BIG HILLS LAKE

WAUSHARA COUNTY, WISCONSIN

COMPREHENSIVE LAKE MANAGEMENT PLAN

Prepared for

Big Hills Lake Protection & Rehabilitation District

June 2003

NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.
Green Bay Office: 4664 Golden Pond Park Ct., Oneida, WI, 54155 Voice: 920-499-5789 Fax: 920-662-9141 www.releeinc.com/NES

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SUMMARY

A comprehensive study of Big Hills Lake, Waushara County, Wisconsin was completed during 2002 and 2003. The study was completed to provide information concerning the lake and its watershed so a comprehensive lake management plan could be written for the lake. Funding for this study and the development of the plan was provided by the Wisconsin Department of Natural Resources Lake Management Grant Program and the Big Hills Lake Protection and Rehabilitation District.

The data from this study were analyzed with data collected during past studies and yielded the following major results:

- Big Hills Lake has good water quality and normally fluctuates within the mesotrophic state.

- The lake mixes many times throughout the year and anoxic conditions do not occur in the hypolimnion of the lake, therefore, internal nutrient loading and fishkills are not a concern.

- Field verification of current land use data indicated that 68% of the land within the Big Hills Lake watershed is forested and this is the most prevalent land use type.

- Modeling of land use data indicated that precipitation and atmospheric fallout are the largest contributors to the lake's phosphorus budget. These sources were closely followed by inputs from shoreland septic systems.

- Modeling of potential changes in the watershed, particularly concerning the addition of new septic systems and the loss of efficiency of existing systems, indicated that only minor changes were needed to create a decrease in water clarity within the lake.

- Big Hills Lake presently has more aquatic plant species in it compared to historic surveys and to other lakes in the state and ecoregion, but the additional species are not indicative to undisturbed systems. This indicates that the lake plant community is likely being affected by outside sources, such as shoreland development and recreational boating.

- There is definite lack of emergent plant species throughout the lake. Even very common species that are found throughout the state and county do not exist in Big Hills Lake (e.g., common arrowhead, bulrushes, and bur-reed). In addition, softstem bulrush was found in Big Hills Lake during past studies, but not the survey completed in 2002. Anthropogenic activities have likely played a role in minimizing the emergent community within the lake.

- Eurasian water-milfoil, an invasive and exotic submergent plant, was found to be the most abundant plant within Big Hills Lake.

- Analysis of current and historic vegetation survey data indicates that Eurasian water-milfoil has spread from the boatlanding and now occurs to some extent in nearly 36 acres of the lake. Furthermore, recreational boating, along with wind and wave action are the likely causes of the spread.

Major recommendations to the Big Hills Lake Protection and Rehabilitation District include the following:

- The best way to protect the water quality within Big Hills Lake will be to minimize the external sources that feed phosphorus into the lake.

- Septic system inspections were recommended to identify and replace faulty septic systems that may be adding phosphorus to the lake.

- Enhancements of the lake's aquatic plant community through native plantings were recommended in conjunction with herbicide applications aimed to reduce the spread of Eurasian water-milfoil.

- Continued lake user education was also stressed as a means to raise awareness of everyone's role in protecting Big Hills Lake as an important natural resource.

INTRODUCTION

Big Hills Lake is a 133-acre lake located in Waushara County, Wisconsin (Figure 1) that has a maximum depth of 22-feet and a mean depth of 12-feet. The Big Hills Lake Management District, now known as the Big Hills Lake Protection and Rehabilitation District was formed in 1977 and has been very active in the monitoring and protection of the lake as not only a recreational resource for swimming, boating, and fishing, but as an important ecosystem valued for its aesthetics and natural function in the Wisconsin landscape. The District has sponsored many monitoring projects over the past two decades including efforts by the Wisconsin Department of Natural Resources, the United States Geological Survey and private consultants. These studies have gathered a great deal of information about Big Hill Lake's biological and chemical characteristics and nutrient loading from the watershed and groundwater.

The purpose of the project reported on here was to collect additional information concerning lake water quality, aquatic vegetation, and influences of the lake's watershed. These data along with the data previously collected were then used to create a lake management plan specific to the needs of Big Hills Lake and the Big Hills Lake Protection and Rehabilitation District. This document is a combination of the final report and the lake management plan.

Notes on the Format of this Document

This document serves two purposes; 1) it fulfills the requirements for final reporting of a study that was partially funded through a Wisconsin Department of Natural Resources (WDNR) Lake Planning Grant, and 2) it is the Lake Management Plan for Big Hills Lake. Care has been taken to keep the technical aspects of the document on laymen's terms as much as possible. To facilitate the ease of reading, certain topics are expanded upon and technical terms are defined in a glossary. Furthermore, the reporting of specific data is kept to a minimum within the text, but is wholly contained within the appendices. The appendices also contain the glossary mentioned above (terms contained in the glossary are italicized within the text).

The study contained four major components, watershed analysis, aquatic vegetation, water quality, and education. Each section of the report and plan are generally separated into these four components.

For ease of reading and document compilation, the large format (11"x17") maps are contained near the end of this report.

RESULTS AND DISCUSSION

Lake Water Quality

Judging the quality of lake water can be difficult because lakes display problems in different ways. However, concentrating on certain aspects or parameters that are important to lake ecology and comparing those values to similar lakes within the same region and historical data from the same lake provides an excellent method to evaluate the quality of a lake's water. To complete this task, three water quality parameters are focused upon:

1. **Phosphorus** is a nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both *algae* and *macrophytes*. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the growth rates of the plants within the lake.

2. **Chlorophyll-*a*** is the pigment in plants that is used during *photosynthesis*. Chlorophyll-*a* concentrations indicate algal abundance within a lake.

3. **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to comprehend. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring lake health. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are inter-related. Phosphorus controls algal abundance, which is measured by chlorophyll *a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural, Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water.

Each of these parameters is also directly related to the *trophic state* of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: *oligotrophic*, *mesotrophic*, and finally *eutrophic*. Every lake will naturally progress through these states; however, under natural conditions (i.e. not influenced by the activities of humans) this progress can take tens of thousands of years. Unfortunately, human influence has accelerated this natural aging process in most Wisconsin lakes. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the health of their lake over time. Yet, classifying a lake into one of three trophic states does not give clear indication of where a lake really exists in its aging process. To solve this problem, the parameters measured above can be used in an index that will indicate a lake's trophic state more clearly.

The complete results of these three parameters and the other chemical data that were collected at Big Hills Lake can be found in Appendix A. The results and discussion of the analysis and comparisons described above can be found in the paragraphs and figures that follow.

Comparisons with Other Datasets

Lillie and Mason (1983) is an excellent source for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Waushara County lakes are included within the study's Central Region and are among 44 lakes randomly picked from the region that were analyzed for water clarity (Secchi disk), chlorophyll *a*, and total phosphorus. These data along with data corresponding to statewide means, historical, current, and average data from Big Hills Lake are displayed in Figures 2-4. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-November) or summer months in the deepest location in the lake (Figure 1). Furthermore, the phosphorus and chlorophyll *a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments (see section on internal nutrient loading).

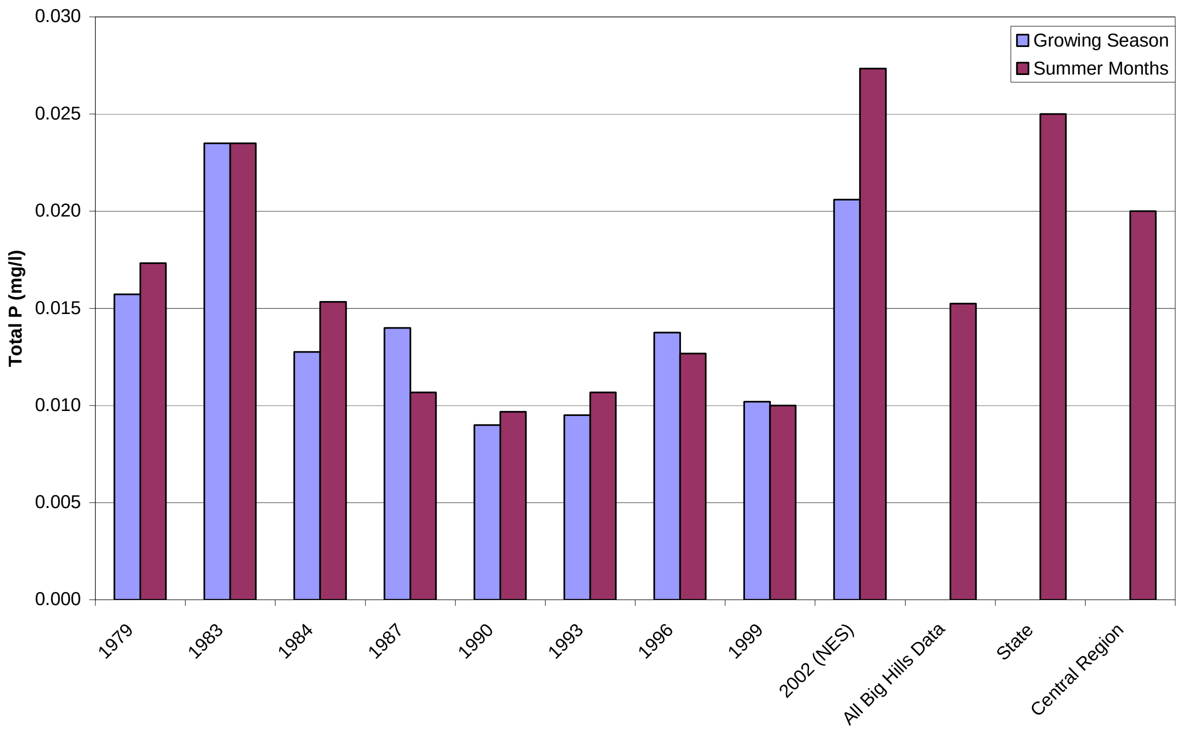

Figure 2. Mean total phosphorus concentrations from Big Hills Lake, state and central region. All means were calculated from summer surface samples.

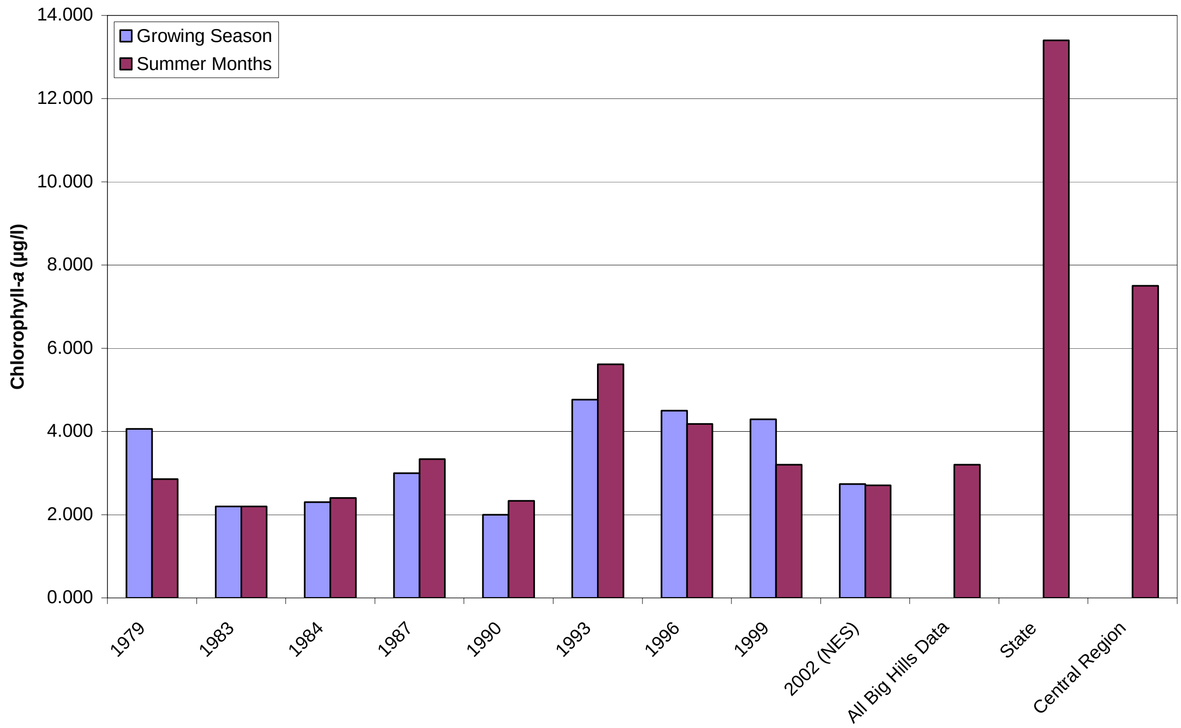

Figure 3. Mean chlorophyll-*a* concentrations from Big Hills Lake, state and central region. All means were calculated from summer surface samples.

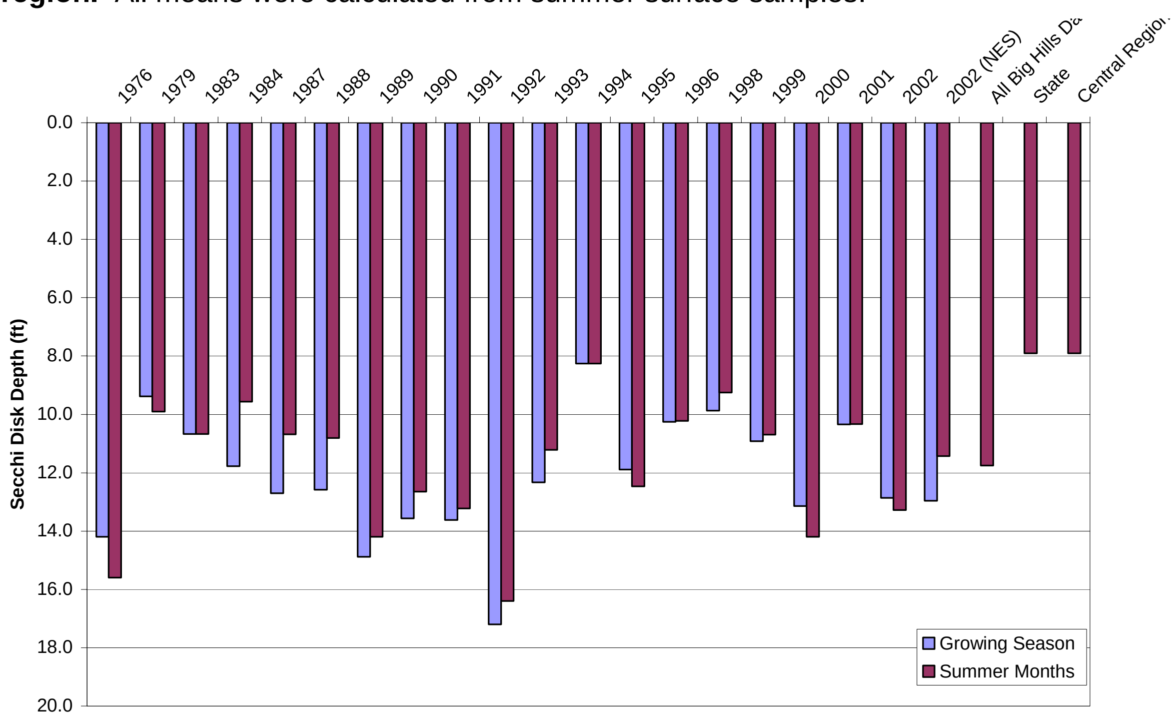

Figure 4. Mean Secchi disk transparencies from Big Hills Lake, state and central region. All means were calculated from summer measurements.

Considering the full set of Big Hills data (historic and current), it is obvious that the values for the three parameters fluctuate from year to year. This is normal because so many factors affect these parameters on a seasonal and annual basis. Precipitation, cloud-cover, nutrient forms (particulate, dissolved), lake use, among others, all determine the concentrations of chlorophyll *a* and phosphorus and how clear the water is. For instance, the summer months mean value for total phosphorus (Figure 2) from the current study is higher than in all previous years and higher than the regional and state means. This phenomenon was likely a result of the wetter than normal spring that occurred in 2002, which likely increased runoff to the lake. Increased runoff means increased nutrients entering the lake. Even though this value may seem high when compared to the other data sets, it is still considered to be a good level compared to the Water Quality Index (WQI) developed by Lillie and Mason (1983) (Table 1). Most importantly, these higher than average levels of phosphorus did not appear to spur algal blooms within the lake, as indicated by the below average chlorophyll *a* concentrations that were found during the same time period.

Table 1. Water Quality Index (WQI) developed by Lillie and Mason (1983) for Wisconsin Lakes.

	Approximate Equivalents				
WQI	**Water Clarity (m)**	**Water Clarity (ft)**	**Chlorophyll-a (µg/l)**	**Total Phosphorus (mg/m^3)**	**WTSI***
Excellent	>6	>19.7	<1	<1	>34
Very Good	3.0-6.0	9.8-19.7	1-5	1-10	34-44
Good	2.0-3.0	6.6-9.8	5-10	10-30	44-50
Fair	1.5-2.0	4.9-6.6	10-15	30-50	50-54
Poor	1.0-1.5	3.3-4.9	15-30	50-150	54-60
Very Poor	<1.0	<3.3	>30	>150	<60

*Calculated from water clarity values.

Overall, when compared to the WQI values in Table 1, the data found in Figures 2-4 indicate that the water quality of Big Hills Lake is quite good and that there is no apparent evidence of changes in water quality over the past 2+ decades. They also indicate that the average levels of these parameters are better than those found in the region and state.

Lake Trophic State and Limiting Nutrient

Figure 5 contains the Wisconsin Trophic State Index (WTSI) (Lillie, et al. 1993) values calculated from average surface levels of chlorophyll-*a*, total phosphorus, and Secchi disk transparencies measured during the summer months in Big Hills Lake. The WTSI is based upon the widely used Carlson Trophic State Index (TSI) (Carlson 1977), but is specific to Wisconsin lakes. The WTSI is used extensively by the Wisconsin Department of Natural Resources (WDNR) and is reported along with lake data collected by Self-Help Volunteers. The data indicate that for the most part, Big Hills Lake fluctuates within the mesotrophic state. As with the data reviewed above, there are occasional higher levels of phosphorus that indicate Big Hills Lake as eutrophic; but again, they do not correspond to higher levels of chlorophyll-*a* or reduced transparency. One possible explanation is that the *limiting nutrient* may not be phosphorus at those times. However, current and historic *nitrogen to phosphorus ratios* do not support this theory. In fact, the summer ratios are commonly higher than 30:1, which indicate a strong phosphorus limitation of algal growth. The likely reason is that much of the phosphorus is in an unusable form (e.g. bound to other molecules or in a particulate form) for algae. Surface concentrations of dissolved phosphorus (useable form for algae) were below detectable levels during the spring and mid-summer samples, indicating the remaining phosphorus is not in a dissolved form.

