Muskegon Lake Area of Concern Stakeholder Involvement and BUI Removal Project

Bear Lake Wetland Restoration Area Monitoring

Final Project Report

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Introduction

Located within the Muskegon Lake Area of Concern (AOC), Bear Lake is a shallow lake that suffers from degraded water quality due to eutrophication. Chronically-elevated phosphorus concentrations support persistent excess algal growth in Bear Lake, and have prompted 1) the inclusion of a Eutrophication and Undesirable Algae Beneficial Use Impairment (BUI) as part of the AOC designation and 2) the issuance of a Total Maximum Daily Load (TMDL) for phosphorus. The TMDL established a target total phosphorus (TP) concentration of 30 μg/L for Bear Lake; the current average TP concentration is 44 μg/L (MDEQ 2008). Previous studies have demonstrated that the major source of excess phosphorus in Bear Lake is the watershed (i.e., external phosphorus loading) rather than the lake sediments (i.e., internal phosphorus loading) (Steinman and Ogdahl 2013a). As the primary tributary to Bear Lake, Bear Creek and its watershed are the focal point for the phosphorus load reduction needed to improve conditions in Bear Lake, remove the BUI, and meet the TMDL target.

Abandoned muck farms previously used for celery production, but subsequently converted into shallow ponds, abut Bear Creek just before it enters Bear Lake. Since the 1930s, surface flow has been hydrologically disconnected between these ponds and Bear Creek/Bear Lake, resulting in the loss of significant ecological values and functions. A habitat restoration and water quality improvement project is planned for this area in 2015, which would involve hydrologic reconnection of the ponds to Bear Creek. Flooded fields such as these can be converted to functional wetlands, which can result in improved habitat for fish and wildlife, as well as efficient retention areas for phosphorus via sorption to sediments and biotic uptake by periphyton, macrophytes, and microbial communities (Reddy et al. 1999). However, given their location and past land use, these former muck fields also could become major sources of phosphorus to Bear Lake with hydrologic reconnection, at least in the short-term (Aldous et al. 2005, Newman and Pietro 2001). Similarly abandoned celery fields located upstream of Mona Lake, another drowned river mouth system in Muskegon County, contributed a significant load of TP to Mona Lake through breaches in the levee (Steinman and Ogdahl 2011). Although there is currently no surface water connection between Bear Creek and the ponds, it is unknown if there is subsurface connection that could be having a negative impact on Bear Creek and Bear Lake.

A recent study found that the ponds contained very high phosphorus concentrations, concluding that remediation was needed prior to reconnection with Bear Creek to avoid negative impacts to Bear Lake (Steinman and Ogdahl 2013b). In particular, Steinman and Ogdahl (2013b) documented very high P concentrations in the sediment and water column of the west pond, and sufficiently-high water column P in the east pond to support a very substantial algal bloom. However, these results were from a one-time sampling event; Steinman and Ogdahl (2013b) recommended additional monitoring to determine the frequency and dynamics of the high P concentrations and algal biomass in the ponds, which resulted in the current study.

The goals of the current project were to 1) establish pre-restoration baseline water quality conditions in the ponds and Bear Creek and 2) determine if the ponds are currently influencing water quality in Bear Creek. We monitored water quality over a seven-month period to capture seasonal variability in key water quality parameters. This information provides a more comprehensive assessment of the water quality status of these ponds and helps inform the future restoration design.

Methods

Site Description

The former muck fields consist of two ponds adjacent to Bear Creek, separated from each other by Witham Drive and isolated from Bear Creek by a levee (Figure 1). Both ponds are on the south side of Bear Creek; the "west pond" is located just downstream of the "east pond" and ~250 meters upstream of Bear Lake (Figure 1). The surface areas of the east and west ponds are 12 acres and 22 acres, respectively. Water from the muck fields was pumped out to facilitate celery farming beginning in the 1930s. Farming was terminated in the east field in 1995 and in the west field in 2002; the pumps were turned off in 2004, allowing the fields to re-flood (G. Mund, personal communication). Excavation for topsoil removal took place in the east pond from ~1995-2002, varying in depth from 3-15 feet depending on the depth to sand (D. Willbrandt, personal communication). The west pond was not excavated.

Monitoring locations included 3 sites in the west pond, 2 sites in the east pond, and 2 sites in Bear Creek, upstream and downstream of the ponds (Figure 1). Sites within the ponds were chosen as a subset of previously-studied sites (Steinman and Ogdahl 2013b) to facilitate comparisons with past data.

