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PEARL 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 Pearl Lake between fall 2010 and fall 2012.

ABOUT PEARL 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. Pearl Lake is located in the township of Leon, east of Wautoma, north of Highway 21, and west of County Highway EE, with one public boat launch located on its southern side. Pearl Lake is a 101-acre seepage lake with surface runoff and groundwater contributing most of its water. Its maximum depth is 50 feet; the lakebed has a steep slope (Figure 1). Its bottom sediments are mostly muck in deeper sections of the lake, and sand with rock along the perimeter.
Figure 1. Contour map of the Pearl Lake lakebed.
The water quality in Pearl 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 Pearl 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 Pearl Lake is called a surface watershed. Groundwater also feeds Pearl 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 Pearl Lake is approximately 1,308 acres (Figure 2). The dominant types of land use in the watershed are forest (58%) and developed land (32%). The land closest to the lake often has the greatest impact on water quality and habitat; Pearl Lake’s shoreland is surrounded primarily by development with fragmented forests and wetlands.

![Pearl Lake Watershed Diagram](imageURL)

**Figure 2. Land Use in the Pearl 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 Pearl 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. Most of the groundwater feeding Pearl Lake comes from the north and northwest.

**Figure 3. Groundwater flow direction near Pearl 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 Pearl Lake was assessed by measuring different characteristics including temperature, dissolved oxygen, water clarity, water chemistry, and algae.

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. Pearl Lake is classified as a seepage lake, or a lake that receives its water primarily through groundwater, and, to a lesser extent, direct runoff and precipitation (Figure 4). Seepage lakes have higher concentrations of minerals such as calcium and magnesium, which are picked up by groundwater moving through soil and rock (Shaw et al., 2000). Seepage lakes generally have longer retention time (length of time water remains in the lake), which affects contact time with nutrients that feed the growth of algae and aquatic plants. Seepage lakes are also vulnerable to contamination moving towards the lake in the groundwater. Examples for Pearl Lake may include septic systems, agriculture, and road salt.

The geologic composition that lies beneath a lake has the ability to influence the temperature, pH, minerals, and other properties in a lake. As groundwater moves, some substances are filtered out, but some materials in the soil dissolve into the groundwater (Shaw et al., 2000). Minerals such as calcium and magnesium in the soil around Pearl Lake are dissolved in the water. The average hardness for Pearl Lake during the 2010-2012 sampling period was 124 mg/L in the west basin and 135 mg/L in the east basin, which is considered hard (Table 1). Hard water provides calcium necessary for building bones and shells for animals in the lake. The average alkalinity was 119 mg/L in both basins; this higher alkalinity can support higher species productivity (Wetzel, 2001). Hardness and alkalinity also play roles in the types of aquatic plants that are found in a lake.

Chloride concentrations, and to lesser degrees sodium and potassium concentrations, are commonly used as indicators of how a lake is being impacted by human activity. The presence of these compounds where they do not naturally occur indicates sources of water contaminants.

Pearl Lake had low average chloride and potassium concentrations in the east and west basins over the monitoring period (Table 2). Sodium was slightly elevated in the east basin, but low in the west basin. Sources of sodium include animal waste, septic systems, fertilizer, and road-salting chemicals.
Atrazine, an herbicide commonly used on corn, was detected in Pearl Lake (0.10 µg/L and 0.11 µg/L DACT). Some toxicity studies have indicated that reproductive system abnormalities can occur in frogs at these levels (Hayes et al., 2001; Hayes et al., 2003). The presence of this chemical suggests that agricultural activities in the surrounding landscape may be impacting the lake.

Table 1. Minerals and physical measurements in Pearl Lake, 2010-2012.

<table>
<thead>
<tr>
<th>Pearl 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 (CU)</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Basin Average</td>
<td>119</td>
<td>25.6</td>
<td>16.4</td>
<td>135</td>
<td>13</td>
<td>1.9</td>
</tr>
<tr>
<td>West Basin Average</td>
<td>119</td>
<td>23.3</td>
<td>16.3</td>
<td>124</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 2. Average water chemistry in Pearl Lake East and West Basins, 2010-2012.

