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AQUATIC PLANT MANAGEMENT PLAN

CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

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Prepared for:

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

FIGURES

TABLES

APPENDICES

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1.0 EXECUTIVE SUMMARY

Cedar Lake is a 147 acre lake located in the town of Schleswig in southwest Manitowoc County, Wisconsin. Recreational boating and waterskiing are popular on Cedar Lake. A public survey indicates that the most important lake concerns on Cedar Lake are water quality, boat traffic, and excessive aquatic plant growth. Cedar Lake exhibits good water quality but experiences periods of dense aquatic plant growth. The aquatic plants on the lake provide important habitat for fish and wildlife, but dense plant growth has historically been a nuisance condition, interfering with recreation on the lake (e.g. boat navigation). The District currently operates one aquatic plant harvester to address nuisance plant growth on the lake and developed an Aquatic Plant Management (APM) Plan to obtain a harvesting permit from the Wisconsin Department of Natural Resources (WDNR).

Water quality data collected between 1997 and 2001 indicate a mesotrophic lake system. Nutrients from both within the lake and from land uses within the watershed are likely enhancing aquatic plant growth. During summer 2005 aquatic plant surveys were completed on Cedar Lake. No aquatic invasive plant species were detected in the Lake during either of the June or August 2005 surveys by Northern Environmental. Nineteen and twenty-two aquatic plant species were found in June and August, respectively - an indicator of a moderately diverse aquatic plant community. The most abundant aquatic plant was muskgrass (*Chara sp.)* Large-leaf pondweed (*Potamogeton amplifolius*) was the second most abundant vascular plant species during June. Wild celery (*Vallisneria americana*) was the second most abundant vascular species during August. Lake users and district commissioners have reported many navigation problems and safety concerns with wild celery plant material in late summer.

WDNR research staff also completed an aquatic plant survey in summer 2005 and potentially identified Eurasian watermilfoil and Curly Leaf Pondweed, two aquatic invasive species. Confirmation of plant specimens is pending and was not available at the time of this report publication.

The District has prepared a comprehensive APM Plan to manage nuisance aquatic plant growth on Cedar Lake which includes the following components

Manual Removal:	Individual property owners can manually remove nuisance aquatic plants in the lake offshore from their property to a maximum width of 30 feet to provide pier or swimming raft access.
Harvesting:	The District will continue mechanical harvesting for navigation purposes in accordance with the conditions of a WDNR-issued harvesting permit.

Other components of the APM Plan include periodic monitoring for aquatic invasive species, nutrient control efforts by the District and landowners within the District, a watercraft inspection program, water quality monitoring, and public education about the value of aquatic plants and threat of aquatic invasive plant species.

2.0 INTRODUCTION

Cedar Lake is located in the town of Schleswig in southwest Manitowoc County, Wisconsin. Figure 1 depicts the lake location [United States Geological Survey (USGS) 1982]. Cedar Lake provides year around activities ranging from, fishing, swimming, non-motorized boating (kayaking, sailing), motorized boating activities (jet boating, speed boating, wake boarding, water skiing, pontoon), scuba diving, snowmobiling, and ice fishing.

Supporting the various recreational interests is difficult during the summer weekends. Boat traffic is a problem at times. A county ordinance regulates boat traffic on Cedar Lake. Boats must travel in a counterclockwise direction if not traveling at slow no-wake speeds between the hours of 11:00 a.m. and 6 p.m. Monday through Saturday and from 11 a.m. to 2 p.m. Sunday. Restricted hours for fast boating allow calmer waters for pontooning, fishing, kayaking and sailing. Although these activities can occur during fast boating hours, the predominant times for the pontooners, fishermen, and kayakers is during the no-wake hours.

Cedar Lake exhibits good water quality but experiences periods of dense aquatic plant growth. While the aquatic plants on the lake provide important habitat for fish and wildlife, dense aquatic plant growth on Cedar Lake has historically interfered with recreation on the lake (e.g. boat navigation). In response to the lake users concerns, the District has operated an aquatic plant harvesting program. Recent changes in Wisconsin's aquatic plant management laws and the subsequent Wisconsin Department of Natural Resources' (WDNR) administration of their aquatic plant management program (NR 109 Wis. Adm. Code) required that the District develop an Aquatic Plant Management Plan (APM Plan).

This APM Plan was designed to meet the District's needs for nuisance plant relief and the WDNR's requirements (e.g. applying for permits under Chapter NR 109 Wisconsin Administrative Code for aquatic plant harvesting). This APM Plan summarizes the lake morphology and lake watershed characteristics; reviews historical aquatic plant management activities; discusses the District's, goals and objectives; presents the aquatic plant ecology; presents results of the recent 2005 aquatic plant survey; evaluates feasible aquatic plant management alternatives; and provides a selected suite of aquatic plant management options in a comprehensive and integrated APM Plan.

2.1 Lake History and Morphology

Cedar Lake is 147 acres in size and has approximately 3.2 miles of shoreline. The lake's mean depth is 9 feet and the maximum depth is reported as 21 feet on the WDNR lake survey map. However depth finders have noted readings of 30 feet below the lake's outlet and 28.9 feet below the October 12, 2005 surface elevation. Figure 2 illustrates the bathymetry of Cedar Lake measured during the June 2005 aquatic plant survey. There is no surface water inlet, but a static water level is artificially maintained on Cedar Lake with a high capacity well at the lake's northeast end. The lake's 18 inch diameter PVC culvert outlet is at the northwest end of the lake. It's invert elevation is 891.03 MSL. The lake level at the time of the July was 3 inches below the culvert inlet invert elevation.

The fishery is comprised of panfish, largemouth bass, and northern pike. A fish survey between 1994 and 1995 identified decreased sizes of bluegill and northern pike when compared to earlier surveys (WDNR 1997). The fishery evaluation identified habitat loss and overharvesting of fish as potential causes of fishery problems. The zebra mussel, an aquatic invasive mussel is present in Cedar Lake.

2.2 Watershed Overview

The Cedar Lake Watershed is approximately 417 acres (Forth and Van Dyke, 2002). Figure 3 illustrates the watershed. The watershed to Lake Ratio is approximately 3:1, a low-ratio lake. A low watershed to lake ratio generally means that runoff within the watershed generally has less of an impact on a lake's water quality. However, these lakes may have a longer retention time and nutrients may remain in the lake for a longer time before leaving the lake.

The watershed lies in a region of glacial drift overlying dolomite bedrock. The watershed is within the Hochheim-Lutzke Soil Association. Soils in this association formed in moraines, outwash terraces, and lacustrine plains and consist of gently sloping to steep, well drained loamy soils (United States Department of Agriculture, 1980).

Nutrients from runoff within the watershed may contribute to abundant aquatic plant growth on Cedar Lake. The Lake Management Plan (Foth and Van Dyke, 2002) identified the following land uses within the watershed.

Residential (107 acres)
Agriculture (100 acres)
Grassland/Open (45 acres)
Wetland (14 acres)
Woodland (150 acres)

Since 2002, several agricultural acres have become residential along the South Cedar Lake Road. Some of the watershed acreage drains to depressions within the watershed.

Potential nutrient loadings to Cedar Lake may be occurring from all of the above land uses. The Lake Management Plan identified runoff from residential properties as the number one sediment and nutrient loading source to Cedar Lake. However, newer WDNR modeling (WILMS®) suggest that the main nutrient loads to Cedar Lake are from agricultural lands (Foth and Van Dyke, 2002). Figure 3 depicts land uses within the watershed (WDNR Land Sat Imagery).

2.3 Water Quality

A series of water quality studies were completed on Cedar Lake between 1997 and 2001 (Foth and Van Dyke, 2002). Key conclusions and recommendations drawn from these earlier studies include the following:

- Cedar Lake was a mesotrophic lake based upon water quality sampling events during 1997-2001. A mesotrophic lake has moderately clear water; may contain excessive nutrients; supports a diverse aquatic plant community; and experiences oxygen depletion in late summer months or winter periods, but can still support a warm water fishery.
- Based upon the sanitary survey and water quality analysis, it is possible that some private on-site wastewater treatment systems (POWTS) are potentially contributing nutrients to Cedar Lake.
- The watershed model indicates that residential land use is not contributing significant nutrient loadings, but increased development within the watershed may have a negative impact on the lake's water quality if surface water runoff is not treated or managed properly.
- The Cedar Lake Management Plan recommended establishing a long-term water quality testing program to accurately determine if the lake is experiencing changes in water quality
- The plan also recommended educating property owners in the District, upgrading malfunctioning on-site sanitary systems, and considering the benefits of installing a public sanitary sewer.

While the recommendations have not been formally adopted, new District commissioners have re-visited the Lake Management Plan and are planning to implement some of the recommended action items. The need to develop an APM Plan regenerated interest into preventing nutrient contributions to the Lake. One particular water quality parameter – water clarity (secchi depth) was particularly high in 2005 (19 feet in June and 16 Feet in August, Site 72 and 20.1 Feet October – Boy Scout Bay in October, 2005). The high water clarity may be due to the presence of zebra mussels in Cedar Lake, an aggressive filter feeder that removes phytoplankton from the water column.

2.4 Aquatic Plant Management History

Lake users have historically reported problems with dense aquatic plant growth on Cedar Lake. A review of WDNR files indicates that individual landowners contracted for chemical treatment of aquatic plants as early as 1957. The District formed in 1967 and acquired an aquatic plant harvester in 1972. The District continued operation of the harvester since then to manage the excessive aquatic macrophyte growth.

A WDNR file review indicated that no formal aquatic plant surveys have previously been completed on Cedar Lake. However, Eurasian Watermilfoil (EWM) was reportedly discovered in Cedar Lake in 1993 (WDNR, 2004). The District believed that it was harvesting EWM, however, EWM was not identified in the 2005 aquatic plant surveys. Nonetheless, dense aquatic plant growth reportedly continues to hamper recreation on Cedar Lake. Wild celery and northern watermilfoil in particular have been problem species. Therefore, an aquatic plant harvester is needed to manage the abundant native vegetation.

2.5 Public Survey

A public survey indicates that the most important lake concerns on Cedar Lake are water quality, boat traffic, and excessive aquatic plant growth. Most respondents rate their experiences on Cedar Lake as very enjoyable and strongly supported the district's harvesting efforts. Results are summarized in Appendix A.

2.6 Goals and Objectives

Since there is no aquatic plant survey information available, a main project objective is to complete an aquatic plant survey, which can then be used to quantify and map the abundance and distribution of aquatic plant species. Since there is no formal APM Plan, another District goal is to develop an integrated aquatic APM Plan. At the time of the grant application, discussions with the District indicated that the following items were important APM Plan goals and objectives:

- Maintain and improve recreational opportunities
- Educate lake users on invasive species and benefits of native aquatic plant communities
- Preserve native aquatic plants
- Protect sensitive areas
- Prevent the spread of aquatic invasive species (AIS), such as Eurasian watermilfoil, Curlyleaf pondweed, and Purple loosestrife
- Protect and improve fish and wildlife habitat
- Continue to manage the potential sources of pollutants already identified through previous studies

Since the initial APM Plan goals were established, one goal was revised to reflect the fact that EWM was not identified in Cedar Lake. The fifth goal listed above should read "Prevent the introduction of Aquatic invasive plant species…"

3.0 PROJECT METHODS

To accomplish the District's goals, the District needs to make informed decisions regarding APM on the Lake. To make informed decisions, the District proposed to:

- Collect, analyze, and interpret basic aquatic plant community data
- Recommend practical, scientifically-sound aquatic plant management strategies

Offsite and onsite research methods were used during this study. Offsite methods included a thorough review of available background information on the Lake, its watershed and water quality. Two aquatic plant community surveys were completed onsite to provide data needed to evaluate aquatic plant management alternatives.

3.1 Existing Data Review

A variety of background information resources were researched to develop a thorough understanding of the ecology of the Lake. Information sources included:

- Local and regional pedologic, geologic, limnologic, hydrologic, and hydrogeologic research
- Discussions with District members
- Available topographic maps and aerial photographs
- Data from WDNR files
- Past Lake Study Reports

These sources were essential to understanding the historic, present, and potential future conditions of the Lake, as well as to ensure that previously completed studies were not unintentionally duplicated. Specific references are listed in Section 7.0 of this report.

3.2 Aquatic Plant Survey and Analysis

The aquatic plant community of the Lake was surveyed during June and August 2005. During those surveys the point intercept sampling method described by Madsen (1999) was used, as is recommended in the draft guidance on APM in Wisconsin (WDNR, 2005). The point intercept method is readily adapted to "whole-lake" or large plot assessments as compared to the transect method that is best used in evaluating study plots or selected areas to evaluate aquatic macrophyte communities.

To use the point intercept method, a base map was developed with 234 sampling points (i.e., intercept points) established on a 100 meter grid (Figure 4). Latitude and longitude coordinates and sample identifications were assigned to each intercept point on the grid (Appendix B). A Trimble GeoXT™ global positioning system (GPS) was used to navigate to intercept points. At each intercept point, plants were observed visually or collected with a rake on a telescopic pole or a rake attached to a rope. All observed plants were identified to the lowest practicable taxonomic level (e.g., typically genus or species) and recorded on field data sheets. Water depth and, when detectable, sediment types at each intercept point were also recorded on field data sheets.

The point intercept method was used to evaluate the existing emergent, submergent, floating-leaf, and free-floating aquatic plants at each intercept point. At each intercept point, a value of "1" was assigned if species were present and a "0" was assigned if a species was absent. For both the June and August surveys, the data for each sample point was entered into the WDNR "Worksheets" (i.e., a data-processing spreadsheet) to calculate the following statistics:

- Community Frequency of occurrence (number of intercept points where aquatic plants were detected divided by the number of intercept points shallower than the maximum depth of plant growth)
- Taxonomic frequency of occurrence (the number of intercept points where a particular taxon (e.g., genus, species, etc.) was detected divided by the total number of intercept points shallower than the maximum depth of plant growth)
- Relative taxonomic frequency of occurrence (the number of intercept points where a particular taxon (e.g., genus, species, etc.) was detected divided by the number of intercept points where any species was detected)
- Simpson diversity index (SDI) is an indicator of aquatic plant community diversity. SDI is calculated by taking one minus the sum of the relative frequencies squared for each species present. Based upon the index of community diversity, the closer the SDI is to one, the greater the diversity within the population.
- Taxonomic richness (the total number of taxa detected)
- Mean intercept point taxonomic richness (the average number of taxa per intercept point)
- Mean intercept point native taxonomic richness (the average number of native taxa per intercept point)

In addition to the above statistics, a Floristic Quality Index (FQI) was calculated for each plant survey. The FQI was developed by Stan Nichols (Wisconsin Geological and Natural History Survey) to help assess lake quality using the aquatic plants that live in a lake. A lake's plant community reflects a lake's water quality and its level of disturbance. In calculating FQI you must identify each species that is present in the lake. After each species is identified, a coefficient of conservatism is assigned to each species and used to calculate FQI (Nichols, 1999). Each plant is assigned a number from 1 to 10. Low nutrient and undisturbed conditions are given a higher number and plants typically found in more nutrient rich and/or disturbed waters are given a lower coefficient of conservatism. Lake quality is quantified by the number of species found, the identity of plants and the coefficient of conservatism.

3.3 Shoreline Characterization

The point intercept method described above establishes grid points. The grid sampling may not accurately characterize emergent and floating leaved plants in shoreline areas. Therefore, a boat tour of the entire lake shoreline was used to map the emergent and floating leaved plant communities.

4.0 AQUATIC PLANTS

Aquatic plants are vital to the health of a water body. Unfortunately, people all too often refer to rooted aquatic plants as "weeds" and ultimately wish to eradicate them. This type of attitude, and the misconceptions it breeds, must be overcome in order to properly manage a lake ecosystem. Rooted aquatic plants (macrophytes) are extremely important for the well being of a lake community and posses many positive attributes. These attributes are what make the littoral zone the most important and productive aquatic habitat in freshwater lakes. Despite their positive role, aquatic macrophytes can become a nuisance when aquatic invasive species (AIS) occupy large portions of a lake and/or excessive growth of AIS or native macrophytes negatively affects recreational activities. When "managing" aquatic plants, it is important to maintain a well-balanced, stable, and diverse aquatic plant community that contains high percentages of desirable native species. To be affective, aquatic plant management in most lakes must maintain a plant community that is:

- Robust
- Species rich
- Diverse
- Mostly native

4.1 The Ecological Role of Aquatic Plants

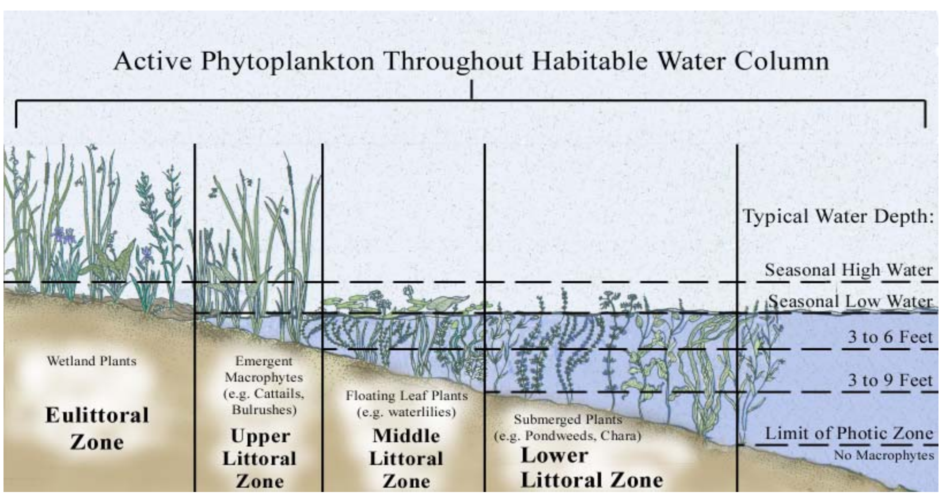
Aquatic plants can be divided into two major groups: microphytes (phytoplankton and epiphytes) composed mostly of single-celled algae, and macrophytes that include macroalgae, flowering vascular plants, and aquatic mosses and ferns. Wide varieties of microphytes co-inhabit all hospitable areas of a lake. Their abundance depends on light, nutrient availability, and other ecological factors. In contrast, macrophytes are predominantly found in distinct habitats located in the littoral (i.e., shallow near shore) zone where light sufficient for photosynthesis can penetrate to the lake bottom. The littoral zone is subdivided into four distinct transitional zones: the eulittoral, upper littoral, middle littoral, and lower littoral (Wetzel, 1983).

Eulittoral Zone: Includes the area between the highest and lowest seasonal water levels, and often contains many wetland plants.

Upper Littoral Zone: Dominated by emergent macrophytes and extends from the water edge to water depths between 3 and 6 feet.

Middle Littoral Zone: Occupies water depths of 3 to 9 feet, extending lakeward from the upper littoral zone. The middle littoral zone is dominated by floating-leaf plants.

Lower Littoral Zone: Extends to a depth equivalent to the limit of the photic zone, which is defined as percent of surface light intensity.



Aquatic Plant Communities Schematic

The abundance and distribution of aquatic macrophytes are controlled by light availability, lake trophic status as it relates to nutrients and water chemistry, sediment characteristics, and wind energy. Lake morphology and watershed characteristics relate to these factors independently and in combination (NALMS, 1997).

In many instances aquatic plants serve as indicators of water quality due to the sensitive nature of plants to water quality parameters such as water clarity and nutrient levels. To grow, aquatic plants must have adequate supplies of nutrients. Microphytes and free-floating macrophytes (e.g., duckweed) derive all their nutrients directly from the water. Rooted macrophytes can absorb nutrients from water and/or sediment. Therefore, the growth of phytoplankton and free-floating aquatic plants is regulated by the supply of critical available nutrients in the water column. In contrast, rooted aquatic plants can normally continue to grow in nutrient-poor water if lake sediment contains adequate nutrient concentrations. Nutrients removed by rooted macrophytes from the lake bottom may be returned to the water column when the plants die. Consequently, killing aquatic macrophytes may increase nutrients available for algal growth.

In general, an inverse relationship exists between water clarity and macrophyte growth. That is, water clarity is usually improved with increasing abundance of aquatic macrophytes. Two possible explanations are postulated. The first is that the macrophytes and epiphytes out-compete phytoplankton for available nutrients. Epiphytes derive essentially all of their nutrient needs from the water column. The other explanation is that aquatic macrophytes stabilize bottom sediment and limit water circulation, preventing resuspension of solids and nutrients (NALMS, 1997).

If aquatic macrophyte abundance is reduced, then water clarity may suffer. Water clarity reductions can further reduce the vigor of macrophytes by restricting light penetration, reducing the size of the littoral zone, and further reducing water clarity. Studies have shown that if 30 percent or less of the area of a lake occupied by aquatic plants is controlled, water clarity will generally not be affected. However, lake water clarity will likely be reduced if 50 percent or more of the macrophytes are controlled (NALMS, 1997).

Aquatic plants also play a key role in the ecology of a lake system. Aquatic plants provide food and shelter for fish, wildlife and invertebrates. Plants also improve water quality by protecting shorelines and the lake bottom, improving water quality, adding to the aesthetic quality of the lake and impacting recreational activities.

4.2 Aquatic Plant Survey (2005)

The aquatic macrophyte community of the Lake included 22 floating leaved, emergent, and submerged aquatic vascular plant species and 2 algal genera during 2005. The surveys include sampling at 234 intercept points and the observed taxa are summarized in Table 1. The distribution of aquatic plant species during June and August 2005 are illustrated in Figures 5a-5d and 6a-6d, respectively.

A diverse plant community inhabited the Lake during 2005. During June and August, the Simpson Diversity Index values of the community were 0.87 and 0.89, respectively (Table 2). Aquatic vegetation was detected at 83% of photic zone intercept points during June, but this value was reduced to 79% by August. Like the frequency of occurrence, the photic zone depth was also diminished between June and August. Specifically, it was reduced by 3 feet, beginning at 19 feet in June and shrinking to 16 feet in August (Table 2).

Despite the reduced frequency of occurrence and photic zone depth, the taxonomic richness of the aquatic plant community increased from 19 taxa in June to 22 taxa in August (Table 2). An average of 2.5 taxa was detected at intercept points during June. Similarly, an average of 2.4 taxa was detected at intercept points during August.

During the June and August surveys, the most abundant aquatic plant was muskgrass (*Chara sp.*). It had a 61 percent frequency of occurrence (percent of photic zone intercept points at which the taxa was detected) during June and a 42 percent frequency of occurrence during August (Table 3). Further, it was detected at 109 and 64 photic zone intercept points during June and August, respectively, and had greater relative frequency values than other taxa (Table 3).

Large-leaf pondweed (*Potamogeton amplifolius*) was the second most abundant vascular plant species during June, occurring at 56 percent of photic zone intercept points and having a 31 percent frequency of occurrence (Table 3). Its relative frequency of occurrence, 13 percent, indicates that it was far less common than muskgrass at vegetated intercept points. Northern watermilfoil (*Myriophyllum sibiricum*) was the third most common taxa during June (Table 3).

Wild celery (*Vallisneria americana*) was the second most abundant vascular species during August. It was detected at 53 photic zone intercept points, had a 35 percent frequency of occurrence, and a 15 percent relative frequency of occurrence (Table 3). Like during June, Northern watermilfoil (*Myriophyllum sibiricum*) was the third most common taxa during August (Table 3).

Invasive species, such as Eurasian water milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*), tend to densely colonize affected lakes and out compete native species. Fortunately, no invasive aquatic species were detected in the Lake during either the June or August 2005surveys.

4.2.1 Free-Floating Plants

No free-floating aquatic plant species were identified during the 2005 aquatic plant survey.

4.2.2 Floating-Leaf Plants

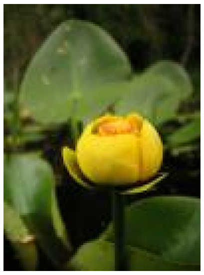
Floating-leaf aquatic plant species were identified during the 2005 aquatic plant surveys and are listed in Table 1. A brief description of these plant species follows.

Brasenia schreberi (Watershield)

Brasenia schreberi (Watershield) has floating leaves with elastic stems with the leaf stalk attaching to the middle of the leaves. All submersed portions of the plant are usually covered with a gelatinous coating. Watershield is commonly identified by the lack of a leaf notch and the central location of the petiole. Watershield is most commonly found growing in soft sediments that contain partially decomposed organic matter. The seeds, leaves, stems and buds are a source of food by waterfowl. The floating leaves also offer shelter and shade for fish and invertebrates (Borman, et al., 1997). Watersheild is a sensitive aquatic plant this is not tolerant of pollutants and adverse human impacts to the lake ecosystem (Nichols, 1999).