Water quality monitoring

Water quality monitoring took place every 3-4 weeks from April through October, 2014, with a total of 8 monitoring events. All sampling events occurred between 09:30 and 11:00. At each monitoring location (Figure 1), a 1 L grab sample was collected and general water quality parameters, including temperature, dissolved oxygen (DO), pH, specific conductance, total dissolved solids (TDS), and turbidity, were measured using a YSI 6600 sonde. Water collection and YSI measurements were taken at mid-depth in the thalweg in Bear Creek and just below the water surface of the ponds. Only one site (East 8) had sufficient water depth (>1.5 m) to allow bottom-water YSI measurements. Secchi disk depth was measured in the ponds to characterize water transparency. Total water column depth was also measured at each pond site.

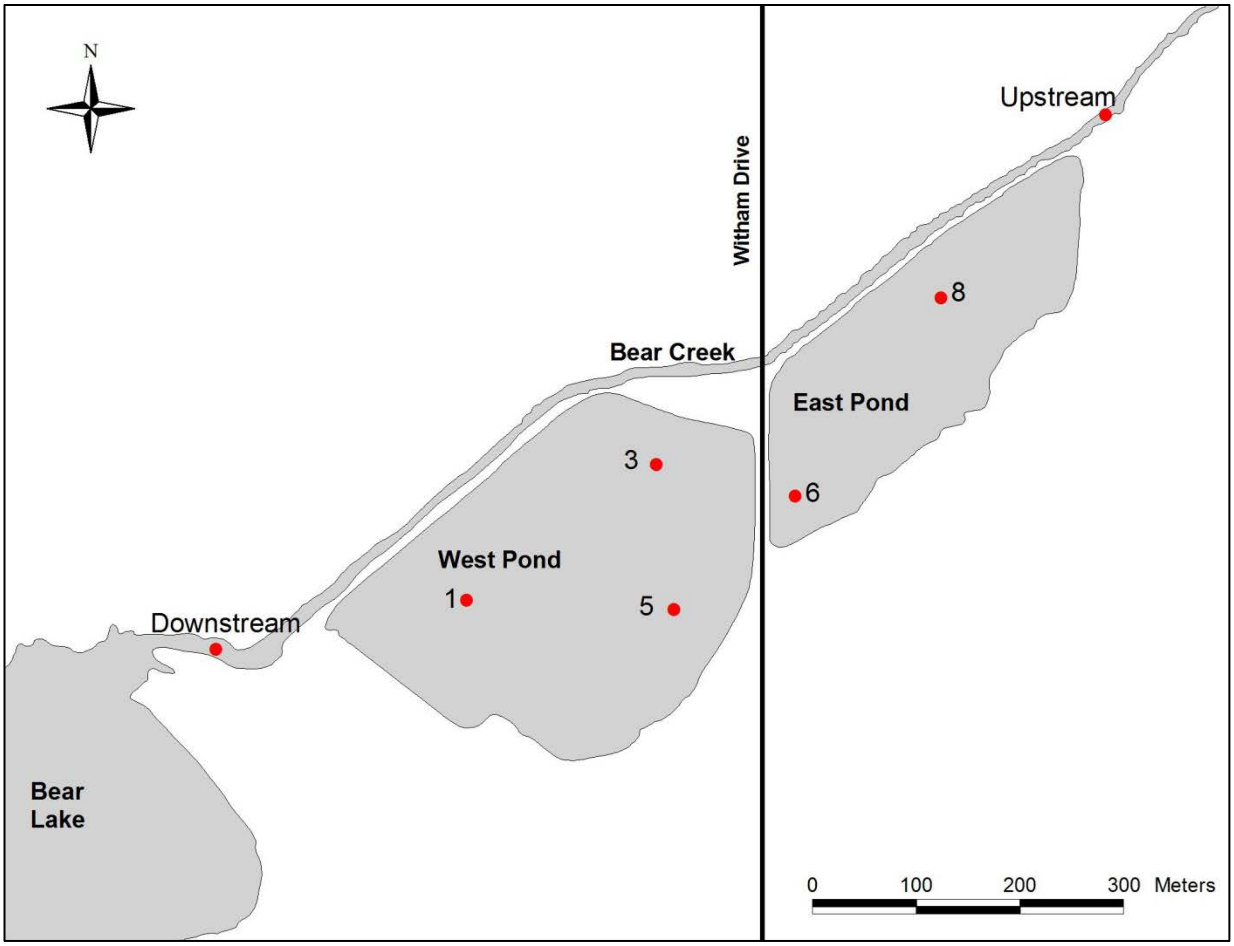

Figure 1: Map of the Bear Lake Wetland Restoration study area, including the east and west ponds, Bear Creek, and its inflow to Bear Lake (far left). Red dots indicate the water quality monitoring locations.

