the most recent drought period extended, as the BOR and climate change scientists believe using periods before 1965 are no longer representative of current or future conditions due to climate change that has already taken place. Baseline conditions for imported water were then altered for future climate change conditions. For greater details on CDM Smith's imported water modeling, refer to the 2018 OC Study.

[8] San Juan Basin is categorized as a subterranean flowing stream, with water extraction regulated by State Water Resources Control Board (SWRCB).

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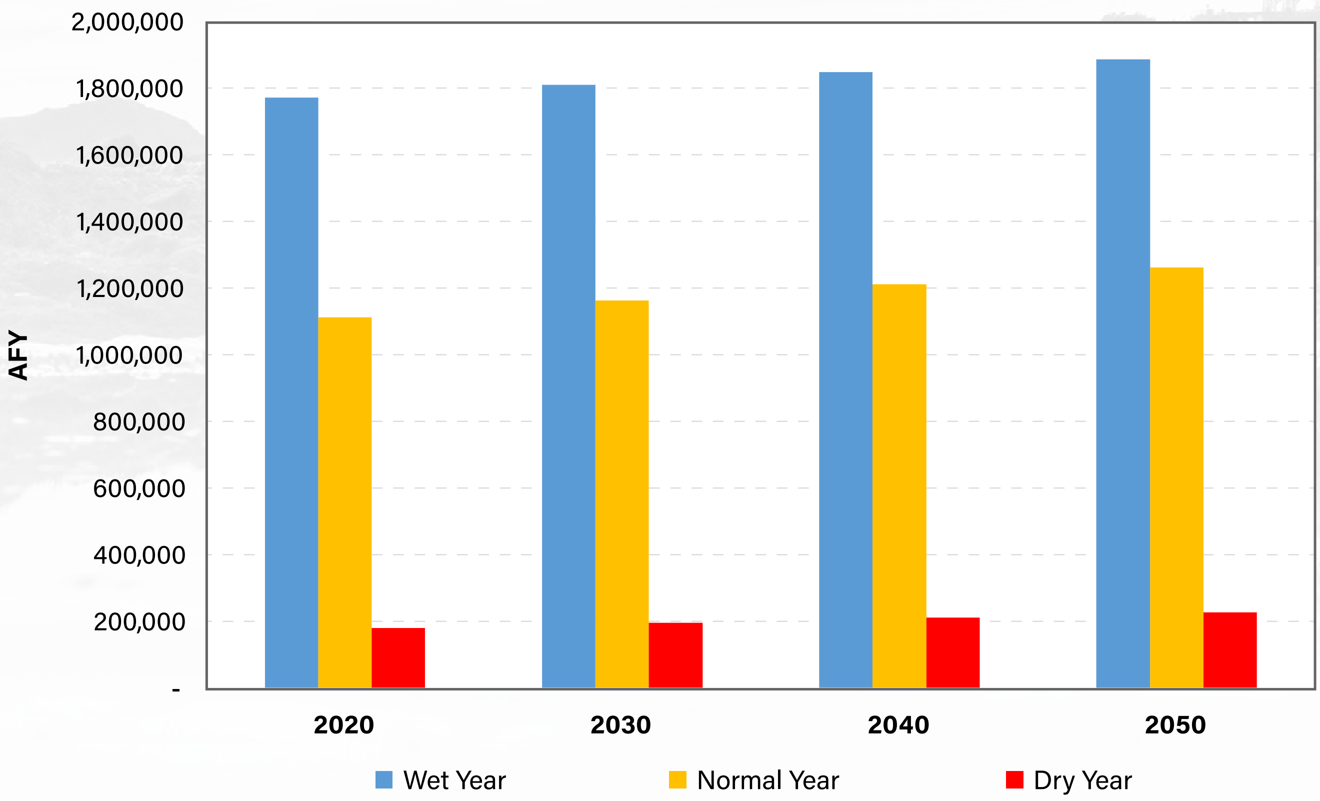
State Water Project Deliveries

Several types of SWP water are made available to SWP contractors under the long-term supply contracts between the SWP contractors and DWR. Among these supplies are Table A water and Article 21 water. Table A water is an allocated annual supply made available throughout the year, while Article 21 water is an interruptible water supply made available only when certain conditions exist (usually during normal years). MET's Table A contract is 1.91 MAF. CDM Smith estimated the changes from current conditions (as represented by the year 2020) for the SWP system based on future climate change (as discussed in **Section 2.1**) and simulated benefits of the DCP. **Figure 3-5** shows changes from current conditions for the warm/wet climate future for three representative hydrologic year types (wet, normal and dry), with wet years being the average of the highest 10th percentile, normal years being the 50th percentile, and dry years being the average of the lowest 10th percentile. Mid-century impacts for the GCMs that were ensembled for this climate future were used to estimate the year 2050 future conditions. It was assumed that climate change impacts between 2020 and 2050 would occur linearly.

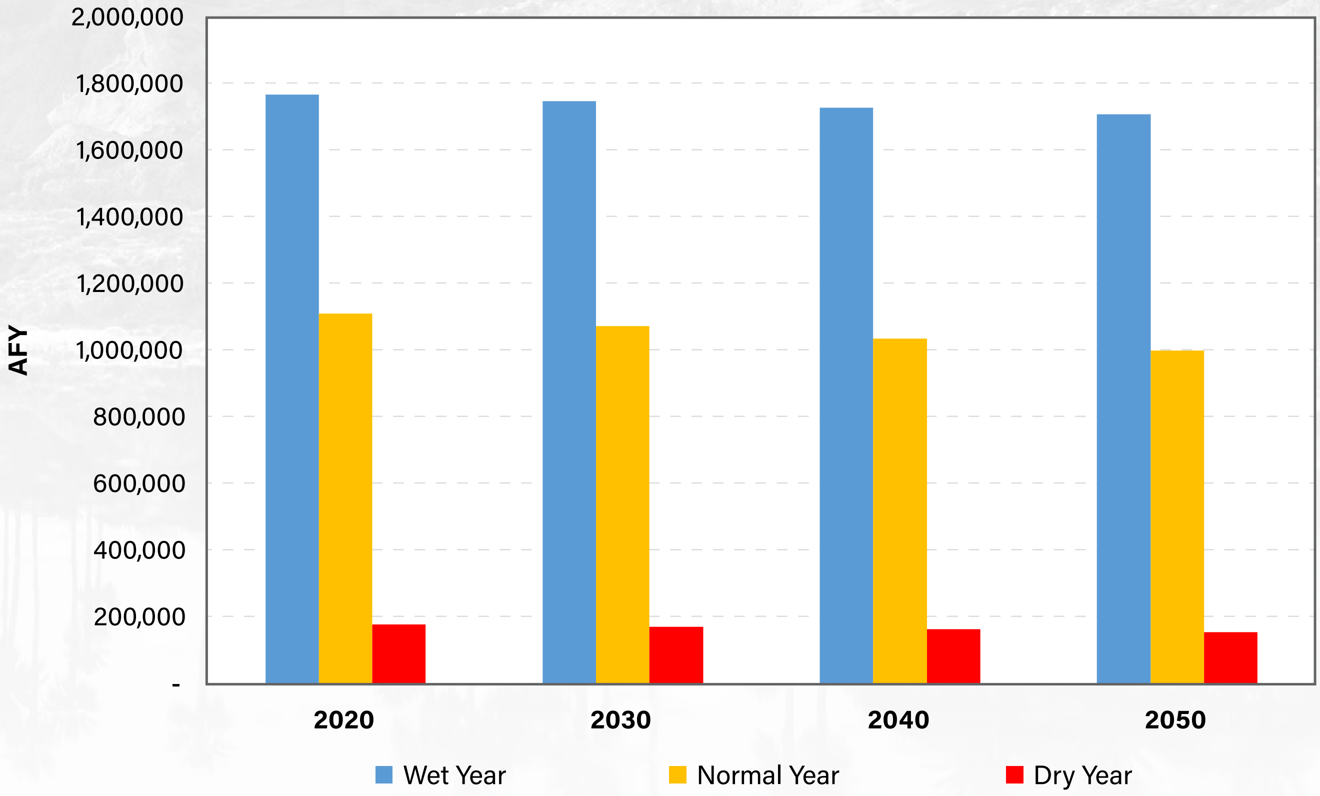
Figure 3-5. State Water Project Deliveries to MET for Warm/Wet Climate Future



Under the warm/wet climate future, there is a forecasted increase in SWP deliveries to MET, with normal year deliveries increasing from 1.11 MAF in 2020 to 1.26 MAF in 2050 (14 percent increase).

Figure 3-6 shows changes from current conditions for the warm/dry climate future for three representative hydrologic year types (wet, normal and dry).

Figure 3-6. State Water Project Forecast Deliveries to MET for Warm/Dry Climate Future



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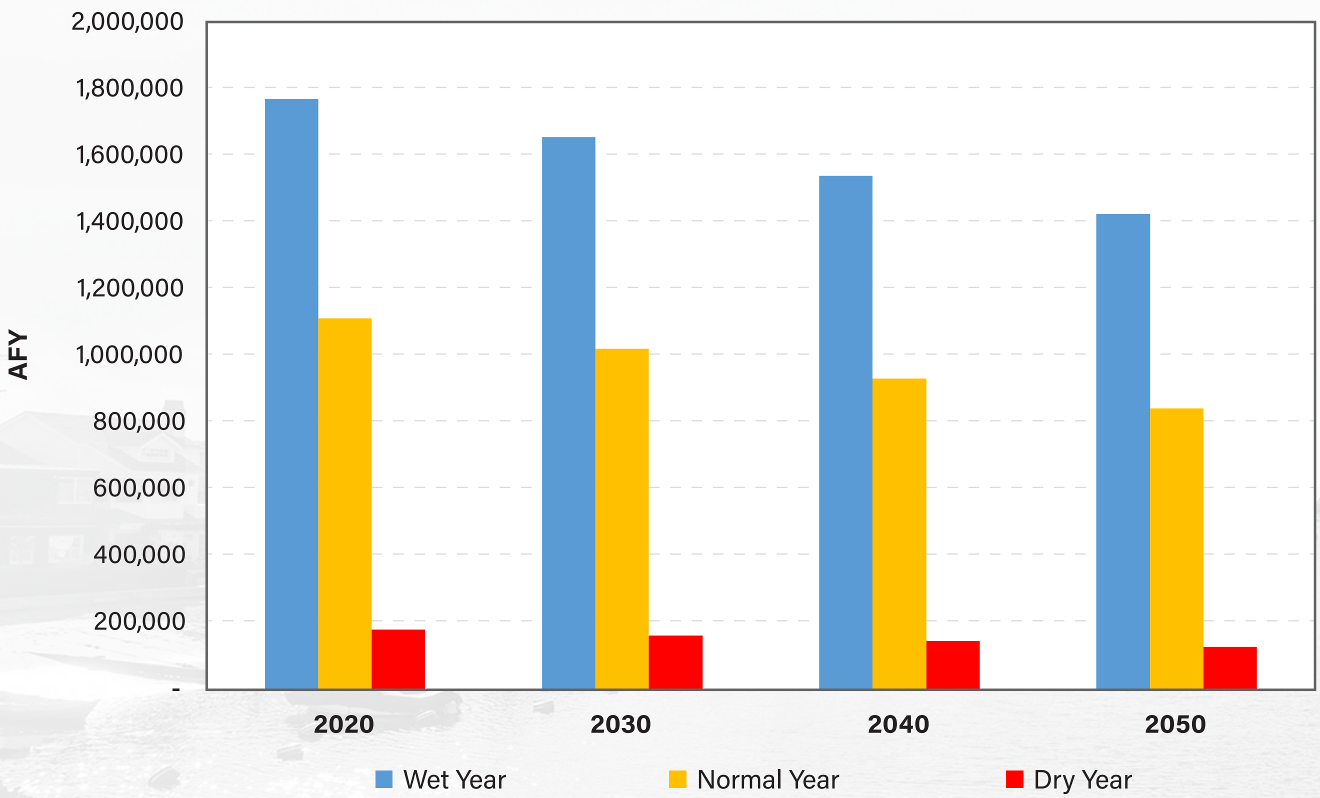
Under the warm/dry climate future, there is a forecasted decrease in SWP deliveries to MET, with normal year deliveries decreasing from 1.11 MAF in 2020 to 1.00 MAF in 2050 (10 percent decrease).

