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Memorandum

To: Diane Lynch, Prior Lake Spring Lake Watershed District
From: Greg Wilson, Barr Engineering Company
Subject: Spring Lake Phase II Sediment Monitoring and Alum Treatment Recommendations
Date: August 23, 2016
Project: 23701062.00 GJW

The Spring Lake sediment core analysis, alum dose determination and application plan (Barr, 2012), prepared for the Prior Lake Spring Lake Watershed District (PLSLWD), called for two to three phases of alum treatment with half of the total dose to be delivered in the first year (fall of 2013) followed by separate phases of alum treatment that are each spaced by three or more years to deliver the remainder of the prescribed dose, depending on the need for further watershed load reductions. It was further suggested that an adaptive management approach should follow the first phase of the alum treatment to further evaluate in-lake phosphorus response and potential interferences from the external (and other internal) phosphorus loading sources. As a result, Barr was recently retained to collect sediment cores and re-evaluate the current potential for sediment phosphorus release in advance of pursuing the second phase of an in-lake alum treatment.

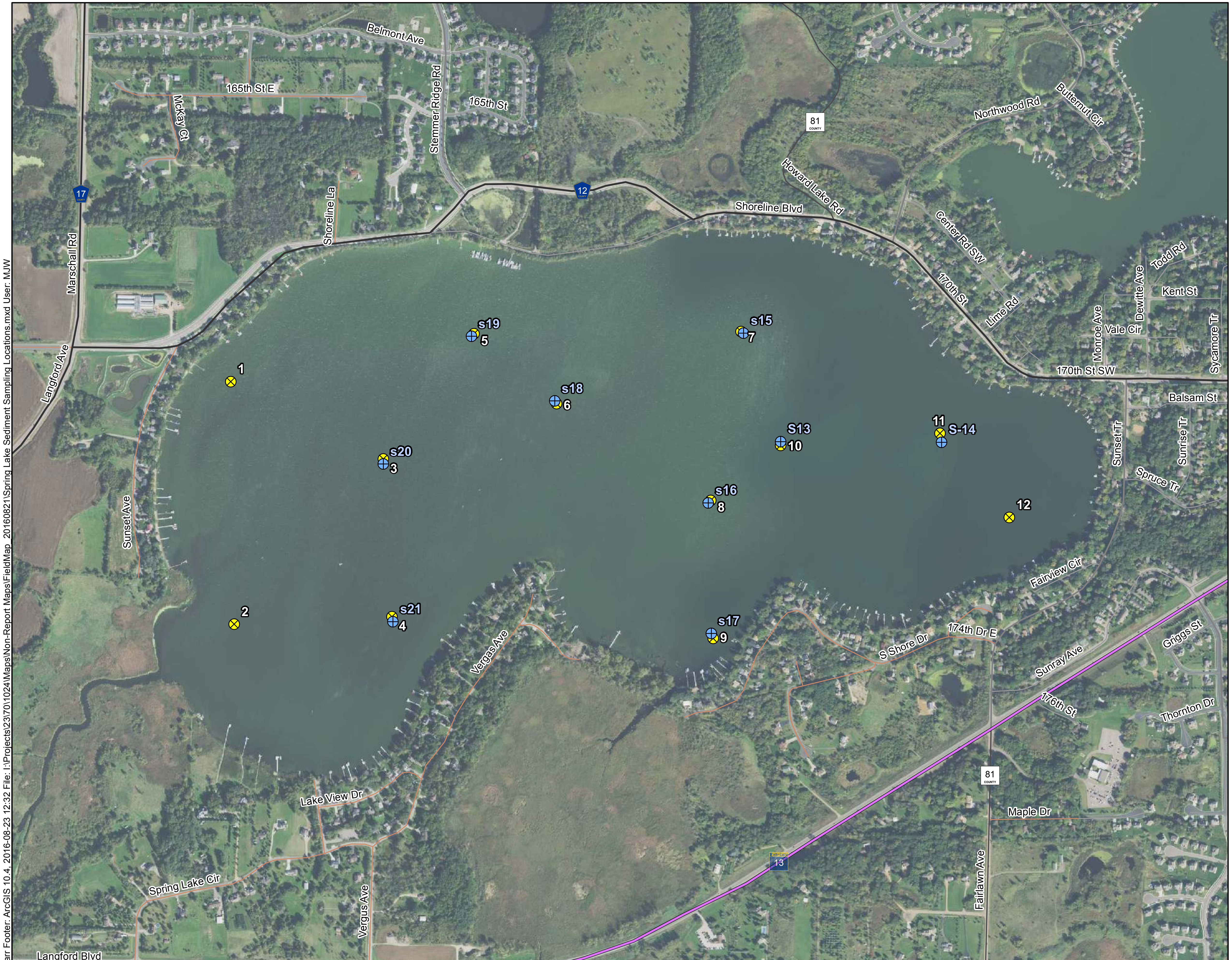
This memorandum is intended to summarize our analysis of lake sediment core sampling/phosphorus fractionation and analysis of recent water quality monitoring data to provide two lines of evidence for assessing the need to pursue the next phase of the Spring Lake alum treatment.

