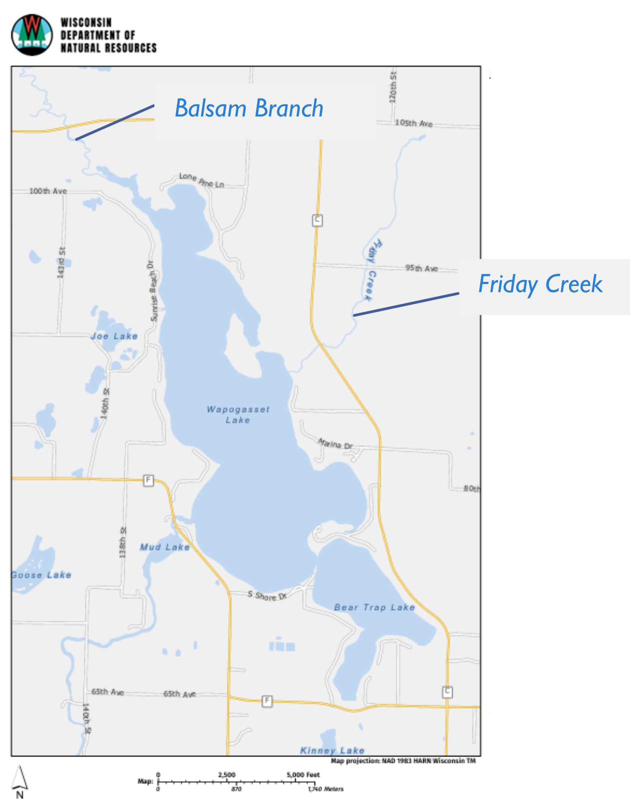
INTERNAL LOAD AND ALUM APPLICATION

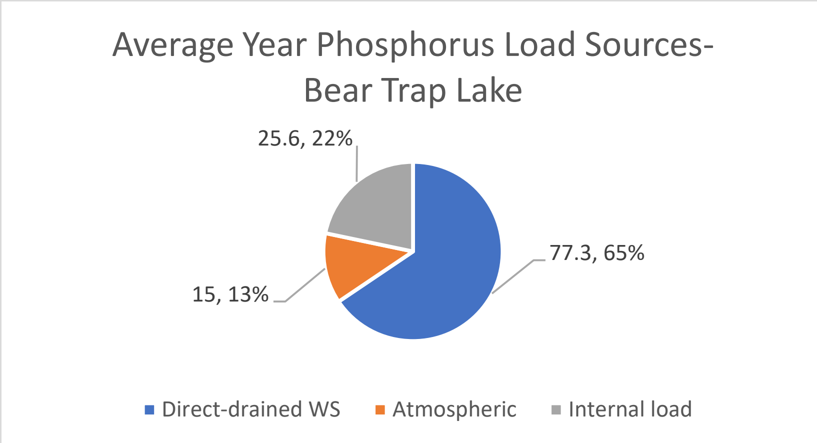
Key Points

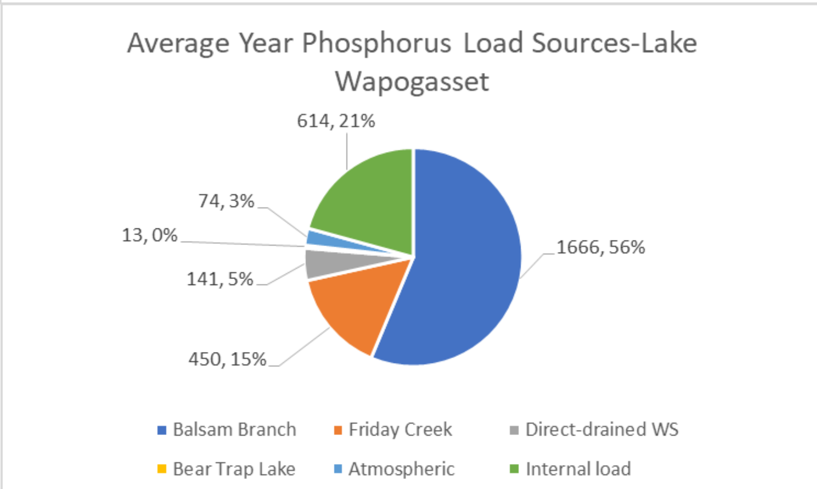
- Internal load comes from lake sediment release of phosphorus (P).
- The impact of internal P load on algae growth and water quality varies from year to year. In poor water quality years, internal load of P is high.
- An alum treatment reduces internal P load from lake sediments. While an alum treatment would result in modest improvements in average years, it would decrease the peaks and frequency of severe algae blooms in the lakes.
- The estimated cost of an alum treatment for Lake Wapogasset is \$3.4 - \$5 million, and for Bear Trap Lake \$360,000.