Figure 3-7 shows changes from current conditions for the hot/dry climate future for three representative hydrologic year types (wet, normal and dry).

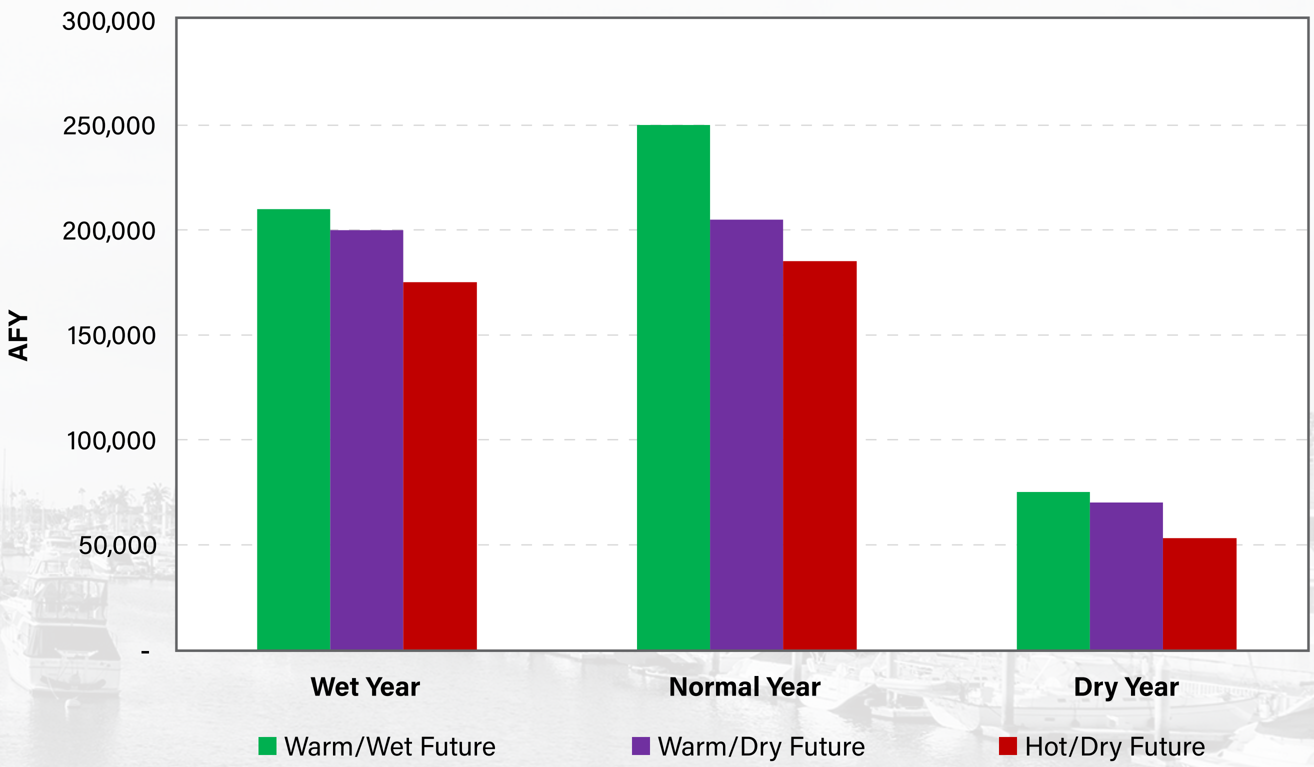
Figure 3-7. State Water Project Forecast Deliveries to MET for Hot/Dry Climate Future



Under the hot/dry climate future, there is a more significant forecasted decrease in SWP deliveries to MET, with normal year deliveries decreasing from 1.11 MAF in 2020 to 0.84 MAF in 2050 (24 percent decrease).

To estimate the additional benefits to SWP deliveries from the DCP for those scenarios that assume its implementation, the DWR's 2022 Draft EIR was utilized. The proposed project for that EIR is Alternative 5 -Bethany Reservoir Alignment with a conveyance capacity of 6,000 cubic feet per second. Incremental supply yields for SWP exports for Alternative 5 were aligned to several year types (e.g., wet, above-normal, below-normal, dry, critically dry). These year types were matched to CDM Smith's hydrology record of 1965-2021. It should be noted that under climate change futures, the number of year-types shift, changing the supply deliveries of the DCP. For example, under the warm/wet climate future there are more wet and above-normal year-types, while under the hot/dry climate future there are more dry and critically dry year-types. The forecast direct SWP deliveries from the DCP shown in **Figure 3-8** represent opportunities to capture high storm flow volumes during extreme precipitation events under different year-types and for the three different climate futures. However, the real value of the DCP to MET and Orange County is even greater when coupled with increases in storage for use in dry years, which will be discussed later in **Section 4**.

Figure 3-8. Forecast SWP Deliveries from the DCP based on Opportunities to Capture High Storm Flow Volumes



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Colorado River Aqueduct Deliveries

CDM Smith utilized the BOR's CRRS model to simulate CRA deliveries to MET under baseline conditions, with the year 2021 Lake Mead storage conditions used for the start of the simulation. The historical hydrology of 1965-2021 was used for estimating direct river contributions to the CRA. Metropolitan and its member agencies participate in transfers and exchanges that augment direct deliveries of the Colorado River into the CRA. Colorado River shortages for the Lower Basin States of Arizona, California and Nevada are currently governed by the BOR's Drought Contingency Plan, which superseded the 2007 Interim Guidelines. Allocations of California's share of shortages to MET are based on priorities established in the California 4.4 Plan and negotiations that took place between MET, Palos Verdes Irrigation District (PVID), Coachella Valley Water District and Imperial Irrigation District (IID) during the development of the Drought Contingency Plan. Lake Mead elevation is used to trigger shortage allocations, which is summarized in **Table 3-6**.

Table 3-6. Allocations of Shortages under BOR Drought Contingency Plan

Lake Mead Elevation (feet)	Colorado River Water Shortage Allocations (AFY)			
	Arizona	Nevada	California	MET
>1075 to 1090	192,000	8,000	0	0
>1050 to 1075	512,000	21,000	0	0
>1045 to 1050	592,000	25,000	0	0
>1040 to 1045	640,000	27,000	200,000	170,000
>1035 to 1040	640,000	27,000	250,000	212,500
>1030 to 1035	640,000	27,000	300,000	255,000
>1025 to 1030	640,000	27,000	350,000	297,500
>1000 to 1025	720,000	30,000	350,000	297,500

Note: The current Lake Mead elevation as of April 25, 2023, is 1,047 feet and is expected to increase to 1,061 feet by December 2023 due to heavy snowpack in summer/fall of 2023.

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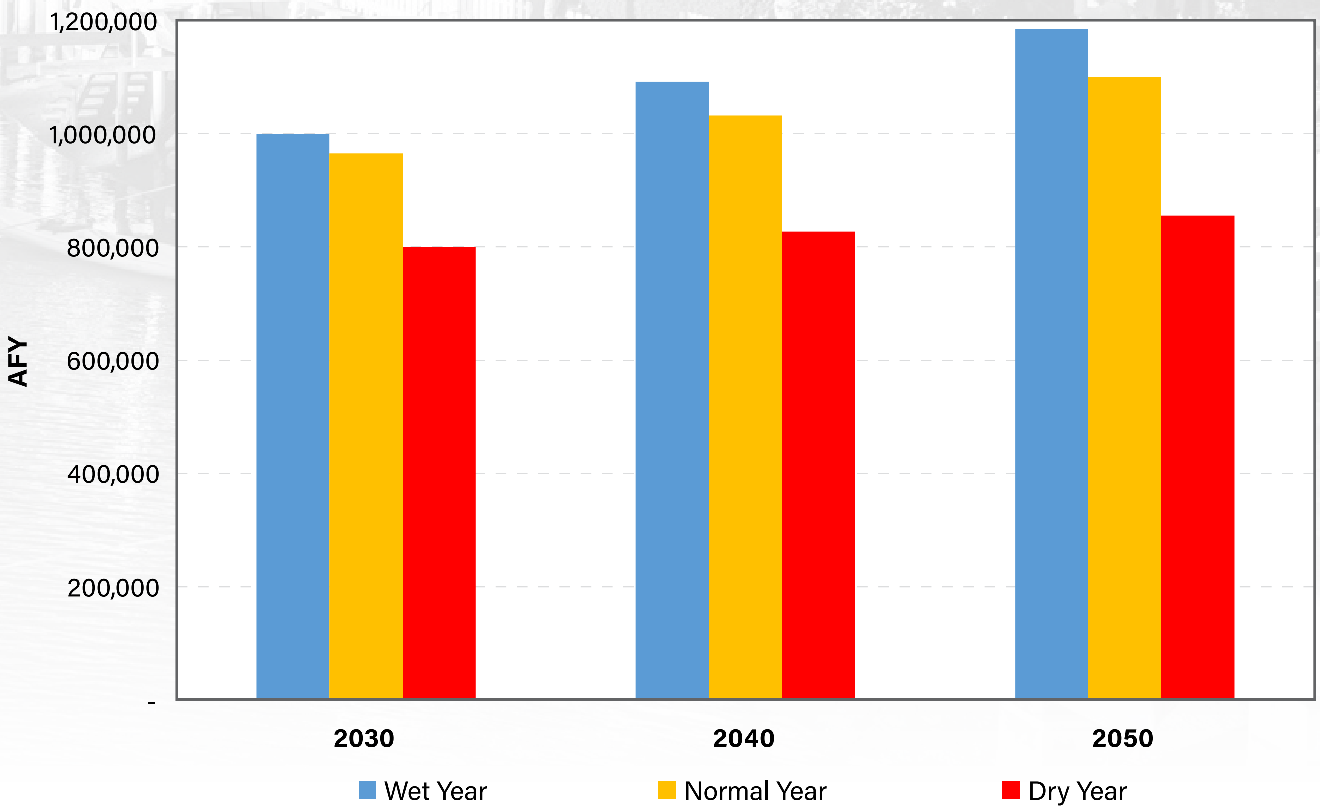
In exchange for taking shortage allocations sooner, California will receive benefits in the form of access to Intentionally Created Surplus (ICS) storage during shortage situations that are not currently allowed. ICS water in Lake Mead is defined as water that has been conserved through an extraordinary conservation measure, such as land fallowing. If Lake Mead elevations drop below 1,000 feet, then allocations are based proportionally based on priorities among the Lower Basin States and within California.