<table>
<thead>
<tr>
<th>Pearl Lake</th>
<th>East Basin Average (mg/L)</th>
<th>West Basin Average (mg/L)</th>
<th>Reference Value (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Medium High</td>
<td>Low Medium High</td>
<td>Low Medium High</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.57          0.63</td>
<td>&lt;0.75 0.75-1.5 &gt;1.5</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>2.2           1.3</td>
<td>&lt;3 3.0-10.0 &gt;10</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>2.0           1.7</td>
<td>&lt;2 2.0-4.0 &gt;4</td>
<td></td>
</tr>
</tbody>
</table>

Dissolved oxygen is an important measure in aquatic ecosystems 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 the decomposition of dead plants and algae reduces oxygen in the lake. Some forms of iron and other metals carried by groundwater can also consume oxygen when the groundwater discharges to 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 Pearl Lake’s east basin from the surface to the bottom at the time of sample collection during the 2010-2012 study. The temperature data illustrated a typical late winter profile in February 2011, with freezing temperatures at the surface and gradual warming with depth (Figure 5). During spring and fall, the lake was mixed with uniform temperatures from surface to bottom. In May 2012, stratification (layering) had just started to develop and the lake remained stratified throughout the summer both years. In mid-summer, the data showed decreasing temperatures with depth ranging as high as 27°C (81°F) at the surface to 7°C (45°F) near the bottom.
Dissolved oxygen concentrations exhibited patterns similar to temperature (Figure 6). In winter, spring and fall, the dissolved oxygen concentrations were nearly uniform through the water column. Of note were low dissolved oxygen concentrations in November 2010 and February 2012 (below 5 mg/L). The low concentrations observed in the fall were likely the result of the lake having just turned. This is a temporary situation where the low oxygen bottom water mixes throughout the water column. Typically, atmospheric oxygen is defused into the water prior to ice cover. The low dissolved oxygen in late winter is cause for concern during longer winters with heavy snow cover. During the summer, concentrations of dissolved oxygen were high near the surface and decreased at depths of about 25 feet. Increases in dissolved oxygen during the summer at depths of 15-28 feet are usually attributed to oxygen production from algal blooms.

**Figure 5. Temperature profiles in Pearl Lake, 2010-2012.**

**Figure 6. Dissolved oxygen profiles in Pearl Lake, 2010-2012.**
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 Pearl Lake, color was relatively low (Table 1), so the variability in transparency throughout the year was primarily due to fluctuating algal concentrations and re-suspended sediment following storms and/or heavy boating activity.

Water clarity measured in Pearl Lake was considered good, ranging from 9 feet to 24 feet in the east basin and from 13.5 feet to 27.5 feet in the west basin (Figure 7 and Figure 8). A large dataset of water clarity measurements is available for Pearl Lake, thanks to citizen monitors. Data has been collected routinely in the east basin during 1986-95, 2010 and 2011. In the west basin, water clarity data is available from 1996 to the present. Over these time periods, only a few measurements were taken on the same day in both basins. In the west basin, when compared with historic data, the average water clarity measured during the study was better in May, similar in October, and poorer in June, July and August. In the east basin, when compared with historic data, the average water clarity measured during the study was better in September, similar in August and November, and poorer in April, May, June, July and October.

**Figure 7.** Water clarity in Pearl Lake, west basin, 2010-2012 and historic (1996-2009).
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 and animal tissue, and sediment. The phosphorus continues to cycle within the lake for many years.

During the study, total phosphorus concentrations in the Pearl Lake’s east basin ranged from a high of 24 ug/L in February 2011 to a low of 3 ug/L in August 2012 (Table 3). The summer median total phosphorus concentrations were 10 ug/L and 8 ug/L in 2011 and 2012, respectively. This is below Wisconsin’s phosphorus standard of 20 ug/L for deep seepage lakes. Inorganic nitrogen concentrations in Pearl Lake were within the natural range for lakes in Waushara County.

Chlorophyll \( a \) is a measurement of algae in the water. Chlorophyll \( a \) concentrations greater than 10 ug/L are perceived as a mild algae bloom, while concentrations greater than 20 ug/L are perceived as a nuisance. Chlorophyll \( a \) concentrations in Pearl Lake varied only slightly throughout the monitoring period, ranging between 0.5 ug/L and 3 ug/L in the east basin and between 1.2 ug/L and 2.4 ug/L in the west basin. It is important to note that the standard Wisconsin Department of Natural Resources protocol for sample acquisition was followed, with a 1-6 foot depth integrated sample collected for analysis. In Pearl Lake, increased dissolved oxygen concentrations from algal blooms occurred at depths of 15-25 feet, so the chlorophyll \( a \) concentrations reported are not a true representation of algal growth in Pearl Lake.
TABLE 3. SEASONAL SUMMARY OF NUTRIENT CONCENTRATIONS IN PEARL LAKE, 2010-2012.