Watershield
Source: University of Florida Website

Nuphar advena (Yellow Pond Lily)



Yellow Pond Lily
Source: University of Florida Website

Nuphar advena (Yellow Pond Lily), shows a preference for soft sediment and water that is 6 feet or less in depth. Floating leaves emerge in early summer from rhizomes that are actively growing in the soft sediments. Flowering occurs throughout the summer and supports a yellow flower. Floating leaves provide shelter and shade for fish as well as habitat for invertebrates (Borman, et al., 1997).

Nuphar variegata (Spatterdock)

Nuphar variegata (Spatterdock) shows a preference for soft sediment and water that is 6 feet or less in depth. Floating leaves emerge in early summer from rhizomes that are actively growing in the soft sediments. Yellow flowers occur throughout the summer. Floating leaves provide cover and shade for fish as well as habitat for invertebrates (Borman, et al., 1997).

Spatterdock
Source: UW Herbarium Website

White Water Lily
Source: UW Herbarium Website

Nymphaea odorata (White Water Lily)

Nymphaea odorata (White Water Lily) has a flexible stalk with a round floating leaf. Most of the leaves float on the water surface. White Water Lily is typically found growing in a variety of sediment types in less than 6 feet of water. Floating leaves emerge in early summer from rhizomes that are growing in the soft sediments. White flowers occur throughout the summer. The floating leaves provide shelter and shade for fish as well as habitat for invertebrates (Borman, et al., 1997).

4.2.3 Submergent Plants

Submergent aquatic plant species were identified during the 2005 aquatic plant surveys and are listed in Table 1. A brief description of some of these plant species follows.

Elodea canadensis (Elodea)

*Elodea canadensis (*Elodea or common waterweed) is an abundant native plant species that is distributed statewide. It prefers soft substrate and water depths to 15 feet (Nichols, 1999). Elodea reproduces by seed and sprigs (USDA, 2002). The stems of elodea offer shelter and grazing to fish, but very dense elodea can interfere with fish movement. Elodea can be considered invasive at times and out-competes other more desirable plants.

Elodea
Source: UW Herbarium Website

Northern watermilfoil
Source: UW Herbarium Website

Myriophyllum sibiricum (Northern watermilfoil)

Myriophyllum sibiricum (Northern watermilfoil) is usually found growing in soft sediment in fairly clear-water lakes. Stems are sparingly branched and fairly erect in water. Leaves are divided like a feather, with five to twelve pairs of thread-like leaflets. Leaves are arranged in whorls. Northern watermilfoil is more desireable than it's invasive cousin, Eurasian watermilfoil, however can also reach nuisance levels posing problems for recreational and navigational patron. Waterfowl eat the foliage and fruit of northern watermilfoil, while beds of this plant provide cover and foraging opportunities for fish and invertebrates.

Najas flexilis (Slender Naiad)

Najas flexilis (Slender Naiad) is sometimes called bushy pondweed and has fine branched stems that emerge from a slight rootstalk. Leaves are paired and sometimes smaller leaves are bunched. Slender Naiad can grow in very shallow and very deep. Waterfowl, marsh birds, and muskrats consume the stems, leaves, and seeds of naiad. The foliage produces forage and shelter opportunities for fish and invertebrates (Borman, et al., 1997).

Slender Naiad
Source: UW Herbarium Website

*Potamogeton amplifolius (*Large-leaf Pondweed)

Large-leaf Pondweed
Source: UW Herbarium Website

*Potamogeton amplifolius (*Large-leaf Pondweed) has robust stems that emerge from black-scaled rhizomes. The submersed leaves are the broadest of any pondweed and are slightly folded. The blade is also lined with many veins (25 to37). Floating leaves are oval and on long stalks. Large-leaf pondweed is most frequently found in soft sediments in water 1 to several feet deep. It is sensitive to increased turbidity. Large-leaf pondweed is commonly grazed by waterfowl. It offers habitat for invertebrates and offers foraging opportunities for fish (Borman, et al., 1997).

*Potamogeton foliosus (*Leafy Pondweed)

*Potamogeton foliosus (*Leafy Pondweed) has a freely branched stems that emerge from slender rhizomes. This plant is easily identifiable by a stipule that is found wrapped around the stem. However, leafy pondweed can be confused with small pondweed. Leafy pondweed tends to bloom early in the season with a short flower stalk and a tight cluster of flowers. Waterfowl eat the fruits of this early to mature aquatic and can be of local importance. Muskrat, beaver, and deer eat the foliage and fruit. Invertebrates and fish forage hide in the foliage (Borman, et al., 1997).

Leafy Pondweed
Source: UW Herbarium Website

Potamogeton illinoensis (Illinois Pondweed)


Illinois Pondweed
Source: University of Florida Website

Potamogeton illinoensis (Illinois Pondweed) has stout stems that emerge from thick rhizomes. Most of the submersed leaves are lance-shaped to oval and either attach directly to the stem or have a short stalk. The leaves often have a sharp, needle like tip. The stipules are free in the axils of the leaves and have two prominent ridges called keels. Floating leaves which have a thick stalk and ellipse shaped blade are sometimes produced. Illinois pondweed is usually found in water with moderate to high pH and fairly good water clarity. The fruit produced by Illinois pondweed can be locally important to ducks and geese. The plant may also be grazed by muskrat, deer and beaver. This pondweed also offers excellent shade and cover for fish and good surface area for invertebrates.

Potamogeton natans (Floating-Leaf Pondweed)

Potamogeton natans (Floating-Leaf Pondweed) has stems that emerge from red-spotted rhizomes. Submersed leaves are stalk-like, with no obvious leaf blade. Floating leaves are heart-shaped at their base. Floating-leaf pondweed is usually found in water less than 1.5 meters deep. Fruit of floating-leaf pondweed is held on the stalk until late in the growing season. It provides valuable grazing opportunities for ducks and geese. It may also be consumed by muskrat, beaver and deer (Borman et al. 1997).


Floating-leaf Pondweed
Source: UW Herbarium Website

Potamogeton praelongis (White-stem Pondweed)


White-stem Pondweed
Source: UW Herbarium Website

Potamogeton praelongis (White-stem Pondweed) has zigzag stems that emerge from a stout, rust-spotted rhizome. Submersed leaves are lance to oval shaped and clasp the stem, wrapping around one-third to one-half the stem's diameter. The leaves have strong veins and the tip of the leaf is boat-shaped and splits when pressed, creating a notch at the end of the leaf. Stipules are white and fibrous, often shredding at the tip over the growing season. They are free in the leaf axils, but usually pressed against the stem. White stem pondweed is usually found in soft sediment in water ranging from 1-4 meters deep and found in lakes with good water clarity. Fruit of white pondweed provides a valuable razing opportunity for ducks and geese. White stem pondweed is considered a good food producer and valuable habitat fro muskellunge.

(*Potamogeton pusillus*) Small Pondweed

Small Pondweed (*Potamogeton pusillus*) has small slender stems, emerges from a slight rhizome, and branches repeatedly near its ends. Small pondweed over-winters as rhizomes and winter buds. There is some limited reproduction by seed. Small pondweed can be locally important as a food source for a variety of wildlife. Waterfowl tend to feed on small pondweed as well as deer, muskrat, and some small fish (Borman, et al., 1997).

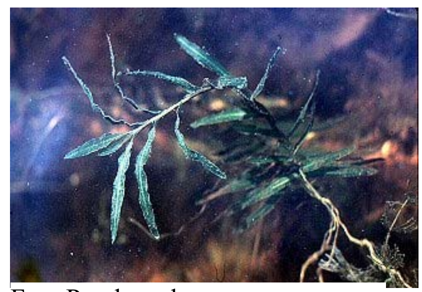

Small Pondweed
Source: UW Herbarium Website

Potamogeton richardsonii (Clasping Leaf Pondweed)

Clasping Leaf Pondweed
Source: UW Herbarium Website

Potamogeton richardsonii (Clasping Leaf Pondweed) is a submergent aquatic plant with sinuous stems that emerge from a spreading rhizome. Oval to somewhat lance-shaped leaves clasp the stem with the heart-shaped base of each leaf covering one-half to three-quarters of the stem circumference. Clasping leaf pondweed can be found growing in a variety of sediment types in water up to 12 feet deep and can tolerate disturbance and is often found growing with *Ceratophyllum demersum* (Coontail) and *Potamogeton pusillus* (Small Pondweed) (Borman, et al., 1997).

Potamogeton robbinsii (Fern Pondweed)



Fern Pondweed
Source: UW Herbarium Website

Potamogeton robbinsii (Fern Pondweed) is a submergent pondweed with robust stems of fern pondweed that emerge from a spreading rhizome. The leaves are strongly two-ranked, creating a feather or fern-like appearance which is most evident when the plant is still in the water. Each leaf is firm and linear, with a base that wraps around the stem. The leaf base is distinctive and has small ear-like lobes at the juncture with the stipule and is fused with the fibrous stipule. The leaves are closely spaced and have a finely serrated margin. Fern pondweed sprouts in the spring and thrive in deeper water. Fern pondweed provides habitat for invertebrates that are grazed by waterfowl and also offers good cover for fish, particularly northern pike (Borman, et al., 1997).

Potamogeton zosteriformis (Flat-Stem Pondweed)

Flat- Stem Pondweed
Source: UW Herbarium Website

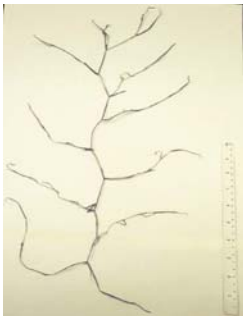
Potamogeton zosteriformis (Flat-Stem Pondweed) is a submergent pondweed with freely-branched stems of flat-stem pondweed that emerge from a slight rhizome. The stems are strongly flattened and have an angled appearance. Flat-stem pondweed has a prominent midvein and many fine, parallel veins. Flat stem pondweed is commonly confused with

Ranunculus flabellaris (Yellow water buttercup)

Yellow Water Buttercup
Source: UW Herbarium Website

Ranunculus flabellaris (Yellow water buttercup) has long, branched stems with leaves that are finely cut into thread-like divisions and either attach directly to the stem or have a very short leaf stalk. Leaves emerge along the stem in an alternate arrangement and are stiff enough to hold their shape when lifted out of the water. Stiff water crowfoot is found in both lakes and streams with higher alkalinity, usually in less than 6 feet of water. New stems emerge from rhizomes in the spring and flowers come into bloom over several weeks. Both fruit and foliage are consumed by a variety of waterfowl. When it is growing in shallow areas it may also be grazed upon by upland birds. Stems and leaves of water crowfoot provide valuable invertebrate habitat and it is considered a fair producer of food for trout (Borman, et al., 1997).

Stuckenia pectinata (Sago Pondweed)



Sago Pondweed
Source: UW Herbarium Website

Stuckenia pectinata (Sago Pondweed) resembles two other pondweeds with needle-like leaves, but sago pondweed tends to be much more common. The fruit and tubers of sago pondweed are very important food sources for waterfowl, while leaves and stems provide shelter for small fish and invertebrates (Borman, et al., 1997).

Valinsneria americana (Wild Celery)

Wild Celery
Source: UW Herbarium Website

Valinsneria americana (Wild Celery) also known as eel-grass or tape-grass, has ribbon-like leaves that tend to grow until they emerge in clusters along the waters surface. Wild celery is a premiere source of food for waterfowl. All portions of the plant are consumed. Beds of wild celery are also considered good fish habitat providing shade, shelter and feeding opportunities (Borman, et al., 1997). The District reports nuisance conditions with wild celery in late summer. This is common in many Wisconsin lakes, although the District noticed an increase in the abundance of wild celery in 2005.

Chara, sp. (Muskgrass / Chara)

Although *Chara, sp.* (Muskgrass / Chara) looks like a vascular plant, it actually is a multi-celled algae. Muskgrass is usually found in hard waters and prefers muddy or sandy substrate and can often be found in deeper water than other plants. Muskgrass beds provide valuable habitat for small fish and invertebrates. Muskgrass is also a favorite waterfowl food. Its rhizoids slow the movement and suspension of sediments and benefit water quality in the ability to stabilize the lake bottom (Borman, et al., 1997). It can easily be identified by it's characteristic "musty" odor.

Chara sp.
Source: UW Herbarium Website

Nitella sp. (Nitella)

Nitella sp.
Source: UW Herbarium Website

Nitella is another type of algae that looks like a vascular plant. Nitella is similar in appearance to muskgrass and is often found in similar habitats. However, Nitella can be distinguished from muskgrass by its stems and branches, which are smooth (Borman, et al., 1997).

4.2.4 Emergent Plants

Emergent aquatic plant species were identified during the 2005 aquatic plant surveys and are listed in Table 1. A brief description of some of these plant species follows.

Sagittaria latifolia (Arrowhead)

Sagittaria latifolia (Arrowhead) is a emergent plant the usually produces leaves that are true to its name – shaped like an arrowhead. Leaves emerge in a cluster from tuber tipped rhizomes. The size and shape of the leaf is highly variable with blades that range form a slender "A" shape to a broad wedge. Common arrowhead is found in the shallow water of lakes, ponds, streams and marshes and usually found in water only ankle-deep, but will sometimes grow in water about 1 meter deep. Common arrowhead is one of the highest value aquatic plants for wildlife and waterfowl depend on the high-energy tubers during migration. The seeds are also consumed by a wide variety of ducks, geese, marsh birds and shore birds. (Borman, et al., 1997).

Scirpus acutus (Hardstem Bulrush)

Hardstem Bulrush
Source: UW Herbarium Website

Scirpus acutus (Hardstem Bulrush) has tall, sturdy stems that emerge from a shallow rhizome. The cylindrical, olive green stems are firm when pressed between your fingers. Hardstem bulrush usually grows in water less than 2 meters deep, but it has been found considerably deeper. Hardstem shows a preference for firm substrate with good water movement in the root zone. Hardstem bulrush offers habitat for invertebrates and shelter for young fish, especially northern pike. The nutlets are consumed by a wide variety of waterfowl, marsh birds and upland birds. (Borman, et al., 1997).

Typha latifolia (Broad-leaf Cattail)

Broad-leaf Cattail
Source: UW Herbarium Website

Typha latifolia (Broad-leaf Cattail) has pale green, sword-like leaves that emerge from a robust, spreading rhizome. The leaves are sheathed around on another at the base and junction of the leaf sheath and blasé the sheath is usually tapered. Broad-leaved cattail can be distinguished from narrow-leaved cattail by the presence of male and female flower spikes immediately adjacent to each other, and the leaves are wider and flatter. Cattails provide nesting habitat for many marsh birds and cover for small fish (Borman, et al., 1997).

4.3 Floristic Quality Index

FQI varies around the state of Wisconsin and ranges from 3.0 to 44.6 with the average FQI of 22.2 (Aquatic Plant Management in Wisconsin - Draft, 2005). FQI is used to help compare lakes around the state and to assess the lake over time. Higher FQI numbers indicate better lake quality. During June, the Lake FQI was 25.2. It increased to 28.4 during August. These FQI values average 26.8, a value slightly above Wisconsin's median of 22.2 (Table 4). This FQI value suggests that the Lake has above average water quality.

4.4 Shoreline Characterization

Emergent and floating leaved plants identified along the shoreline outside of grid sample points included arrowhead, bulrushes, cattails, white water lily, and watershield. The locations of these plant communities is illustrated in Figure 7.

5.0 CONCLUSIONS AND POSSIBLE MANAGEMENT OPTIONS

5.1 Conclusions

Cedar Lake has historically been perceived as a lake with good water quality, and abundant aquatic macrophytes. Water quality data collected between 1997 and 2001 indicate a mesotrophic lake system. Nutrients from both within the lake and from land uses within the watershed are likely contributing nutrients to the lake which can enhance aquatic plant growth. The lake is a popular recreational boating lake. An aquatic plant harvester helps manage dense aquatic plant growth for boating navigation. Most respondents rate their experiences on Cedar Lake as very enjoyable and strongly supported the district's harvesting efforts.

During the June and August 2005 aquatic plant surveys, nineteen and twenty-two aquatic plant species were found, respectively - an indicator of a moderately diverse aquatic plant community. No invasive aquatic plant species were detected in the Lake during either the June or August 2005 surveys completed by Northern Environmental. During the June and August surveys, the most abundant aquatic plant was muskgrass (*Chara sp.)*. Large-leaf pondweed (*Potamogeton amplifolius*) was the second most abundant vascular plant species during June. Wild celery (*Vallisneria americana*) was the second most abundant vascular species during August.

WDNR research staff also completed an aquatic plant survey in summer 2005 and potentially identified Eurasian watermilfoil and Curly Leaf Pondweed, two aquatic invasive species. Confirmation of plant specimens is pending and was not available at the time of this report publication.

Dense growth of wild celery and northern watermilfoil cause navigation problems for boats throughout the summer. One particular problem is the dense growth of wild celery in late summer. The plant tears loose from the bottom and floating mats are encountered across the lake, tangling boat props and causing a potential hazard to water-skiers. This is common in many Wisconsin lakes, although the District noticed an increase in the abundance of wild celery in 2005 (Strebe, 2005).

5.2 Possible Management Options

Some areas of Cedar Lake exhibit aquatic plant growth that interferes with swimming and recreational boating. Dense aquatic plants tangle boat props and the riparian landowners report problems getting their boats from their piers to open water areas. As such, the District has operated an aquatic plant harvesting program. Historically, the harvesting activities were often largely un-regulated. The WDNR promulgated NR 109, Wis. Adm. Code requiring development of APM Plans in order to obtain an aquatic plant management permit for harvesting activities. The NR 109 program is intended to allow management for nuisance conditions but protect aquatic plant communities from improper management. NR 109 requires that an applicant review all available aquatic plant management techniques before selecting a management strategy. Existing physical, biological, and chemical management techniques and current available research were reviewed in detail. A comprehensive comparision of APM techniques, including descriptions about the technology, benefits, drawbacks, and costs are included in Appendix C. Based on these comparisons and the specific aquatic plant problems on Cedar Lake, the following potential management strategies were considered.

5.2.1 Manual Removal

Hand raking or hand pulling can be completed to remove aquatic plants from the water. Benefits include low costs, and the drawbacks are the labor intensive nature of this option. Manual removal by individual landowners can be completed to a maximum width of 30 feet to provide pier or swimming raft access. A permit is not required for hand pulling or raking if the maximum width cleared does not exceed 30 feet. Manual removal exceeding 30 feet in width requires a permit from the WDNR.

5.2.2 Mechanical Harvesting

Aquatic plant harvesting allows easy treatment of large areas of nuisance aquatic plant stands. Advantages of this technology include immediate results, removal of plant material and nutrients, and the flexibility to move to problem areas and at multiple times of the year "as needed". Disadvantages of this method include the limited depth of operation in shallow areas, high initial equipment costs, disposal site requirements, and a need for trained staff to operate the harvester. A full discussion about harvesting is included in Appendix C.

The District currently operates one aquatic plant harvester and a shore conveyer. The District has recently incurred costly repairs to the aging harvester and has initiated the process of purchasing new equipment. A harvester will typically last 10 years, potentially longer with proper use and maintenance.

5.2.3 Aquatic Herbicide Treatment

Use of an aquatic herbicide was considered as a potential management option. A suitable herbicide applied at an appropriate dose by an experienced licensed pesticide applicator can target a problem aquatic plant species. Advantages of chemical herbicides include better control in confined areas (e.g. around docks) than harvesters can achieve. Disadvantages include the potential to affect non-target plant species (if not applied at an appropriate application rate). After an application, water use restrictions may be necessary.

Chemical treatments are discussed at length in Appendix C. While chemical treatments of large areas of native vegetation is not typically supported by WDNR who approve/deny aquatic plant management permits, specific circumstances may be permitted where the native plants exhibit a significant nuisance condition.

6.0 RECOMMENDED ACTION PLAN

Consistent with the goals of the APM Plan, and the feasible aquatic plant management alternatives discussed in Section 5.2, the District has prepared a comprehensive aquatic plant management plan that integrates aquatic plant management techniques for nuisance growth on Cedar Lake. These techniques and other important components of the comprehensive APM Plan are discussed in the following sections.

The District should periodically update this APM Plan to reflect current aquatic plant problems, and the most recent acceptable APM methods. Information is available from the WDNR website: http://dnr.wi.gov/org/water/fhp/lakes/aquaplan.htm or from Northern Environmental upon request.

6.1 Manual Removal

Individual property owners can manually remove nuisance aquatic plants in the lake offshore from their property. Manual removal can be completed to a maximum width of 30 feet to provide pier or swimming raft access. A permit is not required for hand pulling or raking if the maximum width cleared does not exceed 30 feet. Manual removal exceeding 30 feet in width requires a permit from the WDNR. Requests to exceed 30 foot removal width should be brought to the District's attention and alternative management could be considered (e.g. harvesting).

6.2 Mechanical Harvesting

The District will continue mechanical harvesting for navigation purposes using District-owned harvesting equipment. The WDNR reguates mechanical harvesting under Chapter NR109 of the Wisconsin Administrative Code (NR 109 Wis. Adm. Code). The District must comply with the conditions of a WDNR-issued harvesting permit. A copy of the current harvesting permit and NR 109 Wis. Adm. Code is included in Appendix D. Harvesting for aesthetic reasons is not allowed. Harvesting is allowed to provide nuisance relief for navigation subject to the following restrictions.

Areas

Aquatic plant harvesting will be completed on Cedar Lake for navigation purposes only within the permitted area illustrated on Figure 8. Harvester operators shall target nuisance areas of dense submergent aquatic plant growth that interferes with swimming, significant boat traffic or other recreation within this area. The operator shall not harvest emergent (e.g. bulrushes) or floating leaved plants (e.g. water lilies). The harvesting map (Figure 8) illustrates approximately 80 acres where aquatic plants may potentially he harvested. The area illustrated is between 3 and 15 feet of water depth minus areas where floating leaved vegetation is present or shoreline areas that are not developed. The nuisance aquatic plants within the mapped area are only harvested for pier access, swimming areas and boat navigation lanes. Furthermore, the harvester is not operated in less than 3 feet of water depth. Harvesting may occur at half the water column depth and aquatic plants growing to 15 feet are only cut to the 5 foot harvester cutter head depth. Many areas of harvesting may have 15 feet of vertical plant growth and only require a few cuttings to a depth of 5 feet to provide safe boating. Other parts of the lake provide a more sustained growth throughout the summer requiring more intense cutting. Harvesting experience included that this area is probably approximately 12 acres. Residents not wanting an access channel can request "No Cut" in front of their property and this request is honored.

Depth

The harvester operator shall not operate the harvester in less than 3 feet of water depth to prevent disruption of the bottom sediments, turbidity, and/or damage to the cutting head. If any sediments are encountered, the cutter head will be raised immediately. Harvesters will cut approved harvesting areas at half the water column depth. Full cutter depth (5 feet) is only operated at water depths of 10 feet or greater.

Operators

Prior to each harvesting season, each operator will be required to review the APM Plan and conditions of the harvesting permit. Harvester operators will be trained to know the limitations of harvesting (areas and depths). The approved harvesting area map (Figure 8), a copy of the DNR harvesting permit, and the harvesting restrictions listed above will be included in a harvester guidance binder on each aquatic plant harvester. Harvesting operators report to the District commissioners who identify proposed harvesting routes based on plant density and navigation need.

Timing

Timing of aquatic plant harvesting is a useful tool in selective management and therefore is considered an important component of the APM Program activities. Aquatic plant harvesting activities will normally begin after Memorial Day. This date is protective of April and May fish spawning seasons. Based upon past experience, harvesting intensity will typically increase into late summer when wild celery becomes a significant nuisance species.

Record Keeping

The District will maintain detailed records including harvesting dates, harvesting areas, types, and amounts of aquatic plants harvested. A sample record keeping form is included in Appendix E.

Additional specific information about the Cedar Lake harvesting program (completed WDNR harvesting worksheet) is included in Appendix E.

6.3 Sensitive Areas

WDNR often will designate sensitive areas on Wisconsin Lakes. Sensitive Areas are defined as "areas of aquatic vegetation identified by the department as offering critical or unique fish and wildlife habitat, including seasonal or lifestage requirements, or offering water quality or erosion control benefits to the body of water". Sensitive areas are often located where there is little to no shoreline development. Shoreline features (developed areas and undeveloped areas) are illustrated on Figure 9. WDNR has not conducted any sensitive area surveys on Cedar Lake. If such surveys are completed, additional restrictions to the harvesting program or APM in general may be required. Information about sensitive areas is included in Appendix F.

6.4 Watercraft Inspection

The District should develop a watercraft inspection program. This is extremely important to prevent the introductions of AIS such as EWM and curly leaf pondweed into Cedar Lake or the export of the zebra mussel from Cedar Lake. EWM is present in other area lakes and preventing it's introduction into Cedar Lake should be a high priority component of this APM Plan.

