5.0 LINKAGE ANALYSIS AND TMDL (LOAD CAPACITY)

As stated by the USEPA (1999), the linkage analysis is an essential component of the development of a TMDL. A link needs to be established between predicted nutrient loads and the selected numeric target(s) chosen to measure the attainment of beneficial uses. This linkage allows determination of the nutrient loading assimilative capacity of the impaired water, and the amount of loading reduction needed. The nutrient loading assimilative capacity of lakes and requisite loading reductions typically vary with lake levels, which reflect different hydrologic conditions.

The relationship or link between the selected numeric target(s) and the predicted nutrient loads can be determined using a combination of monitoring data, analytical tools (including models), and best professional judgment (USEPA 1999). Ideally, a long-term monitoring data set, with different flow regimes and nutrient loads, would be available for the body of water in order to determine the load capacity under various hydrological regimes.

5.1 Big Bear Lake Water Quality Analysis Simulation Program (WASP6) Model for Total Nitrogen and Total Phosphorus

In order to determine the phosphorus and nitrogen TMDL (load capacity) for Big Bear Lake, the WASP6 model was chosen based upon the available monitoring data, resources for the application, and the time frame available for modeling. The WASP model is an USEPA approved model for TMDL development for receiving water bodies. "WASP6 is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. WASP allows the user to investigate 1, 2, and 3 dimensional systems, and a variety of pollutant types. The time varying processes of advection, dispersion, point and diffuse mass loading and boundary exchange are represented in the model. WASP also can be linked with hydrodynamic and sediment transport models that can provide flows, depths, velocities, temperature, salinity and sediment fluxes" (USEPA 2004). WASP6 includes a pre-processor, WASP eutrophication and organic chemical model processors and a graphical post-processor that enables the results of the WASP model to be compared to the observed field data. The WASP model is comprised of a set of mass balance equations, user-specified input data describing the transport of mass throughout the system, and the rates and constants used in the chemical kinetics equations, all of which are all numerically integrated over time.

The Big Bear Lake WASP water quality model developed by Tetra Tech, Inc. (2004a) includes a hydrodynamic linkage file, a nonpoint source loading file that was created from the HSPF loads (see Section 4), predicted macrophyte nutrient loads and sediment nutrient loads[41] (Figure 5-1). The lake was divided into ten segments to best represent lake dynamics (Figure 5-2). Calibration of total nitrogen and total phosphorus concentrations show that model results match seasonal trends for these constituents (Tetra Tech 2004a).

The model was used to project in-lake nutrient and chlorophyll *a* concentrations resulting from different strategies for managing external and internal nutrient loads. These scenarios and the model results are presented in Table 5-1. The nutrient load capacity of Big Bear Lake, under dry conditions

[41] The sediment nutrient fluxes were incorporated in the WASP model in the segment parameters group. There were spatial differences as well as depth differences in the sediment nutrient fluxes measured at four stations in the lake that had to be taken into account when modeling. For a more detailed description of how these differences were incorporated into the final input parameters of the WASP model, and for a discussion of other aspects of the model setup and assumptions, please consult the WASP modeling report prepared by Tetra Tech (2004a).

only (see below), was determined from the model results that matched the proposed nutrient numeric targets (discussed in Section 3.0)[42]. The results for model runs 20, 20a, 20b, 20d, and 24, indicate that the interim total phosphorus and chlorophyll *a* numeric targets are achieved if phosphate flux is reduced from 50-80% and macrophyte loads are reduced from 10-50%. Model runs 20c, 21b, 22b, 23, and 26a also result in compliance with the interim total phosphorus and chlorophyll *a* numeric targets, but in addition to phosphate flux and macrophyte load reductions, ammonia flux must be reduced from 50-80%. The results for model runs 20b and 20c suggest that in order to meet the final total phosphorus and chlorophyll *a* targets, phosphate loads must be reduced by at least 80% and macrophyte loads by 50%. Model run 20c also includes an 80% reduction in ammonia sediment flux , resulting in total nitrogen concentrations that are closer to the proposed final numeric target (1000ug/L). However, no model simulation resulted in compliance with this numeric target. As discussed below, this is likely attributed to model limitations and incomplete understanding of macrophyte nutrient dynamics in the lake.

It is essential to bear the following points in mind when reviewing the results presented in Table 5-1:

a. *Dry Condition Simulations*

First, **the WASP model cannot be used to predict water quality conditions in Big Bear Lake during wet or average years, since the period for which the model simulation occurred (1999-2003[43],) was characterized by extremely dry conditions.** Thus, the WASP model results can be used to establish the load capacity (TMDL) only for dry conditions. For the purposes of these TMDLs, dry conditions are defined as 0-23 inches of precipitation, 0-3049 AF of inflow and lake levels ranging from 6671 – 6735 feet. These values represent the ranges of lake metrics observed for the 1999-2003 period.

As discussed in Section 2, there are historical water quality data for Big Bear Lake that include wetter conditions, however much of these data were found to be unusable for modeling purposes, primarily because of insufficient detection limits. It is recognized that external nutrient loads are greatest during wet years, and that the effects of inputs at those times are manifested in the lake for an extended period (the residence time of water in the lake is 11 years, and sediment and macrophytes serve as nutrient reservoirs). It is apparent that a high quality, long-term monitoring program is needed to collect this type of data for Big Bear Lake. With these data, the WASP model can be refined to simulate lake water quality during wet and average conditions and to make recommendations for appropriate TMDLs. The implementation of such a monitoring program is an important component of the proposed Implementation Plan (Section 10).

The model simulations presented in Table 5-1 show that any reduction in external loads will not change the predicted water quality concentrations in Big Bear Lake. These results are not unexpected, given that WASP was calibrated only for dry conditions, when internal nutrient loads predominate (see Section 4.5). The model results show that during dry years, there is no justification to require a reduction in external loads; rather, the focus must be on reducing internal loads. It would be inappropriate to conclude, however, that no reductions in external loads would be required under

[42] As discussed in detail later in this section, none of the model simulations resulted in compliance with the proposed final total nitrogen target. Staff believes that this reflects model limitations that are to be addressed as part of the proposed Implementation Plan for this TMDL (see Section 10).

[43]All lake quality-related data used in the model were collected from 2001-2003. The water balance component of WASP used lake levels monitored at the dam from 1999 –2003. HSPF model output was also available for this period. For modeling purposes, plant biomass and sediment flux rates measured in 2002 and 2003 were used also for 1999, 2000 and 2001, since dry conditions prevailed throughout this period.

different hydrologic conditions. As discussed in Section 4.5, external sources contribute large nutrient loads during wet years. The model is not yet calibrated to assess loading capacity, and requisite nutrient load reductions, under those conditions. This deficiency is addressed in the recommended Implementation Plan for this TMDL (see Section 10).

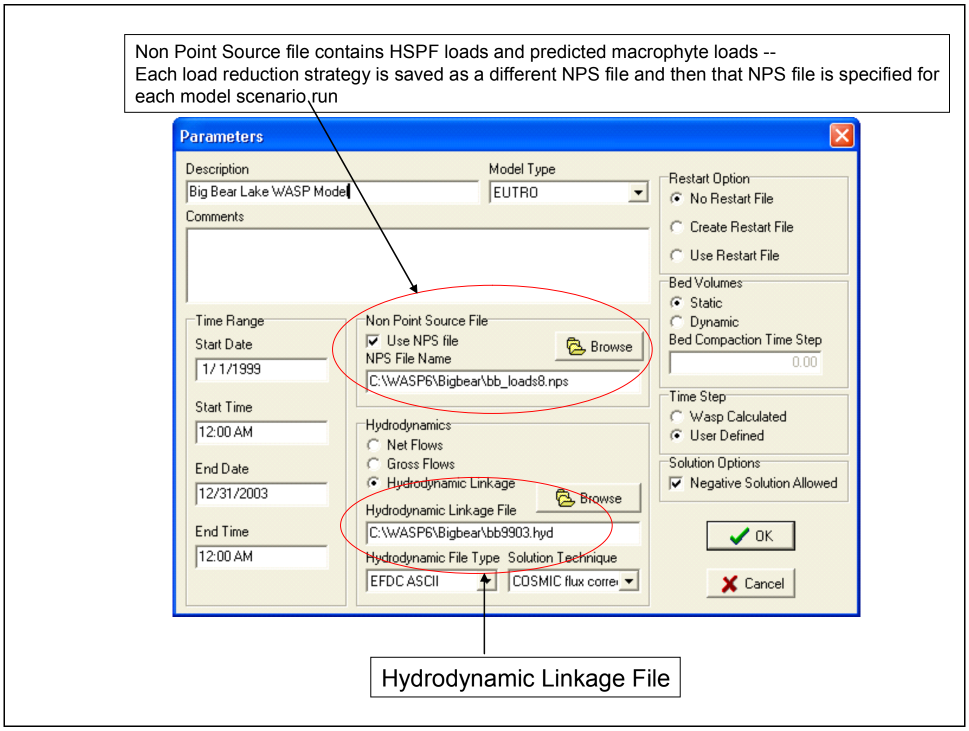

Figure 5-1. WASP Model Interface

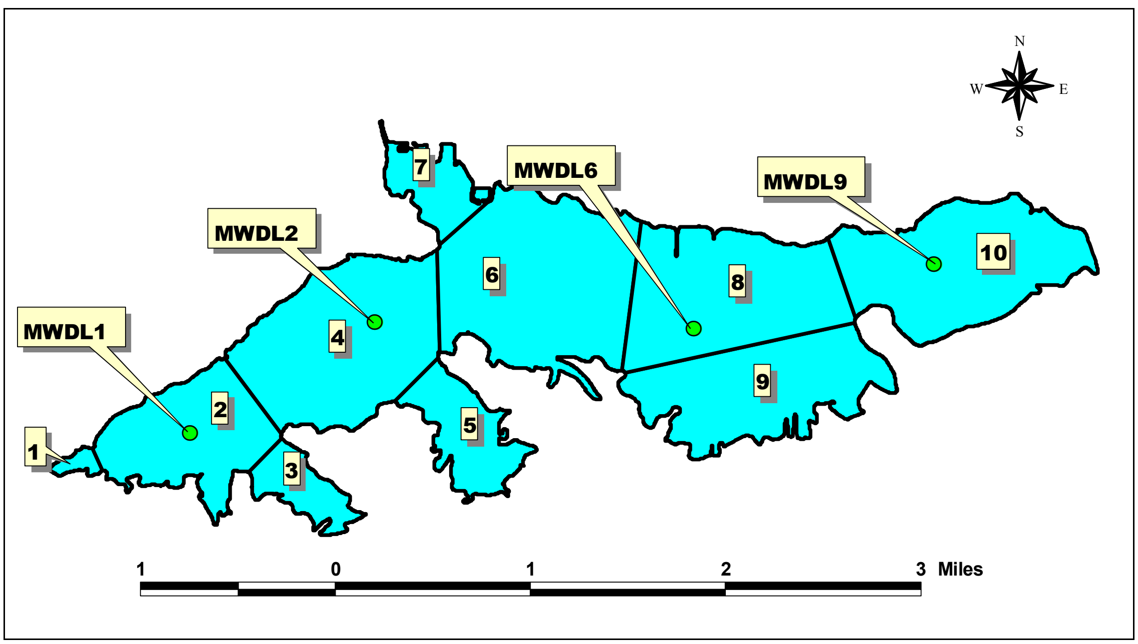

Figure 5-2. WASP segments for Big Bear Lake (Tetra Tech 2004a)

b. *Macrophyte Dynamics*

Second, WASP efforts were constrained by the model's inability to simulate macrophyte nutrient dynamics. Rather, various assumptions regarding macrophyte nutrient loads, rates of uptake and release, etc. had to be simulated via nonpoint source files entered into the model. Each nonpoint source file is essentially a spreadsheet that runs the HSPF and macrophyte load reductions independently of WASP. For each load reduction strategy, a separate nonpoint source file is created that contains the final loads assumed to be contributed by macrophytes and external loads (i.e., HSPF output). The nonpoint source file is then specified in the WASP model interface (see Figure 5-1). As the WASP model is run, it uses the input from the specified nonpoint source file to simulate nutrient processes and output nutrient concentrations.