<table>
<thead>
<tr>
<th>Season</th>
<th>Inorganic Nitrogen (mg/L)</th>
<th>Organic Nitrogen (mg/L)</th>
<th>Total Nitrogen (mg/L)</th>
<th>Soluble Reactive Phosphorus (ug/L)</th>
<th>Total Phosphorus (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>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.56</td>
<td>0.56</td>
</tr>
<tr>
<td>Spring</td>
<td>0.05</td>
<td>0.13</td>
<td>0.20</td>
<td>0.48</td>
<td>0.48</td>
</tr>
<tr>
<td>Summer</td>
<td>0.03</td>
<td>0.07</td>
<td>0.10</td>
<td>0.26</td>
<td>0.42</td>
</tr>
<tr>
<td>Winter</td>
<td>0.03</td>
<td>0.07</td>
<td>0.10</td>
<td>0.26</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Pearl 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. While forests comprise 58% of the watershed, based on modeling results, developed land had the greatest percentage of phosphorus contributions from the watershed to Pearl 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 Pearl Lake watershed.**
Table 4. Modeling data used to estimate phosphorus inputs from land uses in the Pearl Lake watershed (low and most likely coefficients used to calculate range in pounds).

<table>
<thead>
<tr>
<th>Pearl Lake Land Use</th>
<th>Phosphorus Export Coefficient (lbs/acre-yr)</th>
<th>Land Use Area Within the Watershed</th>
<th>Estimated Phosphorus Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Acres</td>
<td>Percent</td>
</tr>
<tr>
<td>Water</td>
<td>0.10</td>
<td>101</td>
<td>8</td>
</tr>
<tr>
<td>Developed</td>
<td>0.27</td>
<td>392</td>
<td>30</td>
</tr>
<tr>
<td>Barren/Herbaceous/Wetland</td>
<td>0.09</td>
<td>99</td>
<td>8</td>
</tr>
<tr>
<td>Forest</td>
<td>0.04</td>
<td>698</td>
<td>53</td>
</tr>
<tr>
<td>Cultivated Agriculture</td>
<td>0.45</td>
<td>18</td>
<td>1</td>
</tr>
</tbody>
</table>

*Values are not exact due to rounding and conversion.
AQUATIC PLANTS

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 which creates diversity that makes the aquatic plant community more resilient and can help to prevent the establishment of non-native aquatic species.

During the 2011 aquatic plant survey of Pearl Lake, sixteen species of aquatic plants were found (Table 5). This number is slightly below average for lakes in the Waushara County Lakes Study. The greatest plant diversity was found in the shallows (Figure 10). Eighty-three percent (141 of 169) sampled sites had vegetative growth. Of the sampled sites within Pearl Lake, the average depth was 15 feet and the maximum depth was 35 feet.

Table 5. List of aquatic plants identified in the 2011 aquatic plant survey of Pearl Lake.

