Waushara County Lakes Study

Big Hills Lake

Spring 2014
University of Wisconsin-Stevens Point
PRIMARY AUTHORS

Authors listed are from the UW-Stevens Point unless otherwise noted.

Aquatic Plants

Sediment Core
Samantha Kaplan
Paul Garrison (Wisconsin Department of Natural Resources)

Shoreland Assessments
Ed Hernandez and Waushara County Land Conservation Department Staff
Dan McFarlane

Water Quality and Watersheds
Nancy Turyk, Paul McGinley, Danielle Rupp and Ryan Haney
Ed Hernandez and Waushara County Land Conservation Department Staff

UW-Stevens Point Students
Melis Arik, Nicki Feiten, Sarah Hull, Chase Kasmerchak, Justin Nachtigal, Matt Pamperin, Scott Pero,
Megan Radske, Anthony Recht, Cory Stoughtenger, Hayley Templar, Garret Thiltgen

Editor: Jeri McGinley

ACKNOWLEDGMENTS

We are grateful to many people for supporting this project by providing insight, enthusiasm, and funding. We would like to recognize our project partners:

Waushara County Watershed Lakes Council

Waushara County Staff and Citizens

Wisconsin Department of Natural Resources Professionals, Mark Sessing and Ted Johnson

Wisconsin Department of Natural Resources Lake Protection Grant Program

Dr. Samantha Kaplan and Dr. Paul McGinley

UW-Stevens Point Water and Environmental Analysis Lab
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMARY AUTHORS</td>
<td>3</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>3</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>5</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>6</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>6</td>
</tr>
<tr>
<td>BIG HILLS LAKE STUDY RESULTS</td>
<td>7</td>
</tr>
<tr>
<td>WAUSHARA COUNTY LAKES STUDY BACKGROUND</td>
<td>7</td>
</tr>
<tr>
<td>ABOUT BIG HILLS LAKE</td>
<td>7</td>
</tr>
<tr>
<td>WHERE IS THE WATER COMING FROM? – WATERSHEDS AND LAND USE</td>
<td>9</td>
</tr>
<tr>
<td>BIG HILLS LAKE SURFACE WATERSHED</td>
<td>10</td>
</tr>
<tr>
<td>BIG HILLS LAKE GROUNDWATER WATERSHED</td>
<td>11</td>
</tr>
<tr>
<td>WATER QUALITY</td>
<td>12</td>
</tr>
<tr>
<td>AQUATIC PLANTS</td>
<td>18</td>
</tr>
<tr>
<td>SHORELANDS</td>
<td>21</td>
</tr>
<tr>
<td>CONCLUSIONS &amp; RECOMMENDATIONS</td>
<td>23</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>26</td>
</tr>
<tr>
<td>GLOSSARY OF TERMS</td>
<td>27</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

FIGURE 1. CONTOUR MAP OF THE BIG HILLS LAKE LAKEBED........................................8
FIGURE 2. LAND USE IN THE BIG HILLS LAKE SURFACE WATERSHED.........................10
FIGURE 3. GROUNDWATER FLOW DIRECTION NEAR BIG HILLS LAKE............................11
FIGURE 4. CARTOON SHOWING INFLOW AND OUTFLOW OF WATER IN A SEEPAGE LAKE.
.................................................................................................................................12
FIGURE 5. TEMPERATURE PROFILES IN BIG HILLS LAKE, 2010-2012..............................14
FIGURE 6. DISSOLVED OXYGEN PROFILES IN BIG HILLS LAKE, 2010-2012....................14
FIGURE 7. WATER CLARITY IN THE EAST BAY OF BIG HILLS LAKE, 2010-2012 AND
HISTORIC. ............................................................................................................................15
FIGURE 8. WATER CLARITY IN THE WEST BAY OF BIG HILLS LAKE, 2010-2012 AND
HISTORIC. ............................................................................................................................15
FIGURE 9. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE BIG HILLS LAKE
WATERSHED. ........................................................................................................................17
FIGURE 10. NUMBER OF AQUATIC PLANT SPECIES AT EACH SAMPLE SITE IN BIG HILLS
LAKE, SEPTEMBER 2013 ......................................................................................................19
FIGURE 11. OVERALL SHORELAND HEALTH AROUND BIG HILLS LAKE, 2011...............22

LIST OF TABLES

TABLE 1. MINERALS AND PHYSICAL MEASUREMENTS IN BIG HILLS LAKE, 2010-2012....12
TABLE 2. BIG HILLS LAKE AVERAGE WATER CHEMISTRY, 2010-2012..............................13
TABLE 3. SEASONAL SUMMARY OF NUTRIENT CONCENTRATIONS IN BIG HILLS LAKE,
2010-2012. ............................................................................................................................16
TABLE 4. MODELING DATA USED TO ESTIMATE PHOSPHORUS INPUTS FROM LAND USES
IN THE BIG HILLS LAKE WATERSHED (LOW AND MOST LIKELY COEFFICIENTS USED TO
CALCULATE RANGE IN POUNDS)............................................................................................17
TABLE 5. AQUATIC PLANT SPECIES IDENTIFIED AND COEFFICIENT OF CONSERVATION
VALUES FOR SPECIES PRESENT IN BIG HILLS LAKE, SEPTEMBER 2013........................18
TABLE 6. DISTURBANCES WITHIN 15 FEET OF SHORE AROUND BIG HILLS LAKE, 2011....21
BIG HILLS LAKE STUDY RESULTS

WAUSHARA COUNTY LAKES STUDY BACKGROUND

Lakes and rivers contribute to the way of life in Waushara County. Local residents and visitors alike enjoy fishing, swimming, boating, wildlife viewing, and the peaceful nature of the lakes. Healthy lakes add value to our communities. They provide places to relax and recreate, and they can stimulate tourism. Like other infrastructure in our communities, lakes require attention and good management practices to remain healthy in our developing watersheds.