Based on the current BOR Drought Contingency Plan, CDM Smith used changed inflows into the Colorado River system under three different climate change futures to alter the baseline conditions. **Figure 3-9** presents CRA forecast deliveries for three representative year-types (e.g., wet, normal, dry) for the warm/wet climate future. The wet year represents the average of the highest 10th percentile, the normal year represents the 50th percentile, and the dry year represents the average of the lowest 10th percentile based on historical hydrology of 1965-2021.

Figure 3-9. Colorado River Aqueduct Forecast Deliveries to MET for Warm/Wet Climate Future



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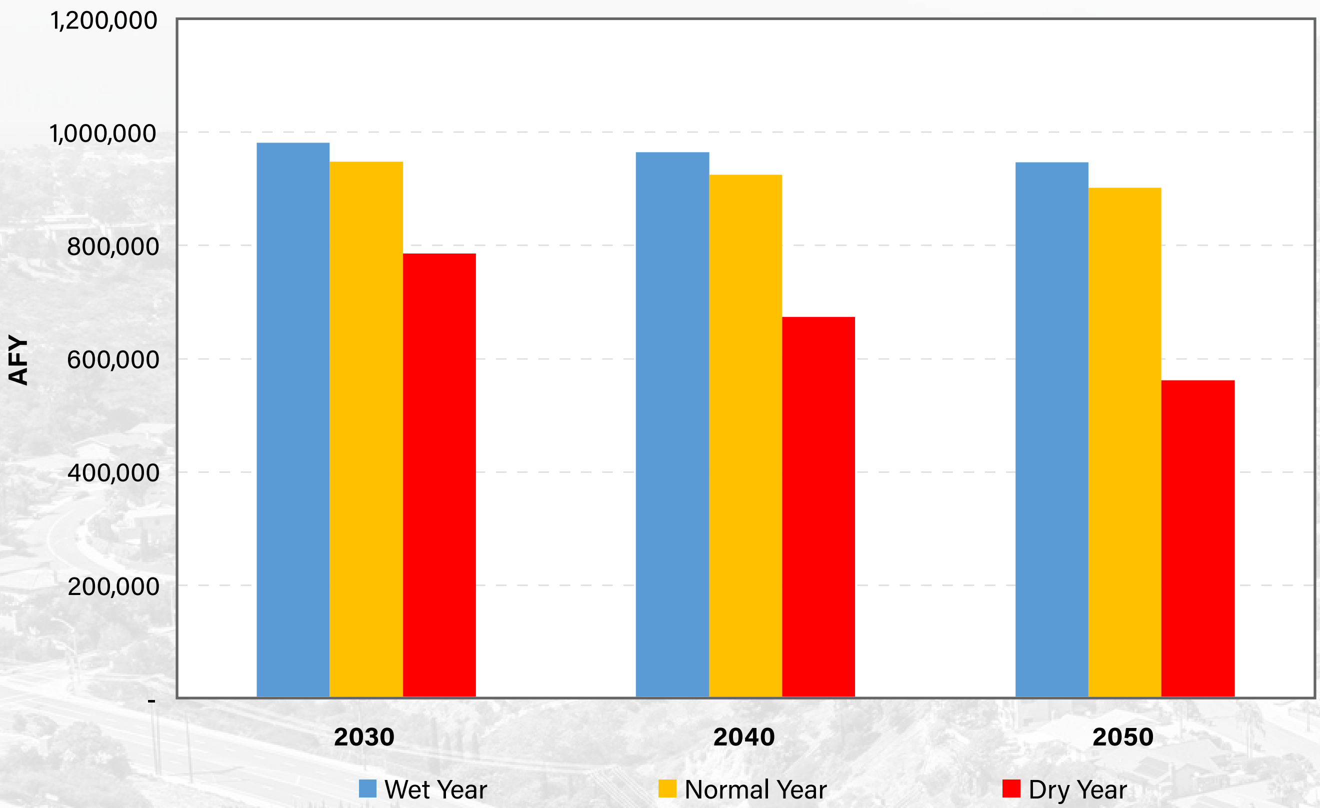
Under a warm/wet climate future, CRA forecast deliveries <u>increase</u> overtime, with normal year deliveries increasing from 0.96 MAF in 2030 to 1.10 MAF in 2050 (15 percent increase).

Figure 3-10 presents CRA deliveries for three representative year-types (e.g., wet, normal, dry) for the warm/dry climate future.

Figure 3-10. Colorado River Aqueduct Forecast Deliveries to MET for Warm/Dry Climate Future



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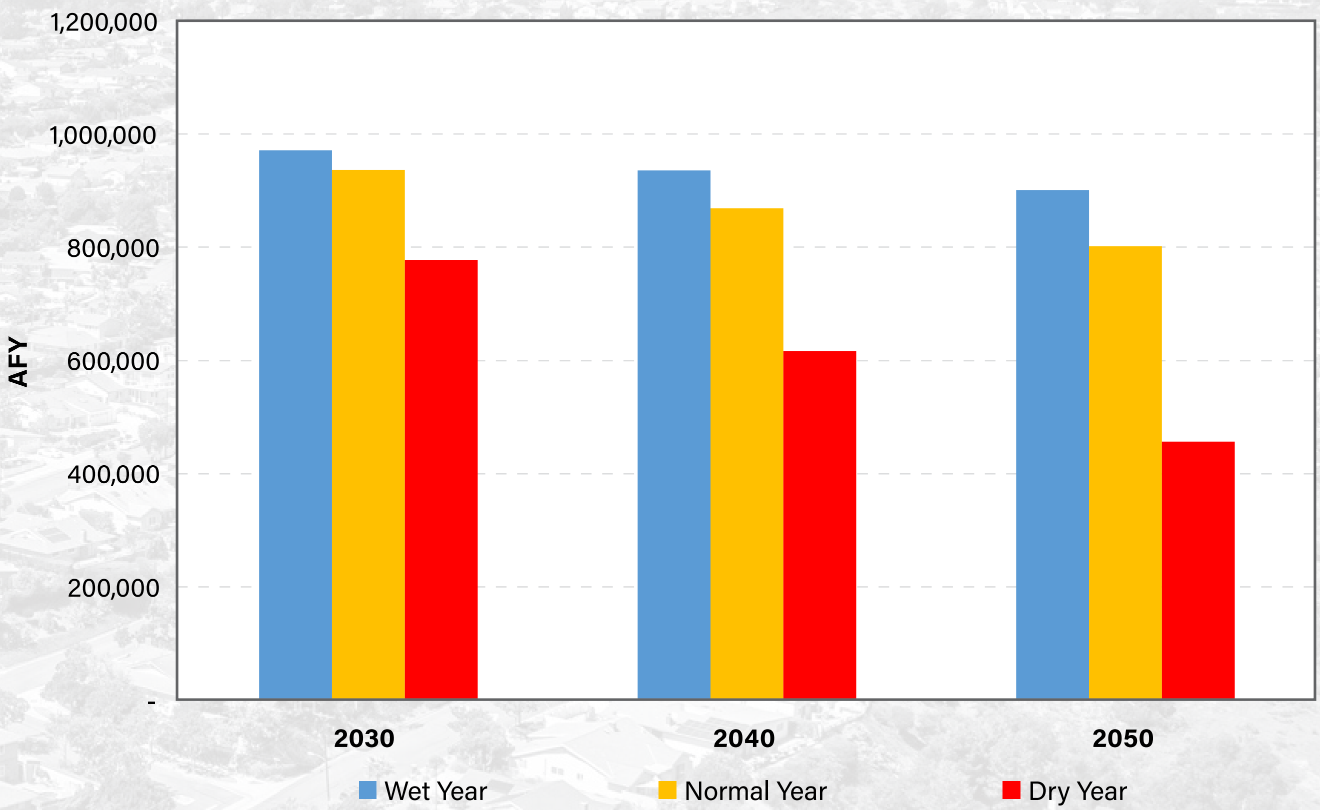
Under a warm/dry climate future, CRA forecast deliveries decrease overtime, with normal year deliveries decreasing from 0.95 MAF in 2030 to 0.90 MAF in 2050 (5 percent decrease). Although dry year deliveries will decrease even more significantly (27 percent decrease).

Figure 3-11 presents CRA deliveries for three representative year-types (e.g., wet, normal, dry) for the hot/dry climate future.

Under a hot/dry climate future, CRA forecast deliveries decrease overtime, with normal year deliveries decreasing from 0.94 MAF in 2030 to 0.80 MAF in 2050 (15 percent decrease). However, dry year deliveries will decrease even more significantly (42 percent decrease).

Figure 3-11. Colorado River Aqueduct Forecast Deliveries to MET for Hot/Dry Climate Future



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Existing MET Storage

The OCSIM model tracks surplus water when direct deliveries of imported water exceed MET water demands. Surplus water is stored to given storage capacities for use during emergencies and dry years. **Table 3-7** summarizes the MET storage used in the OCSIM simulations for the 2023 OC Study.

The January 2022 storage levels from MET operations reports were used as the start of the simulation period. MET's substantial storage has greatly mitigated reduced imported deliveries from the SWP in the past and will be key in reducing impacts from future droughts.

Table 3-7. MET Storage Capacities and Initial Volumes

Storage		Total Capacity (AF)	Non-Emergency Capacity (AF)	January 2022 Non-Emergency Current Storage (AF)
State Water Project Storage	Combined MET and Desert Water Coachella Valley Water District (CVWD) SWP Carryover	Allocation Dependent	350,000	38,000
	Castaic Lake (SWP – flexible storage)	325,000	154,000	0
	Lake Perris (SWP – flexible storage)	65,000	65,000	43,600
	Pyramid Lake (SWP)	158,000	0	0
Colorado River Storage	Desert Water & CVWD Advance Delivery Account1	800,000	800,000	259,000
	Intentionally Created Surplus (ICS)	1,700,000	1,700,000	1,243,000
MET Reservoir Storage	Diamond Valley	810,000	610,000	488,200
	Lake Matthews and Skinner	226,000	124,000	66,700
MET Groundwater Storage	In-Region	215,000	215,000	16,000
	Out-of-Region	1,340,000	1,340,000	522,000
	Cyclic	250,000	250,000	0

New MET Supplies

For those alternatives that have new MET programs (see **Table 2-2**), these supplies are modeled in OCSIM as either base-loaded supply offsets (e.g., Pure Water Southern California or Colorado River water transfers) or as supplies that are used only during dry years and droughts (e.g., new surface water storage).

