DEPARTMENT OF ECOLOGY
Environmental Assessment Program

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SUBJECT: Liberty Lake Dataset Evaluation

Background

I was tasked with looking at a long-term monitoring dataset for Liberty Lake that was collected by Washington State University. The intent of this review was to determine if Liberty Lake was currently meeting the total phosphorus criteria set in the original Liberty Lake Total Maximum Daily Load (TMDL) study done in March, 1993.

Liberty Lake is a 708 acre lake located three miles west of the Idaho state line, near Spokane, Washington. In the 1960s, lake residents noted that nuisance water quality conditions were occurring earlier in the summer, lasting later into the fall, and were becoming more aesthetically displeasing and noticeable each year. By late 1968, tons of decaying aquatic weeds and dried algal mats were being removed from the lake. This prompted the lake residents to become concerned about the lake's health and water quality conditions, and they turned to the Liberty Lake Property Owner's Association to help remediate the problem.

Members of the property owner's association contacted the State of Washington Water Research Center at Washington State University (WSU). A grass roots sampling and testing program was initiated that included homeowners, graduate students, and the WSU Environmental Engineering Laboratories. Originally, constituents tested were water clarity, temperature, conductivity, alkalinity, pH, and dissolved oxygen and on occasion phosphorus, nitrogen, and algae identification. Laboratory analyses and interpretation was carried out at the WSU laboratories.

A modest but more consistent water testing and education program was instituted in 1974; this sampling program continues to date. See Adams, 2005 for a description of the current program.

The property owner's association also requested assistance from Spokane County to protect the lake by constructing a sewer system. In 1973, residents took the initiative to petition, vote, and elect three commissioners to represent a special purpose sewer district. Since 1973, the Liberty

Lake Sewer and Water District has taken many measures to protect the lake and maintain the aesthetic beauty that has brought many residents to the area (Adams, 2005).

Scope of Work

After discussions with staff from Ecology's Eastern Regional Office, an agreed on scope of work was completed. I was asked to do the following:

1. Compile and document the lab and field quality assurance/quality control protocols associated with the data collection effort.
2. Determine the trophic state index for total phosphorus, Secchi clarity and chlorophyll-a.
3. Graph the entire total phosphorus dataset and compare to the suggested TMDL target limit.
4. Determine the total phosphorus (TP)/orthophosphorus (OP) ratio and compare Liberty Lake's ratio to other lakes sampled by Ecology.
5. Graph Secchi disk clarity and total phosphorus data as a scatter plot and compare to a subset of the lakes sampled as part of Ecology's statewide lake monitoring program.