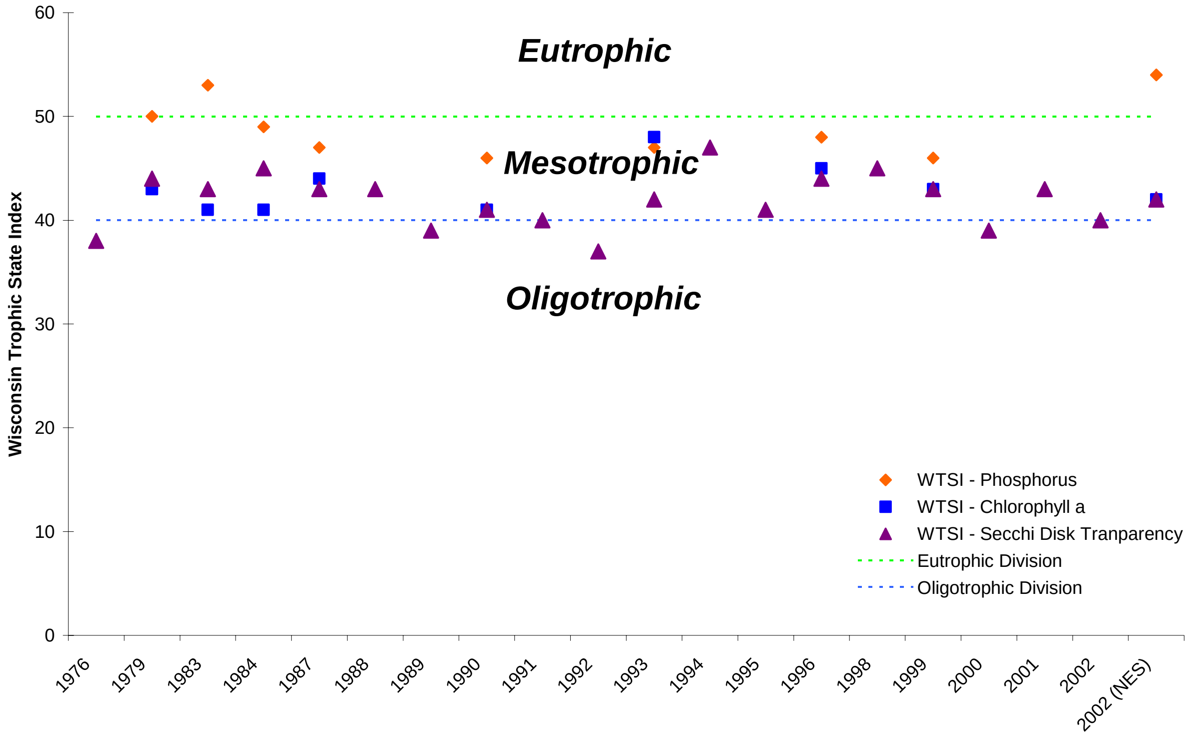

Figure 5. Wisconsin Trophic State Index results for Big Hills Lake.

Internal Phosphorus Loading

The Phosphorus Prediction and Uncertainty Analysis Module of the Wisconsin Lake Modeling Suite (WiLMS) indicated good agreement between observed and modeled data for Big Hills Lake, which in turn, indicates the lake is likely not affected by internal phosphorus loading. This was particularly true for the Nurnberg modeling results, which was designed to model lakes that mix often and do not support an *anoxic hypolimnion* such as Big Hills Lake. In fact, this model showed only 10% variation between observed and modeled phosphorus levels, indicating that only a negligible amount of phosphorus is not accountable as being from external sources. These results are not surprising considering the weak stratification that occurs within Big Hills Lake. In lakes that have strong stratification, the hypolimnion, can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae. This cycle continues year after year and is termed "internal phosphorus loading", a phenomenon that can support nuisance algae blooms decades after external sources are controlled. Internal nutrient loading is especially troubling in seepage lakes such as Big Hills Lake because the nutrients are not flushed out of the system, but remain to be recycled every year.

Temperature and Dissolved Oxygen

The temperature and dissolved oxygen profiles performed at Big Hills Lake show the lake only weakly stratified during a short period in early spring (Figure 6). The profiles also indicate that the lake holds oxygen well throughout the winter as indicated by the March 4, 2002 profile that was taken through the ice.

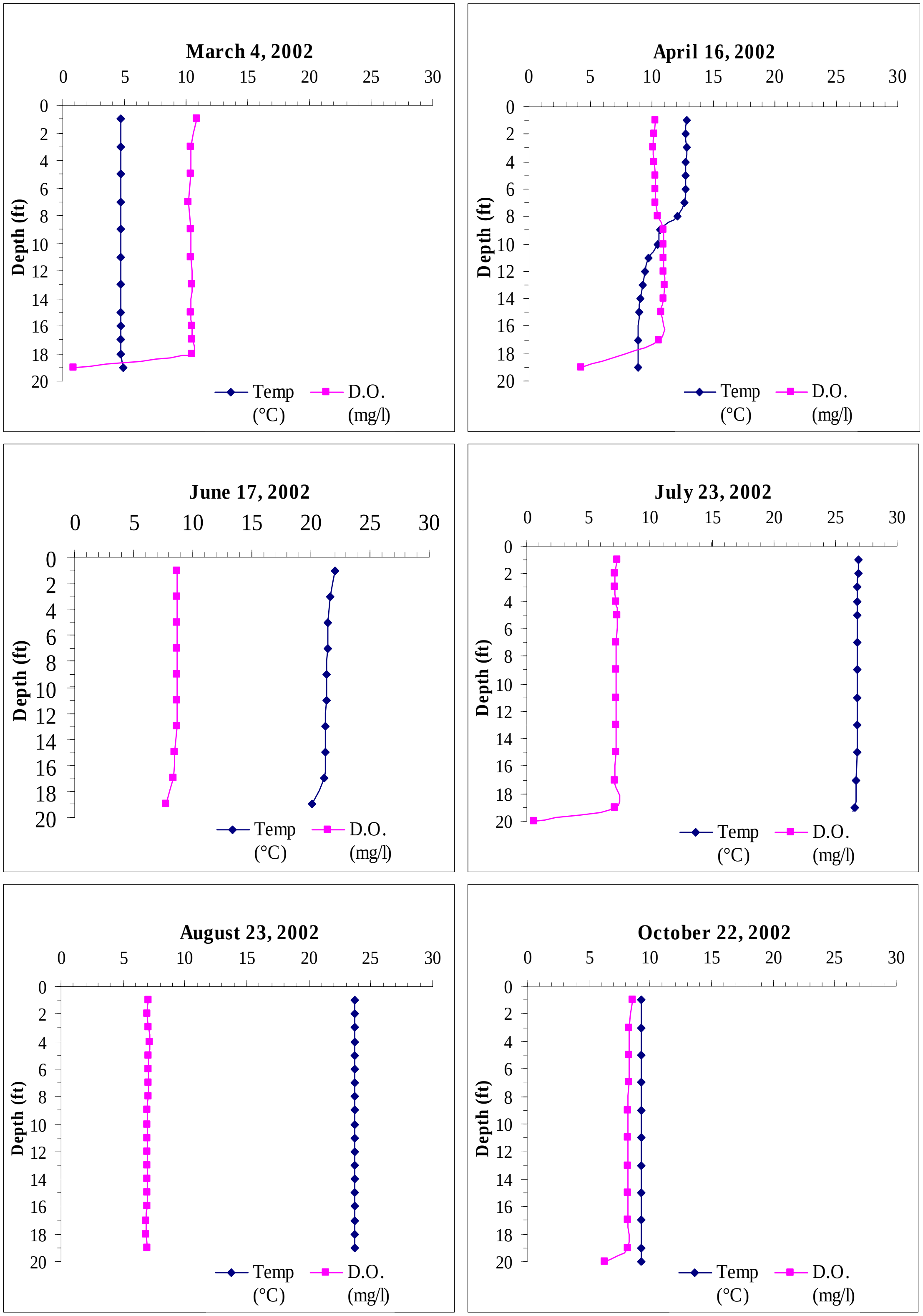

Figure 6. Results of temperature and dissolved oxygen profiles for Big Hills Lake.

Aquatic Vegetation

Although many lake users consider aquatic macrophytes to be "weeds" and a nuisance to the recreational use of the lake, they are actually an essential element in a healthy, functioning lake ecosystem. It is very important that the lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative affects on it.

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Zizania palustris*) both serve as excellent food sources for ducks and geese. In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the *periphyton* attached to them as their primary food source. The plants also provide cover for feeder fish and *zooplankton*, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas were plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by *phytoplankton*, which helps to minimize nuisance algal blooms.

Under certain conditions, plant populations may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced numbers of predator fish and a stunted pan-fish population. *Exotic* plant species, such as Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing *native* plants and reducing *species diversity*. These *invasive* plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

When plant biomass negatively affects the lake ecosystem and limits the use of the resource, plant management may be necessary. The management goals should always include the control of invasive species and restoration of native communities through environmentally sensitive and economically feasible methods.

Aquatic Plant Management and Protection

Many times an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, grass carp (*Ctenopharyngodon idella*) are illegal in Wisconsin and rotovation is not commonly used. Unfortunately, there are no "wonder drugs" that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below. Although all of these techniques may not be applicable to Big Hills Lake, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why they are or are not applicable.

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many new aquatic plant management regulations. The rules for the new regulations have been set forth by the WDNR as NR 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now; including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet along the shoreline and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within the 30 feet. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects. The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreline. Removal of native plants from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreline sediments vulnerable to wave action caused by boating and wind. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife.

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a *shoreland buffer zone.* The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping.

Enhancement activities also include additions of *submergent*, *emergent*, and *floating-leaf* plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Cost

The cost of native, aquatic and shoreland plant restorations are highly variable and depend on the size of the restoration area, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), measures used to protect the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,050.

- The single site used for the estimate indicated above has the following characteristics:
    - An upland buffer zone measuring 35' x 100'.
    - An aquatic zone with shallow-water and deep-water areas of 10' x 100' each.
    - Site is assumed to need little invasive species removal prior to restoration.
    - Site has a moderate slope.
    - Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
    - Plant spacing for the aquatic zone would be 3 feet.
    - Each site would need 100' of biolog to protect the bank toe and each site would need 100' of wavebreak and goose netting to protect aquatic plantings.
    - Each site would need 100' of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
    - There is no hard-armor (rip-rap or seawall) that would need to be removed.

Advantages

Improves the aquatic ecosystem through species diversification and habitat enhancement.
Assists native plant populations to compete with exotic species.
Increases natural aesthetics sought by many lake users.
Decreases sediment and nutrient loads entering the lake from developed properties.
Reduces bottom sediment resuspension and shoreline erosion.
Lower cost when compared to rip-rap and seawalls.
Restoration projects can be completed in phases to spread out costs.
Many educational and volunteer opportunities are available with each project.

Disadvantages

Property owners need to be educated on the benefits of native plant restoration before they are willing to participate.
Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in.
Monitoring and maintenance are required to assure that newly planted areas will thrive.
Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings.

Manual Removal

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not taken out, rather the plants are cut similar to mowing a lawn. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The other cutting method entails a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the plants.

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent rerooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15^{th}.

Cost

Commercially available hand-cutters and rakes range in cost from $85 to $150. Power-cutters range in cost from $1200 to $11,000.

Advantages

Very cost effective for clearing areas around docks, piers, and swimming areas.
Relatively environmentally safe if treatment is conducted after June 15^{th}.
Allows for selective removal of undesirable plant species.
Provides immediate relief in localized area.
Plant biomass is removed from waterbody.

Disadvantages

Labor intensive.
Impractical for larger areas or dense plant beds.
Subsequent treatments may be needed as plants recolonize and/or continue to grow.
Uprooting of plants stirs bottom sediments making it difficult to harvest remaining plants
May disturb *benthic* organisms and fish-spawning areas.
Risk of spreading invasive species if fragments are not removed.

Bottom Screens

Bottom screens are very much like landscaping fabric used to block weed growth in flowerbeds. The gas-permeable screen is placed over the plant bed and anchored to the lake bottom by staking or weights. Only gas-permeable screen can be used or large pockets of gas will form under the mat as the result of plant decomposition. This could lead to portions of the screen becoming detached from the lake bottom, creating a navigational hazard. Normally the screens are removed and cleaned at the end of the growing season and then placed back in the lake the following spring. If they are not removed, sediments may build up on them and allow for plant recolonization on top of the screen.

Cost

Material costs range between $.20 and $1.25 per square-foot. Installation costs vary greatly depending on the size of the area to be covered and the depth of overlaying water.

Advantages

Immediate and sustainable control.
Long-term costs are low.
Excellent for small areas and around obstructions.
Materials are reusable.
Prevents fragmentation and subsequent spread of plants to other areas.

Disadvantages

Installation may be difficult over dense plant beds.
Installation in deep water may require SCUBA.
Not species specific.
Disrupts benthic fauna.
May be navigational hazard in shallow water.
Initial costs are high.
Labor intensive due to the seasonal removal and reinstallation requirements.
Does not remove plant biomass from lake.

Water Level Drawdown

The primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation and either heating or freezing depending on the timing of the treatment. Winter drawdowns are more common in temperate climates like that of Wisconsin and usually occur in reservoirs because of the ease of water removal through the outlet structure. An important fact to remember when considering the use of this technique is that only certain species are controlled and that some species may even be enhanced. Furthermore, the process will likely need to be repeated every two or three years to keep target species in check.

Cost

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive.

Advantages

Inexpensive if outlet structure exists.
May control populations of certain species, like Eurasian water-milfoil for up to two years.
Allows some loose sediments to consolidate.
May enhance growth of desirable emergent species.

Other work, like dock and pier repair and/or dredging may be completed more easily and at a lower cost while water levels are down.

Disadvantages

May be cost prohibitive if pumping is required to lower water levels.
Drastically upsets lake ecosystem with significant effects on fish and other aquatic wildlife.
Adjacent wetlands may be altered due to lower water levels.
Disrupts recreational, hydroelectric, irrigation and water supply uses.
May enhance the spread of certain undesirable species, like common reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*).
Unselective.

Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 10 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor.

Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the later route is chosen, it is very important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Costs

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages

Immediate results.
Plant biomass and associated nutrients are removed from the lake.
Select areas can be treated, leaving sensitive areas intact.

Plants are not completely removed and can still provide some habitat benefits.
Opening of cruise lanes can increase predator pressure and reduce stunted fish populations.
Harvested plant materials produce excellent compost.

Disadvantages

Initial costs are high if the lake organization intends to own and operate the equipment.
Multiple treatments may be required during the growing season because lower portions of the plant and root systems are left intact.
Many small fish, amphibians and invertebrates may be harvested along with plants.
There is little or no reduction in plant density with harvesting.
Invasive and exotic species may spread because of plant fragmentation associated with harvester operation.
Larger harvesters are not easily maneuverable in shallow water or near docks and piers.
Bottom sediments may be resuspended leading to increased turbidity and water column nutrient levels.

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

1. *Contact herbicides* act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. *Systemic herbicides* spread throughout the entire plant and often result in complete mortality.

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to both the applicator and the environment; so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

Fluridone (Sonar®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters were dilution can be controlled. Irrigation restrictions apply.

Glyphosate (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a *surfactant* to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species. This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*).

Diquat (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on to foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.

Endothal (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothal (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, Aqua-Kleen®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions apply.

Advantages

Herbicides are easily applied in restricted areas, like around docks and boatlifts.
If certain chemicals are applied at the correct dosages, they can selectively control certain invasive species, such as Eurasian water-milfoil.
Some herbicides can be used effectively in spot treatments.

Disadvantages

Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly.
Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them.
Many herbicides are nonselective.
Most herbicides have a combination of use restrictions that must be followed after their application.
Many herbicides are slow-acting and may require multiple treatments throughout the growing season.

Cost

Herbicide application charges vary greatly between $250 to $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin. Other states have also used insects to battle invasive plants, such as waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, Wisconsin's climate is a bit harsh for these two invasive plants, so we do not use either biocontrol insect. However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water-milfoil. Wisconsin is also using two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These biocontrol insects are not covered here because purple loosestrife is predominantly a wetland species.

Advantages

Milfoil weevils occur naturally in Wisconsin.
This is likely an environmentally safe alternative to controlling Eurasian water-milfoil.

Disadvantages

Stocking and monitoring costs are high.
This is an unproven and experimental treatment.
There is a chance that a large amount of money could be spent with little or no change in Eurasian water-milfoil density.

Cost

Stocking with adult weevils costs about $1.00/weevil and they are usually stocked in lots of 1000 or more.

Nutrient Reduction

Every plant, whether it is algal or vascular, requires nutrients to grow. The three primary, macronutrients include phosphorus, nitrogen, and carbon. Under normal conditions, lakes in Wisconsin are phosphorus limited and occasionally, nitrogen limited. In other words, one of these nutrients is in short enough supply that it controls plant growth. If more of the nutrient is added to the system, the plant population expands; if the nutrient is taken away, the plant population decreases. However, rooted, vascular plants will not respond to nutrient reductions in the open water as quickly as algal populations will because they have the ability to take up nutrients from the sediment, and unfortunately, there is not a method currently available that will reduce or deactivate phosphorus and nitrogen in lake sediments. Nevertheless, it should be the goal of every lake organization to promote the minimization of all sources of nutrients and pollution entering the lake, whether they are in the form of a *nonpoint-source pollution* like runoff from agricultural and residential lands or *point-source pollution*, like an agricultural drain tile or storm sewer outfall. The reduction of these pollutants will slow the filling of the lake and reduce plant growth in the long-term.

Analysis of Current and Historic Plant Data

We found 22 aquatic plant species within Big Hills Lake during the survey that was conducted during the summer of 2002 (Table 2). Of these species, two are considered to be exotic, reed canary grass (*Phalaris arundinacea*) and Eurasian water-milfoil (*Myriophyllum spicatum*). Reed canary grass is an invasive grass common to wetlands and often the shorelines of Wisconsin. It was originally recommended for planting in wet farmlands so the farmers could use the "wasted areas". It has since spread to many areas of the state. Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 7). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead, it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and hampering recreational activities such as swimming, fishing, and boating.

Table 2. Aquatic plant species occurring in Big Hills Lake during 2002 survey. Species are broken into community type and include coefficients of conservatism used in Floristic Quality Assessment.

	Scientific Name	Common Name	Coefficient of Conservatism (C)	Notes
Emergent	*Carex comosa*	Bristly sedge	5	
	Eleocharis acicularis	Needle spikerush	5	
	Phalaris arundinacea	Reed canary grass		Exotic
	Juncus effusus	Soft stemmed rush	3	
	Scirpus americanus	Threesquare	5	
Floating-leaf	*Polygonum amphibium*	Water smartweed	5	
	Wolffia columbiana	Common watermeal	5	
	Lemna minor	Small duckweed	5	
Submergent	*Elodea canadensis*	Common waterweed	3	
	Myriophyllum spicatum	Eurasian water-milfoil		Exotic
	Potamogeton zosteriformis	Flat-stem pondweed	6	
	Potamogeton natans	Floating-leaf pondweed	5	
	Potamogeton illinoensis	Illinois pondweed	6	
	Potamogeton foliosus	Leafy pondweed	6	
	Potamogeton nodosus	Long-leaf pondweed	7	
	Chara sp.	Muskgrasses	7	
	Myriophyllum sibiricum	Northern water milfoil	7	
	Potamogeton pectinatus	Sago pondweed	3	
	Najas flexilis	Slender naiad	6	
	Potamogeton gramineus	Variable pondweed	7	
	Zosterella dubia	Water stargrass	6	
	Vallisneria americana	Wild celery	6	

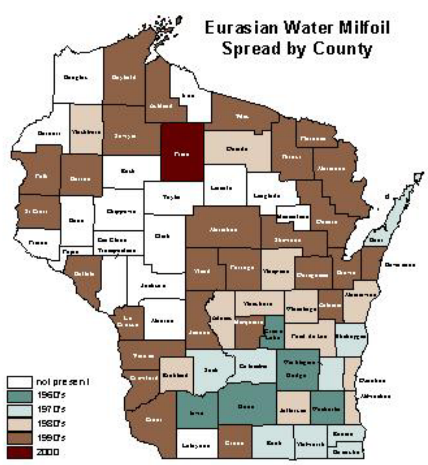

Figure 7. Eurasian water-milfoil spread in Wisconsin counties. Graphic courtesy of Wisconsin DNR.