The Watercraft inspection effort in Wisconsin involves providing information to lake users about what invasive species look like and what precautions they should take to avoid spreading them. It also involves visual inspection of boats to make sure they are "clean" and demonstration to the public of how to take the proper steps to clean their boats and trailers. Watercraft inspectors also install signs at boat landings informing boaters of infestation status, state law, and steps to prevent spreading AIS. The **Clean Boats Clean Waters** Program is sponsored by the DNR, UW Extension, and the Wisconsin Association of

Lakes and offers training to volunteers on how to organize a watercraft inspection program. For more information see the following website: http://www.uwsp.edu/cnr/uwexlakes/CBCW/default.asp. Or contact Laura Felda- Marquardt, Volunteer Coordinator for the Invasive Species Program, UW Extension-Lakes Program at (715) 346-3366 or (715) 365-2659 for details. If any of the above hyperlinks to web addresses become inactive, please contact Northern Environmental for appropriate program and contact information.

6.5 Nutrient Controls

Recognizing that nutrients in runoff and from septic systems can contribute to excessive aquatic plant growth on Cedar Lake, the District previously completed water quality studies to better understand the water quality conditions of Cedar Lake. These efforts were used to develop the Cedar Lake Management Plan. Recommendations in that management plan included several items to control nutrient inputs to the lake: educating people within the watershed on the effects of excessive nutrients in runoff; and considering the benefits of a public sewer system. The District is beginning implementation of those lake management recommendations and other nutrient control efforts such as purchasing phosphorus free fertilizers for resale to area landowners, and development of septic systems review within the District.

The District may also consider encouraging landowners to install a natural shoreline buffer on their property. Offering lakeshore residents within the District who complete such a project a tax credit is one idea.

6.6 Public Education

The District should continue to promote education to lake users about the importance of aquatic plants to the lake ecosystem and prevention of Aquatic Invasive Species introductions. Public education has also been an on-going part of this APM Plan development. Northern Environmental wrote an article about aquatic plant management that was included in a spring 2005 District newsletter. A copy of the article is included in Appendix G. Northern Environmental also met with the District commissioners on May 4th 2005 to discuss the required components of an APM Plan and discuss project goals. The District announced an informational presentation about APM in the local newspaper. Northern Environmental presented information about aquatic plants and aquatic plant management to attendees on July 16, 2005. The presentation included a hands on look at aquatic plant specimens collected from Cedar Lake. Information presented emphasized:

- The values that aquatic plants provide
- The importance of keeping excessive nutrients out of a lake
- The importance of keeping AIS out of the lake.

Several WDNR and UW Extension fact sheets about aquatic plants and aquatic plant management were distributed to attendees at the meeting. A copy of the materials distributed is provided in Appendix G. The District can order copies of WDNR and UW Extension publications by visiting the following website:
http://www.uwsp.edu/cnr/uwexlakes/publications/

If the above hyperlink to web addresses become inactive, please contact Northern Environmental for appropriate program and contact information. Public education should continue with emphasis on the above topics. If you need additional public education materials, contact your WDNR lake coordinator, local UW Extension agent, or Northern Environmental for more information.

6.7 Monitoring

To evaluate the effectiveness of the APM Program, monitoring of multiple components should be completed.

6.7.1 Aquatic Plant Monitoring

Since the survey may have identified EWM and Curley Leaf Pondweed, monitoring for AIS should be a high priority for the District. The District should either contract for annual AIS monitoring or have a volunteer trained to complete the AIS monitoring through the WDNR self help program. At a minimum the harvester operator should be trained to recognize AIS such as EWM and curly leaf pondweed, Additional information about these exotic aquatic plants is available in the educational materials in Appendix G. Additional information is also available from the WDNR website:

http://dnr.wi.gov/invasives/aquatic.htm

or from Northern Environmental upon request. The operator shall report any new AIS to a District Commissioner immediately. The District should complete periodic monitoring for AIS such as EWM and Curly leaf pondweed. Since EWM was not identified in Cedar Lake, but is present on other lakes within the county, at a minimum the public boat launch area should be inspected at least once per year. Grants may be available to help fund hiring professionals to complete these monitoring efforts or local lake enthusiasts can become trained in the WDNR self-help citizen monitoring program. For more information on having volunteers provide AIS monitoring, please visit the following website:

http://dnr.wi.gov/org/water/fhp/lakes/selfhelp/shlmhowto.htm

Or contact your local lake coordinator from the list at:

http://www.dnr.state.wi.us/org/water/fhp/lakes/selfhelp/shlmcont.asp

If any of the above hyperlinks to web addresses become inactive, please contact Northern Environmental for appropriate program and contact information.

Northern Environmental also recommends completing lakewide aquatic macrophyte surveys every 5 to 10 years to monitor changes in the aquatic plant community and the effects of the APM activities. Aquatic plant communities may change with varying water levels, water clarity, nutrient levels, and aquatic plant management. These formal surveys should duplicate the 2005 point intercept survey.

6.7.2 APM Technologies

The APM technologies listed in Appendix C should be re-visited periodically to evaluate if new or improved technologies are available. The professional environmental science community includes universities, state natural resource regulatory agencies (e.g. WDNR), and federal regulatory agencies (e.g. USFWS, USACE, EPA, and USGS). The District is encouraged to “stay current” with this research as the knowledge gained from these endeavors may prove useful for APM activities or overall aquatic ecosystem management in the future.

6.7.3 Public

The District should assess the public's perception of APM on Cedar Lake. Periodic questionnaires (similar to Appendix A) should be solicited in District mailings to evaluate the opinions of lake users about aquatic plants and management on Cedar Lake.

6.7.4 Water Quality

The District previously completed water quality studies to better understand the water quality conditions of Cedar Lake and develop the Cedar Lake Management Plan. Recommendations in that management plan included continued water quality monitoring to evaluate changes in the lake's water quality over time. The Manitowoc County Lakes Association reportedly completes water clarity (secchi disk) monitoring on Cedar Lake, but no water chemistry results are reported on the WDNR self help database. The District is currently planning a 2006 water quality sampling program. A District Commissioner has begun taking dissolved oxygen, temperature and Secchi Disk readings in October 2005 and is applying to become part of the WDNR self help program. Future sampling training of the volunteer is anticipated to allow for future Chlorophyll and Phosphorus sampling.
For more information, please visit:

http://dnr.wi.gov/org/water/fhp/lakes/selfhelp/shlmhowto.htm

Or contact your local lake coordinator from the list at:

http://www.dnr.state.wi.us/org/water/fhp/lakes/selfhelp/shlmcont.asp

If any of the above hyperlinks to web addresses become inactive, please contact Northern Environmental for appropriate program and contact information.

7.0 REFERENCES

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SCALE IN FEET

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CONTOUR INTERVAL 10 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

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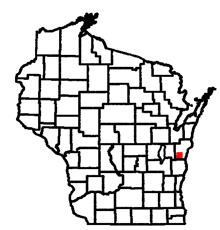

QUADRANGLE LOCATION

BASE MAP SOURCE: USGS 7.5 MINUTE QUADRANGLE, SCHOOL HILL, WISCONSIN, 1992 (NATIONAL GEOGRAPHIC HOLDINGS, INC.)

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WISCONSIN ▲ MICHIGAN ▲ ILLINOIS ▲ IOWA

LAKE LOCATION & LOCAL TOPOGRAPHY

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 1

NOTES:
DEPTH DATA COLLECTED BY NORTHERN ENVIRONMENTAL JUNE 2005
CONTOURS ARE 5 FOOT INTERVALS
BASE MAP SOURCE: USDA-FSA-APFO Digital Ortho MrSID Mosaic 1992

SCALE IN FEET
200 0 200 400

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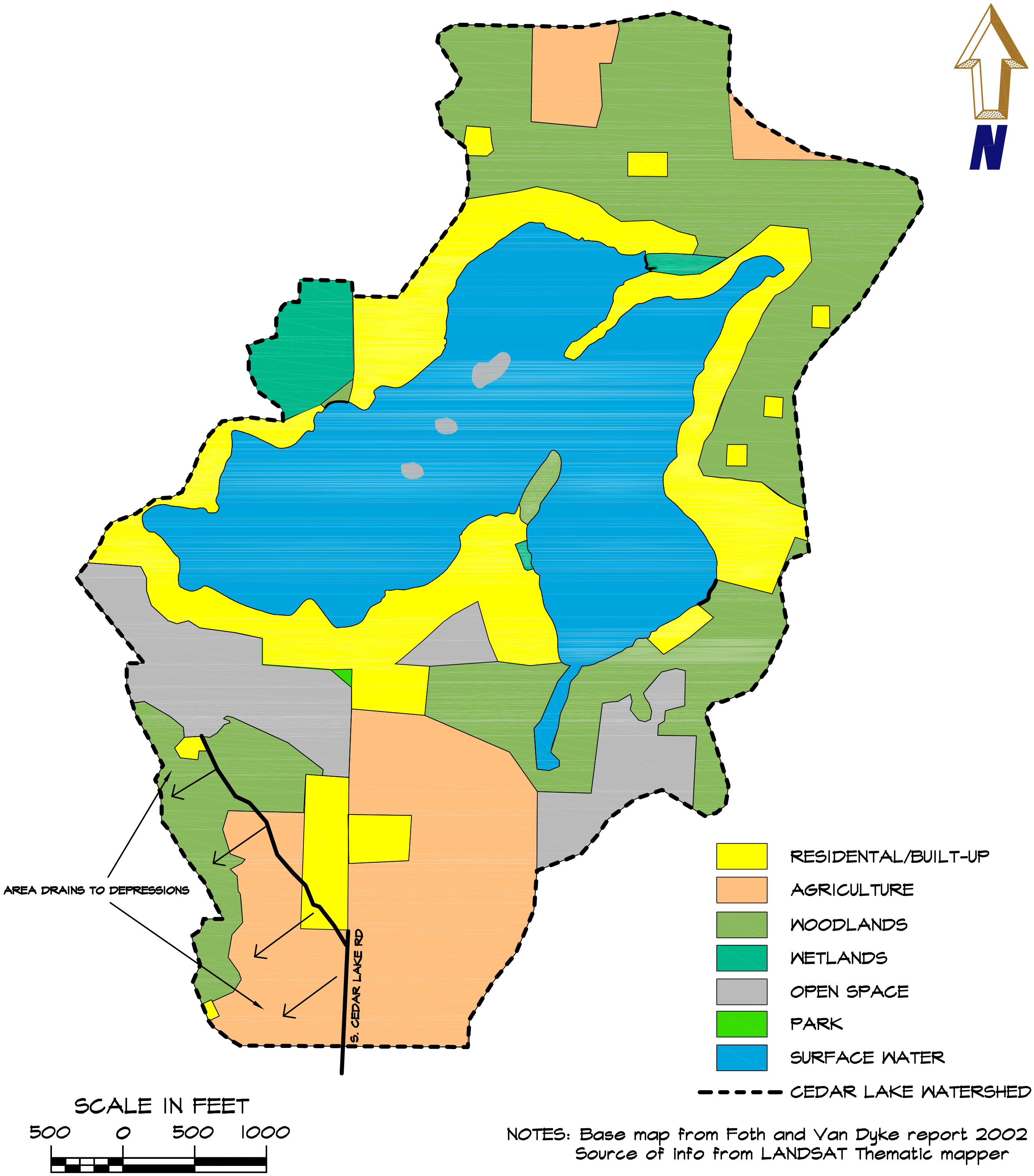
WISCONSIN ▲ MICHIGAN ▲ ILLINOIS ▲ IOWA

LAKE BATHYMETRY MAP

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 2



NOTES: Base map from Foth and Van Dyke report 2002
Source of info from LANDSAT Thematic mapper

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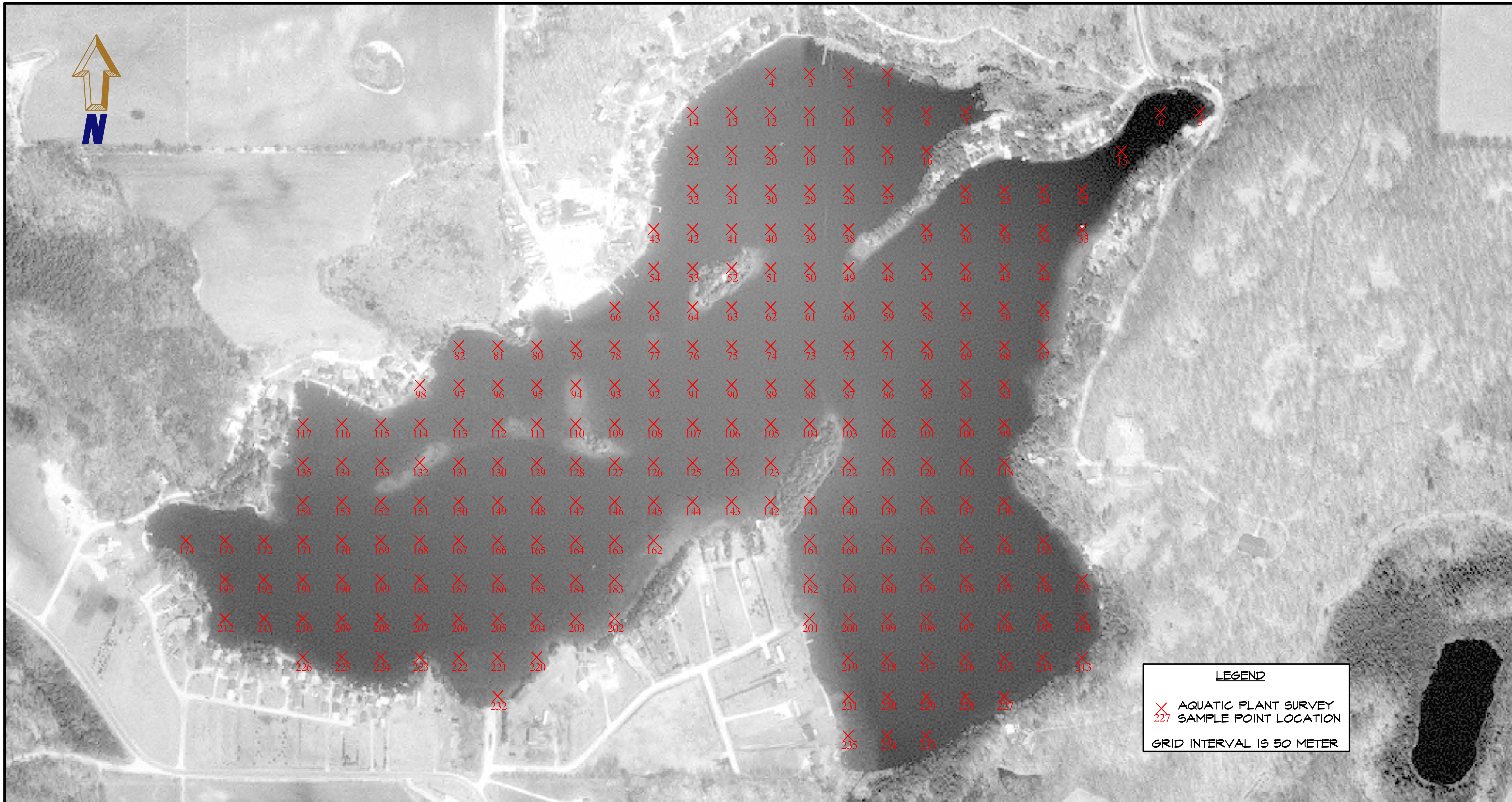
Phone: 800-498-3921 Fax: 920-324-3023
WISCONSIN MICHIGAN ILLINOIS IOWA

WATERSHED AND LAND USES

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

DATE: 10/12/05 | DRAWN BY: DDP | TASK NUMBER: XXX | PROJECT NUMBER: CEL08-3100-0685 | FIGURE 3



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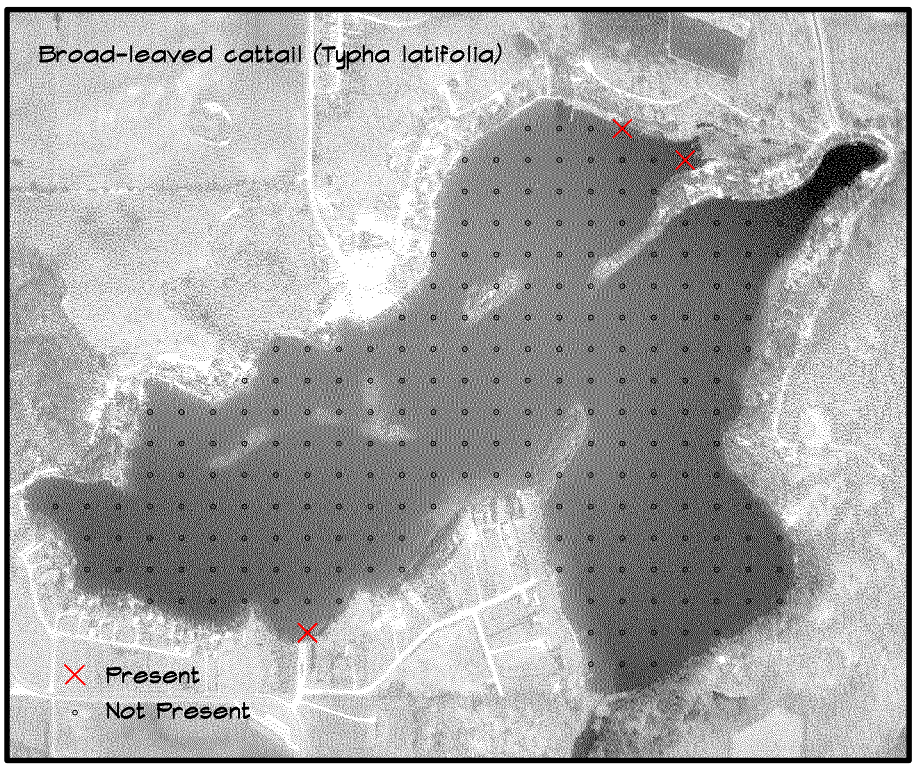
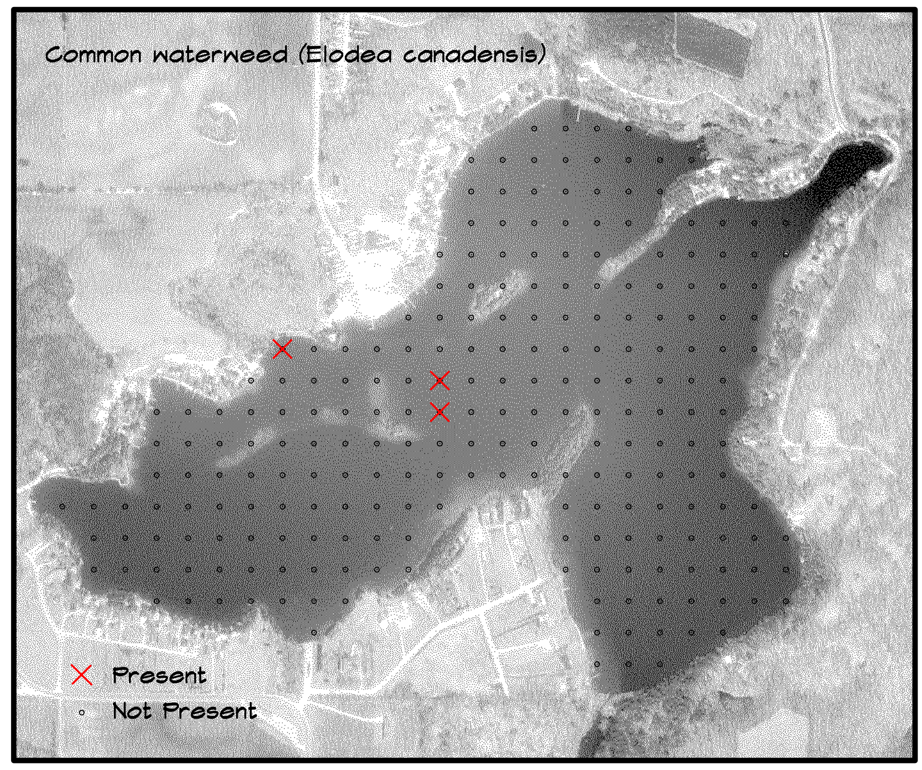
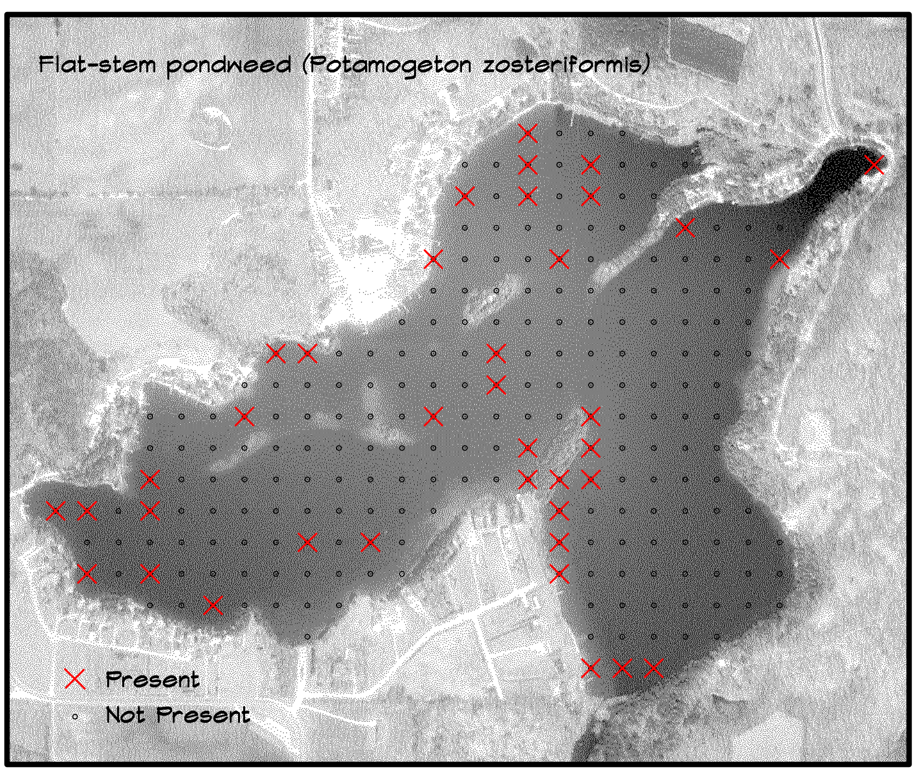
AQUATIC PLANT SURVEY SAMPLE LOCATION

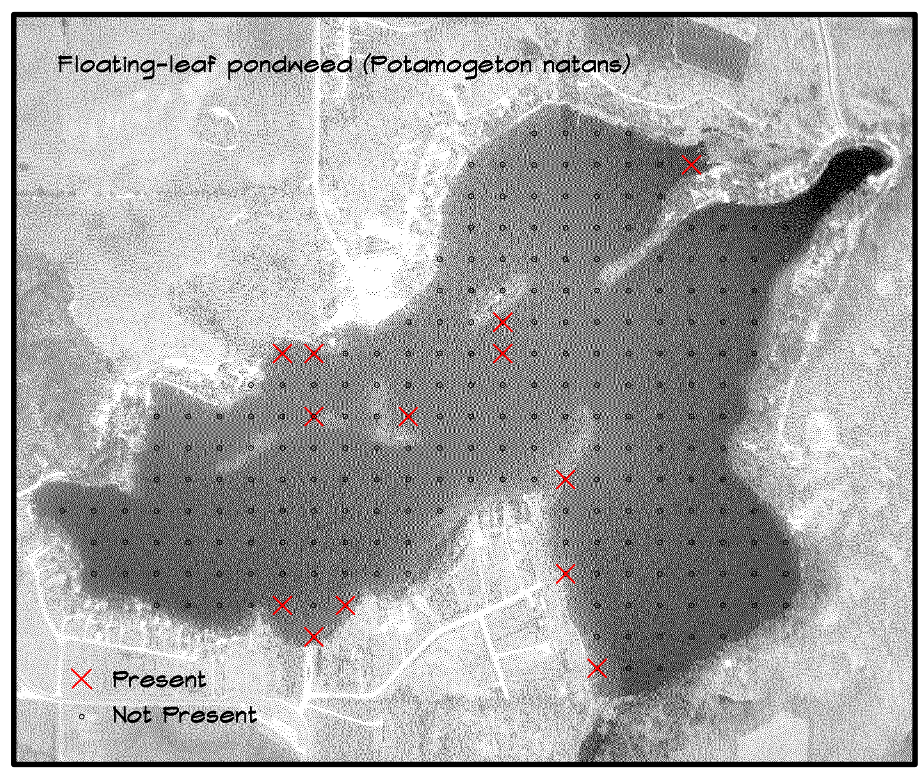
TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