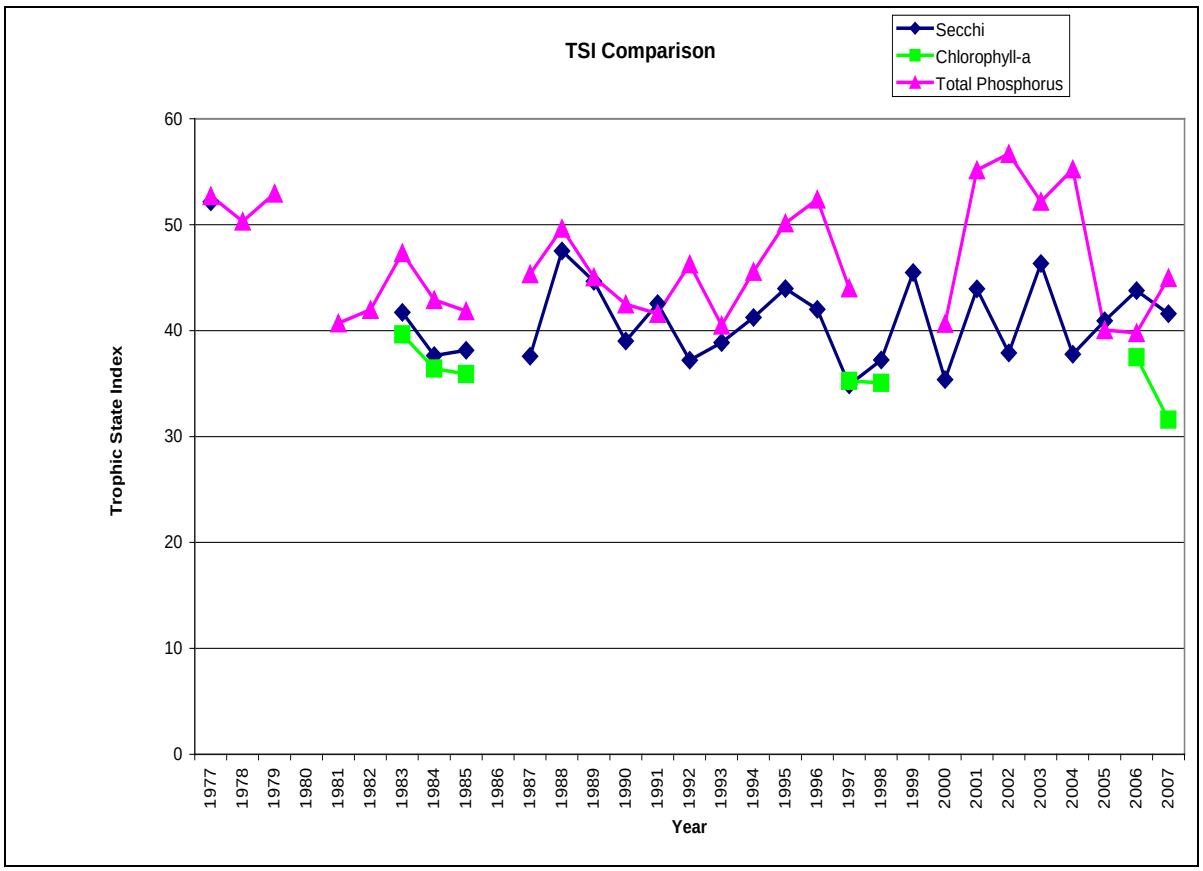
Results

1. Compile and document the lab and field quality assurance/quality control protocols done in association with the data collection effort.

   The Liberty Lake Water Quality Monitoring Plan (Adams, 2005) discusses quality assurance (QA) and quality control (QC) procedures (pages 21-23). Specifically mentioned is the collection of blanks and duplicates as part of the field collection of samples. For the laboratory QC process, the use of duplicates and spikes is mentioned as a way to "establish limits for precision and accuracy for each measurement parameter."

   To date I have been unable to obtain any quality control data for the Liberty Lake dataset.

2. Determine the trophic state index for total phosphorus, Secchi clarity and chlorophyll-a for Liberty Lake.



The Trophic State Index (TSI) is a measurement of a lake's productivity level. Trophic State Index values from 0-39 describe an oligotrophic lake, typically very low in nutrients and biomass. Values from 40-49 describe a mesotrophic lake and from 50 and above, the lake is considered eutrophic; very high in nutrients and plant and animal biomass. Individual TSI's are typically calculated from measurements of Secchi disk depth, total phosphorus and chlorophyll-a. In a perfect world, all three of these TSI values would come out to be the same number.

The designer of the Trophic State Index, Dr. Robert Carlson (Carlson, 1977), emphasizes the TSI number is only an index of the trophic status of a lake and does not define the trophic status. In other words, Secchi depth or total phosphorus is not considered as the basis for the definition of a trophic state but only as indicators of a more broadly defined concept. The best indictor of trophic status may vary from lake to lake and also seasonally, so the best parameter index to use should be chosen on pragmatic grounds.

Carlson feels that since chlorophyll-a values are apparently free from interference of other environmental factors (e.g. colored water can affect the Secchi disk transparency), it may be the TSI derived from chlorophyll-a results is best for estimating algal biomass in most lakes and should be given priority for its use as a trophic state indicator.

