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Sonoma Water Regional Water Supply Resiliency Study

Accelerated 2021-2022 Drought Resiliency Analysis

FINAL DRAFT

April 27, 2022

Sonoma Water

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1. Introduction

Sonoma Water, in conjunction with its retail customers[1], is developing a forward-looking study of the resilience of the regional water system (Resiliency Study). The Resiliency Study seeks to identify the key factors impacting regional water supply resiliency, evaluate the current levels of resiliency, develop a decision support framework model and process, and identify promising opportunities for Sonoma Water and its retail customers to improve regional resilience in the future.

During the phase of the Resiliency Study focusing on building the Decision Support Model (DSM) and outlining risk scenarios, the project team decided to pivot the Resiliency Study to temporarily focus on the on-going drought risks in 2021-2022. This technical memorandum provides an overview of the accelerated drought analysis that is being conducted to identify future risks associated with on-going dry watershed conditions and an evaluation of near- and long-term options to improve drought resilience. Substantial improvements and near real-time modeling updates have occurred since November 2021 to track the changing hydrological conditions. Early findings on the severity and probability of drought, and the effectives of various resilience options are provided at this time. It is anticipated that additional findings and recommendations will be provided in the next revision of this memorandum.

[1] Retail customers include City of Santa Rosa, Town of Windsor, Marin Municipal Water District, City of Cotati, City of Sonoma, City of Rohnert Park, Valley of the Moon Water District, City of Petaluma, and North Marin Water District.

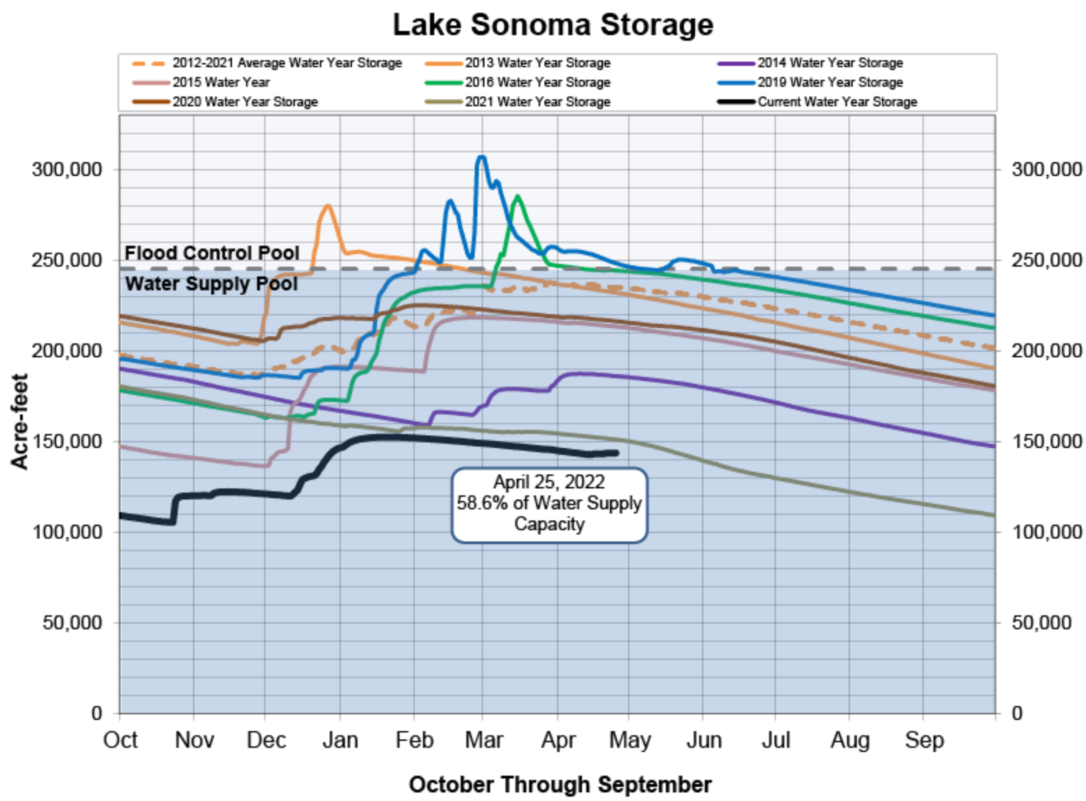
2. Current Drought Conditions

The Sonoma and Marin County region is experiencing it third consecutive dry year of historical significance. The water year (October 1 – September 30) of 2020 ranks as the fifth driest year on record over the last 126 years for this region. The following 2021 water year (WY) was even drier and ranks as the second driest year on record. When considering all two-year periods since 1896, only the 1976-1977 water year period represents a drier condition than the 2020-2021 period. Due to the extreme drought conditions, storage levels in Lake Mendocino, Lake Sonoma, and Marin Municipal Water District reservoirs all reached record lows in October 2021 (Figure 1). While storms in December of 2021 have improved the storage conditions, the remainder of the winter and early spring 2022 precipitation has been substantially below normal. The current outlook for remainder of spring 2022 suggests that precipitation may continue to be below normal.

Reacting to the growing drought conditions, Governor Newsom signed a State of Emergency Proclamation for Sonoma and Mendocino counties in April 2021. In early 2021, Sonoma Water received approval to reduce water releases again from Lake Mendocino through a Temporary Urgency Change Order approved by the State Water Resources Control Board (SWRCB). At the same time, the Sonoma Marin Saving Water Partnership launched an aggressive public outreach campaign to emphasize the need to save water by highlighting actions customers can take to reduce water use and improve water use efficiency. This is in addition to the Partnership's year-round conservation campaign efforts. The Partnership's current regional water use represents a 37 percent reduction in water use, well ahead of the State's required 20 percent reduction in per capita per day water use by 2020. And in June 2021 the SWRCB issued an order that limited Sonoma Water cumulative diversions from July 1 through the end of the order (December 10) to 20 percent below 2020 diversions over the same period. Sonoma Water customers have enacted the appropriate stage of their respective Water Shortage Contingency Plans. Actions taken by Sonoma Water customers have reduced Russian River diversions by 22.7% during this period, thus exceeding the 20% reduction mandate.

The water year total precipitation and average annual temperature in Sonoma County for 1896-2021 are shown in Figure 2 and Figure 3, respectively. Interannual precipitation in the region is highly variable. The wettest year on record occurred in 1983, while the driest year on record occurred in 1977. The most severe droughts generally persisted for two years (e.g.,1976-1977 and 2014-2015), while some less severe droughts persisted for longer than 5 years (e.g., 1986-1992 and 1928-1934). Similar to statewide trends, the region has experienced a considerable warming trend since at least the 1970s, and the most recent 10 years represent the warmest in the record. Figure 4 shows the relative anomaly (difference from long-term mean) in annual average temperature and total precipitation for each year from 1886 through 2021. The wettest years are indicated with blue dots, while the most significant acute periods are indicated in red. The 1976-1977 drought period is the most severe in the record, followed by 2020-2021 and 2014-2015 periods. Of significance, is the finding that the most recent droughts have not only been the result of reduced precipitation but also of a warmer atmosphere. These exceptional warm and dry periods represent the most significant climatic challenge to water management. These periods are exemplified by a lower occurrence of spring storms, prolonged summer and multi-year dry conditions, increased wildfire risks, declining groundwater levels and groundwater contributions to streamflow, greater challenges in sensitive species management, and changes in watershed vegetation.

Figure 1. Lake Sonoma and Lake Mendocino Storage through April 25, 2022.



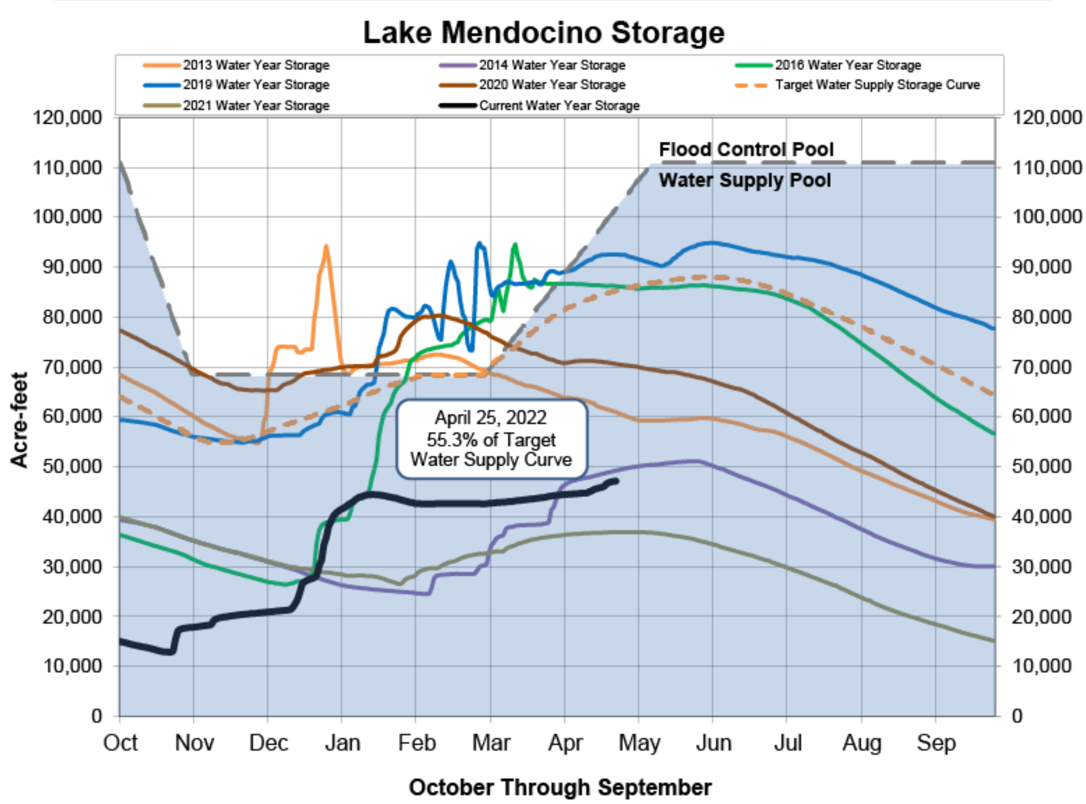
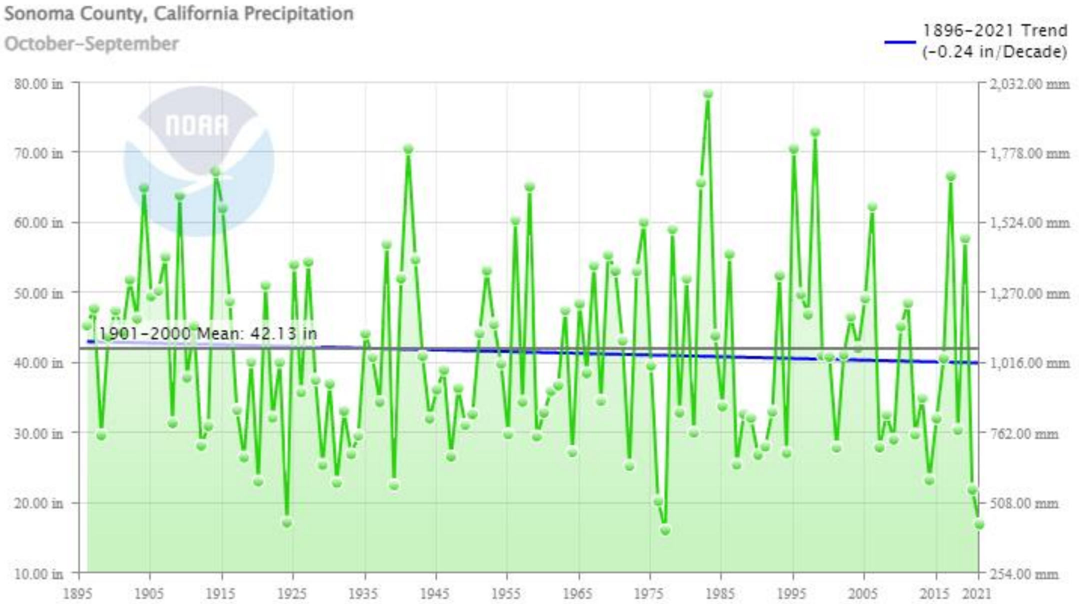


