Bone Lake
Polk, County WI

Internal Load Estimate
2009

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Introduction:

In 2008, the external phosphorus and water budget were updated for Bone Lake, Polk County Wisconsin. There had been determination in a past study that there is internal loading of phosphorus in Bone Lake likely occurring. The study conducted in 2008 did not include analysis of internal loading. Therefore, it was decided that the internal load would be analyzed in 2009. This is the analysis of the data collected for internal loading in Bone Lake. The external loading from 2008 is utilized in this analysis.

Methods:

The internal load in Bone Lake was determined using the Internal Loading Model contained within the Wisconsin Lakes Modeling Suite. The internal load model uses four methods to estimate the internal load. Those four methods are as follows:

<u>Method 1-Mass Budget</u>
The mass budget basis is that the internal loading causes the phosphorus outflow to be greater than the phosphorus inflow. The following equation can be used:

Outflow P mass = External load P mass + Internal load P mass – Sedimentation

The external load in the lake is used along with the outflow P mass to determine the internal load. The outflow is determined by measuring volume weighted total phosphorus profiles to determine the annual total P in the water column.

<u>Method 2-Growing season</u>
The growing season method in-situ phosphorus increases are used to determine the internal loading of phosphorus. This method calculates the increase in mass of phosphorus in the hypolimnion during anoxia. The hypolimentic volumes, volume weighted phosphorus concentrations and area of anoxia at the start of anoxia and just prior to fall turnover are used to calculate the release rate and then change in mass which is the internal load from sediments.

<u>Method 3- In-situ method</u>
This method uses the increase in phosphorus concentration in the fall. Fall turnover phosphorus concentrations just after turnover are used and compared to earlier phosphorus concentrations.

<u>Method 4-Phosphorus release method</u>
This method uses empirical sediment phosphorus release rates and the anoxic area to calculate the internal load.

In order to utilize these methods, phosphorus profiles were collected just at the beginning of anoxia, late anoxia just before estimated fall turnover, and just after fall turnover. In addition, dissolved oxygen and temperature profiles were conducted weekly from May until October to determine the depth of anoxia, anoxia area and the depth of the hypolimnion. In addition, the external load values that were determined in 2008 were used in the same WiLMS model for internal load determination and phosphorus prediction analysis.

