N DROUGHT ASSESSMENT MODELING RESULTS TECHNICAL MEMORANDUM

City of Santa Cruz
Drought Assessment Modeling Results
Technical Memorandum

I. Introduction

Kennedy Jenks Consultants (KJ) supported the development of the City of Santa Cruz's 2026 Urban Water Management Plan (UWMP) by developing model simulations to evaluate potential drought conditions for the City's water supply system. The simulations were developed using the Santa Cruz Water Supply System Model (SCWSM) and the results were used to inform the City's UWMP Drought Risk Assessment (DRA) and Water Service Reliability Assessment (WSRA). The goal for these model simulations was to simulate the Santa Cruz water supply system ability to meet water demands during normal years, dry years, and extended drought periods.

Modeling required for the UWMP includes the DRA scenarios to evaluate the capacity of the City's water supply system to meet water demands during a 5-year drought sequence assuming the drought period starts the subsequent year (i.e. 2026, and the WSRA scenarios to evaluate the capacity of the City's water supply system to meet water demands over the next 25 years, in five-year increments, with the following conditions:

- Single Normal Year;
- Single Dry Year; and
- 5-year Drought Sequence.

The City's UWMP historically has included a DRA and WSRA using both a historical drought sequence and a projection of what a future drought sequence might be considering plausible climate change conditions, resulting in the following list of modeling categories:

- Historic DRA
- Historic WSRA
- Climate Change DRA
- Climate Change WSRA

This memorandum will document modeling assumptions and initial conditions for the above four categories, a summary of how model simulations were executed, and an overview of the modeling results.

II. Modeling Assumptions and Input Conditions

1. Climate Change and Historical Hydrology

Two models developed by the Hydrosystems Research Group at the University of Massachusetts Amherst (UMass) were used to complete this modeling effort: the Drought

Assessment Graphical User Interface (the GUI) and the Santa Cruz Water System Model (SCWSM). The GUI and SCWSM have similar code-bases, but the GUI has the City's historical hydrology built into the program whereas SCWSM utilizes specified 100-year simulations of plausible future climate conditions and hydrology to glean information on the City's ability to meet water demands under changing climate conditions. Model simulations with historic hydrology are thus completed with the GUI and simulations with climate change hydrology are completed with SCWSM. The climate scenario used for the UWMP climate change simulations uses the climate realization R-1270.

a. Historical Climate

The City's historical hydrological record for the San Lorenzo River dates back to 1937. For water supply planning, the City uses a five-tiered annual classification system that classifies water years into five classes based on cumulative annual streamflow (runoff) in the San Lorenzo River at the Big Trees gage in Felton.

For drought modeling efforts, the City has selected to use a 5-year sequence that includes their worst drought years on record: 1973-1977. Although the first 3 years of this sequence are not categorized as dry years, the final two years represent the highest stress on the Santa Cruz water system with the lowest recorded streamflow for the San Lorenzo River in 1977. Figure 1 shows the 1937-2022 flow at Big Trees, and the 1973-1977 sequence. Figure 2 shows 1937-2020 data organized into the 5 primary hydrology categorizations ranking all historical years from driest to very wet. The driest year on record is shown to be 1977.

