TECH MEMO

REPLENISH — Big Bear —

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Project:	Replenish Big Bear Program
Subject:	Water Quality Analysis for the Sand Canyon Recharge Area

Introduction

As part of the Replenish Big Bear Program (Program), up to 380 acre-feet per year (AFY) of Program Water stored in Big Bear Lake will be used for groundwater recharge at the Sand Canyon Recharge Area over a six-month dry weather period. In addition, Program Water stored in Big Bear Lake could also be extracted to irrigate Bear Mountain Golf Course (up to 120 AFY) and for dust control of a bike park at the Snow Summit Ski Resort (up to 120 AFY). This technical memorandum evaluates whether these proposed uses of the blended Program Water stored in Big Bear Lake have the potential to cause violations of any water quality standards in Big Bear Valley Basin, violations of expected waste discharge requirements or otherwise degrade surface or groundwater quality.

Per the Santa Ana River Basin Plan (Basin Plan), the Big Bear Valley Basin has a total dissolved solids (TDS) objective of 300 mg/L, a hardness objective of 225 mg/L, a sodium objective of 20 mg/L, a chloride objective of 10 mg/L, a nitrate as N objective of 5 mg/L, and a sulfate objective of 20 mg/L. As shown in **Table 1**, Big Bear Lake has more stringent water quality objectives, so the proposed use of Program Water (which is purified water) is estimated to improve water quality in Big Bear Lake for TDS, total nitrogen (TN), and maintain similar water quality for total inorganic nitrogen (TIN) as discussed in the Antidegradation Analysis for Proposed Discharges to Stanfield Marsh/ Big Bear Lake and Shay Pond (WSC/LWA, 2022).

Table 1. Water Quality Objectives for Receiving Waters

Water Quality Objective (WQO)	Big Bear Lake	Big Bear Valley
Total Dissolved Solids (TDS), mg/L	175	300
Hardness, mg/L	125	225
Sodium, mg/L	20	20
Chloride, mg/L	10	10
Total Inorganic Nitrogen, mg/L	0.15	--
Nitrate as N	--	5
Sulfate, mg/L	10	20
Total Phosphorus, mg/L (TMDL Objective)	0.035	--
Chlorophyll-a, mg/L (TMDL Objective)	0.014	--

Per conversations with DDW, Big Bear Lake may be designated as a non-restricted recycled water impoundment, and the subsequent use of Program Water stored in Big Bear Lake water for snowmaking, landscape irrigation, dust control, and groundwater recharge via surface application would be subject to recycled water regulations. The non-potable recycled water uses for landscape irrigation, dust control, snowmaking, and nonrestricted impoundment are anticipated to be regulated under the Statewide Water Reclamation Requirements for Recycled Water Use (Oder WQ 2016-0068-DDW). This Order sets rules for recycled water users to avoid the overapplication of recycled water that would result in runoff or groundwater recharge. Therefore, it can be assumed that these proposed uses will not impact the water quality of the Big Bear Valley Basin.

To permit the Sand Canyon groundwater recharge project via surface application, the City of Big Bear Lake Department of Water (BBLDWP), the lead proponent for that portion of the Program, will need to submit a Report of Waste Discharge (ROWD) and technical studies to the Santa Ana Regional Water Quality Control Board to obtain a Waste Discharge Requirements (WDR) permit to implement the proposed uses in the Sand Canyon Recharge Area. As part of the WDR permit process, an antidegradation analysis will be prepared to evaluate the water quality impacts in more detail than this technical memorandum to demonstrate that the project is consistent with state antidegradation policy. An antidegradation analysis is robust and is used by regulators to set permit conditions. Another study that will be completed as part of the ROWD is a Title 22 Engineering Report. This report will describe how the permittee will comply with the regulations applicable to a surface application groundwater recharge project. Overall, the WDR permitting process ensures that the beneficial uses of Big Bear Valley Basin are protected by setting permit requirements to mitigate and/or avoid impacts. These studies will be completed once the design of the advanced water purification facility (AWPF) and Sand Canyon recharge facilities are more developed to provide the necessary information.