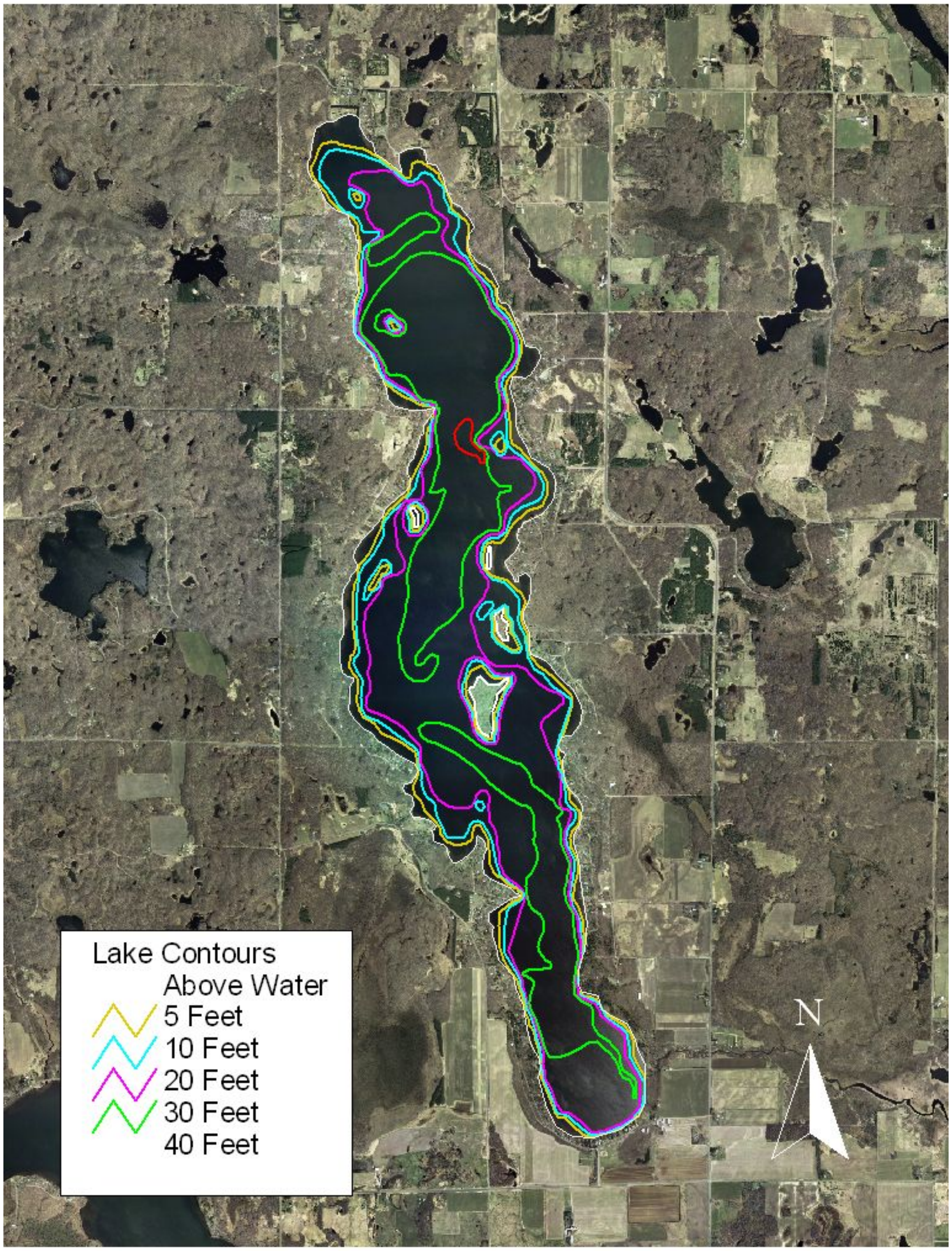

Figure 1: Contour map of Bone Lake[1]

[1] Provided by Dave Peterson, Polk County Land and Water Conservation Dept.

As a follow up, the internal loading release rates were used in another model known as BathTub. The external loading was used from 2008 as well as the 2009 internal loading data. A mass balance was used to help estimate the internal loading from this model.

Results:

Bone Lake did not really ever stratify into a stable configuration of warm water on top and very cold water near the bottom. In early July and until mid July it began to show very limited signs of stratification but it lost that tendency before the end of July. This could allow for mixing of the hypolimnion into the water column, releasing the phosphorus from the hypolimnion. The profile displayed shows data from a wide range of time periods throughout the summer. Data was collected every week for analysis (not all displayed so the graph would not be so cluttered).