Thirty-three lakes in Waushara County were selected for this study. The study focused on learning about the lakes’ water quality, aquatic plant communities, shoreland habitats, watersheds and histories in order to help people make informed lake management decisions. This report summarizes data collected for Big Hills Lake between fall 2010 and fall 2012.

ABOUT BIG HILLS LAKE

To understand a lake and its potential for water quality, fish and wildlife, and recreational opportunities, we need to understand its physical characteristics and setting within the surrounding landscape. The lake is located in the township of Mount Morris, southwest of Saxeville and southeast of Wild Rose, with one public boat launch located on its southwestern side. Big Hills Lake is a 125 acre seepage lake with groundwater and surface runoff contributing most of its water. The maximum depth in Big Hills Lake is 22 feet, and the average water depth is 12 feet (Figure 1). Its bottom sediments are mostly sand along the lake’s perimeter, with some muck found in the deeper, central areas of the lake.
FIGURE 1. CONTOUR MAP OF THE BIG HILLS LAKE LAKEBED.
The water quality in Big Hills Lake is a reflection of the land that drains to it. The water quality, the amount of algae, aquatic plants, the fishery and other animals in the lake are all affected by natural and manmade characteristics. Natural characteristics that affect a lake include the amount of land that drains to the lake, the hilliness of the landscape, types of soil, extent of wetlands, and the type of lake. Within the lake’s watershed, alterations to the landscape, the types of land use, and the land management practices are examples of how people may affect the lake.

It is important to understand where Big Hills Lake’s water originates in order to understand the lake’s health. During snowmelt or a rainstorm, water moves across the surface of the landscape (runoff) towards lower elevations such as lakes, streams and wetlands. The land area that contributes runoff to Big Hills Lake is called a surface watershed. Groundwater also feeds Big Hills Lake; its land area may be slightly different than the surface watershed. The surface watershed is shown in Figure 2.

The capacity of the landscape to shed or hold water and contribute or filter particles determines the amount of erosion that may occur, the amount of groundwater feeding a lake, and ultimately, the lake’s water quality and quantity. Essentially, landscapes with a greater capacity to hold water during rain events and snowmelt help to slow the delivery of the water to the lake. Less runoff is desirable because it allows more water to recharge the groundwater, which feeds the lake year-round - even during dry periods or when the lake is covered with ice.

Land use and land management practices within a lake’s watershed can affect both its water quantity and quality. While forests and grasslands allow a fair amount of precipitation to soak into the ground, resulting in more groundwater and better water quality, other types of land uses may result in increased runoff and less groundwater recharge, and may be sources of pollutants that can impact the lake and its inhabitants. Areas of land with exposed soil can produce soil erosion. Soil entering the lake can make the water cloudy and cover fish spawning beds. Soil also contains nutrients that increase the growth of algae and aquatic plants. Development on the land often results in changes to natural drainage patterns, alterations to vegetation on the landscape, and may be a source of pollutants. Impervious (hard) surfaces such as roads, rooftops, and compacted soil prevent rainfall from soaking into the ground, which may result in more runoff that carries pollutants to the lake. Wastewater, animal waste, and fertilizers used on lawns, gardens and crops can contribute nutrients that enhance the growth of algae and aquatic plants in our lakes.

A variety of land management practices can be put in place to help reduce impacts to our lakes. Some practices are designed to reduce runoff. These include protecting/restoring wetlands, installing rain gardens, swales, rain barrels, and routing drainage from pavement and roofs away from the lake. Some practices are used to help reduce nutrients from moving across the landscape towards the lake. Examples include manure management practices, eliminating/reducing the use of fertilizers, increasing the distance between the lake and a septic drainfield, protecting/restoring native vegetation in the shoreland, and using erosion control practices. Waushara County staff and other professionals can work with landowners to determine which practices are best suited to a particular property.
The surface watershed for Big Hills Lake is approximately 599 acres (Figure 2). The dominant types of land use in the watershed are developed land (57%) and forests (38%). The land closest to the lake often has the greatest impact on water quality and habitat; Big Hills Lake’s shoreland is surrounded primarily by development, wetlands and forest.

**Figure 2. Land use in the Big Hills Lake surface watershed.**
The more the lake’s water interacts with groundwater, the more influence the geology has on the lake. The length of time water remains below ground affects the temperature and chemistry of the groundwater. Groundwater temperature is near constant year round; during the summer, groundwater feeding Big Hills Lake will help keep the lake water cooler.

Groundwater flows below ground from higher to lower elevations, discharging into wetlands, streams and lakes. The groundwater feeding the lakes in Waushara County originates nearby. The black arrows in Figure 3 indicate the general direction of groundwater flow. Much of the groundwater enters Big Hills Lake from the northwest.