Predicted Concentrations of TDS and Selected Constituents in Sand Canyon Recharge

To evaluate the potential impacts that the Program Water stored in Big Bear Lake will have on Big Bear Valley Basin, the same CE-QUAL-W2 model used for Big Bear Lake Analysis (Anderson 2021) was used to simulate the water quality of the blended Program Water and Big Bear Lake at the extraction point. The extraction point is located near Rathbun Creek, and Program Water would be extracted using an existing pump station and pipeline used by the Bear Mountain and Snow Summit Resorts to extract lake water for snowmaking. The model simulated the extraction of Program Water stored in Big Bear Lake for groundwater recharge (380 AFY) and landscape irrigation (120 AFY). The extraction for dust control was not accounted for in the model since the model showed that Big Bear Lake extractions improved water quality (at least for TDS), so this scenario is more conservative as additional extraction would yield better water quality results. This simulation evaluated predicted conditions for a 41-year time period using available meteorological and hydrologic data for 2009-2019 and a probability-based forward forecast using the median hydrologic scenario with about 2,200 AFY of Program Water being discharged into Big Bear Lake. These assumptions are consistent with the assumptions used to evaluate the impacts on Big Bear Lake without the extractions.

The model explicitly calculated TDS and nitrate as N concentrations at the withdrawal segment in the model where Program Water would be extracted for groundwater recharge and landscape irrigation. The concentrations of sodium, chloride, sulfate, and hardness were not explicitly predicted by this model. While the Big Bear Lake Analysis model could be set up to simulate these additional chemical species by assigning them as generic constituents, there is a lack of necessary watershed runoff and Big Bear Lake concentration data upon which to develop such a model. As a result, sodium, chloride, sulfate, and hardness concentrations in Program Water extracted for recharge and landscape irrigation were estimated from model-predicted TDS concentrations based upon chemical data for Big Bear Lake water collected on December 12, 2021 and July 27, 2023 at TMDL Station #9[1] (**Table 2**) and chemical data collected from the effluent of an ongoing pilot treatment facility that is expected to be representative of the purified water ultimately discharged to Big Bear Lake (**Table 3**).

Table 2. MAJOR ION CHEMISTRY IN BIG BEAR LAKE AS MEASURED ON 12/12/2021 AND 7/27/2023 (TMDL STATION #9)

Date	TDS (mg/L)	Hardness [a] (mg/L)	Sodium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
12 Dec 2021	251	157	33	26	18
27 Jul 2023	230	140	23	21	12
Average	***241***	***149***	***28***	***24***	***15***

[1] Per the Big Bear Lake Nutrient Total Maximum Daily Load (Nutrient TMDL) for Dry Hydrologic Conditions (Resolution No. R8-2006-0023), the Stanfield Middle TMDL monitoring is located closest to the discharge and extraction points. Therefore, the water quality at this location was used. This location is at N 34° 15' 25.9" W 116° 53' 56.0".

[a] Hardness presented as mg/L $CaCO_3$

Table 3. MAJOR ION CHEMISTRY IN PROGRAM WATER BASED UPON PILOT PLANT EFFLUENT, TDS CONCENTRATION AS REPRESENTED IN BIG BEAR LAKE ANALYSIS MODELING AND ASSUMED RO EFFLUENT STABILIZATION USING 10 mg/L Calcium (Ca2+)

Date	TDS [a]	Hardness [b]	Sodium	Chloride	Sulfate
22 Jun 2023	50	25	3.7	2.3	<0.03
29 Jun 2023	50	25	3.8	2.3	<0.03
7 Jul 2023	50	25	NA	2.2	0.03
Average	***50***	***25***	***3.8***	***2.3***	***0.03***

[a] TDS as modeled; [b] hardness presented as mg/L $CaCO_3$. A TDS of 50 mg/L was used to be consistent with previous model runs. Based on pilot data, the TDS content is expected to be lower.

[b] Hardness presented as mg/L CaCO3.