Preliminary results of sediment monitoring

Sediment core collection and phosphorus fractionation are essential to understanding the potential for phosphorus release for bottom sediment that can spur algal blooms and water quality problems. Sediment cores were collected from nine locations in Spring Lake that had been previously sampled and analyzed in 2012. Figure 1 shows the locations of the 2012 and 2016 sediment core sampling efforts.

During the 2016 analysis we fractionated the sediment core samples to extract and accurately identify/target the forms of phosphorus that are contributing to internal loading each summer, and subsequently determining the best options for control. Iron-bound phosphorus, organic phosphorus, aluminum-bound phosphorus, and calcium-bound phosphorus will be extracted and analyzed separately. Iron-bound and loosely-sorbed phosphorus are the forms of phosphorus that can most readily contribute to internal loading of phosphorus within a water body. Anoxic conditions (i.e. low oxygen levels) at the sediment interface will convert iron in the sediment to a soluble form, releasing phosphorus that was previously bound to insoluble iron. Organic phosphorus can also contribute to internal loading of biologically available phosphorus. Under normal conditions, aluminum-bound and calcium-bound phosphorus in the sediment do not contribute to internal loading of biologically available phosphorus.

As a part of this analysis, we are also able to use the sediment subsample results from each core to identify the current depth of the alum floc layer within the recent sediment deposition in Spring Lake. Figure 2 shows that the first phase of alum application has resulted in a significant drop in the releasable forms of phosphorus in each of the sediment cores. Depending on the sediment core location, the alum layer appears to reside between two and eight centimeters below the sediment-water interface. It appears that a flood event in 2014, followed by high flows in 2015 and 2016, have resulted in the delivery and sedimentation of additional phosphorus on the surface of the sediment, with greater sedimentation in the deepwater portions of the lake.



2012 Sediment Sampling Locations

2016 Sediment Sampling Locations

Bathymetric Contours

0 800 1,600

Feet

FIGURE 1

SEDIMENT SAMPLING LOCATIONS
Spring Lake
Scott County, MN

Barr Footer: ArcGIS 10.4, 2016-08-23 12:32 File: I:\Projects\23\70\1024\Maps\Non-Report Maps\FieldMap_20160821\Spring Lake Sediment Sampling Locations.mxd User: MJW