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Section 4: Water Supply Reliability Assessment

The results of the water supply modeling for the 2023 OC Study were used to estimate the probability and size of potential MET water shortages, and then allocate those shortages to Orange County. It should be noted that the first set of shortage simulations do not include mandatory water use restrictions that have been required in past severe droughts. Understanding the level of water shortages without demand restrictions is useful when determining the potential economic impact of water shortages.

4.1 MET Regional Reliability

The MET regional supply reliability without demand restrictions is presented for the five planning scenarios in **Figure 4-1** for the year 2030 and in **Figure 4-2** for the year 2050.

Figure 4-1. MET Regional Supply Reliability Forecast in Year 2030

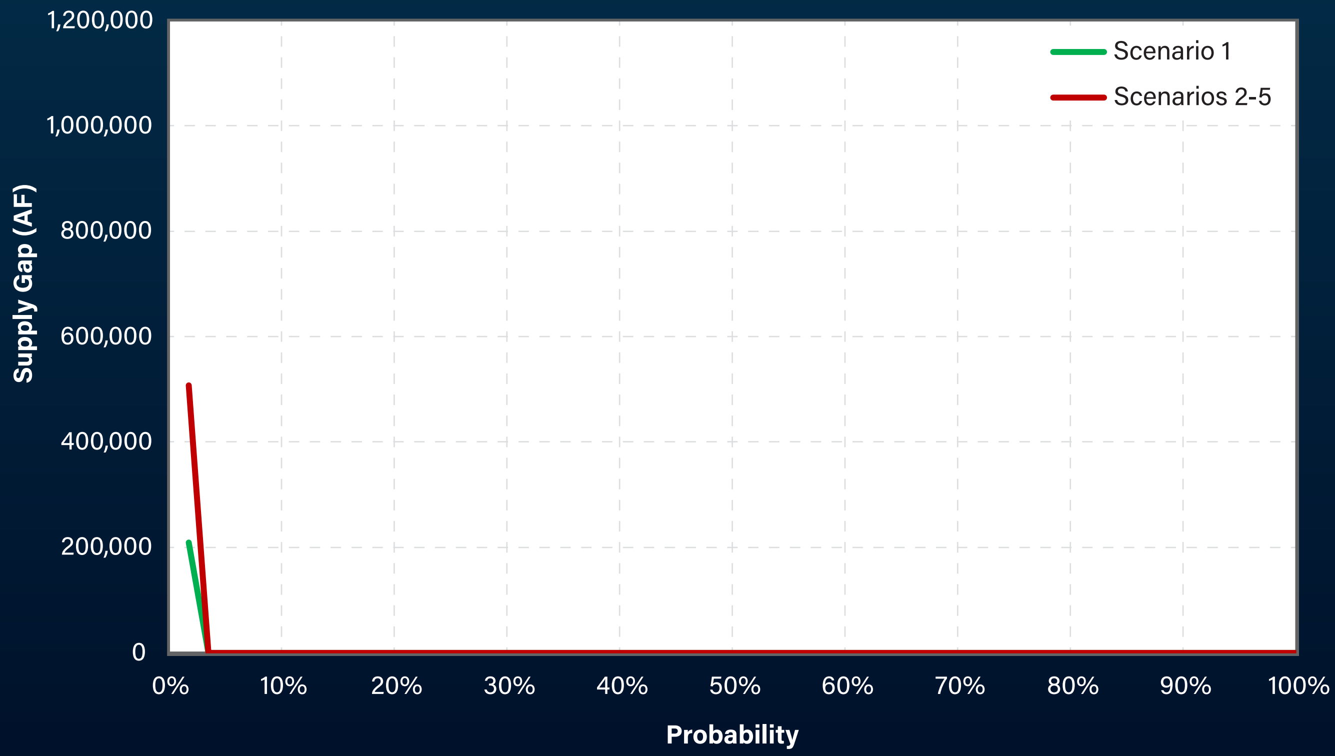

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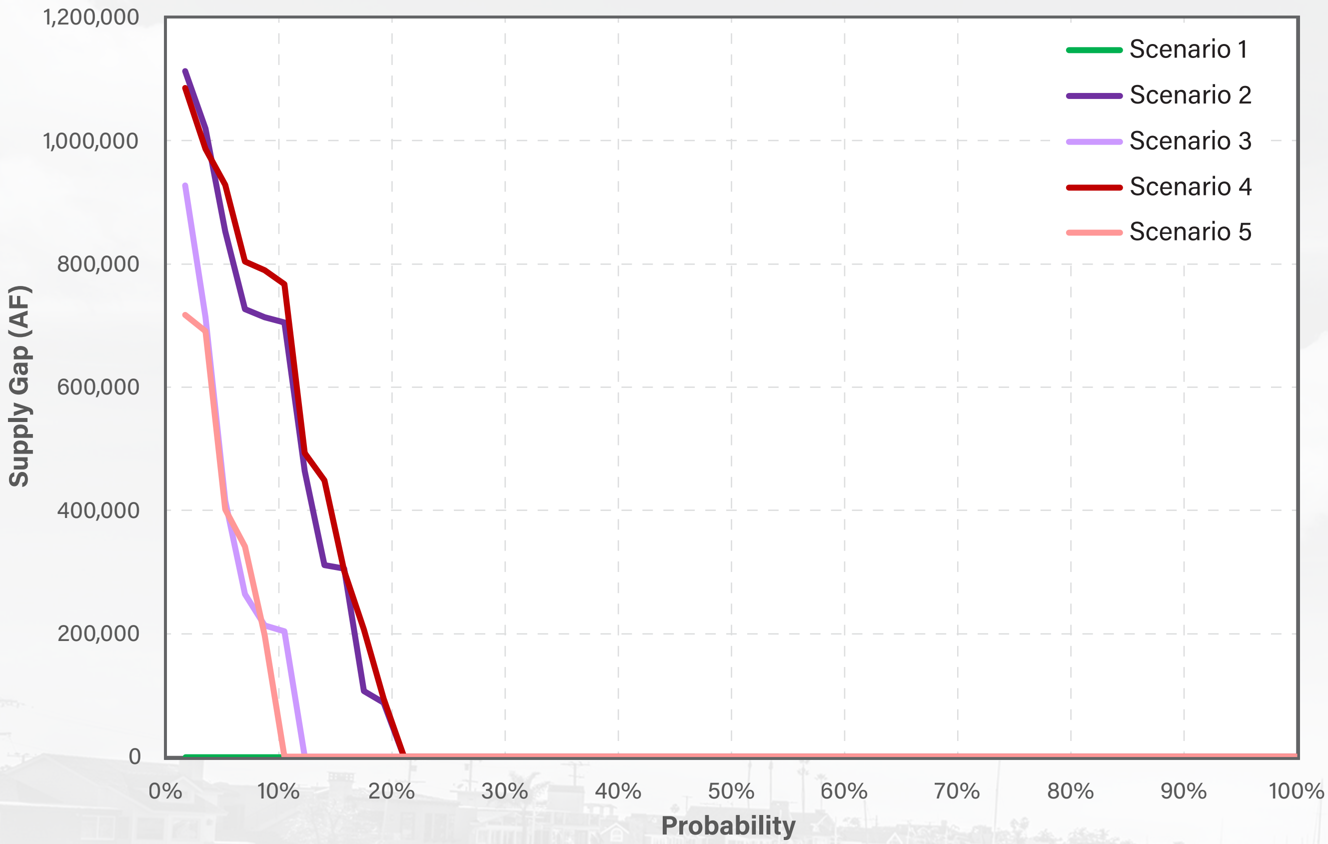
Figure 4-2. MET Regional Supply Reliability Forecast in Year 2050



In 2030, water shortages of any size are expected to occur 3.5 percent of the time. Maximum shortages, which are expected to occur about 1.5 percent of the time, range from 209,000 AFY for Scenario 1 to 508,000 AFY for Scenarios 2-5.

In 2050, MET water shortages of any size are expected to occur between 10 to 21 percent of the time. Maximum MET shortages, which can occur about 3.5 percent of the time, range from 0 AFY for Scenario 1 to 1,085,000 AFY for Scenario 4. When interpreting these results for 2050, it is important to keep in mind the following scenario distinctions:

- While Scenario 1 had shortages in year 2030, those shortages are reduced to zero by 2050 due to: (1) increases in imported water deliveries from 2030-2050 as a result of wetter assumed climate for this scenario; (2) assumed increases in local water supplies in the MET region between 2030 and 2050; and (3) new MET projects assumed to be implemented after 2030, such as the Pure Water Southern California Program and Colorado River water transfer.
- Scenarios 2 and 4 do not include the implementation of the DCP and new MET storage, whereas Scenarios 3 and 5 assume implementation illustrating the value of the DCP.
- While climate change impacts are more significant for Scenarios 4 and 5 (compared to Scenarios 2 and 3), reliability is slightly improved for these scenarios due to assumed increases in water use efficiency and a larger MET Pure Water Southern California program.

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4.2 Orange County Reliability

MET regional water shortages were converted into supply allocations to Orange County based on MET's water allocation formulas under its Water Supply Allocation Plan (WSAP). These formulas reflect existing local water supplies and levels of water use efficiency for Orange County. This provides estimates of MET water deliveries under different hydrologic traces, which are then added to the corresponding local water supplies in order to estimate the probability and size of water shortages for the Orange County Basin, South Orange County and Brea/La Habra. When interpreting results, refer to the scenario distinctions discussed in **Section 4.1**.

South Orange County Reliability

The South Orange County supply reliability without demand restrictions is presented for the five planning scenarios in **Figure 4-3** for the year 2030 and in **Figure 4-4** for the year 2050.