Excluding the two exotics, Big Hills Lake has a *species richness* of 20. This is higher when compared to the *median value* of other lakes within the same ecoregion (Figures 8 and 9). Species richness should not be confused with species diversity. Richness is simply the number of species, while diversity is an index of the number of species and their respective abundances relative to the other species. A diverse plant community has many species that are equally abundant. Although Big Hills Lake has relatively high species richness, the relative frequency of occurrence (Figure 10) and coverage (Figure 11) data indicate that it is not a highly diverse community because it is largely dominated by only a few species, such as Eurasian water-milfoil, muskgrass (*Chara sp.*) and slender naiad (*Najas flexilis*). Furthermore, it is quite evident that there is a definite lack of emergent vegetation around the lake (Figure 12). It was surprising that common emergent species like arrowhead (*Sagittaria latifolia*), and other bulrushes, such as hardstem and softstem bulrush (*Scirpus acutus* and *S. validus*, respectively) were not found in addition to the threesquare. It is especially interesting that we did not find softstem bulrush as was found during the two previous surveys. Northern pike use emergent vegetation for spawning, so the lack of suitable habitat may affect their success. It is likely that *anthropogenic* influences, such as shoreland development and boating may be responsible for the low occurrences of emergents.

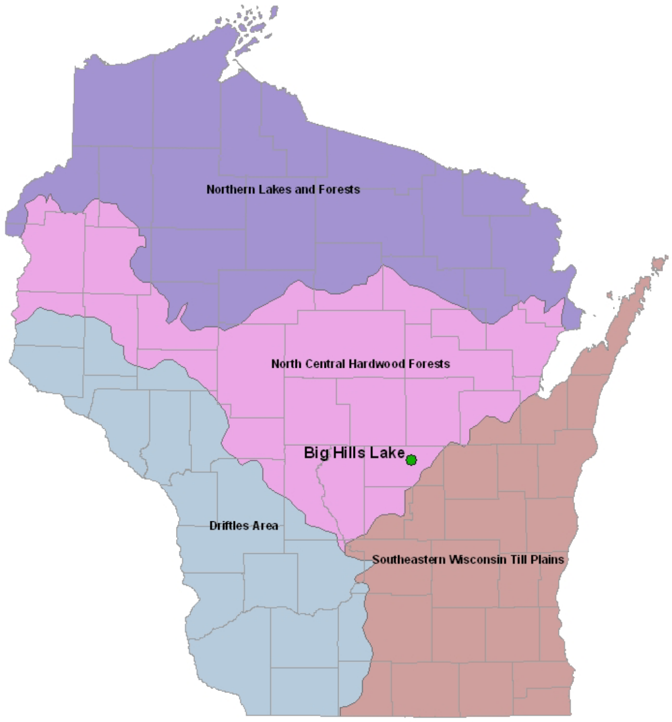

Figure 8. Location of Big Hills Lake relative to the ecoregions of Wisconsin after Nichols 1999 and Omernick and Gallant 1988.

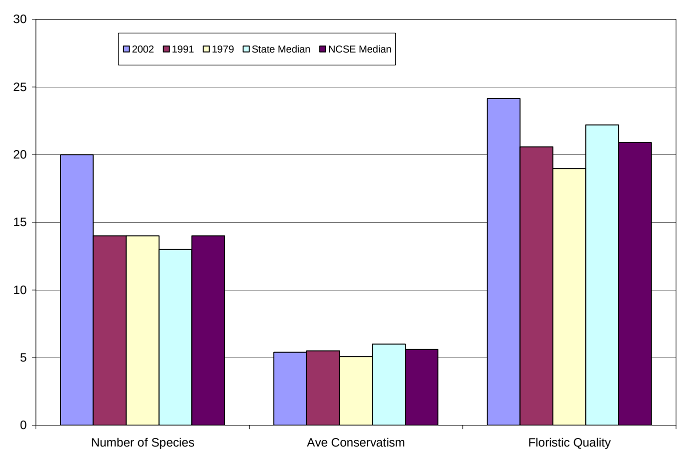

Figure 9. Floristic Quality Assessment (FQA) results for current and historic datasets of Big Hills Lake, the ecoregion and state. The ecoregion results shown are a combination of results from the North Central Hardwood Forest and Southeastern Wisconsin Till Plains ecoregions (Nichols 1999).

Two aquatic plant surveys were completed in addition to the most current inventory fulfilled for this study. The methods for the earlier inventories differed from the methods used for this study in that they were completed via rake tows and not through in-situ observations as with the current inventory (see Methods Section). This fact must be taken into account during the analysis and the reader should realize that differences may not just be attributable only to actual changes overtime.

The Floristic Quality Assessment (FQA) (see Methods Section) completed for Big Hills Lake indicates the species richness found during the current study was well above those found during historic inventories and those found for other lakes in the NCSE ecoregion (Figure 9). However, this pattern does not follow through in the determination of average conservatism and the Floristic Quality Index (FQI), where differences are negligible. Essentially, this means that even though we found more species when compared to the historic inventories and the regional and state medians, those species were not indicative of an undisturbed system. Ignoring the differences in surveying techniques as described above, it could be concluded that there are more species within Big Hills Lake at this time, but those species are relatively common and not indicative of a high quality system. It is true that the FQI for our current data is higher, but this would be expected because we have more species and species richness is a component in the

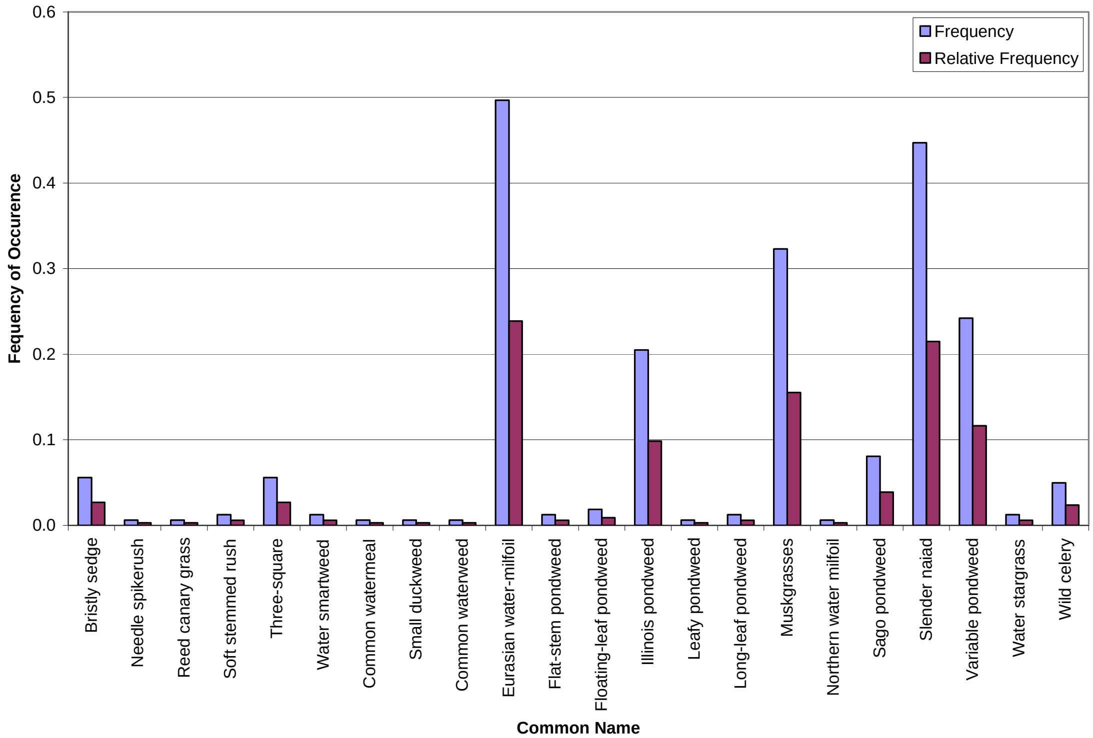

Figure 10. Frequency results for current survey results at Big Hills Lake.

FQI. The current FQI would have been much higher then the others, but it is limited by its lower average conservatism relative to those found in the other datasets. Remember, conservatism is an indication of how sensitive a species is to disturbance. The higher the coefficient of conservatism is for a plant, the less likely that plant will occur in a disturbed system.

Exotic Species

As mentioned above, two exotic species were identified during our aquatic plant survey at Big Hills Lake. Both species are a concern, but the incidence of Eurasian water-milfoil warrants the most because of its potentially devastating affect on the lake ecosystem and its current rate of spread.

Figure 13 depicts the current and past areas of coverage of Eurasian water-milfoil within Big Hills Lake. It is very obvious that this troublesome plant is spreading. It is also obvious (but not surprising) by looking at the locations of occurrence from the 1979 data, that the plant was likely introduced at the boatlanding and has continued to spread throughout the lake from that point. For as much as Eurasian water-milfoil is studied, little is known about its habitat preferences. For instance, it has not been linked with any particular substrate type, including texture or nutrient content. In other words, it has the ability to grow in nearly every type of sediment. This makes it very difficult to predict where it will spread in a lake like Big Hills Lake. Conversely, water celery has a strong substrate preference for sandy areas and can tolerate relatively turbid conditions. These facts make it relatively simple to reasonably predict where water celery will occur and where it will not.

We found Eurasian water-milfoil in every type of substrate available in Big Hills Lake with the exception of sandy rock and coble areas - areas we normally found no rooted plants. We did,

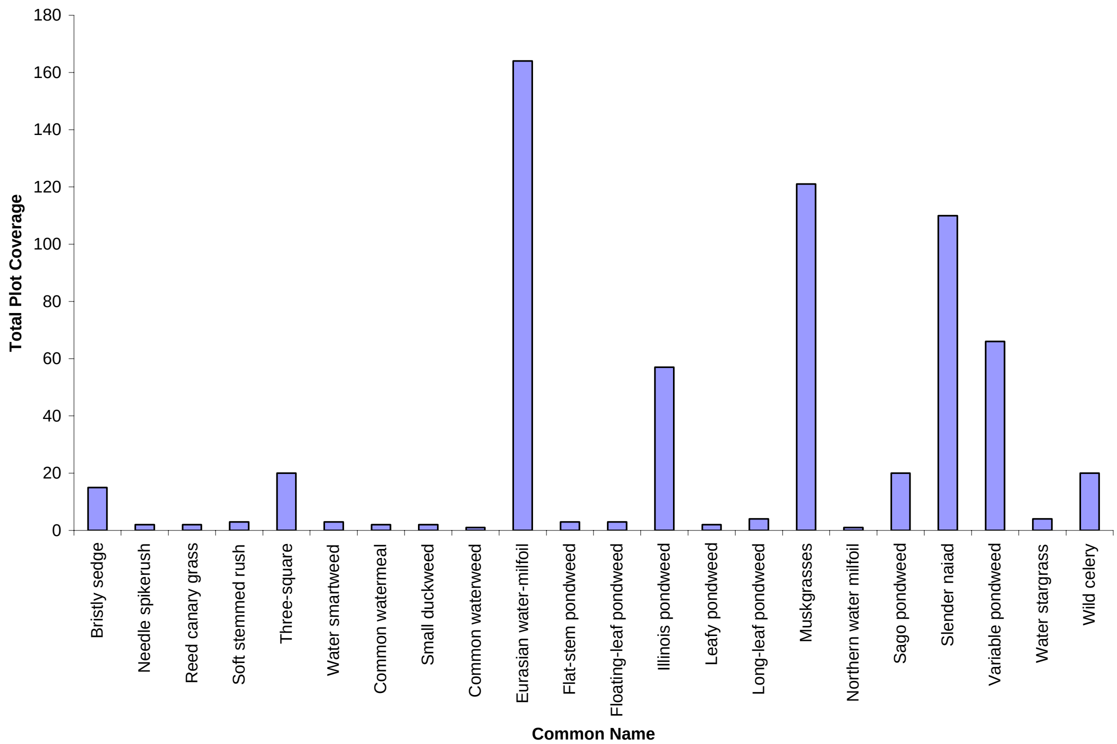

Figure 11. Total Daubenmire coverage results for current survey results at Big Hills Lake.

however, find the highest coverages on silty substrates. Furthermore, the clear waters of Big Hills Lake allowed the plant to grow in a maximum depth of approximately 15-feet. However, on no occasion did we find the plant canopying as it often does in other lakes. In fact, we did not find it closer than two feet from the water surface. At this time there is no verifiable explanation as to why this is the case. A lack of competition by other submergent plant species, in conjunction with excellent water clarity may be one possibility. Another may be cutting by boating activities. Asplund and Cook (1997) found that submergent plant height may be reduced from .66 – 1.96 feet by boats passing over them. Nevertheless, plants growing within two feet of the surface are easily fragmented by boats and other craft traveling at high speeds, which in turn, would help to spread this plant.

Watershed Analysis

The Big Hills Lake watershed is approximately 300 acres, which yields a very favorable watershed to lake area ratio of 2.2:1. In general, lakes with a ratio greater than 10:1 tend to have management problems that revolve around excessive amounts of phosphorus and/or sediments that enter the lake from its drainage basin. This is true because as the drainage area increases, so does the amount of nutrients and sediments that are delivered to the lake. This is not to say that every lake with a watershed to lake area ratio greater than 10:1 experiences problems, because the amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Vegetated areas, such as forests, grasslands, and meadows, allow the water to infiltrate into the ground and do not produce much surface runoff. On the other hand, agricultural areas, particularly row crops, along with residential/urban areas reduce infiltration and increase surface runoff. The increased surface runoff associated with these land coverage types leads to increased pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations.

Field-verified land use data for the Big Hills Lake watershed are listed in Table 3 and displayed in Figures 14 and 15. Currently, the vast majority of land within the Big Hills Lake watershed is forested. As mentioned above, forested areas produce very little surface runoff; in fact, these areas allow over 80% of the precipitation that falls on them to infiltrate the ground. Having a large proportion of the watershed in forested land does a great deal to prevent excessive phosphorus loading to the lake.

Table 3. Land use types and acreages of the Big Hills Lake watershed. Initial coverages were supplied by Waushara County and then field verified.

Land Use Type	Acreage	Percent of Total
Pasture/Grassland	10.5	2%
Forest	205.6	68%
Rural Residential*	84.2	28%
Total	**300.3**	**100%**

*Low density residential with less than one residence per acre.

Modeling results of the land use types listed in Table 3 are shown in Figure 15 (Current Estimate). The results are favorable and expected for a seepage lake with a primarily forested drainage basin such as Big Hills Lake. The results shown in Figure 15 indicate the two biggest contributors to phosphorus loadings to Big Hills Lake are precipitation and atmospheric fallout to the lake surface and potential inputs from septic systems. Of these two sources, the biggest concern rests with the loadings due to septic systems.

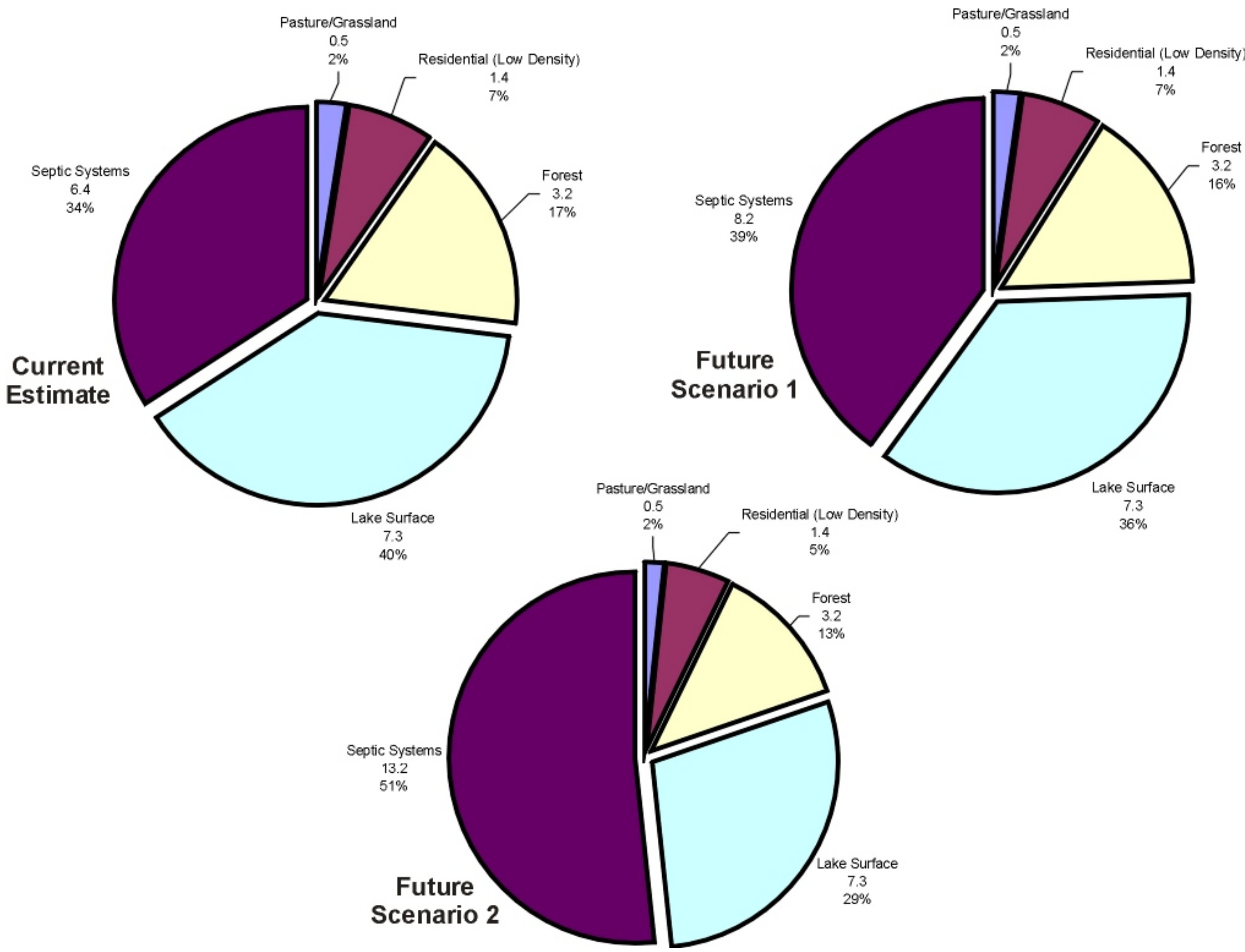

Figure 15. Phosphorus loading values for current and future scenarios from the Big Hills Lake watershed. Loads are listed in lbs/yr of phosphorus.

A formal septic system investigation was not within the scope of this project, nevertheless estimating the potential impact of these sources is very important to the understanding of the phosphorus budget for Big Hills Lake. Therefore, a rough estimation of phosphorus loading from septic systems was calculated using existing data from the report completed by the WDNR in 1983. The model input regarding septic systems is found in Table 4.

Table 4. Input parameter values for comparison septic system scenarios. All scenarios assume each residence has 3.5 occupants. Permanent residencies are occupied 365 days per year, while seasonal residencies are only occupied 60 days per year. One capita year is equal to an individual utilizing the septic system for 365 days. Only systems that are located on sides of the lake that have groundwater flow towards the lake for at least part of the time (Figure 17) were used in the estimates.

	Residencies		Capita Years			Soil Retention Efficiency	Phosphorus Load (lbs/yr)
Scenario	**Permanent**	**Seasonal**	**Permanent**	**Seasonal**	**Total**		
Current Estimate	25	45	87.5	25.9	113.4	75%	6.4
Future Scenario 1	32	55	112	31.7	143.7	75%	8.2
Future Scenario 2	32	55	112	31.7	143.7	60%	13.2

The most important concept to remember concerning the modeling results is that they are only estimates of loading. On its own, an estimate of 6.4 lbs of phosphorus (Current Estimate, Table 4) being added to a lake per year means little because its affect on the lake is dependant on many other variables. Variables such as the volume of the lake, the *water residence time*, and the ultimate fate of the phosphorus all dictate how these loadings affect the health of the lake. In order to create a better understanding of how the phosphorus loads may affect Big Hills Lake; a number of comparisons were calculated (Table 4. and Figure 15) and then related to potential changes in water clarity as measured by Secchi disk depths (Figure 16). One assumption that must be noted in these comparisons is that the changes in clarity would be due to increased algal biomass through increased phosphorus concentrations in the water. It is possible that the increased phosphorus inputs may not exhibit themselves in increased algae blooms, but instead may be exhibited in higher macrophyte biomasses. Either case may lead to an undesirable situation within Big Hills Lake. Assuming that the additional phosphorus loads would be utilized by algae, it is apparent that only a slight increase in the number of septic systems on the lake along with a decrease in their efficiency could have a profound affect on water quality within Big Hills Lake. Both future scenarios are important because they relate potential outcomes of likely situations.