Figure 1. Historical Climate Hydrology

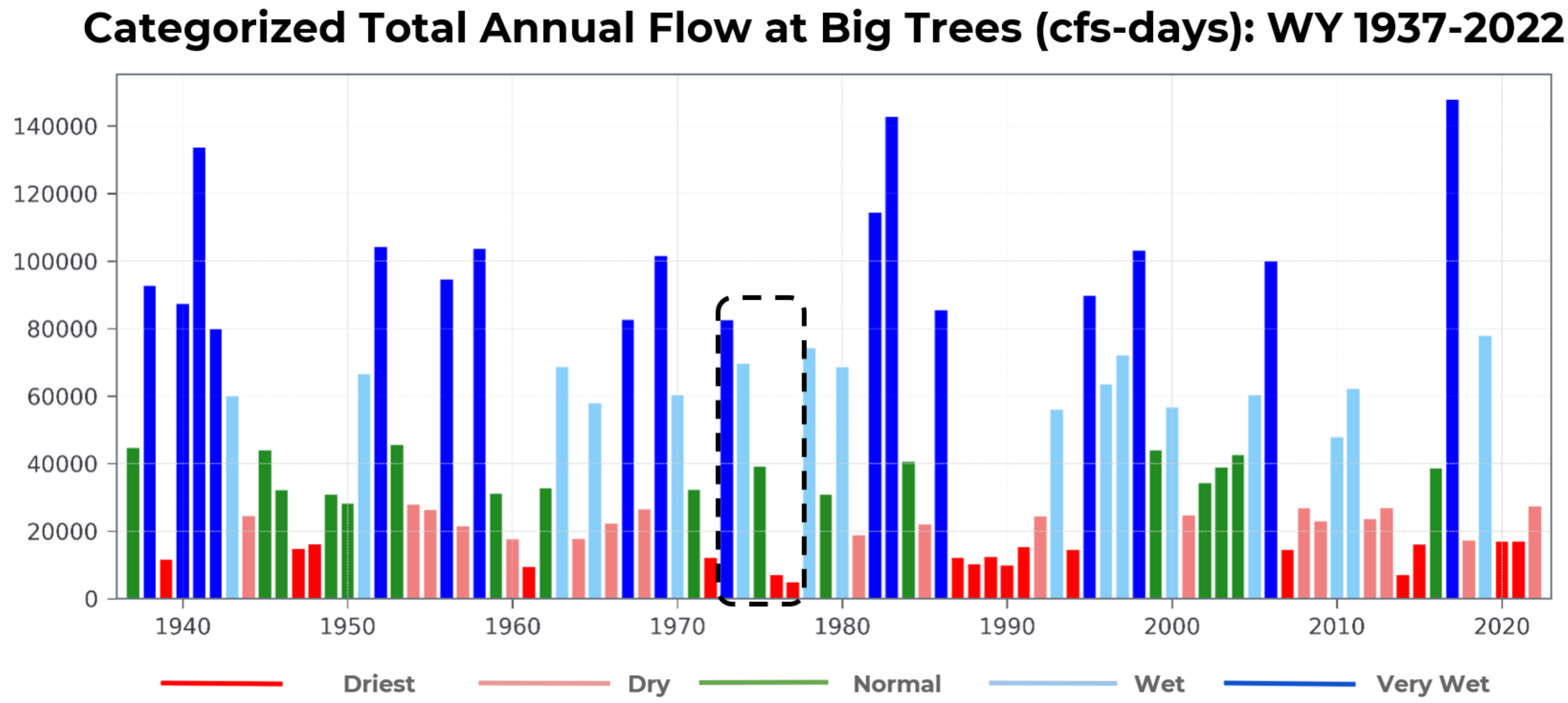
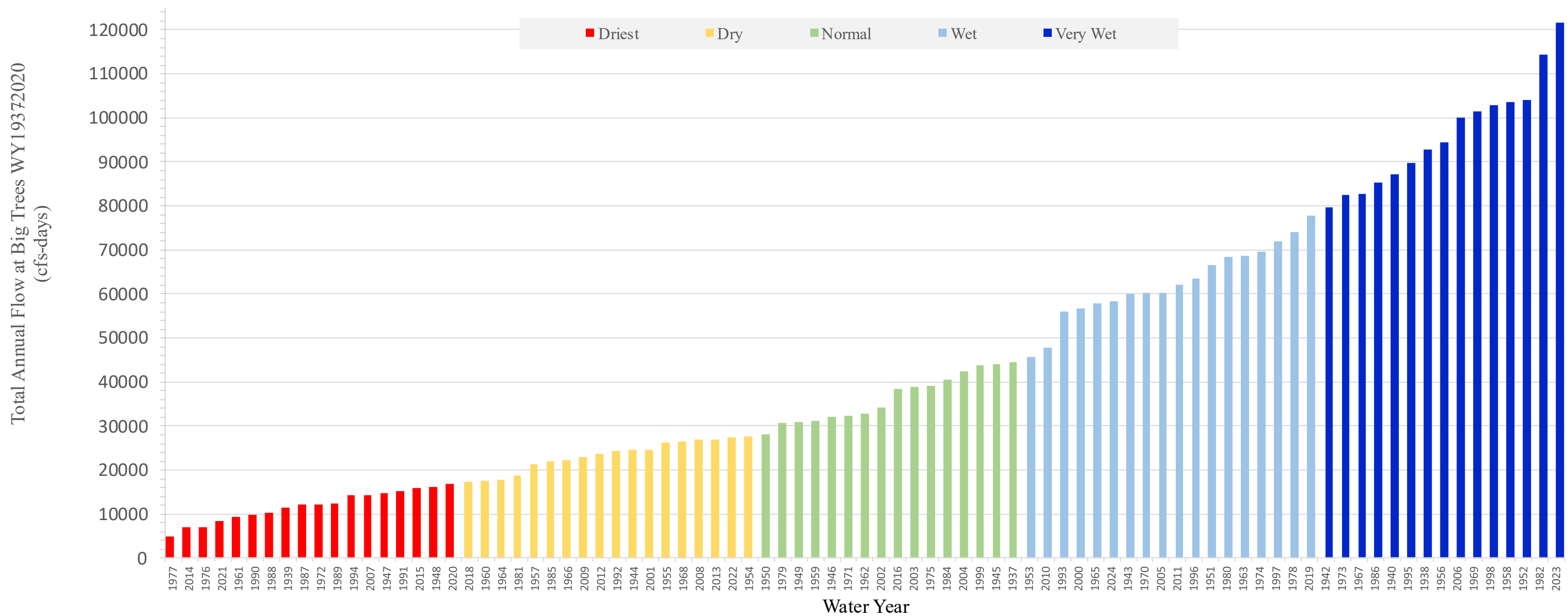


