REPLENISH BIG BEAR: MODELING OF HIGHER FLOWS AND WITH ZERO TP LOAD

Michael A. Anderson, Ph.D.
Coeur d'Alene, ID

February 24, 2022

Acknowledgement of Credit

This report is financed under the Water Quality, Supply and Infrastructure Improvement Act of 2014, administered by State of California, Department of Water Resources.

Introduction

It was previously noted that water quality was predicted to vary markedly with the level of treatment of added Replenish Big Bear (RBB) recycled water, with Alternative 1 (TIN and TP removal) significantly degrading water quality in Big Bear Lake relative to predicted baseline conditions, while Alternative 2 (70% RO) modestly increased average predicted concentrations of TN, TP and chlorophyll-a, and Alternative 3 (100% RO) was predicted to slightly improve average water quality for the 2009-2019 period (Anderson, 2021, Table 22). Long-term simulations for different hydrologic scenarios yielded similar results, with 100% RO yielding predicted water quality typically comparable to baseline conditions. Notwithstanding, some subtle differences were observed between predicted median baseline concentrations and those for Alternative 3 which assumed steady annual flows of 1920 af/yr of 100% RO water (Anderson, 2021, Table 25).

Recent engineering work indicates that slightly higher inflows, up to 2210 af/yr, can be attained by the Replenish Big Bear project by employing additional brine minimization technology (Table 1). Note that a portion of the water produced by RBB may be discharged to Shay Pond and the earlier “Alternative 3” scenario had excluded those flows (up to 80 af/yr) from the analysis. However, to be conservative for permitting purposes, this analysis is based on discharging all of the recycled water produced to the Lake.

Table 1. Initial and recently updated Replenish Big Bear (RBB) flow projections.

Scenario	**Annual RBB Inflow (af)**	**Daily RBB Inflow (MGD)**
Baseline	0	0
Alternative 3 [(a)]	1920	1.71
High Flow (99% recovery) [(b)]	2210	1.57 – 2.18
Mid Flow (90% recovery) [(b)]	2009	1.42 – 1.98

Notes:

[(a)] Alternative 3 was assessed in the 2021 Lake Analysis and assumed that of the total Replenish Big Bear effluent contribution considered in the Lake Analysis (i.e., 2,000 AFY), 80 AFY would be delivered to Shay Pond. Therefore, only 1,920 AFY would be discharged to the Lake.

[(b)] The updated model analysis assumed that no discharge to Shay Pond would occur and all recycled water would be discharged to the Lake under two different total recovery rates scenarios.

Moreover, deliveries are expected to vary seasonally (Fig 1), thus varying from the earlier “Alternative 3” scenario that assumed uniform flows of 1.71 MGD throughout the year. Inflows to the WWTP are lower in the summer months due to reduced inflow.

Since the Replenish Big Bear project does not have a waste load allocation for total P (TP) in the current TMDL, it is proposing to offset the TP load in the project inflows delivered to Big Bear Lake. While RO is extremely effective at removing dissolved and particulate substances, there nonetheless is a small quantity of TP that is expected to evade treatment (the projected RO effluent concentration is 0.03 mg/L, principally as o-PO_4-P). Elimination of all TP through the treatment process is not practicable, so removal of an equivalent load of TP (up to 200 lbs/yr) from elsewhere in the lake or watershed will be necessary.