**Figure 3. Groundwater flow direction near Big Hills Lake.**
Lake water quality is a result of many factors including the underlying geology, the climate, and land management practices. Assessing lake water quality allows us to evaluate current lake health and changes from the past. We can then identify what is needed to achieve a more desirable state or preserve an existing state for aesthetics, recreation, wildlife and the fishery. During this study, water quality in Big Hills Lake was assessed by measuring different characteristics including temperature, dissolved oxygen, water clarity, and water chemistry.

The source of a lake’s water supply is important in determining its water quality and choosing management practices to preserve or influence that quality. Big Hills Lake is classified as a seepage lake, which receives its water primarily via groundwater with lesser inputs from direct runoff and precipitation (Figure 4).

The geology beneath Big Hills Lake can influence the temperature, pH, minerals and other properties. Seepage lakes like Big Hills Lake typically have higher concentrations of minerals such as calcium and magnesium, which dissolve from surrounding soil and rock into the groundwater, making the water hard. The average hardness for Big Hills Lake during the 2010-2012 sampling period was 118 mg/L, which is considered moderately hard (Table 1). Hard water provides the calcium necessary for building bones and shells for animals in the lake. The average alkalinity was 104 mg/L; higher alkalinity in inland lakes can support greater productivity. Hardness and alkalinity also play a role in the type of aquatic plants that are found in a lake (Wetzel, 2001).

![Figure 4. Cartoon showing inflow and outflow of water in a seepage lake.](image)

### Table 1. Minerals and physical measurements in Big Hills Lake, 2010-2012.

<table>
<thead>
<tr>
<th>Big Hills Lake</th>
<th>Alkalinity (mg/L)</th>
<th>Calcium (mg/L)</th>
<th>Magnesium (mg/L)</th>
<th>Hardness (mg/L as CaCO₃)</th>
<th>Color (SU)</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>104</td>
<td>21</td>
<td>16</td>
<td>118</td>
<td>7.7</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Chloride concentrations, and to a lesser degree sodium and potassium concentrations, are commonly used as indicators of how strongly a lake is being impacted by human activity. The presence of these compounds where they do not naturally occur indicates sources of water contaminants. Big Hills Lake had a moderate average chloride concentration of 4.1 mg/L and a relatively low average sodium concentration of 2 mg/L over the monitoring period (Table 2). Chloride sources include animal waste, septic systems, fertilizer, and road-salting chemicals.
Atrazine (DACT), an agricultural herbicide, was detected in the samples that were analyzed from Big Hills Lake (0.10 and 0.11 µg/L), indicating that lake water is being impacted by agricultural activities in the surrounding area. Some toxicity studies have indicated that reproductive system abnormalities can occur in frogs at these levels (Hayes et al., 2001 and Hayes et al., 2003).

### Table 2. Big Hills Lake average water chemistry, 2010-2012.

<table>
<thead>
<tr>
<th>Big Hills Lake</th>
<th>Average Value</th>
<th>Reference Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Medium High</td>
<td>Low Medium High</td>
</tr>
<tr>
<td>Potassium (mg/L)</td>
<td>0.62</td>
<td>&lt;.75 0.75-1.5 &gt;1.5</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>4.7</td>
<td>&lt;3 3.0-10.0 &gt;10</td>
</tr>
<tr>
<td>Sodium (mg/L)</td>
<td>2.0</td>
<td>&lt;2 2.0-4.0 &gt;4</td>
</tr>
</tbody>
</table>

Dissolved oxygen is an important measure in lakes because a majority of organisms in the water depend on oxygen to survive. Oxygen is dissolved into the water from contact with the air, which is increased by wind and wave action. Algae and aquatic plants also produce oxygen when sunlight enters the water, but during some periods of the year the decomposition of dead plants and algae can reduce oxygen in the lake.

In a lake, the water temperature changes throughout the year and may vary with depth. During winter and summer when lakes stratify (layer), the amount of dissolved oxygen is often lower towards the bottom of the lake. Dissolved oxygen concentrations below 5 mg/L can stress some species of cold water fish and over time can reduce the amount of available habitat for sensitive cold water species of fish and other aquatic organisms.

Water temperature and dissolved oxygen were measured in Big Hills Lake from the surface to bottom at the time of sample collection during the 2010-2012 study. Throughout most of the year, temperatures in Big Hills Lake were consistent from top to bottom (Figure 5). Similarly, dissolved oxygen concentrations were relatively constant with depth during spring and early summer months. Big Hills Lake had oxygen concentrations well above 5 mg/L in the upper 15 feet of the water column throughout the year (Figure 6), which suggests that low oxygen levels were not a stressor to the fishery; however, during the summer (June, July and September dates in both 2011 and 2012), dissolved oxygen concentrations typically dropped with depth (commonly around 10-15 feet). During this period, concentrations ranged from near 0 mg/L near the bottom of the lake in August 2012 to 14 mg/L in June 2011. The increased dissolved oxygen observed in June 2011 at depths of 11-16 feet was likely due to an algal bloom.
Water clarity is a measure of the depth that light can penetrate into the water. It is an aesthetic measure and is also related to the depth that rooted aquatic plants can grow. Water clarity is affected by water color, turbidity (suspended sediment), and algae, so it is normal for water clarity to change throughout the year and from year to year.