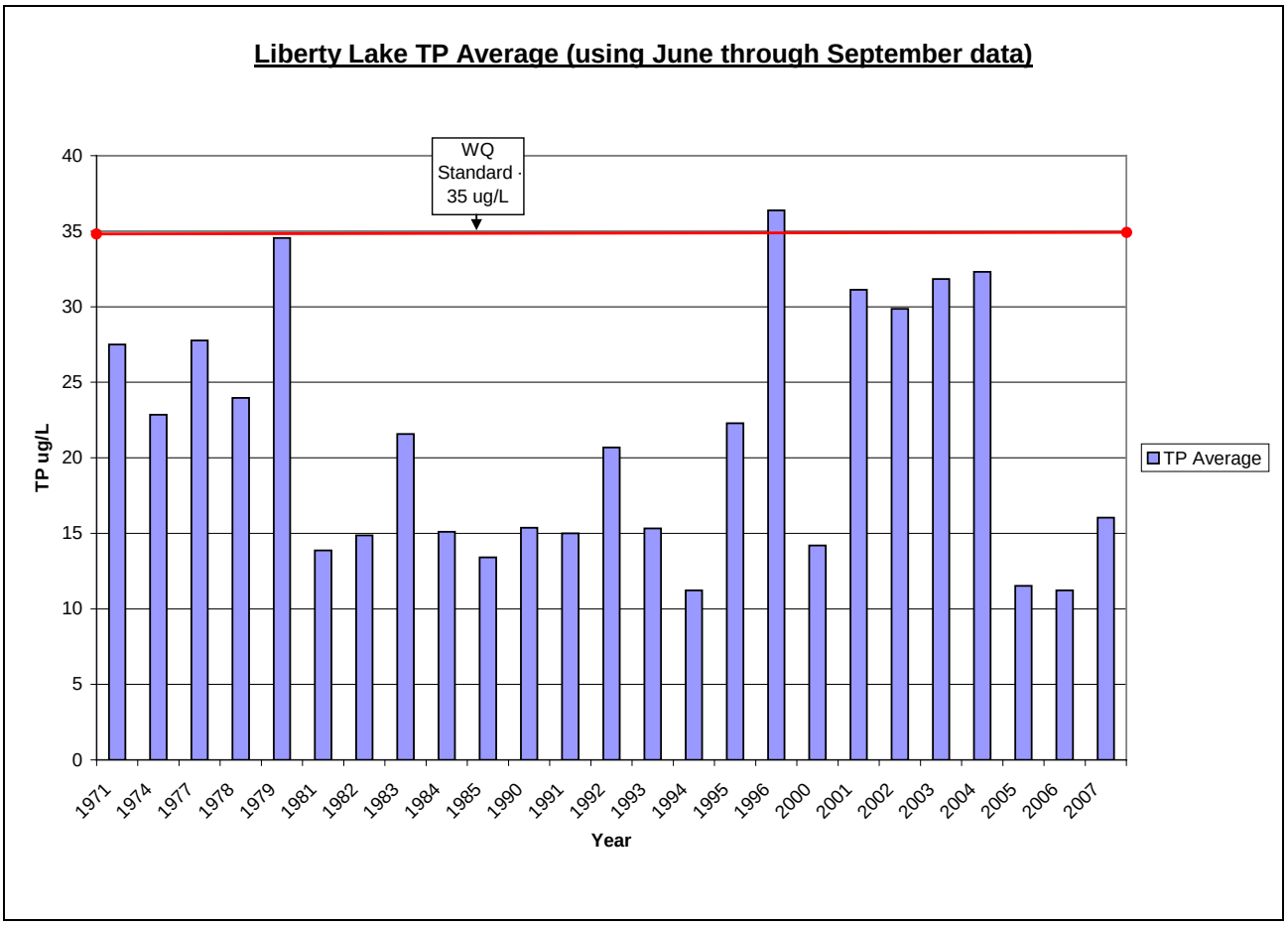
In Carlson, 1977, he stated total phosphorus should correlate best with Secchi disk transparency when phosphorus is the major factor limiting growth. Correlations may be poor during spring and fall turnover when algal production tends to be limited by temperature and light. Carlson also stated that taking epilimnetic samples during summer stratification should show the best agreement between all of the index parameters.