Water samples were transported on ice to the lab, where they were subsampled for analysis of soluble reactive phosphorus (SRP), total phosphorus (TP), and chlorophyll *a* (chl *a*). Water for SRP analysis was syringe-filtered through 0.45-µm membrane filters into scintillation vials and frozen until analysis. SRP and TP were analyzed on a SEAL AQ2 discrete automated analyzer (U.S. EPA 1993). P values below detection were calculated as ½ the detection limit (5 µg/L). Chlorophyll *a* samples were filtered through GFF filters and frozen until analysis on a Shimadzu UV-1601 spectrophotometer (APHA 1992).

Data analysis

General water quality parameters measured with the YSI sonde were summarized for each sampling date by calculating the mean and standard deviation of values measured in each pond. Mean pH was calculated by first determining the equivalent hydrogen ion (H^+) concentration for each pH value, averaging the H^+ values for each pond, then converting the mean H^+ value back to pH; this method did not allow us to calculate standard deviation of the mean.

Secchi depth was expressed as the % of total water column depth by dividing Secchi depth by total depth. This allowed us to easily show that many of the Secchi depth measurements were at the bottom of the water column (i.e., 100%).

Water quality effects of the ponds on Bear Creek were evaluated using paired t-tests on upstream and downstream concentrations of SRP, TP, and chl *a*. Statistical significance was determined by p-values <0.05. Statistical analysis was performed using SigmaPlot 12.5.

Results

General water quality variables varied both seasonally and among site locations. Water temperature exhibited the expected seasonal variation and was also 4-9 °C lower in Bear Creek than in the ponds throughout the study period (Figure 2A). Dissolved oxygen was variable among sites, especially during summer, when surface water of the east pond had very high DO (≥ 11 mg/L) and bottom water had very low DO (< 1 mg/L) (Figure 2B). The west pond had low DO (≤ 5 mg/L) at the surface during 3 of the 4 summer sampling events (Figure 2B). pH was fairly consistent at each location throughout the sampling period. Bear Creek had circumneutral pH and both ponds were alkaline, with mean pH values between 7.4 and 9.7 (Figure 2C). Turbidity was low and consistent throughout the study period at all locations except the east pond; mean turbidity there exceeded 20 NTU from July through October (Figure 2D). Total dissolved solids is derived from specific conductance; therefore, the data patterns were the same for both variables, which increased gradually at each location over the study period (Figure 2E,F). TDS and specific conductance were greater in the ponds than in the creek and were highest in the west pond. All mean specific conductance values were ≥ 600 μS/cm in the west pond (Figure 2F) and reached 600 μS/cm in the east pond by October. Aquatic system impairment is linked to human-induced stress when specific conductance values exceed 600 μS/cm (Uzarski et al., Steinman et al. 2011).