In Big Hills Lake, color was relatively low (Table 1), indicating that the variability in transparency throughout the year is most likely due to fluctuating algal concentrations and re-suspended sediment following storms and/or heavy boating.
Water clarity measurements were taken in two locations: the east bay and west bay. Based on data dating back to 1976, clarity has been very similar in the two bays with averages of 12.7 feet and 12.4 feet, respectively. Water clarity ranged from 7 feet in the east bay in May-June 2012 to 22.5 feet in the west bay in June 2011 (on the same day that clarity measured 22 feet in the east bay). The average 2010-2012 water clarity in the east bay was slightly better than the historic averages in June, July and August, and was better than the historic averages in the west bay from May through September (Figure 7, Figure 8). Compared with historic averages, water clarity in the east bay was worse in April, May, October and November, and poorer in the west bay in April and October. Water clarity in Big Hills Lake is typically poorer during the summer months with the shallowest depths recorded during late summer into fall.

**Figure 7. Water clarity in the east bay of Big Hills Lake, 2010-2012 and historic.**

**Figure 8. Water clarity in the west bay of Big Hills Lake, 2010-2012 and historic.**
Nutrients (phosphorus and nitrogen) are used by algae and aquatic plants for growth. Phosphorus is present naturally throughout the watershed in soil, plants, animals and wetlands. Common sources from human activities include soil erosion, animal waste, fertilizers and septic systems. It is most common for phosphorus to move from the land to the water through surface runoff, but it can also travel to the lake in groundwater. Once in a lake, a portion of the phosphorus becomes part of the aquatic system in the form of plant tissue, animal tissue, and sediment. The phosphorus continues to cycle within the lake for many years.

Total phosphorus concentrations in Big Hills Lake ranged from a high of 33 ug/L in June 2012 to a low of 7 ug/L in August 2012 (Table 3). The summer mean total phosphorus concentration in Big Hills Lake was 14 ug/L and 15 ug/L in 2011 and 2012, respectively. This is below Wisconsin’s phosphorus water quality standard for deep seepage lakes (20 ug/L), but at the 15 ug/L proposed flag value. Inorganic nitrogen was 0.27 mg/L, near the level of 0.3 mg/L that is sufficient to fuel algal blooms throughout the summer (Shaw et al., 2000).

### Table 3. Seasonal Summary of Nutrient Concentrations in Big Hills Lake, 2010-2012.

<table>
<thead>
<tr>
<th>Big Hills Lake</th>
<th>Inorg. N (mg/L)</th>
<th>Org. N (mg/L)</th>
<th>Total. N (mg/L)</th>
<th>SRP (ug/L)</th>
<th>Total P (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Avg</td>
<td>Max</td>
<td>Min</td>
<td>Avg</td>
</tr>
<tr>
<td>Fall</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.63</td>
<td>0.63</td>
</tr>
<tr>
<td>Spring</td>
<td>0.20</td>
<td>0.27</td>
<td>0.34</td>
<td>0.47</td>
<td>0.47</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>0.05</td>
<td>0.12</td>
<td>0.18</td>
<td>0.56</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chlorophyll $a$ is a measurement of algae in the water. In Big Hills Lake, chlorophyll $a$ concentrations varied slightly throughout the monitoring season, ranging from a high of 10 ug/L to a low of 1ug/L. The average for the monitoring period was 3.5 ug/L.

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Big Hills Lake. Land use in the surface watershed was evaluated and used to populate the Wisconsin Lakes Modeling Suite (WILMS) model. In general, each type of land use contributes different amounts of phosphorus in runoff and through groundwater. The types of land management practices that are used and their distances from the lake also affect the contributions to the lake from a parcel of land. Developed land contributed the greatest amount of phosphorus to Big Hills Lake (Figure 9). The phosphorus contributions by land use category, called phosphorus export coefficients, are shown in Table 4. The phosphorus export coefficients have been obtained from studies throughout Wisconsin (Panuska and Lillie, 1995).
**Figure 9.** Estimated phosphorus loads from land uses in the Big Hills Lake watershed.

**Table 4.** Modeling data used to estimate phosphorus inputs from land uses in the Big Hills Lake watershed (low and most likely coefficients used to calculate range in pounds).

<table>
<thead>
<tr>
<th>Big Hills Lake Land Use</th>
<th>Phosphorus Export Coefficient (lbs/acre-yr)</th>
<th>Land Use Area Within the Watershed</th>
<th>Estimated Phosphorus Load Pounds</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.1</td>
<td>125 21</td>
<td>11-33</td>
<td>13</td>
</tr>
<tr>
<td>Developed</td>
<td>0.27</td>
<td>272 45</td>
<td>73-146</td>
<td>88</td>
</tr>
<tr>
<td>Barren/Herbaceous/Wetland</td>
<td>0.09</td>
<td>22 4</td>
<td>2-7</td>
<td>2</td>
</tr>
<tr>
<td>Forest</td>
<td>0.04</td>
<td>181 30</td>
<td>8-15</td>
<td>10</td>
</tr>
<tr>
<td>Cultivated Agriculture</td>
<td>0.45</td>
<td>0 0</td>
<td>0 0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Values are not exact due to rounding and conversion.
Aquatic plants play important roles in a lake’s ecosystem. They provide habitat for the fishery and other aquatic organisms, stabilize the sediment, reduce erosion, buffer temperature changes and waves, and infuse oxygen into the water. Aquatic plants near shore provide food, shelter and nesting material for shoreland mammals, shorebirds and waterfowl. It is not unusual for otters, beavers, muskrats and deer to be seen along a shoreline in their search for food or nesting material. The aquatic plants that attract the animals to these areas contribute to the beauty of the shoreland and lake.