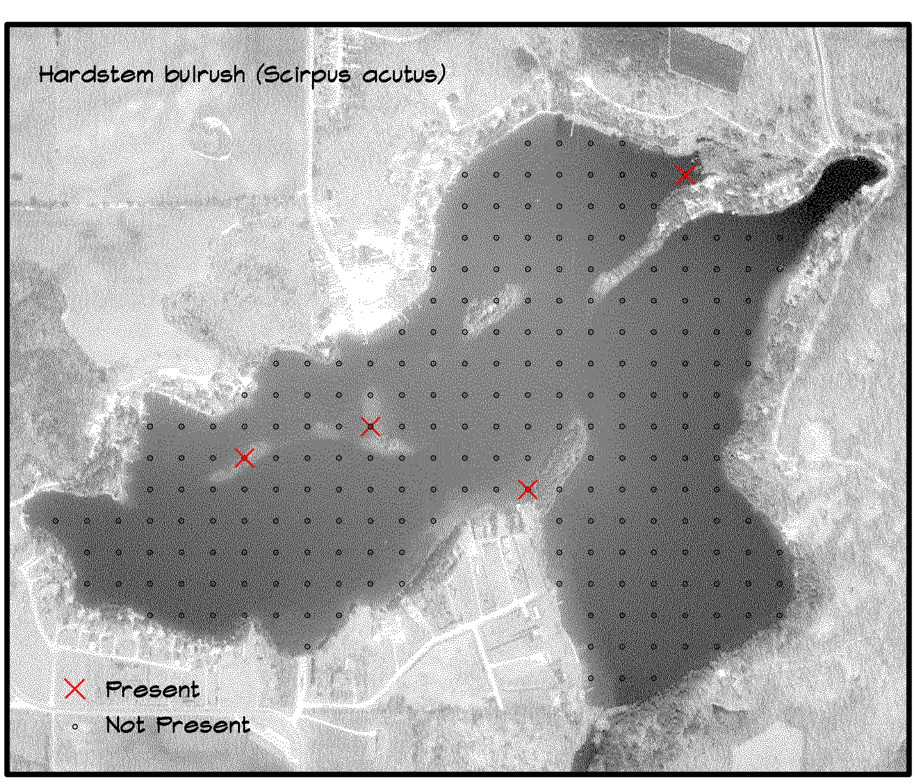
DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 4

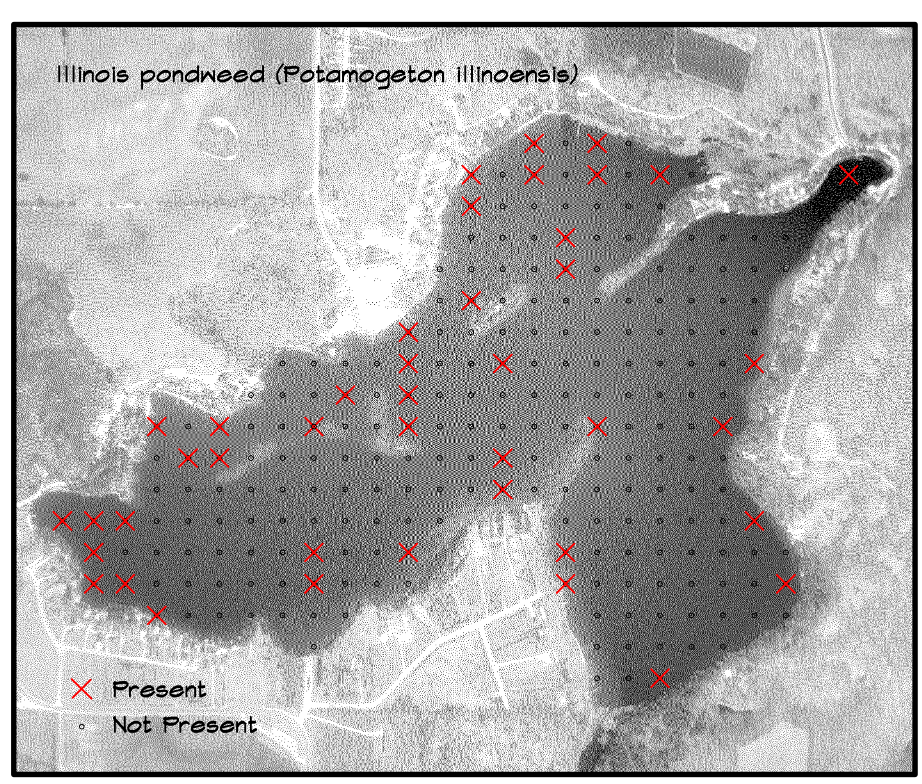


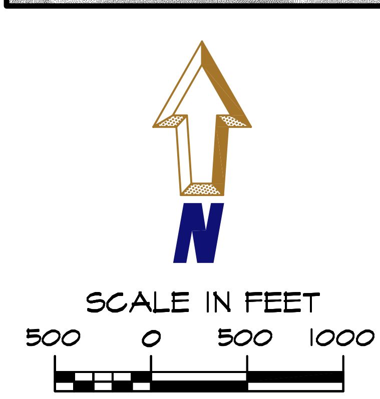












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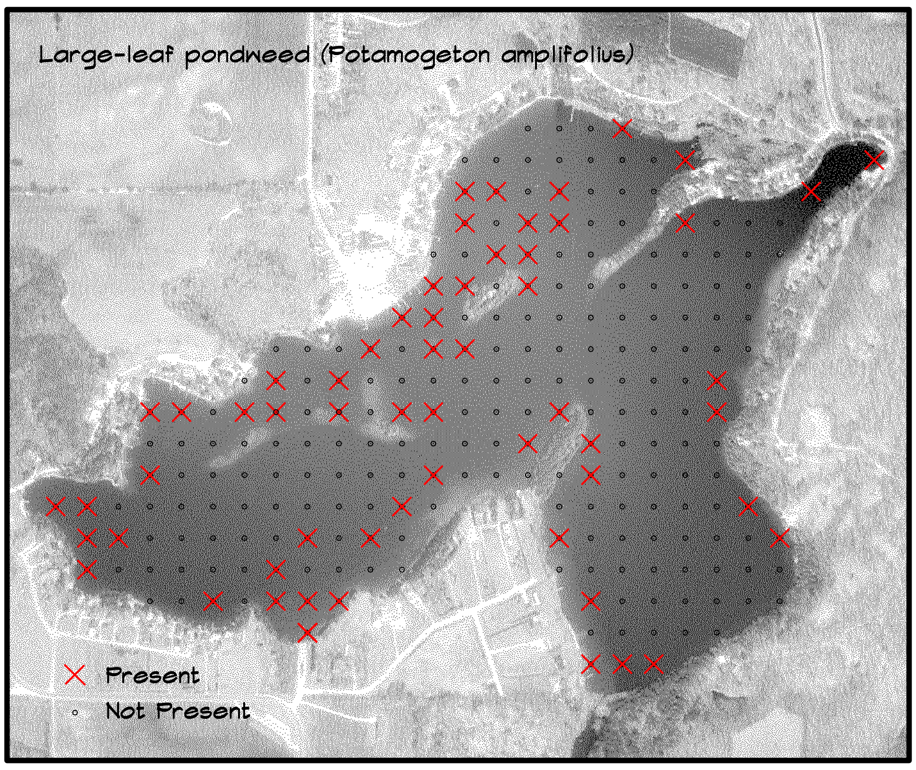
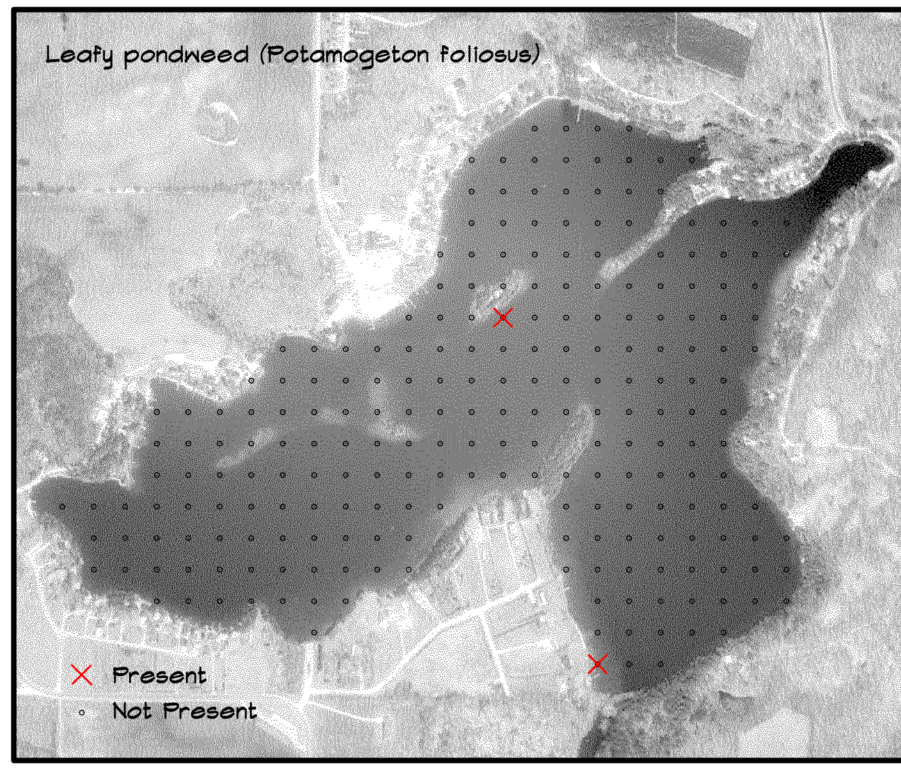
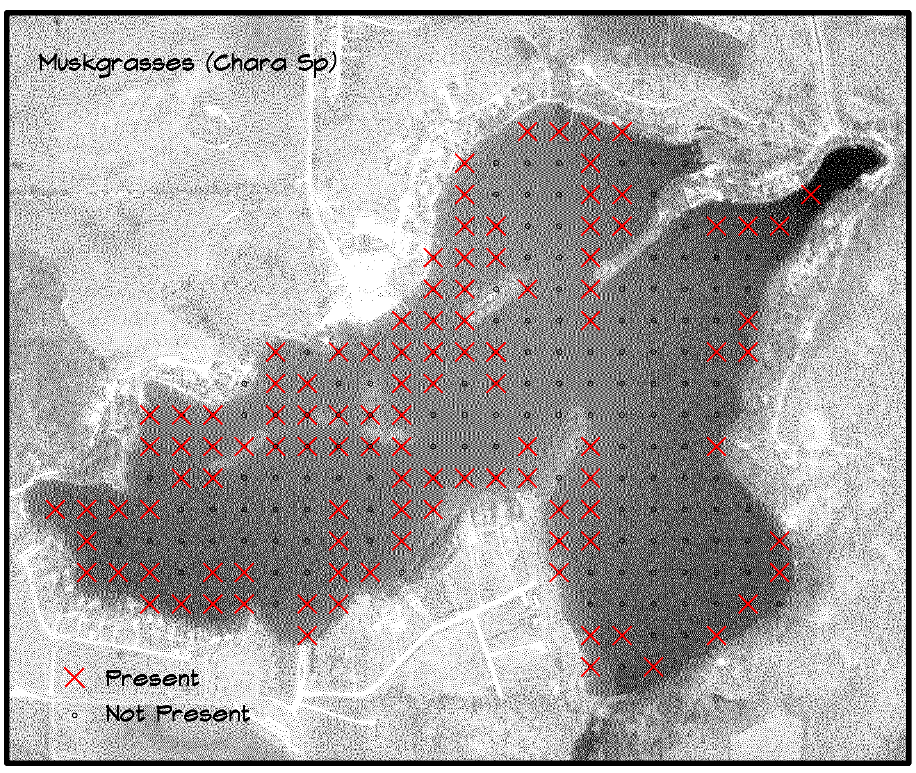
JUNE 2005 AQUATIC PLANT DISTRIBUTION MAP

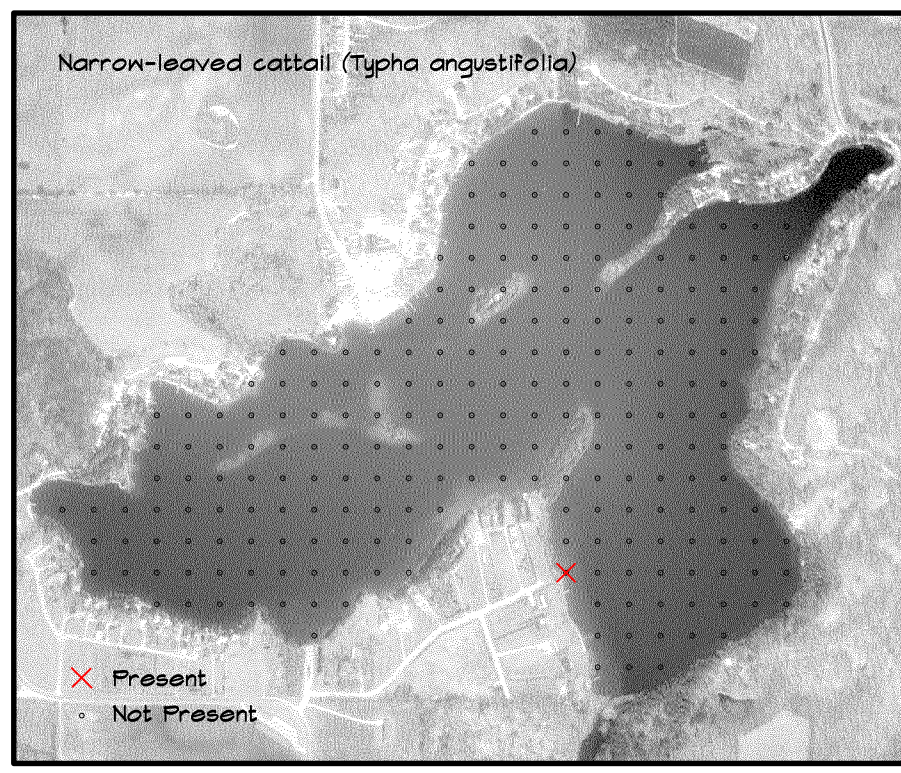
TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

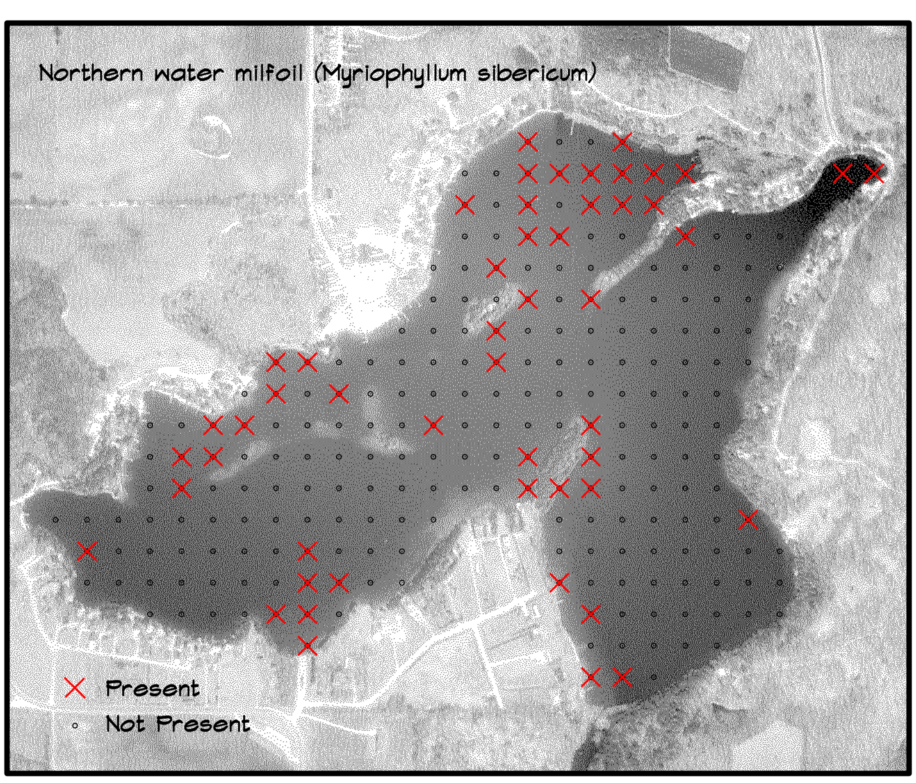
DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 5a

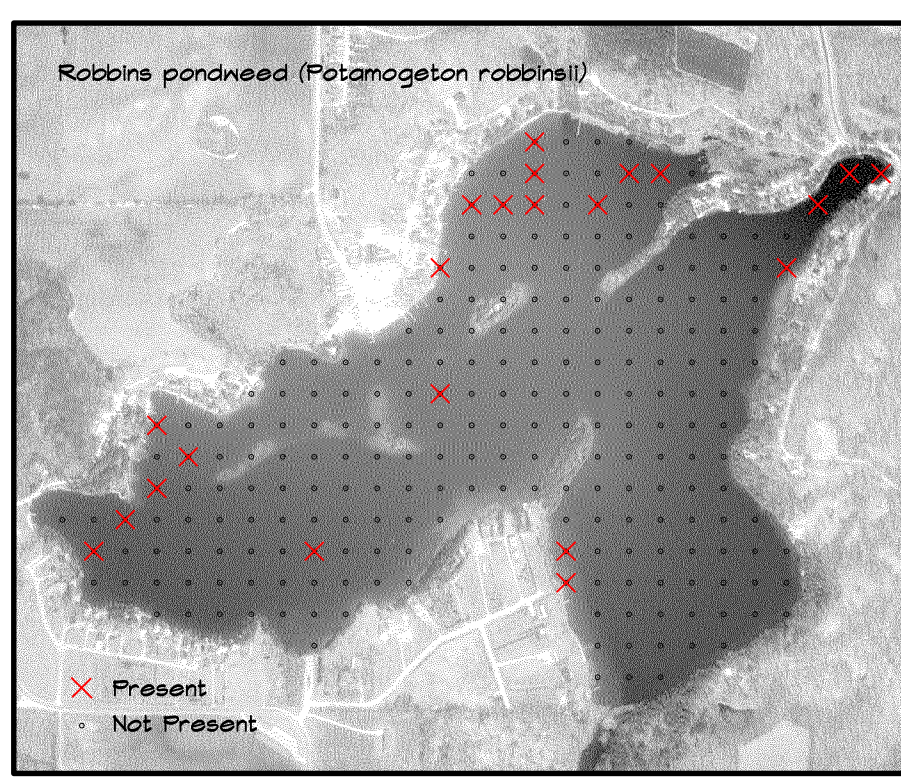


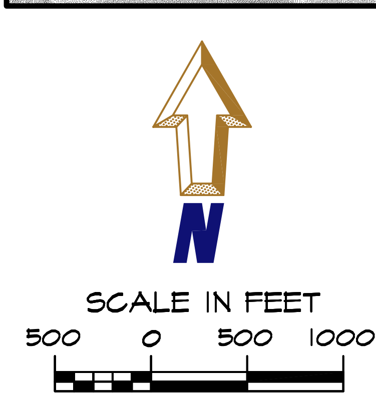












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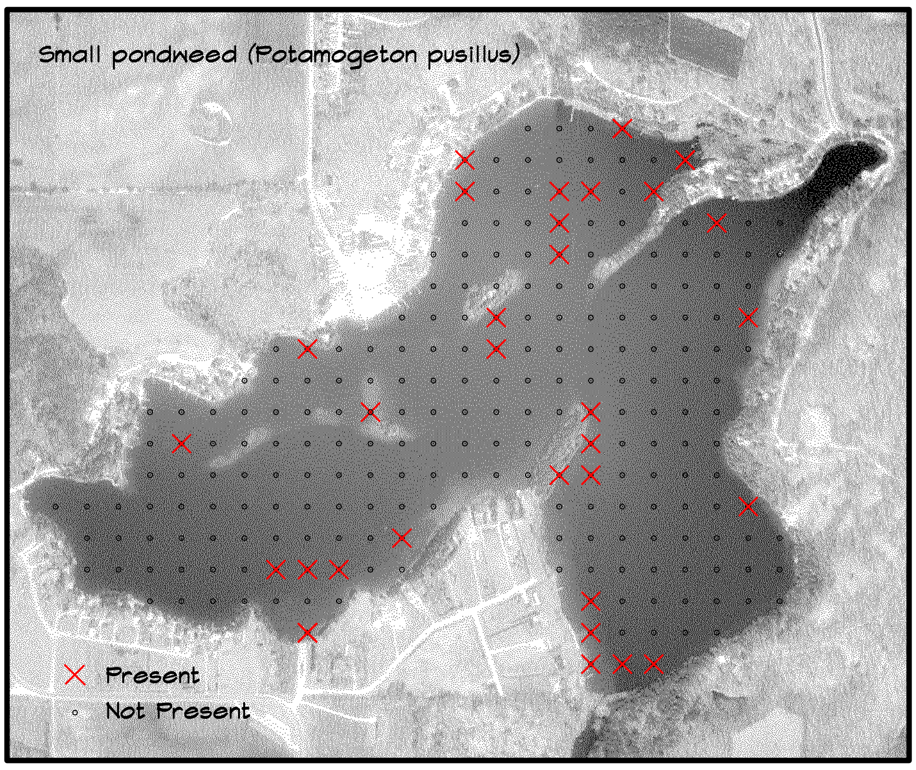
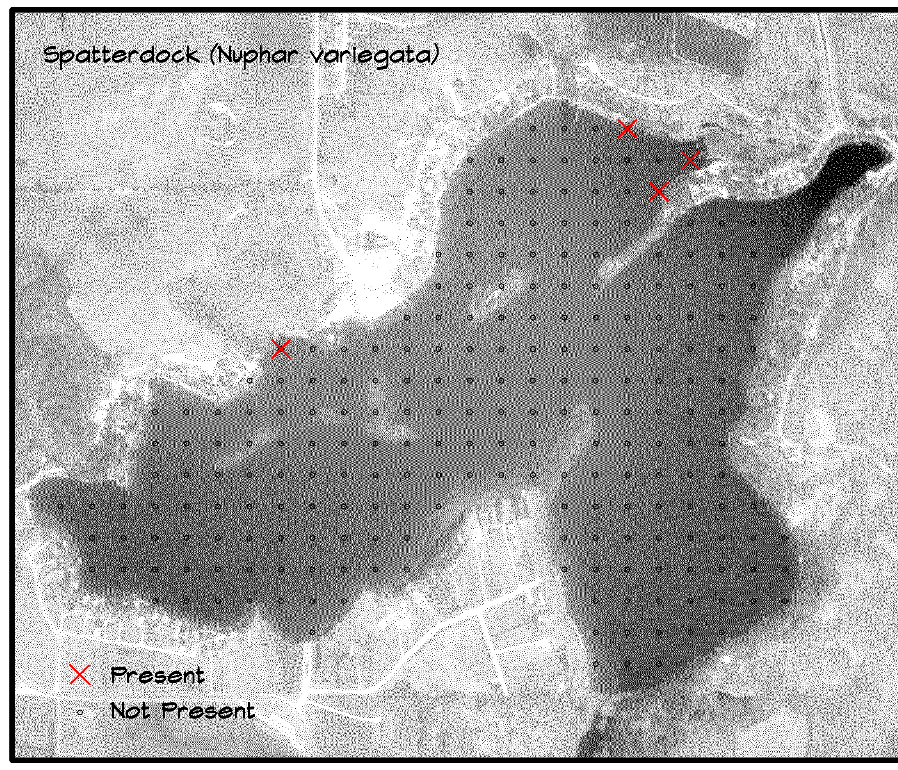
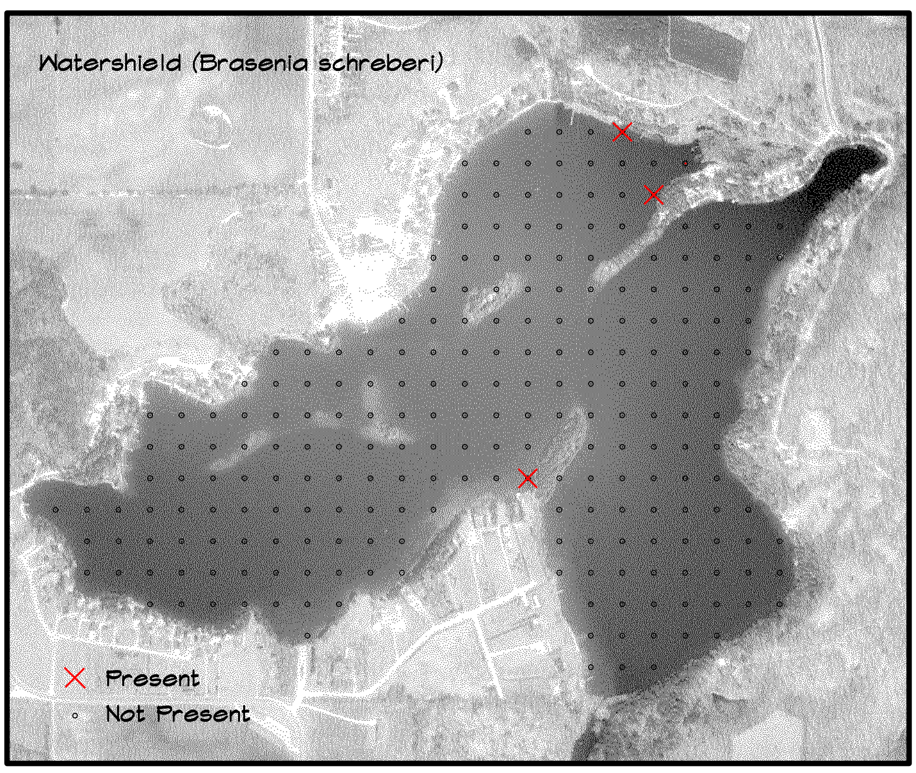
JUNE 2005 AQUATIC PLANT DISTRIBUTION MAP