Figure 5-3 shows the assumptions of macrophyte uptake, re-burial of nutrients (via macrophyte decay) and release of nutrients by macrophytes to the water column that were used in each of the nonpoint source files. Specifying certain percentages of macrophyte uptake, re-burial and water column release of nutrients in the spreadsheet allows the model to be run, but does not reflect the dynamic interrelationships between sediment, water column and macrophytes.

These limitations placed constraints on the loading reduction strategies that could be simulated by WASP. In order to perform the simulations, assumed nutrient loads from macrophytes, input via the nonpoint source files, had to be reduced to enable sediment fluxes to be reduced beyond 50%. This reflects the interconnection recognized in the model (though not simulated dynamically) between sediment releases of nutrients and macrophyte growth. The model recognizes that if sediment nutrient fluxes are reduced, the nutrient loads to the water column would be reduced and there would be less phytoplankton growth (which is simulated by the model) and less assimilation of nitrogen and phosphorus into organic matter. Less organic matter would result in less settling that would deliver nutrients to the sediments. The result would be a decrease in the amount of nutrients recycled from the sediments back into the water column as well as a decrease in nutrient sediment concentrations used for macrophyte growth. Because macrophytes would use nutrients from the water column and from the sediment for growth, any significant reduction in sediment nutrients has to be accompanied in the model simulations by assumed reductions in macrophyte growth and the nutrient loads that those macrophytes would ultimately contribute to the system. If phosphate fluxes were assumed to be reduced by 60%, macrophyte loads had to be reduced by at least 10%. If phosphate fluxes were reduced by 70%, macrophyte loads had to be reduced by at least 25% and if phosphate fluxes were reduced by 80%, macrophyte loads had to be reduced by at least 50%[44]. Staff does not recommend a change in the macrophyte coverage in the lake, only different species composition (see Sections 3.1.2 and 3.1.3). However, a change in macrophyte coverage, and thus macrophyte nutrient loads, had to be assumed for modeling purposes[45].

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[44] Note that the model would not run with phosphate fluxes reduced by 80% and macrophyte loads reduced by 25%. Assumed macrophyte loads between 25 and 50% might allow model simulations with the concomitant assumption of an 80% reduction in phosphate fluxes, but these simulations were not performed.

[45] Staff recognizes that a dramatic decrease in sediment flux rates might result in a decrease in macrophyte growth and coverage. Correlations between macrophyte growth and coverage and sediment flux rates, as well as nutrient water column concentrations can only be made with future monitoring as proposed in the Implementation Plan for this TMDL (see Section 10).

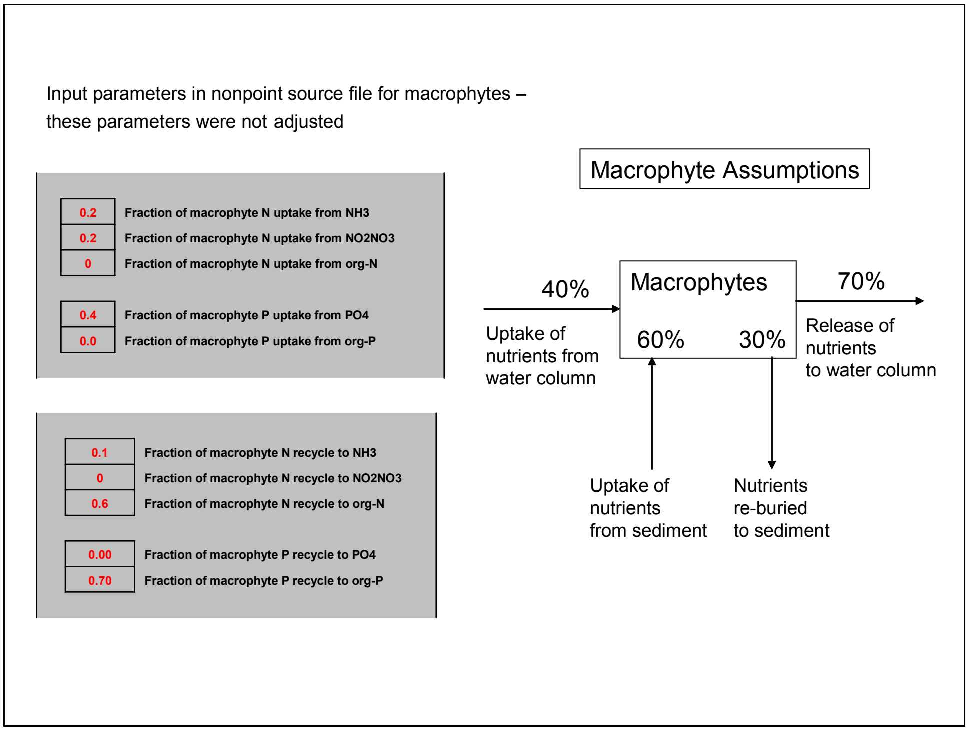

Figure 5-3. Macrophyte assumptions

The lack of macrophyte nutrient dynamic modeling capability also affects significantly the model projections of total nitrogen quality. If phosphate flux reductions are made, with concomitant macrophyte load reductions where necessary to run the model, the total nitrogen concentrations increase significantly (see, for example, the results of model runs 20, 20a 20b, and 20d in Table 5-1). In the model simulations, this results from less phytoplankton growth due to the reduced phosphorus flux (the lake is generally phosphorus limited (Section 3.1)) and less assimilation of nitrogen in the water column into organic matter. Settling that would result in removal of nutrients from the water column to the sediment would also decrease in the simulations. In reality, however, floating macrophytes would be expected to remove some of this water column nitrogen and rooted macrophytes might also remove some of this nitrogen, as long as there are adequate nutrients in the sediment to sustain their growth. The inability to model this process reflects both model limitations and data gaps with respect to current knowledge of macrophyte nutrient dynamics (Tetra Tech 2004a).

The results of the lakewide TMDL monitoring and nutrient sediment flux studies were evaluated to assess the validity of the high total nitrogen concentrations predicted in model scenarios in which phosphate flux was reduced. As previously described (Section 4.3), aluminum sulfate (alum) is applied to lakes to remove phosphorus from the water column (phosphorus precipitation), as well as to prevent phosphorus release from the sediments (phosphorus inactivation). A trial alum project was conducted in an isolated area of Big Bear Lake (Papoose Bay) in October 2003. Monitoring results showed more than a 90% reduction in SRP fluxes from the sediment, and greater than 50% increases in ammonia flux from the sediment. Alum was applied lakewide (with the exception of the east end) in May-June 2004. SRP flux rates from the sediment were reduced by more than 80% in the areas that were treated. Total phosphorus and total nitrogen data from this period and extending back to 2001 to include two applications of the herbicide Sonar (in 2002 and 2003) are shown graphically in Figure 5-4. These results show that total nitrogen concentrations continually and gradually increase from 2001 through 2004. However, the maximum total nitrogen concentrations observed after the lakewide alum project are significantly less than the levels predicted in model simulations that assumed reduced phosphate sediment flux. The inability to model macrophyte nutrient dynamics clearly limits confidence in the total nitrogen results produced by the model simulations. It is also likely that the inability to identify a simulation strategy that would achieve compliance with the proposed final numeric total nitrogen target can be attributed to this model deficiency. While **interim and final numeric targets for total nitrogen were considered initially, it became clear that this model deficiency would need to be addressed to support their propriety. No interim total nitrogen target is proposed. However, in conformance with relevant federal regulations, a final total nitrogen target is specified, with an extended compliance schedule. The intent is to provide time necessary to refine the model and obtain data necessary for calibration. This is a task identified in the proposed Implementation Plan (Section 10).**

c. Macrophyte Density Assumptions

Finally, it must be recognized that the density of macrophytes in the water column used in the model simulations was estimated to be three times the average of that previously measured and reported by BBMWD, Hydmet, Inc., and AquAeTer, Inc., 2003 (Tetra Tech 2004a). This was because of uncertainties regarding the accuracy of the rake method used to calculate biomass samples (see also Section 4.4)[46]. In addition, the model calibration determined that this was the best fit. This larger estimation might have resulted in an overestimate of the actual macrophyte biomass and corresponding nutrient loads, although the calculated density (i.e., 4713 g/m^3) is within the range of observed densities (i.e., 287 to 5414 g/m^3). Macrophyte density can be adjusted in the nonpoint source input files, however, staff did not adjust this parameter because it would have involved re-calibrating the model. As described below (see “Conclusions”), these uncertainties regarding the density of observed macrophytes affected staff’s recommendations regarding nutrient management strategies.

d. Feasibility of Nutrient Reductions Simulated by WASP

It is reasonable to question the technical feasibility of achieving the nutrient load reductions assumed in the WASP model runs. (Economic and other practical considerations of implementing the reductions are addressed in Section 11).

First, with respect to sediment nutrient flux, the reductions assumed were based on literature values for specific lake restoration activities. The application of alum to lakes has been successful in decreasing total phosphorus concentrations and restoring the beneficial uses. Welch and Cooke (1995) report total phosphorus summer reductions ranging from 54% to 80% after phosphorus inactivation in the sediments that lasted from 7-10 years. Eight lakes averaged a 52% total phosphorus reduction after phosphorus inactivation that lasted eight years or more (Welch and Jacoby, 2001).