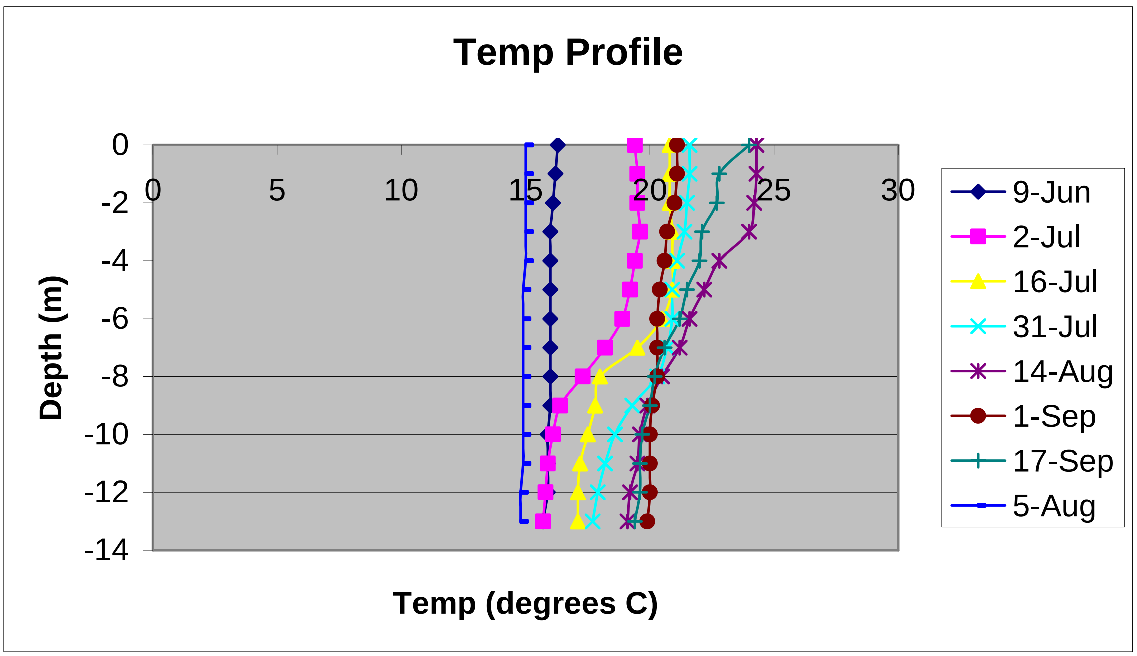

Figure 2: Graph of temperature profile from deep hole in Bone Lake-2009

Anoxia (DO < 1 mg/L) began on about June 9 at 13 meter and continued until late September. Fall turnover occurred sometime between Sept. 23 and Oct. 5. The depth of anoxia increased to about 8 meters and remained there from most of the remaining summer.

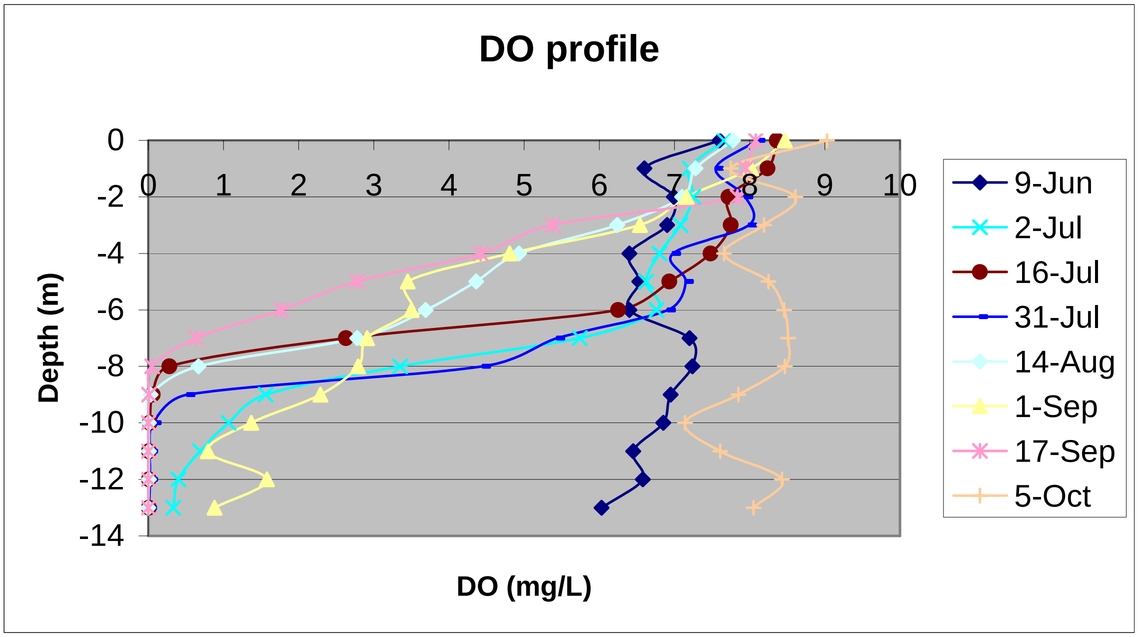

Figure 3: Graph of Dissolved Oxygen profile in deep hole Bone Lake-2009

The anoxic conditions started at 13 meters in late June and increased up to 8 meters throughout the lake in early July. The anoxic conditions continued at or near 8 meters through mid September.