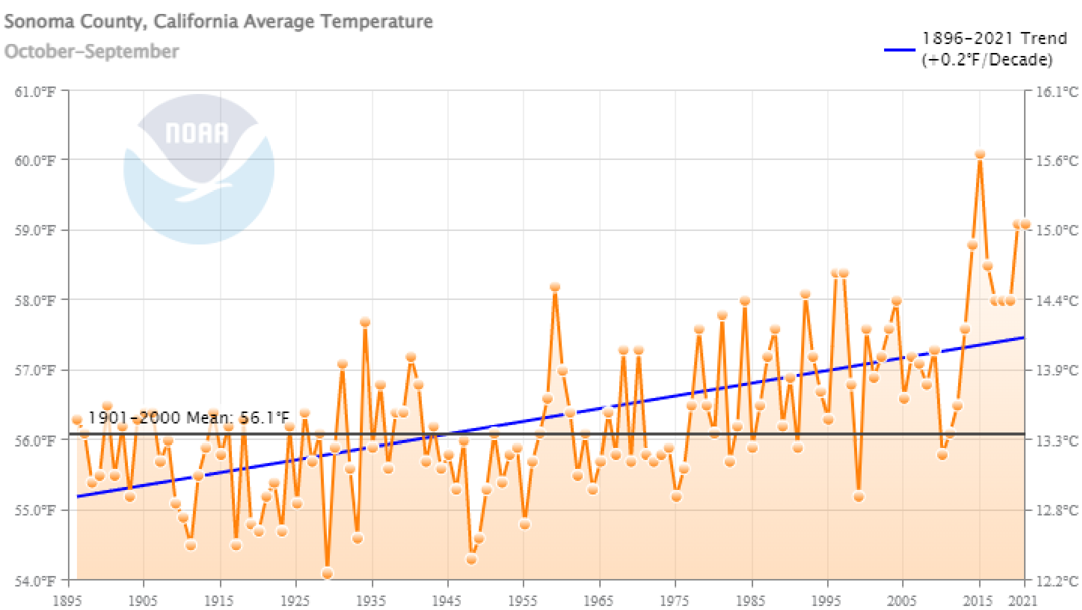
Figure 2. Annual Water Year (October 1- September 30) Precipitation in Sonoma County, 1896-2021.



Source: NOAA National Centers for Environmental information, Climate at a Glance: County Time Series, published January 2022, retrieved on February 4, 2022 from https://www.ncdc.noaa.gov/cag/

Note: Grey line represents 1901-2000 mean; blue line represents trend over 1896-2021. Data represent county average based on station observations and gridded approach conducted by NOAA.

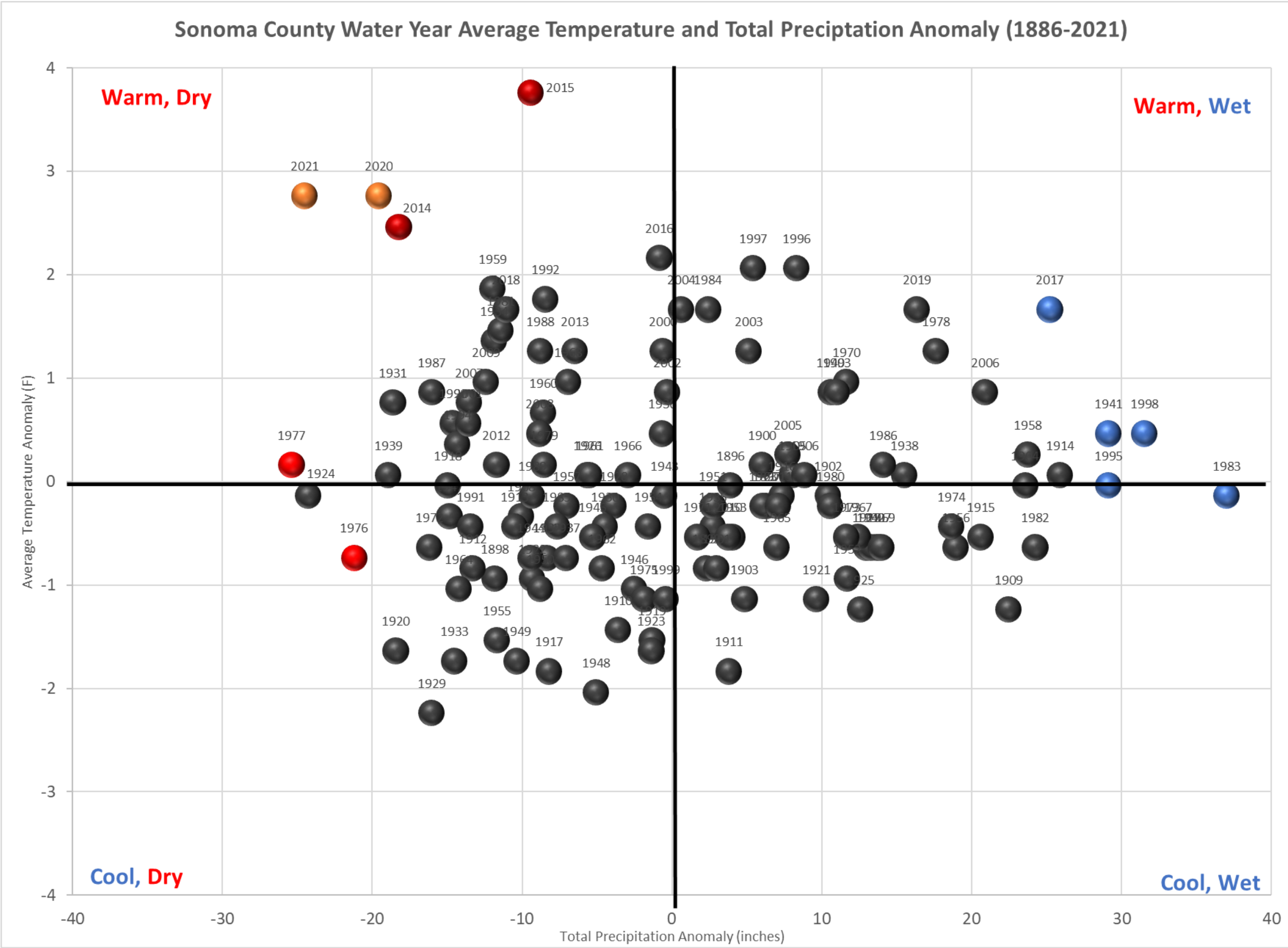
Figure 3. Annual Water Year (October 1- September 30) Average Temperature in Sonoma County, 1896-2021.



Source: NOAA National Centers for Environmental information, Climate at a Glance: County Time Series, published January 2022, retrieved on February 4, 2022 from https://www.ncdc.noaa.gov/cag/

Note: Grey line represents 1901-2000 mean; blue line represents trend over 1896-2021. Data represent county average based on station observations and gridded approach conducted by NOAA.

Figure 4. Annual Water Year (October 1- September 30) Average Temperature and Total Precipitation Anomaly in Sonoma County, 1886-2021.



Note: Yellow and red dots highlight specific extended dry periods (e.g. 1976-1977, 2014-2015, 2020-2021); blue dots highlight particularly anomalous wet years.

3. Decision Support Model

The Sonoma Water Decision Support Model (DSM) serves as a model for evaluating future supply reliability and resiliency of Sonoma Water's and its retail customer's regional water supply system. The DSM integrates the water balance and operations of the Russian River system, Sonoma Water transmission system, and retail customer systems to assess water supply reliability of the regional supply system to its customers. A simplified schematic of the DSM representation of the system is shown in Figure 5.

The Upper Russian River system in DSM includes logic based on Sonoma Water's existing HEC-ResSim and Matlab models. This includes storage and release operations for Pillsbury, Van Arsdale, Mendocino and Sonoma reservoirs. Rules for releases from these reservoirs include releases for various Russian River demands, minimum instream flow requirements, flood, and emergency releases. The Potter Valley Project (PVP) operations included in the model links the Eel River to the Russian River with a minimum instream flow requirement in the East Fork Russian River and deliveries to the Potter Valley Irrigation District (PVID). Discretionary flows are not included in the simulations discussed in this report due to these operations currently not being implemented. Additional Russian River water balance logic include reach depletions for Calpella, Redwood Valley, Hopland, Cloverdale, Healdsburg, Healdsburg Dry Creek Wells, Dry Creek, Healdsburg Fitch Mountain Wells, Town of Windsor, Hacienda, and Russian River County Water District. Each of these demands are input to the model as a daily time series.