The results from the trial alum project in Papoose Bay conducted in October 2003 show that SRP fluxes were reduced by more than 90% immediately after the treatment and reduced by approximately 60% a year after the initial treatment. Results from the lakewide alum project conducted in May-June 2004 show that SRP fluxes were reduced by 93%, 84%, and 82% at Stations MWDL1, MWDL2,

[46] To summarize, the rake method used to calculate plant biomass samples might have underestimated the true biomass of samples. Density of plants was calculated by using the biomass of plants measured in kg/m^2 divided by the plant height in meters, which was derived from the estimated depth (Tetra Tech 2004a).

MWDL6, respectively. A smaller reduction (45%) was also seen at Station MWDL9, located at the east end of Big Bear Lake, even though no alum was applied in the area[47]. This reduction might be attributed to the prevailing winds from the west, which would have carried alum suspended in the water column to this station (Berkowitz and Anderson 2005, 23) So, even though the east end received no direct alum treatment it appears to have benefited from the treatment elsewhere in the lake.

Water column concentrations measured after the conduct of the lakewide alum application in Big Bear Lake during the months of May and June 2004 show a decrease in total phosphorus by an average of 41% in the areas that received alum treatment versus 16% for the east end, which did not receive alum directly. Similarly, chlorophyll *a* concentrations were reduced on average by 31% in the areas that received alum treatment versus a 38% increase for the east end. Total nitrogen concentrations increased an average of 4%. Total phosphorus concentrations after the 2004 lakewide alum treatment are near the concentrations observed in 2002 after the initial Sonar treatment (Figure 5-4b). Macrophytes were not removed from the lake after both the 2002 and 2003 Sonar treatments and likely served as a source of nutrients to algae and to the water column. Another application of Sonar in 2003 further reduced macrophyte biomass, but also removed a sink of nutrients. The effects of the decaying biomass from 2002, as well as lower lake levels (Figures 5-5 and 5-6) are most likely the causes of the decrease in lake water quality seen in 2003. Judging from the increases in chlorophyll *a* concentrations observed at MWDL9, if alum had not been applied lakewide, it is very likely that algae blooms would have been more prolific in 2004, with a corresponding decrease in lake water quality. Alum dosages for Big Bear Lake, and the longevity of the alum application (higher doses results in a longer period of phosphorus inactivation), were based on the money available. It would require a dose of alum 10-times greater than that received in 2004 to inactivate the entire sediment phosphorus pool (BBMWD 2005, 24).

Dredging of the bottom sediments would remove adsorbed nutrients from the system, reducing sediment flux and the growth of algae. Deepening of selected areas by dredging should be effective in controlling macrophytes by limiting the light available for their growth. Macrophytes generally grow in less than 20 feet of water. In one lake, a 90% reduction of total phosphorus and an 80% reduction in total nitrogen were observed when sediment removal occurred (Welch and Cooke 1995). A pilot-scale dredging project for the east end of Big Bear Lake commenced in April 2005. Monitoring will determine the nutrient loads removed by the dredge project and the changes in nutrient flux rates after the dredge project. Until that time, the only available efficacy rates for nutrient removal due to dredging are those in the literature. It can be noted that no whole lake dredging has been proposed for Big Bear Lake, only dredging within selected areas that would improve navigation, reduce macrophyte growth, increase recreational access and improve fisheries habitat in localized areas.

Artificial circulation and hypolimnetic aeration are also methods used to reduce lake stratification and increase dissolved oxygen concentrations at the lake bottom. Increasing dissolved oxygen concentrations decreases sediment nutrient fluxes. Since the 1980s, several aerators have been in operation in Big Bear Lake near the dam. According to the BBMWD, these have had a positive effect on lake water quality, however no data exist to quantify the efficacy of the aerators in reducing whole lake total phosphorus and total nitrogen concentrations. Hypolimnetic aeration has been successful in reducing whole lake total phosphorus by 70% in two lakes for at least one or two years (Welch and Jacoby 2001).

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[47] A revision to the calculations used to determine the volumetric dose of alum was made on the third day of application, which resulted in a shortage of alum. Therefore, alum was not applied to the shallow east end since this area was going to be dredged in 2005 (BBMWD 2005, 9).

Based on the studies described above, a 50-80 percent reduction in internal total phosphorus loading from the sediment appears to be technically feasible.

As discussed in "b", above, reductions in macrophyte nutrient loads are tied to reduction of the sediment flux of phosphate in the model. To the extent that such reductions are effective, they are likely to be the most efficient as well. The application of Sonar or other aquatic herbicides, as well as physical harvesting, reduces macrophyte coverage and associated nutrient loads. However, herbicide reapplication would likely be necessary on a periodic basis, depending on the success of phosphate reduction or other nutrient control strategies. Similarly, repeated physical harvesting has been necessary and has the added disadvantages of potentially spreading fragments of nuisance species to other areas and causing disturbance to bottom dwelling organisms. Dredging can also reduce macrophyte biomass and associated nutrient loads if conducted to depths greater than 10 feet (see Table 2-5).

The technical feasibility of external load reductions is not considered here. As noted previously, because of the dry conditions simulated by the model, changes in external loads have no effect on resultant total nitrogen and total phosphorus concentrations in the lake. Accordingly, no external load reductions are recommended by staff as part of this TMDL (see Sections 5.2 and 6.0). The technical and economic feasibility of reducing external loads will need to be examined once the model is calibrated to address the wet conditions that result in significant external nutrient loading to the lake, and as recommendations for a TMDL and wasteload/load allocations based on those conditions are developed.

Conclusions

The results of simulations of model runs 20, 20a, 20b, 20d, and 24 suggest that the proposed interim total phosphorus and chlorophyll *a* targets can be achieved by various combinations of phosphate flux reductions of 50% or more and macrophyte load reductions from 10-50%. Staff considered the factors described in a-d, above, in recommending the appropriate combination of such reductions to calculate the load capacity that meets the interim total phosphorus and chlorophyll *a* numeric targets (see Section 5.2). Specifically, staff recommends that the reduction assumptions in model run 20a be used to calculate load capacity for the interim targets, i.e., a 60% reduction in phosphate sediment flux and a 25% reduction in macrophyte phosphorus and nitrogen loads (the 25% reduction is assumed to be split evenly between phosphorus and nitrogen) [48].

As discussed in Section 3.1.2, for a healthy lake ecosystem, staff believes that macrophyte coverage should range from 30-60% on a total lake basis. Different percentages of macrophyte coverage would result in varying levels of nutrient loads[49]. Staff does not propose any reductions in macrophyte coverage but, rather, changes in species composition (Sections 3.1.2 and 3.1.3) [50]. However, as discussed in "b", above, for the model to run, it is necessary to assume a reduction in macrophyte loads. Because of uncertainties in the measured density of the macrophytes (Section 4.4), the possibility that macrophyte loads might be overestimated in the model simulations (see "c", above), and uncertainties regarding the assumptions used in the nonpoint source file for macrophyte uptake

[48] The uptake of these nutrients was specified evenly between nitrogen and phosphorus in the nonpoint source file.
[49] Note that there are no studies that currently show correlations between water column concentrations and macrophyte coverage, or correlations between sediment nutrient flux reductions and macrophyte coverage. Further research might identify such correlations.
[50] Briefly, Staff's proposed approach is to ensure a more balanced, diverse macrophyte community –one that is not dominated by the noxious aquatic plant Eurasian watermilfoil and the nuisance plant coontail.

and re-burial of nutrients, the assumption of a 25% reduction in nutrient loads from macrophytes for the proposed **interim** numeric targets, split evenly (12.5%) between total N and total P appears to be reasonable and appropriate.

Model run 20b suggests that phosphate loads have to be reduced by at least 80% and macrophyte loads by 50% in order to meet the final total phosphorus and chlorophyll *a* targets. For the reasons just described, staff again believes that it is appropriate to assume a macrophyte nutrient load reduction of 25% (12.5% P and 12.5% N), rather than 50%, to meet the proposed final targets. Because of model limitations, this management scenario could not be evaluated using WASP. This deficiency is to be addressed as part of the proposed Implementation Plan and changes to the recommended macrophyte load strategy (and TMDL) can be made based on that effort. It should be emphasized that the WASP model simulations described in this report represent the initial effort to predict water quality concentrations after implementing lake management strategies, such as alum application and dredging. The actual effect of implementation of these strategies on macrophyte growth will be determined through appropriate monitoring. Those results will be used to make appropriate revisions to the model assumptions and TMDL.

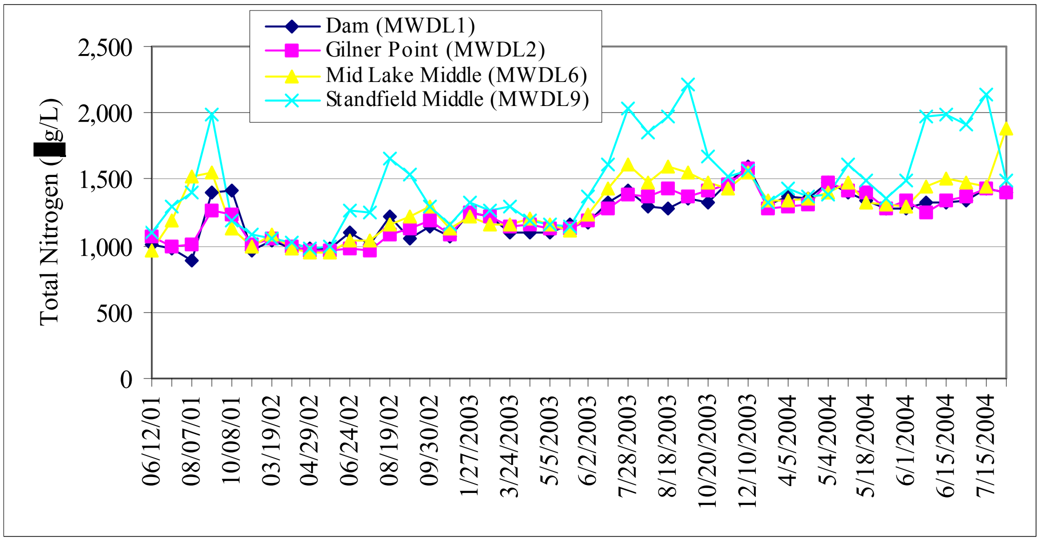
Model run 20c, with an assumed 80% reduction in ammonia flux, shows lower projected lake nitrogen concentrations. Without a lake-wide dredging project, such a reduction in ammonia flux is not likely. Even with this assumed reduction, however, the predicted nitrogen concentration of 2700 μg/L still does not meet the proposed final nitrogen target of 1000 μg/L. Again, no nutrient reduction strategy simulated with the model results in compliance with the final nitrogen target. Staff believes that this result is a function of model limitations and the state of understanding of macrophyte dynamics (see "b", above). The proposed Implementation Plan includes requirements for further monitoring and model update so that reasonable and appropriate nitrogen reduction strategies can be identified.