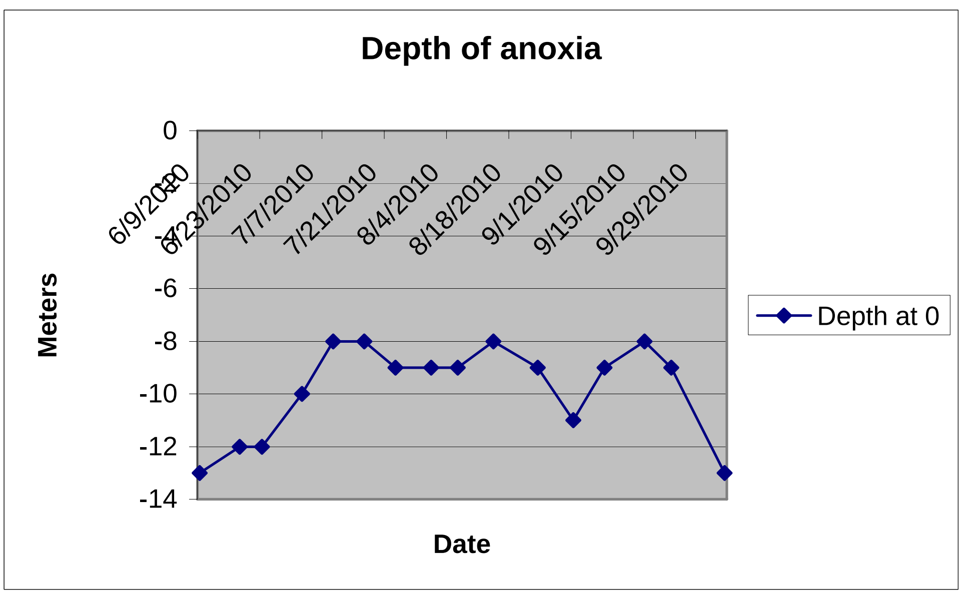

Figure 4: Graph of depth of anoxia (DO<1mg/L) in deep hole Bone Lake-2009

The phosphorus data indicates a rather substantial internal load as the phosphorus increased immensely from June to September and the fall turnover time. One issue with determining internal loading in this lake is the lack of stratification. Although the lake did go anoxic, it didn't stratify. As a result, the phosphorus is not trapped in the hypolimnion until fall turnover. This allows the phosphorus to mix into the water column during the sediment release and cause for a more difficult estimate of the load with the methods used.

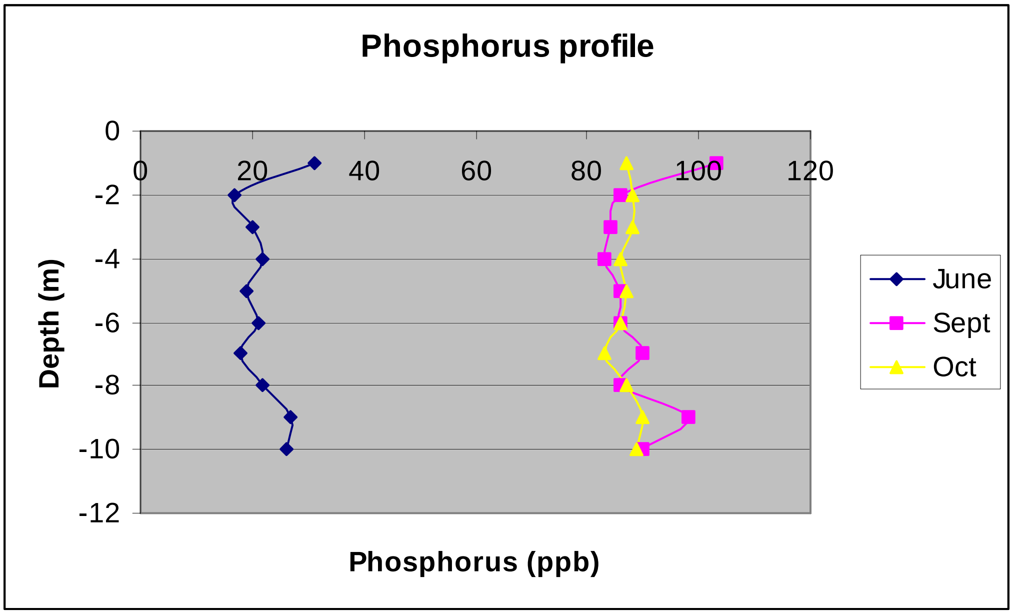

Figure 5: Graph of mean phosphorus profile Bone Lake-2009

The following table summarizes the internal load amounts from the various methods.