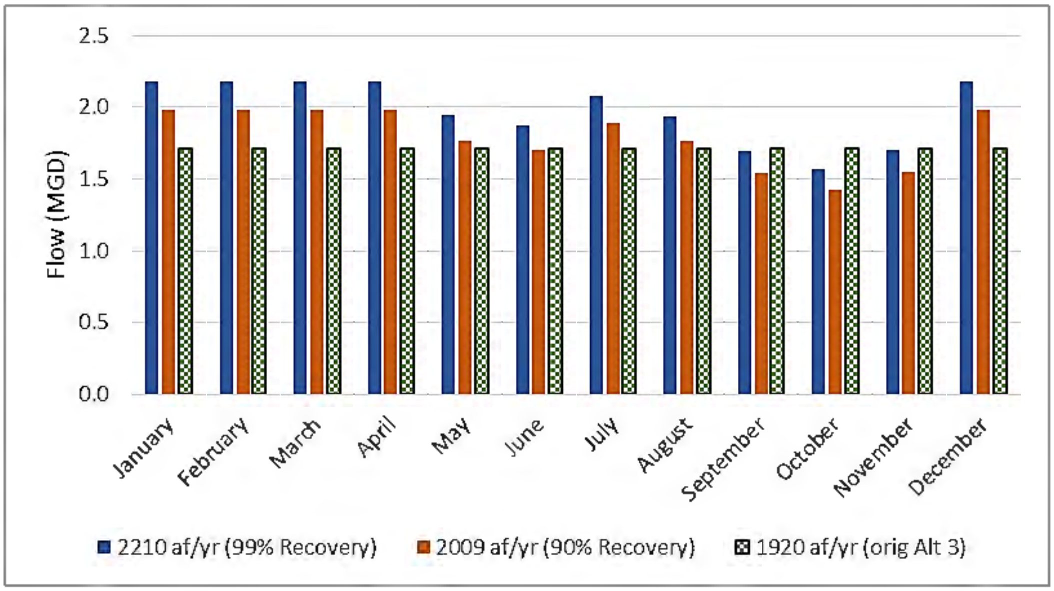

Fig. 1. Monthly flow rates (projected 2040) for Replenish Big Bear under three project inflow scenarios.

In light of these factors, further modeling was conducted to evaluate predicted water quality under these operational scenarios (increased and time-varying flows, with and without TP offset) for comparison with the previously predicted baseline condition and Alternative 3 scenario. Given the complexity of nutrient budgets of lakes, array of possible offset strategies, and equivalence of a given form of nutrient irrespective of its particular origin, TP offset will be modeled as equivalent to 0 influent concentration. This is an approximation that holds when considering whole-lake nutrient budget, but is nonetheless a simplification; depending upon details of offset, hydrodynamic considerations and other factors, some modest lateral gradients in water quality may result. The 50th percentile hydrologic scenario for 2009-2050 was used in this analysis, noting that it includes a wide array of runoff conditions, included extended drought and as well as periods of high runoff. All other hydrologic, meteorological, biological, chemical and sedimentological factors, variables and conditions were identical to those used in prior simulations of long-term future conditions (Anderson, 2021).

Results

Long-term averaged predicted concentrations of TDS, TIN, total P, total N and chlorophyll-a were lower with addition of RBB water compared with predicted baseline conditions (no supplementation) (Table 2). For reference, TMDL target values are included in the table. Focusing on chlorophyll-a as the key response target, baseline conditions were predicted to yield growing-season average chlorophyll-a concentration that slightly exceeded (by 0.1 µg/L) the TMDL target value of 14 µg/L, while Alternative 3 matched the target value, and larger inputs of RBB inflow that varied seasonally (Fig. 1) yielded values below baseline and TMDL target values (Table 2). Zeroing out the load of TP in RBB inflow yielded further reductions in chlorophyll-a; larger inflow volumes with reduced summer flows and no net TP loading were predicted to yield growing season average chlorophyll-a concentrations as low as 9.5 - 10.2 µg/L, significantly below predicted baseline and TMDL concentrations (Table 2).

Table 2. Long-term average predicted concentrations of total P, total N and chlorophyll-a in Big Bear Lake under different operational scenarios (total P and total N expressed as annual average concentrations; chlorophyll-a shown as growing season average concentrations).

Operational Scenario (all at 50th % hydrology)	TDS (mg/L)	TIN (mg/L	Total P (µg/L)	Total N (mg/L)	Chlorophyll-a (µg/L)
Baseline	**195**	**0.069**	**47.7**	**1.15**	**14.1**
Alternative 3 (1920 af)	182	0.052	43.3	1.07	14.0
2210 af (99% recovery)	**179**	**0.045**	**42.3**	**1.04**	**13.1**
2009 af (90% recovery)	**180**	**0.041**	**43.4**	**1.06**	**12.9**
2210 af + 0 total P	179	0.072	39.9	1.00	10.2
2009 af + 0 total P	180	0.040	40.9	1.00	9.5
TMDL target			***35.0***		***14.0***