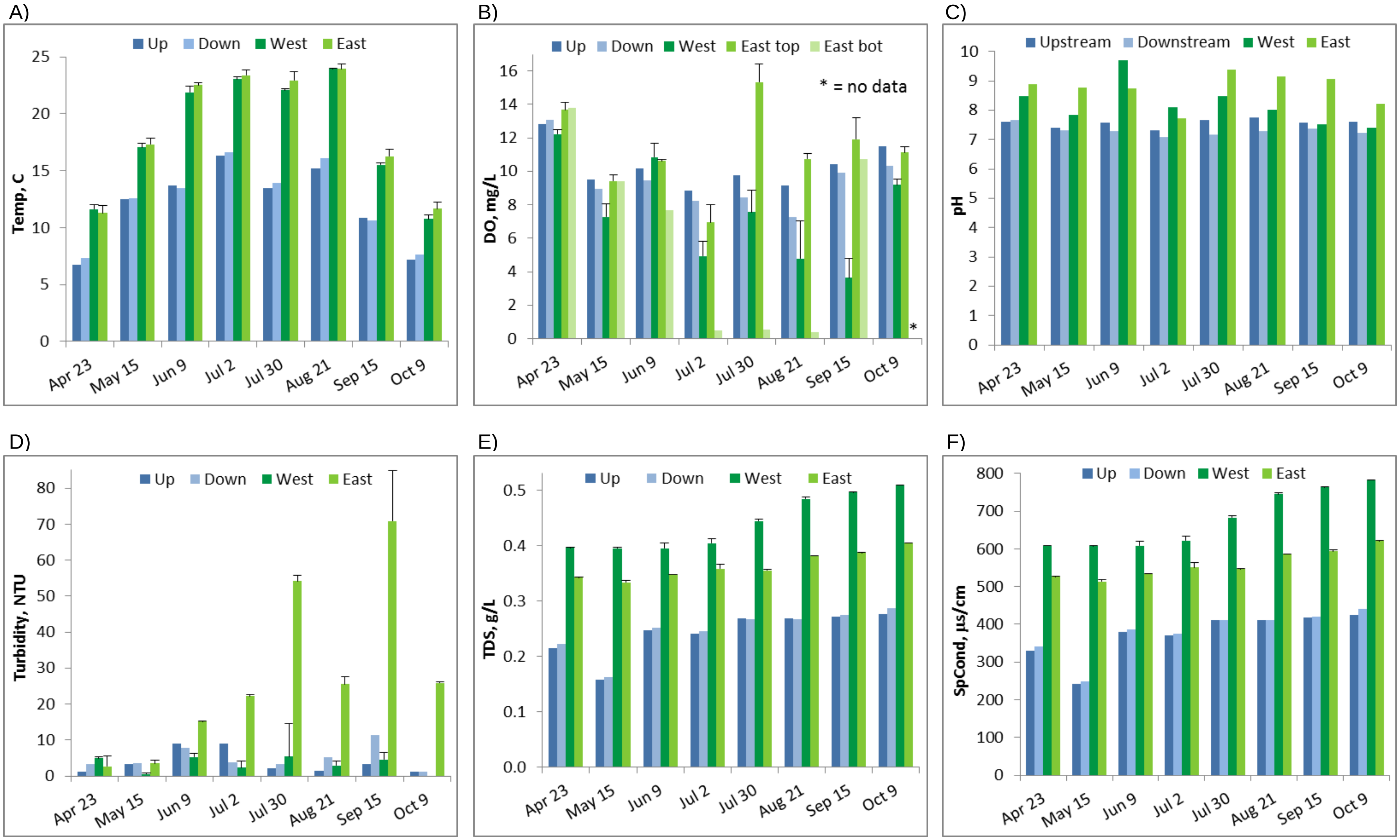

Figure 2. Summary of general water quality parameters measured during the study period: A) temperature, B) dissolved oxygen (DO), C) pH, D) turbidity, E) total dissolved solids (TDS), and F) specific conductance (SpCond). Data bars for the east and west ponds represent the mean (+ SD) value of the sites in each pond for each monitoring date (west: n=3, east: n=2). See text for explanation of pH data.

Secchi depth, expressed as the percentage of total water column depth, exhibited contrasting seasonal trends in the two ponds. In the west pond, Secchi depth was ~40% of the total water column depth in April, but increased to 100% of the water column depth (i.e., at the bottom of the pond) for the remainder of the study period (Figure 3). Secchi depth in the east pond was 100% of the water column depth at East 6 in April and May and 87% of the water column depth at East 8 in April (Figure 3). Thereafter, Secchi depth in the east pond was quite shallow, ultimately reaching < 10 % (< 0.3 m) during the summer and remaining there through October (Figure 3), consistent with the high turbidity and TDS values.