Concentrations of sodium, chloride, sulfate, and hardness were estimated from the Big Bear Lake Analysis model predicted TDS values over time using a ratio approach in which the relative contributions of these ions to TDS were assumed to be fixed at values derived from **Table 2** and **Table 3.** The resulting ratios are shown in **Table 4**. For example, sodium at an average concentration of 28 mg/L under natural runoff conditions (i.e., no Program Water) represented 12% of TDS ($R_{Big\ Bear\ Lake}$=28/241=0.12) in Big Bear Lake and 8% ($R_{Effluent}$=3.8/50=0.08) in Program Water. A simple mixing model, in which natural runoff and Program Water represented about 75% and 25% of total runoff under average conditions, respectively, allows for calculation of approximate flow-weighted average concentration ratios (R) via an equation of the form:

$$R = R_{Big\ Bear\ Lake}*0.75 + R_{Effluent}*0.25$$

Concentrations (C) of sodium, chloride, sulfate and hardness in Program Water withdrawn from Big Bear Lake for recharge were then estimated from Big Bear Lake Analysis predicted TDS values at the withdrawal location simply as:

$$C = R*TDS$$

Table 4. CONCENTRATION RATIOS BASED UPON AVERAGE VALUES IN BIG BEAR LAKE AND PILOT PLANT EFFLUENT

Date	Hardness [a]	Sodium	Chloride	Sulfate
Big Bear Lake ($R_{Big\ Bear\ Lake}$)	0.65	0.12	0.10	0.06
Pilot Effluent ($R_{Effluent}$)	0.50	0.08	0.05	0.00
Weighted Average (R)	***0.59***	***0.11***	***0.08***	***0.05***

[a] Hardness presented as mg/L $CaCO_3$

The Big Bear Lake Analysis model previously simulated TDS and nitrate as N concentrations at the withdrawal location in Big Bear Lake supplemented with about 2,200 AFY Program Water (Anderson, 2022). The mean, median, minimum, and maximum concentrations from the model simulation are summarized in **Table 5**. The concentrations of TDS and nitrate as N in the Program Water withdrawn from Big Bear Lake for recharge and irrigation averaged 165.8±37.7 and 0.029±0.059 mg/L, respectively.

As noted previously, the lack of information about concentrations of sodium, chloride, sulfate, and hardness in runoff and Big Bear Lake precluded their direct modeling in recharge flows and necessitated projecting their concentrations. Thus, it was assumed that changes in TDS yield corresponding changes in the concentrations of these constituent ions at the flow-weighted average concentrations ratios provided in **Table 4**. While this represents an approximation, it is geochemically consistent with the conservative behavior of sodium and chloride in all natural waters except hypersaline brines. Sulfate is geochemically conservative up to the solubility limit for gypsum in most natural waters, but is subject to microbial reduction under strongly reducing conditions (which are not widely present in Big Bear Lake) as well as reoxidation. Like sulfate, hardness is not likely to be perfectly conservative, owing in this case to some potential for precipitation of calcium carbonate ($CaCO_3$), although redissolution from bottom sediments can also occur; nonetheless Magnesium(2+) would under most conditions would be conservative, so substantial deviations in the relative concentration of hardness with TDS seems unlikely.

Overall, water withdrawn from Big Bear Lake and used for recharge of Sand Canyon and landscape irrigation is predicted to have mean concentrations of 18.2, 13.3 and 8.3 mg/L for sodium, chloride, and sulfate, respectively, and a mean hardness value of about 97.8 mg/L $CaCO_3$ (**Table 5**). Maximum concentrations of these ions that would be present in recharge water under protracted drought were on the order of about 50% higher than mean values, although the use of average relative flows would be expected to skew somewhat predicted concentrations under both extreme runoff and drought conditions. The Program Team will work with the Santa Ana Regional Water Board during the development of the WDR permit for Sand Canyon Recharge Area to consider the possibility of using extended averaging periods (such as a 5-year or 10-year average) for compliance for some constituents, recognizing that variable local hydrology may result in short term changes in recharge water quality that may balance out over a longer period and still maintain compliance with water quality objectives. In addition, the recharge operation will be operated adaptively based on groundwater levels and water quality trends and can be paused if needed to ensure compliance with permitted water quality limits.

