Big Arbor Vitae Lake

Vilas County, Wisconsin

Beaver Dam Phosphorus Study

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This effort was truly a team-based project and could not have been completed without the input of the following individuals:

Big Arbor Vitae Lake Association

Larry Stein

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Kevin Gauthier
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INTRODUCTION

Beaver ponds change the surrounding landscape by flooding riparian zones and inundating previously dry land with water. Further, beaver ponds are positioned so that runoff from catchment areas must pass through them. With the expansion of flooded land, ponding a previously completely lotic system and thus creating a unique ecosystem with differing biological and chemical processes, a beaver dam pond has the potential to alter nutrients and other water quality parameters as they are transported downstream. The cycling of nutrients in stream beaver ponds is complex and may result in a net release or gain of downstream nutrients depending upon the environmental conditions present.

Trapping of particulate matter, anoxia, chemical precipitation/absorption as well as the structural integrity of the dam itself may influence downstream water quality parameters from upstream segments. Some research has been completed on these systems, with varying results. In Wyoming, it was concluded that beaver ponds sequestered nutrients (phosphorus and nitrogen) within deposited sediments (Maret et al. 1987). Devito et al. (1989) reported low retention – full flow-through – of waterborne phosphorus and nitrogen in two central Ontario beaver ponds. Klotz (1998) found that of five central New York beaver ponds studied, three increased phosphorus concentrations (one dramatically during ice cover) while the remaining two were consistent in reducing phosphorus during all points of the year. These studies indicate that beaver dam impacts on water quality may not be predictable and are heavily dependent upon site specific biological and chemical characteristics.

During a management planning project on Big Arbor Vitae Lake, Vilas County, it was discovered that beaver dams were located on two lake tributary streams. The Big Arbor Vitae Lake Management Plan (2014) documented high nutrient and algae levels in Big Arbor Vitae Lake, along with describing the need for a nutrient budget analysis to be completed in order to better understand nutrient sources. As preparation for a more intensive nutrient budgeting study on Big Arbor Vitae Lake, phosphorus was monitored on the lake's two tributary streams Total as well as soluble reactive phosphorus samples were collected from three locations on two Big Arbor Vitae Lake tributary streams during June, August and October of 2014 and February of 2015. Samples were collected from the sub-surface and sent to the Wisconsin State Lab of Hygiene (WSLOH) in Madison, Wisconsin for chemical analysis. During each event, additional parameters such as temperature, dissolved oxygen, depth and pH were collected. Onterra developed the study to understand how phosphorus may change from upstream to downstream reaches of these streams, with consideration to the location of beaver dam ponds and how they may influence water quality. This study was funded through a Wisconsin Department of Natural Resources Small-Scale Lake Planning Grant.

SITE DESCRIPTIONS

The two sampling areas consist of tributary streams on the east and north-west sides of Big Arbor Vitae Lake (Map 1). The eastern tributary (referred to in this report as BAVE) drains land along the eastern portion of the lake's watershed. Two beaver dams are known to pool water on this stream; one at a snowmobile trail crossing 330 meters upstream from the lake and one at the tributary's terminal point where it enters Big Arbor Vitae Lake. The western stream (referred to in this report as BAVW) drains a northern portion of Big Arbor Vitae Lake's watershed, eventually entering Big Arbor Vitae Lake through a Buckhorn Rd culvert.

When the project was first conceived, it was believed that a single dam was located on the eastern tributary, right at the mouth of the stream. It wasn't until the project began that a second dam was found, upstream of the known beaver dam. Therefore, the original sampling design (which mirrored that of the western tributary) was modified. Table 1 displays the description of BAVE sampling locations.

Table 1. Big Arbor Vitae Lake east tributary sampling site descriptions.

Site	Description	Depth (ft)
BAVE3	Upstream site. 450 m from beaver dam pool	3
BAVE2	Mid-stream, within beaver dam. 10 m upstream from dam	3
BAVE1	300 m from upstream dam, 30 m upstream from lake and terminal dam	4

It was known at the beginning of this project that one beaver dam existed on the western tributary stream. The sampling design for this stream then was then to capture phosphorus concentrations in three locations, each described in Table 2.

Table 2. Big Arbor Vitae Lake west tributary sampling site descriptions.