Supplementation with RBB inflow also lowered concentrations of total P and total N relative to predicted baseline levels (Table 2). This is consistent with the reduced concentrations of total N and total P (and most dissolved forms of N and P) in RO water relative to watershed runoff concentrations (Anderson, 2021, Table 20), with concentrations projected to be only 40% - 80% of average watershed runoff concentrations (Anderson, 2021, Table 21). Interestingly, zeroing out the influent TP concentration not only lowered the predicted average total P concentration but also reduced the predicted total N concentrations, highlighting the complex biogeochemical coupling of these two key nutrients. While it is important to recognize the uncertainty in model predictions, it is nonetheless noteworthy that revised project flows, with varying seasonal flow and TP offset, yielded average chlorophyll-a concentrations significantly below baseline and TMDL values and also yielded long-term average TN concentrations approaching or reaching 1 mg/L, which is being considered by the Regional Water Board. Predicted long-term average TP concentrations remained above the TMDL target, but were nonetheless meaningfully lower than the predicted baseline level (Table 2). Average TDS and TIN concentrations were also lower than predicted baseline conditions (with exception of 2210 af + 0 TP, where a period of higher NO_3-N was predicted).

Inter-annual differences in water quality are nonetheless expected to persist. Cumulative distributions functions (CDFs) highlight the predicted wide range in annual and growing season average concentrations (Fig. 2). While addition of RBB inflow shifted CDFs to lower annual average total P and total N concentrations and growing season average chlorophyll-a concentrations, wide ranges in predicted concentrations remained in place (Fig. 2). Thus, the growing season average chlorophyll-a target of 14 µg/L was predicted to be exceeded about 53% of the time under baseline conditions, and exceeded about 41% and 31% of the time with RBB inflows of 2210 af/yr without and with TP offset, respectively (Fig. 2c; Table 3). Results for all scenarios are summarized in Table 3.

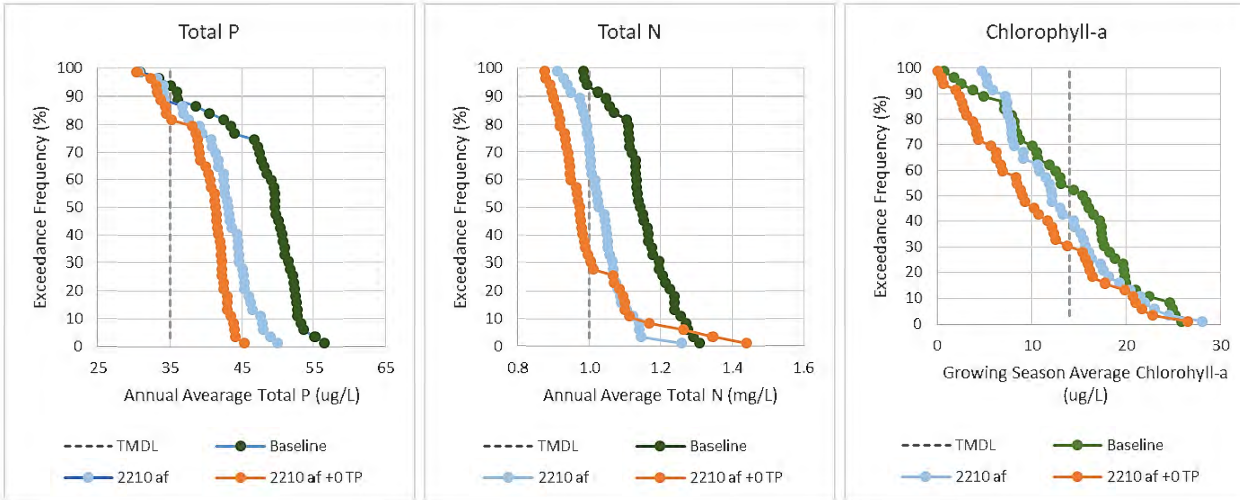

Fig. 2. Cumulative distribution functions for predicted annual total P and total N concentrations and growing season average chlorophyll-a concentrations for baseline condition and with 2210 af RBB inflow with and without TP offset.

Table 3. Predicted frequency of exceeding TMDL target under baseline conditions and different RBB inflow and TP offset scenarios (annual average or growing season average basis). Observed annual exceedance frequencies for 2009-19 period shown in parentheses under Baseline.

Variable	**Baseline**	**1920 af**	**2210 af**	**2210 af+0 TP**	**2009 af**	**2009 af+0 TP**
Total P	94 % (100%)	87 %	87 %	82 %	91 %	90 %
Total N[a]	91 % (na)	72 %	72 %	30 %	80 %	55 %
Chlorophyll-a	53 % (55%)	51 %	41 %	31 %	40 %	22 %

[a]*possible TMDL target*

References

Anderson, M.A. 2021. *Big Bear Lake Analysis: Replenish Big Bear.* Final Report. 65 pp.