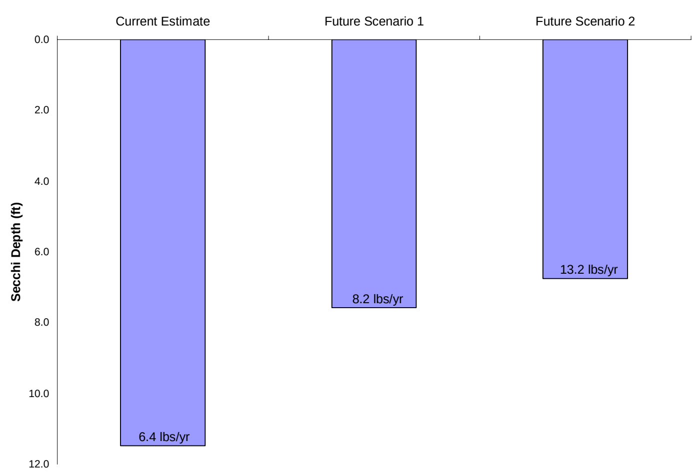

Figure 16. Related Secchi disk depths for different phosphorus loading scenarios. Observed Secchi disk values were used to calculate the average corresponding to the Current Estimate. WiLMS was used to estimate the other averages based on projected phosphorus inputs, also calculated in WiLMS.

Future Scenario 1 was created to mimic the development of the Girl Scout property on the west side of the lake into permanent and seasonal residencies. This is a concern for two reasons: 1) as indicated in Figure 17 there is a definite flux of groundwater into the lake from those properties, and

2) the soils of those properties (like most of the properties around the lake) are primarily composed of excessively drained, sandy, Plainfield series soils that serve well to drain septic effluent away from the septic field, but do little to prevent pollutants from entering the groundwater (USDA SCS 1989) and moving into the lake. One limitation must be noted for this scenario – the potential loading from the Girl Scout camp was not considered and assumed to be low. Future Scenario 2 estimates phosphorus loadings to the lake in the future, after the soils surrounding the septic fields of the properties around the lake have lost some of their ability to retain phosphorus. This projected loss of efficiency is accomplished by reducing the soil retention coefficient in the WiLMS model from the value of 75% utilized in Future Scenario 1 to 60% while leaving the other input values the same. Again, this is a likely occurrence because as septic fields age, they loose their ability to retain (filter out) pollutants, such as phosphorus, nitrogen, and fecal coliform bacteria.

An additional comparison was created to demonstrate the effect of converting a small portion of the forested areas around the lake into developed, lakeshore lots. Two areas were conceptually developed into a total of 11 lots with 100-feet of lake frontage each, equaling a total of 6.6-acres of rural residential land use coverage. Seven of the properties were considered seasonal and four were considered permanent residencies. Other parameters used matched those found in Future Scenario 1 (Table 4). The results of this small change indicate that the new properties would add approximately 1 lbs/yr of phosphorus to Big Hills Lake and reduce its average Secchi disk reading by 0.2 feet when compared to the estimates found in Future Scenario 1. Again, a small change in phosphorus loading can lead to potentially noticeable changes in lake water quality.

RECOMMENDATIONS

Lake Water Quality

Water Quality Protection

As outlined in the Results and Discussion Section, the water quality of Big Hills Lake appears to have remained consistently good over the past two decades; therefore, there are no steps that need to be taken to correct problems. The most appropriate plan is to protect the current water quality of the lake through implementation of the recommendations stated in the Watershed and Aquatic Vegetation sections.

Water Quality Monitoring

Continuous water quality monitoring is an essential component in any lake management plan. Long-term datasets help lake managers detect subtle trends in water quality that cannot be detected with only a year or season's worth of data. Important parameters to include are, chlorophyll-*a*, total phosphorus, Secchi disk transparency, and dissolved oxygen profiles. The Secchi disk information is currently being collected on an annual basis through the efforts of the District's Self-Help Volunteers and should continue. The other data would not necessarily need to be collected on an annual basis, but should be collected at least every three years. The additional data collection over Secchi disk transparency could be implemented in one of the following fashions:

- The Wisconsin Department of Natural Resources has recently initiated a volunteer sampling program through their Small-scale Lake Planning Grant program. Through this program, a lake organization can receive the equipment and chemicals necessary to collect phosphorus and chlorophyll-*a* data for five years. Applications for this grant program are only accepted during the August cycle. For more information, please contact your local WDNR Lakes Coordinator.
- The Water and Environmental Analysis Lab (WEAL) of UW-Stevens Point offers many lake monitoring packages through their Lake Water Quality Program. The Chlorophyll and Phosphorus Monitoring Program would be the most appropriate for use at Big Hills Lake. Through this program, a volunteer from the District would collect water samples using equipment and chemicals supplied by WEAL and then ship them to WEAL for analysis. For more information please visit: https://www.uwsp.edu/cnr/etf/Lake.htm.
- A natural resource consultant could be contracted to collect periodic samples from Big Hills Lake and then have them analyzed by a certified lab. If this course were followed, the District should be sure to hire a qualified consultant that would provide annual reports and data analysis.

Aquatic Vegetation

The results from the aquatic plant survey and analysis raised two concerns; 1) that the aquatic plant community within Big Hills Lake has a definite lack of emergents and species that indicative of a non-disturbed system, and 2) that Eurasian water-milfoil has spread at a considerable rate over the last 23 years. It is very important for every District member to understand that these problems are likely inter-related and that addressing one without the other would be futile. All aquatic plant management plans need to include protection, and if needed, the enhancement of the lake's aquatic plant community; therefore the following recommendations are made concerning the aquatic plants within Big Hills Lake.

In order to slow the spread of Eurasian water-milfoil, it is recommended that 2,4-D (Navigate®, Aqua-Kleen®, etc.) treatments be completed on a portion or all of the areas indicated in Figure 13. An herbicide treatment is preferred over harvesting because harvesting activities may actually spread Eurasian water-milfoil through fragments that are produced, but not collected by the harvester. Harvesting is only appropriate for lakes that have reached the maximum extent of infestation. Big Hills Lake is far from reaching this point because there are many areas, especially in the eastern lobe that could be infested. In the end, the fragmentation associated with harvesting could lead to the spread of Eurasian water-milfoil to these unaffected areas.

2, 4-D is the herbicide of choice because of its selectivity towards broad leaf species like Eurasian water-milfoil. If all areas were to treated, a total of 36 acres, it would cost between $13,680 and $14,760 at a rate of $360-$410 per acre. These cost estimates are considering the same application rate (pounds of chemical per acre) for all areas of the lake that are considered to have Eurasian water-milfoil, as indicated in Figure 13. Therefore, these estimates may be high because the applicator may not need to treat all the areas with the same application rate. In a situation like this, most applicators will simply boat around the lake looking for areas of infestation and only apply the amount of chemical needed to control the plant in that particular area. In the end, the cost would likely be lower than those indicated above, but this can only be determined by the applicator.

The cost could be reduced by only treating a portion of the lake. If economic considerations cause this to be the case, it is recommended that the densest areas be treated first and that the District treat as much as they can afford. Although this method would not reduce the rate of spread as much as if all areas were treated, it would still have beneficial effects. Also, if the District finds that it can afford to treat more than the 6.8 acres that are considered to be the densest infestations (Figure 13), it is recommended that the additional application concentrate on the western lobe of the lake beginning near and moving out from the boatlanding. Following this protocol would likely yield the greatest affect by treating the densest, most heavily used areas.

The most effective timing of herbicide treatments of Eurasian water-milfoil, to say the least, is not clear. Many experts believe the best results are found if the treatments are applied in early June. This line of thought is supported by three facts. First, 2,4-D is a systemic herbicide that needs to be absorbed by the plants to take affect. During the spring, Eurasian water-milfoil is growing at an incredible rate; therefore it will absorb the maximum amount of chemical, which ultimately leads to their demise. Second, the density of Eurasian water-milfoil biomass has not reached its peak at this time, so it will require a lower application rate and result in a lower application cost. Third, affects on native plants are reduced because they are not rapidly growing.

Experts have also found good results with treatments of 2,4-D treatments in the fall. During this time, the plant is still growing, so absorption is not a concern. To reduce the affects on native plants, fall treatments should be conducted after the native species have seeded out and started to die back. Waiting for the native plants to die back also increases the herbicide available for absorption by Eurasian water-milfoil. The timeframe for these treatments could be as late as September, but this should be confirmed with the local WDNR Aquatic Plant Specialist.

Treatments have also been completed during mid summer when Eurasian water-milfoil colonies are at their densest. There are three drawbacks to this treatment timeframe, 1) dense stands of Eurasian water-milfoil may require a higher rate of application (higher cost), 2) native plants are at their peak biomasses and growth rates, which increases their susceptibility to the treatment, and 3) treating the dense stands may result in localized dissolved oxygen deficiencies as a result of plant decomposition.

We recommend either the spring or fall treatment be utilized at Big Hills Lake. If the fall treatment were used, it could likely be completed during 2003, while the spring treatment would need to be conducted in 2004. Concern over additional spread of the plant is minimal and should not be part of the Districts decision as to when the treatment should occur. Advantages of waiting until the spring of 2004 include the additional funds that will likely be available through the District's budget, which would mean that a larger area could be treated; and that spring treatments have a proven affect on Eurasian water-milfoil opposed to the less-proven record of fall treatments. In the end, the decision is the District's and the local WDNR Aquatic Plant Management Specialist.

No matter what timeframe is chosen, follow-up, including monitoring and additional treatments, is very important. The best long-term results are found with continued monitoring that dictates additional treatments. In lakes with limited areas of infestation, follow-up treatments may only include hand-pulling of remaining, unaffected plants. This is probably not a feasible path for Big Hills Lake because the infestation is fairly wide-spread; therefore, follow up treatments would be completed with additional 2,4-D treatments. Additional treatments would be less costly because the areas that need to be treated should be reduced by the initial application. If the initial treatment were completed during the spring of 2004, monitoring would need to be completed during the summer of 2004, preferably in July and possibly again in September. If Eurasian water-milfoil plants were found in the treated areas during either of the monitoring surveys, additional treatments could be completed that summer or fall. The lake should then be surveyed during the spring of 2005 to determine application areas for that spring (if they are required and the District is willing to accept the costs).

If a treatment was completed during the fall of 2003, the lake would need to inventoried during the spring of 2004. At that time, the need for additional spring applications could be determined and executed, if required. Monitoring should then be repeated during the summer and fall of that year as stated above.

Monitoring could be completed either by the firm completing the applications, volunteers from the District, or by a qualified natural resource consultant. Cost savings would be the obvious advantage to using District volunteers, while experience and ready access to the necessary GPS equipment needed to properly mark the colonies would be the advantages of using professionals.

If the District decides to complete the herbicide treatments, it is also recommended that they attempt to enhance the aquatic native aquatic plant community as well. This would be accomplished by planting native aquatic plants in the areas that were treated. Only areas that had dense stands of Eurasian water-milfoil would need to be planted with submergent species because other areas of the lake have sufficient submergents to spread to the areas where the Eurasian water-milfoil once existed. Other areas of the lake that do not receive excessive boat-induced wave action should be restored with emergent species. One possible area for emergent enhancement would be in the bay near the boat landing. Other areas would need to be determined by the District using their knowledge of boat traffic patterns.

It cannot be stressed enough how important this part of the plan is. The use of herbicide treatments would help to take away some of the competitive advantage that the Eurasian water-milfoil has over native species. Removing the Eurasian water-milfoil through herbicide applications would open areas of the lake for recolonization either by natives or the Eurasian water-milfoil. Introducing native plants to these areas would help ensure that those areas are established by desirable plants and help prevent recolonization by exotics. Please note that only native plants that occur in Big Hills Lake now or have occurred in the past should be used for the plantings. This is especially true of the submergents; exceptions could be made for the emergents if the introduced species were common in the area (e.g. common arrowhead, bur-reed, etc.). Professional advice from the WDNR or a qualified consultant must be sought regarding all plantings.

The cost of these enhancements would depend on a number of variables, including the size of areas to be replanted, the types of plants used, the source of the plants, and the costs of installation. It is likely that District members would be able to install some the submergent plants in shallower areas; installation in deeper areas would need to be completed using SCUBA. There are firms that can be contracted to complete the installations in deeper areas. Other lake groups have used diving clubs to install plants at a substantial cost savings.

Finally, if the District decides to have an application completed during the spring of 2004, it is further recommended that the densest areas of infestation be marked with buoys to keep boat traffic in those areas to a minimum. This would help to reduce fragmentation and subsequent spread of Eurasian water-milfoil. Two steps would need to be taken before these buoys are placed; 1) the local WDNR Conservation Warden should be contacted to discuss the buoys, and 2) notices should be placed at the boatlanding and in the District newsletter to inform boaters on the purpose of the buoys.

Contracting a Herbicide Applicator

We recommend that the District contact at least three herbicide applicators to collect proposals and bids concerning the proposed treatment of Eurasian water-milfoil at Big Hills Lake. Each applicator should submit the following:

1. A full cost breakdown for herbicide application, travel expenses, preparation of permit application, and additional costs for post-treatment monitoring.
2. An application plan outlining brand of 2,4-D, areas of application, treatment schedule, and if applicable, post-treatment monitoring.
3. Contact information for at least three clients that have been served in the last two years.

It is important that the District hire an experienced and reputable applicator to complete the treatments; therefore, all references should be contacted for information.

Three possible firms are listed below:

Aquatic Biologists, Inc.	Marine Biochemists	Lake Management, Inc.
N5174 Summit Court	6316 W. Eastwood Ct.	541 Westview Drive
Fond du Lac, WI 54935	Mequon, WI 53092	Barron, WI 54812
(920) 921-6827	888-558-5106	(715) 537-3669

Additional applicators can be found on the UW-Extension website under the Lake List.

Watershed

As mentioned in the Results and Discussion section, the current state of the Big Hills Lake watershed is favorable to the health of the lake. The fact that the majority of the watershed is currently forested assures that excess runoff carrying phosphorus and other pollutants will not enter the lake. However, there should be some concern over present and future septic systems near the lake. With the exception of conversion of forested areas to residential lots or agricultural use, an increased loading rate from septic systems will likely have the greatest impact on the health of Big Hills Lake. Increased loading from septic systems could occur in primarily two ways: 1) septic system failure and/or decreased efficiency, and 2) additional septic systems being installed around the lake. Both possibilities appear to be imminent.

Newer septic systems tend to function better than older systems, so the immediate concern should be with the existing, older systems on the lake. By state law, a septic system is considered to be failing if untreated wastewater is backed up into the building, seeps to the soil surface, enters surface or groundwater, or moves into the soil's saturated zone. With the exception of being backed up into the building, all of these failures could potentially increase nutrient loading to Big Hills Lake. The Wisconsin Department of Commerce estimates that nearly 1-in-5 septic systems are failing in Wisconsin.

Unfortunately, dealing with septic system issues on lakes is traditionally a very touchy subject because dealing with a failing system can result in a large expense for the property owner. However, if the protection of Big Hills Lake is truly the goal of the District and its members, these inhibitions towards septic system problems must be overcome to meet this goal. According to the draft copy of the Big Hills Lake Management District's Long Range Plan of 1996, 25 septic systems were tested and those found to be faulty were corrected at the owner's expense. This must have occurred sometime after 1985 and before 1996 when the plan was written. The willingness of the District to confront these problems in the past (likely over a decade ago) indicates that there is a base to expand upon concerning the septic systems around the lake.

Fortunately, newly installed systems in Waushara County are required to keep a regular maintenance schedule, including pumping and inspections every three years. A maintenance schedule such as this will do a great deal to protect the lake as the old Girl Scout property is developed. Furthermore, the work already completed by the District concerning the setbacks will help minimize impacts from the newly installed residences and their septic systems. Unfortunately, neither the county nor the state requires similar maintenance schedules for older systems; therefore, the push for septic system inspections, maintenance, and even replacement needs to be from the District and its members.

It is recommended that the District pass a resolution to have all systems not covered by the county's regulations described above inspected within the next two years. Grants may be available to fund up to 75% of these efforts through the WDNR Lake Planning Grant Program. Furthermore, the District should require all properties to have their septic tanks pumped at least every three years, depending on the size of the tank and the amount the system is used. Determining the schedule for different classifications of systems based on their size and use could likely be determined by the company that would be contracted to complete the inspections. This plan should go as far as having reminder cards sent out to property owners that would require their return and the signature of a licensed plumber or sanitation service after the pumping is completed. Records would be maintained by the District. Penalties for noncompliance could be determined by the District, but it is likely that the possibility of a property being listed in the District's newsletter as not performing its maintenance pumping would be enough to keep most owners in compliance. The cost involved with the development of this program, including the cost of card printing, could also be partially funded through the grant mentioned above.

If systems are found to be failing, they may be required by county or state regulations to be corrected. The Wisconsin Department of Commerce partially funds private sewage system replacements through their Wisconsin Fund, Private Sewage System Replacement and Rehabilitation Grant Program, but the requirements are stringent and include that the system must be serving the owner's principal residence and that the owners not make in excess of a specified annual income. More information about this grant program can be found on the Dept. of Commerce website or by calling (608) 267-7113.

Education

Education is an incredibly important aspect of any lake management plan. Informing District members about District activities is very import, but the education of its members is as important, if not more important. Educational topics should include:

- Lake Stewardship
  - A lake steward understands their affect on the lake ecosystem and takes measures to protect and enhance it. They also understand that protecting the ecosystem as a natural resource and not just a recreational resource is important to all lake uses, including fishing, swimming, boating, and enjoying the aesthetics of the lake.
- The Use of Herbicides in Lakes
  - This is an especially important topic for Big Hills Lake. Education on this topic should include the benefits and drawbacks of herbicide use along with information on why these chemicals have an acceptable risk associated with their use.
- Property Management
  - This topic can be tied to lake stewardship and should include information on the use of lawn fertilizers, the maintenance of septic systems, and methods of blending structures with the natural landscape. This topic should also include information on natural buffer strips that can be used to minimize soil erosion and nutrient loading to the lake from private properties.

METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Big Hills Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake. Samples were collected with a 3-liter Van dorn bottle at the subsurface (S) and near bottom (B), and occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following normal protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included:

	Spring		**June**		**July**		**August**		**Fall**		**Winter**	
Parameter	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Dissolved Phosphorus	●	●			●	●						
Chlorophyll <u>a</u>	●	●	●		●		●		●			
Total Kjeldahl Nitrogen	●	●			●	●					●	●
Nitrate-Nitrite Nitrogen	●	●			●	●					●	●
Ammonia Nitrogen	●	●			●	●					●	●
Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Total Suspended Solids	●	●			●	●	●	●	●	●	●	●
Calcium	●	●			●							

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was be completed using a Hydrolab DataSonde 4.