Figure 2. Historical Years Organized by water year type



b. Climate Change Realization R-1270-p1

As part of the Long-Term Vulnerability Assessment (LTVA) completed in collaboration with UMass, the City selected a climate realization to simulate how the water system would perform during an extreme drought period under temperature, precipitation, and climate variations. This realization, known as R-1270-p1, with a temperature increase of 2ºC, no precipitation differential, and a 10% increase in climate variability was selected in the Securing Our Water Future policy adopted by Santa Cruz City Council in 2022 and subsequently utilized in both WSAIP and UWMP modeling efforts. For UWMP modeling, the five-year drought selected for R-1270-p1 spans 2055-2059, the driest period in the 100-year simulation. The selected single driest year is 2059, and the selected normal year is 2040. Figure 3 shows the 100-year climate simulated sequence classified by the five-tiered annual classification system. Figure 4 shows 100-year R-1270-p1 simulated years ranked from driest to very wet

Figure 3. Climate Change Realization R-1270-p1 Hydrology

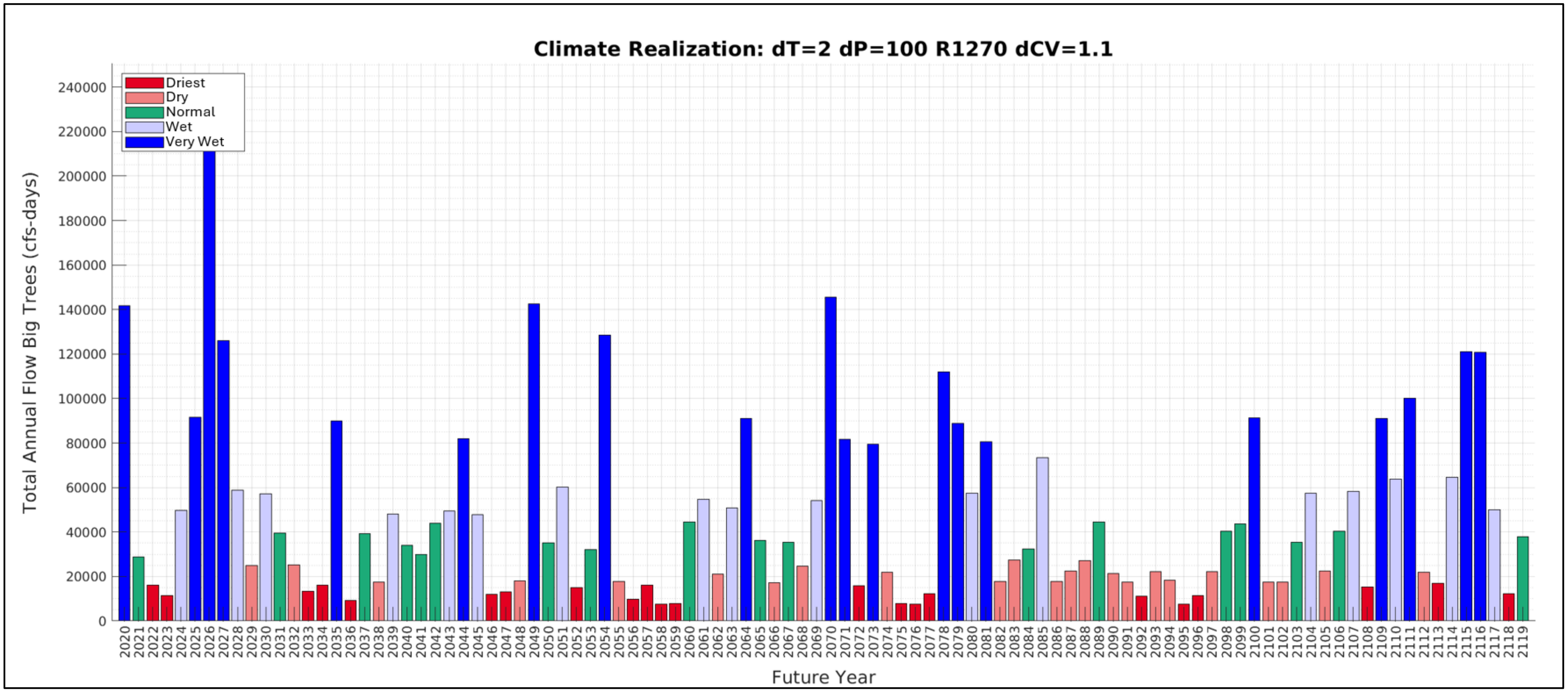
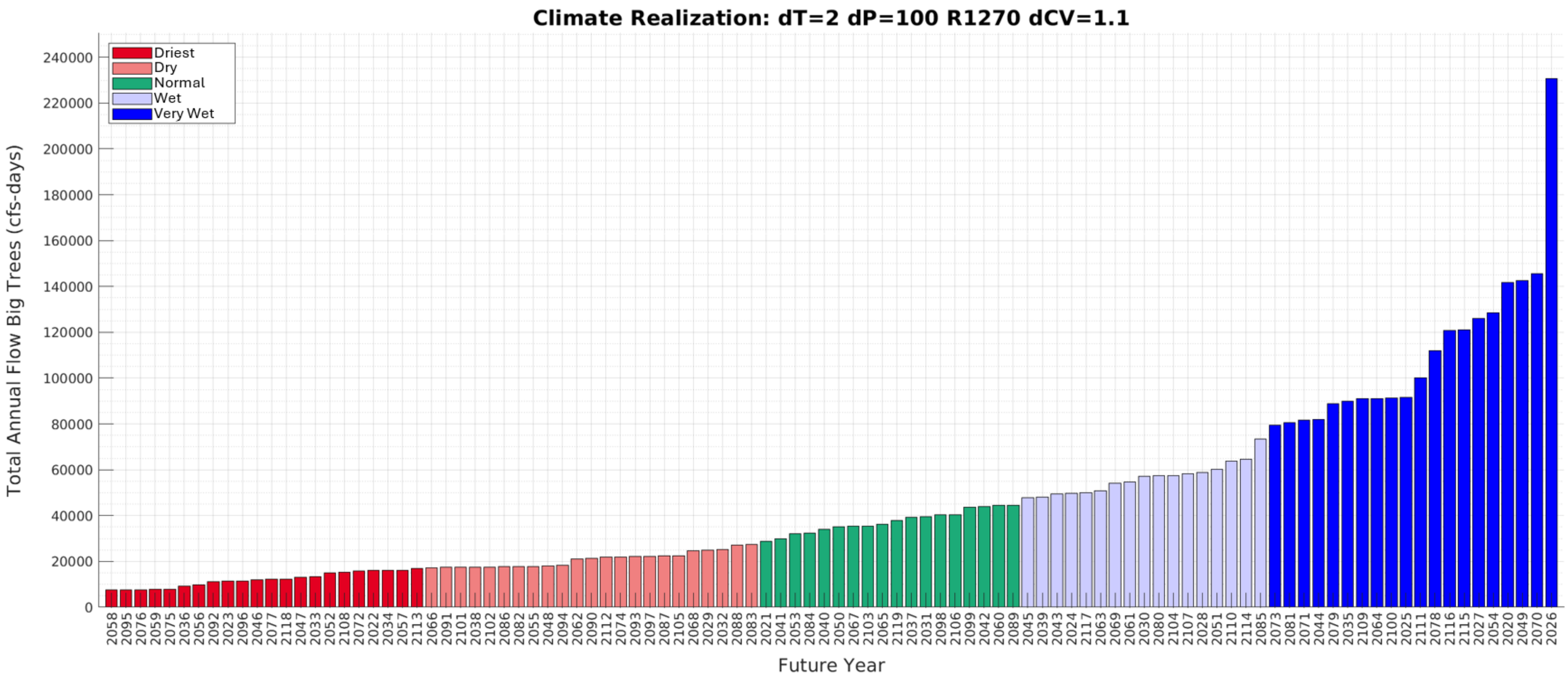


Figure 4. Climate Change Realization R-1270-p1 Years Organized by water year type