The rapid and dominant growth of aquatic invasive plants, such as Eurasian watermilfoil (EWM), can reduce the recreational value of a lake. Aquatic invasive plants may also outcompete and cause a decline in native vegetation, which degrades habitat diversity and can alter the aquatic ecosystem.

An aquatic plant survey was conducted on Big Hills Lake in September 2013 by Golden Sands RC&D, Inc. Fifteen species of aquatic plants were found in Big Hills Lake, with one additional species observed visually (Table 5). The sixteen aquatic plant species observed within Big Hills Lake was below average when compared with the other lakes in the Waushara County Lakes Study. The greatest diversity of plant species was found in the far eastern and western ends of the lake (Figure 10). Forty-six percent (142 of 312) of the sites visited had vegetative growth. The greatest depth at which aquatic plant growth was observed was 20 feet.

Table 5. Aquatic plant species identified and coefficient of conservatism values for species present in Big Hills Lake, September 2013.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Sampled</th>
<th>Visuals</th>
<th>C value</th>
</tr>
</thead>
<tbody>
<tr>
<td>muskgrass</td>
<td>Chara spp.</td>
<td>x</td>
<td>x</td>
<td>7</td>
</tr>
<tr>
<td>common waterweed</td>
<td>Elodea canadensis</td>
<td>x</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Eurasian watermilfoil</td>
<td>Myriophyllum spicatum</td>
<td>x</td>
<td>x</td>
<td>0</td>
</tr>
<tr>
<td>slender naiad</td>
<td>Najas flexilis</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>southern naiad</td>
<td>Najas guadalupensis</td>
<td>x</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>stoneworts</td>
<td>Nitella spp.</td>
<td>x</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>variable pondweed</td>
<td>Potamogeton gramineus</td>
<td>x</td>
<td>x</td>
<td>7</td>
</tr>
<tr>
<td>Illinois pondweed</td>
<td>Potamogeton illinoensis</td>
<td>x</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>floating-leaf pondweed</td>
<td>Potamogeton natans</td>
<td>x</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>white-stem pondweed</td>
<td>Potamogeton praelongus</td>
<td>x</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>small pondweed</td>
<td>Potamogeton pusillus</td>
<td>x</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>flat stem pondweed</td>
<td>Potamogeton zosteriformis</td>
<td>x</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>white water crowfoot</td>
<td>Ranunculus aquatilis</td>
<td>x</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>three-square bulrush</td>
<td>Schoenoplectus pungens</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>sago pondweed</td>
<td>Stuckenia pectinata</td>
<td>x</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>water celery</td>
<td>Vallisneria americana</td>
<td>x</td>
<td>x</td>
<td>6</td>
</tr>
<tr>
<td>filamentous algae</td>
<td></td>
<td>x</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 10. Number of aquatic plant species at each sample site in Big Hills Lake, September 2013.
The dominant plant species found in Big Hills Lake was muskgrass (*Chara* spp.), followed by variable pondweed (*Potamogeton gramineus*). *Chara* spp. is a favorite waterfowl food and also offers cover for fish. The foliage and fruit of variable pondweed may be eaten by muskrat, beaver and deer (Borman, 2001).

The Floristic Quality Index (FQI) evaluates how close a plant community is to undisturbed conditions. Each plant is assigned a coefficient of conservatism value (C value) that reflects its sensitivity to disturbance, and these numbers are used to calculate the FQI. C values range from 0 to 10. The lower the number, the more tolerant the plant is of disturbance. Having more aquatic plants with low C values than high C values is an indicator of disturbance, as the lower C value plants better tolerate the stresses caused by disturbance. A C value of 0 is assigned to exotic species. The FQI for Big Hills Lake was 23.3, which was average when compared to all of the other lakes in the Waushara County Lakes Study.

In Big Hills Lake, C values ranged from 0 to 8 (Table 5). One invasive plant species was sampled, EWM, which has a C value of 0. Three of the sixteen species found in Big Hills Lake had a C value of 8: southern naiad (*Najas guadalupensis*), white-stem pondweed (*Potamogeton praelongus*), and white water crowfoot (*Ranunculus aquatilis*). The species with the highest frequency of occurrence within vegetated areas was *Chara* spp., with a C value of 7.

Invasive species are present in Big Hills Lake. During the September 2013 survey, EWM was found at one site on the far western side of the lake. EWM can create dense beds that can damage boat motors, make areas non-navigable, stunt or alter the fishery, create problems with dissolved oxygen, and prevent activities like fishing and swimming. This plant can produce a viable seed; however, its primary mode of reproduction and spread is fragmentation. A one-inch fragment is enough to start a new plant, making EWM very successful at reproducing. Management practices have been in place since May 2009 to control EWM in Big Hills Lake.