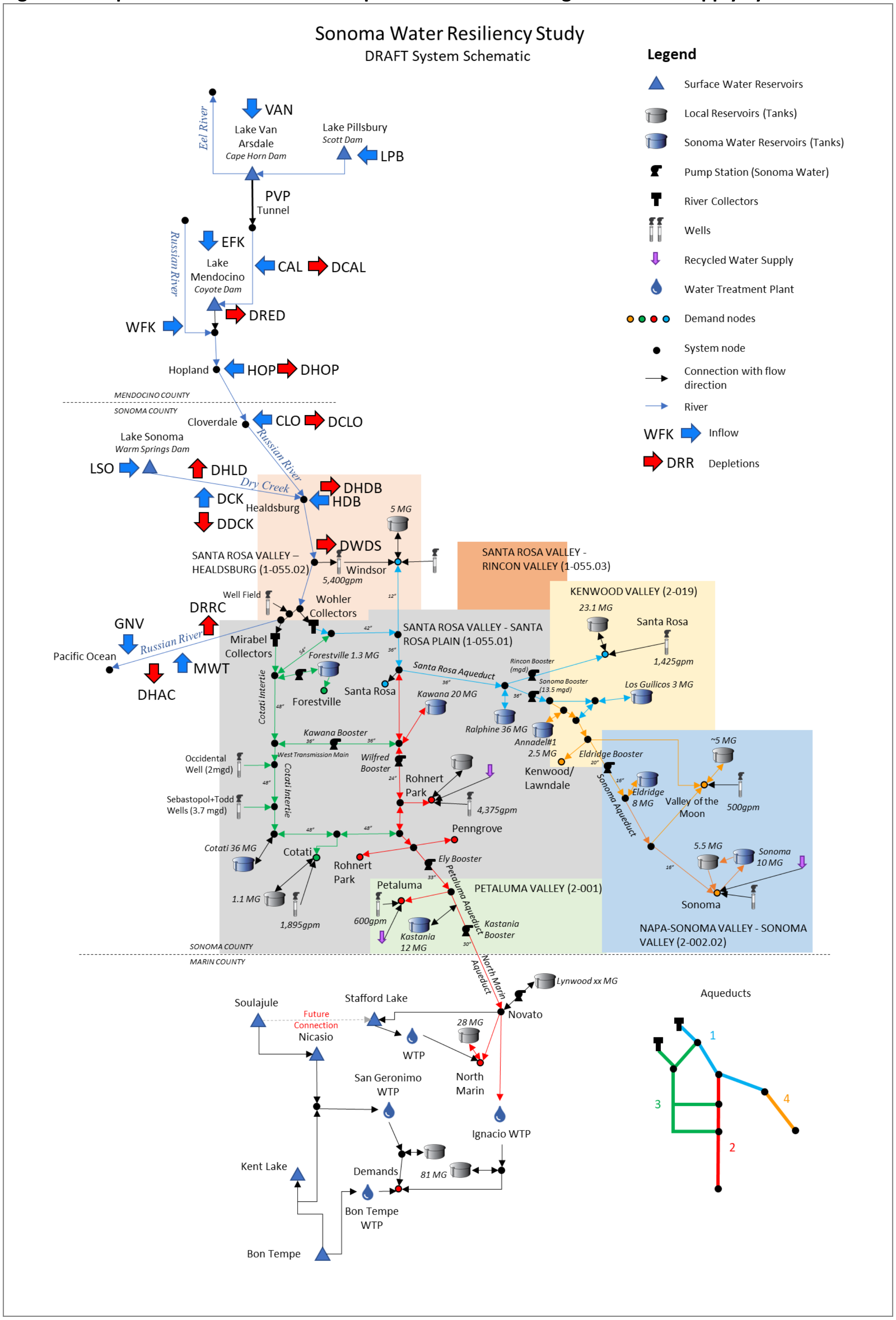
The Sonoma Water transmission system includes operations associated with the Mirabel and Wohler Russian River diversion facilities, Santa Rosa Plain groundwater wells, and transmission system which includes pipelines, pump stations, storage tanks, and aqueduct turnouts to Sonoma Water's retail customers. Facility capacities and operations were derived from Sonoma Water facility guides, review of existing models, and through meetings with Sonoma Water staff.

Finally, simplified representations of each retail customer system and operations were developed. Jacobs met with each retail customer engineering and operation staff, reviewed existing water system plans, and developed the level of detail necessary for the resiliency assessment. For each retail customer, model elements are included for each water source (aqueduct, local groundwater, recycled water, and local surface water) available in the service area. For most retail customers, the Sonoma Water deliveries through the aqueduct is the primary water source. However, for other customers, local surface supplies or groundwater make up a significant portion of the supplies to meet customer demands. For North Marin Water District (NMWD) and Marin Municipal Water District (MMWD), elements are included to simulate the operations of Lake Stafford (NMWD) and Soulajule, Nicasio, Kent and Phoenix (MMWD) reservoirs. For each retail customer, demands consistent with the projections included in the 2020 Urban Water Management Plan (UWMP) are set as total retail customer demand. Priorities and maximum delivery of each water source are then set in the model to indicate the water operation preferences for each retail customer. In general, during dry years recycled water and local groundwater are delivered at priority to satisfy the demand, followed by local surface water and aqueduct supplies.

The DSM simulates operations on a daily timestep for the desired period set in the model control. A historical validation simulation was conducted for the period of 2009-2017. For the validation simulation, model demands were set equal to actual historical deliveries. The model was then simulated with historical recycled water and groundwater supplies, historical surface hydrology, and historical reservoir and project operations criteria. Model simulated storage levels at Lake Mendocino, Lake Sonoma, and Marin reservoirs, simulated Russian River diversion at Mirabel and Wohler facilities, and delivery of water by source for each retail customer were compared to historical reported values and to HEC-ResSim simulated storage levels. Review of the initial simulations led to subsequent improved representations of the PVP, instream flows, and transmission system capacities and storage operations. Final validation simulations compare very well to storage levels, river diversions, and delivery to member agencies.

A more complete discussion of the DSM development, validation, and simulations will be included in the full Resiliency Study report.

Figure 5. Simplified Schematic of DSM Representation of the Regional Water Supply Systems



4. Future Drought Scenarios

As part of the Resiliency Study, the risks to the regional water supply system associated with future droughts is to be addressed along with opportunities improve the system resiliency in response to these conditions. In October/November of 2021, the project team was asked to accelerate the development of the DSM in order to address the immediate drought risk that was growing throughout the summer and fall. The ability to investigate the risks to the regional water supply system under a range of potential hydrological conditions for 2022 and beyond was desired. Longer-term drought risks and opportunities to improve resilience to droughts beyond the near-term will be covered in the final Resiliency Study.

To address the near-term need, the team began preparing the DSM for monthly, near real-time projections of future conditions using the actual storage conditions and future plausible hydrological conditions for the five-year period represented by water years 2022-2026. The historical hydrology for the period of record 1910-2017 was compiled and incorporated into the DSM. Storage conditions for Lake Pillsbury, Lake Mendocino, Lake Sonoma, and MMWD reservoirs were updated with actual November 1, 2021 storage levels, and subsequently updated for December 1, 2021 and January 1, 2022 levels. For the purpose of this memorandum, the modeling results primarily focus on the simulations with January 1, 2022 initial conditions.

The DSM was simulated using 108 traces of hydrology sampled from the historical hydrological period of 1910-2017. For example, one trace includes hydrology derived from the 5-year hydrological period of 1928-1932, another derived from the historical period of 1976-1980, and another from 2012-2016. Stochastic simulations using a technique called the index sequential method allow sampling of all 108 traces while maintaining the hydrological sequences of the past. In doing so, the probability of low storage and delivery shortage conditions can be derived from the ensemble of simulations.

The historical hydrology was reviewed and compared to the hydrological sequences found using climate change projections. Based on early simulations, it was found that the hydrology of the water year 1976-1977 period represents the most severe two-year extended drought scenario. Droughts of duration longer than two years have been identified in both the historical record and future projections, but the severity of the 1976-1977 period make it particularly challenging to water management. Thus, a stress test hydrology scenario was derived that includes the effects of the current 2020-2021 drought and then assumes that 2022-2026 is represented by the dry hydrological sequence of 1976-1980. This stress test hydrology is then used for evaluating the resilience of the regional water supply system and effectiveness of various drought management options.

5. Baseline Simulations and Results

Baseline model simulations represent the future in which “no action” is taken to mitigate drought impacts. The baseline is useful to describe the scale of the drought problem and better understand the timing of risks. This simulation is also the reference for the subsequent evaluation of water management option effectiveness (e.g. how much each option reduce the drought water shortage?).

The initial conditions, hydrology, and local water supply and demand assumptions are described below. The results of both the stochastic simulations and the stress test hydrology simulations are subsequently presented.

5.1 Initial Conditions

Since the storage conditions were evolving rapidly during the course of this analysis, the DSM was updated with new initial conditions for Lake Pillsbury, Lake Mendocino, Lake Sonoma, and MMWD reservoirs each month starting with November 1, 2021 storage levels. These were subsequently updated for December 1, 2021 and January 1, 2022 levels. Table 1 shows the actual storage in Lake Mendocino, Lake Sonoma, and MMWD reservoirs for these three dates. The storms of December significantly increased the storage conditions in all reservoirs. For the purpose of this memorandum, the modeling results primarily focus on the simulations with January 1, 2022 initial conditions.

Table 1. Storage Conditions for Lake Mendocino, Lake Sonoma, and MMWD Reservoirs

Date	Lake Mendocino	Lake Sonoma	MMWD Storage
Nov 1, 2021	17,895 AF	120,152 AF	41,077 AF
Dec 1, 2021	20,882 AF	121,069 AF	45,841 AF
Jan 1, 2022	41,430 AF	146,680 AF	73,176 AF

5.2 Hydrology

Based on early simulations, it was found that the hydrology of the water year 1976-1977 period represents the most severe two-year extended drought scenario. Thus, a stress test hydrology scenario was derived that includes the effects of the current 2020-2021 drought and then assumes that 2022-2026 is represented by the dry hydrological sequence of 1976-1980. This stress test hydrology is then used for evaluating the resilience of the regional water supply system and effectiveness of various drought management options.

5.3 Water Supply and Demand Assumptions

The primary assumptions for water supply and demands for the future period were derived from published data sources in the UWMPs. However, during retail customer meetings and correspondence some of the groundwater well production numbers were revised based on updated information and that the wells are, in some cases operated seasonally or for only partial days. Table 2 presents the local supplies available to each retail customer. Surface water supplies available to North Marin WD and Marin Municipal WD are simulated dynamically in the DSM and vary depending on hydrology and local reservoir storage condition.

Table 2. Existing Local Supplies Available to Sonoma Water's Retail Customers

Retail Customer	Groundwater Well Production (AFY)	Recycled Water (AFY)	Surface Water (AFY)
Town of Windsor	50	396	0
City of Santa Rosa	1157	140	0
Valley of the Moon WD	604	0	0
City of Sonoma	235	0	0
City of Cotati	448	0	0
City of Rohnert Park	2577	1,004	0
City of Petaluma	785	393	0
North Marin WD	0	658	Varies (dynamic)
Marin Municipal WD	0	750	Varies (dynamic)

Table 3 presents the water demands for each retail customer. The demand estimates for 2025 are derived from the 2020 UWMPs for each customer. No demand reductions are assumed in the baseline simulation.