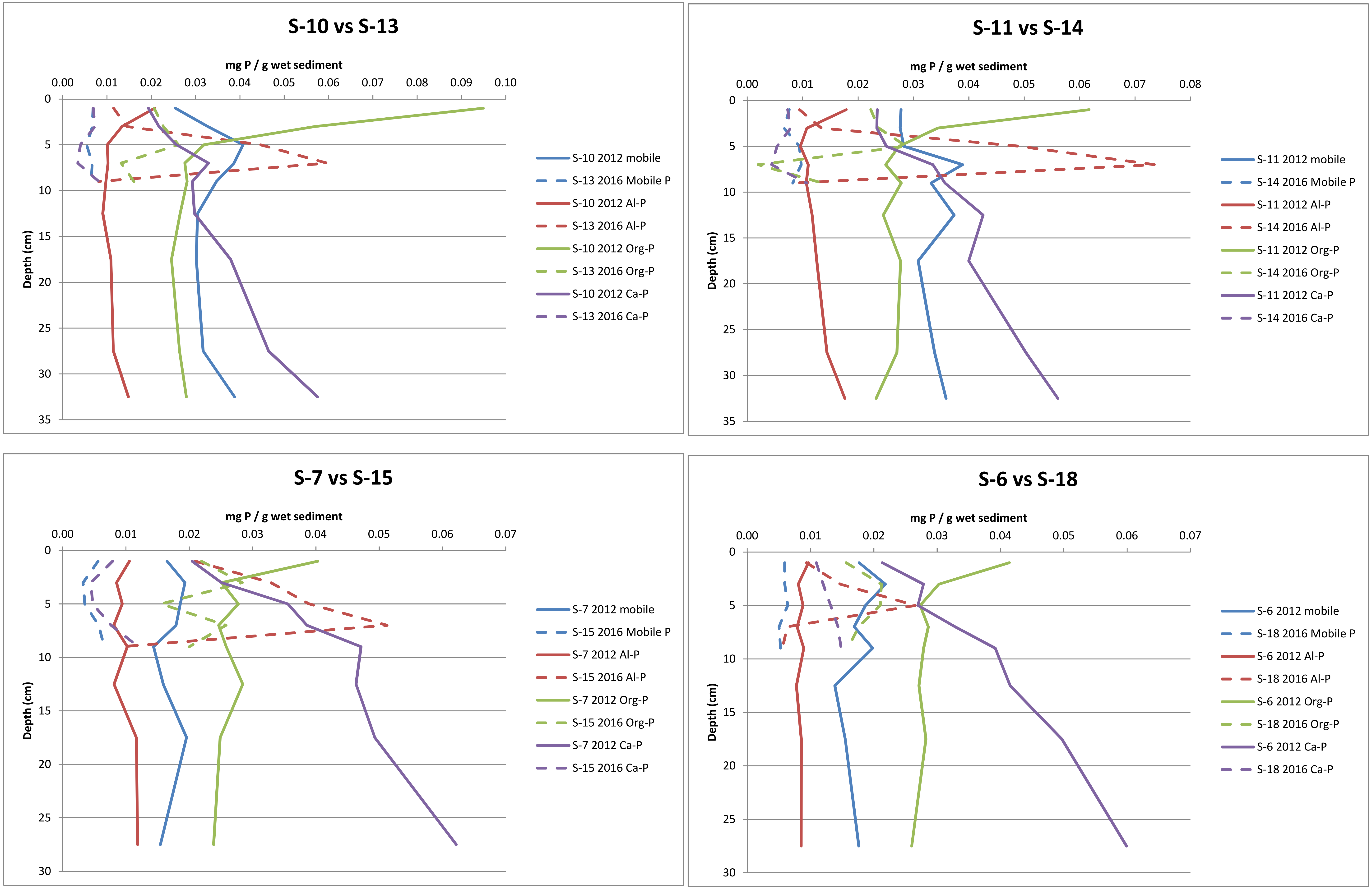


Figure 2 Summary of sediment phosphorus fractionation results for select sediment cores

Analysis of lake water quality monitoring data

Figure 3 shows that the Spring Lake surface water summer average phosphorus concentrations have been consistently lower since the first phase of the alum treatment occurred in the fall of 2013. Since the lake water quality standard is 60 µg/L, it Figure 3 shows that the 47 µg/L average total phosphorus concentration during the last three years both meets the standard and is 53 percent lower than 100 µg/L average phosphorus concentration from the ten years prior to the alum application. This water quality improvement since the alum treatment has translated to improvements in chlorophyll-a and Secchi depth measurements, as well, but not to the same extent as it has for total phosphorus. Average chlorophyll-a concentrations are 41 percent lower since the alum treatment and average Secchi depth measurements are 33 percent higher. The recent chlorophyll-a concentrations are not meeting MPCA's lake water quality standard for Spring Lake, but the recent Secchi depth average of 1.5 meters is meeting its respective standard.