Site	Description	Depth (ft)
BAVW3	Upstream site. 570 m from beaver dam pool	< 1
BAVW2	Mid-stream, within beaver dam. 10 m upstream from dam	3
BAVW1	200 m downstream from dam, 25 m upstream from lake	2

The streams were observed to differ greatly in their appearance. The eastern tributary, BAVE, is heavily stained in appearance when compared to the western stream, BAVW. Floating-leaf aquatic plant species are prevalent near BAVE1, along with some submergent species such as coontail and flat-stem pondweed. Upstream, at sites BAVE2 and BAVE3, aquatic vegetation decreases substantially, with the exception of surrounding emergent wetland species (sedges, rushes, etc.). Water depth is consistently about 3 ft in this stream, with the exception of the pool at BAVE1, where depth of 4 feet may be found. pH was determined to be consistently weakly acidic (6.2-6.4) at all segments of the stream. Oxygen is typically monitored in phosphorus dynamics studies as this nutrient may be released from underwater sediments when conditions become anoxic. Low oxygen, defined here as under 2.0 mg/L, was recorded at all locations at least once. All locations held low oxygen in August. In February of 2015, dissolved oxygen was not able to be recorded due to very low temperatures, which caused the measuring probe to malfunction. It is believed that anoxic conditions were present along this stream however due to the strong sulphurous scent encountered once a sampling hole was drilled through the ice.

Onterra staff observed sites BAVW1 and BAVW2 to hold clear water and much submergent aquatic plants, such as coontail, northern water milfoil, wild celery and other common aquatic plants such as floating-leaf lily species. Water depth was roughly 1-1.5 feet near BAVW1 and increased to 2.5-3 ft behind the pooled dam at BAVW2. Near BAVW3, the water level was reduced to approximately 8-10 inches and the aquatic plant community was replaced with a light gray, flocculent, heavily organic substrate along with exceptionally clear water. During all sampling visits, and at all BAVW sampling sites, dissolved oxygen was found to be in excess of 8 mg/L with the exception of one August reading at BAVW1 (5.9 mg/L). Very cold temperatures prevented February oxygen data from being collected. At downstream locations (BAVW1 and BAVW2) pH levels were measured at 7.0 while BAVW3 pH was measured at 9.0.

PHOSPHORUS CONCENTRATION RESULTS

Photograph 1. Western and eastern tributary streams, Big Arbor Vitae Lake, WI. Left: Sole beaver dam, photo taken from downstream looking upstream. Right: Furthest downstream beaver dam, photo taken from site BAVE1 looking downstream towards Big Arbor Vitae Lake (pictured in background).

Total phosphorus results, broken down by particulate and dissolved phosphorus concentrations and by three sampling events on Big Arbor Vitae's tributaries are presented in Figure 1. Total phosphorus ranged from 23.9 to 72.3 ug/L at all locations and across all sampling events. On BAVE, samples across all time periods and locations averaged 41.2 ug/L.

In June, total phosphorus was measured at 88.9 ug/L at BAVE3, the most upstream site. This was the highest concentration measured on either tributary, and was nearly twice as high as the second highest reading on the stream that day. This sample passed all QA/QC procedures at the WSLOH. Because of the very high level of phosphorus contained in the sample it is believed there may have been contamination of the sample at some point prior to or during collection. Therefore, this value has been removed from the analysis. A dissolved phosphorus value of 9.0 ug/L at this location is believed to be valid. Total phosphorus decreased from the eastern tributary most upstream to midstream location once, in August. During all sampling periods, phosphorus concentrations increased from the midstream to downstream sampling location on this tributary.

Phosphorus concentrations were monitored in a similar manner in the western tributary, BAVW. Total phosphorus concentrations were largely lower than those measured in BAVE; concentrations ranged from 20.2 to 34.8 ug/L at all locations and across all sampling events, with an average of 26.6 ug/L. On all three summer sampling events, total phosphorus increases slightly from upstream to downstream locations, though this increase is more apparent in June than in August or October. Dissolved phosphorus, rather than particulate, was the portion of increasing phosphorus within this stream. A winter sample could not be collected on BAVW3 due to shallow water column depths and unsafe ice conditions. During this time midstream concentrations were slightly higher than furthest downstream concentrations.