Internal load method from WiLMS	**P load (kg/yr)**
Complete mass budget	161
Growing season In Situ Phosphorus increases	266
In Situ increases in the fall	314
Phosphorus release rate and anoxic area	172

Table 1: Summary of internal load estimates from WiLMS.

The internal load module uses these four methods to estimate the internal load. The estimated internal load is **289.9 kg/yr.**

The Osgood mixing index is 2.5. This indicates that the lake is polymectic, which means it mixes several times a year. This is consistent with the DO/temperature profiles as they show that the lake was anoxic for a long period, but never really stratified. This is an unstable configuration and increases the chance the lake will mix. As a result, the phosphorus released from the sediment can reach the water column before fall turnover.

When including the external load, the following phosphorus loading estimates were generated from WiLMS and BathTub:

Phosphorus load	Most likely kg(WiLMS)	Kg from BathTub
Internal load	290	429
External load	989	1504
Total load	1278	1934

Table 2: Summary of internal and external loading WiLMS and BathTub

The range for internal load was a low of 161 kg to 378 kg per year (12.5% - 29.6%) from WiLMS and 429 kg per year (22.2%) from BathTub. This internal load with the external load (leading to the total load) predicts a mostly likely total phosphorus concentration of 96 ppb. The actual concentration mean was 52 ppb. When the predicted model fit option was used, this output fit all models for lakes similar to Bone Lake. The predicted output in an anoxic lake similar to Bone was 53 ppb, which is nearly a perfect fit. This suggests that the estimates are reasonable.

In BathTub, the internal and external load were both estimated higher, but the percentage toward the total load was similar to WiLMS. The data from BathTub predicts a phosphorus value very close to the field data, which indicates the estimates are reasonable.

When comparing internal to external loading from WiLMS, the internal load makes up 22.7% of the total while the external load makes up 77.3% of the total load. In BathTub that estimate is 22% is internal and 78% external.

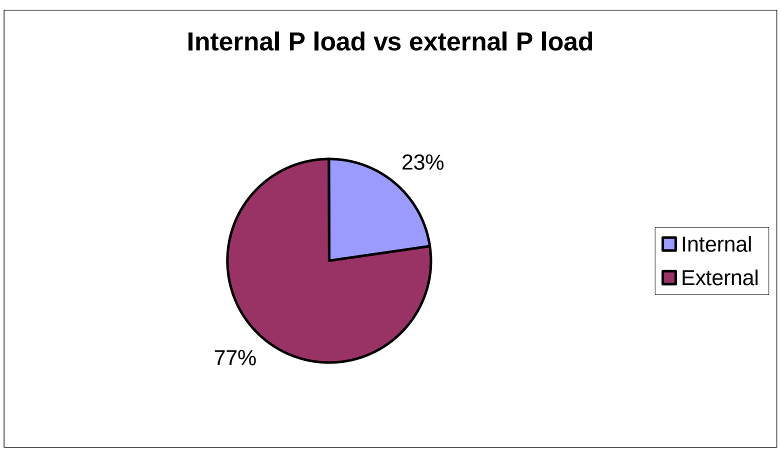

Figure 6: Graph of internal and external percentages of total P load

To compare the loading, the external load data from 2008 was used. The year 2009 had similar dry conditions. This would mean that the external load should be very low compared to more normal precipitation years. Since the external load should be at a minimum, the phosphorus increase observed would be significantly impacted by the amount of the internal load, which appears to be the case with nearly 25% of the phosphorus coming from sediment release. Interestingly the phosphorus values in Bone Lake in the summer of 2008 were much lower. Upon review of the volunteer monitoring data, it appears that the lake didn't undergo nearly the anoxic conditions as 2009. This would indicate that internal loading is a significant contributor of phosphorus in any given year. It is not known why the lake tends to go anoxic one year and not the next.

References:

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