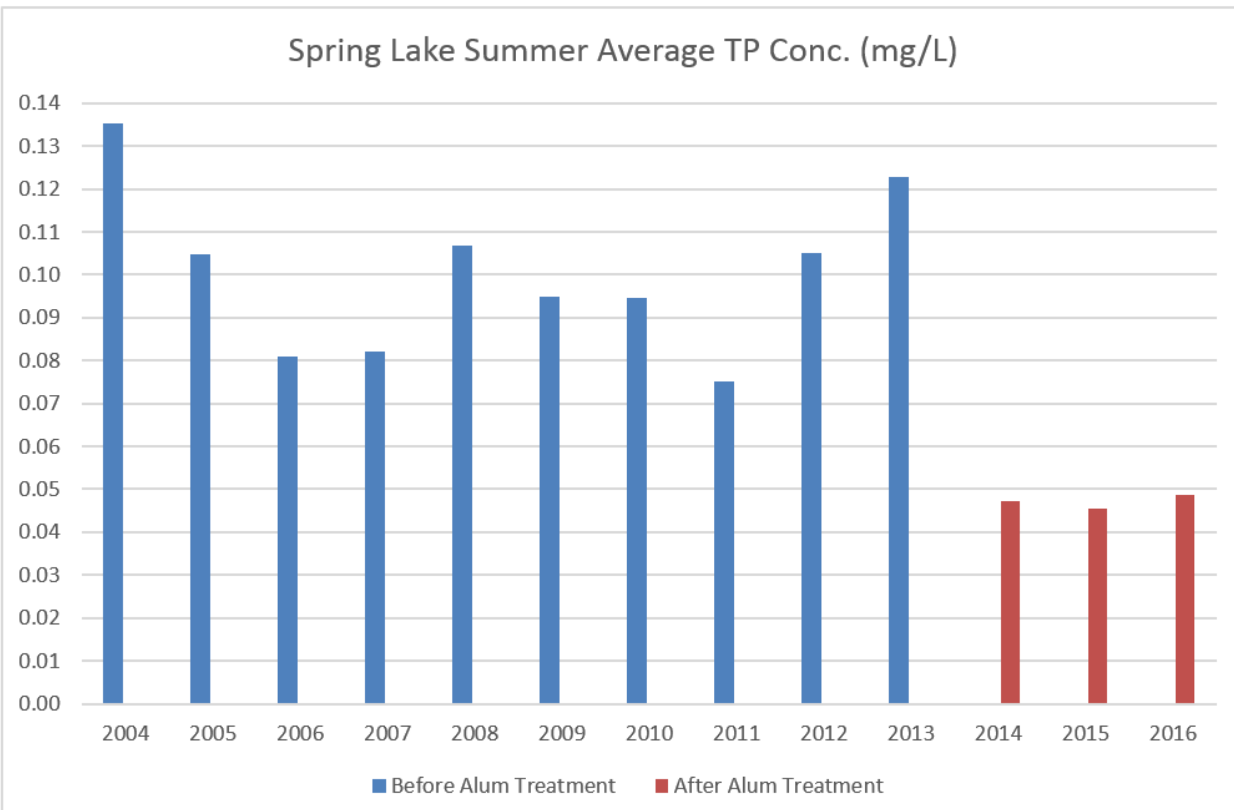


Figure 3 Summer average surface water phosphorus before/after alum treatment

Figure 4 shows more details regarding the surface water phosphorus dynamics in Spring Lake both before and after the alum application. Again, the figure shows that surface water phosphorus is consistently lower in each of the last three years and was consistently meeting the lake water quality standard with two exceptions—the spring and early summer of 2014 (during the flood event) and the fall of 2015. Even with the small spike in the fall of 2015, Figure 4 shows that lake water quality has been much improved and has not been subject to the same magnitude of internal loading that has traditionally been problematic during the latter half of each of the previous summers.