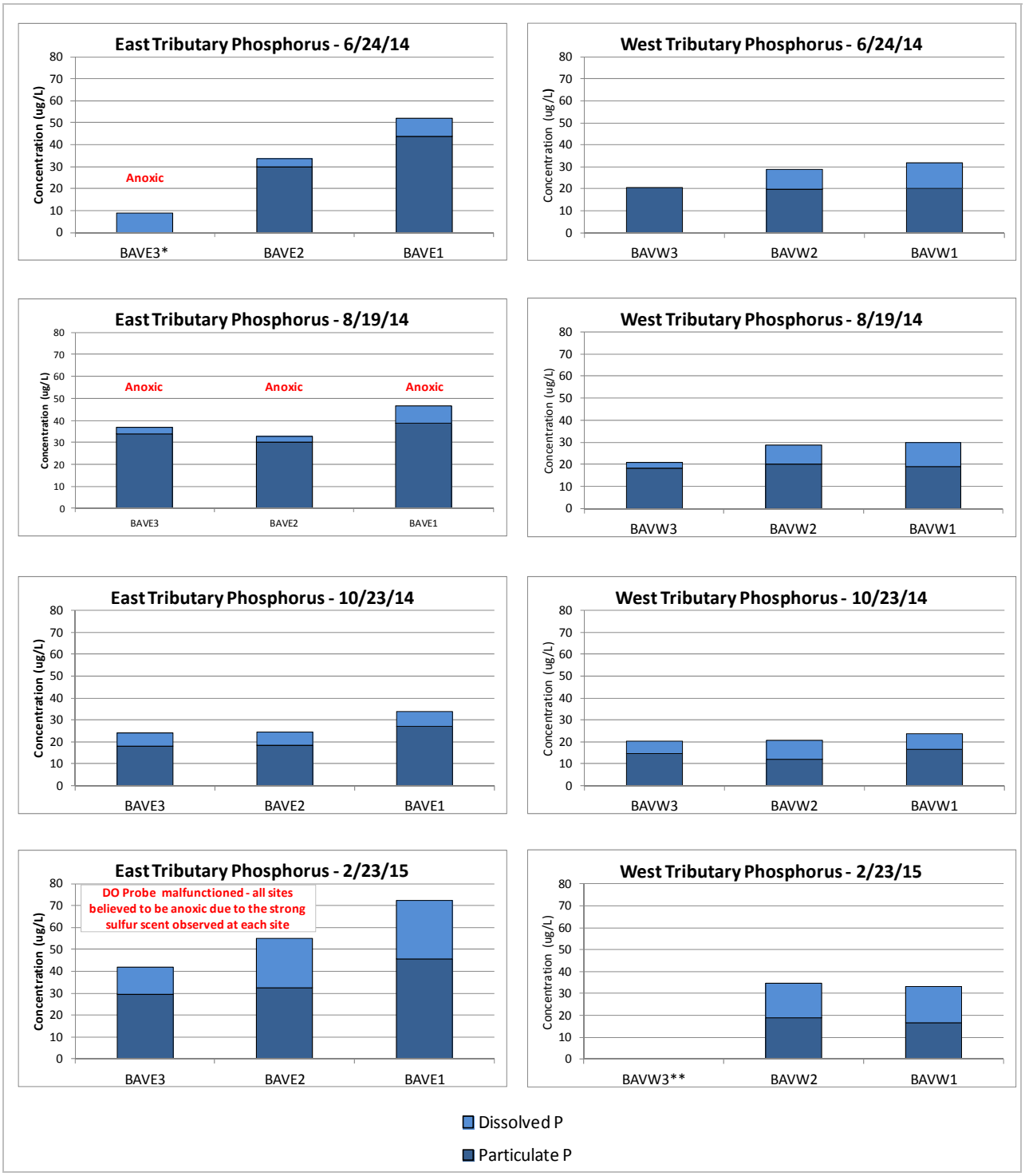

Figure 1. Phosphorus concentrations from two Big Arbor Vitae Lake tributaries. Sites arranged from upstream (left) to downstream (right) on each bar chart. Anoxic conditions (<2.0 mg/L DO) depicted in red font.