LAKE MODEL RESULTS

According to the results of a recent lake modeling analysis of phosphorus (P) sources to Lake Wapogasset and Bear Trap Lake, the internal P load to the lakes varies from year to year. Internal load comes mainly from lake sediment release of P. Lake sediments release P when the lake water temperatures stratify in the summer and oxygen levels decrease near the lake bottom. When the lake loses temperature stratification and mixes, P-rich bottom waters are brought to the surface and increase algae growth. Phosphorus is the limiting ingredient that fuels algae growth in the lakes. Phosphorus load also comes from the watershed, atmospheric deposition, and groundwater. Lake Wapogasset receives water and P from two tributaries: the Balsam Branch and Friday Creek. Watershed P loading is discussed in another fact sheet in this series.







WS = Watershed

Internal loading from lake sediments is a significant, but variable, source of P for both lakes. Temperature and dissolved oxygen profiles indicated prolonged periods of low oxygen in deep water in 2024 and 2025. Sediments release P in anoxic (very low oxygen) conditions. Further, both lakes have the potential to mix during the growing season, increasing the likelihood that sediment-released P may reach surface waters. Lake Wapogasset is more prone to mixing than Bear Trap Lake. Sediment core testing confirmed substantial potential for P release, particularly in Lake Wapogasset.

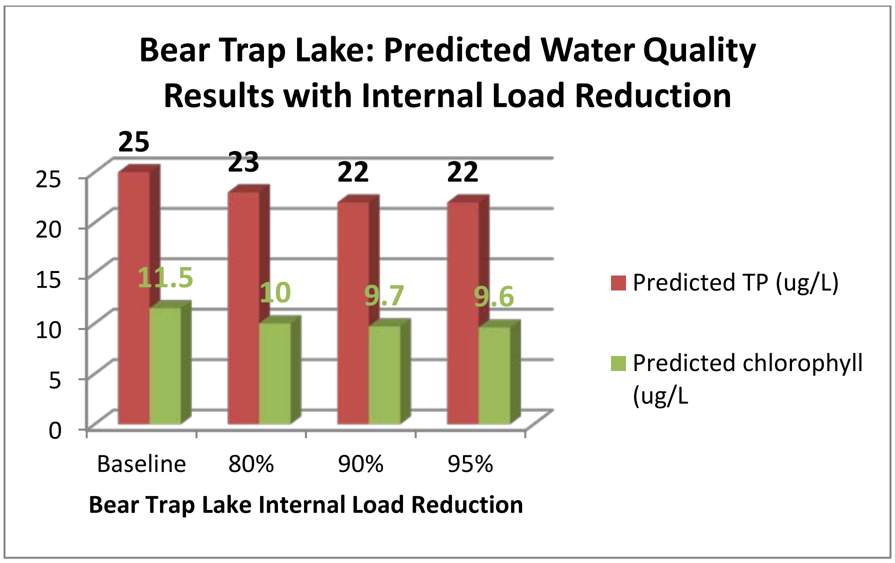
The actual amount of internal loading depends on the timing and extent of stratification breakdown and mixing, which vary from year-to-year. Internal loading estimates for the study years were relatively low when compared with estimates from previous studies. In Bear Trap Lake, internal loading accounted for 20% of phosphorus loading in 2024 and 7% in 2025. In Lake Wapogasset, internal loading accounted for 13.5% of loading in 2024 and 5% in 2025. Lower surface P concentrations resulted in both lakes in 2025 as compared to 2024.