Staff recommends that the 80% reduction in phosphate sediment flux assumed in model run 20b, together with a 25% reduction in macrophyte phosphorus and nitrogen loads (split evenly between phosphorus and nitrogen) be assumed in calculating the nutrient loading capacity for the proposed final numeric targets.

Table 5-1. WASP model scenarios and average nutrient concentrations for the four main lake TMDL stations for each model run

MODEL RUN	EXTERNAL LOAD REDUCTION	MACROPHYTE LOAD REDUCTION	P04-P SEDIMENT FLUX REDUCTION	AMMONIA SEDIMENT FLUX REDUCTION	TOTAL N (µg/L)	TOTAL P (µg/L)	CHLA[1] (µg/L)
Model Run 15q	Calibration	Calibration	Calibration	Calibration	1259	48	15
Model Run 16	50%	none	none	none	1259	48	15
Model Run 16b	100%	none	none	none	1259	48	15
Model Run 17	none	none	50%	none	2788	40	12
Model Run 17c	25%	none	50%	none	2788	40	12
Model Run 17d	50%	none	50%	none	2788	40	12
Model Run 18	none	none	50%	50%	1202	40	12
Model Run 19	none	none	75% for segment 10	75% for segment 10	1247	47	15
Model Run 20	none	50%	50%	none	3617	24	7
Model Run 20a	none	25%	60%	none	3802	30	8
Model Run 20b	none	50%	80%	none	5253	19	3
Model Run 20c	none	50%	80%	80%	2736	19	3
Model Run 20d	none	25%	70%	none	4329	29	7
Model Run 21	none	none	80% in segments 2 and 4	80% in segments 2 and 4	1252	42	13
Model Run 21b	none	50%	80% in segments 2 and 4	80% in segments 2 and 4	1599	26	9
Model Run 21c	50%	50%	80% in segments 2 and 4	80% in segments 2 and 4	1600	26	9
Model Run 22	none	none	80% in segments 8 and 10	80% in segments 8 and 10	1201	45	14
Model Run 22b	none	50%	80% in segments 8 and 10	80% in segments 8 and 10	1444	29	11
Model Run 22c	50%	50%	80% in segments 8 and 10	80% in segments 8 and 10	1445	29	11
Model Run 23	none	25%	50%	50%	1684	32	10
Model Run 24	none	10%	60%	none	3510	35	10
Model Run 25	none	50%	none	none	1167	32	13
Model Run 25a	none	25%	none	none	1199	40	14
Model Run 26a	none	25%	70%	70% in segments 8&10; 40% in segments 2&4	3301	29	7
Numeric Targets (Interim)						**35**	**10**
Numeric Targets (Final)					**1000**	**20**	**5**

[1]Chla averages are growing season averages (May 1-Oct. 31); TP, TN and Chla concentrations were summarized from the model output using the years 2001-2003.



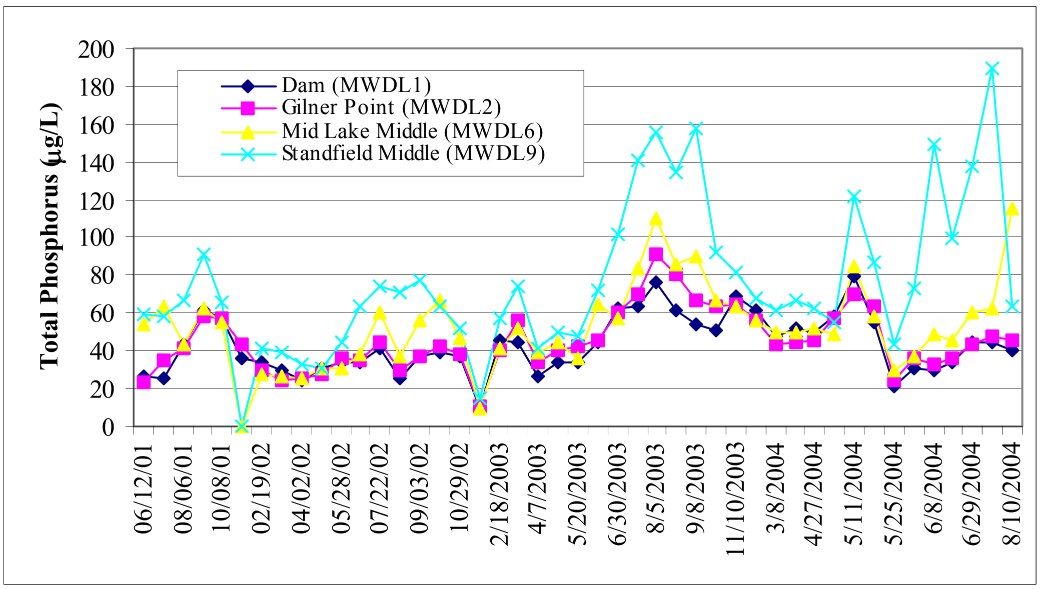


Figure 5-4 a) Total nitrogen and b) Total phosphorus photic zone water column concentrations from 2001-2004.

Note: 1st Sonar application was initiated on May 13, 2002 and concluded on June 12, 2002.
2nd Sonar application was initiated on June 5, 2003 and concluded on July 9, 2003.
Trial alum application (Papoose Bay only) was initiated and concluded on October 22, 2003
Lakewide alum application was initiated on May 24, 2004 and concluded on June 19, 2004.

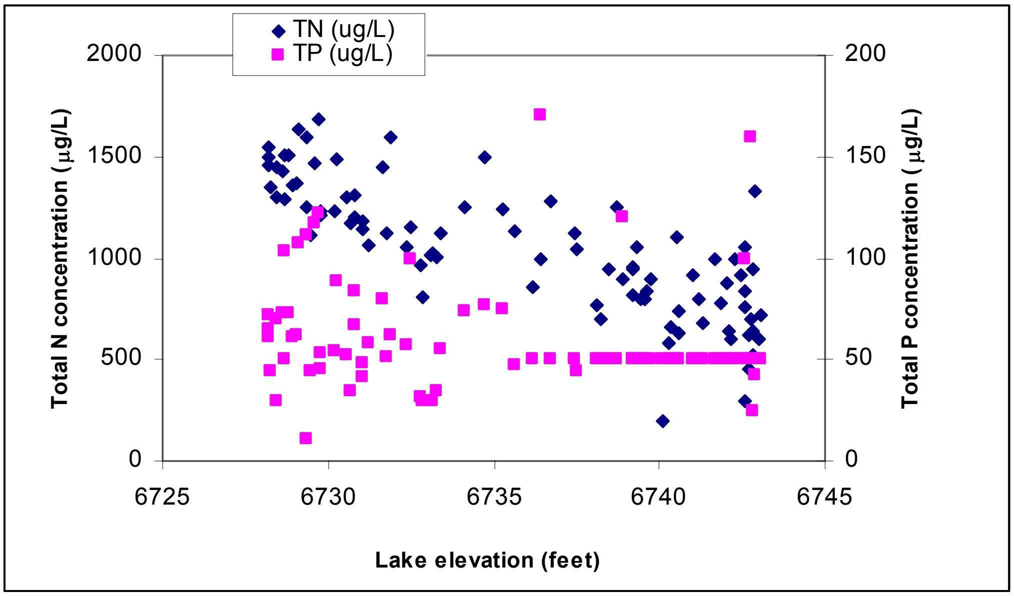


Figure 5-5. Total N and Total P concentrations as a function of lake elevation

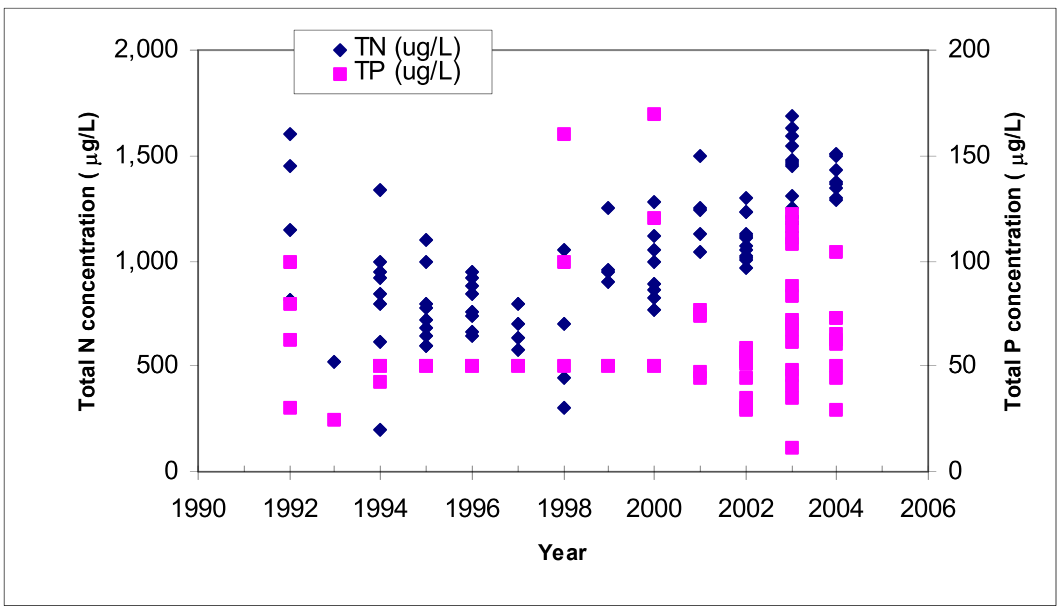


Figure 5-6. Total N and Total P concentrations as a function of year

Note: 1st Sonar application was initiated on May 13, 2002 and concluded on June 12, 2002.
2nd Sonar application was initiated on June 5, 2003 and concluded on July 9, 2003.
Trial alum application (Papoose Bay only) was initiated and concluded on October 22, 2003
Lakewide alum application was initiated on May 24, 2004 and concluded on June 19, 2004

5.2 Proposed TMDLs

Tables 5-2 and 5-3 summarize the proposed phosphorus and nitrogen TMDLs for Big Bear Lake under dry conditions, defined by the conditions observed from 1999-2003. During this period, the precipitation ranged from 0-23 inches, inflow ranged from 0-3049 AF and lake levels ranged from 6671 –6735 feet. The TMDLs include the allowable loads from all external sources and those from internal lake sediments and macrophytes, expressed in terms of annual averages for calendar years (January 1- December 31) that meet the dry condition definition as expressed above.