Figure 4-3. South Orange County Supply Reliability Forecast in Year 2030

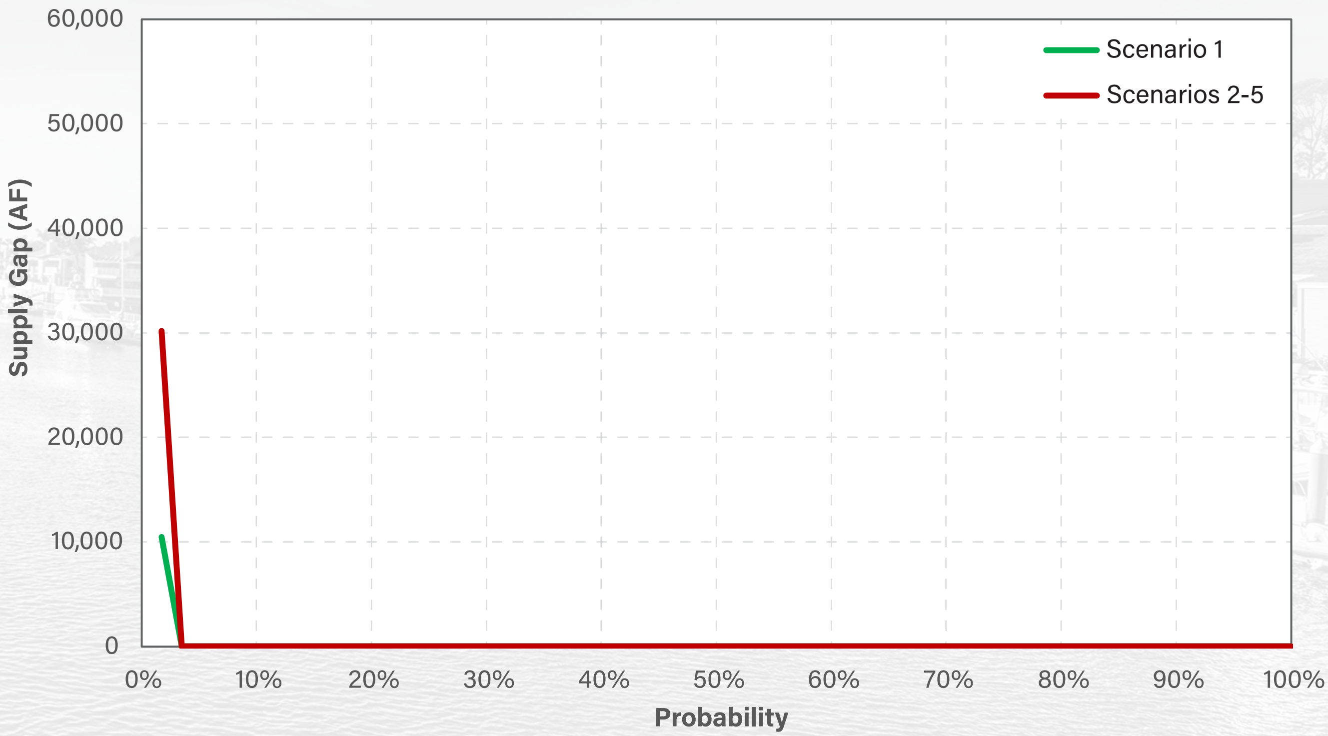

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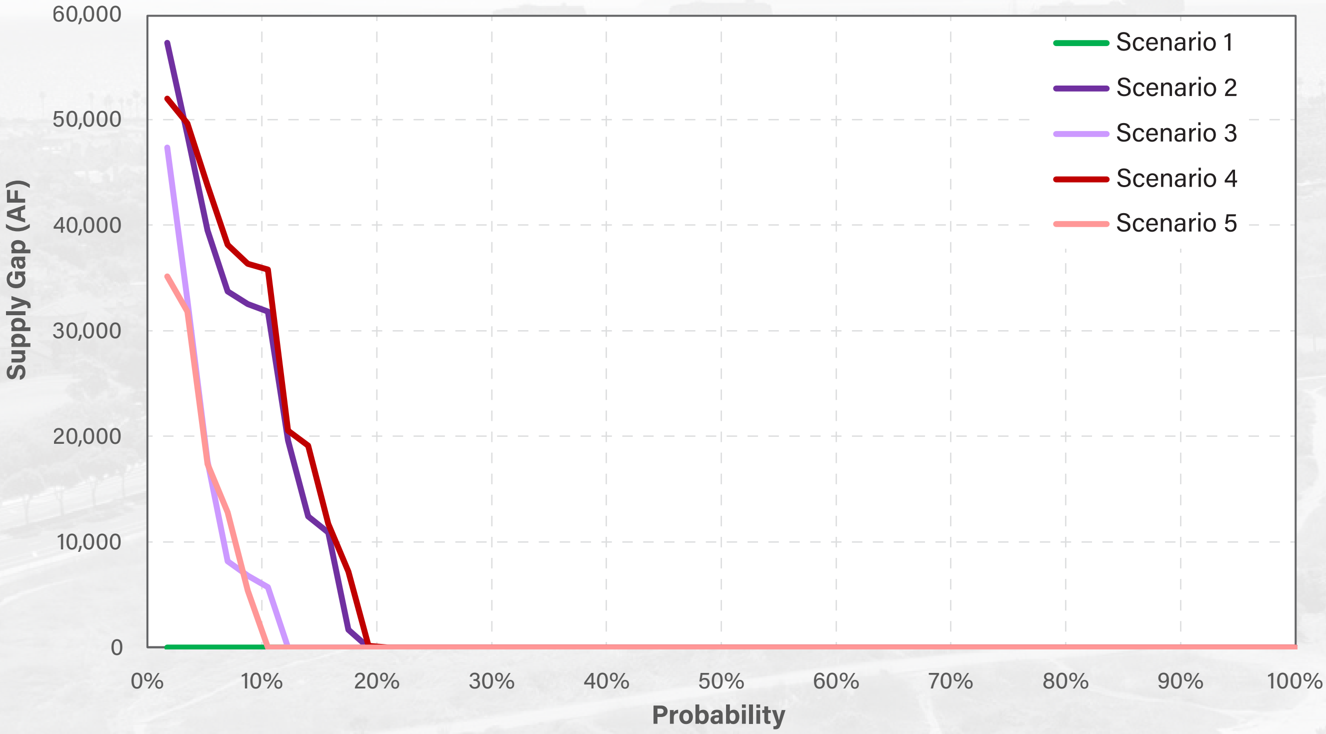
Figure 4-4. South Orange County Supply Reliability Forecast in Year 2050



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Orange County Basin Reliability

The Orange County Basin supply reliability without demand restrictions is presented for the five planning scenarios in **Figure 4-5** for the year 2030 and in **Figure 4-6** for the year 2050.

Figure 4-5. Orange County Basin Supply Reliability Forecast in Year 2030

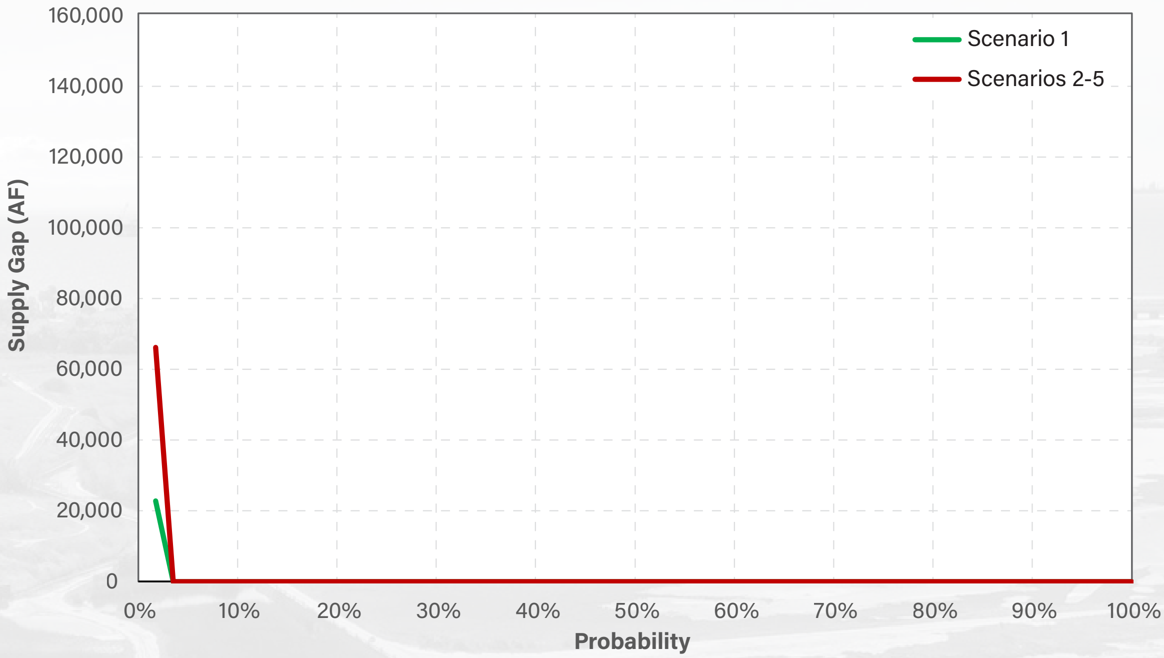
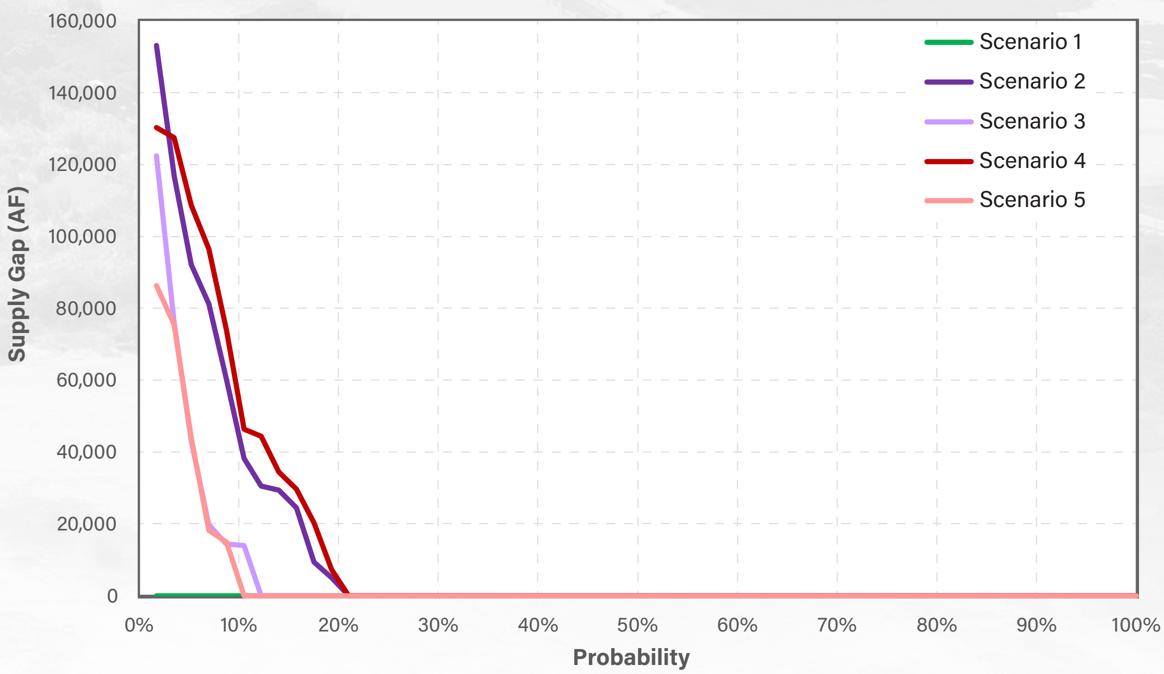


Figure 4-6. Orange County Basin Supply Reliability Forecast in Year 2050



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Brea/La Habra Reliability

The Brea/La Habra supply reliability without demand restrictions is presented for the five planning scenarios in **Figure 4-7** for the year 2030 and in **Figure 4-8** for the year 2050.