Table 3. Retail Customer Existing and Future Water Demands (AFY, 2020 UWMPs)

Retail Customer	2020	2025
Town of Windsor	4,288	4,910
City of Santa Rosa	19,387	21,660
Valley of the Moon WD	2,236	2,897
City of Sonoma	2,168	2,331
City of Cotati	950	1,021
City of Rohnert Park	6,755	6,829
City of Petaluma	8,007	8,705
North Marin WD	8,206	10,084
Marin Municipal WD	27,450	26,726

Notes:

(1) 2020 Values obtained from actual demands reported on chapter 4 of the 2020 UWMPs

(2) 2025 Values based on projections reported in chapter 7 of the 2020 UWMPs

(3) Excludes demand for environmental stream releases from MMWD reservoirs

5.4 Reservoir Storage Results

Under the stochastic mode of simulation, 108 different outcomes are generated based on sampling of the historical hydrology. From this ensemble of outcomes, probabilities can be derived to estimate the approximate likelihood of a certain storage condition occurring. Figures 6, 7, and 8 show the resulting storage probabilities for Lake Mendocino, Lake Sonoma, and MMWD reservoirs, respectively.

For the purposes of this report, we define critical storage levels as those which will indicate a water delivery shortage to downstream water uses (Lake Mendocino storage below 20,000 AF, Lake Sonoma storage below 25,000 AF, and MMWD combined reservoir storage below 10,000 AF). The modeling results suggest that the probability of reaching these critical storage levels is relatively low in all reservoirs but remains a possibility in the coming year(s). Results indicate a one percent probability of low point storage in 2023, and five percent probability in 2024, 2025, 2026 in Lake Mendocino; a one percent probability of low storage in 2023 for Lake Sonoma; and up to five percent probability of low storage in 2025 and 2026 for MMWD reservoirs. It should be noted that the near-term critical conditions simulated in the DSM are associated with the 1976-1980 hydrologic sequence (primarily 1976 and 1977). We use this 5-year hydrological period as a stress test and present the results of this sequence in Figures 9, 10, and 11.

Figure 6. Projected Lake Mendocino Storage Probabilities Based on Stochastic Simulations

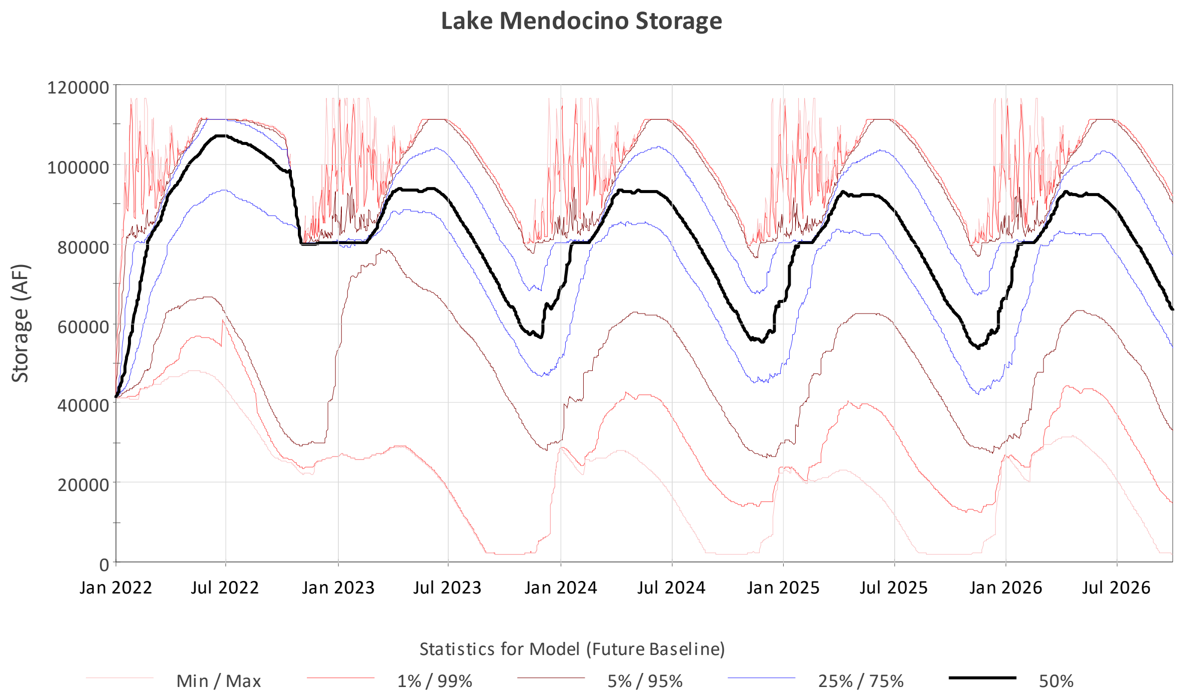


Figure 7. Projected Lake Sonoma Storage Probabilities Based on Stochastic Simulations

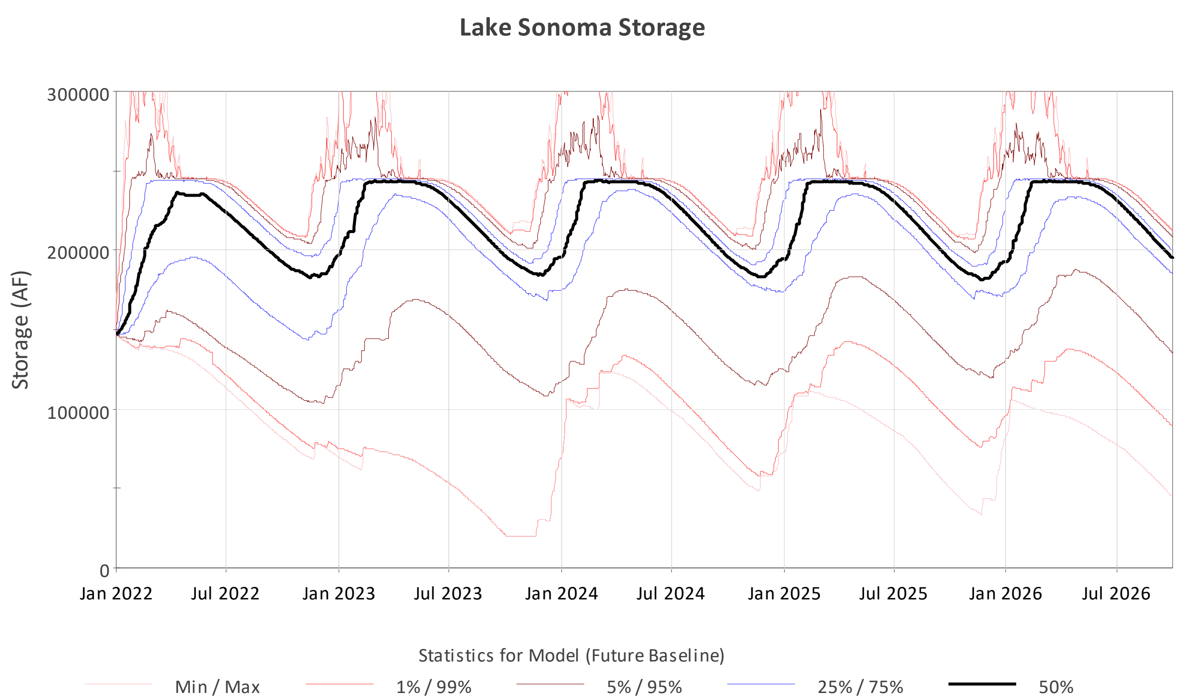


Figure 8. Projected MMWD Reservoir Storage Probabilities Based on Stochastic Simulations