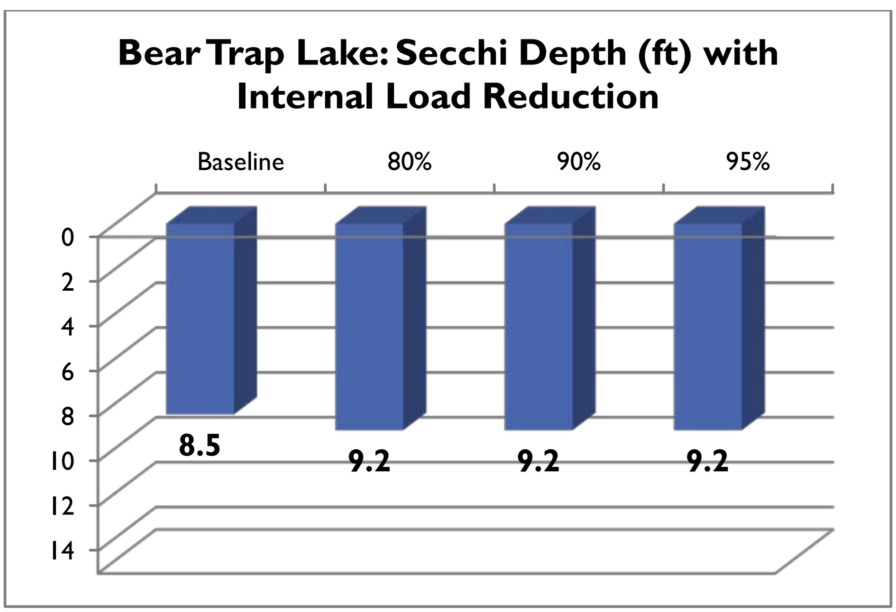
Further, a 10-year analysis of lake water quality indicated that internal loading made up a higher proportion of the P load over the long-term as compared to 2024 and 2025: 22% for Bear Trap Lake and 21% for Lake Wapogasset. Variability in internal loading poses challenges for lake management. In some years, internal loading has little impact on water quality. In other years, it is a substantial portion of the P load.