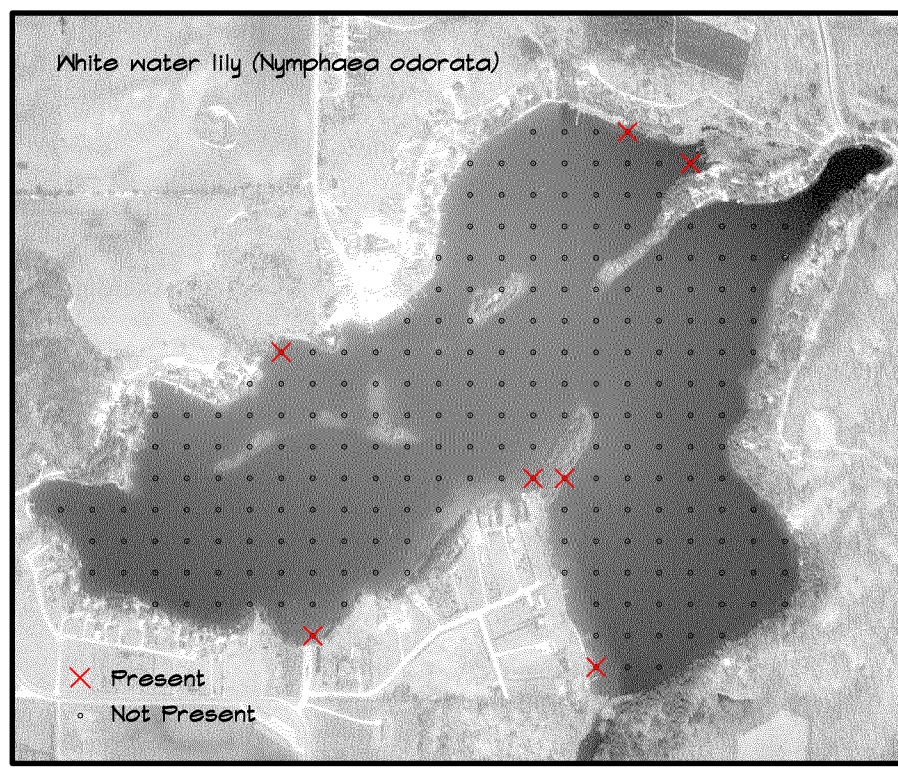
TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

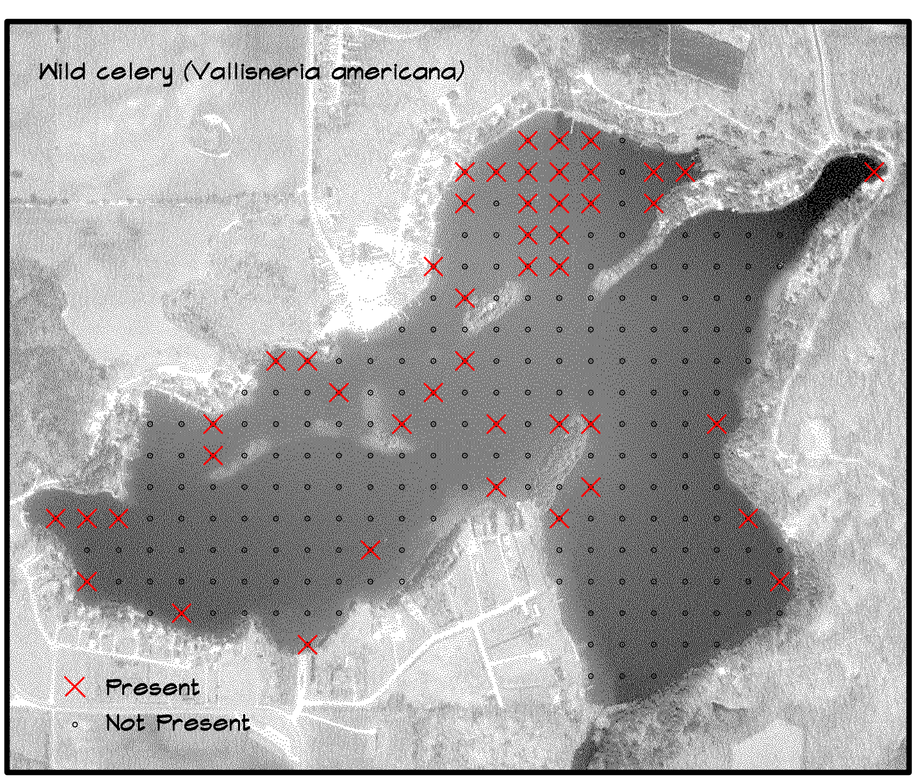
DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 5b

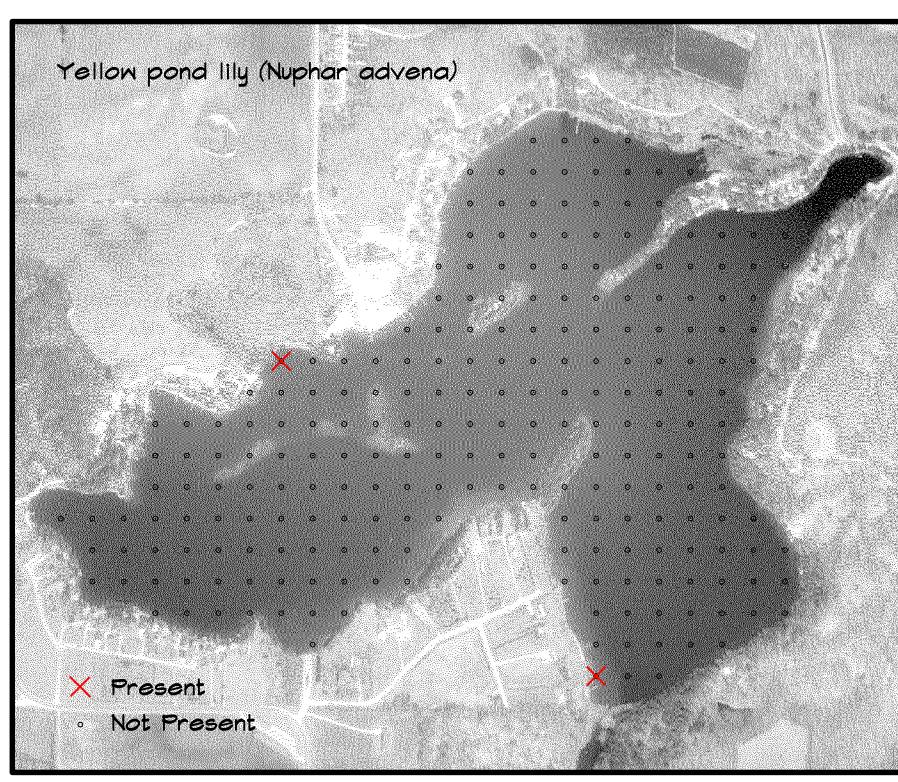


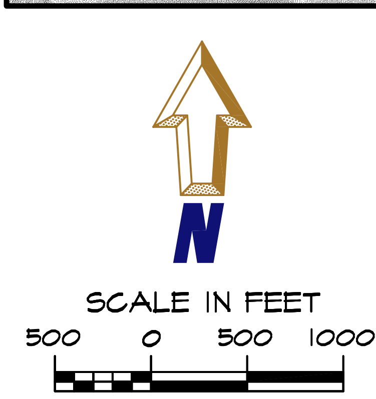












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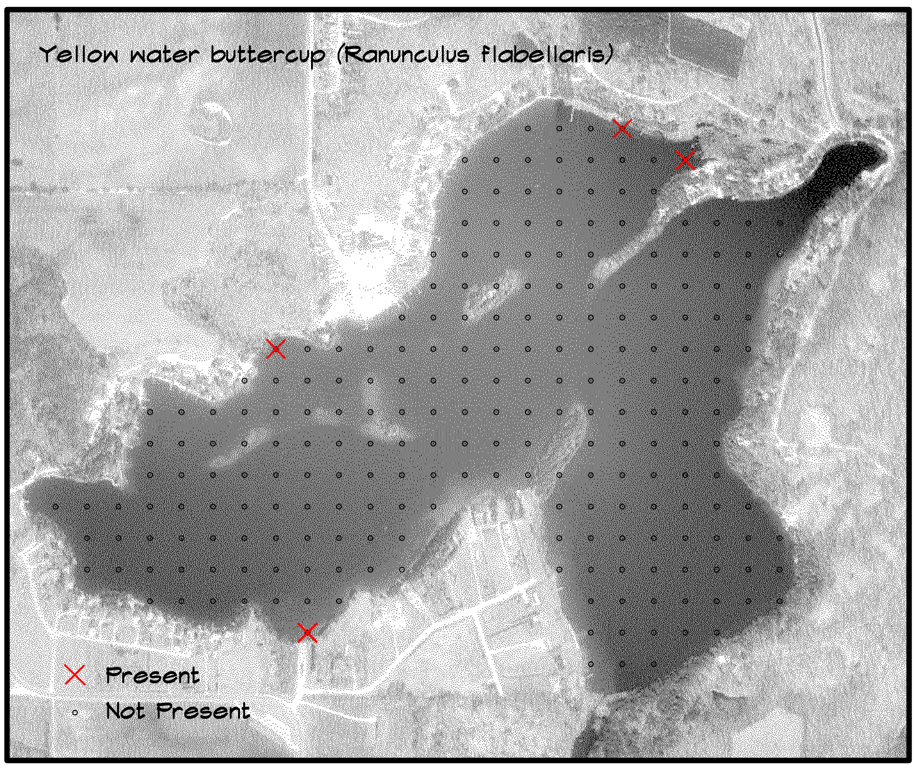
JUNE 2005 AQUATIC PLANT DISTRIBUTION MAP

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 5c



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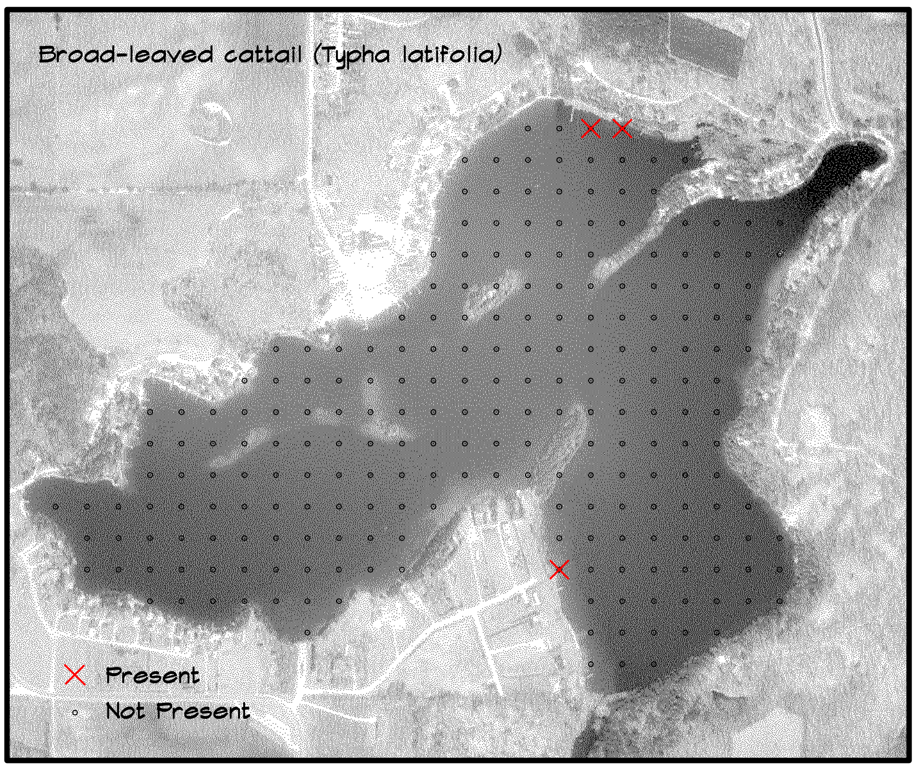
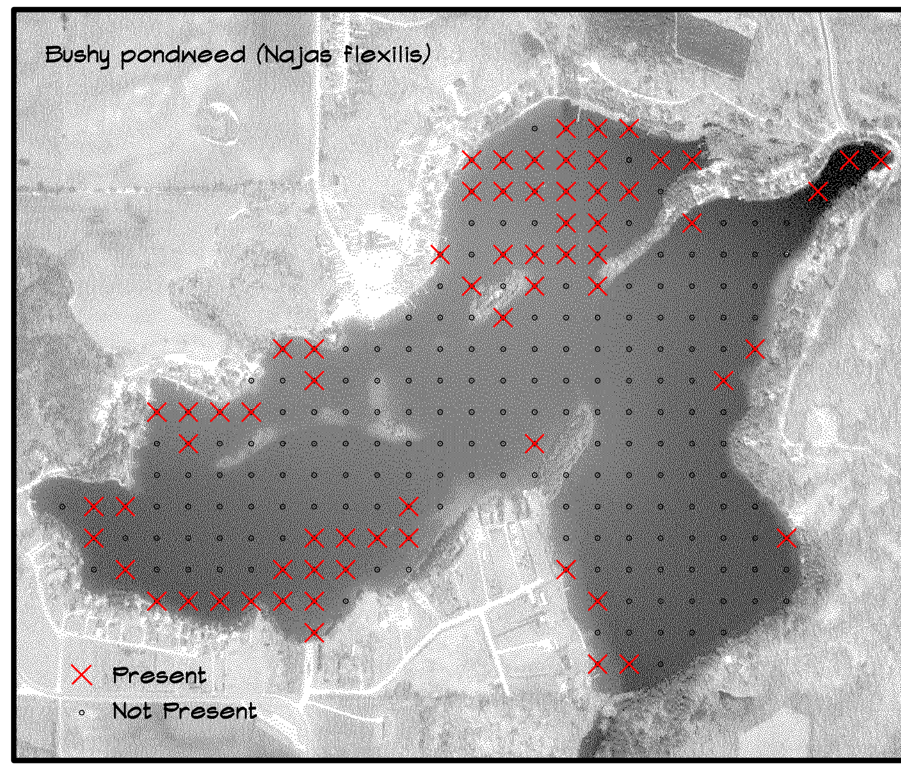
JUNE 2005 AQUATIC PLANT DISTRIBUTION MAP

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

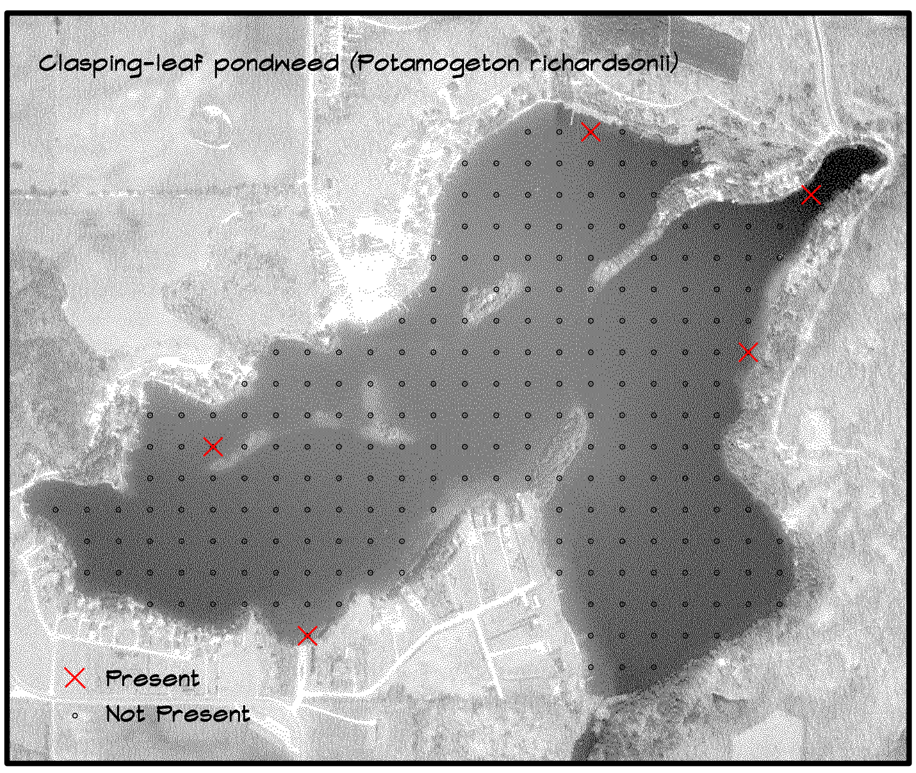
DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 5d



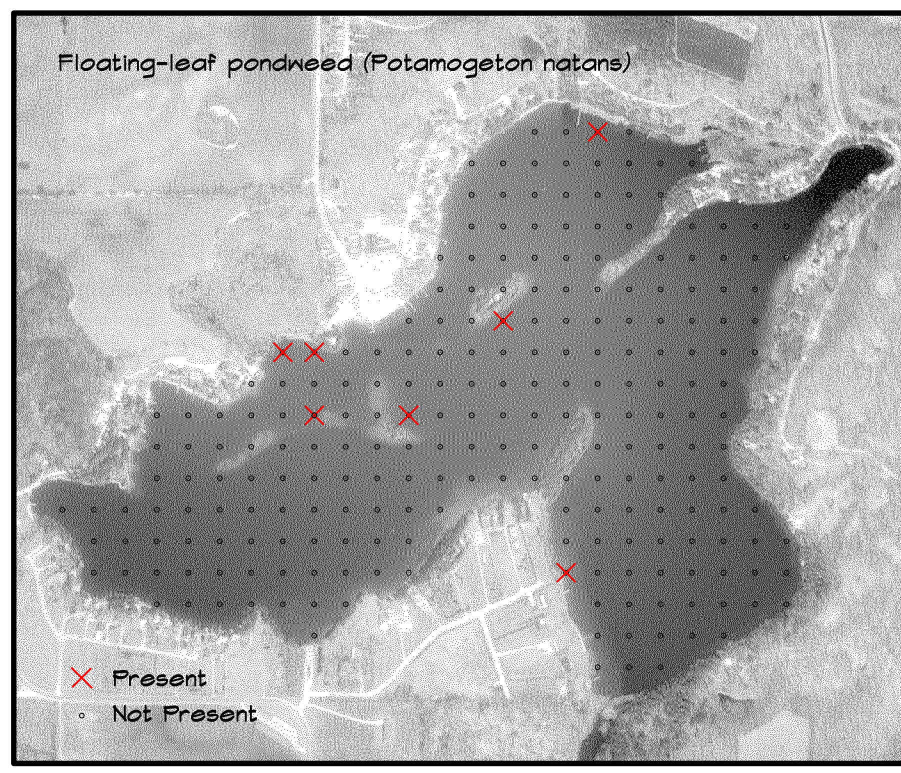
Broad-leaved cattail (Typha latifolia)



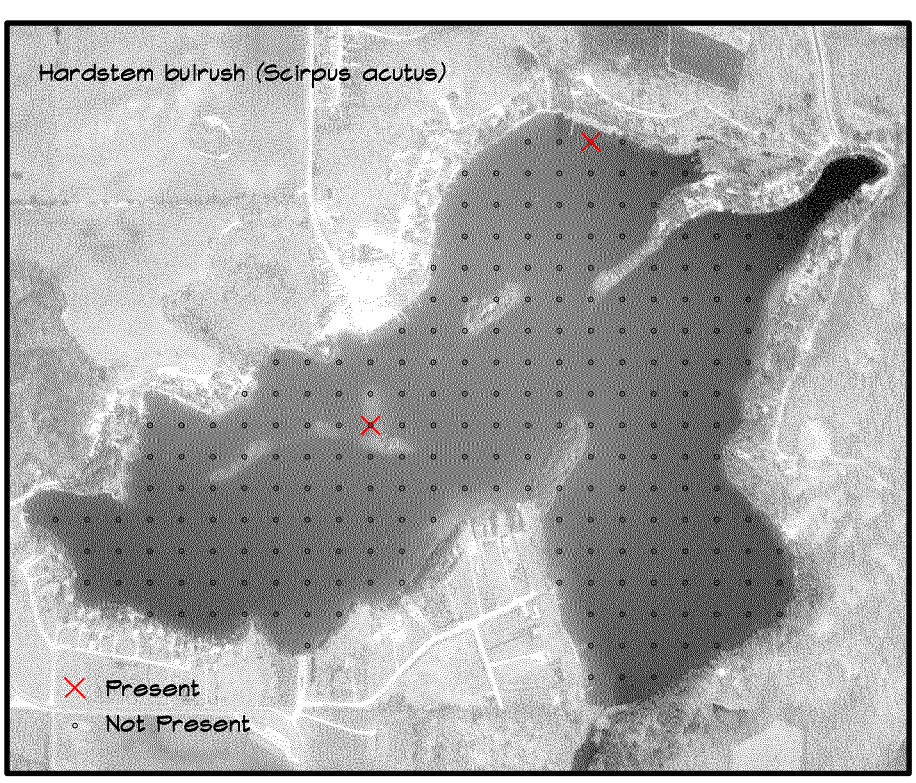
Bushy pondweed (Najas flexilis)



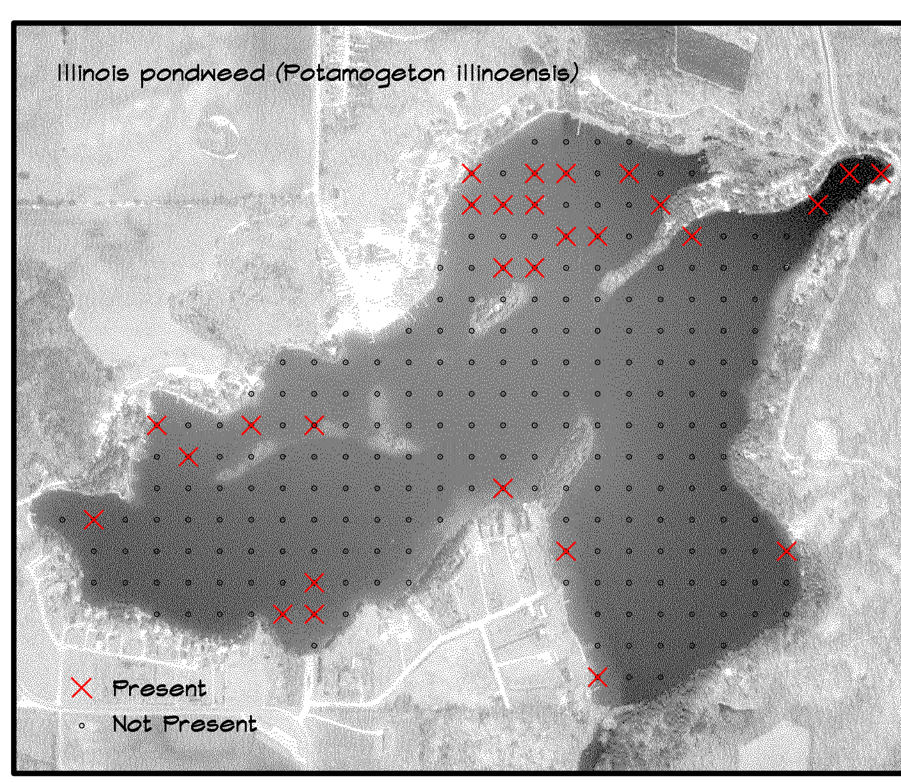
Clasping-leaf pondweed (Potamogeton richardsonii)



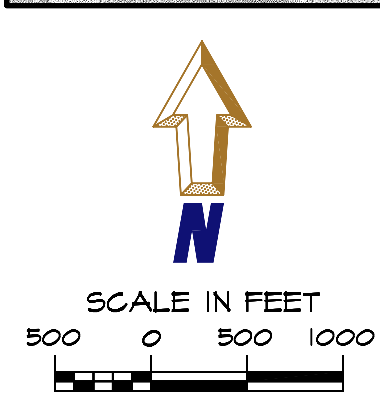
Floating-leaf pondweed (Potamogeton natans)