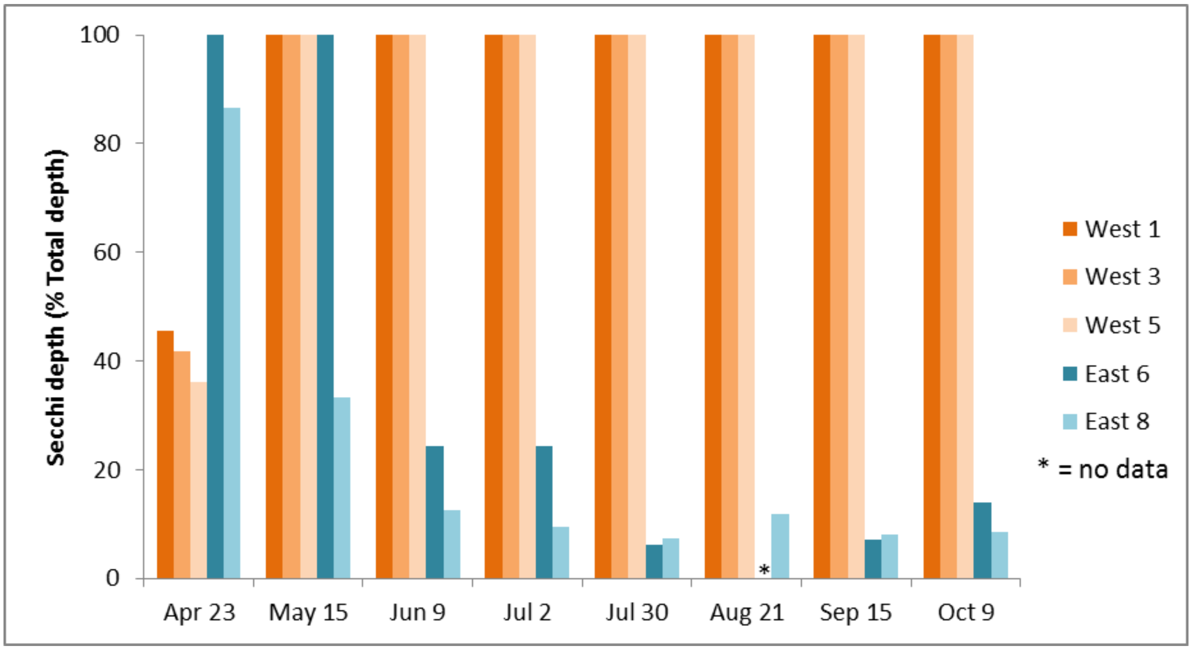

Figure 3. Secchi disk depth for each pond site, expressed as the percentage of total water column depth. Data bars equal to 100% indicate the Secchi depth was at the bottom of the water column.

Phosphorus concentrations were widely variable among the three study locations. They were extremely high in the west pond, with SRP ranging from 150 µg/L to 1200 µg/L and TP concentrations ranging from 390 µg/L to 1430 µg/L (Figure 4). Although the east pond had lower P concentrations than the west pond, TP concentrations were still elevated, ranging from 40 µg/L to 280 µg/L (Figure 4). In contrast to the west pond, SRP concentrations in the east pond were low, ranging from < 5 µg/L to 10 µg/L. Seasonal trends were evident in the pond data; P concentrations were more variable among sites during the summer and TP tended to increase over the study period (through September) in the east pond (Figure 4). All TP samples from both ponds exceeded the 30 µg/L TMDL target for Bear Lake.

Phosphorus concentrations were generally low in Bear Creek, with SRP ranging from <5 µg/L to 9 µg/L and TP ranging from 13 µg/L to 48 µg/L (Figure 4). Downstream P concentrations were often lower than upstream P concentrations (Figure 4), suggesting the ponds are not a major source of P to Bear Creek. Indeed, there was no statistically significant difference between P concentrations upstream and downstream of the ponds ($p > 0.05$). Most TP samples from Bear Creek were below the 30 µg/L TMDL target, with the exception of those collected in May and September (Figure 4).

Chlorophyll *a* concentrations also were widely variable among the study locations. In contrast to P concentrations, chl *a* was extremely high in the east pond and concentrations were lower, but still elevated at times in the west pond (Figure 5). In the east pond, chl *a* concentrations were ≥ 50 µg/L from early July through the end of the study period, and ranged from 5.1 µg/L in April to 230 µg/L on July 30 (Figure 5). Most chl *a* samples collected from the west pond were below 10 µg/L. However, chl *a* was elevated (30-45 µg/L) at all west pond sites in April and at a subset of sites in May, late July, and September (Figure 5). The highest chl *a* concentration measured in the west pond (66 µg/L) was possibly due to filamentous algae or duckweed in the sample, which were prolific at the time and difficult to avoid (Figure 5). Chlorophyll *a* concentrations were low (≤ 3 µg/L) in Bear Creek and were well below the 10 µg/L restoration target for the Muskegon Lake AOC (Figure 5). There was no statistically significant difference between chl *a* concentrations upstream and downstream of the ponds ($p > 0.05$). Seasonal variation was evident at all sites, with a decreasing trend over the study period in Bear Creek and the west pond, and an increasing trend in the east pond (Figure 5).