WATER QUALITY MODEL PREDICTIONS

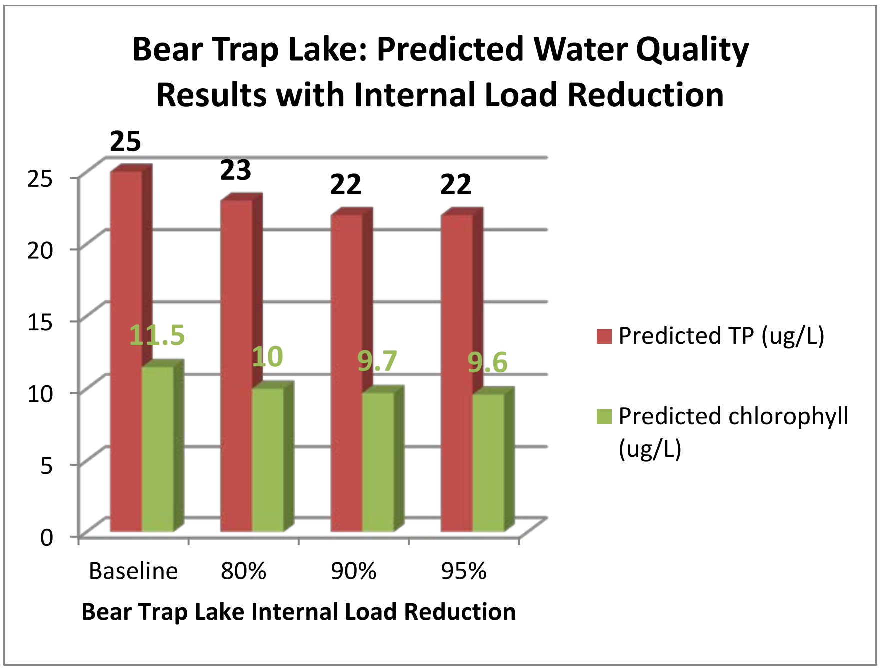
BEAR TRAP LAKE

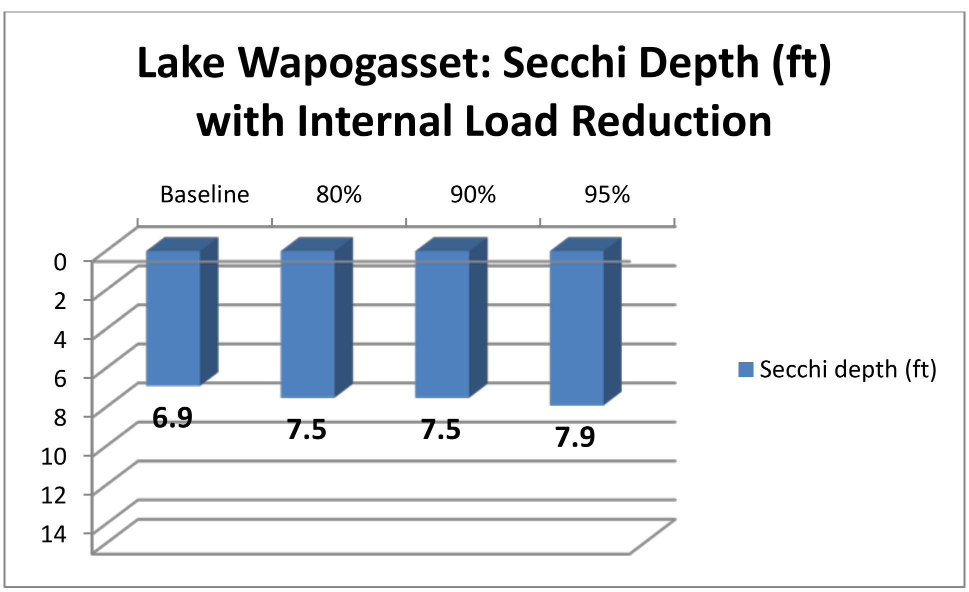
Because the internal load was only 22% over a 10-year period, predicted lake water quality improvements resulting from an alum treatment are modest as shown in figures below. Internal load reductions of 80 -95% are possible with an alum treatment. If internal loading was mitigated via an alum treatment, the model predicts total P concentration would decrease by 2 µg/L with an 80% internal load reduction and 3 µg/L with a 90-95% internal load reduction in an average year. The Secchi depth prediction for 80-95% internal load reduction is 9.2 feet from a baseline of 8.5 feet. Changes in water quality would be most evident in late summer. In years when internal loading was high, an alum treatment would have had a significant effect. For example, in 2017 the total phosphorus was 39 µg/L, and internal load reduction with an alum treatment could have reduced that value nearly in half to 23 or 22 µg/L. Coupling internal load reductions with watershed loading reductions predicts greater improvements.





Lake water quality improvements with internal load reductions are also modest for Lake Wapogasset in an average year. If internal loading was mitigated via an alum treatment, reducing the internal P load by 80-95%, the model predicts the total P concentration would decrease by 4 µg/L to 33 µg/L from a baseline of 37µg/L. The Secchi depth prediction for an 80-95% reduction is 7.5 feet from a baseline of 6.9 feet. Internal load reductions of 80-95% are possible with an alum treatment. Changes in water quality would be most evident in late summer. An alum application would have less impact in years like 2024 and 2025, when there was less lake mixing, because the internal load would already be low. In years when internal loading was high, an alum treatment would have had a significant effect. For example, in 2016 the total phosphorus was 58 µg/L, and internal load reduction with an alum treatment could have reduced that value nearly in half to 33 µg/L with corresponding decrease in algae growth.