**BAVE3 total phosphorus 6/24/14 sample was reported at 88.9 ug/L. It is believed that this value is erroneous and has been removed from analysis.*
***BAVW3 was not sampled during 2/23/15 due to minimal water column depth between stream sediment and ice cover.*

Big Arbor Vitae Lake surface water total phosphorus data was collected during May, June, July and August in 2014 by volunteers through the Citizens Lake Monitoring Network. Data compiled from these events indicate the surface water growing season average concentration was 31.8 ug/L (SWIMS, 2015). Therefore, the downstream samples from BAVE in June and August represent total phosphorus concentrations that are 64% (52.0 ug/L) and 46% (46.4 ug/L) higher, respectively, than in-lake conditions during this time. Though February samples were collected during ice cover and are thus not entirely comparable to summer conditions, total phosphorus concentrations were 128% higher than summer in-lake concentrations (40.5 ug/L higher).

Concentrations at the furthest downstream BAVW site were slightly lower (June - 0%, 31.7 ug/L and August - 6%, 29.8 ug/L) than the in-lake concentration of 31.8 ug/L during this same time period. A February sample at BAVW1 was slightly lower (4%, a difference of 1.2 ug/L) than the growing season in-lake concentration.

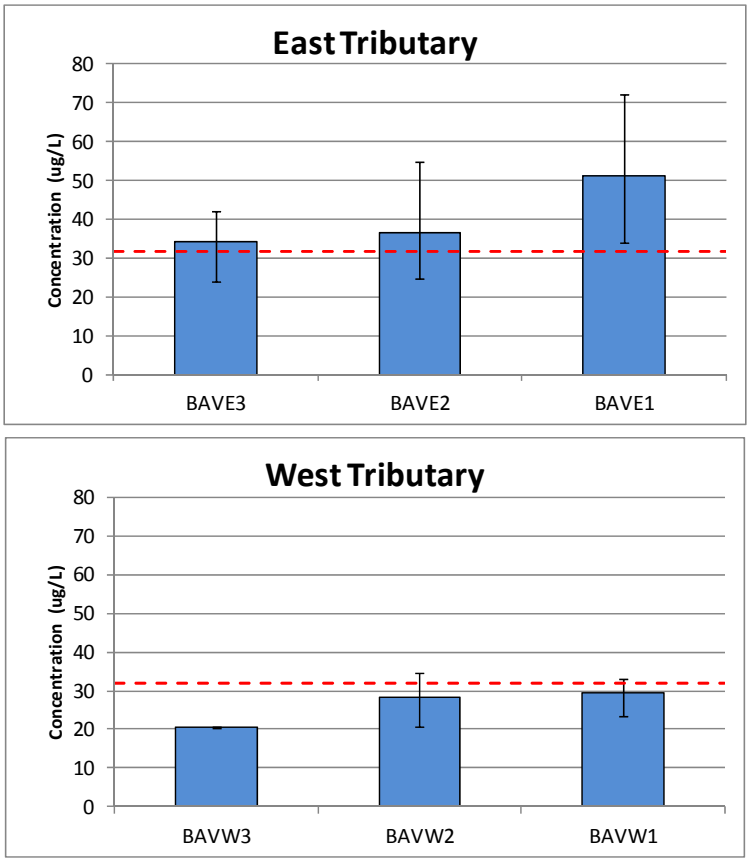

Figure 2. Tributary stream total phosphorus summary statistics and Big Arbor Vitae Lake growing season average. Sites arranged from upstream (left) to downstream (right) on each bar chart. Bar chart data displays the site average, while the error bars indicate the maximum and minimum values for these sites across all four sampling periods. Red dashed line indicates the Big Arbor Vitae Lake growing season average concentration for 2014.

SUMMARY & DISCUSSION

The scale of this project was not sufficient to quantify annual nutrient loads of phosphorus to Big Arbor Vitae Lake, nor would the effort tell researchers the exact mechanisms of phosphorus cycling within the beaver dam pools that are found on the tributaries leading to Big Arbor Vitae Lake. However, the sampling efforts on the eastern (BAVE) and western-northwestern (BAVW) tributaries were effective at reaching their intended goal, which was to provide an insight into periodic in-stream conditions and, more importantly, an indication of intermittent phosphorus dynamics within and downstream of these beaver dams. This goal was created with the intention of further understanding the complexities of the nutrient loading sources to Big Arbor Vitae Lake.