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Coefficient of Conservatism Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emergent Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Schoenoplectus pungens</em></td>
<td>three-square bulrush</td>
<td>5</td>
</tr>
<tr>
<td><em>Schoenoplectus tabernaemontani</em></td>
<td>softstem bulrush</td>
<td>4</td>
</tr>
<tr>
<td><strong>Floating Leaf Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Potamogeton natans</em></td>
<td>floating-leaf pondweed</td>
<td>5</td>
</tr>
<tr>
<td><strong>Submergent Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ceratophyllum demersum</em></td>
<td>coontail</td>
<td>3</td>
</tr>
<tr>
<td><em>Chara spp.</em></td>
<td>muskgrass</td>
<td>7</td>
</tr>
<tr>
<td><em>Elodea canadensis</em></td>
<td>common waterweed</td>
<td>3</td>
</tr>
<tr>
<td><em>Heteranthera dubia</em></td>
<td>water star-grass</td>
<td>6</td>
</tr>
<tr>
<td><em>Myriophyllum sibiricum</em></td>
<td>northern watermilfoil</td>
<td>6</td>
</tr>
<tr>
<td><em>Najas flexilis</em></td>
<td>slender naiad</td>
<td>6</td>
</tr>
<tr>
<td><em>Nitella spp.</em></td>
<td>nitella</td>
<td>7</td>
</tr>
<tr>
<td><em>Potamogeton amplifolius</em></td>
<td>large-leaf pondweed</td>
<td>7</td>
</tr>
<tr>
<td><em>Potamogeton foliosus</em></td>
<td>leafy pondweed</td>
<td>6</td>
</tr>
<tr>
<td><em>Potamogeton illinoensis</em></td>
<td>Illinois pondweed</td>
<td>6</td>
</tr>
<tr>
<td><em>Potamogeton zosteriformis</em></td>
<td>flat-stem pondweed</td>
<td>6</td>
</tr>
<tr>
<td><em>Stuckenia pectinata</em></td>
<td>sago pondweed</td>
<td>3</td>
</tr>
<tr>
<td><em>Vallisneria americana</em></td>
<td>wild celery</td>
<td>6</td>
</tr>
</tbody>
</table>
The dominant plant species in the survey was muskgrass (*Chara, spp.*), followed by slender naiad (*Najas flexilis*) and Illinois pondweed (*Potamogeton illinoensis*). Muskgrass is a favorite food source for a wide variety of waterfowl, and muskgrass beds offer cover and food to fish, especially young trout, largemouth bass, and smallmouth bass. The stems, leaves and seeds of slender naiad are important food sources for waterfowl and marsh birds, and this common aquatic plant species also provides habitat for fish. Illinois pondweed is also an important food source for a variety of waterfowl, and this submersed plant species offers shade and cover for fish, and habitat for invertebrates. Sago pondweed provides food to waterfowl and is used as cover and habitat by invertebrates and fish (Borman et al., 2001).

The Floristic Quality Index (FQI) evaluates the closeness of a plant community to undisturbed conditions. Each plant is assigned a coefficient of conservatism (C-value) that reflects its sensitivity to disturbance. These numbers are used to calculate the FQI. C-values range from 0 to 10. The higher the number, the more intolerant the plant is of disturbance. A C-value of zero is assigned to non-native species. The C-values in Pearl Lake ranged from 3 to 7, with an average C-value of 5.5 (Table 5). The 2011 FQI for Pearl Lake was 21.2, which was below average compared with other lakes in the Waushara County Lakes Study. No species of special concern in Wisconsin were found in Pearl 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 zero to one. Values closer to one represent higher amounts of biodiversity. Pearl Lake had an SDI value of 0.78, which represents average biodiversity when compared with the other lakes in the Waushara County Lakes Study.

One aquatic invasive species was observed during the 2011 survey, curly-leaf pondweed (CLP), so a special survey was conducted in June 2012 to look specifically for this species. During the June 2012 survey, CLP was found in a single location in Pearl Lake, but not in dense patches. In some lakes, CLP behaves as another member of the aquatic plant community, but in others it can become more aggressive, colonizing large areas. CLP has a unique life cycle. It begins growing under the ice in winter and by early spring has a competitive advantage over still-dormant native species. CLP typically dies off in late June/early July, and its decomposing tissue releases phosphorus into the warm water. The timing of this phosphorus release can help to enhance algal blooms. In Pearl Lake, CLP appears to be functioning as a member of the aquatic plant community and does not currently show any invasive tendencies; however, it should continue to be monitored to evaluate its aggressiveness.
Figure 10. Number of aquatic plant species observed at each sample site in Pearl Lake, 2011.
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 professionals from 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 Pearl 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 shorelands indicate locations where changes in management or mitigation may be warranted. A large portion of Pearl Lake’s shorelands are in moderate condition, with numerous stretches having challenges that should be addressed, including some stretches that received the poorest ranking. A summary of shoreland disturbances within 15 feet of the water is displayed 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 Pearl Lake, 2011.