Aquatic Vegetation

Transect Surveys and Macrophyte Community Mapping

Quantitative aquatic vegetation surveys were conducted during August 1 and 5, 2002 by sampling transects located along the shoreline of the lake (Figure 12). Sampling was completed via boating, wading, and snorkeling. In order to map the macrophyte communities and to assist in determining the frequency and location of transects, visual inspections were completed throughout the lake using a combination of sketches and notes created on hardcopy maps and position data recorded with a Trimble GeoExplorer 3 GPS/Data Collector. On each transect, a ten-foot diameter circle was sampled within each of five different depth ranges (Table 5). The maximum depth of sampling was determined through field observation of the approximate maximum depth of aquatic vegetation growth. At each sampling location, substrate type and species composition were recorded.

Table 5. Depth codes and ranges sampled during transect surveys.

Depth Code	Depth Range (feet)
1	0.0-1.5
2	1.5-3.0
3	3.0-5.0
4	5.0-10.0
5	>10.0

A visual estimate of percent foliage cover for each species was also recorded at the sampling locations. Coverage is determined as the perpendicular projection to the ground from the outline of the aerial parts of the plant species and is typically reported as the percent of total area (e.g., substrate or water surface) covered (Brower et al. 1990). For emergent and floating-leaf vegetation, the percent of water surface covered was used in the visual estimate, and for submergent vegetation the percent of substrate covered was used. After the collection of field data, the Daubenmire Classification Scheme (Mueller-Dumbois and Ellenberg 1974) was used to rank each species observed according to estimated foliage cover (Table 6). By providing a range of percent foliage cover for each rank, the Daubenmire Classification Scheme helps to minimize errors due to observer bias, visual estimation, etc.

Table 6. Daubenmire Classification Scheme cover ranking system.

Percent Foliage Cover	Rank
0-5	1
5-25	2
25-50	3
50-75	4
75-95	5
95-100	6

The collected transect data was used to estimate frequency of occurrence and relative frequency of occurrence for each species observed. The frequency of occurrence is defined as the number of times a given species occurred on the total plots of all transects sampled. The relative frequency of occurrence is the frequency of that species divided by the sum of the frequencies of all species in the community (Brower et al. 1990). Sum coverage is the total Daubenmire cover found for each plant.

Floristic Quality Assessment

A Florist Quality Assessment (FQA) was applied to the aquatic vegetation species lists generated for Big Hills Lake using the methodology of Nichols (1999). FQA is a rapid assessment metric used to assist in evaluating the floristic and natural significance of a given area. The assessment system is not intended to be a stand alone tool, but is valuable as a complementary and corroborative method of evaluating the natural floristic quality of a lake ecosystem.

The primary concept in FQA is species conservatism. Each native species found in the lake was assigned a coefficient of conservatism (*C*) ranging from 0 to 10. The coefficient of conservatism estimates the probability that a plant is likely to occur in a landscape relatively unaltered from what is believed to be pre-settlement condition. A *C* of 0 indicates little fidelity to a natural community, and a *C* of 10 is indicative of restriction to high quality, natural areas. The FQA was applied by calculating a mean coefficient of conservatism for all species observed in the lake. The mean *C* was then multiplied by the square root of the total number of species to yield a

Floristic Quality Index (FQI). Examination of the floristic quality index within the context of statewide and regional trends was used to provide an overall evaluation of the floristic quality of Big Hills Lake.

Watershed Analysis

The watershed analysis began with an accurate delineation of Big Hills Lake's drainage area using U.S.G.S. topographic survey maps. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land use data supplied by Waushara County were then combined to determine the preliminary watershed land use classifications. The watershed delineation and land use classifications were field verified during the fall of 2002.

The preliminary data were then corrected with the field verified data within the GIS and watershed area and acreages for each land use type were calculated. These data, along with historic and current water quality data were inputted into the Wisconsin Lake Modeling Suite (WiLMS) to determine potential phosphorus loads to the lake.

Population and use data concerning the septic system analysis were generalized data taken from the Wisconsin Department of Natural Resources report of 1983.

Education

Educational components were accomplished through a "Kick-off Meeting" held in June 2002, project updates created for inclusion in the District's newsletter, an article that appeared in the Oshkosh Northwestern, and a "Project Completion Meeting" at which the final report and recommendations were presented to the District. All of these materials are included in Appendix D.

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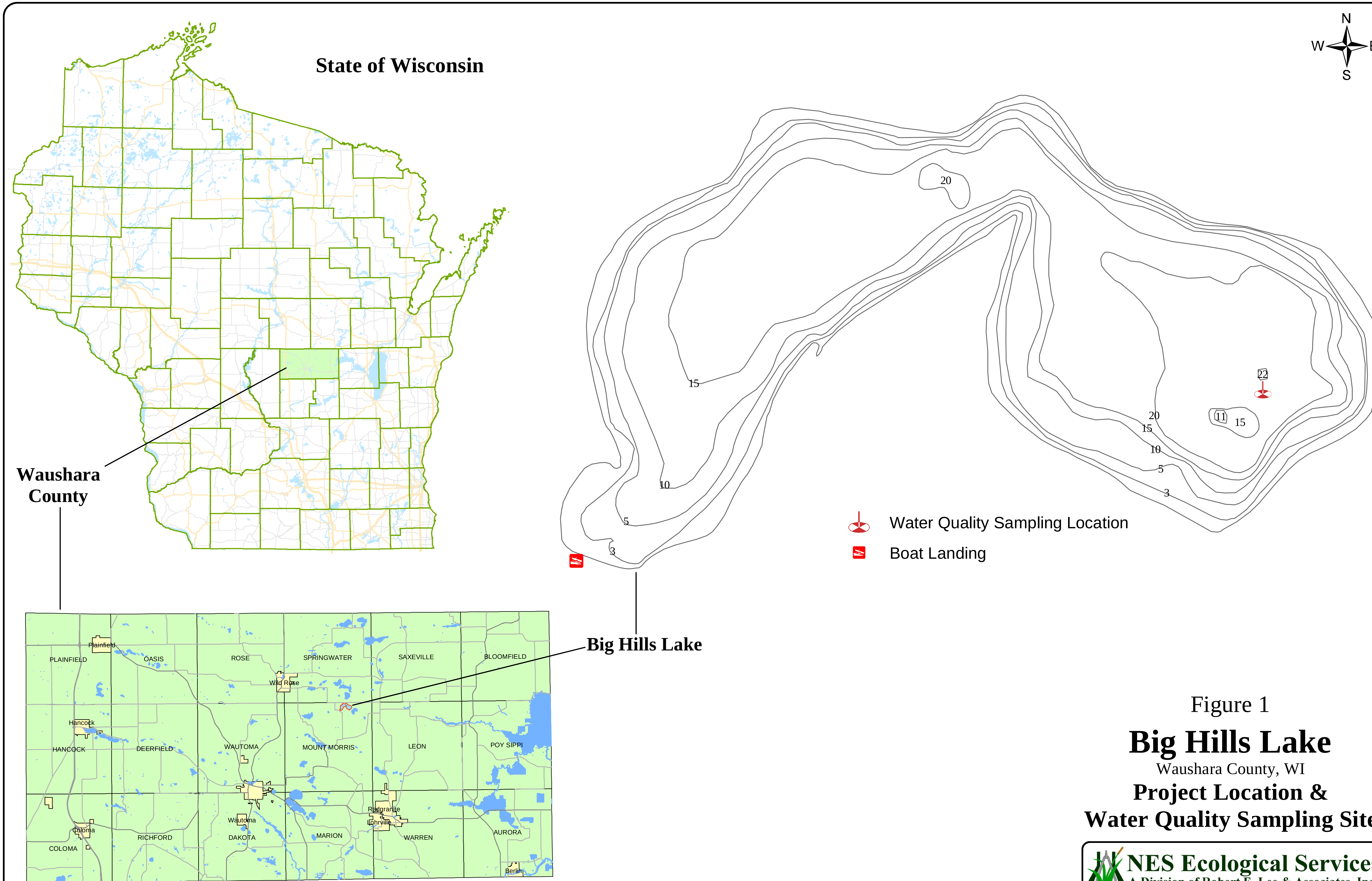

Figure 1

Big Hills Lake

Waushara County, WI

Project Location & Water Quality Sampling Site

NES Ecological Services

A Division of Robert E. Lee & Associates, Inc.

Figure 12

Big Hills Lake

Waushara County, WI

Aquatic Plant Communities

Submergent Communities

Species Listed in Order of Dominance

- Eurasian Water-milfoil,
- Muskgrass,
- Muskgrass, Slender Naiad
- Muskgrass, Variable Pondweed
- Water Celery,

Emergent Communities

Species Listed in Order of Dominance

- Threesquare
- Transects

N W E S

NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.

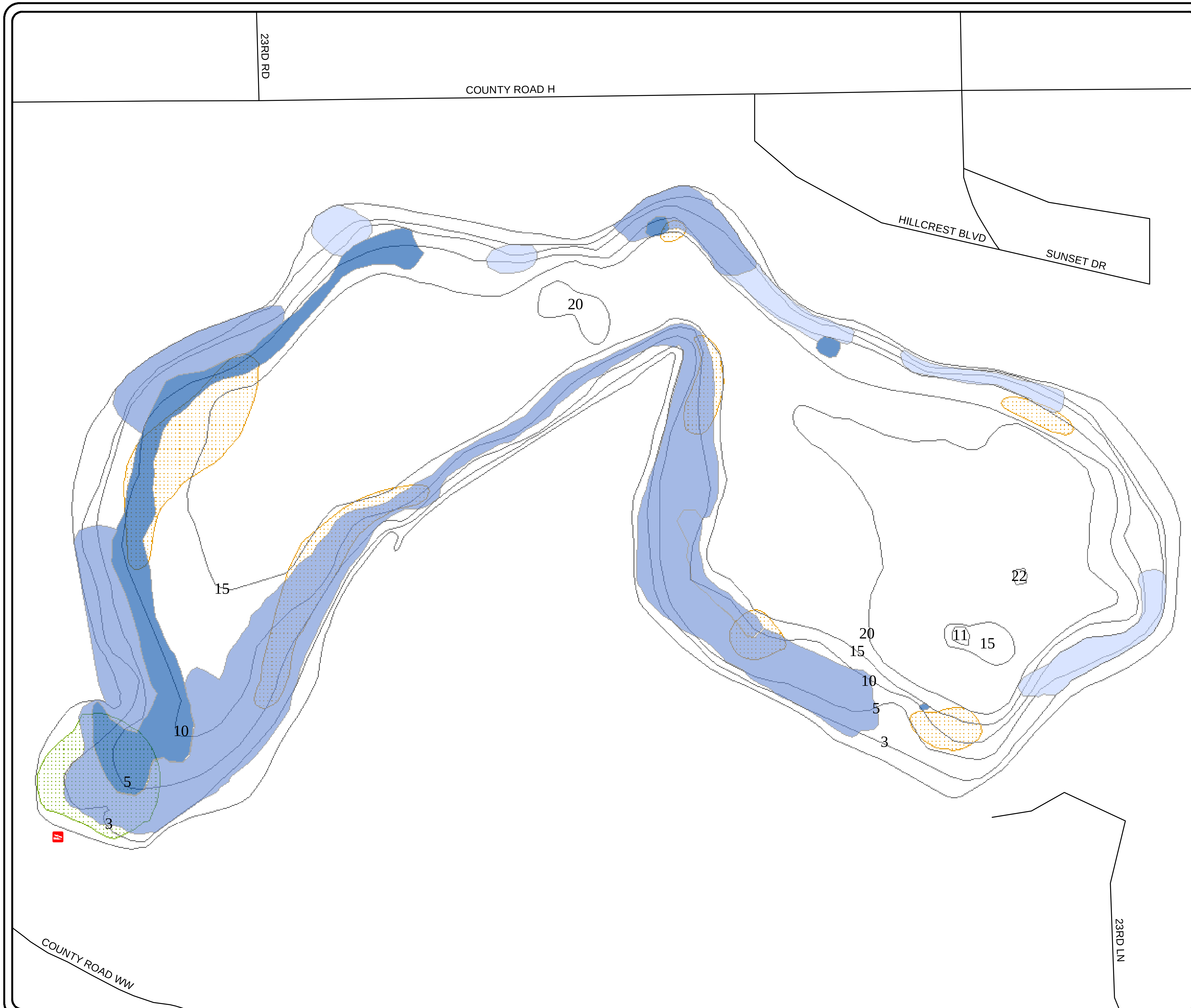

Figure 13

Big Hills Lake

Waushara County, WI

Eurasian Water-milfoil Locations and Densities

Density Classification (2002)

- Very Sparse (4.2 ac.)
- Sparse (25.0 ac.)
- Dense (6.8 ac.)

Previous Areas of Occurence

- 1991
- 1979

N W E S

NES Ecological Services
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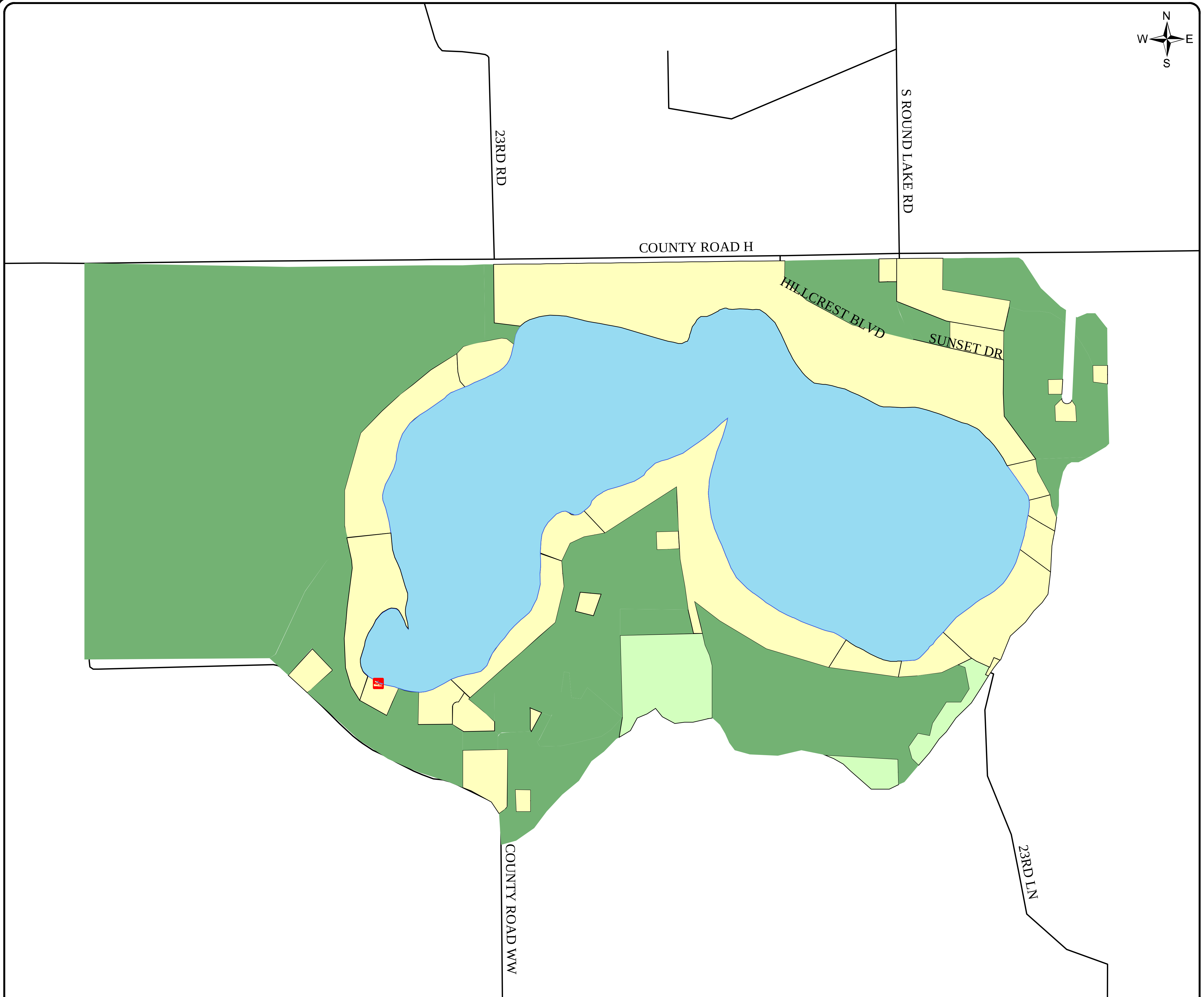
Figure 14

Big Hills Lake

Waushara County, WI

Watershed Land Use Classifications



Land Use Classification

- Forested
- Lake
- Pasture/Grass
- Rural Residential

NES Ecological Services
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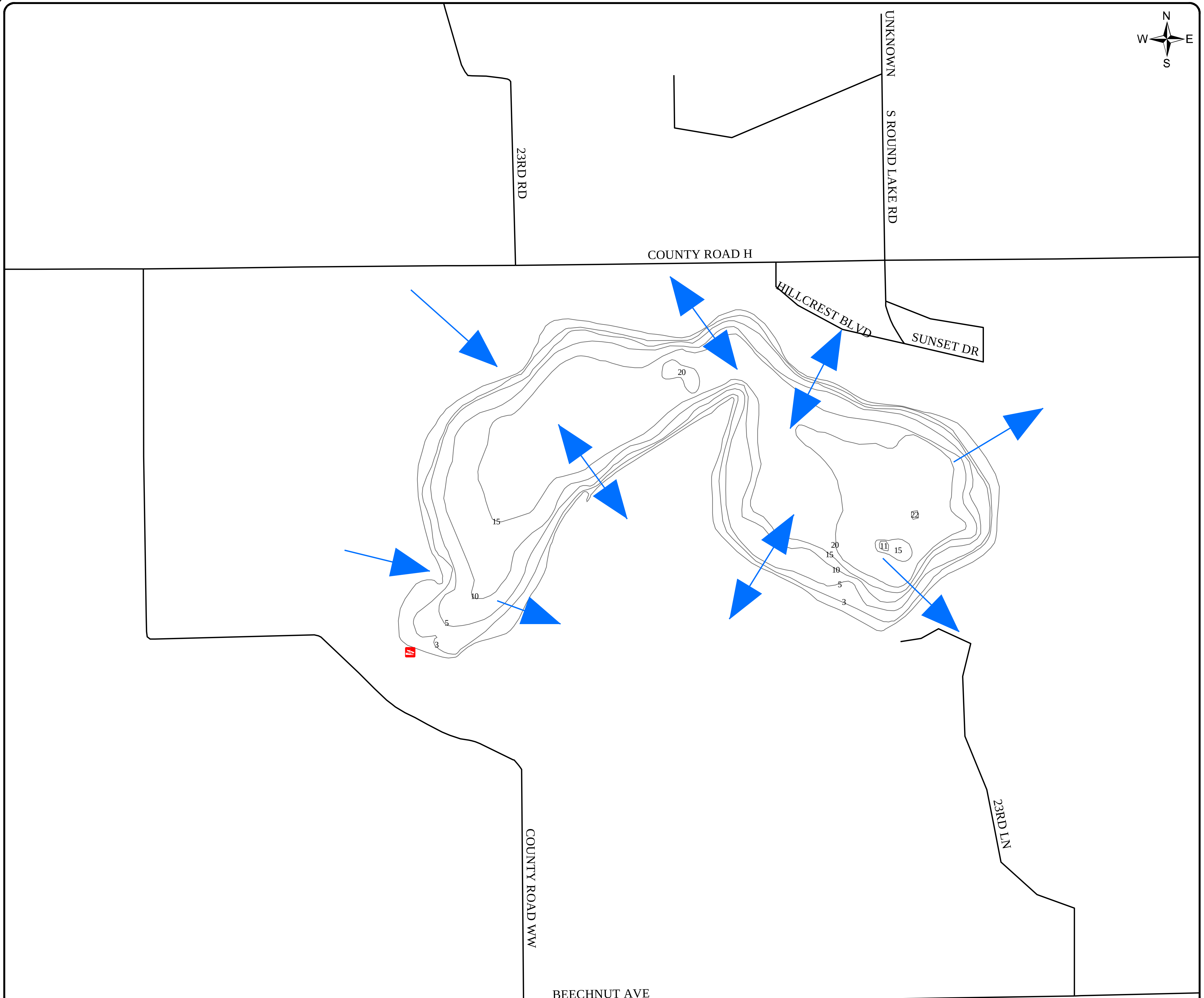
Figure 17