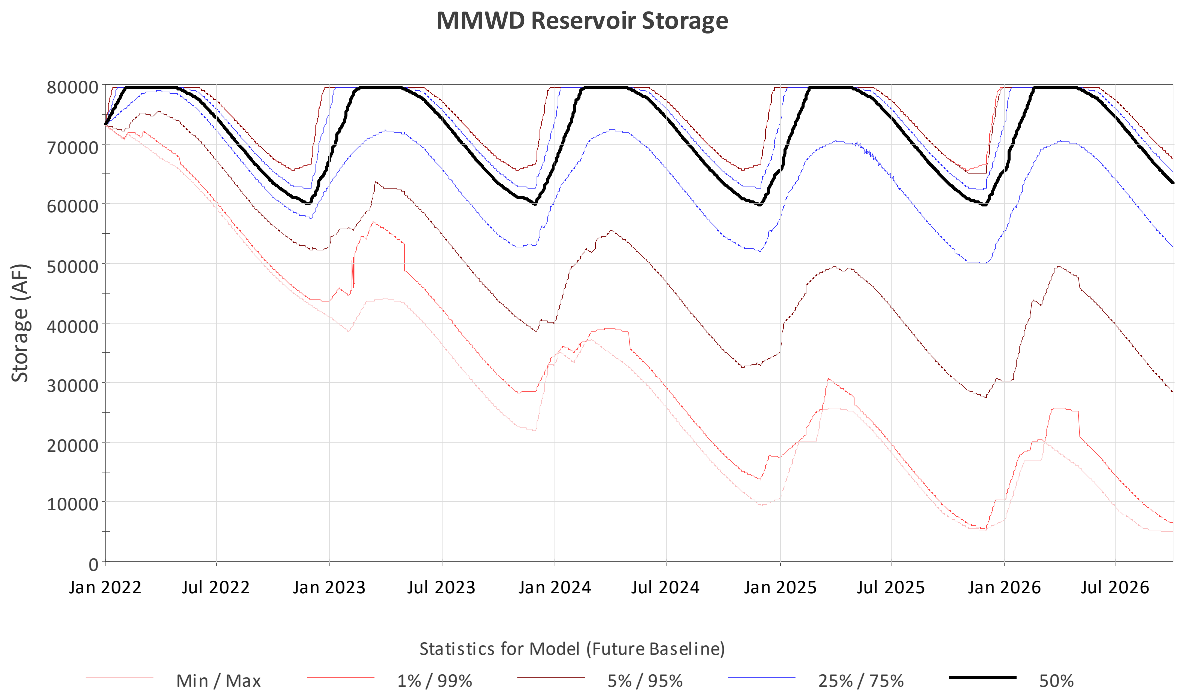


Figure 9. Projected Lake Mendocino Storage using Stress Test Hydrology

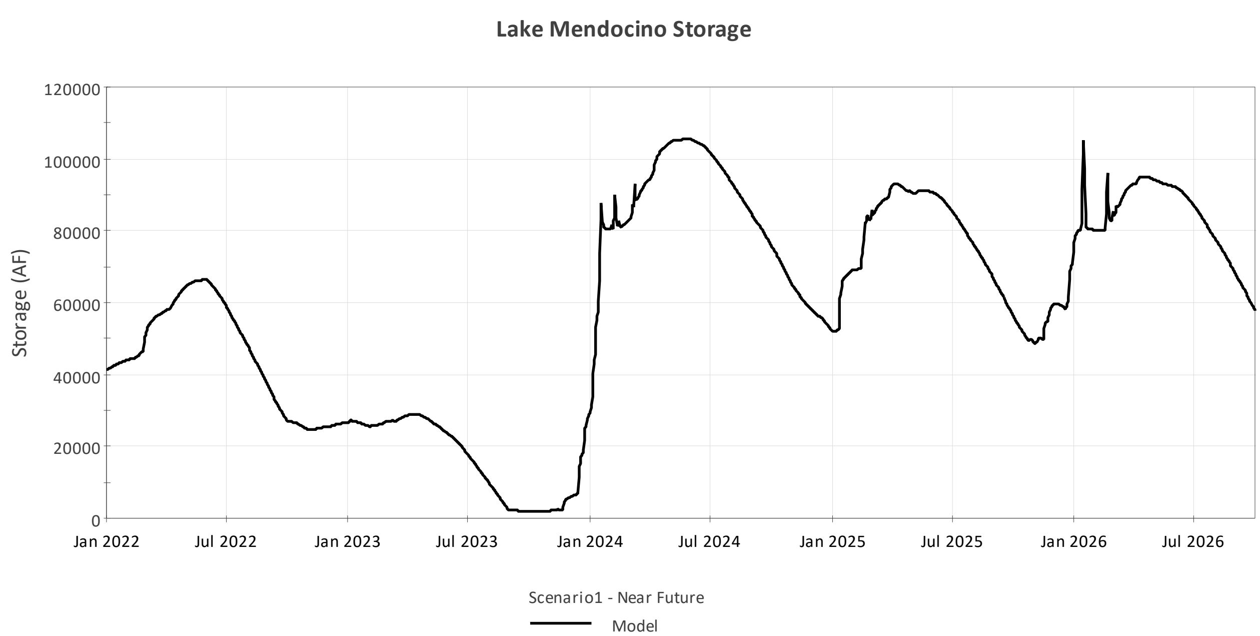


Figure 10. Projected Lake Sonoma Storage using Stress Test Hydrology

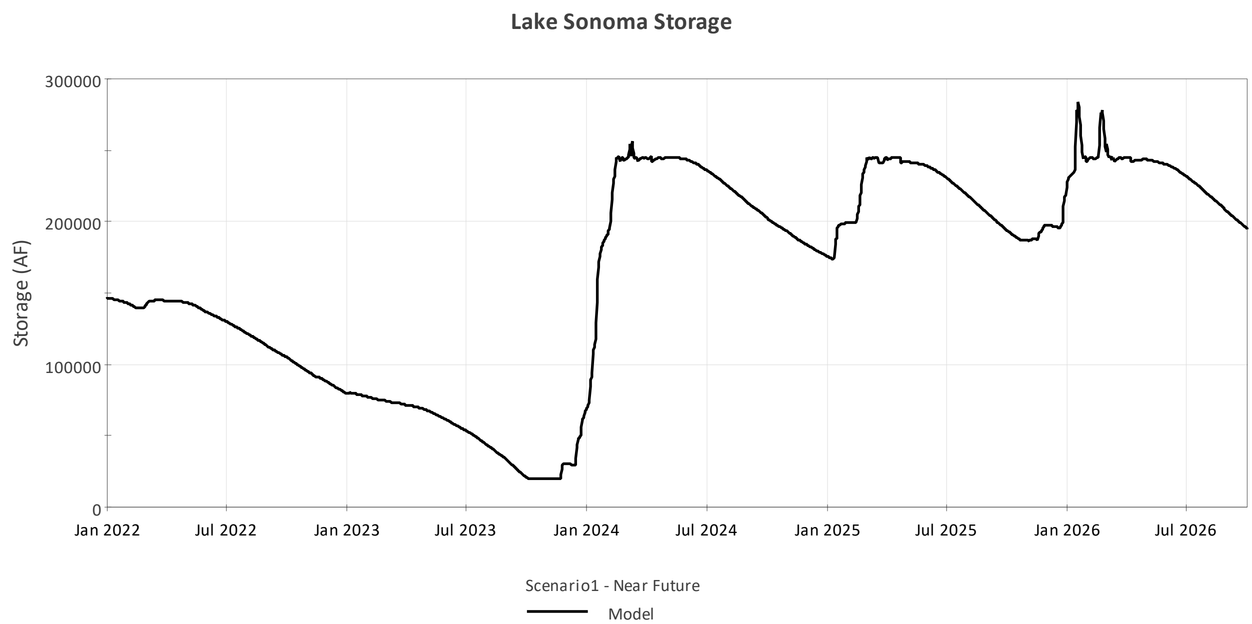
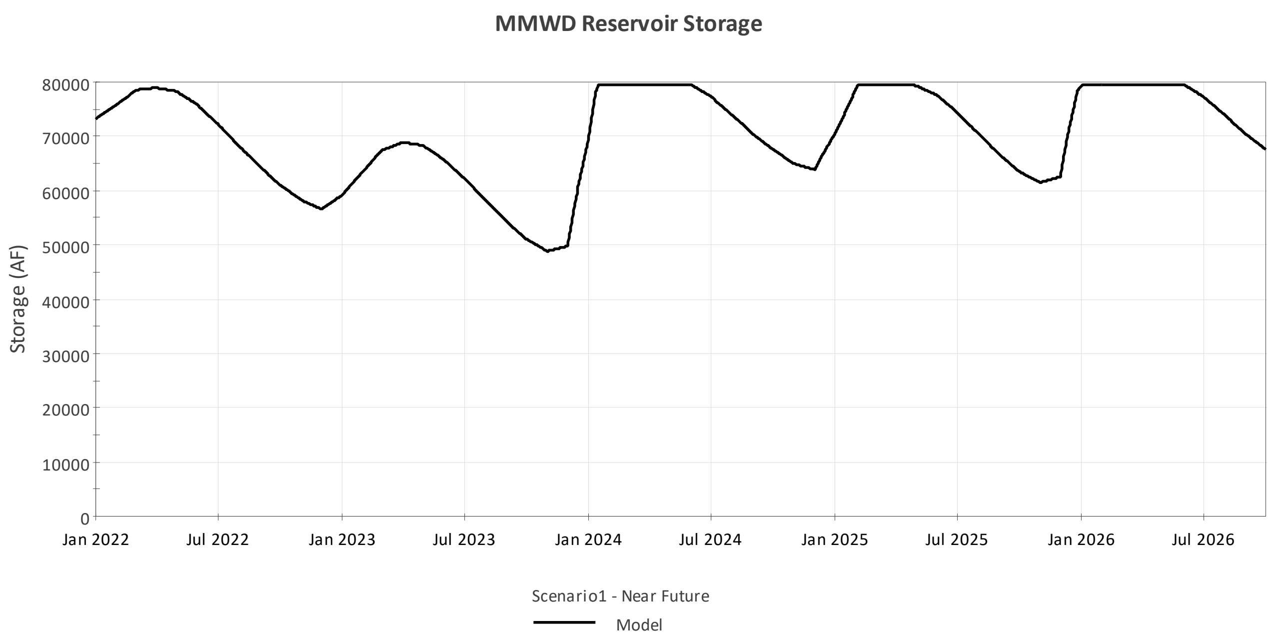


Figure 11. Projected MMWD Reservoir Storage using Stress Test Hydrology



5.5 Shortage Results

The current modeling results suggest the probability of retail customer delivery shortage is also very low. Results indicate a one percent probability of shortage in 2023 and 2024 under the baseline assumptions. The results for magnitude of shortage under the stress test hydrology for November, December, and January initial conditions are shown in Table 4. The December 2021 storms greatly reduced the magnitude of potential shortage from the conditions that were projected in November and early December. The most recent update of storage conditions indicates that shortages will likely not exceed 7,000 AF. This magnitude of potential shortage represents approximately 7 percent Sonoma Water delivery over the two years in which shortages occur.

Table 4. Projected Delivery Shortage to Retail Customers under Stress Test Hydrology

Initial Storage Conditions	NO ACTION Projected 5-Year Shortage Total	Shortage as % of Sonoma Water Delivery*	Shortage as % of Total Water Demand*
Nov 1, 2021	25,600 AF	25%	13%
Dec 1, 2021	23,200 AF	23%	12%
Jan 1, 2022	6,900 AF	7%	4%

6. Potential Drought Management Options

As part of this accelerated drought resiliency planning effort, Jacobs met with most retail customers to develop ideas on the range of drought management options that should be considered in the near- and long-term. These potential drought management options were organized into 4 major categories that include (1) options that increase water supply, (2) options that reduced water demand, (3) options that improve operations, and (4) options that modify policy and regulations. Examples of potential drought management options in each of the categories are listed below:

1. **Increase Supply**
   - Increase groundwater production (new or rehabilitated wells)
   - Winter water diversion (from Russian River)
   - Regional groundwater bank
   - Alexander Valley Flood-Managed Aquifer Recharge (FloodMAR)
   - Sonoma Developmental Center water supply
   - Expand recycled water supply
   - Ocean desalination and/or brackish water desalination
   - Water transfers and interconnection with other Bay Area supplies
2. **Reduce Demand**
   - Water conservation and water use efficiency in municipal, CII, and agricultural sectors
3. **Improve Operations**
   - Kastania Pump Station improvements
   - Expand surface storage of existing reservoirs
   - Lake Sonoma Forecast Informed Reservoir Operations (FIRO)
   - Increase recycled water storage
   - Improve and integrate regional storage operations
   - Lake Mendocino variable gates and outlet channel improvements
4. **Modify Policy and Regulations**
   - Regulatory flexibility through Temporary Urgency Change Permits (TUCPs)
   - Change in Russian River hydrologic index for instream flow setting

Table 5 lists each drought management option and a brief description for those that were carried forward and analyzed in the drought resilience assessment. The table also indicates whether the option should be considered “near-term” or “long-term” to reflect the speed at which the project could be active and begin delivery of drought resilience benefits. In general, “near-term” options are expected to begin delivering benefits by 2024, and “long-term” options could begin delivering benefits beyond 2024.