With regard to the differences shown in the TSI values for Liberty Lake, I shared my "TSI Comparison" graph with Dr. Carlson and got the following response: "Another way to look at it is that some of the differences are only a few TSI values apart. Such deviations are easily expected in most datasets. By enhancing the scale of the Y-axis, the differences are exaggerated, whereas they are really pretty close for most years. However, the near lack of correlation on either the daily or annual data argues that these variables (*Secchi transparency, total phosphorus and chlorophyll-a)* are really not related" (personal communication).

I also ran a t-test to see if the TSI values for Secchi depth and total phosphorus were significantly different from each other; there was not enough chlorophyll-a data for use in this comparison. I did this for both daily and annual TSI values for each parameter. The result was that there is a significant difference between TSI values for Secchi depth and total phosphorus. If the t-test is done on a year by year basis, some years will show the difference between the two parameter TSI's is significant while in other years it's not. The reason for this is that the variability of the parameter dataset is high.

There can be other explanations as to why the Secchi trophic state index is lower than the total phosphorus trophic state index. For example, if the Secchi TSI was consistently lower than the total phosphorus TSI, nitrogen limitation could be a possibility. In Liberty Lake, except for a few years, the Secchi TSI values were lower than the total phosphorus TSI values. This could be the influence of nitrogen limitation on the system. In future data collection efforts, calculating the total phosphorus/total nitrogen ratio could be a valuable piece of information in getting a clearer picture of Liberty Lake and determining the nutrient limitation status.