Hardstem bulrush (Scirpus acutus)



Illinois pondweed (Potamogeton illinoensis)



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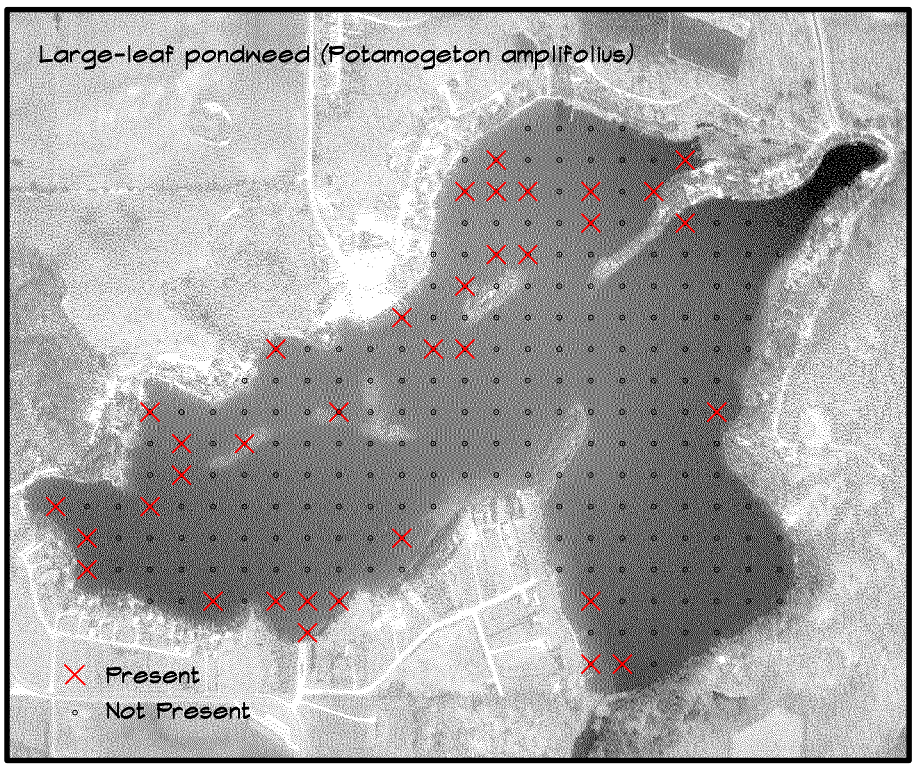
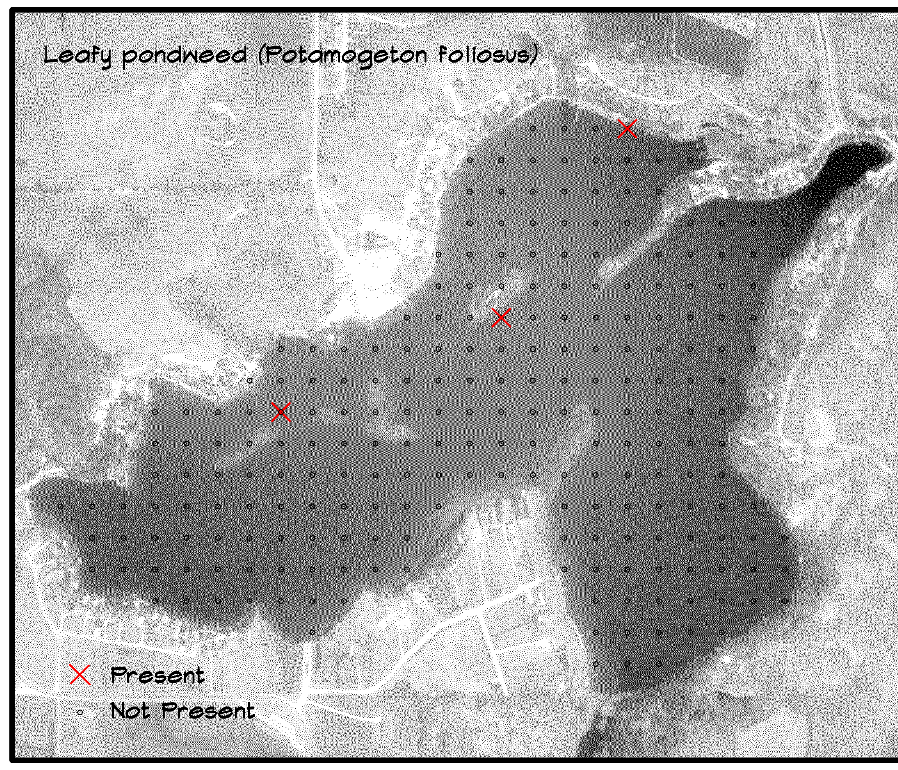
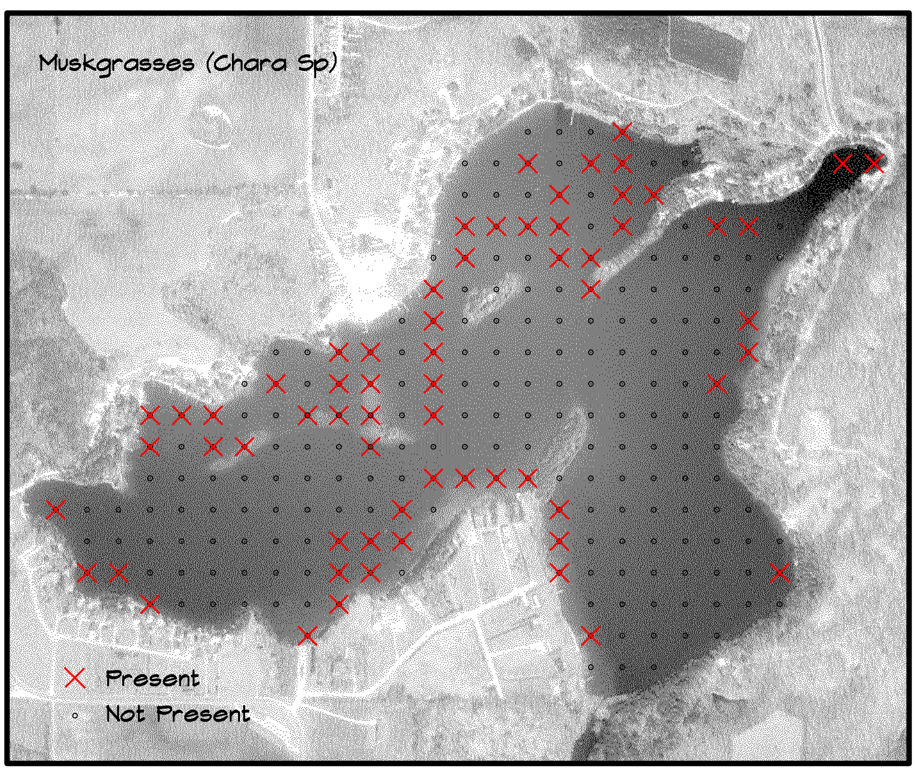
AUGUST 2005 AQUATIC PLANT DISTRIBUTION MAP

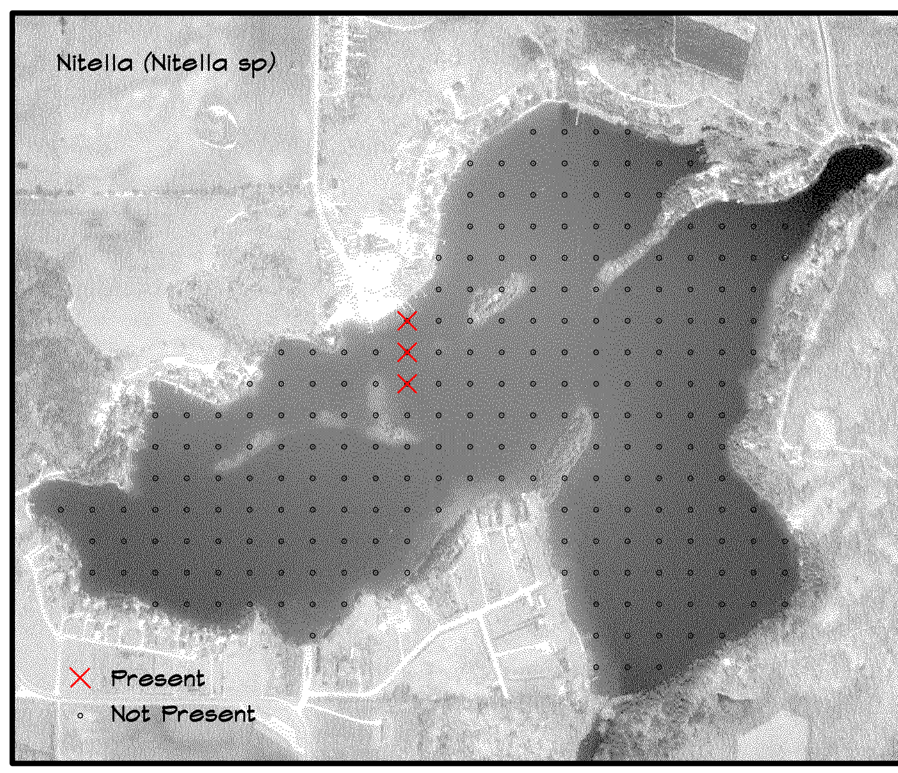
TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

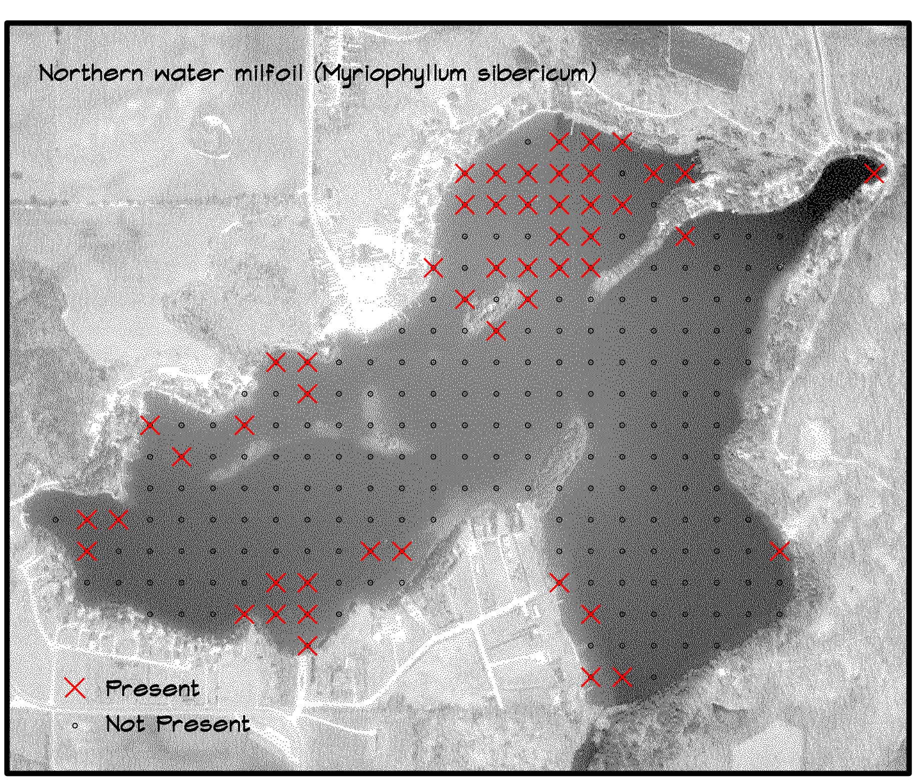
DATE: 10/12/05 | DRAWN BY: DDP | TASK NUMBER: XXX | PROJECT NUMBER: CEL08-3100-0685 | FIGURE 6a

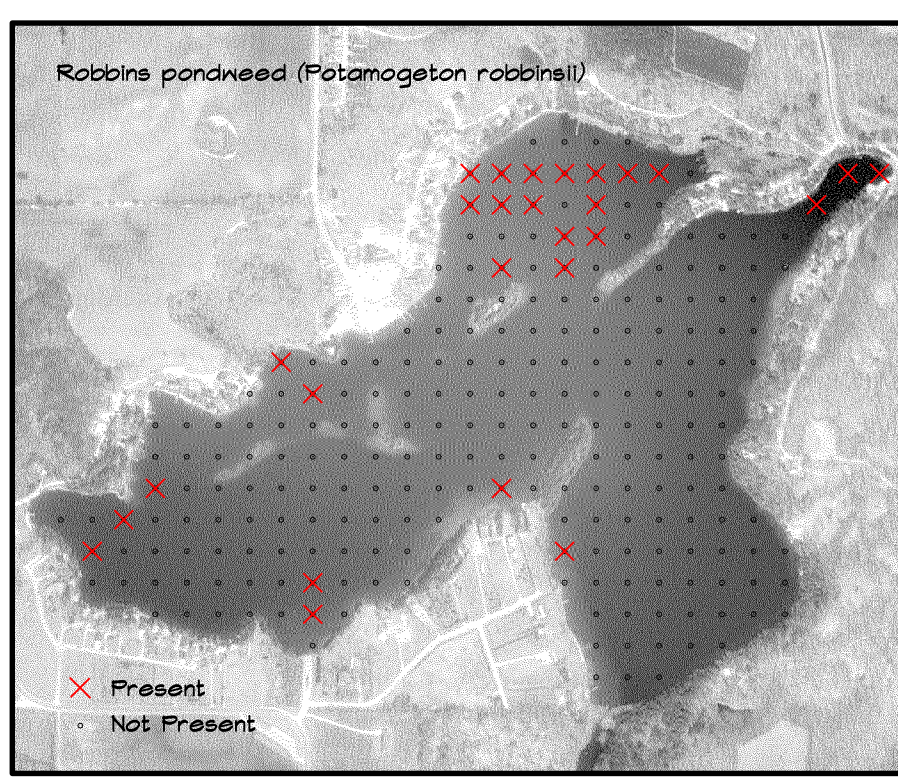


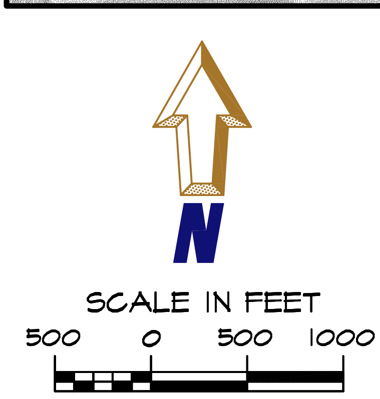












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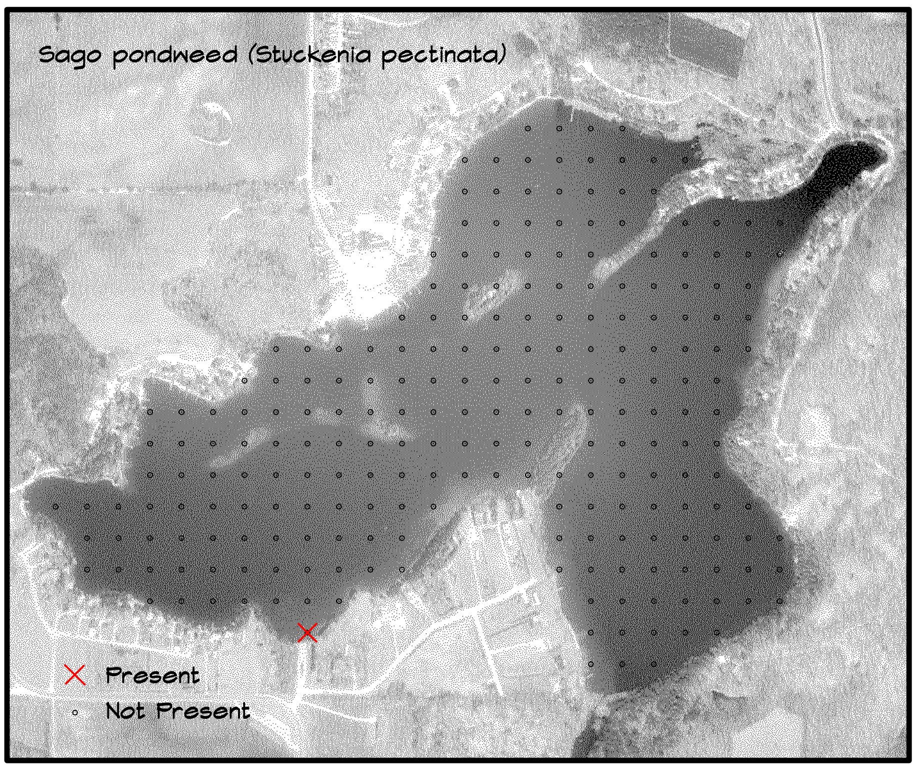
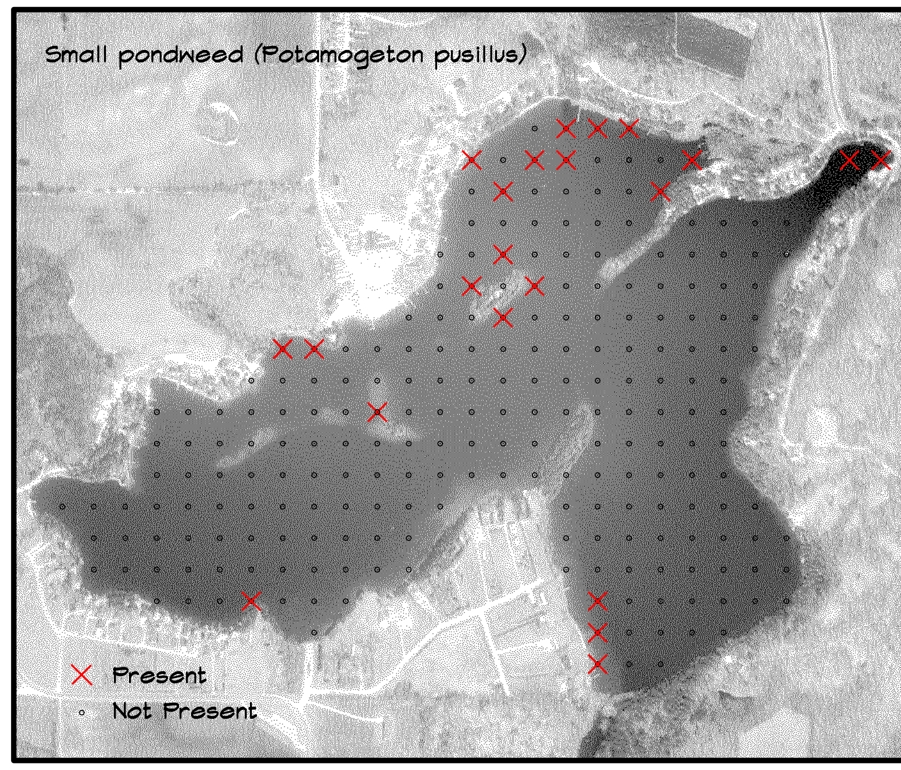
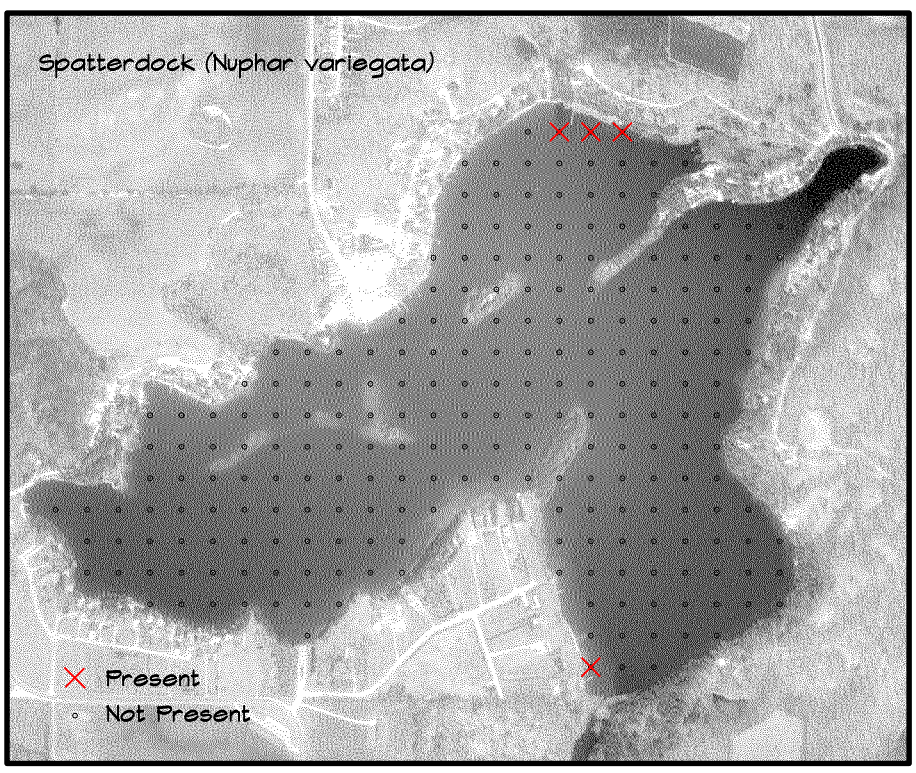
JUNE 2005 AQUATIC PLANT DISTRIBUTION MAP

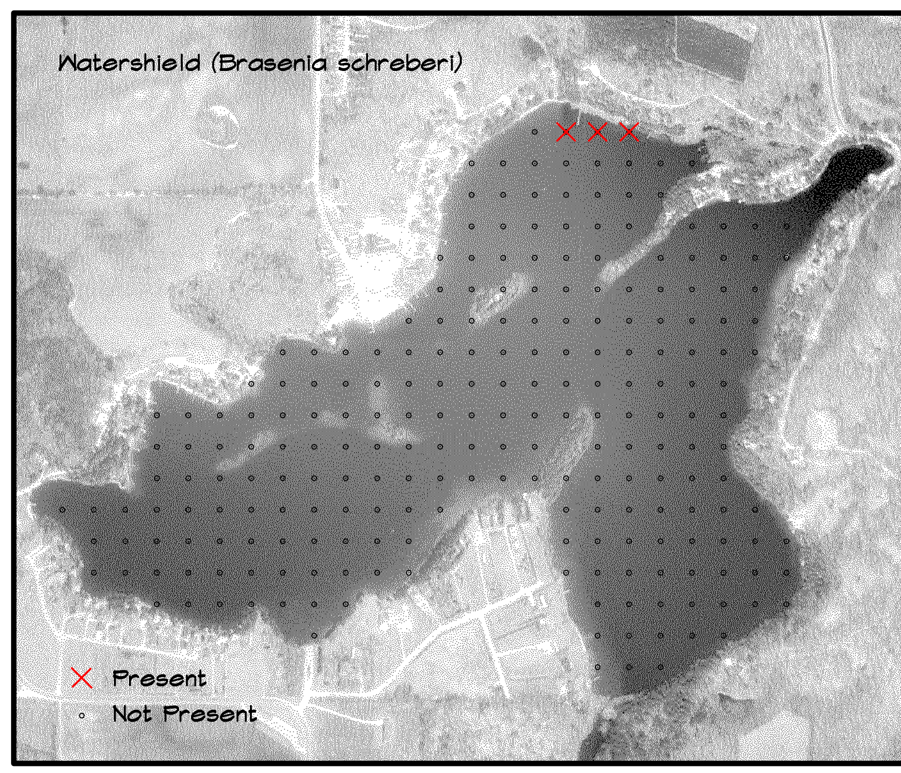
TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

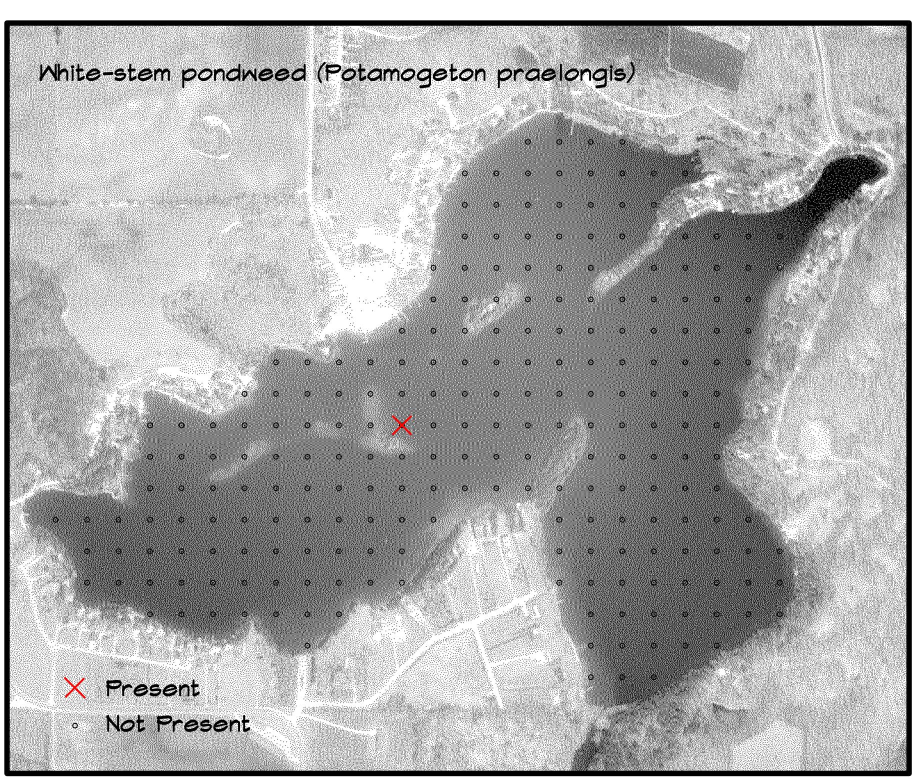
DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 6b