The Simpson Diversity Index (SDI) quantifies biodiversity based on a formula that uses the number of species surveyed and the number of individuals per site. The SDI uses a decimal scale from 0 to 1. Values closer to one represent higher amounts of biodiversity. The SDI of Big Hills Lake for the 2013 survey was 0.77. This represents an average biodiversity when compared to all of the other lakes in the Waushara County Lakes Study.

Aquatic plants play another important role in the lake’s ecosystem by using nutrients that would otherwise be available to algae. Any management activities should be planned to minimize the disturbance of native species in the water and on shore in order to maintain the balance between aquatic plants and algae. In addition, care should be taken to minimize raking the lake bed and pulling plants, since disturbing these valuable open spaces may allow invasive aquatic plants such as EWM to establish.
SHORELANDS

Shoreland vegetation is critical to a healthy lake’s ecosystem. It provides habitat for many aquatic and terrestrial animals including birds, frogs, turtles, and many small and large mammals. It also helps to improve the quality of the runoff that is flowing across the landscape towards the lake. Healthy shoreland vegetation includes a mix of tall grasses/flowers, shrubs and trees which extend at least 35 feet landward from the water’s edge.

To better understand the health of the Waushara County lakes, shorelands were evaluated by the Center for Land Use Education and Waushara County as a part of the Waushara County Lakes Study. The survey inventoried the type and extent of shoreland vegetation. Areas with erosion, rip-rap, barren ground, seawalls, structures and docks were also inventoried.

A scoring system was developed for the collected data to provide a more holistic assessment. Areas that are healthy will need strategies to keep them healthy, and areas with potential problem areas and where management and conservation may be warranted may need a different set of strategies for improvement. The scoring system is based on the presence/absence and abundance of shoreline features, as well as their proximity to the water’s edge. Values were tallied for each shoreline category and then summed to produce an overall score. Higher scores denote healthier shorelines with good land management practices. These are areas where protection and/or conservation should be targeted. On the other hand, lower scores signify ecologically unhealthy shorelines. These are areas where management and/or mitigation practices may be desirable for improving water quality.

The summary of scores for shorelands around Big Hills Lake is displayed in Figure 11. The shorelands were color-coded to show their overall health based on natural and physical characteristics. Blue shorelands identify healthy shorelands with sufficient vegetation and few human disturbances. Red, orange, and yellow shorelands indicate locations where changes in management or mitigation may be warranted. Large stretches of Big Hills Lake’s shorelands are in fair shape with challenges that should be addressed. Some stretches were ranked as poor. A summary of shoreland disturbances can be found in Table 6. For a more complete understanding of the ranking, an interactive map showing results of the shoreland surveys can be found on Waushara County’s website at http://gis.co.waushara.wi.us/ShorelineViewer/.

Table 6. Disturbances within 15 feet of shore around Big Hills Lake, 2011.

<table>
<thead>
<tr>
<th>Disturbance</th>
<th>Length of Shore Feet</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial beach</td>
<td>9440</td>
<td>67</td>
</tr>
<tr>
<td>Barren, bare dirt</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Boat landing</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dock/pier at water</td>
<td>12539</td>
<td>89</td>
</tr>
<tr>
<td>Gully erosion</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Undercut banks erosion</td>
<td>688</td>
<td>5</td>
</tr>
<tr>
<td>Mowed lawn</td>
<td>3483</td>
<td>25</td>
</tr>
<tr>
<td>Rip-rap</td>
<td>9244</td>
<td>66</td>
</tr>
<tr>
<td>Seawall</td>
<td>6641</td>
<td>47</td>
</tr>
</tbody>
</table>
Figure 11. Overall shoreland health around Big Hills Lake, 2011.

Waushara County Shoreline Assessment

BIG HILLS LAKE

Map Date -- July, 2011
Aerial Date -- April, 2010
CONCLUSIONS & RECOMMENDATIONS

There are many aspects to the assessment of the health of a lake. This study included the evaluation of water quality, land use, shoreland health, and the aquatic plant community. It provided a picture of Big Hills Lake that, with the addition of fishery and other data, can be used by the community in the development of lake management strategies.

In general, each type of land use contributes different amounts of phosphorus, nitrogen and pollutants in runoff and through groundwater. The types of land management practices that are used and their distances from the lake affect the contributions to the lake from a parcel of land. The Big Hill Lake watershed includes 299 acres of land. Developed land comprises more than one-half of the land use in the watershed, followed by forested land which makes up 38% of the watershed.