3. Graph the entire total phosphorus dataset and compare to the suggested TMDL target limit.

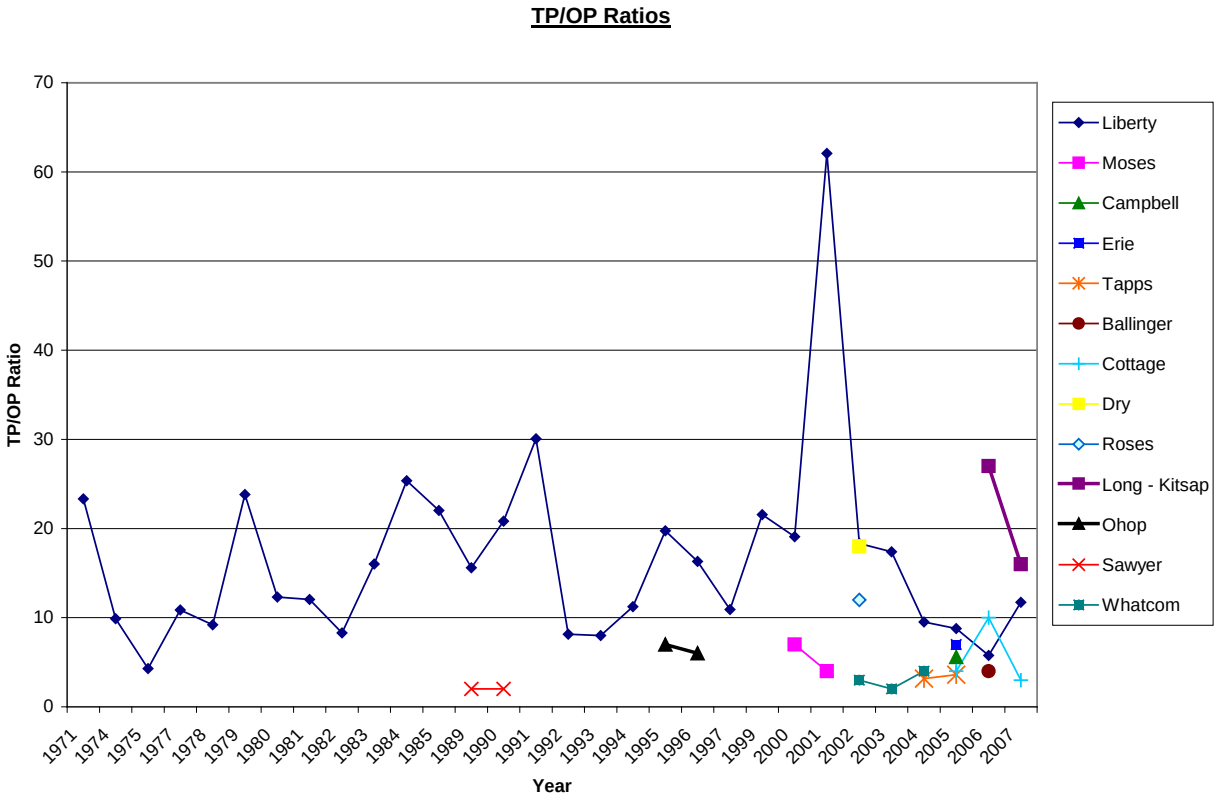


The Liberty Lake TMDL specified a loading capacity of 529 kg total phosphorus/year. It did not specify a summer epilimnetic level, which is what the Washington State Water Quality Standards propose as a criterion.

Washington's Water Quality Standards propose a summer epilimnetic maximum total phosphorus criterion of 35µg/L for an upper mesotrophic lake and a maximum criterion of 20µg/L for a lower mesotrophic lake in the Columbia Basin Ecoregion. The average total phosphorus Trophic State Index for Liberty Lake, from 1977 through 2007, was 47. This puts Liberty Lake in the upper mesotrophic category.

Except for 1996, Liberty Lake was consistently below 35µg/L of total phosphorus.

4. Determine the total phosphorus (TP) to orthophosphorus (OP) ratio and compare Liberty Lake's ratio to other lakes sampled by Ecology.



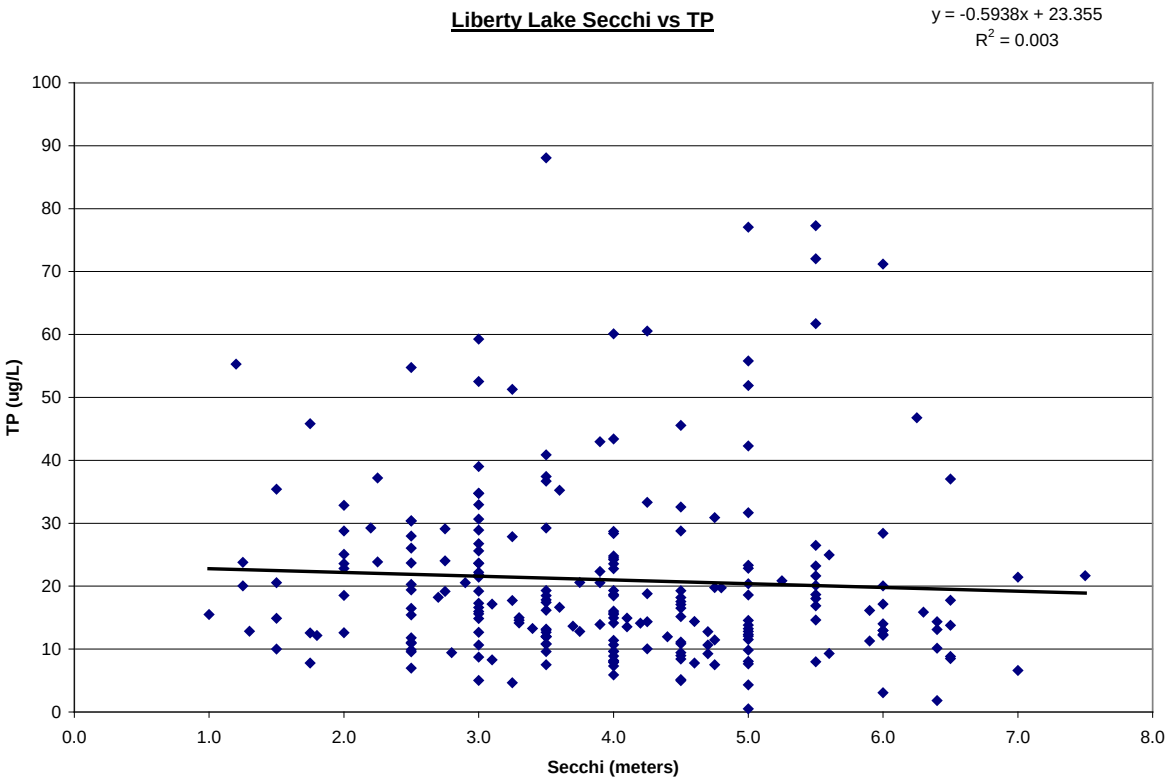
Unfortunately, Ecology does not have much orthophosphorus data from lakes without which the total phosphorus to orthophosphorus (TP/OP) ratio cannot be calculated. The above graph shows the available data from Ecology's Environmental Information Management (EIM) database as compared to the Liberty Lake dataset. The values for total phosphorus and orthophosphorus used to calculate the ratio were annual average values. There appears to be a lot of annual variability in the total phosphorus/orthophosphorus ratios from Liberty Lake. Except for 2002, 2006 and 2007, the Liberty Lake TP/OP ratios were all above what was found in other lakes from around the state.