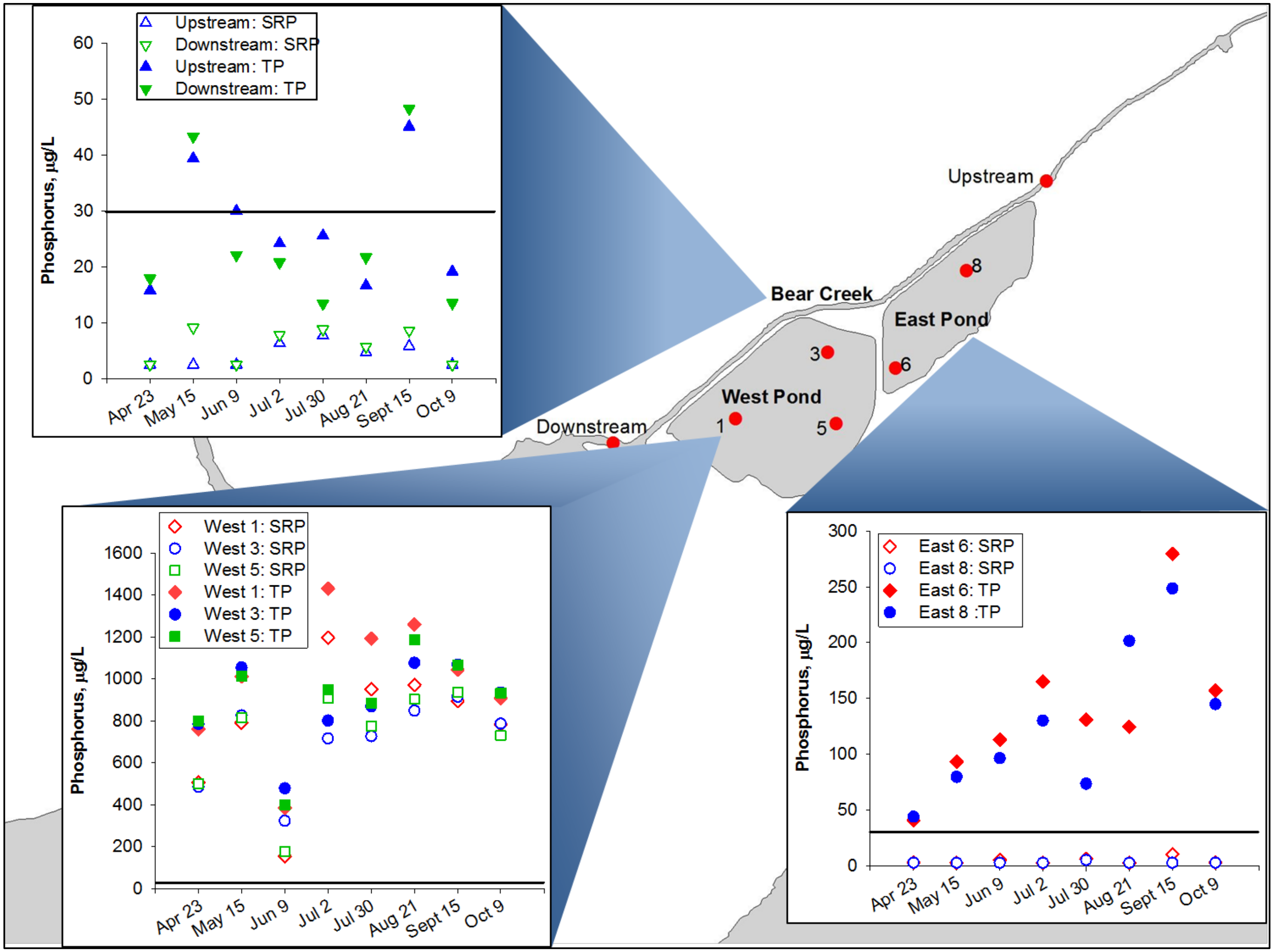

Figure 4. Soluble reactive phosphorus (SRP) and total phosphorus (TP) concentrations in Bear Creek, the west pond, and the east pond measured during the project period. Note the different y-axis scales on the three graphs. The black horizontal line on each graph shows the 30 µg/L TP target established by the Bear Lake TMDL (MDEQ 2008).