- Dissolved oxygen is required for many aquatic organisms including fish. Big Hills Lake had sufficient dissolved oxygen concentrations through most of its depths throughout the year.
- Water clarity was best early in the growing season and poorest during late summer and into fall in Big Hills Lake.
- Identifying and taking steps to maintain or improve water quality in Big Hills Lake depends upon understanding the sources of nutrients to the lake and identifying those that are manageable. Based on lake models, developed land contributed the greatest amount of phosphorus to Big Hills Lake.
- The summer mean total phosphorus concentration in Big Hills Lake was 14 ug/L and 15 ug/L in 2011 and 2012, respectively. This is below Wisconsin’s phosphorus water quality standard for deep seepage lakes (20 ug/L), but at the 15 ug/L proposed flag value.
- The moderate concentrations of hardness moving into the lake with groundwater help to reduce the algal response; however, these buffering effects can become overwhelmed.
- Inorganic nitrogen was 0.27 mg/L. Concentrations above 0.3 mg/L are sufficient to enhance algal blooms throughout the summer. Inorganic nitrogen typically moves to lakes with groundwater. Sources include fertilizers, septic systems, and animal waste.
- Atrazine (DACT), an agricultural herbicide, was detected in the samples that were analyzed from Big Hills Lake, indicating that lake water is being impacted by agricultural activities in the surrounding area. Some toxicity studies have indicated that reproductive system abnormalities can occur in frogs at these levels. The presence of this chemical indicated that agricultural activities were influencing the water quality in Big Hills Lake.
- Over-application of chemicals and nutrients should be avoided. Landowners in the watershed should be made aware of their connection to the lake and should work to reduce their impacts through the implementation of water quality-based best management practices.

Shoreland health is critical to a healthy lake’s ecosystem. Big Hills Lake’s shoreland was assessed for the extent of vegetation and disturbances. Shoreland vegetation provides habitat for many aquatic and terrestrial animals, including birds, frogs, turtles, and many small and large mammals. Vegetation also helps to improve the quality of the runoff that is flowing across the landscape towards the lake. Healthy shoreland vegetation includes a mix of tall grasses/flowers, shrubs and trees extending at least 35 feet inland from the water’s edge. Alone, each manmade disturbance may not pose a problem for a lake, but on developed lakes, the collective impact of these disturbances can be a problem for lake habitat and water quality.
• Large stretches of Big Hills Lake’s shorelands are in fair shape with challenges that should be addressed. Some stretches were ranked as poor.
  o Structures such as seawalls, rip-rap (rocked shoreline), and artificial beach can result in habitat loss.
  o Erosion can contribute sediment to the lake, which can alter spawning habitat and carry nutrients into the lake.
  o Unmanaged runoff from rooftops of structures located near shore can also contribute sediment to the lake.
  o Docks and artificial beaches can result in altered in-lake habitat. Denuded lakebeds provide opportunities for invasive species to become established and reduce habitat that is important to fish and other lake inhabitants.
  o Strategies should be developed to ensure that healthy shorelands remain intact and efforts should be made to improve shorelands that have disturbance. Depending upon the source of the disturbances, erosion should be controlled, vegetation should be restored, and/or excess runoff should be minimized.
  o Dissemination of relevant information to property owners is the recommended first step towards maintaining healthy shorelands.
• The Waushara County Land Conservation Department and Natural Resources Conservation Service (NRCS) have professional staff available to assist landowners interested in learning how they can improve water quality through changes in land management practices.

Aquatic plants are the forested landscape within a lake. They provide food and habitat for a wide range of species including fish, waterfowl, turtles, and amphibians, as well as invertebrates and other aquatic animals. They improve water quality by releasing oxygen into the water and utilizing nutrients that would otherwise be used by algae. A healthy lake typically has a variety of aquatic plant species that creates the diversity needed to make the aquatic plant community more resilient and help prevent the establishment of non-native aquatic species.

• The diversity of an aquatic plant community is defined by the type and number of species present throughout the lake. Sixteen species of aquatic plants were found in Big Hills Lake, which is below average compared with other lakes in the Waushara County Lakes Study.
• Three of the sixteen aquatic plant species found in Big Hills Lake were considered high quality plants (with a C value of 8), including southern naiad, white-stem pondweed and white water crowfoot.
• The species with the highest frequency of occurrence within vegetated areas was Chara. Chara is a favorite waterfowl food and also offers cover for fish. The foliage and fruit of variable pondweed may be eaten by muskrat, beaver, and deer.
• One aquatic invasive species, Eurasian watermilfoil (EWM), was observed during the survey of Big Hills Lake.
  o EWM can create dense beds that can damage boat motors, make areas non-navigable, stunt or alter the fishery, create problems with dissolved oxygen, and prevent recreational activities such as fishing and swimming.
  o This plant can produce a viable seed; however, its primary mode of reproduction and spread is fragmentation. A one-inch fragment is enough to start a new plant, making EWM very successful at reproducing.
  o Management practices have been in place since May 2009 to control EWM in Big Hills Lake.
• The amount of disturbed lakebed from raking or pulling plants should be minimized, since these open spaces are “open real estate” for aquatic invasive plants to establish.

• Early detection of aquatic invasive species (AIS) can help to prevent their establishment should they be introduced into the lake. Boats and trailers that have visited other lakes can be a primary vector for the transport of AIS.

• Programs are available to help volunteers learn to monitor for AIS and to educate lake users at the boat launch about how they can prevent the spread of AIS.
REFERENCES


GLOSSARY OF TERMS

**Algae:** One-celled (phytoplankton) or multicellular plants either suspended in water (plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll a (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Numerous species occur. Algae are an essential part of the lake ecosystem and provide the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short.

**Atrazine:** A commonly used herbicide. Transports to lakes and rivers by groundwater or runoff. Has been shown to have toxic effects on amphibians.

**Blue-Green Algae:** Algae that are often associated with problem blooms in lakes. Some produce chemicals toxic to other organisms, including humans. They often form floating scum as they die. Many can fix nitrogen (N2) from the air to provide their own nutrient.