Only dissolved phosphate (inorganic form of phosphorus) can be used directly for algal growth. The majority of inorganic phosphate present in a lake is in the form of orthophosphate. Typically, orthophosphate (OP) values are relatively high in the winter and decrease as the spring bloom of algae begins.

However, when surface phosphate levels are low, phytoplankton excrete extracellular enzymes called alkaline phosphatases. These enzymes have the ability to free up phosphate which is bound to organic molecules. Luxury consumption of phosphate (the uptake of more phosphate than is required for growth) by algae results in the storage of polyphosphate granules in the cell. These may contain sufficient phosphorus for many algal cell divisions and help to carry phytoplankton through short periods of phosphorus depletion. Depending on where and at what

depth samples are collected, this could be part of the explanation of why algal blooms are present in a lake even though measured phosphorus levels are lower than expected.

5. Graph Secchi and total phosphorus data as a scatter plot and compare to a subset of the lakes sampled as part of Ecology's statewide lake monitoring program.



The above scatter plot shows Secchi depth values compared to total phosphorus (TP) values. I also did similar scatter plots using data from other Eastern Washington lakes showing the relationship of Secchi depth versus total phosphorus. The lakes included: Spokane County – Clear, Medical, Liberty, Newman and Eloika; Pend Oreille County – Diamond, Sacheen and Horseshoe.

The table below shows the results of the individual lake scatter plots. I included Liberty Lake, using just the Ecology collected data from 1998, in this table as a comparison to the larger Liberty Lake dataset collected by Washington State University.

Lake	Intercept	X-coefficient	R^2	N
Liberty	24.594	-1.2789	0.0849	8
Clear	58.348	-4.7211	0.0625	18
Medical	84.821	-2.9116	0.0004	6
Newman	25.879	-0.1911	0.0016	7
Eloika	78.167	-15.454	0.3492	12
Diamond	21.869	-1.0116	0.4557	4
Sacheen	108.4	-11.892	0.0709	7
Horseshoe	38.265	-5.3341	0.2181	8

In both the Liberty Lake graph and table, there is very little correlation between the two parameters of Secchi depth and total phosphorus (the R^2 values are very low; a perfect correlation between Secchi and total phosphorus would show an R^2 value of +1 or - 1). These results could be interpreted as Liberty Lake being typical, in this regard, to other lakes in Eastern Washington. The dataset for the Eastern Washington lakes is small ("N" equals the number of Secchi depth and total phosphorus samples used in the calculation of the R^2 values); this could also be a factor in the lack of correlation between Secchi depth and total phosphorus.

Conclusions

- It should be remembered Carlson developed his Trophic State Index from an extremely large worldwide lake dataset in order to take into consideration all types of lakes and their associated variability. There is the potential if you plotted the Liberty Lake dataset within Carlson's original dataset, it might not show as much TSI variability compared with all the other lakes in the Carlson dataset.
- It appears Liberty Lake is meeting the Water Quality Standard suggested summer epilimnetic total phosphorus criterion of 35µg/L.
- It is difficult to come to any strong conclusions with regard to confidence in the total phosphorus results due to my not having copies of the quality control results for this dataset.

References

Adams, BiJay, 2005. Liberty Lake Water Quality Monitoring Plan, November/2005. Liberty Lake Sewer and Water District, Liberty Lake, WA. 36pp.

Carlson, Robert, 1977. A trophic state index for lakes. Limnology and Oceanography. 22(2): 361-369.