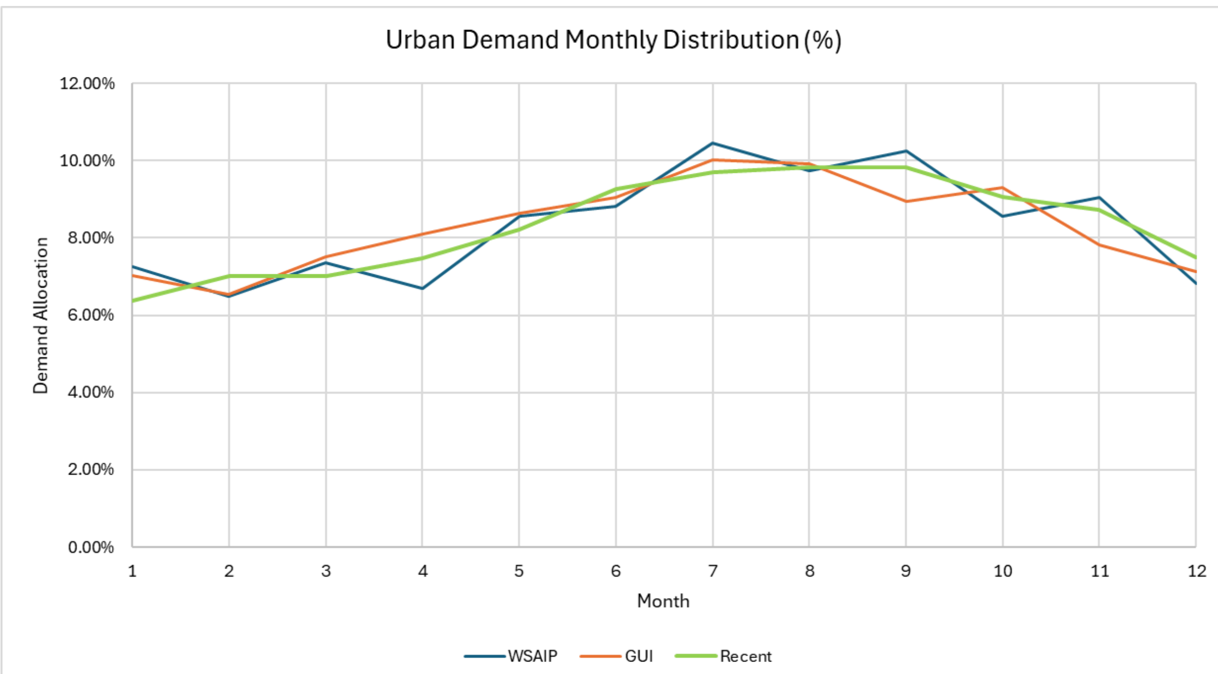


2. Demand Distribution

The GUI and the SCWSM models were originally developed with similar but not identical water demand distribution curves as shown in Figure 5 that closely follow recent water demand data from the City. To ensure comparable results between climate and historical hydrology simulations, the monthly profile for urban demand distribution used on the GUI was also used in the SCWSM.

During modeling, it was discovered that SCWSM has a high sensitivity to changes in monthly demand distribution. Tests discovered that variations in water supply deficits between the default SCWSM and GUI distributions ranged from 80 million gallons and 120 million gallons, with SCWSM default distributions yielding the higher deficit. Figure 5 shows the difference in monthly demand distribution between the GUI, SCWSM, and recent demand data. While all distributions follow a similar pattern, it is predicted that the variation in September demand is what is driving the difference in supply deficit.

Figure 5.Urban Water Demand Monthly Distribution.



3. Water Supply Projects

The WSAIP identified different water supply alternatives the City could implement to create a diversified water supply portfolio that would allow them to meet water demands during severe drought conditions.

The City selected a WSAIP Portfolio, Portfolio 1D, as the starting point for implementation that included the following water supply projects:

1. Conversion of 4 existing groundwater extraction wells (Beltz Wells 8, 9, 10, 12) to Aquifer Storage and Recovery (ASR) wells capable of injecting and extracting water from the groundwater basin.

2. Construction of 2 new ASR wells.

3. Intertie connections and improvements to allow for water transfers between the City and both Scotts Valley and Soquel Creek Water Districts.

4. An expansion of a regional indirect potable reuse project, Pure Water Soquel in partnership with Soquel Creek Water District.

The ASR well conversion and new wells, and the water transfer projects are incorporated into the DRA and WSRA model simulations based on the year in which these projects are planned to be completed and operational. The assumptions used for the ASR wells and transfers are summarized in the following sections.

The expansion of Pure Water Soquel was not included in the model simulation at this time, therefore there are no assumptions used for this specific project.

a. ASR Wells

For both the DRA and WSRA simulations, all wells are modeled as ASR wells. The current 4 groundwater wells, Beltz Wells 8, 9, 10, 12, are simulated as ASR wells with injection rates as defined in the below tables, Table 1 and Table 2. Injection rates are included in all simulations, even in years prior to groundwater wells being converted to ASR wells as injections only occur when there is no drought present and thus does not impact available supply.

Extraction rates used for the current 4 groundwater wells, Beltz Wells 8, 9, 10, 12, remain the same extraction rates for these wells once converted to ASR wells. The difference in extraction capacities used is based on the conditions under which the wells are expected to operate. During a severe drought, as is simulated with the DRA, the wells are expected to operate at higher extraction rates as shown in Table 1. During normal years and long term operations, as simulated with the WSRA, the wells are expected to operate at their sustainable extraction rates shown in Table 2, which are based on extraction rates modeled for ensuring groundwater basin sustainability for long term use. Injection and extraction rates used were provided by the City based groundwater modeling efforts consistent with the Santa Cruz Mid-County basin Groundwater Sustainability Plan.