More specific than understanding in-stream conditions and phosphorus concentration of these tributaries, this study aimed to determine if the beaver dams along the streams are acting to increase or decrease phosphorus as water flows downstream. The data collected within this project appear to show mixed answers to the question of whether beaver dam pools act as sinks or sources of phosphorus. In the clear-watered western tributary, some dissolved phosphorus may have been accumulated as water moved downstream, however total phosphorus concentrations did not increase substantially during this study. In the stained eastern tributary, dissolved phosphorus increased slightly while particulate and thus total phosphorus increased from upstream to downstream during all four sampling events. It is hypothesized that the sediments within the east tributary beaver dam pools are producing dissolved phosphorus; colloidal particles in the stained water may then be sorping to the phosphorus which would produce particulate phosphorus.

During the times in which sampling was conducted, the western tributary (BAVW) was producing phosphorus concentrations at or below the in-lake phosphorus growing season average for Big Arbor Vitae Lake in that same year. Therefore, BAVW may not be contributing significant phosphorus to the lake when compared in this manner. However, on all sampling dates, the eastern tributary at the furthest downstream site (BAVE1) was contributing phosphorus concentrations higher than the in-lake concentrations, during two sampling periods up to 64% and 128% more. There was a general decreasing trend in downstream phosphorus concentrations as the open water sampling season went by. This is likely due to the streams originally having larger runoff from early spring/summer precipitation, then slowly reaching baseflow conditions in the late summer with groundwater comprising a higher percentage of the flow. Regardless, even with late summer flow, total phosphorus concentrations increased downstream, particularly between the downstream and midstream locations where the beaver dams are located. It is very likely that a substantial amount of phosphorus loading occurs during the ice covered months, when anoxic conditions are likely. Flow was observed coming over each beaver dam during this time, indicating that the water was indeed reaching the lake.

These results indicate that the beaver dams on the eastern tributary may be facilitating biochemical processes that are increasing phosphorus concentrations downstream as they reach Big Arbor Vitae Lake. Within the western tributary, differing local variables (water or soil chemistry, geologic or morphometric variation, etc.) could be reducing ponded water biochemical reactions that would increase phosphorus availability to the water column.

PROJECT RECOMMENDATIONS

With the release of a preliminary report in early February of 2015, a recommendation was given to the Big Arbor Vitae Lake Association to investigate obtaining of a WDNR permit for removal of beavers and beaver dams from the eastern tributary. A recommendation for "no action" was given for the western tributary. The association understands that the removal of the eastern beaver dams, while reducing the loading of some phosphorus to the Big Arbor Vitae Lake system, would likely result in no detectable change in the lake's water quality or a reduction in the documented algae blooms and abundant aquatic plant growth that occurs in the lake. Further studies to quantify all phosphorus inputs would be required, as would other actions to address these inputs, to alter the lake's water quality to a measurable degree.

The Big Arbor Vitae Lake Association sought a local trapper to set traps along the eastern tributary during the tail end of the 2014-2015 beaver trapping season. No beavers or active beaver sign (tracks) were encountered near the dams or beaver hut, which led the trapper to believe that there was no current beaver activity occurring along this stream. When the late February sampling data were obtained, the hypotheses generated from the open water season data were strengthened. It was at this point that the Big Arbor Vitae Lake Association moved forward with pursuing a WDNR permit to remove the beaver dams on at this location.