These TMDLs are based on the conclusions drawn in the preceding section regarding the effects and feasibility of loading reduction scenarios simulated by the WASP model. The TMDLs, as well as the WLAs and LAs (Section 6.0) are based on the average of simulated nutrient loads from the 5-year period, 1999-2003. Estimated existing nutrient loads are also based on the average of nutrient loads from this 5-year period (Table 4-5).

As discussed in the preceding section, the proposed TMDLs are projected to assure compliance with the recommended interim and final numeric targets identified in Section 3.1, with the exception of the final numeric target for nitrogen. Again, staff believes that the apparent failure to achieve the final nitrogen numeric target reflects model limitations and data gaps, both of which are to be addressed as part of the implementation of these TMDLs (see Section 10). This will entail data collection, model refinement and, likely, refinement of the TMDLs.

Table 5-2. Nutrient TMDL to achieve the interim target of phosphorus (35 µg/L) for Big Bear Lake during dry conditions (to be met as soon as possible, but no later than 2010) represented as annual averages for dry calendar years (January 1 – December 31) (all numbers in lbs/yr)

	TP load	Existing TP load
Internal loading	24,255*	39,331
External loading	1757	1757
TMDL	**26,012**	**41,088**

*Assumes a 60% reduction in internal phosphorus sediment loading and a 12.5% reduction in macrophyte TP loads

Table 5-3. Nutrient TMDLs to achieve the final targets of phosphorus (20 µg/L) and nitrogen (1000 µg/L) for Big Bear Lake for dry conditions (to be met as soon as possible, but no later than 2015) represented as annual averages for dry calendar years (January 1 – December 31) (all numbers in lbs/yr)

	TP load	**Existing TP load**	**TN load**	**Existing TN load**
Internal loading	19,978*	39,331	254,710^{+}	269,328
External loading	1757	1757	26,190	26,190
TMDL	**21,735**	**41,088**	**280,900**	**295,518**

*Assumes an 80% reduction in internal phosphorus sediment loading and a 12.5% reduction in macrophyte TP loads
$^{+}$Assumes a 12.5% reduction in macrophyte TN loads

The next section describes the allocation of these proposed TMDLs to different sources.

6.0 TMDL ALLOCATIONS

As discussed in Section 4.0, nutrient loads to Big Bear Lake come from both point source and nonpoint source discharges. The TMDLs must account for both types of inputs, as well as a margin of safety. This is expressed as follows:

TMDL = ΣWLA + ΣLA + MOS

where:

WLA = wasteload allocations for point source discharges
LA= load allocations for nonpoint source discharges, and
MOS=Margin of Safety

The Margin of Safety is incorporated in the proposed Big Bear Lake nutrient TMDLs via conservative assumptions. No explicit numeric MOS is included (see Section 8.0).

In order to derive the proposed waste load allocations (WLAs) for point source discharges and load allocations (LAs) for nonpoint source discharges, staff utilized the HSPF model results from Hydmet, Inc. (2004), the WASP model results from Tetra Tech (2004a), in-lake sediment release studies from Anderson and Dyal (2003) and Anderson et al. (2004) and macrophyte studies from ReMetrix (2004) to determine current nitrogen and phosphorus loading. The allowable loads defined by the TMDLs (Tables 5-2 and 5-3) were allocated among the sources, and the reduction required from each of the sources was then determined. Like the TMDLs, the proposed WLAs and LAs apply to dry water years only and are expressed as annual averages (see Section 5.2). As previously indicated, the proposed implementation plan will require the responsible parties to monitor the wet and average hydrological events to calibrate the model and develop TMDLs/allocations that address all hydrological conditions.

Point source discharges of nutrients to Big Bear Lake include urban storm and non-stormwater runoff (MS4 and Caltrans). The recommended wasteload allocations for this source do not include any assumptions to account for future growth because the watershed is close to its build-out capacity.

Nonpoint source discharges of nutrients considered in the HSPF simulation include forest and resort runoff. Nonpoint and point source discharges of nutrients considered in the WASP simulation for Big Bear Lake include those from atmospheric deposition, HSPF simulation including forest, resort and urban runoff and internal loading from sediments and macrophytes. Although resuspension and settling processes occur in Big Bear Lake, and settling loads could be calculated from the WASP model output, these two processes were not used to calculate the internal loading amount from sediment. No data have been collected for these two processes, both of which are very dynamic. Therefore, staff believes that using only the actual measured sediment flux rates to calculate nutrient loads from sediment is a reasonable approach for the Big Bear Lake nutrient TMDLs.

The proposed wasteload and load allocations can be expressed as follows:

ΣWLA = Urban (MS4) WLA

ΣLA = forest LA + resort LA + internal sediment LA + atmospheric deposition LA + internal macrophyte LA

Accordingly, the proposed nutrient TMDLs are expressed as:

TMDL = MS4 WLA + forest LA + resort LA + int. sediment LA + atmos LA + int. macrophyte LA

Again, no explicit MOS is incorporated in the proposed TMDLs.

Proposed WLAs and LAs to achieve the interim phosphorus target and final phosphorus and nitrogen targets for all sources for Big Bear Lake for dry hydrological conditions are shown in Tables 6-1 and 6-2, respectively. The following discussion describes the derivation of the LAs and WLAs.

Table 6-1. Proposed interim TMDL, wasteload and load allocations for Big Bear Lake during dry conditions (to be achieved as soon as possible, but no later than 2010)*

		TP load allocation (lbs/yr)	Existing TP load (lbs/yr)	Reduction (%)
TMDL		**26012**	**41088**	**37**
WLA		**475**	**475**	**0**
	Urban	475	475	**0**
LA		**25537**	**40613**	**37**
	Internal sediment source	8555	21388	**60**
	Internal macrophyte source	15700	17943	**12.5**
	Atmospheric deposition	1074	1074	**0**
	Forest	175	175	**0**
	Resort	33	33	**0**
MOS		**0**		

*Specified as an annual average based on a calendar year (January 1-December 31) for dry hydrological conditions only.

Table 6-2. Proposed final TMDLs, wasteload and load allocations for Big Bear Lake during dry conditions (to be achieved as soon as possible, but no later than 2015)*

		TP load allocation (lbs/yr)	Existing TP load (lbs/yr)	Reduction (%)	TN load allocation (lbs/yr)	Existing TN load (lbs/yr)	Reduction (%)
TMDL		**21735**	**41088**	**47**	**280900**	**295518**	**5%**
WLA		**475**	**475**	**0**	**3445**	**3445**	**0**
	Urban	475	475	0	3445	3445	0
LA		**21260**	**40613**	**48**	**277455**	**292073**	**5%**
	Internal sediment source	4278	21388	80	152386	152386	0
	Internal macrophyte source	15700	17943	12.5	102324	116942	12.5%
	Atmospheric deposition	1074	1074	0	21474	21474	0
	Forest	175	175	0	460	460	0
	Resort	33	33	0	811	811	0
MOS		**0**			**0**		

*Specified as an annual average based on a calendar year (January 1-December 31) for dry hydrological conditions only.

Atmospheric Deposition
The proposed load allocation for atmospheric deposition for Big Bear Lake is the same as the estimated existing load discussed in Section 4.2 (TN = 21,474 lbs/yr, TP = 1,074 lbs/yr). Based on this value, atmospheric loading contributes 7% of the nitrogen load and nearly 3% of the phosphorus load to Big Bear Lake. Studies to be conducted in the watershed should allow refinement of the allocation based on watershed-specific data. Future reduction of this source is contingent on implementation of relevant air quality management plans by the Southern California Air Quality Management District (SCAQMD) and/or the California Air Resources Board (CARB).

Internal Nutrient Loads from Sediment
To determine the internal sediment loading allocation for Big Bear Lake, staff assumed that the alum project, in conjunction with the planned east end dredge project, will reduce phosphorus loads by 60% in order to meet the proposed interim total phosphorus TMDL and interim numeric target of 35 µg/L (see discussion in Section 5.1). An 80% reduction in internal phosphorus loading rate is assumed in order to meet the final numeric phosphorus TMDL and target (20 µg/L). Because the restoration projects have the potential to reduce phosphorus loads more than nitrogen loads, no reduction of sediment nitrogen loads was assumed for the purposes of the load allocation.

Internal Nutrient Loads from Macrophytes
To determine the internal macrophyte loading allocations for Big Bear Lake, staff assumed a 25% reduction, split evenly between total nitrogen and total phosphorus, to meet both the interim and final TMDLs. As shown in Tables 6-1 and 6-2, the proposed LAs for macrophyte loads are 15,700 lbs/yr of phosphorus (interim and final) and 102,324 lbs/yr of nitrogen (final[51]), respectively. Note that these loads are still greater than those loads calculated previously for the Big Bear Lake nutrient budget report (Section 5.1). For this reason, even though a 50% reduction in macrophyte loads was required to meet the proposed final phosphorus numeric target, staff believes that only a 25% reduction in macrophyte loads is appropriate (see Section 5.1, Conclusions).

Urban Storm and Non-stormwater runoff, forest and resort
The remaining existing or potential nutrient sources (i.e., urban runoff, runoff from forest and resort land uses) originate from the various land use practices in the watershed. Because there is no reduction required for any of the external HSPF simulated nutrient loads to meet the proposed dry condition TMDLs, the proposed WLAs are the same as the existing urban loads and the proposed LAs for forest and resort discharges are the same as the existing loads.

As stated above, the TMDL allocations proposed in Tables 6-1 and 6-2 apply as annual averages during dry hydrological conditions only, which means that the average loads from each source over a calendar year that is characterized as dry (see Section 5.2) shall not exceed the allocations specified in Tables 6-1 and 6-2. The proposed allocations to meet the interim TP TMDL under dry conditions are proposed to be achieved as soon as possible, but no later than 2010. The proposed allocations to meet the final TP and TN TMDLs under dry conditions are to be achieved as soon as possible, but no later than 2015.

The proposed implementation plan includes requirements for the responsible parties to collect additional data to enable the calibration of the models for wet and average hydrological periods (see Section 10). As previously indicated, TMDLs, WLA and LAs for wet and/or average hydrological conditions will be proposed once additional data have been collected.

[51] As described in Section 3.1.1., only a final total nitrogen target is proposed.