Table 5. MODEL-PREDICTED (TDS AND NITRATE AS N) AND PROJECTED (SODIUM, CHLORIDE, SULFATE, AND HARDNESS) CONCENTRATIONS (mg/L) IN RECHARGE AND IRRIGATION PROGRAM WATER WITHDRAWN FROM BIG BEAR LAKE UNDER THE MEDIAN HYDROLOGIC SCENARIO SUPPLEMENTED WITH ABOUT 2,200 AFY OF PROGRAM WATER

Parameter	TDS	Nitrate as N	Sodium	Chloride	Sulfate	Hardness [a]
Mean ± sd	165.8 ± 37.7	0.029 ± 0.059	18.2 ± 4.1	13.3 ± 3.0	8.3 ± 1.9	97.8 ± 22.2
Median	159.7	<0.001	17.6	12.8	8.0	94.2
Minimum	105.4	<0.001	11.6	8.4	5.3	62.2
Maximum	258.2	0.3	28.4	20.7	12.9	152.4

[a] Hardness presented as mg/L $CaCO_3$

Assessment of Water Quality Impacts

Table 6 presents a water quality comparison of the Program Water stored in Big Bear Lake that would be used for groundwater recharge at Sand Canyon and/or irrigate the projected recharge and irrigation Bear Mountain Golf Course, the mean values from **Table 5**, Big Bear Basin water quality objectives, and the ambient water quality of Big Bear Valley Groundwater basin in the Sand Canyon Recharge Area. The ambient water quality of the Sand Canyon Recharge Area was estimated by averaging water quality data from five drinking water wells near the Sand Canyon Recharge Area. The groundwater quality data were collected in 2014, 2017, and 2021.

The projected Program Water stored in Big Bear Lake for subsequent Lake uses and the ambient water quality near the Sand Canyon Recharge Area were assessed to determine if the proposed future uses of Program Water stored in Big Bear Lake would result in concentrations that exceed existing ambient water quality and/or relevant WQOs or criteria. In order to determine whether the Sand Canyon Recharge Area Project would violate water quality standards, the model predicted mean concentrations for the Program Water stored in Big Bear Lake that would be used for groundwater recharge and/or irrigation were compared against the following:

- If the Project Water stored in Big Bear Lake is below the ambient and most stringent WQO or criterion, no degradation is anticipated.
- If the Program Water stored in Big Bear Lake is above the ambient water quality, but below the most stringent WQO or criterion, there is assimilative capacity available, which would indicate that the WQO would not be violated.
- If the Program Water stored in Big Bear Lake is above the most stringent WQO or criterion, but below the ambient water quality, there is a possibility of water quality improvements, which would provide benefit by improving conditions and help improve conditions to help attain the WQO.

- Finally, if the Program Water stored in Big Bear Lake is above ambient water quality and the most stringent WQO or criterion degradation is anticipated, a complete analysis may be required.

Table 6. COMPARISON OF MOST STRINGENT WATER QUALITY OBJECTIVE OR CRITERION TO THE SAND CANYON RECHARGE GENERAL AREA WATER QUALITY AND PROJECTED PROGRAM WATER IN RECHARGE AND IRRIGATION WITHDRAWN FROM BIG BEAR LAKE UNDER THE MEAN HYDROLOGIC SCENARIO SUPPLEMENTED WITH ABOUT 2,200 AFY

Parameter	TDS	Nitrate as N	Sodium	Chloride	Sulfate	Hardness
Big Bear Valley WQO	300	5	20	10	20	225
Big Bear Valley Average Concentration in Sand Canyon Recharge Area	324	4	17	15	35	277
Model Predicted Mean for Recharge/Irrigation Program Water ± sd	165.8 ± 37.7	0.029 ± 0.059	***18.2 ± 4.1***	***13.3 ± 3.0***	8.3 ± 1.9	97.8 ± 22.2

Note:
Blue – Projected Program Water stored in Big Bear Lake quality is below the ambient and most stringent WQO or criterion. No degradation is anticipated.
Black – Projected Program Water stored in Big Bear Lake quality is above the ambient, but below the most stringent WQO or criterion. Further analysis may be needed to determine impacts on water quality.