Big Hills Lake

Waushara County, WI

Groundwater Flow Direction (WDNR 1983)



Direction of Groundwater Flow

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A

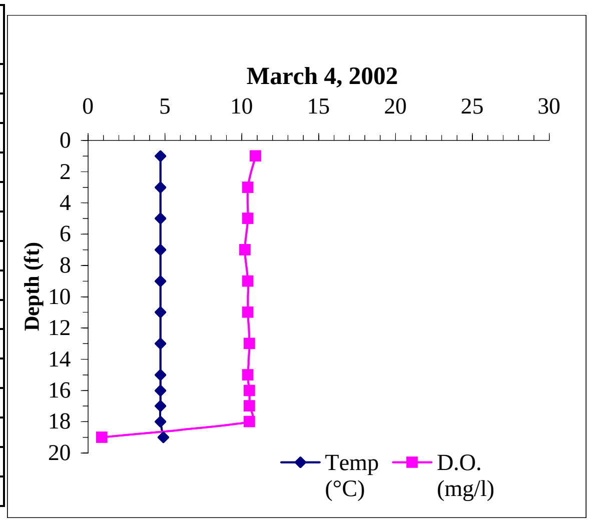
APPENDIX A

Water Quality Dataset Collected During 2002

Big Hills Lake

Date: **03-04-02** **Max Depth (ft):** 21.2
Time: 10:00 **BHLS Depth (ft):** 3.0
Weather: 0degrees, clear, snow 3 days earlier **BHLB Depth (ft):** 18.0
Ent: BGN **Verf:** BN/JE **Secchi Depth (ft):** 15.9

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	4.7	10.9	7.8	194
3.0	4.7	10.4	7.8	195
5.0	4.7	10.4	7.7	195
7.0	4.7	10.2	7.8	195
9.0	4.7	10.4	7.8	195
11.0	4.7	10.4	7.8	194
13.0	4.7	10.5	7.9	195
15.0	4.7	10.4	7.8	195
16.0	4.7	10.5	7.8	195
17.0	4.7	10.5	7.8	195
18.0	4.7	10.5	7.8	195
19.0	4.9	0.9	7.4	219



Parameter	BHLS	BHLB
Total P (mg/l)	0.012	0.014
Dissolved P (mg/l)		
Chl a (µg/l)		
TKN (mg/l)	0.580	0.768
NO_4+NO_3-N (mg/l)	0.116	0.125
NH_3-N (mg/l)	0.051	0.054
Total N (mg/l)		0.893
Lab Cond. (µS/cm)		
Lab pH		
Alkal (mg/l $CaCO_3$)		
Total Susp Sol (mg/l)	2	4
Calcium (mg/l)		

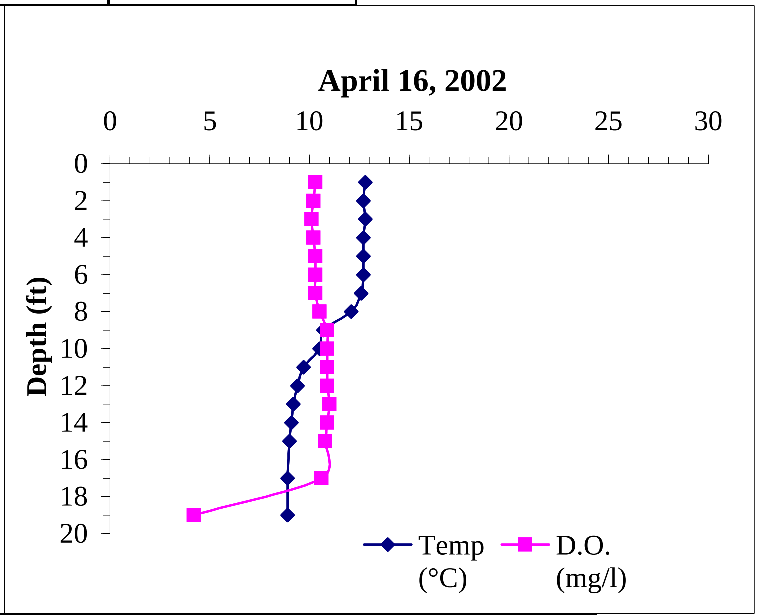
Notes: 0.7' Ice

Big Hills Lake

Date: **04-16-02** **Max Depth (ft):** 21.4
Time: 10:56 **BHLS Depth (ft):** 3.0
Weather: **BHLB Depth (ft):** 18.0
Ent: BGN **Verf:** BN/JE **Secchi Depth (ft):** 18.9

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	12.8	10.3	8.0	185
2.0	12.7	10.2	8.0	185
3.0	12.8	10.1	8.0	185
4.0	12.7	10.2	8.0	186
5.0	12.7	10.3	8.0	186
6.0	12.7	10.3	8.0	185
7.0	12.6	10.3	8.0	186
8.0	12.1	10.5	8.0	184
9.0	10.7	10.9	8.0	183
10.0	10.5	10.9	8.0	183
11.0	9.7	10.9	8.0	183
12.0	9.4	10.9	8.0	184
13.0	9.2	11.0	8.0	183
14.0	9.1	10.9	8.0	183
15.0	9.0	10.8	8.0	184
17.0	8.9	10.6	8.2	183
19.0	8.9	4.2	8.2	208

Parameter	BHLS	BHLB
Total P (mg/l)	0.010	0.014
Dissolved P (mg/l)		
Chl a (µg/l)	2	7
TKN (mg/l)	0.580	0.640
NO_4+NO_3-N (mg/l)	0.202	0.173
NH_3-N (mg/l)	0.049	0.031
Total N (mg/l)	0.782	0.813
Lab Cond. (µS/cm)	217	217
Lab pH	8.02	8.1
Alkal (mg/l $CaCO_3$)	92	92
Total Susp Sol (mg/l)		
Calcium (mg/l)	20.9	20.9

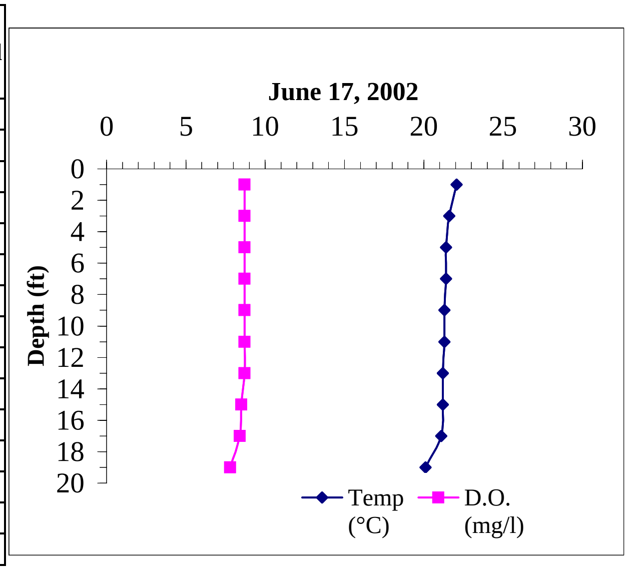


Notes:

Big Hills Lake

Date: **06-17-02** **Max Depth (ft):** 21.2
Time: 10:51 **BHLS Depth (ft):** 3.0
Weather: clear 74 **)epth (ft):** 18.0
Ent: BGN **VER** BN/JE **Secchi Depth (ft):** 15.9

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	22.1	8.7	8.6	207
3.0	21.6	8.7	8.6	207
5.0	21.4	8.7	8.6	208
7.0	21.4	8.7	8.6	207
9.0	21.3	8.7	8.7	208
11.0	21.3	8.7	8.7	208
13.0	21.2	8.7	8.7	208
15.0	21.2	8.5	8.6	208
17.0	21.1	8.4	8.6	209
19.0	20.1	7.8	8.3	211



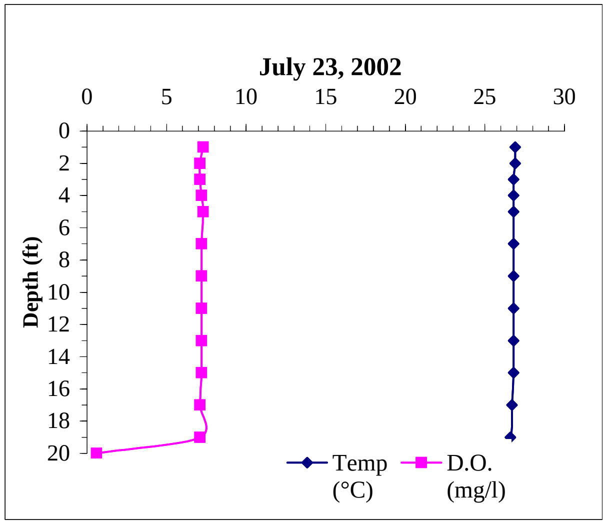
Parameter	BHLS	BHLB
Total P (mg/l)	0.039	0.031
Dissolved P (mg/l)		
Chl a (µg/l)	1	
TKN (mg/l)		
NO_4+NO_3-N (mg/l)		
NH_3-N (mg/l)		
Total N (mg/l)		
Lab Cond. (µS/cm)		
Lab pH		
Alkal (mg/l $CaCO_3$)		
'otal Susp Sol (mg/l)		
Calcium (mg/l)		

Notes:

Big Hills Lake

Date: 07-23-02 **Max Depth (ft):** 20.8
Time: 10:27 **BHLS Depth (ft):** 3.0
Weather: 72 clear **Depth (ft):** 18.0
Ent: BGN **Verf:** BN/JE **Secchi Depth (ft):** 10.2

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (μS/cm)
1.0	26.9	7.3	9.0	210
2.0	26.9	7.1	8.9	211
3.0	26.8	7.1	9.0	210
4.0	26.8	7.2	9.0	211
5.0	26.8	7.3	9.0	211
7.0	26.8	7.2	9.0	211
9.0	26.8	7.2	9.0	210
11.0	26.8	7.2	9.0	211
13.0	26.8	7.2	9.0	211
15.0	26.8	7.2	9.0	211
17.0	26.7	7.1	9.0	211
19.0	26.6	7.1	10.2	211
20.0	25.7	0.6	10.2	250



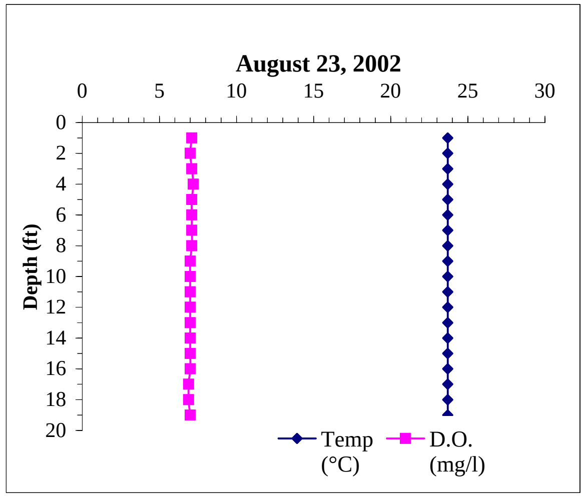
Parameter	BHLS	BHLB
Total P (mg/l)	0.033	0.014
Dissolved P (mg/l)	0.000	
Chl a (μg/l)	1.61	
TKN (mg/l)	0.610	0.530
NO_4+NO_3-N (mg/l)	0.017	0.016
NH_3-N (mg/l)	0.039	0.023
Total N (mg/l)	0.627	0.546
Lab Cond. (μS/cm)	217	217
Lab pH	8.61	8.59
Alkal (mg/l $CaCO_3$)	94	93
Total Susp Sol (mg/l)	5	4
Calcium (mg/l)	22.4	

Notes:

Big Hills Lake

Date:	**08-23-02**	**Max Depth (ft):**	21.2
Time:	9:52	**BHLS Depth (ft):**	3.0
Weather:	overcast, 65, rain	**BHLB Depth (ft):**	18.0
Ent:	BGN **Verf:** TAH/TSN	**Secchi Depth (ft):**	8.2

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	23.7	7.1	8.8	216
2.0	23.7	7.0	9.0	216
3.0	23.7	7.1	8.9	216
4.0	23.7	7.2	8.9	217
5.0	23.7	7.1	8.9	217
6.0	23.7	7.1	8.8	217
7.0	23.7	7.1	8.8	217
8.0	23.7	7.1	8.7	216
9.0	23.7	7.0	8.7	217
10.0	23.7	7.0	8.7	217
11.0	23.7	7.0	8.7	217
12.0	23.7	7.0	8.7	217
13.0	23.7	7.0	8.7	217
14.0	23.7	7.0	8.7	217
15.0	23.7	7.0	8.7	217
16.0	23.7	7.0	8.7	217
17.0	23.7	6.9	8.7	217
18.0	23.7	6.9	8.6	217
19.0	23.7	7.0	8.6	217

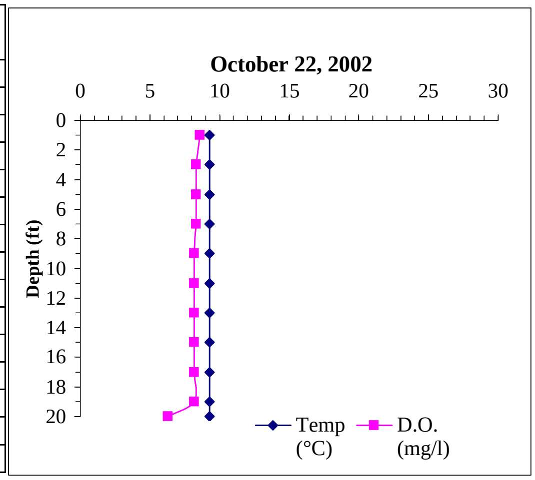


Parameter	BHLS	BHLB
Total P (mg/l)	0.010	0.016
Dissolved P (mg/l)		
Chl a (µg/l)	5.5	
TKN (mg/l)		
NO_4+NO_3-N (mg/l)		
NH_3-N (mg/l)		
Total N (mg/l)		
Lab Cond. (µS/cm)		
Lab pH		
Alkal (mg/l $CaCO_3$)		
Total Susp Sol (mg/l)	4	5
Calcium (mg/l)		

Notes:

Date:	**10-22-02**	**Max Depth (ft):**	21.2
Time:	10:00	**BHLS Depth (ft):**	3.0
Weather:	Overcast	**BHLB Depth (ft):**	18.0
Ent:	tsn **Verf:** TAH/TSN	**Secchi Depth (ft):**	11.6

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	9.3	8.6	8.5	213
3.0	9.3	8.3	8.5	213
5.0	9.3	8.3	8.5	214
7.0	9.3	8.3	8.5	213
9.0	9.3	8.2	8.4	213
11.0	9.3	8.2	8.4	213
13.0	9.3	8.2	8.4	213
15.0	9.3	8.2	8.3	213
17.0	9.3	8.2	8.3	213
19.0	9.3	8.2	8.3	213
20.0	9.3	6.3	7.9	218



Parameter	BHLS	BHLB
Total P (mg/l)	0.011	0.008
Dissolved P (mg/l)		
Chl a (µg/l)	3.57	
TKN (mg/l)		
NO_4+NO_3-N (mg/l)		
NH_3-N (mg/l)		
Total N (mg/l)		
Lab Cond. (µS/cm)		
Lab pH		
Alkal (mg/l $CaCO_3$)		
Total Susp Sol (mg/l)	2	2
Calcium (mg/l)		

Notes:

B

APPENDIX B

Comprehensive Aquatic Vegetation Survey Data

Transect	Depth Range	Substrate	Acronym	Aerial Cover	Max Veg Z	Species	Common Name	Daubenmire Cover	Plot_ID
1	1	sandy	cxcom	5		Carex comosa	Bristly sedge, bottle brush sedge	2	1,1
1	1	sandy	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	1,1
1	1	sandy	potpe	5		Potamogeton pectinatus	Sago pondweed	2	1,1
1	1	sandy	sciam	5		Scirpus americanus	Three-square, chairmaker's rush	2	1,1
1	1	sandy	chasp	1		Chara sp.	Muskgrasses, stoneworts	1	1,1
1	2	sandy	potgr	20		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	1,2
1	2	sandy	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	1,2
1	2	sandy	chasp	1		Chara sp.	Muskgrasses, stoneworts	1	1,2
1	3	sandy	chasp	1		Chara sp.	Muskgrasses, stoneworts	1	1,3
1	3	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	1,3
1	3	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	1,3
1	4	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	1,4
1	4	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	1,4
1	4	sandy	potpe	1		Potamogeton pectinatus	Sago pondweed	1	1,4
1	5	silty	myrsp	20		Myriophyllum spicatum	Eurasian water-milfoil	2	1,5
1	5	silty	potfo	20		Potamogeton foliosus	Leafy pondweed	2	1,5
1	5	silty	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	1,5
2	1	sandy	noveg			NO VEG	NO VEG	0	2,1
2	2	sandy	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	2,2
2	3	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	2,3
2	3	sandy	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	2,3
2	4	silty sand	myrsp	20		Myriophyllum spicatum	Eurasian water-milfoil	2	2,4
2	4	silty sand	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	2,4
2	5	silty	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	2,5
3	1	sandy	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	3,1
3	1	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	3,1
3	2	sandy	chasp	60		Chara sp.	Muskgrasses, stoneworts	4	3,2
3	2	sandy	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	3,2
3	2	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	3,2
3	2	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	3,2
3	3	silty sand	chasp	60		Chara sp.	Muskgrasses, stoneworts	4	3,3
3	3	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	3,3
3	3	silty sand	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	3,3
3	4	silty sand	chasp	10		Chara sp.	Muskgrasses, stoneworts	2	3,4
3	4	silty sand	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	3,4
3	4	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	3,4
3	4	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	3,4
3	5	silty	myrsp	80		Myriophyllum spicatum	Eurasian water-milfoil	5	3,5
3	5	silty	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	3,5
3	5	silty	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	3,5
4	1	cobble w/sand	noveg			NO VEG	NO VEG	0	4,1
4	2	sand w/cobble	potil	10		Potamogeton illinoensis	Illinois pondweed	2	4,2
4	2	sand w/cobble	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	4,2
4	3	silty sand	chasp	40		Chara sp.	Muskgrasses, stoneworts	3	4,3
4	3	silty sand	potil	5		Potamogeton illinoensis	Illinois pondweed	2	4,3
4	3	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	4,3
4	4	silty sand	potil	10		Potamogeton illinoensis	Illinois pondweed	2	4,4
4	4	silty sand	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	4,4
4	4	silty sand	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	4,4
4	4	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	4,4
4	4	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	4,4
4	5	silty	myrsp	60		Myriophyllum spicatum	Eurasian water-milfoil	4	4,5
4	5	silty	potil	20		Potamogeton illinoensis	Illinois pondweed	2	4,5
4	5	silty	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	4,5
4	5	silty	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	4,5
5	1	sand w/cobble	chasp	1		Chara sp.	Muskgrasses, stoneworts	1	5,1
5	1	sand w/cobble	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	5,1
5	1	sand w/cobble	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	5,1
5	1	sand w/cobble	potil	1		Potamogeton illinoensis	Illinois pondweed	1	5,1
5	2	sand w/cobble	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	5,2
5	2	sand w/cobble	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	5,2
5	3	silty sand	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	5,3
5	3	silty sand	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	5,3
5	3	silty sand	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	5,3
5	3	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	5,3
5	4	silty sand	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	5,4
5	4	silty sand	potil	5		Potamogeton illinoensis	Illinois pondweed	2	5,4
5	4	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	5,4
5	4	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	5,4
5	5	silty sand	noveg			NO VEG	NO VEG	0	5,5
6	1	cobble	cxcom	1		Carex comosa	Bristly sedge, bottle brush sedge	1	6,1
6	2	cobble	noveg			NO VEG	NO VEG	0	6,2
6	3	sand	chasp	1		Chara sp.	Muskgrasses, stoneworts	1	6,3
6	4	cobble w/silt	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	6,4
6	4	cobble w/silt	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	6,4
6	4	cobble w/silt	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	6,4
6	4	cobble w/silt	potil	5		Potamogeton illinoensis	Illinois pondweed	2	6,4