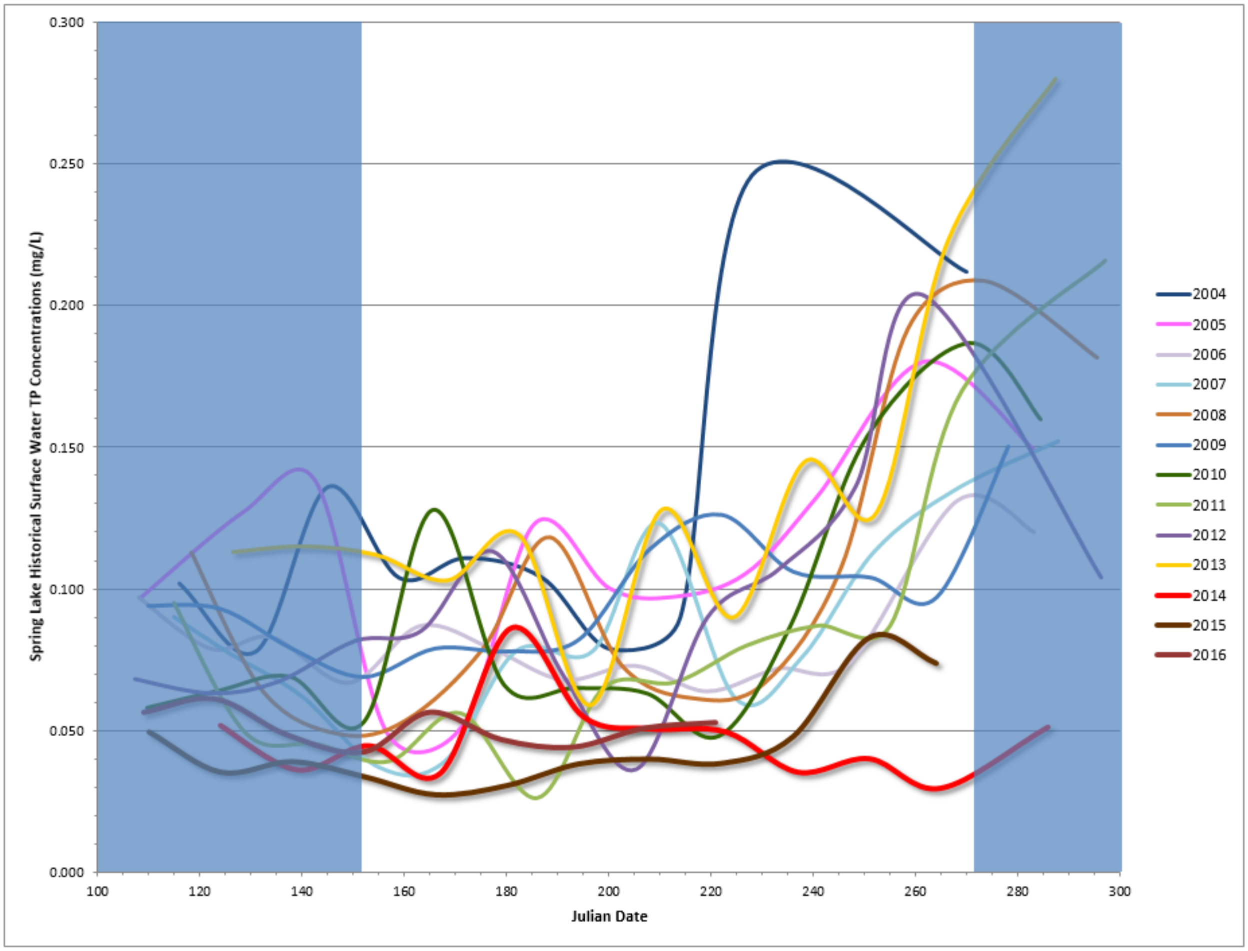


Figure 4 Comparison of Spring Lake surface water phosphorus concentrations

Figure 5 shows more details regarding the bottom water phosphorus dynamics in Spring Lake both before and after the alum application. This bottom water phosphorus data provides the best representation of how well the first phase of the alum treatment has worked as it is more independent of the effect of stormwater inputs (although the figure does show a concentration spike following the recession of the 2014 flood waters) than the surface water quality measurements. Bottom water quality is much improved since the alum treatment with average total phosphorus concentrations during that last three years that are 67 percent lower than the previous ten years.