Figure 4-7. Brea/La Habra Supply Reliability Forecast in Year 2030

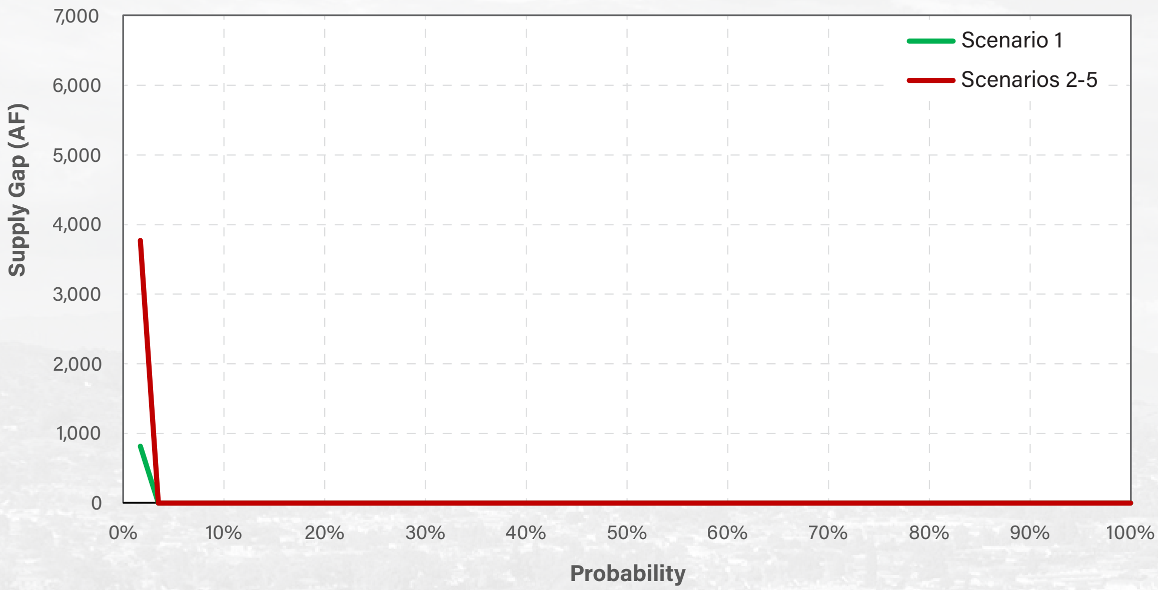
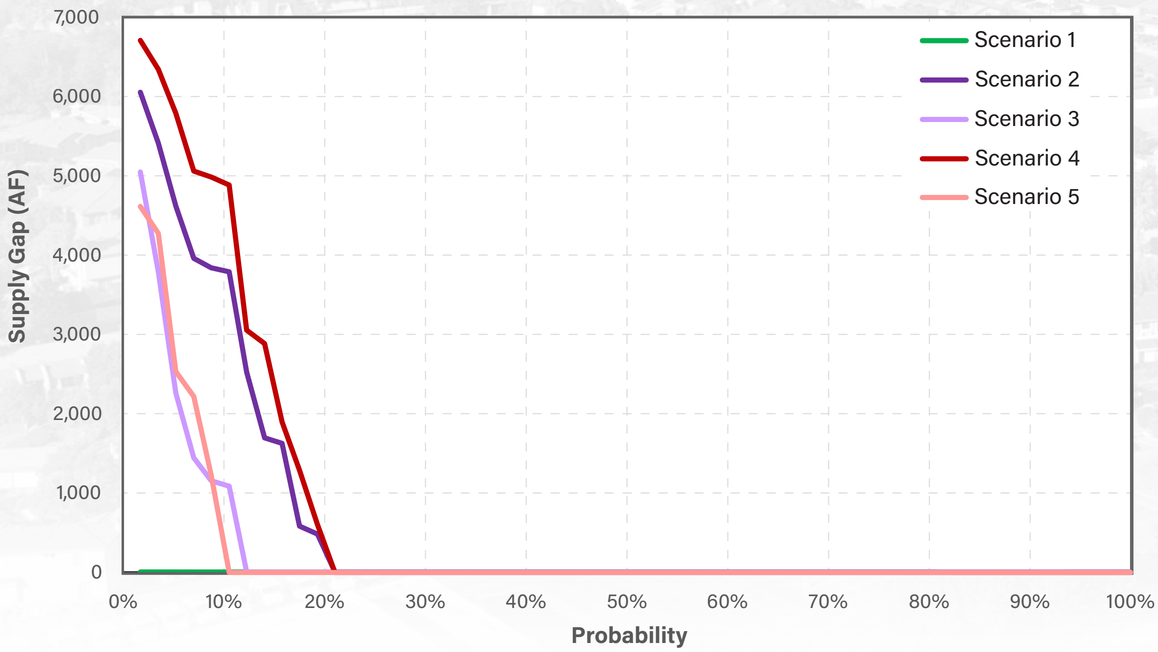
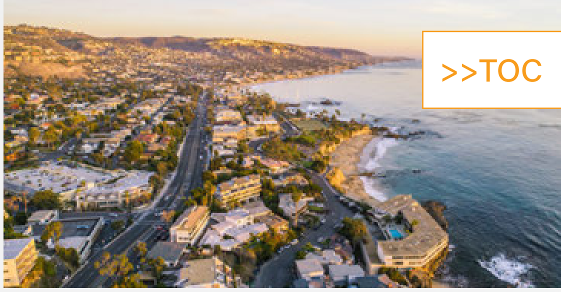


Figure 4-8. Brea/La Habra Supply Reliability Forecast in Year 2050





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4.3 Summary of Reliability Assessment

The summary of maximum water shortages for the MET region and study areas in Orange County are shown in **Table 4-1** without water demand restrictions. These maximum water shortages are expected to occur 1.5 percent of the time for the year 2030 and 3.5 percent of the time for 2050.

Table 4-1. Maximum Water Shortages Forecasts without Demand Restrictions

	Max Shortage (AFY) in 2030, Occurs 1.9% of Time					Max Shortage (AFY) in 2050, Occurs 3.5% of Time				
Region	**Sc1**	**Sc2**	**Sc3**	**Sc4**	**Sc5**	**Sc1**	**Sc2**	**Sc3**	**Sc4**	**Sc5**
MET Service Area	209,000	508,000	508,000	485,000	485,000	0	1,100,000	927,000	1,085,000	718,000
Orange County Basin	24,000	66,000	66,000	70,000	70,000	0	153,000	122,000	130,000	86,000
South Orange County	10,000	30,000	30,000	31,000	31,000	0	57,000	47,000	52,000	35,000
Brea/La Habra	1,000	3,000	3,000	4,000	4,000	0	6,000	5,000	7,000	5,000

Assuming 15 percent mandatory water demand restrictions at the retail level, that would likely be imposed during a critical drought, the maximum water shortages in Table 4-1 can be reduced as shown in **Table 4-2**

Table 4-2. Maximum Water Shortages Forecasts with Demand Restrictions

	Max Shortage (AFY) in 2030					Max Shortage (AFY) in 2050				
Region	**Sc1**	**Sc2**	**Sc3**	**Sc4**	**Sc5**	**Sc1**	**Sc2**	**Sc3**	**Sc4**	**Sc5**
MET Service Area	0	33,000	33,000	15,000	15,000	0	535,000	362,000	538,000	171,000
Orange County Basin	0	6,000	6,000	9,000	9,000	0	87,000	59,000	67,000	23,000
South Orange County	0	10,000	10,000	11,000	11,000	0	37,000	27,000	32,000	15,000
Brea/La Habra	0	0	0	1,000	1,000	0	3,000	2,000	4,000	2,000

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Depending on the scenario, net MET regional water shortages (assuming 15 percent retail-level demand restrictions) for Scenarios 2-5 range from 171,000 to 538,000 AFY in year 2050. In the Orange County Basin, net shortages for Scenarios 2-5 range from 23,000 to 87,000 AFY in year 2050. For South Orange County, net shortages for Scenarios 2-5 range from 15,000 to 37,000 AFY in year 2050; and range from 2,000 to 4,000 AFY for Brea/La Habra in year 2050.

The net water shortages in Orange County can be reduced to near-zero levels with the operations of recently developed supply projects (such as Irvine Ranch Water District's Central Valley Water Banking Program), temporarily increasing the utilization of groundwater in the Orange County Basin above prescribed overdraft targets, and with planned future reuse and desalination projects in South Orange County.

Note: While the scenarios presented in the 2023 OC Study represent five distinct plausible futures, there were many more scenarios that could have been evaluated. Furthermore, a true 'black swan' event scenario—one that represents all of the worst-case outcomes of the uncertainties occurring—was not evaluated. Nonetheless, the OC Study team believes that the five scenarios used for this study represent a reasonable range of potential outcomes that are appropriate for long-term water supply planning.

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Section 5: Economic Impacts of Water Shortages

In 2021, MWDOC initiated a study to determine the "value of water" to Orange County by estimating the economic impacts of hypothetical 15 and 30 percent water shortages in Orange County[9]. This study was not meant to imply that these water shortages would occur, but instead examined the economic consequences if they did occur. The approach used for this study is consistent with approaches used by MET, DWR[10], and other agencies to determine the value of proposed water projects. The goal of these approaches is to provide insights for making future water supply investments.

This MWDOC economic study assumed that water shortages would be proportionally allocated to residential and non-residential customers. However, it should be noted that some water providers may prioritize shortage allocations differently than assumed for this study. Note: There may be alternative approaches to evaluating the value of water, other than the one used for this study.

[9] The Economic Impact of Water Shortages in Orange County, prepared by the Brattle Group on July 15, 2022.
[10] DWR Economic Analysis Guidebook January 2008 located at: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/CDWA%20et%20al/SDWA%20273.pdf, Chapter 3 Economic Analysis Methods, pages 15-17.

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5.1 Summary of Economic Impacts

To determine the reduced economic output for industrial/commercial customers, a contingent valuation survey was done with 401 businesses in Orange County. Through detailed questions posing different scenarios of reduced water supply, businesses indicated a range of potential reductions in output/services. Then the economic input-output IMPLAN[11] model was used to convert reported percent reductions in output/services into dollar impacts.

To determine the impact for residential customers, a welfare loss function based on water demand/price curves were developed for single-family and multifamily residential homes. By restricting water demands by 15 and 30 percent, the estimated willingness-to-pay for not reducing water demand was estimated.