ALUM TREATMENT FOR INTERNAL LOAD MITIGATION

Aluminum sulfate has been used to control internal phosphorus (P) loading from sediment for more than 50 years in the United States. Aluminum sulfate reacts with water to form aluminum hydroxide, a white floc that settles to the sediment surface within days. The alum floc has a high affinity for P and needs to chemically react within days to a month. Otherwise, the alum floc reacts to form a crystalline structure and loses reactivity with P. Thus, the alum dose can be split into smaller partial portions applied over time to increase aluminum hydroxide exposure to sediment mobile P.

Wapogasset and Bear Trap Lakes were treated with alum in October 1999. The Al dosage was 40 g/m2 over depths greater than 15 ft in both lakes. Shallow areas were treated with 16 g Al/m2. A dam failure on the Balsam Branch, located upstream of Wapogasset Lake, with extensive sediment and nutrient loading in April 2001 coincided with increased summer total P concentrations in Wapogasset Lake in 2002. Summer total P declined to a mean of 30 µg/L between 2003 and 2005 and increased to greater than 40 µg/L between 2006 and 2008. Thus, with the exception of summer 2002, mean summer total P concentrations were 31 µg/L for 6 years post alum application versus a mean summer total P concentration of 42 µg/L prior to alum application (from 1995 to 1999).

Bill James, with UW Stout Limnological Center, evaluated alum dosing in preparation for the 2026 lake management plan update. His work included analysis of lake sediment samples characteristics and release of P under anaerobic conditions in the laboratory. Results demonstrated a high potential for P release from lake sediments. As discussed previously, this may or may not occur in a given year because of in-lake conditions of stratification and mixing. Results were also used to establish an alum dose to depress internal loading in each lake.

ALUM DOSING CONCLUSIONS

The recommended overall alum dose was high at 175 g/m^2 and 145 g/m^2 for Wapogasset and Bear Trap Lakes, respectively. The high Al dose in Wapogasset Lake was related to high concentrations of phosphorus in the sediment that needed to be immobilized. Similarly, the high recommended Al dose in Bear Trap Lake was due to moderately high sediment redox P concentrations and denser sediment (i.e., lower moisture or porewater content).

It is recommended that these total Al doses be split into smaller, annual doses for the first three years, then biennially. Because buffering capacity is relatively high compared to the split Al dose recommendations, alum (rather than buffered alum) can be safely used without temporarily lowering pH below 6.

Hypolimnetic anoxia (near lake sediments) during summer stratification can extend to the 20-ft depth in both lakes. Anoxic sediments below this depth contour potentially contribute to internal P loading. The anoxic sediment area at the 20-ft depth contour encompasses 504 acres in Wapogasset Lake. Treating this area with alum will be potentially very expensive (> $ 5 million dollars overall). The area below the 25-ft depth contour is 304 acres. Treating this sediment with alum would cost roughly $3.4 million dollars. In contrast, the area below the 20-ft depth contour is only 45 acres in Bear Trap Lake, and the estimated cost is $630,000 dollars.

IMPACT OF CURLY LEAF PONDWEED HARVESTING

Decomposition of aquatic plants is another source of internal P load to the lakes. Because curly leaf pondweed (CLP) dies back by late June or early July, its breakdown is a potential source of P that can fuel summer algae growth.

The Sanitary District has harvested CLP, an aquatic invasive species, since 2017. Any in-lake P reduction from removal of CLP would be reflected in the ten-year average total P used for the model development. Total mean annual P removal from harvested CLP has been 42.9 kg in Lake Wapogasset and 14.8 kg in Bear Trap Lake from 2017 - 2025. This represents 1.45% of the total average year P load in Lake Wapogasset and 12.5% of the average year total P load in Bear Trap Lake.

However, the calculated removal of P from CLP represents gross phosphorus mass, and the exact impact on in-lake phosphorus concentration is unknown. It is unlikely that all of this phosphorus would have remained available in the water column to fuel algae growth. In a study on Bone Lake in Polk County (Schieffer, 2010), it was determined that only about 25% of the phosphorus potentially released from CLP remained in the water column. If similar results occurred in these lakes, the CLP reduction in Lake Wapogasset would result in a 0.4% reduction of the total phosphorus load, and 3.15% reduction of the total phosphorus load in Bear Trap Lake.

SOURCES

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