Transect	Depth Range	Substrate	Acronym	Aerial Cover	Max Veg Z	Species	Common Name	Daubenmire Cover	Plot_ID
6	4	cobble w/silt	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	6,4
6	5	rock w/silt	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	6,5
7	1	sandy	noveg			NO VEG	NO VEG	0	7,1
7	2	sandy	noveg			NO VEG	NO VEG	0	7,2
7	3	silty sand	chasp	50		Chara sp.	Muskgrasses, stoneworts	4	7,3
7	3	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	7,3
7	4	sandy	valam	30		Vallisneria americana	Wild celery, eel-grass, tape-grass	3	7,4
7	4	sandy	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	7,4
7	4	sandy	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	7,4
7	4	sandy	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	7,4
7	4	sandy	potil	1		Potamogeton illinoensis	Illinois pondweed	1	7,4
7	4	sandy	potna	1		Potamogeton natans	Floating-leaf pondweed	1	7,4
7	5	sandy	valam	40	13	Vallisneria americana	Wild celery, eel-grass, tape-grass	3	7,5
7	5	sandy	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	7,5
7	5	sandy	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	7,5
7	5	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	7,5
7	5	sandy	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	7,5
8	1	sand w/cobble	noveg			NO VEG	NO VEG	0	8,1
8	2	sandy	noveg			NO VEG	NO VEG	0	8,2
8	3	sandy	noveg			NO VEG	NO VEG	0	8,3
8	4	sandy	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	8,4
8	5	sandy	noveg			NO VEG	NO VEG	0	8,5
9	1	cobble	noveg			NO VEG	NO VEG	0	9,1
9	2	sandy	chasp	10		Chara sp.	Muskgrasses, stoneworts	2	9,2
9	2	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	9,2
9	2	sandy	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	9,2
9	2	sandy	potil	1		Potamogeton illinoensis	Illinois pondweed	1	9,2
9	3	silty sand	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	9,3
9	3	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	9,3
9	3	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	9,3
9	3	silty sand	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	9,3
9	4	silty sand	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	9,4
9	4	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	9,4
9	4	silty sand	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	9,4
9	5	silty	noveg		15	NO VEG	NO VEG	0	9,5
10	1	sand w/cobble	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	10,1
10	2	sand w/cobble	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	10,2
10	3	sand	najfl	20		Najas flexilis	Slender naiad, bushy pondweed	2	10,3
10	4	silty sand/cobble	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	10,4
10	5	silty sand/cobble	noveg		13	NO VEG	NO VEG	0	10,5
11	1	sandy cobble	noveg			NO VEG	NO VEG	0	11,1
11	2	silty sand	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	11,2
11	2	silty sand	potil	5		Potamogeton illinoensis	Illinois pondweed	2	11,2
11	3	sandy silt	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	11,3
11	3	sandy silt	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	11,3
11	4	sandy silt	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	11,4
11	5	silty sand	noveg			NO VEG	NO VEG	0	11,5
12	1	sand w/cobble	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	12,1
12	2	sand w/cobble	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	12,2
12	3	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	12,3
12	3	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	12,3
12	4	silty sand	noveg			NO VEG	NO VEG	0	12,4
12	5	silty	myrsp	80		Myriophyllum spicatum	Eurasian water-milfoil	5	12,5
12	5	silty	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	12,5
12	5	silty	potil	1		Potamogeton illinoensis	Illinois pondweed	1	12,5
12	5	silty	potpe	1		Potamogeton pectinatus	Sago pondweed	1	12,5
13	1	sand w/cobble	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	13,1
13	1	sand w/cobble	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	13,1
13	2	sandy silt	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	13,2
13	3	silty gravel	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	13,3
13	3	silty gravel	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	13,3
13	4	silty gravel	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	13,4
13	4	silty gravel	myrsp	5		Myriophyllum spicatum	Eurasian water-milfoil	2	13,4
13	4	silty gravel	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	13,4
13	5	silty	myrsp	5		Myriophyllum spicatum	Eurasian water-milfoil	2	13,5
13	5	silty	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	13,5
14	1	sandy	sciam	5		Scirpus americanus	Three-square, chairmaker's rush	2	14,1
14	1	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	14,1
14	2	sandy	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	14,2
14	2	sandy	myrsp	5		Myriophyllum spicatum	Eurasian water-milfoil	2	14,2
14	2	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	14,2
14	2	sandy	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	14,2
14	3	sandy	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	14,3
14	3	sandy	najfl	20		Najas flexilis	Slender naiad, bushy pondweed	2	14,3
14	3	sandy	myrsp	5		Myriophyllum spicatum	Eurasian water-milfoil	2	14,3
14	3	sandy	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	14,3
14	3	sandy	valam	5		Vallisneria americana	Wild celery, eel-grass, tape-grass	2	14,3

Transect	Depth Range	Substrate	Acronym	Aerial Cover	Max Veg Z	Species	Common Name	Daubenmire Cover	Plot_ID
14	4	silty sand	potil	30		Potamogeton illinoensis	Illinois pondweed	3	14,4
14	4	silty sand	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	14,4
14	4	silty sand	potpe	10		Potamogeton pectinatus	Sago pondweed	2	14,4
14	4	silty sand	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	14,4
14	4	silty sand	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	14,4
14	5	silty	myrsp	80	17	Myriophyllum spicatum	Eurasian water-milfoil	5	14,5
14	5	silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	14,5
14	5	silty	potil	1		Potamogeton illinoensis	Illinois pondweed	1	14,5
15	1	sandy	noveg			NO VEG	NO VEG	0	15,1
15	2	sandy	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	15,2
15	2	sandy	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	15,2
15	3	sandy	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	15,3
15	4	silty sand	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	15,4
15	4	silty sand	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	15,4
15	4	silty sand	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	15,4
15	4	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	15,4
15	5	silty sand	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	15,5
15	5	silty sand	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	15,5
15	5	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	15,5
15	5	silty sand	potil	1		Potamogeton illinoensis	Illinois pondweed	1	15,5
16	1	sandy	noveg			NO VEG	NO VEG	0	16,1
16	2	sandy	noveg			NO VEG	NO VEG	0	16,2
16	3	sandy	chasp	50		Chara sp.	Muskgrasses, stoneworts	4	16,3
16	4	silty sand	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	16,4
16	4	silty sand	myrsp	10		Myriophyllum spicatum	Eurasian water-milfoil	2	16,4
16	5	silty	myrsp	40		Myriophyllum spicatum	Eurasian water-milfoil	3	16,5
16	5	silty	potil	1		Potamogeton illinoensis	Illinois pondweed	1	16,5
17	1	sandy	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	17,1
17	1	sandy	myrsp	5		Myriophyllum spicatum	Eurasian water-milfoil	2	17,1
17	1	sandy	valam	5		Vallisneria americana	Wild celery, eel-grass, tape-grass	2	17,1
17	1	sandy	potpe	1		Potamogeton pectinatus	Sago pondweed	1	17,1
17	1	sandy	sciam	1		Scirpus americanus	Three-square, chairmaker's rush	1	17,1
17	2	sandy	valam	60		Vallisneria americana	Wild celery, eel-grass, tape-grass	4	17,2
17	2	sandy	zosdu	5		Zosterella dubia	Water stargrass	2	17,2
17	2	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	17,2
17	2	sandy	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	17,2
17	3	sandy	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	17,3
17	3	sandy	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	17,3
17	3	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	17,3
17	3	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	17,3
17	4	sandy	chasp	100		Chara sp.	Muskgrasses, stoneworts	6	17,4
17	4	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	17,4
17	4	sandy	potil	1		Potamogeton illinoensis	Illinois pondweed	1	17,4
17	5	silty	myrsp	80		Myriophyllum spicatum	Eurasian water-milfoil	5	17,5
17	5	silty	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	17,5
18	1	sandy	cxcom	10		Carex comosa	Bristly sedge, bottle brush sedge	2	18,1
18	1	sandy	sciam	10		Scirpus americanus	Three-square, chairmaker's rush	2	18,1
18	1	sandy	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	18,1
18	1	sandy	potpe	5		Potamogeton pectinatus	Sago pondweed	2	18,1
18	1	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	18,1
18	2	sandy	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	18,2
18	2	sandy	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	18,2
18	2	sandy	potpe	1		Potamogeton pectinatus	Sago pondweed	1	18,2
18	2	sandy	valam	1		Vallisneria americana	Wild celery, eel-grass, tape-grass	1	18,2
18	3	sandy	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	18,3
18	3	sandy	potgr	30		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	3	18,3
18	4	silty sand	noveg			NO VEG	NO VEG	0	18,4
18	5	silty	myrsp	30		Myriophyllum spicatum	Eurasian water-milfoil	3	18,5
18	5	silty	potil	5		Potamogeton illinoensis	Illinois pondweed	2	18,5
19	1	sandy	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	19,1
19	1	sandy	myrsp	10		Myriophyllum spicatum	Eurasian water-milfoil	2	19,1
19	1	sandy	potpe	5		Potamogeton pectinatus	Sago pondweed	2	19,1
19	1	sandy	potpe	5		Potamogeton pectinatus	Sago pondweed	2	19,1
19	1	sandy	cxcom	1		Carex comosa	Bristly sedge, bottle brush sedge	1	19,1
19	2	sandy	potgr	20		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	19,2
19	2	sandy	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	19,2
19	2	sandy	potpe	5		Potamogeton pectinatus	Sago pondweed	2	19,2
19	3	sandy	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	19,3
19	3	sandy	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	19,3
19	3	sandy	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	19,3
19	4	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	19,4
19	5	silty	myrsp	90		Myriophyllum spicatum	Eurasian water-milfoil	5	19,5
20	1	sandy	chasp	10		Chara sp.	Muskgrasses, stoneworts	2	20,1
20	1	sandy	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	20,1
20	1	sandy	sciam	10		Scirpus americanus	Three-square, chairmaker's rush	2	20,1
20	2	sandy	noveg			NO VEG	NO VEG	0	20,2
20	3	sandy	noveg			NO VEG	NO VEG	0	20,3

Transect	Depth Range	Substrate	Acronym	Aerial Cover	Max Veg Z	Species	Common Name	Daubenmire Cover	Plot_ID
20	4	silty sand	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	20,4
20	4	silty sand	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	20,4
20	4	silty sand	potno	10		Potamogeton nodosus	Long-leaf pondweed	2	20,4
20	4	silty sand	potil	1		Potamogeton illinoensis	Illinois pondweed	1	20,4
20	5	silty	myrsp	90		Myriophyllum spicatum	Eurasian water-milfoil	5	20,5
21	1	sandy	noveg			NO VEG	NO VEG	0	21,1
21	2	sandy	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	21,2
21	2	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	21,2
21	2	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	21,2
21	2	sandy	potpe	1		Potamogeton pectinatus	Sago pondweed	1	21,2
21	3	silty sand	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	21,3
21	3	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	21,3
21	4	silty sand	potil	20		Potamogeton illinoensis	Illinois pondweed	2	21,4
21	4	silty sand	myrsp	5		Myriophyllum spicatum	Eurasian water-milfoil	2	21,4
21	4	silty sand	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	21,4
21	5	silty	myrsp	40		Myriophyllum spicatum	Eurasian water-milfoil	3	21,5
21	5	silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	21,5
22	1	sandy	sciam	20		Scirpus americanus	Three-square, chairmaker's rush	2	22,1
22	1	sandy	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	22,1
22	1	sandy	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	22,1
22	1	sandy	eleac	5		Eleocharis acicularis	Needle spikerush, hairgrass	2	22,1
22	1	sandy	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2	22,1
22	1	sandy	potpe	5		Potamogeton pectinatus	Sago pondweed	2	22,1
22	1	sandy	cxcom	1		Carex comosa	Bristly sedge, bottle brush sedge	1	22,1
22	2	silty sand	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	22,2
22	2	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	22,2
22	3	silty sand	potil	5		Potamogeton illinoensis	Illinois pondweed	2	22,3
22	3	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	22,3
22	3	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	22,3
22	4	silty sand	potil	30		Potamogeton illinoensis	Illinois pondweed	3	22,4
22	4	silty sand	myrsp	25		Myriophyllum spicatum	Eurasian water-milfoil	3	22,4
22	4	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	22,4
22	5	silty	myrsp	90		Myriophyllum spicatum	Eurasian water-milfoil	5	22,5
23	1	sandy	sciam	30		Scirpus americanus	Three-square, chairmaker's rush	3	23,1
23	1	sandy	junef	1		Juncus effusus	Soft stemmed rush	1	23,1
23	1	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	23,1
23	1	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	23,1
23	1	sandy	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	23,1
23	2	sandy	noveg			NO VEG	NO VEG	0	23,2
23	3	sandy	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	23,3
23	3	sandy	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	23,3
23	3	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	23,3
23	4	silty sand	myrsp	40		Myriophyllum spicatum	Eurasian water-milfoil	3	23,4
23	4	silty sand	potil	20		Potamogeton illinoensis	Illinois pondweed	2	23,4
23	4	silty sand	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2	23,4
23	5	sandy silty	myrsp	20		Myriophyllum spicatum	Eurasian water-milfoil	2	23,5
23	5	sandy silty	potil	10		Potamogeton illinoensis	Illinois pondweed	2	23,5
23	5	sandy silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	23,5
23	5	sandy silty	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1	23,5
24	1	sandy	myrsp	30		Myriophyllum spicatum	Eurasian water-milfoil	3	24,1
24	1	sandy	cxcom	20		Carex comosa	Bristly sedge, bottle brush sedge	2	24,1
24	1	sandy	potil	20		Potamogeton illinoensis	Illinois pondweed	2	24,1
24	1	sandy	potno	5		Potamogeton nodosus	Long-leaf pondweed	2	24,1
24	1	sandy	sciam	5		Scirpus americanus	Three-square, chairmaker's rush	2	24,1
24	1	sandy	eloca	1		Elodea canadensis	Common waterweed	1	24,1
24	2	ditritus sand	myrsi	1		Myriophyllum sibiricum	Northern water milfoil, spiked water milfoil	1	24,2
24	2	ditritus sand	potzo	1		Potamogeton zosteriformis	Flat-stem pondweed	1	24,2
24	3	silty sand	myrsp	40		Myriophyllum spicatum	Eurasian water-milfoil	3	24,3
24	3	silty sand	valam	30		Vallisneria americana	Wild celery, eel-grass, tape-grass	3	24,3
24	3	silty sand	potil	10		Potamogeton illinoensis	Illinois pondweed	2	24,3
24	3	silty sand	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	24,3
24	3	silty sand	potna	1		Potamogeton natans	Floating-leaf pondweed	1	24,3
24	4	silty	myrsp	80		Myriophyllum spicatum	Eurasian water-milfoil	5	24,4
24	4	silty	potzo	20		Potamogeton zosteriformis	Flat-stem pondweed	2	24,4
24	4	silty	zosdu	10		Zosterella dubia	Water stargrass	2	24,4
25	1	ditritus sand	junef	20		Juncus effusus	Soft stemmed rush	2	25,1
25	1	ditritus sand	lemmi	20		Lemna minor	Small duckweed, water lentil, lesser duckweed	2	25,1
25	1	ditritus sand	phaar	10		Phalaris arundinacea	Reed canary grass	2	25,1
25	1	ditritus sand	polam	10		Polygonum amphibium	Water smartweed, water knotweed	2	25,1
25	1	ditritus sand	wolco	10		Wolffia columbiana	Common watermeal	2	25,1
25	1	ditritus sand	cxcom	5		Carex comosa	Bristly sedge, bottle brush sedge	2	25,1
25	1	ditritus sand	potna	1		Potamogeton natans	Floating-leaf pondweed	1	25,1
25	2	ditritus sand	noveg			NO VEG	NO VEG	0	25,2
25	3	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	25,3
25	3	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	25,3
25	3	silty sand	potil	1		Potamogeton illinoensis	Illinois pondweed	1	25,3
25	4	silty	myrsp	90		Myriophyllum spicatum	Eurasian water-milfoil	5	25,4

Transect	Depth Range	Substrate	Acronym	Aerial Cover	Max Veg Z	Species	Common Name	Daubenmire Cover	Plot_ID
25	4	silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	25,4
25	4	silty	potil	1		Potamogeton illinoensis	Illinois pondweed	1	25,4
25	4	silty	potpe	1		Potamogeton pectinatus	Sago pondweed	1	25,4
26	1	sandy	cxcom	10		Carex comosa	Bristly sedge, bottle brush sedge	2	26,1
26	1	sandy	unk1	5		Unknown #1	Unknown #1	2	26,1
26	1	sandy	unk2	1		Unknown #2	Unknown #2	1	26,1
26	2	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	26,2
26	3	silty sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	26,3
26	3	silty sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	26,3
26	4	silty	myrsp	100		Myriophyllum spicatum	Eurasian water-milfoil	6	26,4
27	1	sandy cobble	chasp	10		Chara sp.	Muskgrasses, stoneworts	2	27,1
27	1	sandy cobble	cxcom	5		Carex comosa	Bristly sedge, bottle brush sedge	2	27,1
27	1	sandy cobble	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	27,1
27	2	sandy	chasp	10		Chara sp.	Muskgrasses, stoneworts	2	27,2
27	2	sandy	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	27,2
27	3	silty	chasp	1		Chara sp.	Muskgrasses, stoneworts	1	27,3
27	3	silty	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	27,3
27	3	silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	27,3
27	4	silty	myrsp	80		Myriophyllum spicatum	Eurasian water-milfoil	5	27,4
28	1	sandy	sciam	70		Scirpus americanus	Three-square, chairmaker's rush	4	28,1
28	1	sandy	chasp	10		Chara sp.	Muskgrasses, stoneworts	2	28,1
28	1	sandy	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	28,1
28	1	sandy	polam	1		Polygonum amphibium	Water smartweed, water knotweed	1	28,1
28	2	sandy	chasp	5		Chara sp.	Muskgrasses, stoneworts	2	28,2
28	3	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	28,3
28	3	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	28,3
28	4	silty sand	myrsp	5		Myriophyllum spicatum	Eurasian water-milfoil	2	28,4
28	4	silty sand	potil	5		Potamogeton illinoensis	Illinois pondweed	2	28,4
28	5	silty	myrsp	80		Myriophyllum spicatum	Eurasian water-milfoil	5	28,5
28	5	silty	potil	1		Potamogeton illinoensis	Illinois pondweed	1	28,5
29	1	gravel sand	noveg			NO VEG	NO VEG	0	29,1
29	2	sandy	noveg			NO VEG	NO VEG	0	29,2
29	3	silty sand	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	29,3
29	3	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	29,3
29	4	silty sand	chasp	30		Chara sp.	Muskgrasses, stoneworts	3	29,4
29	4	silty sand	potil	20		Potamogeton illinoensis	Illinois pondweed	2	29,4
29	4	silty sand	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2	29,4
29	4	silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	29,4
29	5	silty	myrsp	20		Myriophyllum spicatum	Eurasian water-milfoil	2	29,5
29	5	silty	najfl	20		Najas flexilis	Slender naiad, bushy pondweed	2	29,5
30	1	rocky silty sand	noveg			NO VEG	NO VEG	0	30,1
30	2	rocky silty sand	noveg			NO VEG	NO VEG	0	30,2
30	3	rocky silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	30,3
30	3	rocky silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	30,3
30	4	silty sand	myrsp	10		Myriophyllum spicatum	Eurasian water-milfoil	2	30,4
30	5	silty	myrsp	5		Myriophyllum spicatum	Eurasian water-milfoil	2	30,5
31	1	rocky sand	chasp	10		Chara sp.	Muskgrasses, stoneworts	2	31,1
31	2	rocky silty sand	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	31,2
31	2	rocky silty sand	valam	10		Vallisneria americana	Wild celery, eel-grass, tape-grass	2	31,2
31	2	rocky silty sand	myrsp	1		Myriophyllum spicatum	Eurasian water-milfoil	1	31,2
31	3	rocky silty sand	noveg			NO VEG	NO VEG	0	31,3
31	4	silty sand	potil	20		Potamogeton illinoensis	Illinois pondweed	2	31,4
31	5	silty	potil	30		Potamogeton illinoensis	Illinois pondweed	3	31,5
31	5	silty	myrsp	20		Myriophyllum spicatum	Eurasian water-milfoil	2	31,5
32	1	sandy rock	noveg			NO VEG	NO VEG	0	32,1
32	2	sandy rock	noveg			NO VEG	NO VEG	0	32,2
32	3	sandy rock	noveg			NO VEG	NO VEG	0	32,3
32	4	rocky silty sand	noveg			NO VEG	NO VEG	0	32,4
32	5	silty	myrsp	10		Myriophyllum spicatum	Eurasian water-milfoil	2	32,5
32	5	silty	potil	10		Potamogeton illinoensis	Illinois pondweed	2	32,5
33	1	sandy	noveg			NO VEG	NO VEG	0	33,1
33	2	silty sand	chasp	20		Chara sp.	Muskgrasses, stoneworts	2	33,2
33	2	silty sand	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1	33,2
33	3	silty sand	noveg			NO VEG	NO VEG	0	33,3
33	4	silty	noveg			NO VEG	NO VEG	0	33,4
33	5	silty	myrsp	10		Myriophyllum spicatum	Eurasian water-milfoil	2	33,5