<table>
<thead>
<tr>
<th>Disturbance</th>
<th>Length of Shoreline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feet</td>
</tr>
<tr>
<td>Artificial beach</td>
<td>4,829</td>
</tr>
<tr>
<td>Barren, bare dirt</td>
<td>0</td>
</tr>
<tr>
<td>Boat landing</td>
<td>56</td>
</tr>
<tr>
<td>Dock/pier at water</td>
<td>11,068</td>
</tr>
<tr>
<td>Gully erosion</td>
<td>484</td>
</tr>
<tr>
<td>Undercut banks erosion</td>
<td>0</td>
</tr>
<tr>
<td>Mowed lawn</td>
<td>2,239</td>
</tr>
<tr>
<td>Rip-rap</td>
<td>7,208</td>
</tr>
<tr>
<td>Seawall</td>
<td>9,512</td>
</tr>
</tbody>
</table>
Figure 11. Overall shoreland health around Pearl Lake, 2011.
CONCLUSIONS & RECOMMENDATIONS

In general, most of the measures taken in Pearl Lake indicated good overall health. However, water clarity appears to be declining in the summer, and an agricultural chemical was identified in the lake water. Pearl Lake has hard water, which helps to limit the amount of phosphorus available for growth by algae and aquatic plants.

- Chloride, potassium and sodium are indicators of human influences on lake water quality. In Pearl Lake, concentrations of these elements were low.
- Water clarity appears to have declined over time in Pearl Lake.
  - In the west basin, when compared with past data (1996-2009), the average water clarity during the study was better in May, similar in October, and poorer in June, July and August.
  - In the east basin, when compared with past data (1986-1995), the average water clarity during the study was better in September, similar in August and November, and poorer in April, May, June, July and October.
- Chlorophyll $a$ is a measurement of algae in the water. Chlorophyll $a$ concentrations in both basins of Pearl Lake were low; however, it is important to note that the standard Wisconsin Department of Natural Resources protocol for sample acquisition was followed, with samples collected in the upper 6 feet of water. In Pearl Lake, increased dissolved oxygen concentrations from algal blooms occurred at depths of 15-25 feet, so the chlorophyll $a$ concentrations reported are not a full representation of the algal growth in Pearl Lake.
- Atrazine, an herbicide commonly used on corn, was detected in Pearl Lake (0.10 µg/L and 0.11 µg/L DACT).
  - Some toxicity studies have indicated that reproductive system abnormalities can occur in frogs at these levels.
  - The presence of this chemical suggests that agricultural activities in the surrounding landscape may be impacting the lake.
  - Private wells should be tested to ensure that concentrations are below the drinking water standards.

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 the land.

- During the study, the total phosphorus concentrations in the east basin of Pearl Lake ranged from 3 to 24 µg/L. The summer median total phosphorus concentrations were 10 and 8 µg/L in 2011 and 2012, respectively. This is below Wisconsin’s phosphorus standard of 20 µg/L for deep seepage lakes.
- Identifying and taking steps to maintain or improve water quality in Pearl Lake depends upon understanding the sources of nutrients to the lake and identifying those that are manageable. While forests comprise 58% of the watershed, based on modeling results, developed land were the greatest source of phosphorus contributions from the watershed to Pearl 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.
• Routine monitoring of water quality can help to track changes in Pearl Lake. A monitoring plan should be designed and carried out. A different sampling protocol is recommended for chlorophyll $a$ analyses, since algal blooms appear to be occurring at depths well below six feet.

Shoreland health is critical to a healthy lake’s ecosystem. Pearl 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.

o A large portion of Pearl Lake’s shorelands are in moderate condition, with numerous stretches having challenges that should be addressed, including some stretches that received the poorest ranking.
  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 disturbance, 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 Pearl Lake. This number is slightly below average for lakes in the Waushara County Lakes Study.
• One aquatic invasive species was observed during the 2011 survey, curly-leaf pondweed (CLP).
During the June 2012 survey, CLP was found in a single location, but was not found in dense patches. In Pearl Lake, this species appears to be functioning as a member of the aquatic plant community and does not currently show invasive tendencies.
  o Monitoring for CLP in Pearl Lake should be conducted annually by citizens in June to evaluate if it is spreading.

- Eurasian watermilfoil (EWM) was confirmed in Pearl Lake in 1994, but was not observed during the survey in 2011. EWM was found and treated in 2013 (Golden Sands Resource Conservation & Development Council, Inc. website).
  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 Continued vigilance in looking for EWM in Pearl Lake is necessary to ensure that it does not become established. Citizens should learn to identify this plant and contact the appropriate authorities if they suspect it is present.

- 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”.

**Overturn:** 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.”