Table 5. Potential Drought Management Options Considered in the Analysis

Drought Management Option	Option Description	Near-Term/ Long-Term
Baseline	Future Baseline without drought management options	
Increase Groundwater Production (Sonoma Water)	Increase/rehabilitate groundwater production wells in the Santa Rosa Plain including Todd Road Well (1.4 mgd) by December 2021, Sebastopol Road Well (2.1 mgd) by May 2022, and Occidental Road Well (2.0 mgd) by August 2022.	Near-term
Increase Groundwater Production (Retail Customers)	Additional new or rehabilitated well production to be considered for Windsor (0.32 by 2024, 0.97 mgd, six months operation by 2026), Valley of the Moon (0.5 mgd), City of Sonoma (0.12 mgd by 2024), City of Cotati (1.25 mgd), City of Petaluma (0.78 mgd by 2022).	Near-term
Winter Water Diversion (with Kastania PS Improvements)	Excess winter water would be diverted from Russian River collectors and delivered directly to retail customers. Retail customers would prioritize receiving Sonoma Water supplies during this winter period and preserve (or augment) local supplies (particularly for MMWD and NMWD) in storage for use in subsequent dry season(s). This option utilizes existing infrastructure and within current diversion rights. Work toward developing an annual risk management and operations plan for this operation.	Near-term
Regional Groundwater Bank	This project concept would create and manage groundwater banks in three areas: Santa Rosa Plain, Sonoma Valley, and Petaluma Valley. Excess winter water would be recharged into available storage in these groundwater basins, stored, and subsequently extracted for dry year use. Winter water extraction would be limited to Sonoma Water Russian River rights and diversion infrastructure. New ASR wells would be constructed for both recharge and extraction. In-lieu recharge with recycled water supply delivery could also be considered. Assume that up to 1,500 to 5,000 acre-feet of storage could be made available in Santa Rosa Plain, Sonoma Valley, and Petaluma Valley groundwater basins. Extraction water would be used for either direct delivery in the overlying service areas (in-lieu) or pumped into the Sonoma Water transmission system for regional delivery.	Long-Term

Drought Management Option	Option Description	Near-Term/ Long-Term
Alexander Valley FloodMAR	This project proposes to capture Russian River peak flows for subsequent diversion onto Alexander Valley agriculture land for aquifer recharge. Wells on the Jackson Family Wines (JFW) property will pump Russian River underflows during flood periods into a new pipeline that will convey water to properties throughout Alexander Valley. Existing on-farm irrigation and frost protection infrastructure will be used to apply water to the land. Ultimately, the water will infiltrate to groundwater. This project could reduce summer and fall Russian River depletions and allow for either increased storage or retain more water in the channel for downstream water supply uses. Sonoma Water recently received $400k from the County of Sonoma to evaluate flood-MAR viability in Alexander Valley and potentially develop a pilot scale system. Assume water delivery can be applied to 2,000 acres with maximum application/recharge rate of 0.5 feet per day.	Long-Term
Sonoma Developmental Center Water Supply	SDC's main potable water system is served by a conventional surface water treatment plant with a design capacity of 1.8 mgd. Treated water has consistently produced high quality exceeding permit requirements. Current production for SDC use is less than 0.56 mgd. This project concept would increase the production to original design capacity and use the additional supply for either recharge in Sonoma Valley groundwater basin or for direct use in Valley of the Moon or City of Sonoma service areas. Use of existing 2.05 million gallon water storage tanks would allow for temporary regulatory storage.	Long-Term
Expand Recycled Water Supply	Increase delivery and use of recycled water for non-potable purposes. Assume implementation of North Bay Water Reuse Program Phase 2 Projects which increase contractors' recycled water availability as: NMWD (Novato Sanitary District, 326 AFY), MMWD (153 AFY), Petaluma (223 AFY). Excludes increases in delivery to wetlands, agriculture, or for uses not in service area. Assume 10% increase in UWMP recycled water delivery estimates for all other contractors.	Long-Term
Ocean Desalination (low)	Emergency desalination of 3.6 mgd ocean desalination production (available package plants) in Marin County. Assume delivery of emergency desalination water would be delivered to MMWD.	Long-Term
Ocean Desalination (high)	Expanded ocean desalination of up to 10 mgd. Assume expanded desalination supply could be delivered to MMWD and NMWD.	Long-Term
Petaluma Brackish Groundwater Desalter	Brackish groundwater desalter in lower Petaluma Valley. Assumed at capacity of 3.6 mgd. Assume delivery of groundwater supply to Petaluma, NMWD, and MMWD.	Long-Term

Drought Management Option	Option Description	Near-Term/ Long-Term
Water Transfers and Interconnection with Bay Area Water Agencies	Drought year water transfers would be negotiated and purchased from Central Valley water agricultural users and conveyed through interconnections with Bay Area water agencies (EBMUD or City of Vallejo). Based on current MMWD reports, assume 8 mgd could reliably be delivered.	Long-Term
Expanded Water Conservation and Water Use Efficiency (10%)	Expand programs for water conservation in municipal and CII sectors. Assume a 10 percent reduction in total water use from 2020 UWMP demands could be achieved in each of these sectors. Reductions limited to ensure that health and safety demands are always satisfied.	Near-term
Expanded Water Conservation and Water Use Efficiency (20%)	Expand programs for water conservation in municipal and CII sectors. Assume a 20 percent reduction in total water use from 2020 UWMP demands could be achieved in each of these sectors. Reductions limited to ensure that health and safety demands are always satisfied.	Near-term
Expanded Water Conservation and Water Use Efficiency (30%)	Expand programs for water conservation in municipal and CII sectors. Assume a 30 percent reduction in total water use from 2020 UWMP demands could be achieved in each of these sectors. Reductions limited to ensure that health and safety demands are always satisfied.	Near-term
Expanded Water Conservation and Water Use Efficiency (high + RR)	Expand programs for water conservation in agricultural, municipal, and CII sectors. Assume a 30 percent reduction in total water use could be achieved in these sectors. This action includes a 30 percent reduction in Russian River on-river depletions in addition to a 30 percent reduction to the in the municipal and CII sectors.	Near-term
Kastania Pump Station Improvements	MMWD proposes to rehabilitate and operate the Kastania Pump Station to address the emergency drought conditions. Minor modifications include refurbishment and operation of one of the existing pump sets, installation of approximately 100 linear feet of 30-inch yard piping and a 6-foot by 8-foot flowmeter vault and resurfacing of existing driveway. The modifications would increase the operable capacity to deliver aqueduct water to MMWD by about 6.5 mgd. Improvements could be completed by the early 2022.	Near-term
Expand Surface Storage	Capacity and rule curve changes to reflect increase in water conservation pool storage due to Lake Stafford Adjustable Weir. Increases in storage capacity at Lake Stafford of 700 AF.	Long-Term
Lake Sonoma Forecast Informed Reservoir Operations (low)	The process for viability assessment at Lake Sonoma is in process. This option is relatively small deviation that includes a 9,500 AF increase in storage in the conservation pool during October 1 through February 28 and 19,000 AF increase during March 1 through September 30.	Near-term/ Long-term
Lake Sonoma Forecast Informed Reservoir Operations (high)	The process for viability assessment at Lake Sonoma is in process. This option involves a larger deviation that includes a 19,000 AF increase in storage in the conservation pool during October 1 through February 28 and 38,000 AF increase during March 1 through September 30.	Near-term/ Long-term

Drought Management Option	Option Description	Near-Term/ Long-Term
Regulatory Flexibility through TUCPs	Reduce minimum instream flow requirements in the Russian River to approximately 50-70 cfs consistent with actions taken in 2021 due to drought conditions.	Near-term

Several near-term drought resiliency options were either in progress or were believed to be implementable in a relative short time. These options, listed below, were combined into a near-term package and simulated to test the ability of these measures to address the immediate drought risks.

- Maximize delivery of natural flows from Russian River system
- Kastania Pump Station rehabilitation
- Increase groundwater production (Sonoma Water)
- Increase groundwater production (Retail Customers)
- Regulatory flexibility through TUCPs
- Water conservation and water use efficiency (Retail Customers and diverters)

Near-term package simulations were conducted with a variable 10, 20, and 30 percent retail customer conservation as compared to 2020 UWMP demands to test the sensitivity. Figures 12, 13, and 14 show the resulting simulated storage conditions for Lake Mendocino, Lake Sonoma, and MMWD reservoirs.

For all reservoirs, the “near-term” package of options provides sufficient capability to address the critically low storage conditions. For Lake Mendocino, the “regulatory flexibility through TUCPs” and “Russian River depletion reductions” provides the greatest increase in storage. For Lake Sonoma, the “regulatory flexibility through TUCPs”, “increase groundwater production”, and “water conservation” options all support higher storage. For MMWD reservoir storage, the “winter water” and “water conservation” options support significantly increased storage.

The projected shortage that was present in the baseline simulation is also resolved with implementation of the “near-term” package of options. Figure 15 shows the shortage using the stress test hydrology for the baseline (in black), individual options (in blue), and the near-term package (in green). Water conservation, TUCPs, and increasing groundwater production all reduce the projected shortage individually, and, when combined in a package, provide sufficient capability to resolve all projected shortages in the simulations. Water conservation levels offer additional capability to bolster storage should the drought be more severe than that simulated. It is anticipated that reductions in Russian River diversions would likely be necessary to show good faith when requesting for continuing flexibility in TUCPs.

Figure 12. Projected Lake Mendocino Storage with Near-Term Package using Stress Test Hydrology

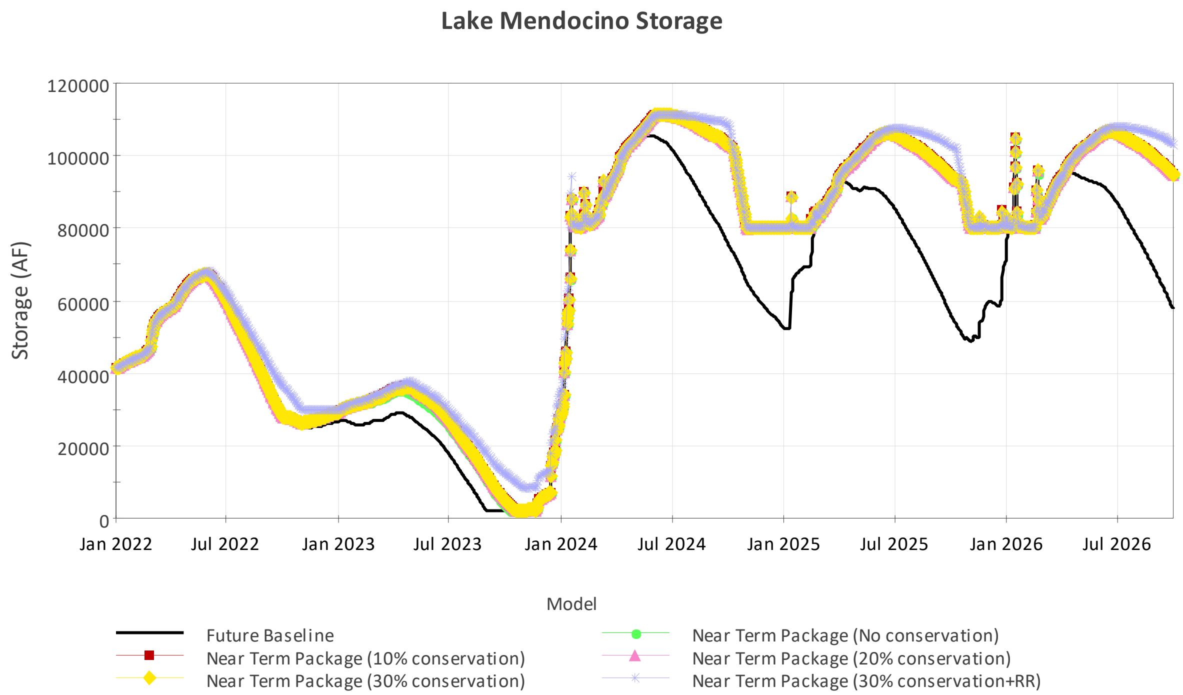


Figure 13. Projected Lake Sonoma Storage with Near-Term Package using Stress Test Hydrology