7.0 SEASONAL VARIATION AND CRITICAL CONDITIONS

TMDLs must include consideration of seasonal factors and critical conditions. Consideration of seasonal variations in nutrient TMDLs is necessary to account for variations in the rates of nutrient input and internal cycling in aquatic ecosystems that occur naturally and, in some cases, as the result of human activities. In Big Bear Lake, external loading of nutrients is greatest during the winter and spring months, when there is higher precipitation and snow melt runoff. As spring arrives, macrophytes start to grow using nutrients sorbed to the lake sediments and present in the water column. As summer progresses, higher temperatures and increased production of algae and/or macrophytes can lead to decreases in dissolved oxygen concentration. If anoxic conditions develop, nutrient releases from the sediment will increase, spurring more algal growth. Soluble phosphorus and nitrogen release from the sediments is greatest during the summer due to increased temperatures and lower dissolved oxygen concentrations (Anderson and Dyal, 2003). As fall arrives and water temperatures decline, macrophytes die-off and decay and nutrients are released back into the water column or are taken up by attached algae. This process can in turn cause a short burst of algae growth. Decaying plant matter is deposited on the lake bottom and mineralized.

Consideration of the critical conditions in a body of water ensures that even under the worst water quality conditions, water quality standards will be met through the implementation of the TMDLs. The most critical condition for attainment of aquatic life and recreational uses in Big Bear Lake occurs during summer, when the greatest release of phosphorus and nitrogen from the sediment occurs and when it is typically dry, with little inflow and decreased lake levels, causing increases in nutrient concentrations. During dry periods, internal loads from the sediment and macrophytes are the most important sources of nutrients driving the eutrophication process. Macrophyte biomass is also at its peak during late summer/early fall. Both macrophyte growth and algae can deplete oxygen, leading to stresses on aquatic life and increasing the rate of nutrient release from the sediment. The summer period is also the peak period for recreational activities in the lake.

The nutrient TMDLs for Big Bear Lake account for seasonal and annual variations in external and internal phosphorus loading, as well as critical conditions, in the following ways:

1) The proposed TMDLs address the critical dry conditions by focusing on the control of the internal sediment loads that dominate during these periods. Attainment of the TMDLs requires removal or inactivation of sediment phosphorus. Reductions in internal phosphorus and nitrogen loads will reduce the risk of oxygen depletion in the hypolimnion. Preventing oxygen depletion, and enhancing oxygenation with in-lake aerators will also reduce phosphorus release. The proposed TMDLs addresses the critical conditions by requiring that total phosphorus loads from sediment be reduced by 60% and total phosphorus and total nitrogen loads from macrophytes be reduced each by 12.5% to meet the proposed interim phosphorus TMDL. To meet the proposed final total phosphorus and total nitrogen TMDLs, total phosphorus loads from sediment must be reduced by 80% and total phosphorus and total nitrogen loads from macrophytes must be reduced by 12.5% each.

2) The proposed TMDLs recognize that different nutrient inflow and cycling processes dominate the lake during different seasons. These processes are simulated in the WASP model (though, as already noted (Section 5.1), they are not all simulated dynamically), using data from a multi-year period. As discussed previously (Section 5.1), the WASP model used data collected from 2001-2003 and extrapolated to 1999 and 2000. Nutrient flux rates were obtained during both summer and fall in 2002 and 2003 as well as winter in 2003 (Anderson and Dyal, 2003; Anderson et al., 2004). Tetra Tech (2004a) incorporated these different flux rates into the time functions that represent the fluxes as a function of either time of year or depth. Similarly, the macrophyte loads

incorporated the growing cycle to estimate the peak biomass and also used the growing season average depths from 1999-2003 to determine total biovolume of macrophytes in each segment (Tetra Tech, 2004a). Thus, the results of the WASP model are a reflection of all of the seasonal processes. Although it would be preferable to include a longer period of record that includes wet and average years and to develop TMDLs that take these annual variations in hydrologic conditions into account, this was not possible because the data were not available. This is addressed in the proposed implementation plan.

3) The proposed implementation plan (Section 10) includes requirements for additional data collection and analyses designed to better understand nutrient dynamics in the lake under varying hydrologic conditions, which should allow for refinement of the lake model and revisions of the TMDLs, where appropriate.

8.0 MARGIN OF SAFETY

TMDLs must include an explicit or implicit margin of safety (MOS) to account for uncertainty in determining the relationship between pollutant loads and impacts on water quality. An explicit MOS can be provided by reserving (not allocating) part of the TMDL and therefore requiring greater load reductions from existing and/or future sources. An implicit MOS can be provided by conservative assumptions in the TMDL analysis. The assumptions that account for the MOS must be adequately identified.

Sources of uncertainty in the Big Bear Lake nutrient TMDL development analysis include: 1) the lack of watershed specific data on total phosphorus and total nitrogen loading from surface runoff to allow calibration of the water quality component of the watershed model; 2) the lack of discharge measurements from the tributaries; 3) the inherent seasonal and annual variability in delivery of total phosphorus and total nitrogen from external sources, and in nutrient cycling within Big Bear Lake; 4) assumptions made about the rate of nutrient release from the sediment and the efficiency of potential lake treatment technologies; 5) assumptions made about the contribution of nutrient loads from macrophytes and the inherent annual variability in delivery of total phosphorus and total nitrogen from macrophyte die-off and decay; 6) the absence of a high elevation weather station to obtain data needed to calibrate the watershed model; 7) assumptions made about the estimated biomass of macrophytes and the percentage of nutrients that are recycled to the water column and to the sediments; 8) assumptions made about the contribution of total nitrogen and total phosphorus from atmospheric loads; 9) the lack of established relationships between in-lake total nitrogen and total phosphorus concentrations and either algae growth or macrophyte coverage; 10) the inability of the WASP model to model macrophyte nutrient dynamics, likely leading to total nitrogen predictions that do not achieve the proposed final target; and 11) the lack of measured sedimentation and resuspension rates. In addition, the lake and tributary water column monitoring and the sediment and macrophyte studies were carried out during dry years; therefore, the WASP model can only be used to predict water quality during dry hydrological conditions.

To address these uncertainties, conservative approaches were applied in setting the numeric targets, TMDLs, WLAs, and LAs. Staff selected the proposed interim total phosphorus numeric target conservatively by using the 25th percentile of data collected before the application of the aquatic herbicide Sonar (see Section 3.1.1). The data used were collected at different times of the year, not only during summer, when phosphorus concentrations are higher. The numeric targets are also proposed as annual averages. The intent is to set targets that will, when achieved, result in improvement of the trophic status of Big Bear Lake year-round. Again, staff is well aware of the need to obtain data necessary to support development of model capability and TMDLs that address wet and average hydrologic conditions, as well as dry conditions. The WASP model setup also included conservative assumptions, such as estimating a higher macrophyte density than what had been calculated previously. These approaches therefore address the MOS implicitly. As new data are collected under various hydrologic conditions, data gaps will be filled, an uncertainty analysis can be conducted and the MOS and TMDLs can be adjusted as appropriate.

9.0 IMPLEMENTATION PLAN

Federal regulations require the State to identify measures needed to implement TMDLs in the state water quality management plan (Basin Plan) (40 CFR 130.6). California law requires that Basin Plans have a program of implementation to achieve water quality objectives (Water Code Section 13242). The implementation program must include a description of actions necessary to achieve the objectives, a time schedule for these actions, and a description of the surveillance and monitoring activities to determine compliance with the objectives. TMDLs are not water quality standards and do not establish new water quality objectives; rather, they are a mechanism to attain existing standards, including narrative and numeric objectives. An implementation plan ensures that the TMDL achieves this purpose.

Staff proposes that the Big Bear Lake nutrient TMDLs be adopted as phased TMDLs. The phased implementation framework provides time to conduct further monitoring and assessment, including refining the existing watershed and in-lake models. The results of these studies are expected to provide the analytical basis for modifying the TMDLs, WLAs, LAs and/or other elements of the TMDLs.

The proposed Basin Plan amendment, shown in Attachment A, includes an implementation plan and monitoring program designed to implement the TMDLs and evaluate their effectiveness. Implementation is expected to result in compliance with the proposed nutrient TMDLs and allocations for Big Bear Lake and thereby ensure protection of the beneficial uses of this body of water. The proposed implementation plan includes requirements directed at both point and nonpoint sources. Implementation of the Big Bear Lake nutrient TMDLs is the responsibility of the dischargers of nutrients, including the U.S. Forest Service, Big Bear Mountain Resorts, the City of Big Bear Lake, Caltrans, County of San Bernardino, and the San Bernardino County Flood Control District. The Big Bear Municipal Water District is committed to be a cooperating partner, working with the stakeholders to implement the Big Bear Lake nutrient TMDLs.

Given the lack of data on beneficial use impacts to Rathbun, Grout, and Summit Creeks from nutrients, the proposed TMDL implementation plan includes a requirement to investigate these creeks.

Regional Board staff plan to coordinate implementation with the following agencies, programs and policies:

- The Regional Board's Watershed Management Initiative (WMI) program for the Big Bear Lake watershed
- The Regional Board's permitting and enforcement sections
- The Regional Board's stormwater section
- The State Board's Nonpoint Source (NPS) Implementation and Enforcement Policy
- The Big Bear Lake TMDL Workgroup coordinated by the Big Bear Municipal Water District (BBMWD)
- The U.S. Forest Service, San Bernardino National Forest (Big Bear Lake Ranger Station) and the existing (Management Agency Agreement) MAA between the SWRCB and the Forest Service regarding control of nonpoint source pollution from forest activities within California
- The U.S. Army Corps of Engineers and the Corps' Feasibility Study within the Big Bear Lake watershed
- The U.S. Fish and Wildlife Service, and
- The California Department of Fish and Game

9.1 Implementation Actions by the Regional Board

In order to implement the TMDLs, WLAs and LAs, Board staff proposes that the Regional Board undertake the following actions. Proposed dates for implementation of these actions are specified in the proposed Basin Plan amendment (Attachment A).

1. Establish New Waste Discharge Requirements/Conditional Waivers
   a) The Regional Board will work with the responsible parties and the Big Bear Municipal Water District to issue a general NPDES permit for restoration activities (e.g., alum or herbicide) planned for Big Bear Lake. A requisite provision of that permit would be aquatic plant monitoring.

   b) Review the State Board's new NPS policy and act accordingly with respect to nonpoint sources. This could include drafting new WDRs/conditional waivers for the Big Bear Mountain Resorts and ensuring that the MAA and its provisions between the USFS and SWRCB are being met through the issuance of new WDRs/conditional waivers.