As shown in **Table 6,** the existing water quality of the Basin near the Sand Canyon recharge area exceeds the WQOs for TDS, chloride, sulfate, and hardness. The Program Water stored in Big Bear Lake is estimated to be of better quality than ambient and the most stringent WQO for TDS, nitrate as N, sulfate, and hardness, so no degradation is predicted since the Program Water is anticipated to improve water quality conditions and comply with WQOs. The sodium concentration in the Program Water stored in Big Bear Lake is estimated to be above the ambient water quality but below the WQO. Therefore, there is some limited assimilative capacity. The estimated chloride concentration in the Program Water stored in Big Bear Lake is estimated to be below the ambient water quality, but above the WQO. Therefore, the project has the potential to improve or maintain the existing water quality conditions of the basin near the Sand Canyon recharge area, even though the WQO for chloride is exceeded.

Per the Basin Plan, the presence of sodium in drinking water may be harmful to persons suffering from cardiac, renal, and circulatory diseases. As noted in the Basin Plan, the California Department of Health Services (now Division of Drinking Water) and the EPA have not established a limit on the concentration of sodium in drinking water, but recommend for sodium concentrations to not exceed 180 mg/L in groundwaters designated MUN (municipal use) as a result of controllable water quality factors. As shown in **Table 6**, the sodium concentration in the Program Water stored in Big Bear Lake is less than 20 mg/l, well below this threshold and therefore would not be harmful to the MUN use of this Basin. Excess concentrations of sodium in irrigation water reduce soil permeability to water and air. The Basin Plan, groundwaters designated as AGR (agricultural) must not exceed a sodium absorption ratio (SAR[2]) of 9 as a result of controllable water quality factors. The groundwater basin is not designated as an AGR therefore, this threshold is not applicable, however, the water from the Basin is used to irrigate a golf course. For comparison purposes, the SAR for the Program Water stored in Big Bear Lake is 0.8, so using the Program Water for irrigation is not expected to be problematic.

Per the Basin Plan, excess chloride concentrations lead primarily to economic damage rather than public health hazards. Excess Chlorides can significantly affect the corrosion rate of steel and aluminum and can be toxic to plants. Per the Basin Plan, a safe value for irrigation is considered to be less than 175 mg/L of chloride. Excess chlorides affect the taste of potable water, so drinking water standards are generally based on potability rather than on health. The secondary maximum contaminant upper limit for chloride is 500 mg/L (CCR, Division 4, Chapter 15, Article 16, § 64449), so chloride concentrations should not exceed this limit in groundwaters designated as MUN. As shown in **Table 6**, the chloride concentrations in the Basin and the Program Water stored in Big Bear Lake are approximately 15 mg/l, far below the 500 mg/L and 175 mg/L thresholds discussed above, and therefore the Program Water stored in Big Bear Lake would not be harmful to the MUN use of the Basin and would be suitable for irrigation use.

Conclusions

The Program Water stored in Big Bear Lake is estimated to be of better quality than ambient and the most stringent WQO for TDS, nitrate as N, sulfate, and hardness and is therefore anticipated to improve water quality conditions in the Basin. Although the Program Water stored in Big Bear Lake is projected to have a higher concentration than the established chloride WQO objective, the discharge is necessary to provide important economic and social benefits, the discharge may help reduce current ambient chloride concentrations in the Basin, and the beneficial uses of the Basin would be protected.

As part of the WDR permit process, an antidegradation analysis will be prepared to evaluate the water quality impacts in more detail than this technical memorandum and demonstrate that the project is consistent with state antidegradation policy.

[2] Sodium absorption ratio (SAR) = $\frac{Sodium}{[0.5(calcium+magnesium)]^{\wedge}0.5}$, in Meq/L

References

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