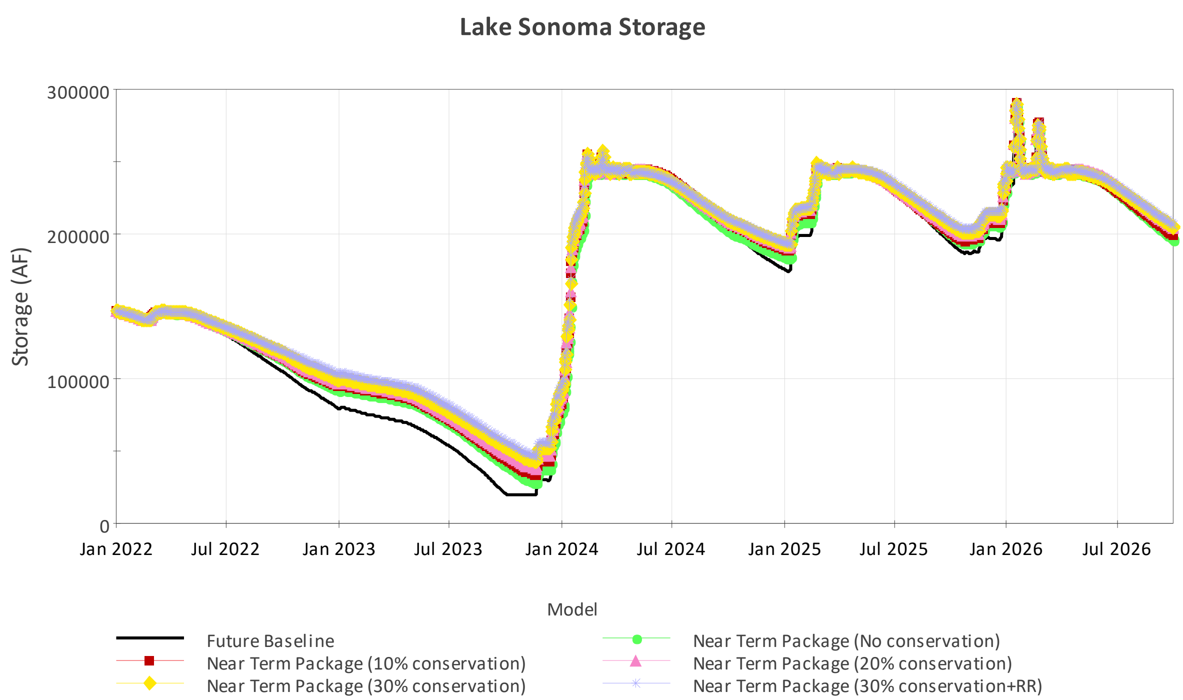


Figure 14. Projected MMWD Reservoir Storage with Near-Term Package using Stress Test Hydrology

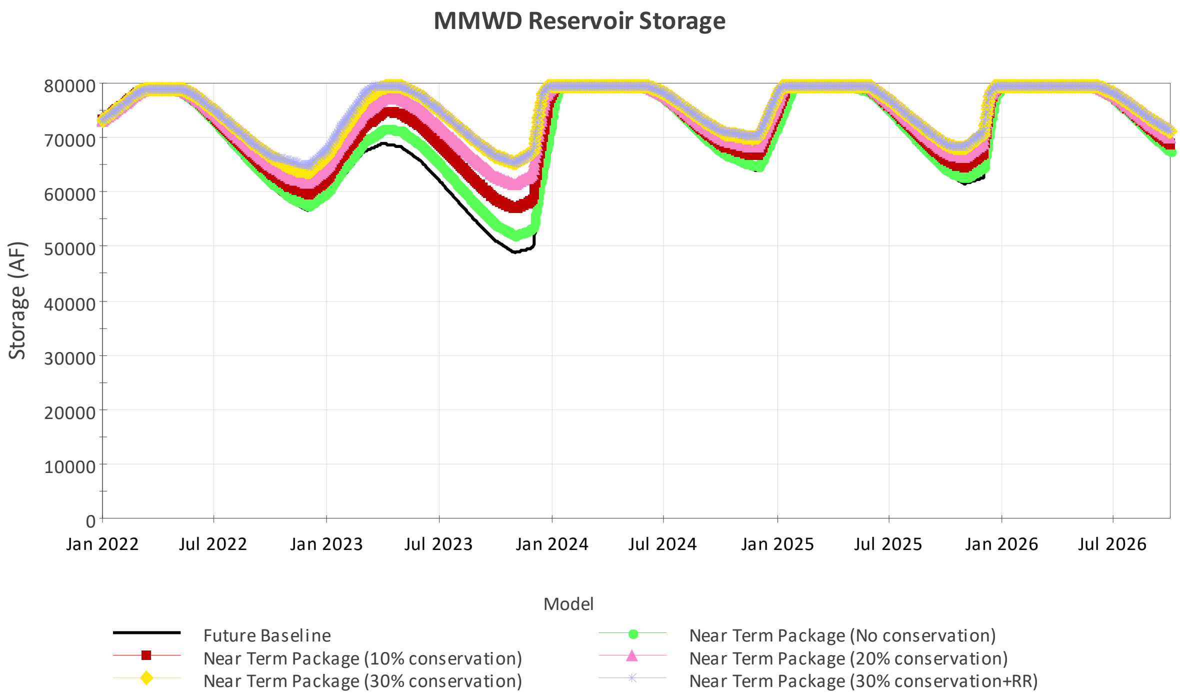
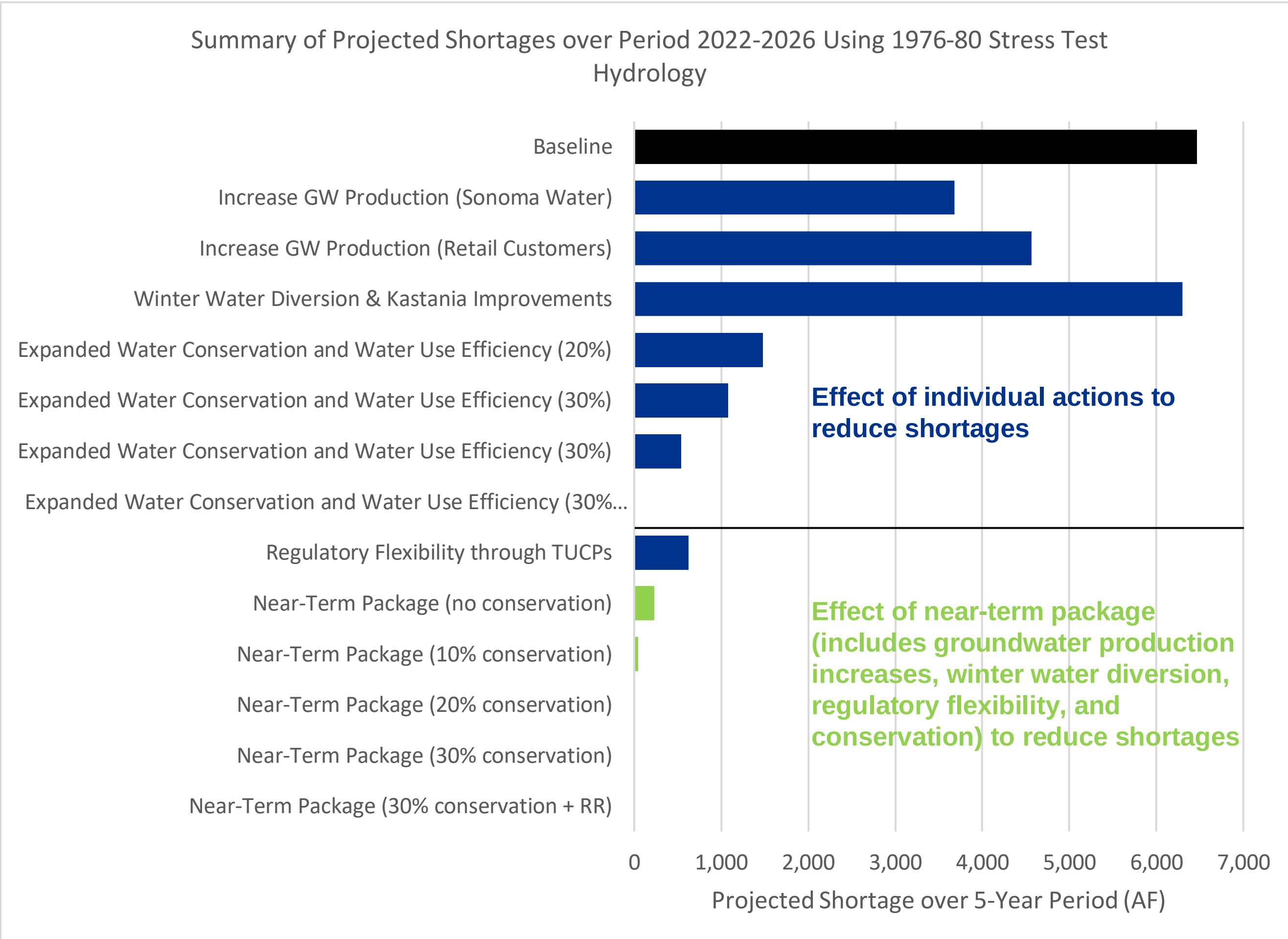


Figure 15. Projected Shortage with Baseline and Near-Term Package Options using Stress Test Hydrology



7. Evaluation of Drought Management Options

After compiling and evaluating the potential drought management options, an evaluation was performed on each in order to provide a characterization with respect to criteria such as cost, feasibility, implementation timing and complexity, permitting, legal, environmental, and jurisdiction. The complete list of evaluation criteria is shown in Table 6. For each criterion, a rating scale of 1 through 5 was used to characterize the concept related to the specific measure. The characterization of drought management options in this fashion is designed to allow Sonoma Water and its retail customers to begin to evaluate promising options for further study or implementation.