2. Revise Existing Waste Discharge Requirements
   The Regional Board shall review and revise, as necessary, the following existing NPDES permit to incorporate the appropriate WLAs, compliance schedules and monitoring program requirements.
   Waste Discharge Requirements for the San Bernardino County Flood Control District, the County of San Bernardino and the City of Big Bear Lake, Areawide Urban Runoff, NPDES No. CAS 618036 (Regional Board Order No. R8-2002-0012)

3. Review/Revise Site-Specific Water Quality Objectives for Big Bear Lake
   The Regional Board shall review, and revise as necessary, the numeric water quality objectives for total phosphorus and total inorganic nitrogen for Big Bear Lake. The Regional Board shall examine the appropriateness of establishing numeric water quality objectives for total nitrogen for Big Bear Lake. Finally, the Regional Board shall consider whether it would be appropriate to develop numeric or narrative objectives based on the response variables identified in Section 3 of this report (chlorophyll *a*, macrophyte coverage and percentage of nuisance aquatic vascular plant species). It may be appropriate to consider such objectives in lieu of numeric objectives for phosphorus and/or nitrogen.

4. Review collected data on beneficial use impairment from nutrients in Rathbun Creek, Summit Creek, and Grout Creek and assess whether TMDLs need to be developed or if these creeks should be recommended for delisting from the 303(d) list of impaired waters.

5. Utilize new monitoring data and model simulations to establish load and wasteload allocations for wet and average hydrological periods and/or to revise the dry weather nutrient TMDLs.

6. Conduct Atmospheric deposition studies
   During the watershed modeling, literature searches suggested that atmospheric deposition could be a significant source of the total nutrient load in the overall nutrient budget of Big Bear Lake. Atmospheric deposition of nitrogen and phosphorus will be quantified through analysis of rainwater and dryfall samples in the Big Bear Lake watershed. Coordination with the SCAQMD and CARB will be encouraged to determine any effective means of reducing nutrient loads from atmospheric deposition.

9.2 Implementation Actions by Other Agencies/Entities

The first phase of these dry condition TMDLs does not require that steps be taken to reduce external nutrient loading, which occurs principally during wet years. However, it is recognized that external inputs remain in the lake for an extended period and contribute significantly to internal sediment loading and macrophyte growth, which are addressed by these TMDLs. Accordingly, the proposed implementation plan includes requirements for external nutrient dischargers to participate in the development of internal sediment loading control measures and macrophyte reduction/aquatic plant management programs. The parties are required to continue to conduct watershed and in-lake monitoring, which will be used to refine the dry condition TMDLs and to develop TMDLs for wet and average hydrologic conditions. The parties are also required to participate in programs designed to refine the watershed and in-lake nutrient models and to develop a multimetric index for Big Bear Lake. Each of these tasks is described in the proposed Basin Plan amendment (Attachment A). The monitoring related tasks are described in more detail in the next section (Section 10).

9.3 Implementation Schedule

Regional Board staff proposes that the interim target for Big Bear Lake (see Section 3, Table 3-1) and the allocations specified in Table 6-1 be met as soon as possible but no later than 2010. Staff recommends that the final targets for Big Bear Lake (see Section 3, Table 3-1) and allocations (Table 6-2) be met as soon as possible but no later than 2015.

10.0 MONITORING PROGRAM RECOMMENDATIONS

Section 13242 of the California Water Code specifies that Basin Plan implementation plans must contain a description of the monitoring and surveillance programs to be undertaken to determine compliance with water quality objectives. As part of the incorporation of the proposed Big Bear Lake nutrient TMDLs into the Basin Plan, specific monitoring requirements are proposed in order to evaluate the effectiveness of actions and programs implemented pursuant to the TMDL. These requirements are described below and specified in the proposed Amendment (Attachment A). Since the Big Bear Lake TMDLs are proposed as phased TMDLs, follow-up monitoring and evaluation is essential to validate and revise the TMDLs as necessary and to develop wet and/or average TMDLs, WLAs and LAs.

10.1 Big Bear Lake In-lake Monitoring Program

The Big Bear Municipal Water District and various stakeholders in the watershed, along with Regional Board staff, implemented a Big Bear Lake in-lake monitoring program in 2001. This program, which is currently on-going, consists of the collection of water quality data along with depth profile measurements at stations in Big Bear Lake on a year-round basis. The purpose of this program is to evaluate changes in lake water quality due to nutrient input or other environmental factors. This monitoring program has been funded by stakeholders as well as by various grant programs.

Staff recommends that the proposed Basin Plan amendment include the requirement that the responsible parties continue the in-lake monitoring program to assess the response of the lake to the nutrient loadings and to determine if the load reductions result in the achievement of numeric targets (as proposed in Section 3.0).

10.2 Watershed-wide Nutrient Water Quality Monitoring Program

A watershed-wide nutrient monitoring program was implemented in 2001 by the Big Bear Municipal Water District and various stakeholders in the watershed along with Regional Board staff and is currently on-going. The purpose of this monitoring program has been to collect data needed to develop the nutrient TMDLs, as well as other TMDLs. The monitoring program consists of the collection of stream flow and water quality data in the Big Bear Lake watershed. Because there are no USGS stream gages in this watershed, this program is key to developing accurate loading estimates from the watershed and accurate inflow measurements. This watershed-wide monitoring program has been instrumental in the development of the proposed nutrient TMDLs and is critical to enable development of wet and/or average TMDLs, WLAs and LAs and the implementation plan.

The proposed Basin Plan amendment specifies that the responsible parties shall continue to implement this watershed-wide nutrient monitoring program and focus on collecting nutrient data from specific nutrient sources (e.g., open space/forest lands, urban runoff, and the ski resorts). The locally-built weirs and ISCO stormwater samplers that have been installed as part of the watershed-wide monitoring program, or other acceptable flow monitoring and sampling devices, must also be continually operated and maintained, and water quality samples need to be collected from all stations at the frequency identified in the Basin Plan Amendment (Attachment A) to quantify nutrient loads from various sources in the watershed. In addition, a high elevation weather station should be installed and maintained in order to obtain the necessary data for calibration of the present watershed model. The data generated will not only be used to evaluate TMDL compliance, but will also be used to calibrate/update the current watershed model.

10.3 Special studies

Finally, staff believes that there is a need to conduct special, nutrient-related studies in the watershed. These studies should be jointly undertaken by the responsible parties as identified in Section 9.0.

- In-lake treatment of sediment to remove nutrients: The applicability of various in-lake treatment technologies to prevent/reduce the release of nutrients from lake sediments needs to be evaluated in order to develop a long-term strategy for control of nutrients from the sediment. Examples of treatment technologies include aeration, alum treatment, wetland treatment, fishery management, and dredging. The BBMWD has already implemented many of these in-lake treatment technologies (e.g., alum treatment and aeration) and will conduct a pilot dredging study in 2005. The findings of these in-lake treatment technologies need to be summarized and strategies developed based on cost and effectiveness of reducing nutrient loads from in-lake sediments.

- Model update/development: Update/revision of the watershed nutrient model developed by Hydmet, Inc. (2004) will be needed in the future as additional data are generated. An updated watershed model could be used to determine BMP effectiveness and to determine TMDL, WLA and LA compliance. The model could also be used as a tool to evaluate potential pollutant trading options. Update/revision of the in-lake model will also be needed in the future as additional data are generated. A new in-lake model may be developed to more accurately simulate macrophyte and sediment processes. An updated in-lake model or new in-lake model will be used for developing wet and/or average TMDLs, WLAs and LAs, as well as future refinement of the proposed dry TMDLs, WLAs, LAs and numeric targets.

- Aquatic Plant Management Plan: Development and implementation of an Aquatic Plant Management Plan by the responsible parties identified in Section 9.0 to address strategies for aquatic plant control, monitoring aquatic vegetation and tracking changes in macrophyte habitat through vegetation assessments and GIS mapping, and effectiveness of prior treatment strategies.

- Multimetric Index: Development of a multimetric index for Big Bear Lake by the responsible parties identified in Section 9.0. The index will incorporate biological, chemical and physical parameters. This index will incorporate sampling to calculate trophic state, aquatic macrophyte biomass and species, fish assemblages, shore zone habitat, phytoplankton, and zooplankton for effective assessment of improvement in overall lake health.

11.0 ECONOMIC CONSIDERATIONS

Regional Water Boards are required to adopt TMDLs as basin plan amendments. There are three statutory triggers for consideration of economics in basin planning. These triggers are:

- Adoption of an agricultural water quality control program (Water Code Section 13141). The Regional Board must estimate costs and identify potential financing sources in the Basin Plan before implementing any agricultural water quality control plan.
- Adoption of water quality objectives (Water Code Section 13241). The Regional Board is required to consider a number of factors, including economics, when establishing or revising water quality objectives in the Basin Plan.
- Adoption of a treatment requirement or performance standard. The Regional Board must comply with the California Environmental Quality Act (CEQA) when amending the Basin Plan. CEQA requires that the Board consider the environmental effects of reasonably foreseeable methods of compliance with Basin Plan amendments that establish performance standards or treatment requirements, such as TMDLs. The costs of the methods of compliance must be considered in this analysis.

It should be noted that in each of these three cases, there is no statutory requirement for a formal cost-benefit analysis.

There are no agricultural operations in this watershed, therefore the first statutory trigger does not apply. The adoption of this TMDL does not constitute the adoption of new or revised water quality objectives, so the second statutory trigger also does not apply here[52]. The proposed TMDLs do not require the implementation of external load control measures. However, the proposed implementation plan requires the stakeholders to take steps to reduce internal sediment and macrophyte nutrient loading, and to participate in monitoring and other efforts designed to assess compliance with and refine the TMDLs, and to develop TMDLs for wet and average hydrologic conditions. The costs to be considered are those associated with these actions.

The proposed implementation plan requires continuation of the on-going watershed and lake monitoring to assess the effectiveness of lake improvement strategies and to determine compliance with the TMDL numeric targets. Studies identified in Section 10 are also required as part of the TMDL implementation plan. Most of the studies are funded under two Prop. 13 Phase III grants awarded to the Big Bear Municipal Water District and the East Valley Resource Conservation District. These studies are scheduled to begin in 2005 and 2006. In addition, funding for monitoring programs will be covered through 2006 under these grants. Table 11-1 shows some of the costs of the ongoing monitoring.

[52] As discussed in Section 3.1, it appears that the numeric objectives established in the Basin Plan for total phosphorus and total inorganic nitrogen in Big Bear Lake are not protective and need to be revised. The numeric targets, and thus the TMDLs, WLAs and LAs, are not based on these objectives. Rather, they are based on best professional judgment of the levels necessary to comply with the narrative objectives established in the Basin Plan (Section 2.1).