LITERATURE CITED

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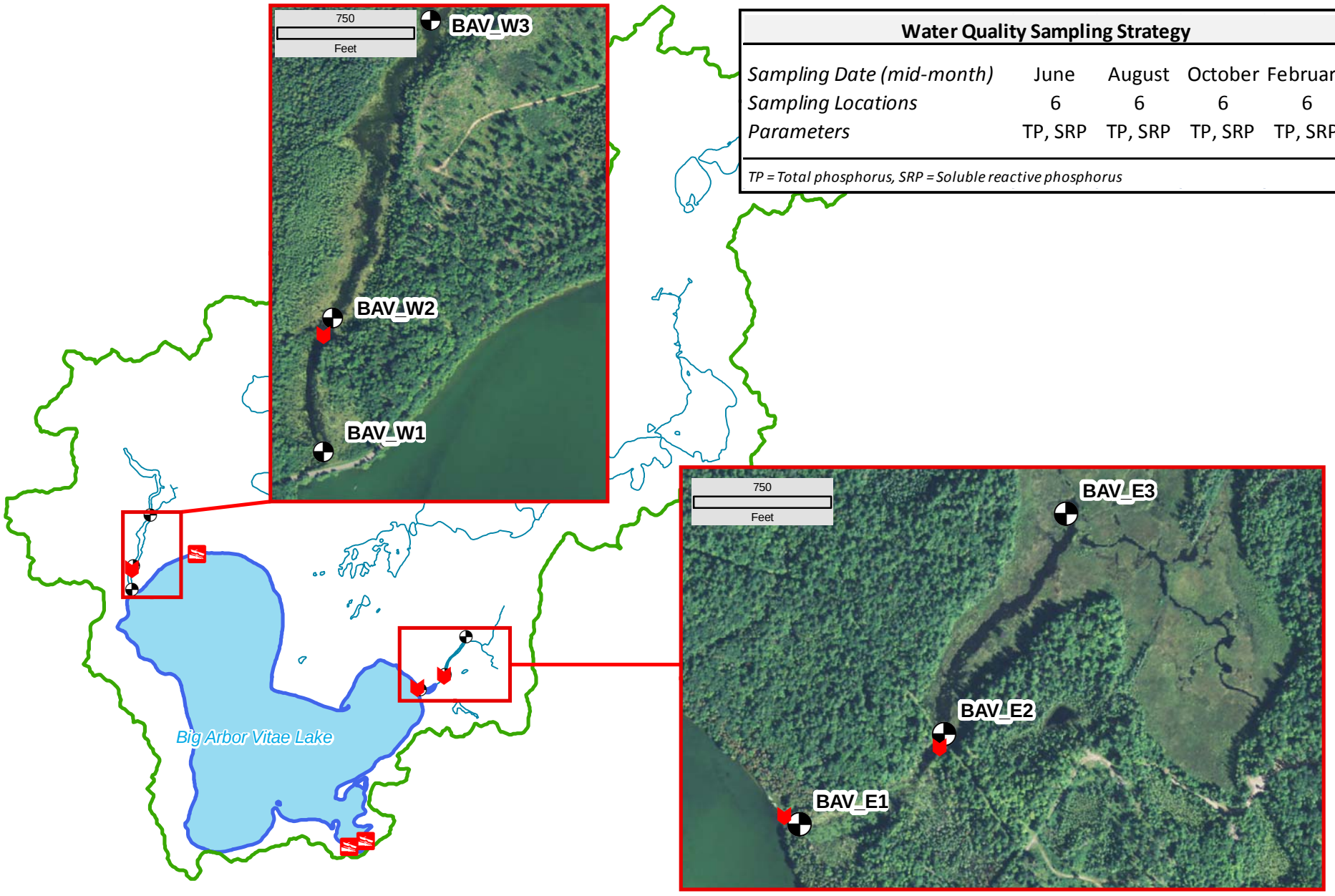

Water Quality Sampling Strategy

	June	August	October	February
Sampling Date (mid-month)				
Sampling Locations	6	6	6	6
Parameters	TP, SRP	TP, SRP	TP, SRP	TP, SRP

TP = Total phosphorus, SRP = Soluble reactive phosphorus

N W E S

4,250
Feet

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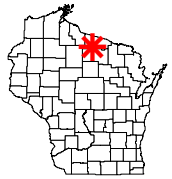
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2010
Watershed: WDNR & Onterra
Beaver Dam Locations mapped by Onterra
Map date: May 10, 2013
Filename: BAV_BeaverDam_Monitoring.mxd


Project Location in Wisconsin

Legend

- Big Arbor Vitae Lake
- WDNR Hydro Arc Shapefile
- Watershed Boundary
- Public Boat Landing
- Water Quality Monitoring Point
- Beaver Dam

Map 1

Big Arbor Vitae Lake

Vilas County, Wisconsin

Beaver Dam Study Monitoring Locations