Table 7 shows the draft results of the application of the criteria to each drought management option. The anticipated drought benefit for the near-term stress test and future drought are shown in the first columns. Only the options that were included in the near-term package have results for the near-term stress test, while all options have estimated benefits in terms of either shortage reductions or storage improvements for the future drought period. The benefits for most options are larger in the future drought period for two reasons. First, some of the options like the regional groundwater banks and Lake Sonoma FIRO require a preceding wet sequence to build the storage before providing benefit in subsequent drought years. And second, the future drought period benefit includes substantial storage increase benefits that are derived from actions like water conservation that was not accounted for in the near-term drought analysis which only considered contribution to shortage reductions.

Timing for implementation was estimated based on discussions with team members or from available documentation. Costs are estimated as the capital and O&M costs for the particular option divided by the expected supply increase or demand reduction. For options that are anticipated to be regional in nature and provide water through the Sonoma Water transmission system, O&M costs were estimated at $615 per acre-foot per year based on Sonoma Water rate schedules for prime contractors. Other per acre-foot charges included in Sonoma Water standard water rates are not currently included. Drought management options that are considered sub-regional or local in that the supply provided may not enter the Sonoma Water transmission system does not include Sonoma Water O&M rates, but has an estimated separate O&M rate. All costs should be considered draft and will be updated with a range in the next revision.

Table 6. Evaluation Characterize Drought Management Options

		Rating				
Criteria	**Description**	**1**	**2**	**3**	**4**	**5**
Cost	Estimate of capital and annual costs.	Cost per acre-foot of supply or demand reduction. ($/AFY)				
Timing	Estimate of time required before project could be implemented considering planning, design, permitting, and implementation.	Year in which project could be implemented (Year)				
Environmental	Anticipated impacts on the natural environment	Significantly positive impacts are likely to exist, and negative impacts are not readily apparent	Moderately positive impacts are anticipated at some locations while other locations may or may not have negative impacts of a lesser degree	Option does not have an impact or impacts are expected to be neutral	Moderately negative impacts are anticipated at some locations while other locations may or may not have positive impacts of a lesser degree	Significant negative impacts are likely to exist, and positive impacts are not readily apparent.
Feasibility	Maturity of the concept and technical ability to implement.	Regularly implemented in USA at scale proposed	Occasionally implemented somewhere in the world at similar scale	Regularly implemented but at smaller scales	Occasionally implemented somewhere in the world or has not been done, but peer review articles indicate promise	Has not been done and no peer review articles exist or they indicate challenges.
Energy	Estimated change in energy required to implement and operate.	Requires no additional energy, or results in net positive generation	Minor increases in energy use (less than 5%).	Modest increases in energy use (less than 15%).	Large increases in energy use (less than 30%).	Major changes in energy use (greater than 30%)
Permitting/Legal	Anticipated permitting and legal challenges	Does not require an EIR or other major permits	Requires an EIR or other major permits, but similar projects of this scale have been approved in the past 20 years	Requires an EIR or other major permits, but similar projects of smaller scale have been approved in the past 20 years	Requires an EIR and no precedent exists for the option.	Requires an EIR and similar options have been declined during the permit process
Social	Description of positive or negative socioeconomic effects.	Significantly positive impacts are likely to exist, and negative impacts are not readily apparent	Moderately positive impacts are anticipated at some locations while other locations may or may not have negative impacts of a lesser degree	Option does not have an impact or impacts are expected to be neutral	Moderately negative impacts are anticipated at some locations while other locations may or may not have positive impacts of a lesser degree	Significant negative impacts are likely to exist, and positive impacts are not readily apparent.

Jurisdiction	Primary jurisdiction for implementation	Primarily involves Sonoma Water facilities and control	Requires Sonoma Water and other County department actions	Requires Sonoma Water Contractor actions	Requires utility or state agency/ federal actions	Requires private citizens and landholder actions

Table 7. Potential Drought Management Options Considered in the Analysis

Drought Management Option	Drought Benefit, Near-Term Stress Test (AF)	Drought Benefit, Future Drought (AF)	Cost ($/AFY)	Timing	Environmental	Feasibility	Energy	Permitting/ Legal	Social	Jurisdiction
Increase Groundwater Production (Sonoma Water)	2400	2100	$700	2022	3	1	3	1	3	1
Increase Groundwater Production (Retail Customers)	2100	1300	$500-$3,000	2022	3	1	3	1	3	3
Winter Water Diversion (with Kastania Improvements)	500	6800	$650	2021	3	1	3	1	3	3
Regional Groundwater Bank		8300	$800-$900	2025	3	2	3	3	4	5
Alexander Valley FloodMAR		100	$600-$700	2023	3	3	3	2	3	4
Sonoma Developmental Center Water Supply		100	$800-$1,000	2025	3	3	3	3	3	4
Expand Recycled Water Supply		1200	$2,300-$3,000	2025	2	2	3	3	3	4
Ocean Desalination (low)		8200	$3,200-$3,500	2022	4	3	3	4	3	5
Ocean Desalination (high)		25700	$3,200-$3,500	2025	4	4	4	5	4	5
Petaluma Brackish Groundwater Desalter		8200	$1,500-$2,000	2025	3	3	3	3	3	4
Water Transfers and Interconnection with Bay Area Water Agencies		18100	$2,400	2023	4	4	3	3	4	4
Expanded Water Conservation and Water Use Efficiency (low)	5400	27000	$350	2021	1	1	1	1	2	5
Expanded Water Conservation and Water Use Efficiency (high)	6200	41600	$450	2021	2	2	1	1	4	5
Expanded Water Conservation and Water Use Efficiency (high + RR)	6800	58600	$500	2021	2	2	1	1	4	5

Expand Surface Storage (Lake Stafford weir)		100	$550	2022	3	3	2	2	3	3
Lake Sonoma Forecast Informed Reservoir Operations (low)		9700	$30	2022	3	2	1	2	2	4
Lake Sonoma Forecast Informed Reservoir Operations (high)		26400	$30	2023	3	2	1	3	2	4
Regulatory Flexibility through TUCPs	6300	61600	$30	2021	4	1	1	2	3	4
Notes:			Estimate of capital and annual costs. Projects with * indicate that SW O&M included for regional transmission.	Estimate of time required before project could be implemented.	Anticipated impacts on the natural environment	Maturity of the concept and technical ability to implement	Estimated increase in energy required to implement and operate	List of permits required and status if option has begun permitting process.	Description of positive or negative socioeconomic effects.	Primary jurisdiction for implementation

8. Summary and Recommendations

The accelerated drought resiliency analysis presented in this memorandum has helped meet the need of the moment to characterize the risk and potential solutions for the possibility of continuing dry conditions. Droughts are a way of life in most of California and robust drought planning should be considered a normal water management practice. The recent drought has challenged the regional water system and raised awareness of water managers to work collaboratively and seek integrated solutions for proactive drought planning.

The DSM has undergone substantial improvements during this accelerated drought analysis and is now well situated to address additional risks. The major modeling accomplishments are listed below:

- Russian River, Transmission System, and Retail Customer Systems have been interconnected
- DSM has been validated for system water supply and operations
- Representation of retail customer systems is adequate for this level of analysis
- DSM can simulate individual years or stochastic simulations involving ensemble of hydrology

Through this interactive engagement process, the DSM has been used to help identify near-term and long-term drought risks; Specifically,

- Existing hydrologic conditions continue to be challenging
- December storms have altered near-term drought outlook, but have not eliminated the risk
- Unlikely, but possible risk to Lake Mendocino storage and Lake Sonoma storage (2023), and delivery (2023-24)
- Stress test hydrology of WY 1976-1980 is used to test drought options

A range of drought management options have been evaluated in this accelerated study. Despite the conceptual nature of this analysis some significant findings can be stated:

- For all reservoirs, the “near-term” package of options including increasing Sonoma Water and retail customer groundwater production, increasing diversion of winter water with Kastania PS improvements, regulatory flexibility through TUCPs, and water conservation provides sufficient capability to address the potential for critically low storage conditions.
- For the scenarios analyzed, the near-term package of options eliminates stress-test shortages with moderate levels of water conservation
- Winter water diversions, water conservation, and groundwater production helps reduce shortages and can bolster or save storage in reservoirs
- Conservation and regulatory flexibility under TUCPs are the most important in bolstering Lake Sonoma and Mendocino storage
- Longer-term actions of regional groundwater bank and Lake Sonoma FIRO will provide significant benefit for future droughts but require initial wet period to begin storage phase

- Larger alternative supply options need further evaluation and adequate comparisons to Russian River options and water conservation

Based on the results of this accelerated drought resiliency analysis, several recommendations are provided. To address the acute and on-going drought in 2022, it is important to ***accelerate implementation of the actions identified as near-term drought management options***. Increasing groundwater production at both Sonoma Water and retail customer wells will add a temporary “new” supply to the regional water system, while increasing winter water diversion of Russian River supply will reduce the need for withdrawal of water from local reservoirs. Continuing water conservation efforts and regulatory flexibility on reservoir releases for instream flows will both help close the gap between supply and demand and increase storage in reservoirs for the potential of a prolonged drought. State and federal drought resiliency grant opportunities exist to move these actions forward.

The 2020-2022 drought is providing a real-time stress test of the regional water management system. And while the focus is on resolving this near-term challenge, it is important to recognize that droughts are a natural part of the hydroclimate of the region. This drought will eventually be broken and followed by a period of wet years, until yet another drought occurs. Planning for both the current and future droughts is important. For ***future droughts, we have the ability to plan more effectively and ensure activation of drought management options that are more regional in nature***. Forecast-Informed Reservoir Operations at Lake Sonoma has the potential to increase reservoir storage in the years just preceding the onset of drought and provide additional storage for an extended drought. Similarly, a regional groundwater bank could provide opportunities for underground storage of wet year/season supply for use in drought years and provide a mechanism for in-lieu exchanges to occur throughout the region. Developing integrated operations of Russian River storage, Marin storage, and groundwater storage could lead to synergies that increase the effective storage for the region and increase the region’s resilience. Finally, the development and expansion of water reuse, desalination, and water purchase options needs to be further explored.

Along with all of these water supply and operational improvements, water conservation needs to be a foundational tool to help manage the water demand in the long-term and during acute periods of drought. These longer-term options will be further explored in the Resiliency Study and related efforts by Sonoma Water and its retail customers and additional recommendations will be put forward in late 2022.