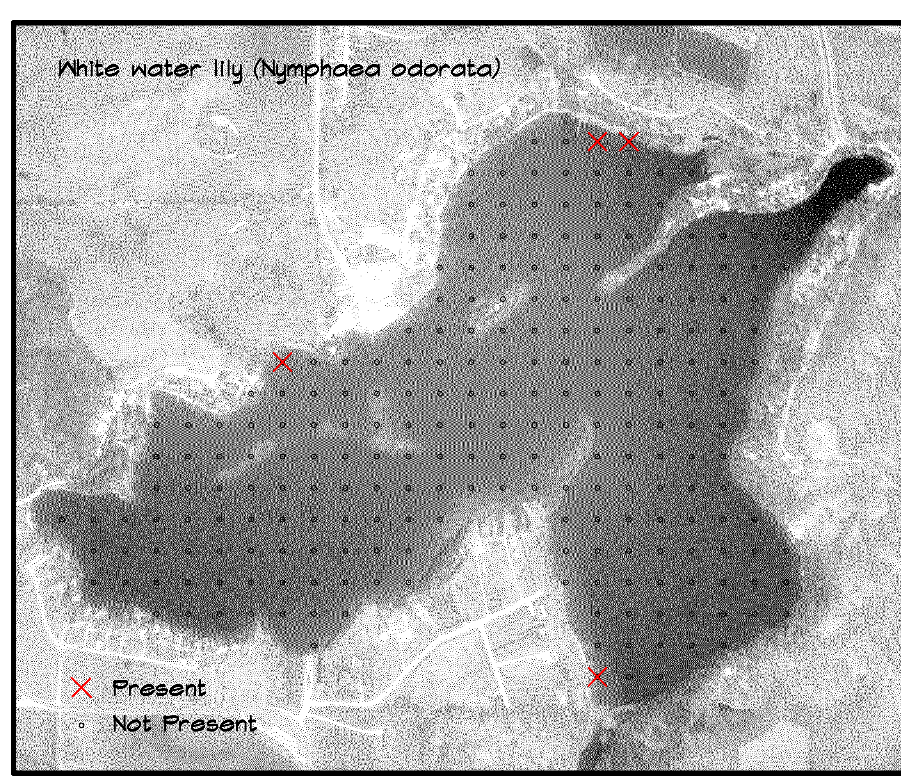


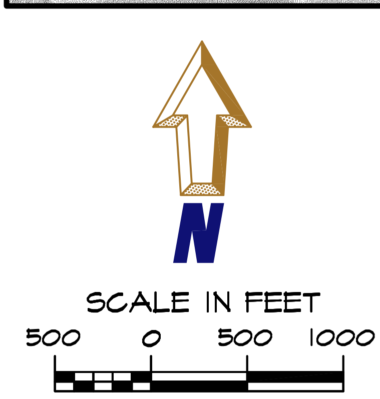












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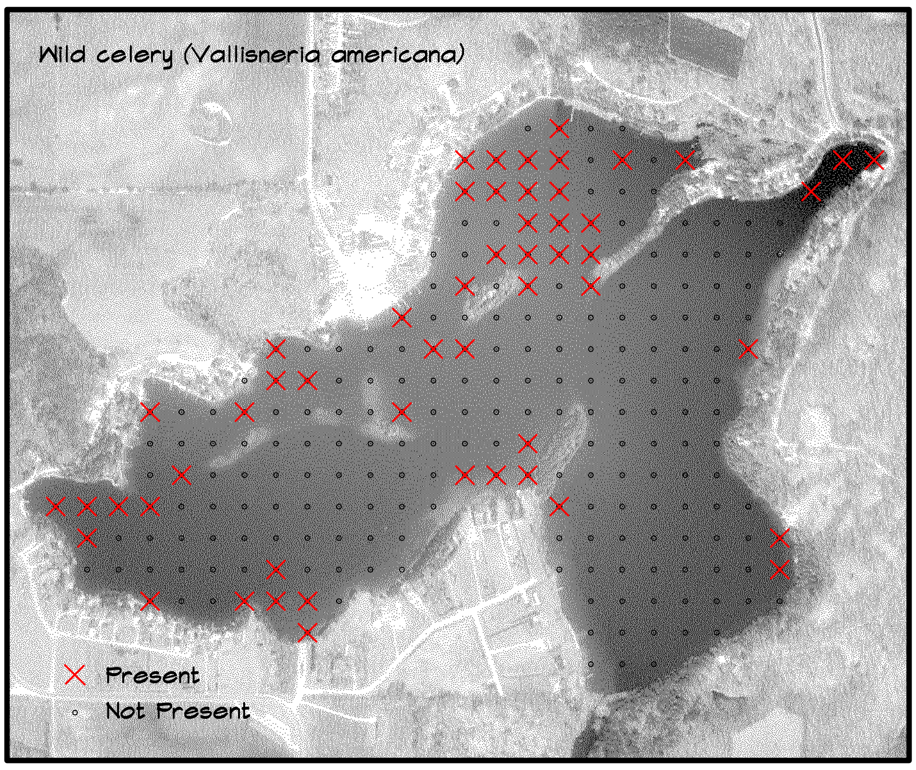
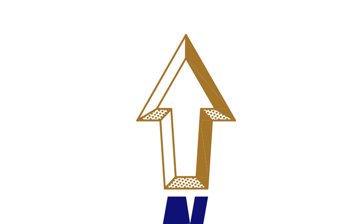
JUNE 2005 AQUATIC PLANT DISTRIBUTION MAP

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 6c





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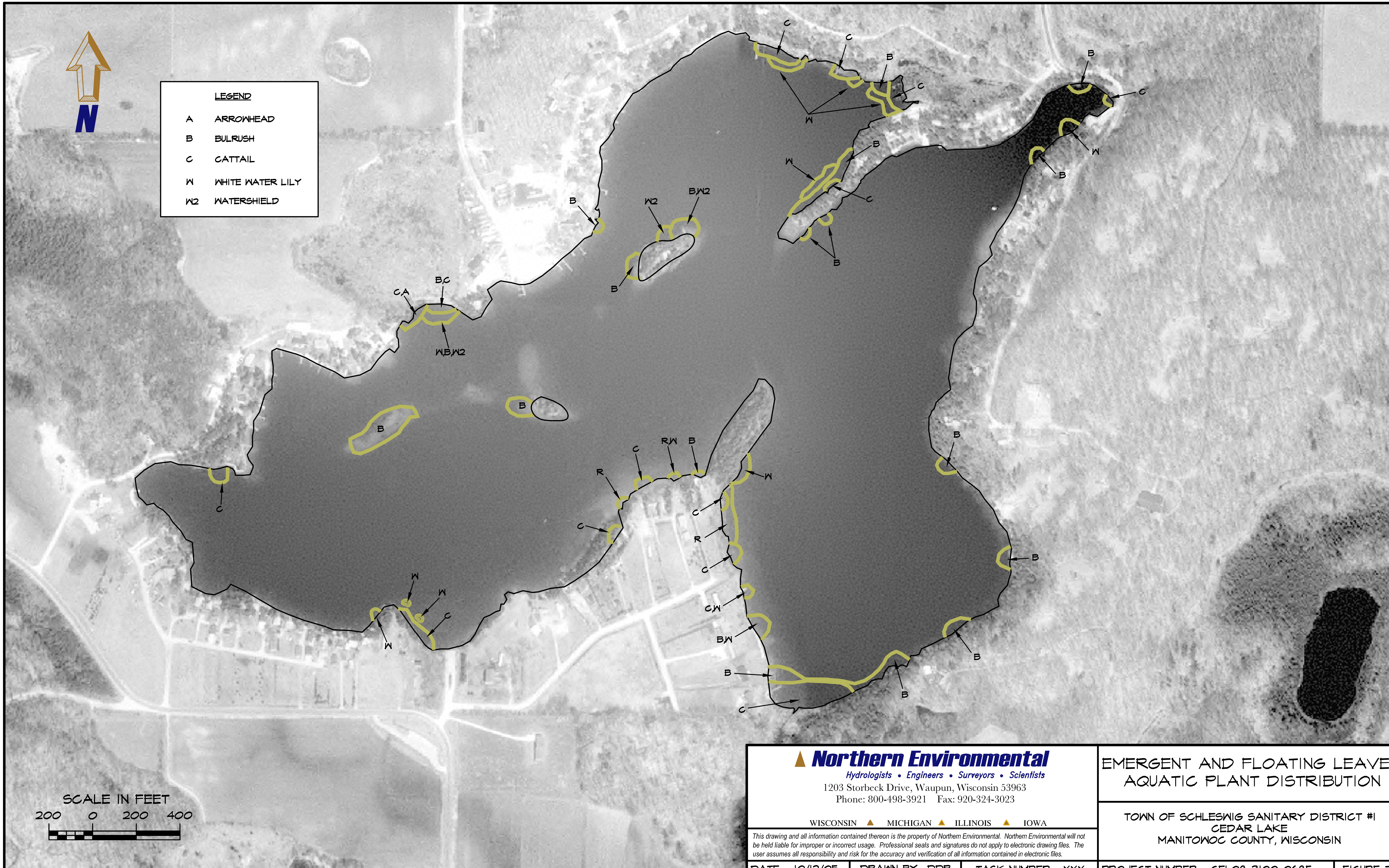
JUNE 2005 AQUATIC PLANT DISTRIBUTION MAP

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 6d



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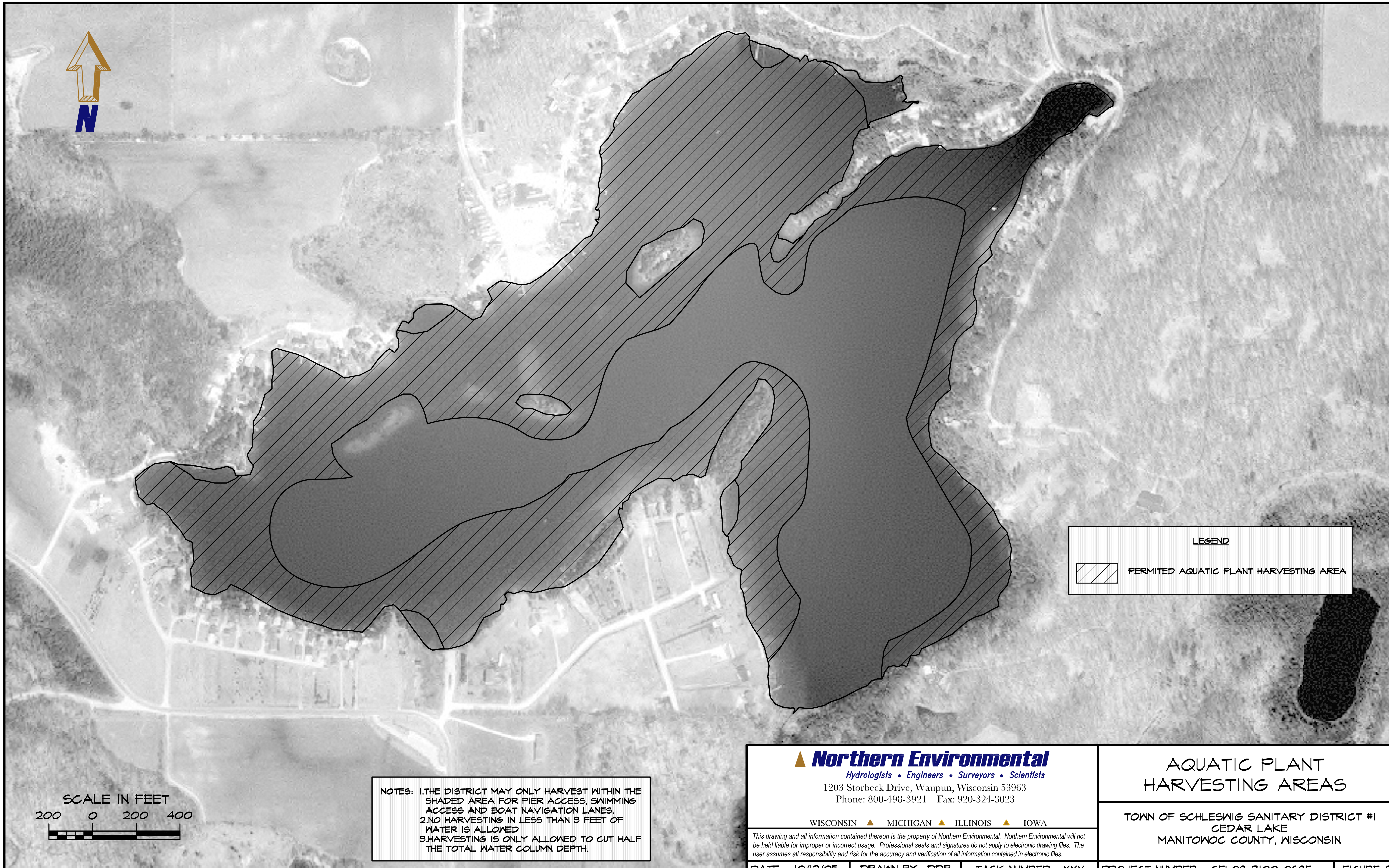
EMERGENT AND FLOATING LEAVED AQUATIC PLANT DISTRIBUTION

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

DATE: 10/12/05 | DRAWN BY: DDP | TASK NUMBER: XXX | PROJECT NUMBER: CEL08-3100-0685 | FIGURE 7



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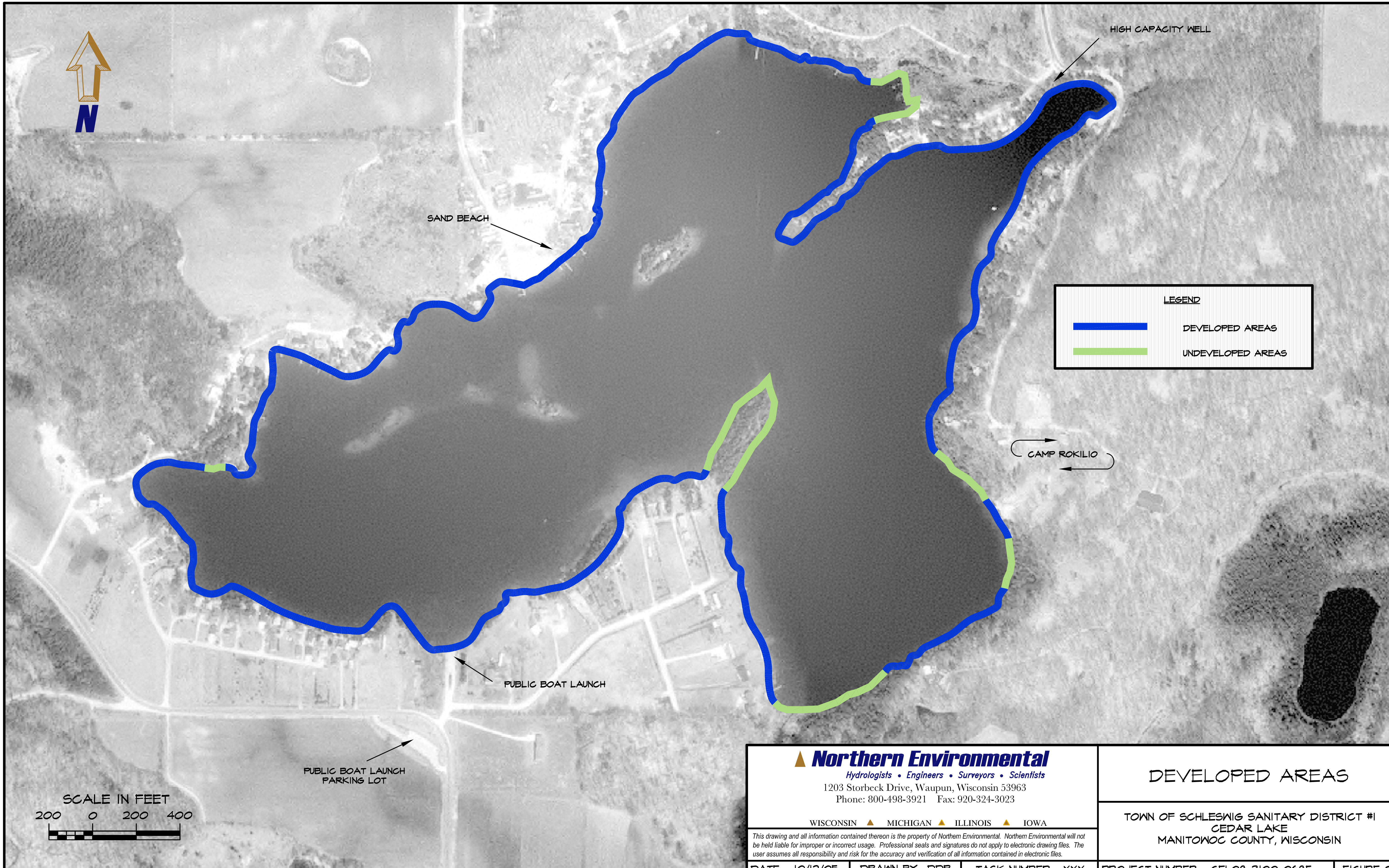
AQUATIC PLANT HARVESTING AREAS

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 8



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DEVELOPED AREAS

TOWN OF SCHLESWIG SANITARY DISTRICT #1
CEDAR LAKE
MANITOWOC COUNTY, WISCONSIN

DATE: 10/12/05	DRAWN BY: DDP	TASK NUMBER: XXX	PROJECT NUMBER: CEL08-3100-0685	FIGURE 9

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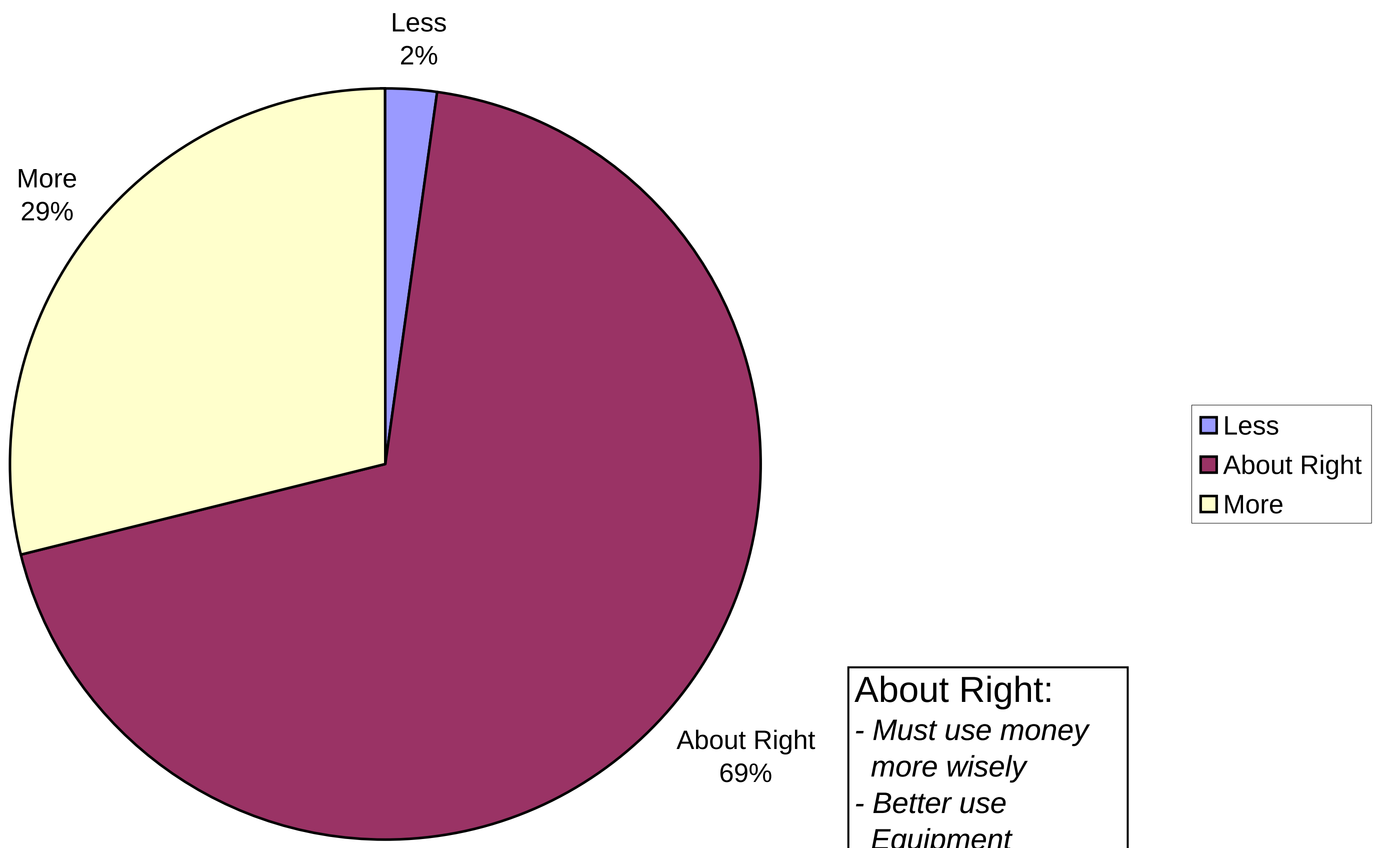
APPENDIX A

PUBLIC SURVEY INFORMATION

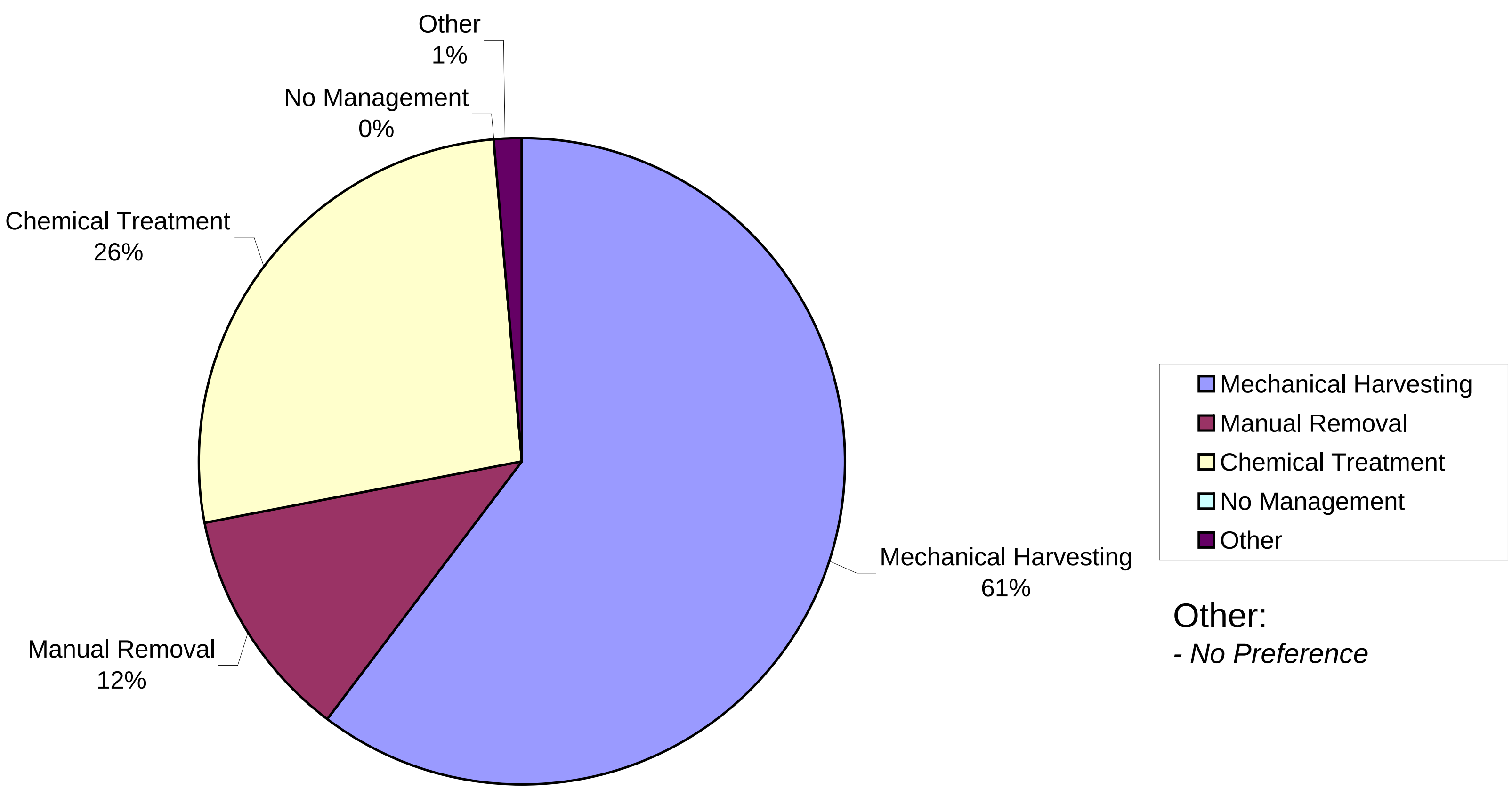
How much do you think the District should invest in aquatic plant managment?