C

APPENDIX C

Lake Term Glossary

Appendix C. Lake Term Glossary

Algae	Microscopic plants that use sunlight as an energy source. Algae can be unicellular (Diatoms), filamentous (many green or blue-green species), colonies in a gelatinous mass (many blue-greens) or more complicated colonies like *Chara sp.*
Anthropogenic	An occurrence caused or produced by the action of humans.
Anoxic	Devoid of dissolved oxygen.
Benthic	Pertaining to a river bed or lake floor
Contact Herbicide	A plant specific pesticide which causes extensive cellular damage exclusively to the areas of the target which come in contact with the herbicide (Affects contacted area only)
Ecosystem	The interaction of a community of organisms with each other and with the characteristics that make up their environment (Aquatic ecosystem, Northern Boreal Forest)
Emergent	An aquatic plant having most of its vegetative parts above the water surface (Cattail, Common Arrowhead)
Epilimnion	The upper most layer of water within a stratified lake. During the summer, this layer holds the warmest water and during the winter it holds the coldest water. This layer continuously circulates.
Exotic	A non-native organism that has been introduced into an area (Purple Loosestrife, Eurasian Water Milfoil)
Floating-leaf	Plants rooted in the sediment or free-floating with leaves lying flat on the water surface (Duckweed, White Water Lilly)
Hypolimnion	The deepest layer of water within a stratified lake. In the winter it holds the warmest water and in the summer it holds the coldest water.
Invasive	An organism which readily colonizes a disturbed area and tends to take it over by out-competing other plants. These can be native (Cattail) or exotic species (Purple Loosestrife).
Limiting Nutrient	The nutrient, usually phosphorus or at times, nitrogen, that is in shortest supply and controls the rate of growth in algae and macrophytes.
Littoral Zone	Pertaining to the shallow water zone of a lake that has sufficient light penetration to support macrophytes.
Macrophyte	A multi celled plant, usually with roots, stems, and leaves. A vascular plant (Cattail, Eurasian water-milfoil, pondweeds)
Median Value	A value in a set which has an equal number of observations above it and below it
Metalimnion	This is the layer between the epilimnion and the Hypolimnion that has the greatest range of temperature change with depth. The metalimnion contains the thermocline, but is not the same thing.
Native	An organism that is naturally occurring to an area (White Water Lilly, Northern Water-milfoil)

Nitrogen to Phosphorus Ratio	Results of this ratio indicate if algal growth within a lake is limited by nitrogen of phosphorus. If the ratio is greater than 16:1, the lake is considered phosphorus limited; if it is less than 16:1, it is considered nitrogen limited. The key ratio of 16:1 is related to the normal nitrogen to phosphorus ration found in most algae.
Non-Point Source Pollution	A source of pollution that comes from an indirect point of discharge (Overland flow)
Periphyton	A community of algae, and fragments of algae, which are attached to submerged objects such as plants and stones
Photosynthesis	The process in which chlorophyll producing organisms convert CO2 and water into sugar and oxygen, using sunlight as an energy source
Phytoplankton	Free-floating (not attached) algae.
Point Source Pollution	A source of pollution that comes from a direct point of discharge (Drain Tile Outfall)
Senesce	To complete a life cycle; to die off
Shoreland Buffer Zone	A buffer of native plants and habitat that occurs between the lake and developed property. The buffer zone serves to filter sediment and nutrients that wash off of a developed area before they reach the lake.
Species Diversity	An index that relates the number of species to their relative abundances. A community with many species with similar numbers (abundances) is more diverse than a community with the same number of species, but only a few of the species dominate the area with their abundances.
Species Richness	The total number of species occurring in a community
Submergent	An aquatic plant growing entirely under the water surface (Coontail, Large-leaf pondweed, Eurasian water-milfoil)
Systematic Herbicide	A plant specific pesticide which causes systematic cellular damage after coming in contact with the target. These herbicides spread through the entire plant.
Water Residence Time	The average amount of time water resides in a lake. Usually measured in years or days. A lake with a long residence time would have a slow flushing rate.
Zooplankton	Microscopic animals that are free-floating with in a water body. Many prey on algae and are an important food source for young fish.

D

APPENDIX D

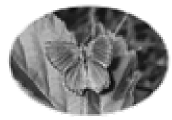
Education Component Materials

Big Hills Lake Protection & Rehabilitation District

Timothy A. Hoyman, CLM
NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.

Presentation Outline

- Introduction to Lake Ecology
- Current Lake and Watershed Project
  - Goals
  - Components
  - Timeline



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General Lake Ecology

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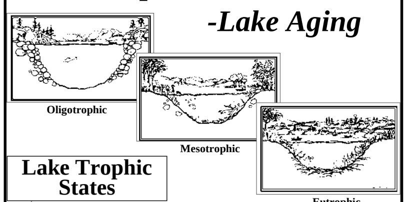
General Lake Ecology

Eutrophication
-Lake Aging



Lake Trophic States

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General Lake Ecology

Cultural Eutrophication

Accelerated eutrophication caused by human activity.

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General Lake Ecology

Point Source Pollution

- *Agricultural Drain Tiles*
- *Storm Sewers*
- *Treatment Plant Effluent*

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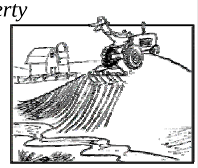
General Lake Ecology

Non-Point Source Pollution

- *Lakeshore Property*
- *Agricultural*
- *Urban*



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General Lake Ecology

Internal Nutrient Loading

-May be significant source of phosphorus after external loads are minimized.

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General Lake Ecology

Conclusions

Consequences if Loadings are not *Inventoried*, *Monitored*, and *Minimized*

- Accelerated Eutrophication
- Loss of Recreation Value
- Degraded Aesthetics
- Lower Property Values

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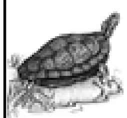
Comprehensive Lake Management Plan

Current Project

Study and Plan Goals



- Baseline Data
- Diagnostic / Feasibility
- Strategic Plan

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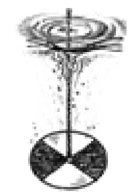
Current Project

Study Components

- Public Participation
- Watershed Assessment
- Water Quality
- Aquatic Vegetation



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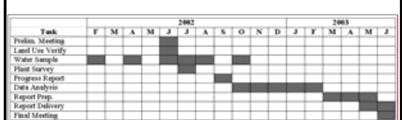
Current Project

Project Timeline



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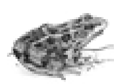
Current Project

Your Participation is Important to the Success of this Project



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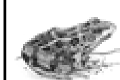
Current Project

- Concerns
- Observations
- Questions



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Contact Information

Tim Hoyman
NES Ecological Services
4664 Golden Pond Park Ct.
Oneida, WI 54155
(920) 499-5789
t.hoyman@releeinc.com

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Lake management under way in Waushara

BY PATRICIA WOLFF
OF THE NORTHWESTERN

BERLIN – A little purple loosestrife here. A little Eurasian water-milfoil there. Some zebra mussels over here.

The spread of non-native, invasive plants and animal species are a threat to lakes all over Wisconsin, said Tim Hoyman, an aquatic ecologist with NES Ecological Services.

Many lake districts in the state are waging war against those threats.

Hoyman's Green Bay company is working with four lake districts in Waushara County to develop lake management plans aimed at correcting problems that are already there and avoiding new ones.

Managing a lake district is a lot like managing your health or your pocketbook, Hoyman said.

With all three, an ounce of prevention is worth a pound of cure.

"When it comes to health and finances, the person who starts early does better than the person who waits until he's 55. It's the same with lakes. It's better to keep them healthy," Hoyman said.

That was the idea that convinced the boards of directors of the Alpine Lake Protection and Rehabilitation District, the Little Hills Management District, the Marl Lake District and the Big Hills Lake Protection and Rehabilitation District to go after state grants to help with their planning.

The DNR's Lake Management Grant program pays up to 75 percent of the cost of planning projects. The average lake management plan costs roughly $10,000 and takes many months to complete, Hoyman said.

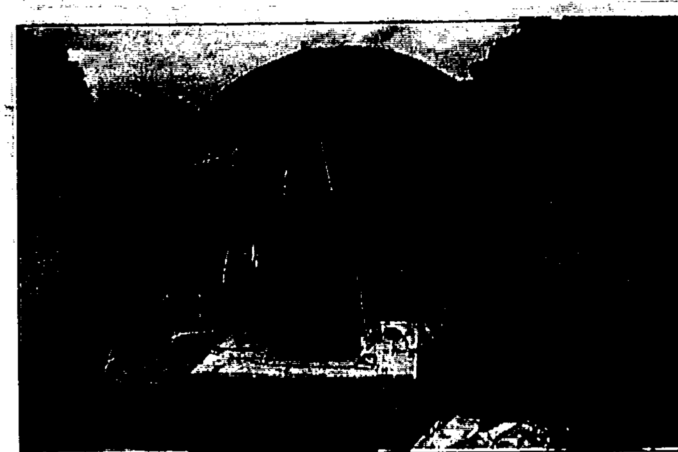
The people in the Marl-Lake District in the town of Deerfield got into planning to update a 1995 plant study.

"We wanted to see if we have Eurasian water-milfoil. So far, we have none. We have a healthy lake," Barry Wilson said.

He'd like to keep it that way. NES Ecological Services will help, Wilson said.

Wilson has been spending time on the 40-acre Marl Lake six miles west of Wautoma since 1946. Thirty-three prop-

LAKES, PAGE C2 ▶



SPECIAL TO THE NORTHWESTERN

JAMES HAVEL, an ecologist with NES Ecological Services of Green Bay, records aquatic plant survey data at Alpine Lake in Waushara County.

Lakes: DNR will prepare list of recommendations for lake districts once studies are complete

FROM PAGE C1

erty owners have homes on the lake, popular for swimming, boating and fishing. Fishermen and women ply the waters for bass, northern, bluegills, crappie and perch, Wilson said.

Wilson, who is retired, said he enjoys watching the wildlife that live around the lake. "Turkeys come down to drink. We see blue herons, ducks, everything you can think of," he said.

Each of the four lakes being studied is different and each requires a specific management plan to protect and improve it, Hoyman said.

"Lake Alpine has historically had aquatic plant problems, both in the form of rooted aquatic plants and algae," Hoyman said.

"Marl Lake and Little Hills Lake are not dealing with specific problems, but Big Hills Lake does support a healthy population and potentially problematic plant, Eurasian water-milfoil," he said.

Eurasian water-milfoil is a non-native plant that inhabits many of Wisconsin's lakes and occurs in lakes in most counties in the state. As of 2001, the plant had shown up in 15 of Waushara County's 100 lakes.

Eurasian water-milfoil is a problem because it grows earlier in the spring than other native plants, creating a canopy that blocks light from reaching other plants. At its worst, it can nearly take over a lake, causing navigation and swimming problems and upsetting the ecosystem to harm fish and other aquatic organisms, Hoyman said.

Once NES Ecological Services and the DNR have finished studying the four lakes, they will prepare a list of recommendations for the lake districts to implement.

In addition to the invasion of non-native species, people in lake districts are concerned about sediments, nutrients and other pollutants from watersheds getting into lakes. Development of homes around lakes contributes to the problem when property owners remove native vegetation and put in turf grass. This destroys habitat around the lake, Hoyman said.

"The best way for a lake to stay healthy is to let it function as a natural ecosystem," Hoyman said.

Patricia Wolff: (920) 361-0770 or pwolff@smgpo.gannett.com

Big Hills Lake Comprehensive Management Plan Project Update

The Big Hills Lake project is moving along as planned. Many of the tasks that we discussed during the Kick-off meeting have been completed and the associated data awaits analysis later this fall. Five lake water quality samples have been collected including one during last winter and spring, and three during this past summer. An additional sample will be collected during the fall turnover event that will help us understand the amount of internal phosphorus loading that occurs within the lake each year. The sample analyses that we have received back from the State Lab of Hygiene do not indicate anything out of the ordinary; however, the water clarity has been good considering the wet and hot weather the lake has received over the spring and summer. Many of the lakes in the area are experiencing algal blooms, however, Big Hills Lake exhibited good water clarity throughout the summer with the shallowest Secchi disk reading of 8.2 feet occurring late in August.

A paddle-boater enjoys Big Hills Lake during our vegetation survey early in August.

The aquatic plant survey has also been completed with two days worth of fieldwork occurring the first week in August. Although we did find a great deal of the no-native plant, Eurasian water-milfoil (*Myriophyllum spicatum*) it did not seem to be reaching the surface or causing navigational problems. Our data analyses later this fall will tell us more.

We have also received a great deal of data concerning the Big Hills Lake watershed through the much-appreciated cooperation of Waushara County and the East Central Regional Planning Commission. The data they supplied will help us determine the affects the watershed has on the lake and will be critical for the development of the lake management plan.

The importance of your participation was stressed during our discussions at the Kick-off meeting held in June. To date, we have not received any comments or questions from any of the lake residents (with the exception of your commissioners). Please remember that your comments are important and greatly appreciated, so please do not hesitate to provide comments or ask questions.

For more information, please contact Tim Hoyman, NES Ecological Services. t.hoyman@releeinc.com
2825 South Webster Avenue Green Bay, WI 54301-2878 Voice: 920-499-5789 Fax: 920-336-9141
www.releeinc.com/NES

Big Hills Lake Protection & Rehabilitation District

Big Hills Lake Comprehensive Lake Management Plan

June 7, 2003

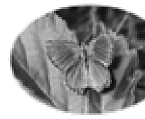
Timothy A. Hoyman, CLM

NES Ecological Services

A Division of Robert E. Lee & Associates, Inc.

Presentation Outline

- Project Objectives
- Study Results
- Management Recommendations



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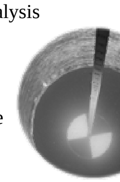
Project Objectives

- Data Collection and Analysis
  - Watershed
  - Aquatic Plants
  - Water Quality
- Develop Comprehensive Management Plan



NES Ecological Services

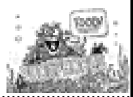
Study Results

Water Quality

↑ Phosphorus (Limiting Plant Nutrient)

↑ Chlorophyll-*a* (Algal Abundance)

↓ Water Clarity (Secchi Disk)



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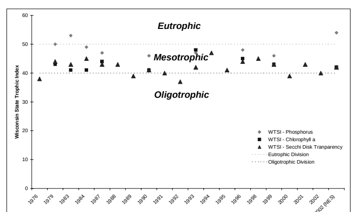
Study Results

Water Quality



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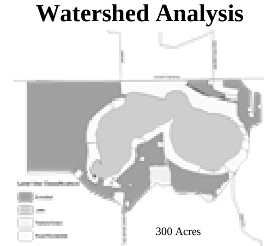
Study Results

Watershed Analysis



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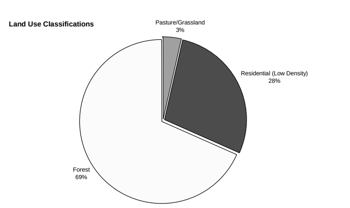
Study Results

Watershed Analysis



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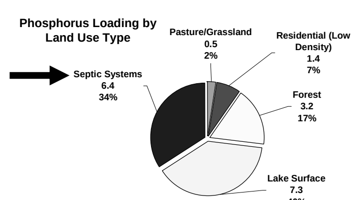
Study Results

Watershed Analysis



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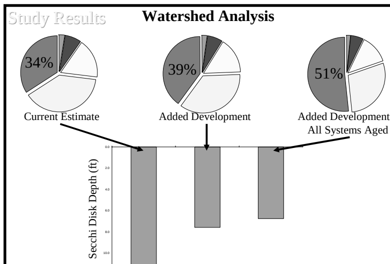
Study Results

Watershed Analysis



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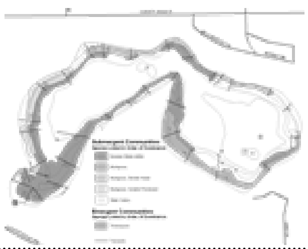
Study Results

Aquatic Vegetation



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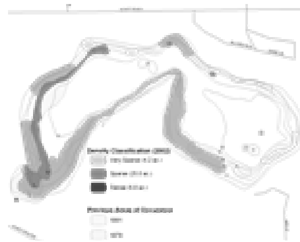
Study Results

Aquatic Vegetation



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Recommendations

Water Quality

"A lake is a mirror of its watershed."

Protect and Restore Water Quality by Reducing Phosphorus Loads

(Follow the watershed plan.)

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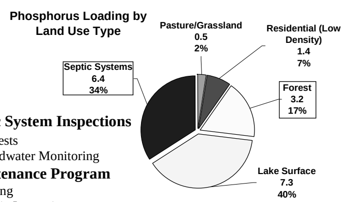
Recommendations

Watershed



Septic System Inspections
- Soil Tests
- Groundwater Monitoring

Maintenance Program
- Pumping
- Periodic Inspections

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Recommendations

Aquatic Vegetation

Two Primary Concerns:

Eurasian Water-milfoil

Native Species

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Recommendations

Aquatic Vegetation

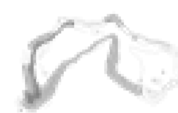
Eurasian Water-milfoil

~~Harvesting~~

~~Sediment Blanket~~

Chemical Treatment

~~Do Nothing~~



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Recommendations

Aquatic Vegetation

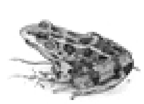
Chemical Treatment

Herbicide: 2,4-D

Cost: $325-$500 per acre

Timing: Spring or Fall

Result: Reduction in current abundances and rate of spread



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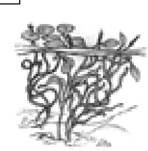
Recommendations

Aquatic Vegetation

Native Species Enhancement

Areas where Eurasian water-milfoil treatments occurred.

Emergents around shoreline



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