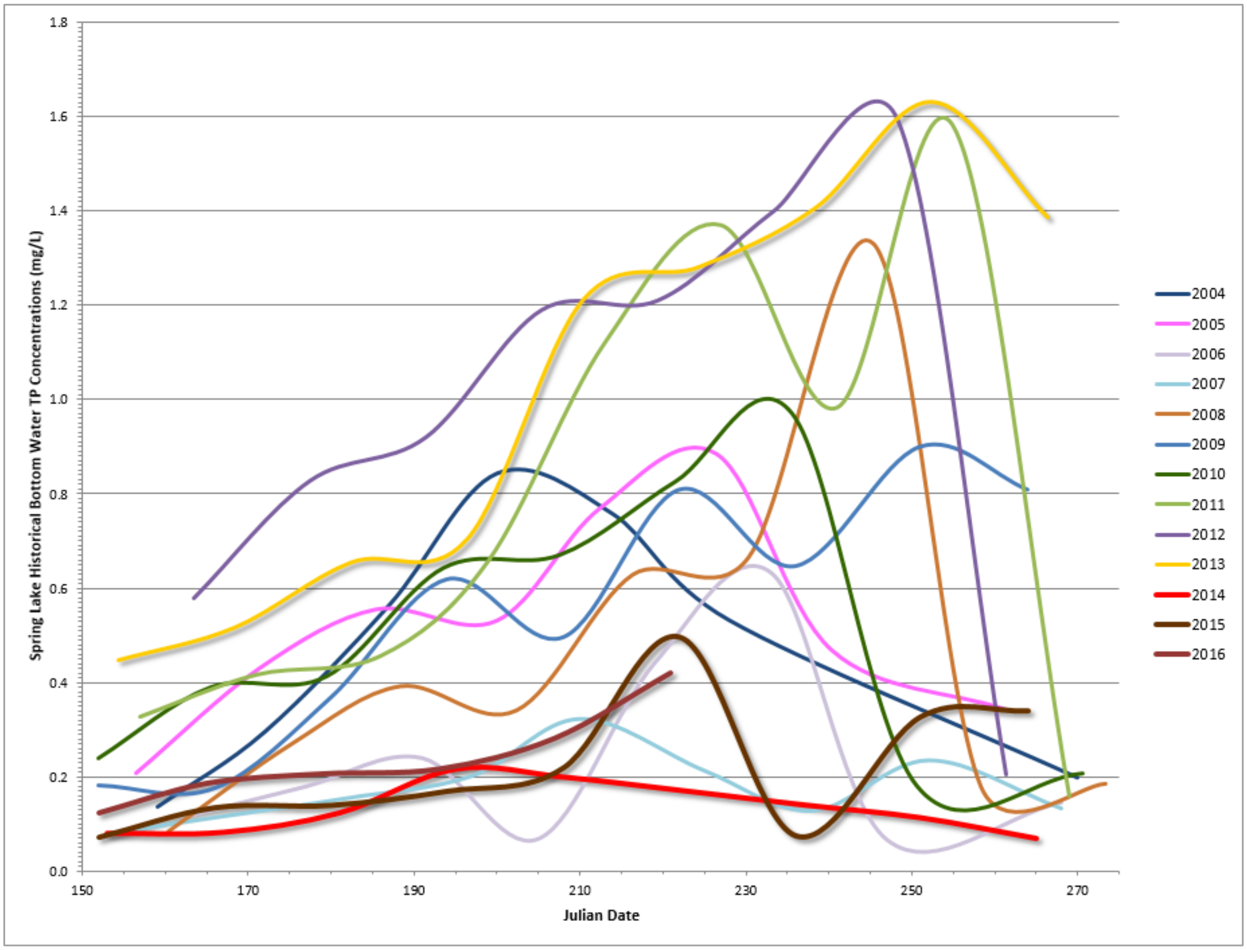


Figure 5 Comparison of Spring Lake bottom water phosphorus concentrations

Conclusions and recommendations for the next phase of alum treatment

Based on our analysis of the sediment core and lake water quality monitoring data, we have drawn the following conclusions to consider in making recommendations for the next phase of the Spring Lake alum treatment:

- The first phase of alum application has resulted in a significant drop in the releasable forms of phosphorus in the sediment
- Depending on the sediment core location, the alum layer appears to reside between two and eight centimeters below the sediment-water interface
- A flood event in 2014, followed by high flows in 2015 and 2016 have resulted in the delivery and sedimentation of more phosphorus to the surface of the sediment, with greater sedimentation in the deepwater portions of the lake
- Surface water quality is much improved since the alum treatment
    - Total phosphorus concentrations are 53 percent lower

    - Chlorophyll-a concentrations are 41 percent lower
    - Secchi depth measurements are 33 percent higher
- Bottom water quality is much improved since the alum treatment with average total phosphorus concentrations during that last three years that are 67 percent lower than the previous ten years

Given the data and conclusions, it is expected that PLSLWD could hold off on the next phase of the alum treatment for another year or two and continue to monitor the lake water quality for deterioration. It is recommended that PLSLWD continue to pursue opportunities to implement additional Best Management Practices in the Spring Lake watershed as a large load of phosphorus remains untreated each year, especially during high flows.