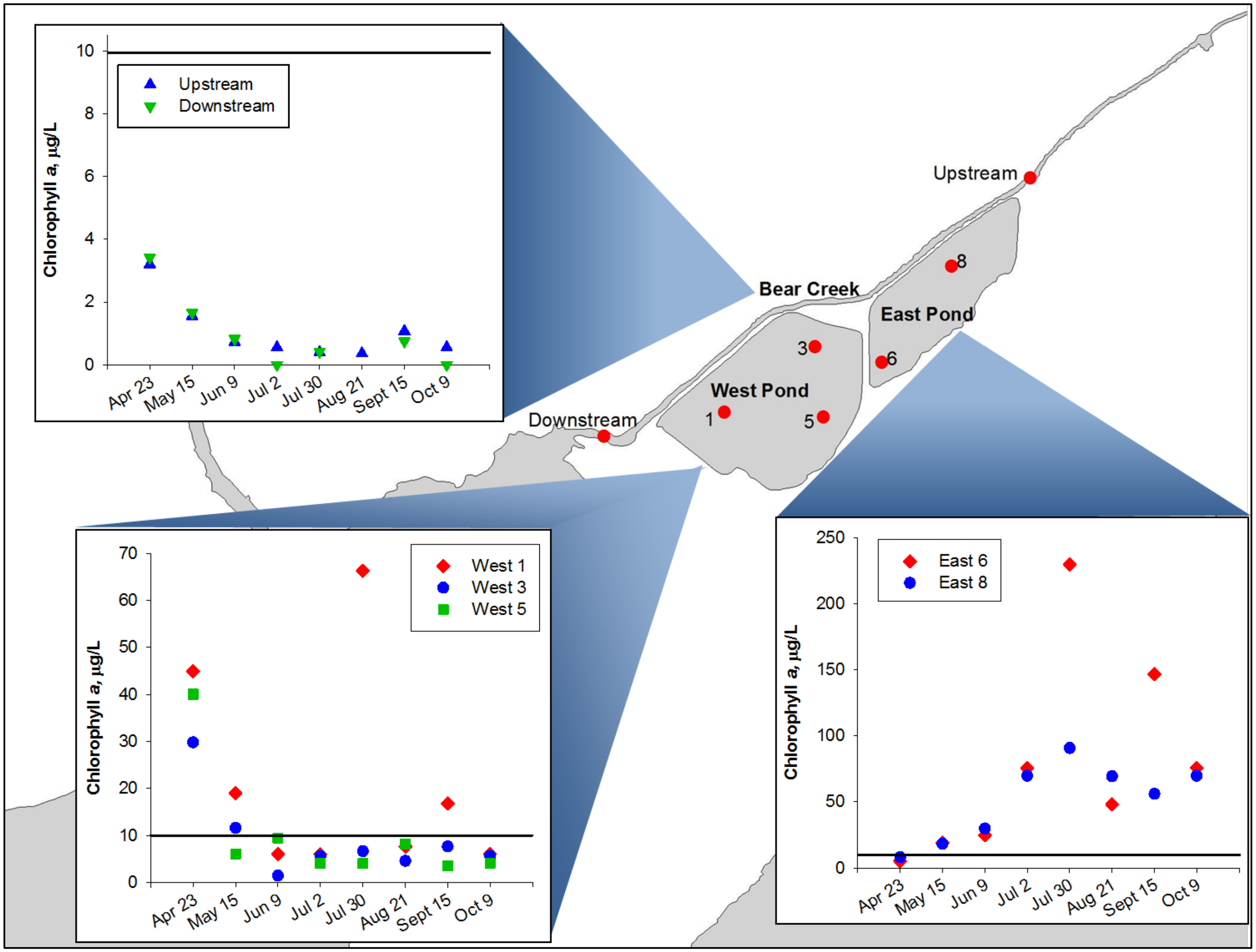

Figure 5. Chlorophyll *a* (chl *a*) concentrations in Bear Creek, the west pond, and the east pond measured during the project period. Note the different y-axis scales on the three graphs. The black horizontal line on each graph shows the 10 µg/L chl *a* restoration target for the Muskegon Lake Area of Concern (AOC).