Lastly, lost revenues for water utilities in Orange County was estimated by reducing water sales 15 and 30 percent to residential, industrial, commercial, and institutional customers based on current water rates.

All economic impacts were estimated in 2021 dollars, with no escalation into the future. **Table 5-1** summarizes the mid-point estimate of these economic impacts to the entire Orange County.

Table 5-1. Economic Impacts to Orange County for Hypothetical Water Shortages in $2021

	Water Shortage Impacts ($M)	
Region	**15% Shortage**	**30% Shortage**
Reduced Output for Businesses	$5,108	$10,868
Welfare Losses for Residential	$241	$818
Lost Revenues for Water Utilities	$96	$191
Total	**$5,445**	**$11,877**

[11] https://implan.com

5.2 Applying Economic Impacts to 2023 OC Study Results

The results of MWDOC's economic study were applied to the 2023 OC Study simulations of maximum water shortages based on the following methodology:

1. Summarize the maximum water shortages over time based on the average results for Scenarios 2-5 (Scenario 1 was omitted as it assumes a more optimistic assumption regarding climate change). Then express these maximum water shortages as a percent of unmet demand.

2. Match the 15 and 30 percent shortage events from the economic study summarized in Table 5-1 to the results from Step 1. For those years in which the percent shortages fall in between the 15 and 30 percent shortage event, the economic impacts were interpolated.

3. Estimate the probability that the maximum shortage event is expected to occur over time and multiply the maximum economic impacts by this probability in order to get an expected average impact in current year dollars—similar to the classic risk formula where: average impact = likelihood x consequence.

4. Escalate the current year expected average economic impact for all future years, using an escalation factor of 3 percent per year. Then estimate the total present value economic impact, by discounting future year impacts using a discount rate of 5 percent per year, and summing the years to get a present value total.

5. Estimate the value of water, expressed as dollars per acre-foot, by taking the total present value economic impact (dollars) divided by the sum of present value water shortages (acre-feet).

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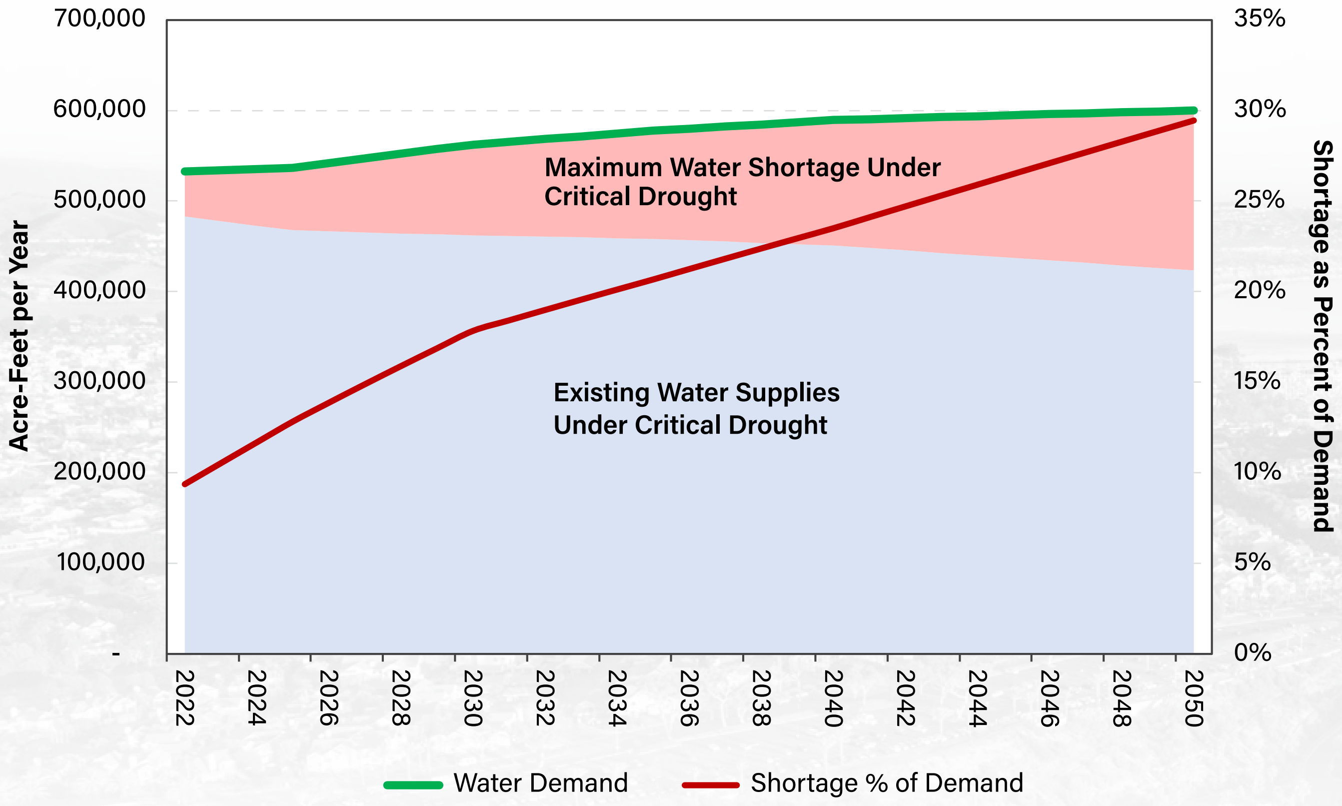
The maximum water shortages, averaged for Scenarios 2-5, for Orange County in total are shown in **Figure 5-1**. Shown in this figure is total water demand, existing water supplies, the maximum water shortages, and the maximum water shortages expressed as a percent of unmet demand.

Figure 5-1. Maximum Water Shortages based on Average of 2023 OC Study Scenarios 2-5



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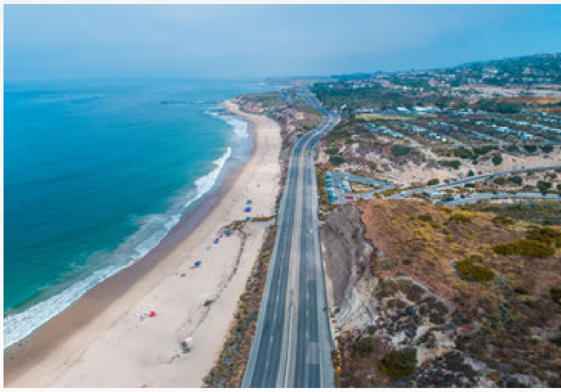


Matching the percent of unmet water demands in Figure 5-1 to economic impacts in Table 5-1 results in the maximum annual economic impact for future years, as summarized in **Table 5-2**. Also shown in **Table 5-2** is the probability that the maximum shortage event is expected to occur, which when multiplied by the maximum economic impact results in the expected average annual economic impact.

Table 5-2. Economic Impacts of Water Shortages in $2021

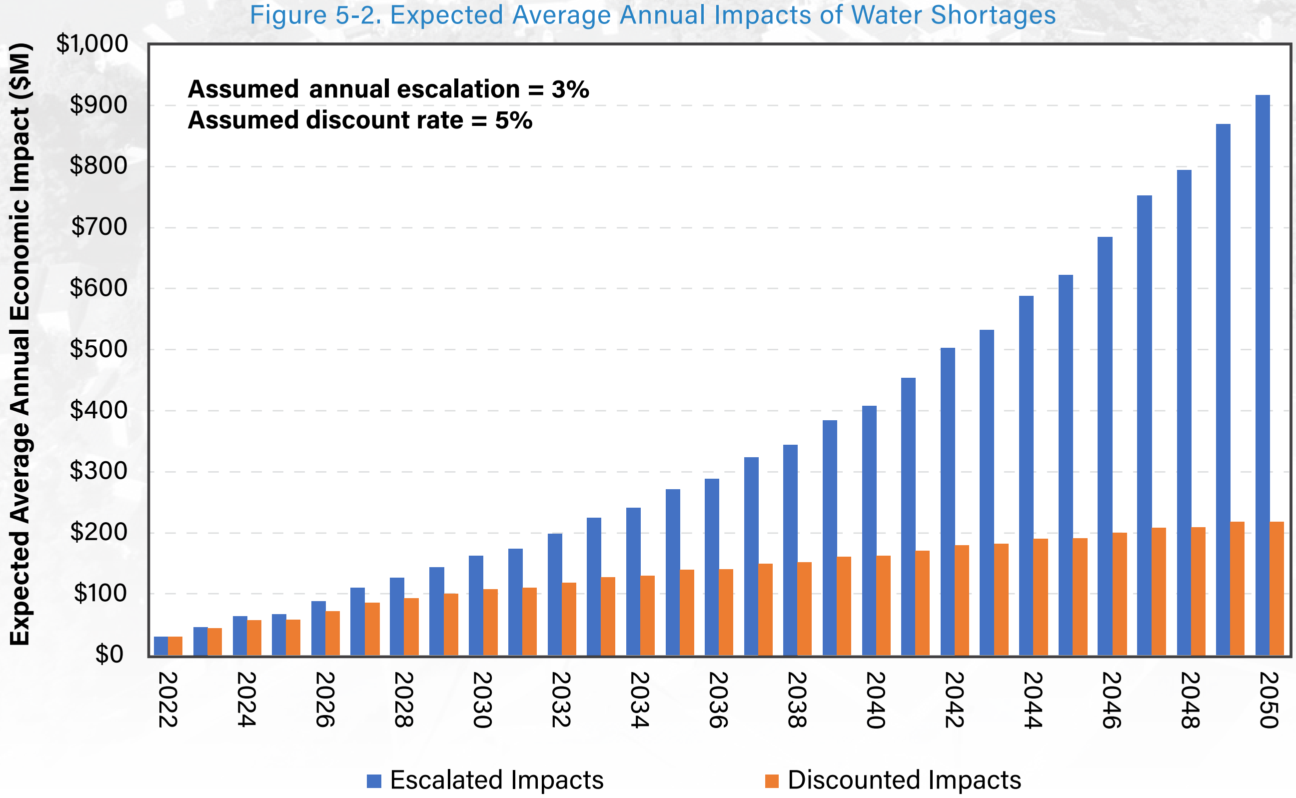
Year	Maximum Annual Economic Impact ($M)	Probability of Maximum Shortage Event Occuring	Expected Average Annual Economic Impact ($M)
2025	$3,729	1.7%	$62
2030	$6,731	1.9%	$128
2035	$8,018	2.3%	$184
2040	$8,875	2.7%	$240
2045	$10,162	3.0%	$315
2050	$11,448	3.5%	$401

Irvine Ranch Water District's Michelson Water Recycling Plant. Courtesy of IRWD

The expected average annual economic impact in **Table 5-2** was escalated at 3 percent per year, then discounted at 5 percent per year in order to arrive at a total present value (see **Figure 5-2**).