Table 1. Drought Risk Assessment Well Extraction Rates

Well ID	Injection (MGD)	Extraction (MGD)
Beltz9	0.22	0.72
Beltz10	0.14	0.44
Beltz8	0.17	0.65
Beltz12	0.3	0.69
Total Beltz Wells	**0.83**	**2.5**

Notes:

MGD: Million Gallons/day

Table 2. Water Service Reliability Assessment Well Extraction Rates.

Well ID	Injection (MGD)	Extraction (MGD)
Beltz9	0.22	0.63
Beltz10	0.14	0.39
Beltz8	0.17	0.65
Beltz12	0.3	0.69
Total Beltz Wells	**0.83**	**2.36**
ASR1	0.36	0.62
ASR2	0.09	0.69
Total Beltz and New ASR Wells	**1.28**	**3.67**

Notes:

MGD: Million Gallons/day

b. Transfers with Scotts Valley and Soquel Creek Water Districts

Both the DRA and WSRA simulations included water transfers from Scotts Valley Water District (SVWD) and Soquel Creek Water District (SqCWD), with increasing transfer capacities based on the years in which these water supply project improvements are expected to be completed. Transfer capacities from SVWD start at 0.7 MGD and increase to 1 MGD. Transfer capacities from SqCWD start at 1 MGD and increase to 1.4 MGD.

For the WSRA simulations, completed using the SCWSM model, transfers are set to the maximum capacity for all simulations since the water supply projects for these transfers are expected to be completed by the timeline WSRA simulations cover.

For DRA simulations of individual years, these upgrades are reflected in alignment with the City's Capital Investment Program and the planned timeline for completion of these water supply project modifications.

It should be noted that transfers from the City of Santa Cruz to Scotts Valley are only turned on for the single normal year simulations under WSRA simulations as Santa Cruz does not expect to transfer water out of the system during droughts. The City does not transfer water to SqCWD under any simulation.

4. Other Assumptions

The WSRA includes increased capacity at the Graham Hill Water Treatment Plant (GHWTP) from 16.5 MGD to 18 MGD and increased capacity at the Tait Diversion and Coast Pump Station from 7.5 MGD to 18 MGD consistent with planned projects included in the City's Capital Investment Program (CIP).

For all model simulations, the starting level for Loch Lomond reservoir in the first year of each simulation was set to 2,573 MG, as this was the Loch Lomond level as of January 1, 2026, with the following years in the simulation starting Loch Lomond level from the previous year reservoir level end point.

5. DRA Assumptions

The assumptions used for the DRA simulations using historical climate and hydrology are shown in Table 3. These assumptions were developed with collaboration with the City, based on the expected water supply conditions for the next 5 years.

Table 3. DRA simulations with Historic Hydrology.

Model Simulation ID	DRA-H-2026	DRA-H-2027	DRA-H-2028	DRA-H-2029	DRA-H-2030
Analysis Years	2026	2027	2028	2029	2030
Hydrologic Years Used	Historic 1973 (year 1)	Historic 1974 (year 2)	Historic 1975 (year 3)	Historic 1976 (year 4)	Historic 1977 (year 5)
Demand (BG)	2.5	2.5	2.6	2.6	2.6
Reservoir Starting Level (MG)	2,573	2,860[a]	2,860[a]	2,629[a]	2,038[a]
Capacity of Water Transfers to City (MGD)	SVWD = 0.7	SVWD = 0.7	SVWD = 0.7 SqCWD = 1.0	SVWD = 0.7 SqCWD = 1.0	SVWD = 1 SqCWD = 1.4
Water System Conditions	GHWTP Capacity = 16.5MGD Tait Diversion and Coast Pump Station Capacity = 7.5 MGD Groundwater and ASR total extraction at 2.5 MGD				

Notes:

[a] Starting Reservoir Levels are the output of the 12/31 reservoir level of the previous year.
BG: Billion Gallons
MG: Million Gallons
MGD: Million Gallons/day

The assumptions used for the DRA simulations using climate change hydrology are shown in Table 4. The climate simulations were completed using the conditions for each planning year. A demand of 2.9 billion gallons was used for all planning year simulations, and the demand data was adjusted in data post processing.

Table 4. DRA simulations with R-1270-p1 Hydrology.