Table 11-1. Cost estimates for nutrient TMDL monitoring

Medium	**Study type**	**Cost per sample $**
Sediment	Core flux	278
Sediment	Sediment traps	3000
Water	Composite -photic	175
Water	Discrete -bottom	95
Water	Phytoplankton	120
Water	Zooplankton	120
Water	Tributaries	140
Plant tissue	Biomass, aquatic plant species identification	112
Water	Hydroacoustic transect	275
Plant tissue	Biomass by scuba diving	511

Table 11-2 shows the costs associated with certain types of restoration activities.

By the end of 2007, the amount of money spent in the Big Bear Lake watershed for developing and implementing the Big Bear Lake TMDLs will have amounted to well over $4 million (Table 11-3). This amount includes grants funded by Proposition 13, Section 319(h) of the Clean Water Act and TMDL funds provided by the State. The USEPA also provided $50,000 for the WASP model effort. Not taken into consideration are the TMDL Task force budget of $90,000 per year, other funds contributed by the BBMWD, the $100,000 the U.S. Army Corps of Engineers spent on a reconnaissance study, or the money now being spent as part of the Corps' feasibility study.

Phase II of the Big Bear Lake Nutrient TMDLs is likely to address nutrient discharges from the various land uses in the watershed (urban, resort and forest) during average and wet conditions. Obviously, there are likely to be costs associated with any required reductions identified in Phase II. At that time, those economic impacts would be evaluated.

Table 11-2. Estimated costs of lake management options for Big Bear Lake

LAKE MANAGEMENT TECHNIQUE	TREATMENT ASSUMPTIONS	COST RANGE PER ACRE TREATED ($)
Sediment Nutrient Flux Control		
Aeration	Full or partial lift, prevention of anoxia	800 to 2,000
	Full or partial lift, DO> 5 mg/L	1,000 to 3,000
	Layer aeration, prevention of anoxia within layer	500 to 1,000
	Layer aeration, DO> 5 mg/L	700 to 1,200
Dredging	Average sediment depth = 2ft	15,000 to 50,000
	Average sediment depth = 5ft	25,000 to 80,000
Nutrient Activation	Alum with no buffering, external load controlled	500 to 700
Macrophyte Control		
Herbicide Treatment with Fluridone (SONAR)	Liquid formulation, single treatment	500 to 1,000
	Liquid formulation, triple treatment	1,000 to 2,000
	Pellet formulation	800 to 1,200
Harvesting	Moderately dense, submerged vegetation	200 to 600
	Very dense or difficult to cut/handle	1,000 to 1,500

Source: Table provided as a task deliverable for a Proposition 13 grant (Contract # 02-069-258-1 with the BBMWD) –reformatted by RWQCB staff

Table 11-3. Sources and amounts of funding for the Big Bear Lake Watershed

Funding Source	Project	Deliverables	Amount	Recipient
State TMDL funds	Nutrient monitoring	Watershed and lake nutrient monitoring from June 01-Oct.02	$40,000	BBMWD
State TMDL funds	Nutrient Budget	HSPF model WASP model Sediment core-flux analyses and sediment characterization Watershed and lake nutrient monitoring ISCO samplers Plant tissue analyses	$77,000	BBMWD
Prop. 13	Pilot-scale remediation	Lake wide fish survey Lake wide macroinvertebrate study Biological surveys (zooplankton, phytoplankton) Access database of all monitoring data Trial alum project in Papoose Bay Big Bear Lake Atlas website	$200,000	BBMWD
Federal 319(h) funds	Nutrient and plant remediation	Sonar application Pre-and post- treatment aquatic macrophyte surveys	$120,000	BBMWD
Prop. 13	High resolution aerial mapping	Low and high altitude aerial photography GIS coverages (DTM, contours, utility, parcels)	$490,000	SBC/City of Big Bear Lake
Prop. 13	Large-scale alum application	Lake wide alum application Water quality monitoring prior to, during and after project Sediment core-flux data	$500,000	BBMWD
Prop. 13	Lake and Tributary monitoring support	Continued water quality monitoring-2005 Phytoplankton and zooplankton analyses Preliminary macrophyte index	$80,000	BBMWD
Prop. 13	BMP implementation	BMP implementation in Snow Forest area NPS education	$250,208	EVRCD
Federal 106(g) funds	WASP model	WASP model Updated HSPF model runs	$50,000	RWQCB8
Prop. 13	Lake dredging and study	Continued water quality monitoring Studies needed for TMDL implementation High elevation weather station Monumented cross-sections Dredging of east end Update to Access database Model plan	$2,300,000	BBMWD

12.0 CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA)

The Secretary of Resources has certified the Basin Planning process as "functionally equivalent to" the preparation of an Environmental Impact Report (EIR) or a Negative Declaration pursuant to the California Environmental Quality Act (CEQA). However, in lieu of these documents, the Regional Board is required to prepare the following: the Basin Plan amendment; an Environmental Checklist that identifies potentially significant adverse environmental impacts of the Basin Plan amendment; and, a staff report that describes the proposed amendment, reasonable alternatives, and mitigation measures to minimize any significant adverse environmental impacts identified in the CEQA checklist. The Basin Plan amendment, Environmental Checklist, and staff report together are functionally equivalent to an EIR or Negative Declaration.

The draft Environmental Checklist (Attachment B to this report) concludes that there would be no potentially significant impacts on the environment caused by adoption of this Basin Plan amendment. Therefore, no mitigation measures are required.

This staff report will be followed by another report that includes comments received on the proposed amendment, staff responses to those comments, and a discussion of any changes made to the proposed amendment as the result of the comments or further deliberation by the Board, and/or Board staff. This follow-up report would address any additional CEQA considerations, including economics, that might arise as the result of any changes to the proposed amendment.

Consideration of Alternatives

1. No Project Alternative

The "No Project" alternative would be no action by the Regional Board to adopt TMDLs with implementation measures and a monitoring program. This alternative would not meet the purpose of the proposed action, which is to correct ongoing violations of the Basin Plan numerical objectives for TIN and total phosphorus, as well as narrative objectives regarding algae, and to prevent adverse impacts to beneficial uses. This alternative would result in continuing water quality standards violations and threats to public health and safety, and the local economy. This alternative would not comply with the requirements of the Clean Water Act.

2. Alternatives

The Regional Board could consider TMDLs based on alternative numeric targets, such as more restrictive numeric targets. However, the proposed numeric targets are based on the best scientific information now available concerning the eutrophic status of Big Bear Lake and factors contributing to that status. The proposed targets provide the best assurance that the narrative water quality objective for algal growth will be achieved and that the beneficial uses will be protected.

The Board could also consider an alternative TMDL implementation strategy that is based on a different compliance schedule approach. Adoption of a longer schedule would prolong non-attainment of the water quality standards. The proposed compliance schedule approach reflects the timing of implementation of projects for Big Bear Lake that are expected to result in improvements in lake water quality. The proposed compliance schedule also considers the need for additional studies to fill data gaps, particularly the collection of data during wet and average hydrological conditions, and address uncertainties in the TMDL calculation. The proposed compliance schedules are therefore considered reasonable.

3. Proposed Alternative

Staff believes that the recommended TMDLs reflect a reasoned and reasonable approach to the improvement of the beneficial uses of Big Bear Lake. The proposed implementation schedule also provides a realistic time frame in which to complete the tasks required by the TMDL.

13.0 PUBLIC PARTICIPATION

Federal TMDL regulations require public participation to give the public an opportunity to review and comment on the TMDLs. A number of opportunities for public participation are afforded throughout the entire TMDL Basin Plan Amendment process and through the CEQA review process.

- Basin Plan amendments require advanced public notice and a public hearing (CWC § 13244).
- CEQA requires circulation of a Notice of Filing to the public and interested public agencies.
- Public workshops are held by the Regional Board to consider evidence and testimony related to the proposed TMDL.
- Regional Board staff must prepare written responses to comments that are received at least 15 days before the Board's scheduled action (public hearing). For those late comments for which written responses are infeasible and for oral comments at the Board meeting, staff must respond orally at the Public Hearing.
- Draft TMDLs, Basin Plan Amendments, Public Notices, Notice of Filing, CEQA documentation are made available on the Regional Board's website.
- After Regional Board adoption of the Basin Plan Amendment, the SWRCB and the USEPA have their review and approval processes, which affords more opportunities for public participation.
- Documentation of all public participation, including copies of hearing notices, press releases, written public comments and written responses, and tapes or minutes of hearing testimony will be included in the administrative record of the Basin Plan amendments.

In June 2000, Regional Board staff convened a TMDL workgroup to assist staff in the development of the Big Bear Lake nutrient TMDLs. Soon thereafter, the Big Bear Municipal Water District hired Tim Moore of Risk Sciences as the TMDL facilitator. The BBMWD created the Big Bear Lake TMDL Task Force, which includes representatives from the Big Bear Municipal Water District, San Bernardino County Flood Control District, City of Big Bear Lake, the Big Bear Area Regional Wastewater Authority, Caltrans, Regional Board staff, Big Bear Mountain Resorts and recently, the USFS. The BBMWD also created a TMDL fund to pay for studies in the watershed. Contributors to date include the BBMWD, the City of Big Bear Lake, the San Bernardino County Flood Control District and the Big Bear Area Regional Wastewater Authority. The Big Bear Municipal Water District has been instrumental in assisting Regional Board staff in the development of the Nutrient TMDLs by compiling existing data, designing, coordinating and implementing the watershed and in-lake monitoring programs, and reviewing the results of studies conducted in the watershed. BBMWD has also secured a number of grant funds, including a Clean Water Act Section 319(h) grant that was used to reduce Eurasian watermilfoil, and several Proposition 13 funds (see Table 11-3). The Proposition 13 funds have funded a macroinvertebrate study, pilot and full-scale alum projects, lake and tributary monitoring, to name just a few items. In addition, the County of San Bernardino along with the City of Big Bear Lake was awarded a Proposition 13 grant to obtain aerial photos of the entire Big Bear Lake watershed for implementation of their stormwater program and for other projects within the watershed. The East Valley Resource Conservation District was also awarded a Proposition 13 grant to work with the USFS in reducing sediment and nutrient loads from an abandoned ski area in the watershed. Altogether, by the end of 2007, more than 4 million dollars will have been spent by the state and US EPA to develop and implement these TMDLs (Table 11-3).

14.0 STAFF RECOMMENDATION

Direct staff to prepare a Basin Plan amendment and related documentation to incorporate the TMDLs for nutrients for Big Bear Lake shown in Attachment A for consideration at a future public hearing.

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Appendix A – Summary of nutrient water quality for the 303(d) listed tributaries

Appendix B – Minitab results

Appendix C – Trophic State Indices

ATTACHMENT A

Resolution No.

To be submitted at a later date