The sum of the discounted expected average economic impacts in Figure 5-2 is **$4 billion**, while the discounted water shortages is **1.6 MAF**. The "value of water" or benefit can also be expressed as a unit value of approximately **$2,500/AF**. This benefit can now be compared to the unit cost of new water supply projects, with that the calculation being the present value of capital and O&M costs divided by the present value of water supply over life of the project. Water supply projects in Orange County identified in the 2018 OC Study ranged from **$1,950 to $2,350/AF**, indicating that there would be a net positive economic impact from their development.

Figure 5-2. Expected Average Annual Impacts of Water Shortages



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Section 6: Conclusions

6.1 Summary of Findings

The results of the 2023 OC Study are summarized in four key findings, which are:

KEY FINDING 1

Under a hot/dry climate future (which recent evidence seems to suggest might be the current path), coupled with 15 percent mandatory water demand restrictions and optimistic future water supply assumptions (i.e., maximum levels of local and regional reuse, increased water use efficiency, new water transfers and storage, and implementation of the Delta Conveyance Project), the analysis indicates that water shortages in the MET service area and Orange County can still occur. The maximum water shortage in 2050 under these future conditions (as represented in Scenario 5) is 171,000 AFY for MET and 40,000 AFY for all of Orange County. The probability of these maximum shortages occurring is 3.5 percent.

KEY FINDING 2

Within Orange County, these net water shortages can be reduced to near zero values utilizing recent investments made by local water agencies in reuse and water banking, temporarily maximizing local groundwater beyond overdraft targets, and with planned new water supply projects.

KEY FINDING 3

The maximum value of the Delta Conveyance Project, when coupled with 250,000 AF of new regional storage, is estimated to be 367,000 AFY for MET and 63,000 AFY for Orange County. The Delta Conveyance Project also reduces the probability that any shortage occurs by about 10 percent—meaning a doubling of the time between shortage conditions from once every 5 years to once every decade.

KEY FINDING 4

Based on MWDOC's 2022 report on the Economic Impacts of Water Shortages in Orange County, the value of water supply investments in Orange County is estimated to be approximately $2,500/AF in present value terms. In comparison, the present value unit costs of recently completed and planned water supply projects in Orange County range from $1,950-$2,350/AF. Therefore, it can be interpreted that these Orange County projects represent a net economic benefit to Orange County.

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6.2 Recommendations

Based on the findings from the 2023 OC Study, the following recommendations are being made:

Recommendation 1

Orange County water agencies should continue to make investments in water reuse, water use efficiency, water transfers and banking, groundwater/surface water conjunctive use, and desalination.

Recommendation 2

Orange County officials should advocate for a balanced regional portfolio of water supplies for MET that includes: (a) implementation of MET's Pure Water Southern California program; (b) implementation of the Delta Conveyance Project; (c) new regional storage, which could include participation in the proposed Sites Reservoir Project; (d) continued financial support for water use efficiency and local projects, and (e) exploration of regional seawater desalination.

Recommendation 3

Orange County and MET should continue to study the evolving science of climate change and its impacts on water demands and supplies, as well as develop adaptive management strategies to mitigate these impacts.

In summary, there is no one or two silver bullets that will provide full water supply reliability for the MET region and Orange County under a likely warmer and drier climate future through the year 2050. The findings from this comprehensive assessment justify an "all of the above strategy" to ensure a robust regional economy and quality of life for our residents for decades to come.

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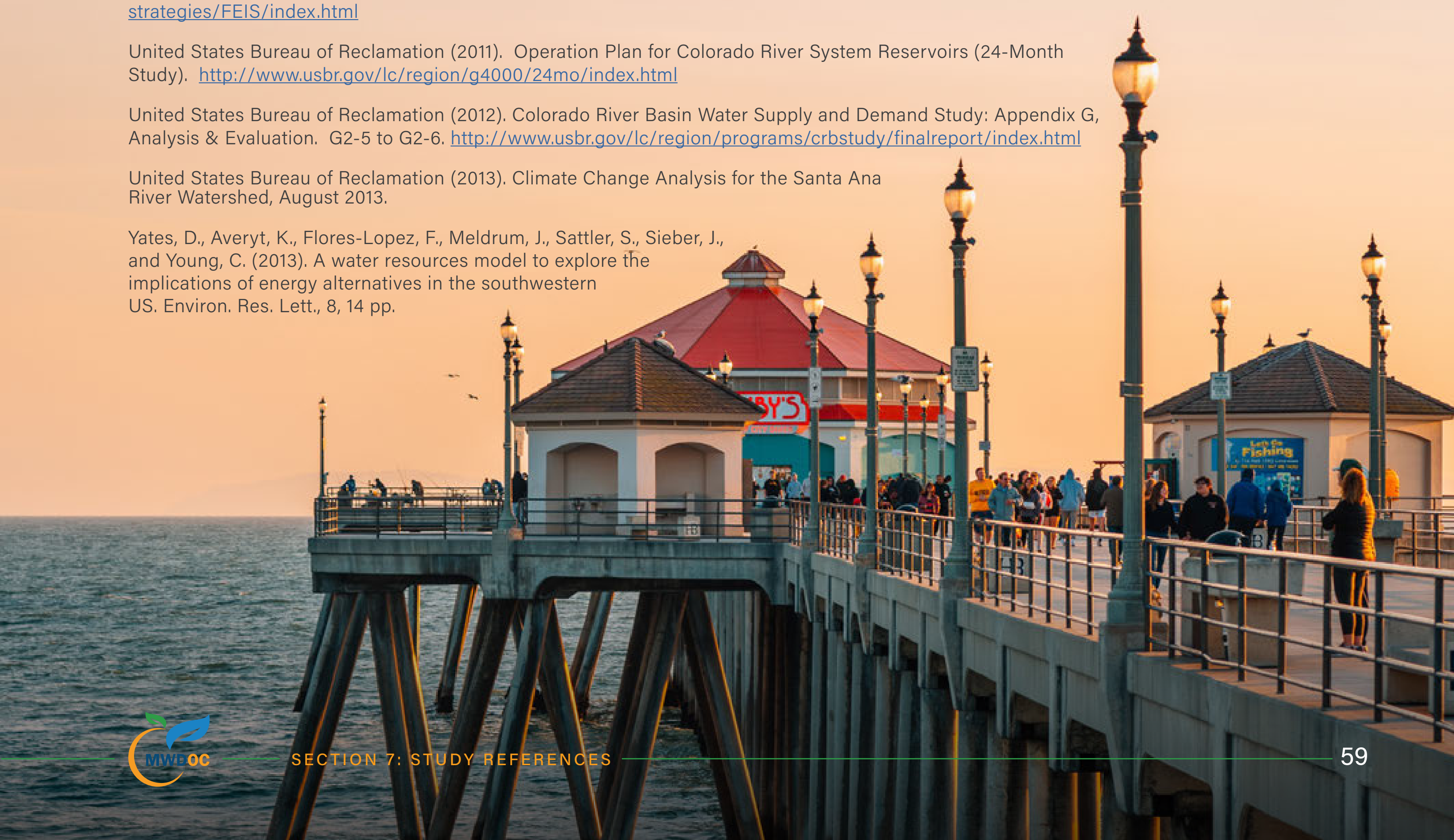

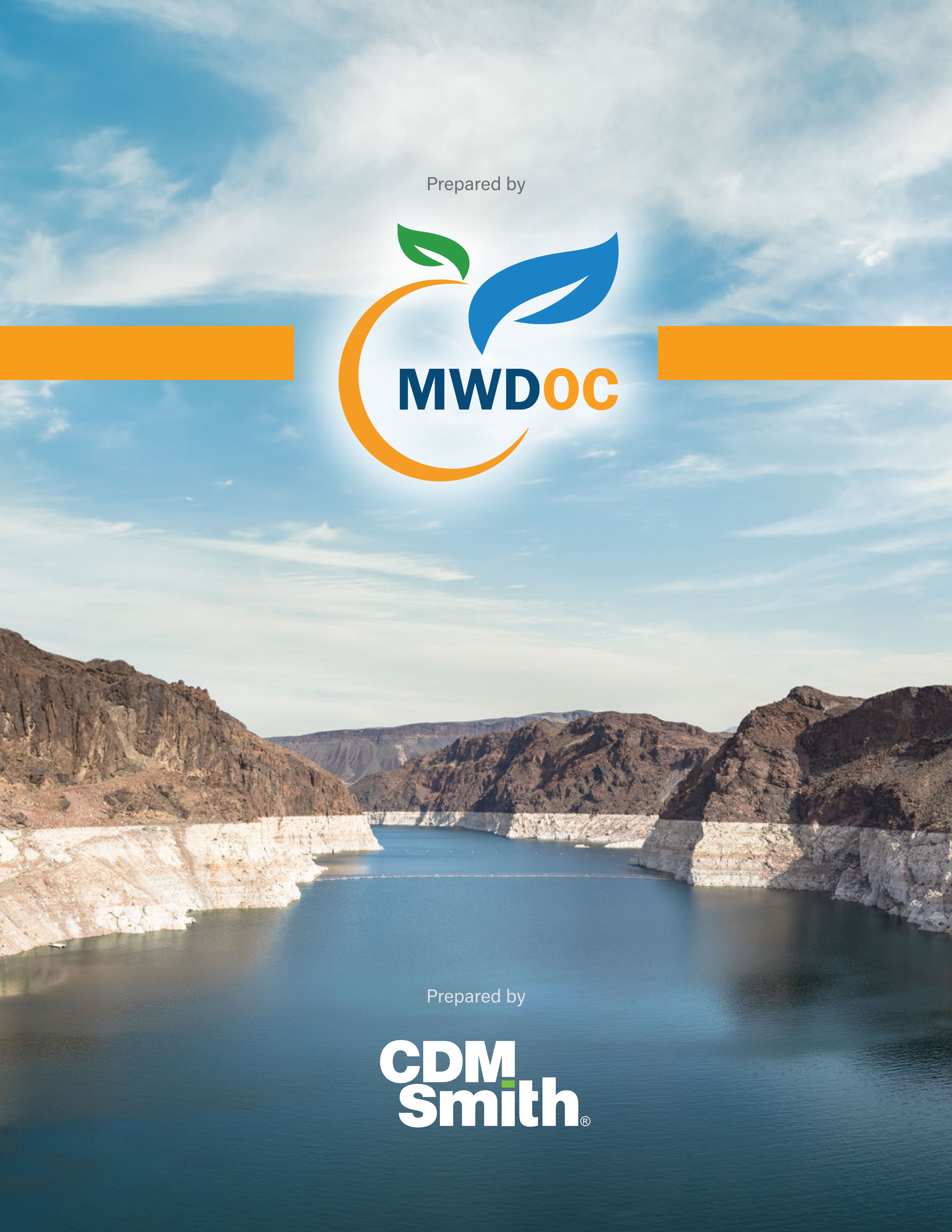

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