Model Simulation ID	DRA-C-2026	DRA-C-2027	DRA-C-2028	DRA-C-2029	DRA-C-2030
Analysis Years	2026	2027	2028	2029	2030
Hydrologic Years Used	R-1270-p1 (year 1, 2055)	R-1270-p1 (year 2, 2056)	R-1270-p1 (year 3, 2057)	R-1270-p1 (year 4, 2058)	R-1270-p1 (year 5, 2059)
Demand[a] (BG)	2.9	2.9	2.9	2.9	2.9
Reservoir Starting Level (MG)	2,573	2,645[b]	2,308[b]	1,712[b]	1,071[b]
Capacity of Water Transfers to City[c] (MGD)	SVWD = 1 SqCWD = 1.4	SVWD = 1 SqCWD = 1.4	SVWD = 1 SqCWD = 1.4	SVWD = 1 SqCWD = 1.4	SVWD = 1 SqCWD = 1.4
Existing Water System Conditions	GHWTP Capacity = 16.5MGD Tait Diversion and Coast Pump Station Capacity = 7.5 MGD Groundwater and ASR total extraction at 2.5 MGD				

Notes:

[a] Input demand set to 2050 demand of 2.9 BG, demand adjusted for individual years in data post-processing.
[b] Starting Reservoir Levels are automatically assigned by SCWSM based on the previous year.
[c] Transfers are modeled at the max rate planned in 2030 and are post-processed to match conditions for each previous year.
BG: Billion Gallons
CPS: Coastal Pump Station
MG: Million Gallons
MGD: Million Gallons/day

6. WSRA Assumptions

The assumptions used for the WSRA simulations using historical climate and hydrology are shown in Table 3. These assumptions were developed with collaboration with the City, based on the expected water supply conditions the system will be operated at for these timeframes based on the City's CIP. The assumptions used for the WSRA simulations using climate change hydrology are shown in Table 4.

Table 5. WSRA Simulations with Historical Hydrology

Model Simulation ID	RA-H-2030a	RA-H-2030b	RA-H-2030c	RA-H-2035a[b]	RA-H-2035b[b]	RA-H-2035c[b]
Analysis Years	2030	2030	2030	2035	2035	2035
Demand [a] (BG)	2.9	2.9	2.9	2.9	2.9	2.9
Hydrologic Years Used	Historic 2010 (normal)	Historic 1977 (single dry)	Historic 1973 - 1977 (drought)	Historic 2010 (normal)	Historic 1977 (single dry)	Historic 1973 - 1977 (drought)
Reservoir Starting Level (MG)	2,573	2,573	2,573	2,573	2,573	2,573
Capacity of Water Transfers to City (MGD)	SVWD = 1 SqCWD = 1.4			SVWD = 1 SqCWD = 1.4		
Water System Conditions	GHWTP at 16.5MGD Tait/CPS at 7.5 MGD ASR wells extraction at 2.36 MGD			GHWTP to 18MGD Tait/CPS to 18MGD ASR Wells extraction at 3.67 MGD		

Notes:

[a] Input demand set to 2050 demand of 2.9 BG. Demand adjusted for individual years in data post-processing
b These runs provided results for 2035-2050.
CPS: Coastal Pump Station
MG: Million Gallons
MGD: Million Gallons/day

Table 6. WSRA Simulations with R-1270-p1 Hydrology

Model Simulation ID	RA-C-2030a	RA-C-2030b	RA-C-2030c	RA-C-2035a[b]	RA-C-2035b[b]	RA-C-2035c[b]
Analysis Years	2030	2030	2030	2035	2035	2035
Demand [a] (BG)	2.9	2.9	2.9	2.9	2.9	2.9
Hydrologic Years Used	R-1270-p1 (normal)	R-1270-p1 (single dry)	R-1270-p1 (drought)	R-1270-p1 (normal)	R-1270-p1 (single dry)	R-1270-p1 (drought)
Reservoir Starting Level (MG)	2,573	2,573	2,573 [b]	2,573	2,573	2,573[b]
Capacity of Water Transfers to City (MGD)	SVWD = 1 SqCWD = 1.4			SVWD = 1 SqCWD = 1.4		
Water System Conditions	GHWTP at 16.5MGD Tait/CPS at 7.5 MGD ASR wells extraction at 2.36 MGD			GHWTP to 18MGD Tait/CPS to 18MGD ASR Wells extraction at 3.67 MGD		

Notes:

[a] Input demand set to 2050 demand of 2.9 BG, demand adjusted for individual years in data post-processing.
[b] These runs provided results for 2035-2050.

BG: Billion Gallons
CPS: Coastal Pump Station
MG: Million Gallons
MGD: Million Gallons/day

III. Drought Risk Assessment Modeling Results

1. Historical Hydrology Simulations

A summary of the results obtained for the DRA simulations with the conditions listed in Table 3 with historical hydrology is presented in Table 7.

Table 7. Historic DRA Results

Model Simulation ID	DRA-H-2026	DRA-H-2027	DRA-H-2028	DRA-H-2029	DRA-H-2030
North Coast Sources (MG)	549	727	500	472	483
San Lorenzo River (MG)	1,472	1,662	1,875	1,190	834
Loch Lomond (MG)	388	95	143	304	258
GW and/or ASR (MG)	0	0	0	288	428
Transfers SVWD (MG)	91	16	35	157	266
Transfers SqCWD (MG)	0	0	46	189	330

2. Climate Change Hydrology Simulations with R-1270-p1

A summary of the results obtained for the DRA simulations with the conditions listed in Table 4 with climate change hydrology is presented in Table 8.