**Calcium (Ca++):** The most abundant cation found in Wisconsin lakes. Its abundance is related to the presence of calcium-bearing minerals in the lake watershed. Reported as milligrams per liter (mg/l) as calcium carbonate (CaCO3), or milligrams per liter as calcium ion (Ca++).

**Chloride (Cl-):** The chloride ion (Cl-) in lake water is commonly considered an indicator of human activity. Agricultural chemicals, human and animal wastes, and road salt are the major sources of chloride in lake water.

**Chlorophyll a:** Green pigment present in all plant life and necessary for photosynthesis. The amount present in lake water depends on the amount of algae, and is therefore used as a common indicator of algae and water quality.

**Clarity:** See “Secchi disk.”

**Color:** Color affects light penetration and therefore the depth at which plants can grow. A yellow-brown natural color is associated with lakes or rivers receiving wetland drainage. Measured in color units that relate to a standard. The average color value for Wisconsin lakes is 39 units, with the color of state lakes ranging from zero to 320 units.

**Concentration units:** Express the amount of a chemical dissolved in water. The most common ways chemical data is expressed is in milligrams per liter (mg/l) and micrograms per liter (ug/l). One milligram per liter is equal to one part per million (ppm). To convert micrograms per liter (ug/l) to milligrams per liter (mg/l), divide by 1000 (e.g. 30 ug/l = 0.03 mg/l). To convert milligrams per liter (mg/l) to micrograms per liter (ug/l), multiply by 1000 (e.g. 0.5 mg/l = 500 ug/l).

**Cyanobacteria:** See “Blue-Green Algae.”

**Dissolved oxygen:** The amount of oxygen dissolved or carried in the water. Essential for a healthy aquatic ecosystem in Wisconsin lakes.

**Drainage basin:** The total land area that drains runoff towards a lake.

**Drainage lakes:** Lakes fed primarily by streams and with outlets into streams or rivers. They are more subject to surface runoff problems, but generally have shorter residence times than seepage lakes.

**Emergent:** A plant rooted in shallow water and having most of its vegetative growth above water.

**Eutrophication:** The process by which lakes and streams are enriched by nutrients, and the resulting increase in plant and algae. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

**Groundwater drainage lake:** Often referred to as a spring-fed lake, it has large amounts of groundwater as its source and a surface outlet. Areas of high groundwater inflow may be visible as springs or sand boils. Groundwater drainage lakes often have intermediate retention times with water quality dependent on groundwater quality.
**Hardness:** The quantity of multivalent cations (cations with more than one +), primarily calcium (Ca++) and magnesium (Mg++) in the water expressed as milligrams per liter of CaCO₃. Amount of hardness relates to the presence of soluble minerals, especially limestone or dolomite, in the lake watershed.

**Intermittent:** Coming and going at intervals, not continuous.

**Macrophytes:** See “Rooted aquatic plants.”

**Marl:** White to gray accumulation on lake bottoms caused by precipitation of calcium carbonate (CaCO₃) in hard water lakes. Marl may contain many snail and clam shells. While it gradually fills in lakes, marl also precipitates phosphorus, resulting in low algae populations and good water clarity. In the past, marl was recovered and used to lime agricultural fields.

**Mesotrophic:** A lake with an intermediate level of productivity. Commonly clear water lakes and ponds with beds of submerged aquatic plants and mediums levels of nutrients. See also “eutrophication”.

**Nitrate (NO₃-):** An inorganic form of nitrogen important for plant growth. Nitrate often contaminates groundwater when water originates from manure, fertilized fields, lawns or septic systems. In drinking water, high levels (over 10 mg/L) are dangerous to infants and expectant mothers. A concentration of nitrate-nitrogen (NO₃-N) plus ammonium-nitrogen (NH₄-N) of 0.3 mg/L in spring will support summer algae blooms if enough phosphorus is present.

**Oligotrophic:** Lakes with low productivity, the result of low nutrients. Often these lakes have very clear waters with lots of oxygen and little vegetative growth. See also “eutrophication”.

**Overtturn:** Fall cooling and spring warming of surface water increases density, and gradually makes lake temperatures and density uniform from top to bottom. This allows wind and wave action to mix the entire lake. Mixing allows bottom waters to contact the atmosphere, raising the water's oxygen content. Common in many lakes in Wisconsin.

**Phosphorus:** Key nutrient influencing plant growth in more than 80% of Wisconsin lakes. Soluble reactive phosphorus is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

**Rooted aquatic plants (macrophytes):** Refers to higher (multi-celled) plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects and provide food for many aquatic and terrestrial animals. Overabundance of such plants, especially problem species, is related to shallow water depth and high nutrient levels.

**Secchi disk:** An 8-inch diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration).

**Sedimentation:** Materials that are deposited after settling out of the water.

**Stratification:** The layering of water due to differences in density. As water warms during the summer, it remains near the surface while colder water remains near the bottom. Wind mixing determines the thickness of the warm surface water layer (epilimnion), which usually extends to a depth of about 20 feet. The narrow transition zone between the epilimnion and cold bottom water (hypolimnion) is called the metalimnion. Common in many deeper lakes in Wisconsin.

**Watershed:** See “Drainage basin.”