Conclusions

The results of this study include both good and bad news with respect to the water quality implications of reconnecting Black Creek to the flooded celery fields. The discouraging finding is the confirmation of what was previously reported by Steinman and Ogdahl (2013b); the water quality in the ponds that overlie the former muck fields adjacent to Bear Creek is highly degraded and is in need of remediation before reconnection with Bear Creek. The extremely high water column P concentrations, particularly in the west pond, are especially disconcerting because they are up to ~50× greater than the TMDL target for phosphorus in Bear Lake and a large proportion of the P is in bioavailable form (SRP). Although P concentrations were lower in the east pond than in the west, they were still up to 9× greater than the 30 µg/L TMDL target and should also be considered a threat to downstream water quality. In contrast to the west pond, bioavailable P in the east pond was low, most likely due to rapid uptake by the over-abundant algal community, as evidenced by the very high chlorophyll *a* concentrations.

The more encouraging news was that our analysis indicated that the ponds are not currently influencing water quality in Bear Creek, thus suggesting that subsurface flow from the ponds to the creek is not significant. However, subsurface water samples taken from shallow wells (currently being done by USGS) will indicate the degree to which subsurface flow influences overall hydrology and water quality in the system, with respect to both Bear Creek and Bear Lake.

As discussed by Steinman and Ogdahl (2013b), restoration of the former muck fields provides a unique opportunity to retain nutrients that would otherwise reach Bear Lake. However, it is critical that appropriate actions are taken during the restoration process to abate the abundant P in the system. Care must be taken in the course of restoration to not contribute additional P to Bear Lake, which is already P-rich and subject to cyanobacterial blooms. Steinman and Ogdahl (2013b) provided details on three possibilities for P mitigation in the ponds, including treatment and polishing cells, sediment dredging, and coupled chemical inactivation and water drawdown. Addressing the P issue should be a critical component of the habitat restoration project. The baseline conditions characterized by this study will aid in future evaluation of restoration effects.

Acknowledgements

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References

Aldous A., P. McCormick, C. Ferguson, S. Graham, and C. Craft. 2005. Hydrologic regime controls soil phosphorus fluxes in restoration and undisturbed wetlands. Restoration Ecology 13: 341–347.

APHA. 1992. Standard Methods for the Examination of Water and Wastewater. 18th Edition. American Public Health Association.

MDEQ. 2008. Total maximum daily load for phosphorus for Bear Lake, Muskegon County. Lansing (MI): Michigan Department of Environmental Quality.

Newman S. and K. Pietro. 2001. Phosphorus storage and release in response to flooding: implications for Everglades stormwater treatment areas. Ecological Engineering 18: 23-38.

Reddy, K.R., R.H. Kadlec, E. Flaig, and P.M. Gale. 1999. Phosphorus retention in streams and wetlands: a review. Critical Reviews in Environmental Science and Technology 29: 83-146.

Steinman, A.D., and M.E. Ogdahl. 2011. Does converting agricultural fields to wetlands retain or release phosphorus? Journal of the North American Benthological Society 30: 820-830.

Steinman, A.D., M.E. Ogdahl, and C.R. Ruetz III. 2011. An environmental assessment of a small shallow lake (Little Black Lake, MI) threatened by urbanization. Environmental Monitoring and Assessment 173: 193-209.

Steinman, A.D., and M.E. Ogdahl. 2013a. Bear Creek / Bear Lake (Muskegon County) Watershed Implementation (2) Project: Internal Phosphorus Loading. Annis Water Resources Institute, Grand Valley State University. http://www.gvsu.edu/cms4/asset/DFC9A03B-95B4-19D5-F96AB46C60F3F345/final_report_awri.pdf

Steinman, A.D., and M.E. Ogdahl. 2013b. Muskegon Lake AOC Habitat Restoration Design: Bear Lake Hydrologic Reconnection/Wetland Restoration. Annis Water Resources Institute, Grand Valley State University. http://www.gvsu.edu/cms4/asset/DFC9A03B-95B4-19D5-F96AB46C60F3F345/bear_muck_final_report_final.pdf

U.S. EPA. 1993. Methods for Chemical Analysis of Inorganic Substances in Environmental Samples. EPA-600/4-79R-93-020/100.

Uzarski, D.G., T.M. Burton, M.J. Cooper, J.W. Ingram, and S. Timmermans. 2005. Fish habitat use within and across wetland classes in coastal wetlands of the five Great Lakes: development of a fish-based index of biotic integrity. Journal of Great Lakes Research 31: 171-187.