Table 8. Climate DRA Results

Model Simulation ID	DRA-C-2026	DRA-C-2027	DRA-C-2028	DRA-C-2029	DRA-C-2030
North Coast Sources (MG)	673	456	394	400	463
San Lorenzo River (MG)	1,507	869	861	593	1,196
Loch Lomond (MG)	138	325	367	526	20
GW and/or ASR (MG)	38	372	388	411	359
Transfers SVWD (MG)	66	208	260	314	226
Transfers SqCWD (MG)	78	270	331	358	288

IV. Water Service Reliability Assessment Modeling Results

1. Historical Hydrology Simulations

A summary of the results obtained for the WSRA simulations with the conditions listed in Table 5 with historical hydrology is presented in Table 9, Table 10, and Table 11.

Table 9. Normal and Single Dry Historic Water Service Reliability Results

Model Simulation ID	RA-H-2030a	RA-H-2030b	RA-H-2035a	RA-H-2035b
North Coast Sources (MG)	554	483	554	483
San Lorenzo River (MG)	1,778	581	1,911	681
Loch Lomond (MG)	53	472	53	294
GW and/or ASR (MG)	0	418	0	632
Transfers SVWD (MG)	121	284	88	272
Transfers SqCWD (MG)	94	361	94	337

Table 10. 5-Year Drought (2030-2034) Historic Water Service Reliability Results (RA-H-2030c)

Model Simulation ID	RA-H-2030c	RA-H-2031c	RA-H-2032c	RA-H-2033c	RA-H-2034c
North Coast Sources (MG)	549	727	500	472	483
San Lorenzo River (MG)	1,406	1,731	1,777	965	581
Loch Lomond (MG)	315	80	143	336	472
GW and/or ASR (MG)	0	0	0	300	418
Transfers SVWD (MG)	148	31	113	244	284
Transfers SqCWD (MG)	181	31	66	282	361

Table 11. 5-Year Drought Historic Water Service Reliability Results (RA-H-2035c)

Model Simulation ID	RA-H-2035c	RA-H-2036c	RA-H-2037c	RA-H-2038c	RA-H-2039c
North Coast Sources (MG)	549	727	500	472	483
San Lorenzo River (MG)	1,512	1,839	1,939	1,066	681
Loch Lomond (MG)	315	80	143	241	294
GW and/or ASR (MG)	0	0	0	434	632
Transfers SVWD (MG)	143	24	51	226	272
Transfers SqCWD (MG)	181	31	66	261	337

2. Climate Change Hydrology Simulations with R-1270-p1

A summary of the results, obtained for the WSRA simulations with the conditions listed in Table 6 with climate change hydrology is presented in Table 12, Table 13, and Table 14. All results are presented in Million Gallons (MG).

Table 12. Normal and Single Dry Climate Water Service Reliability Results

Model Simulation ID	RA-C-2030a	RA-C-2030b	RA-C-2035a	RA-C-2035b
North Coast Sources (MG)	348	400	348	400
San Lorenzo River (MG)	1,446	593	1,561	693
Loch Lomond (MG)	219	546	190	358
GW and/or ASR (MG)	259	388	364	597
Transfers SVWD (MG)	160	315	118	305
Transfers SqCWD (MG)	168	360	119	348

Table 13. 5-Year Drought (2030-2034) Climate Water Service Reliability Results (RA-C-2030c)

Model Simulation ID	RA-C-2030c	RA-C-2031c	RA-C-2032c	RA-C-2033c	RA-C-2034c
North Coast Sources (MG)	673	456	394	400	463
San Lorenzo River (MG)	1,608	968	860	631	1,167
Loch Lomond (MG)	139	342	384	506	19
GW and/or ASR (MG)	36	353	368	388	339
Transfers SVWD (MG)	66	209	261	315	228
Transfers SqCWD (MG)	78	272	333	360	292

Table 14. 5-Year Drought (2035-2039) Climate Water Service Reliability Results(RA-H-2035c)

Model Simulation ID	RA-C-2035c	RA-C-2036c	RA-C-2037c	RA-C-2038c	RA-C-2039c
North Coast Sources (MG)	673	456	394	400	463
San Lorenzo River (MG)	1,720	1,073	963	692	940
Loch Lomond (MG)	127	210	245	358	320
GW and/or ASR (MG)	35	530	551	597	508
Transfers SVWD (MG)	66	197	245	305	209
Transfers SqCWD (MG)	78	234	302	348	260

V. Conclusions

The DRA and WSRA simulations showed how the water supply system could perform with implementation of planned water supply projects, under potential near-term and future drought conditions.