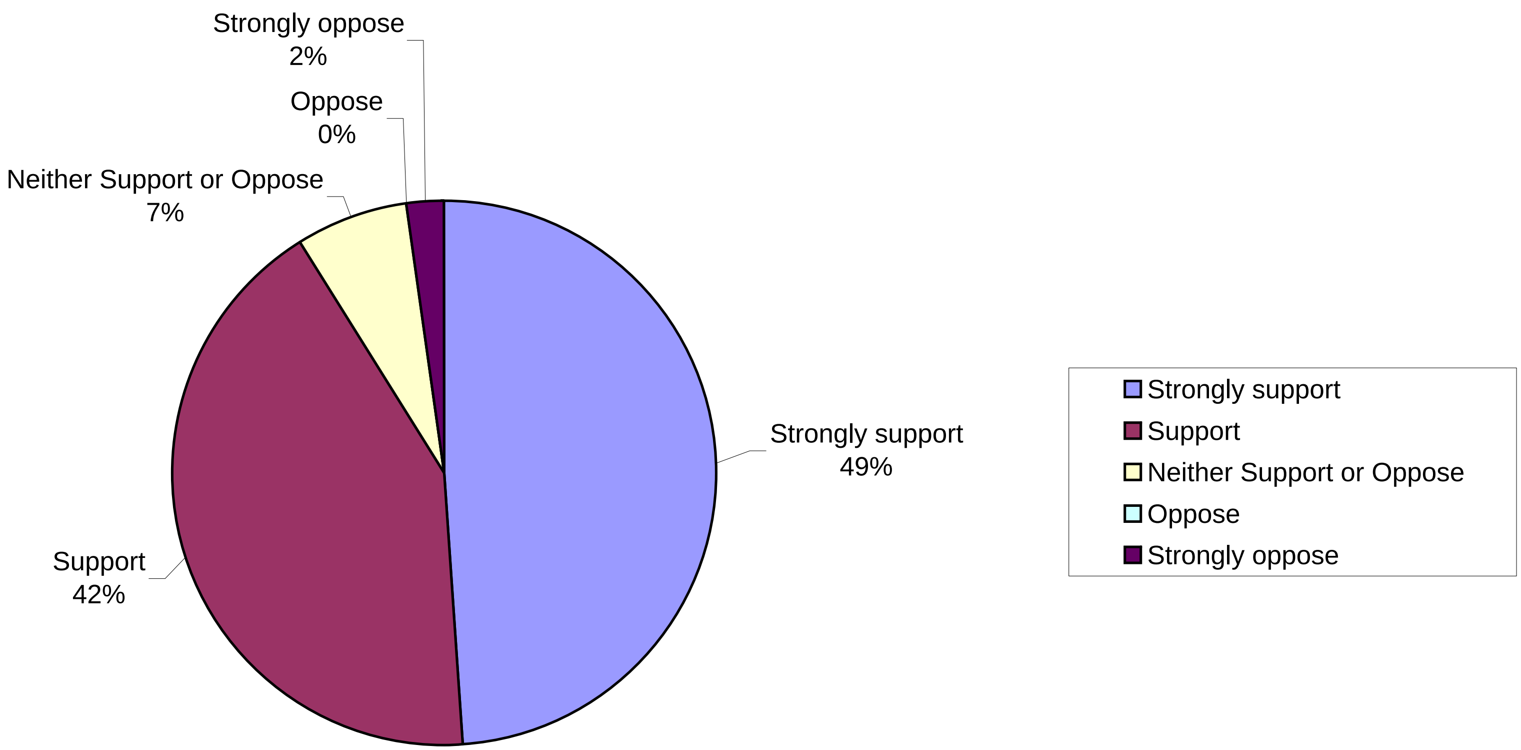
More:
- *10%*
- *25%*
- *5K-10K*
- *10K*
- *Whatever it takes*

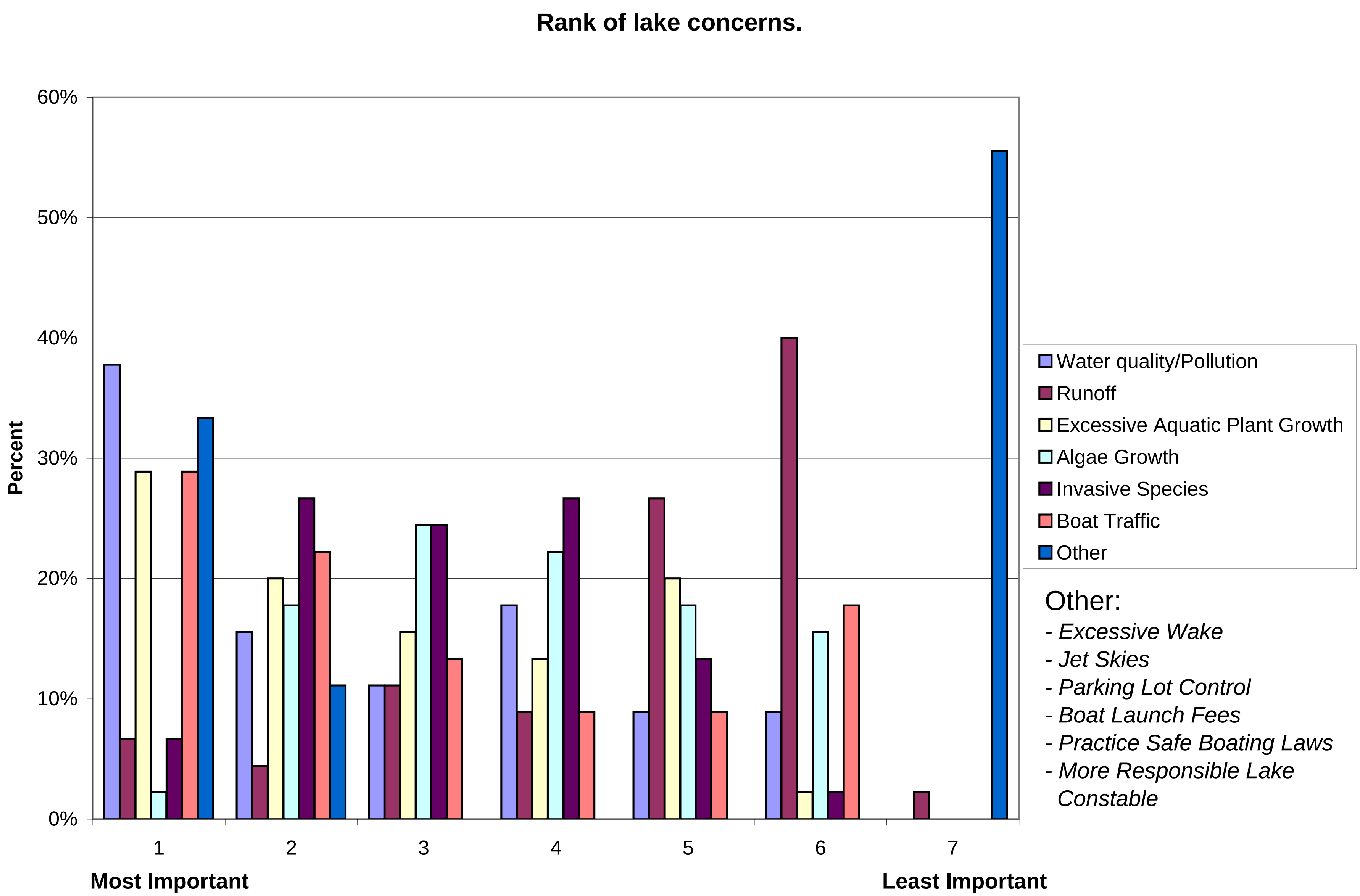
About Right:
- *Must use money more wisely*
- *Better use Equipment*

What other methods would you like to see used to manage aquatic plants?

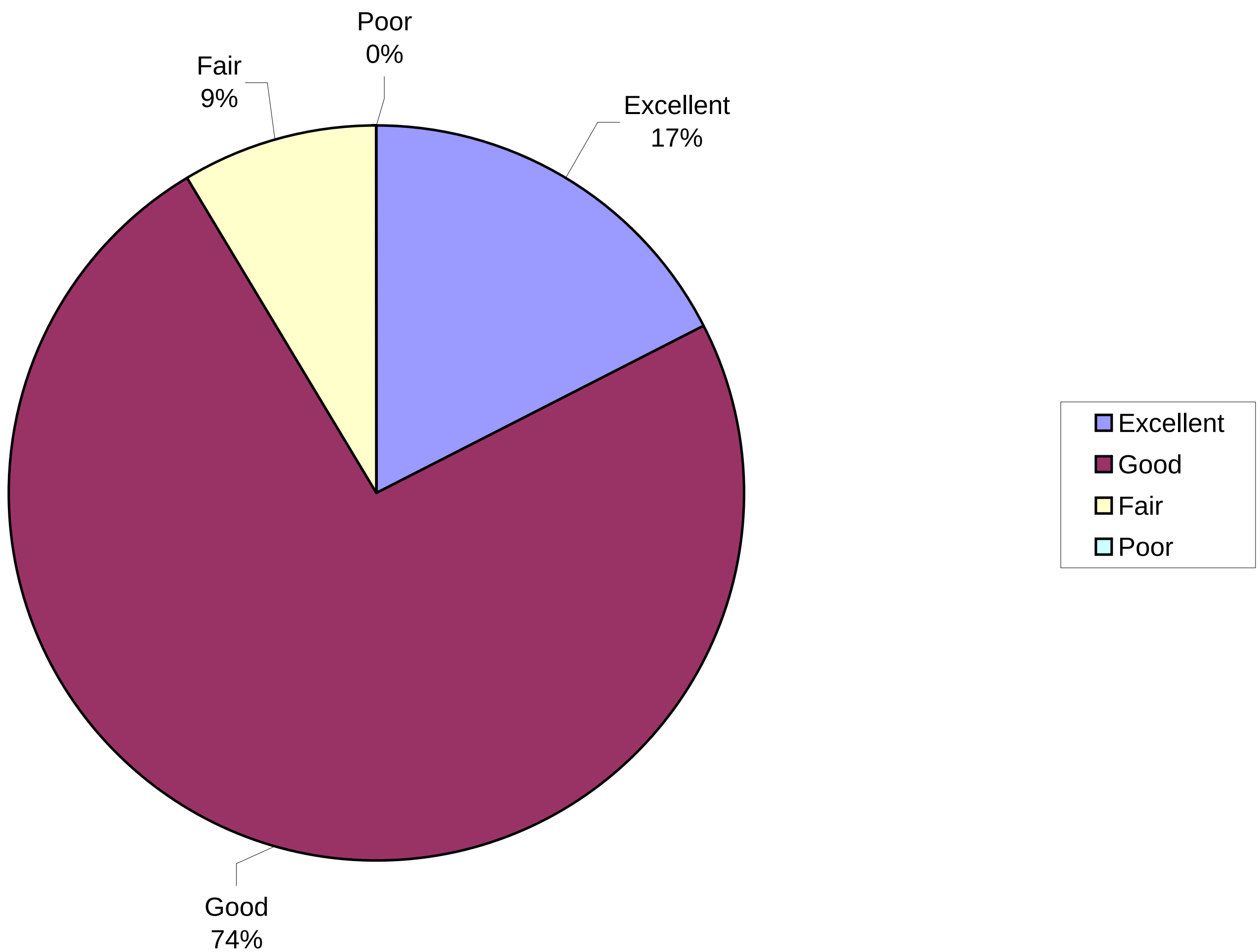


Rank your opinion of the District's current aquatic plant managment efforts (aquatic plant harvesting).

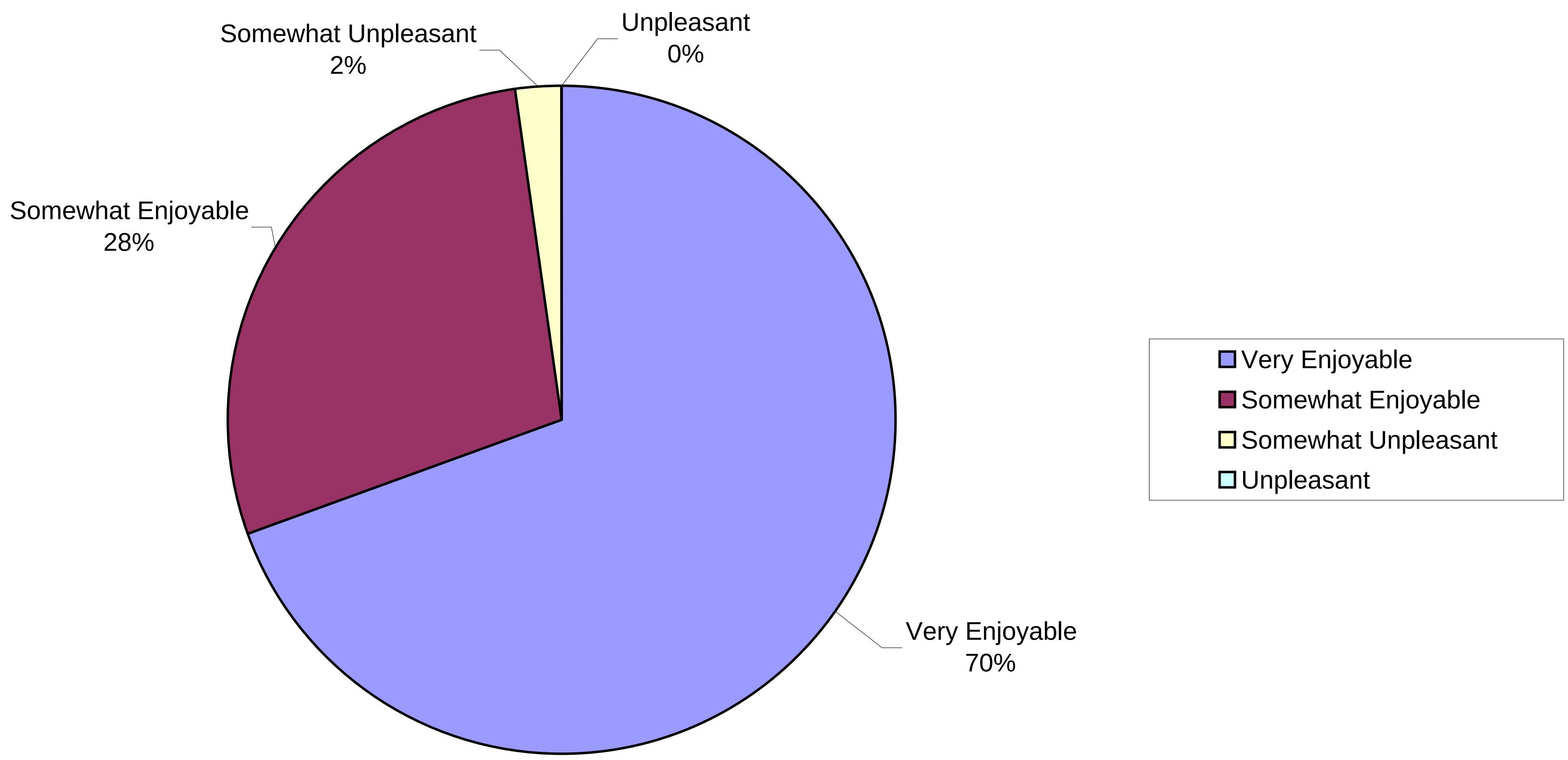


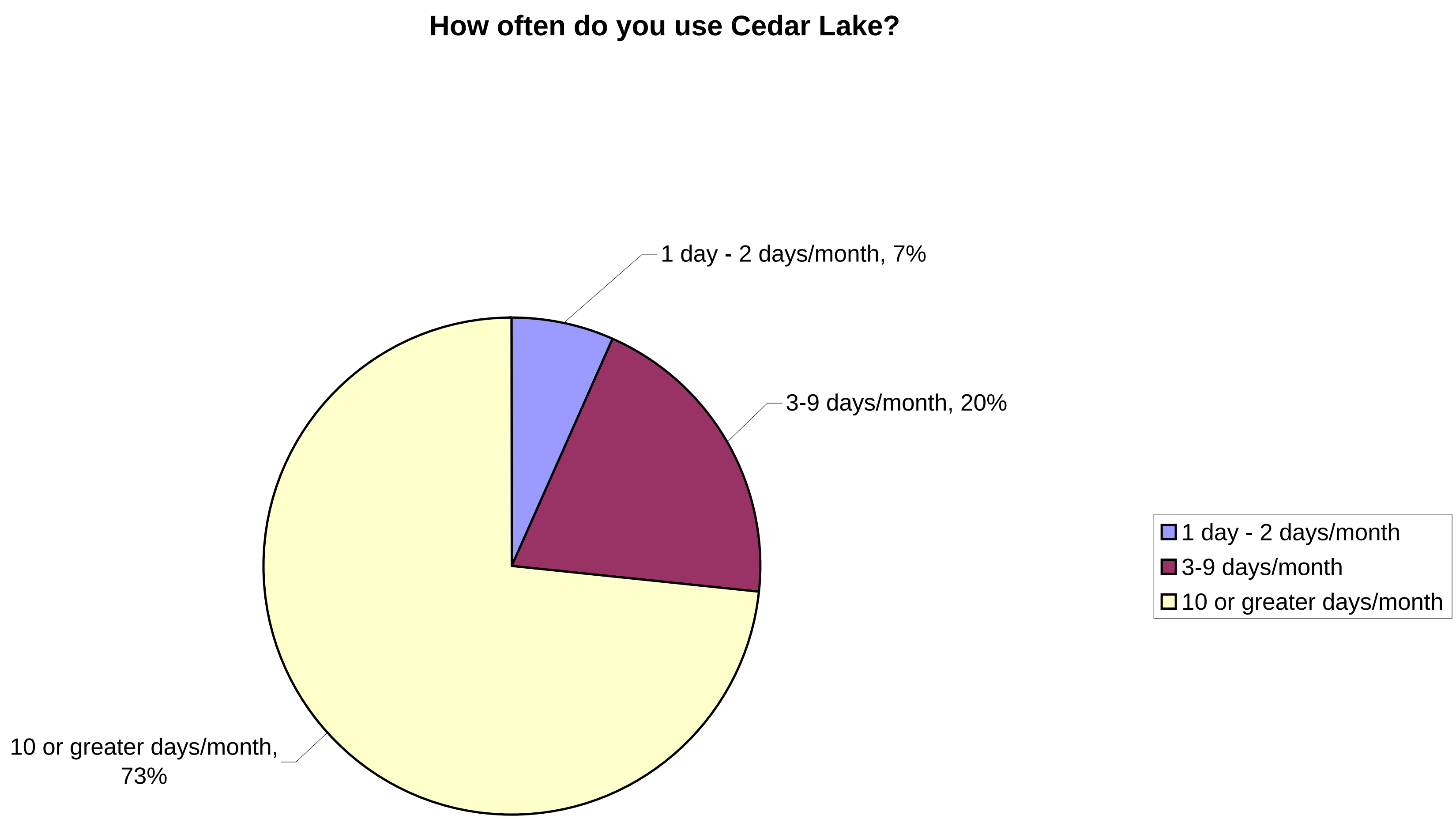

Rank of lake concerns.
Percent
60%
50%
40%
30%
20%
10%
0%
1
2
3
4
5
6
7
Most Important
Least Important
Water quality/Pollution
Runoff
Excessive Aquatic Plant Growth
Algae Growth
Invasive Species
Boat Traffic
Other
Other:
- Excessive Wake
- Jet Skies
- Parking Lot Control
- Boat Launch Fees
- Practice Safe Boating Laws
- More Responsible Lake Constable

How would you rate the quality of Cedar Lake as an aquatic resource?

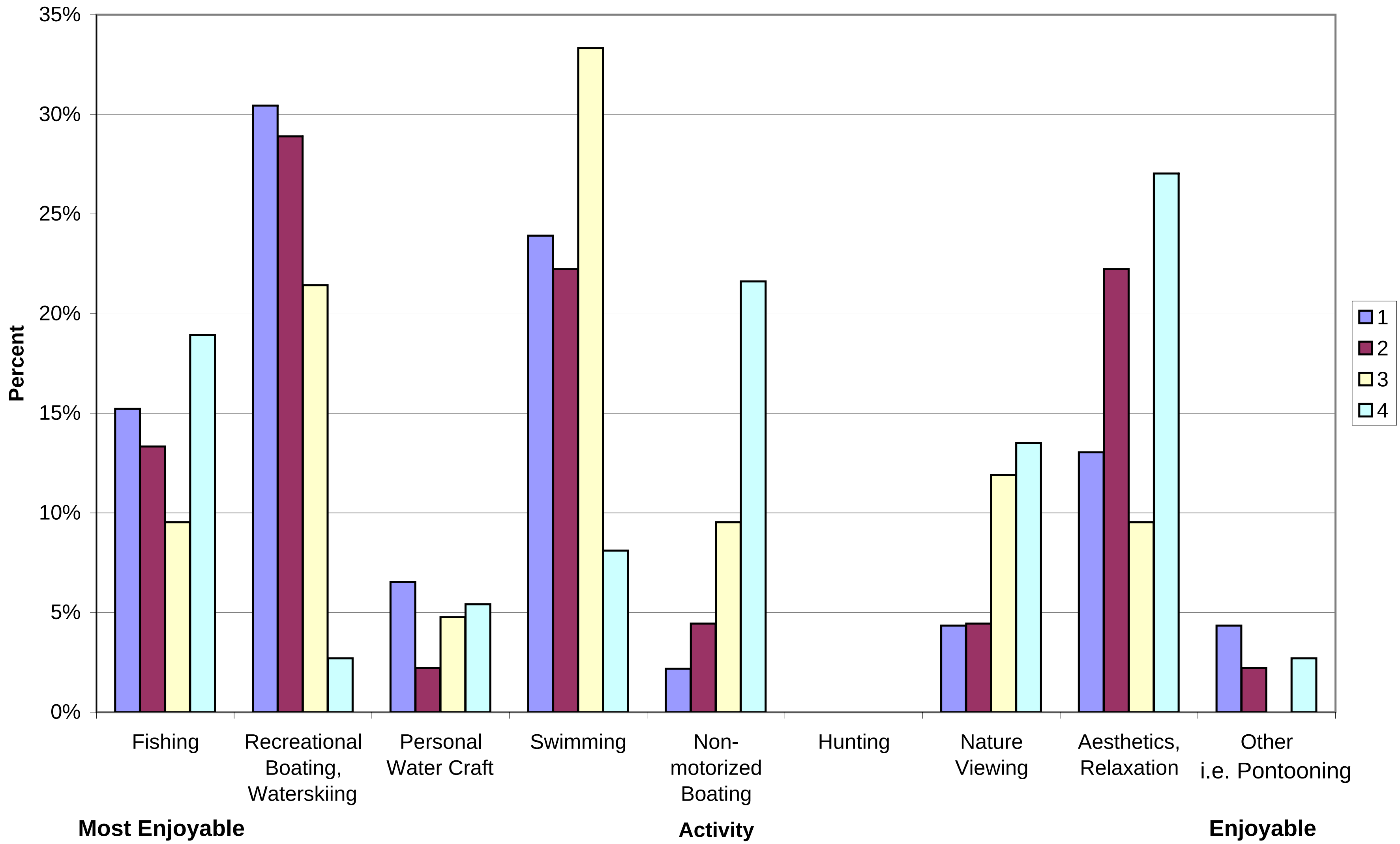


Overall, how would you rate your experiences on Cedar Lake?

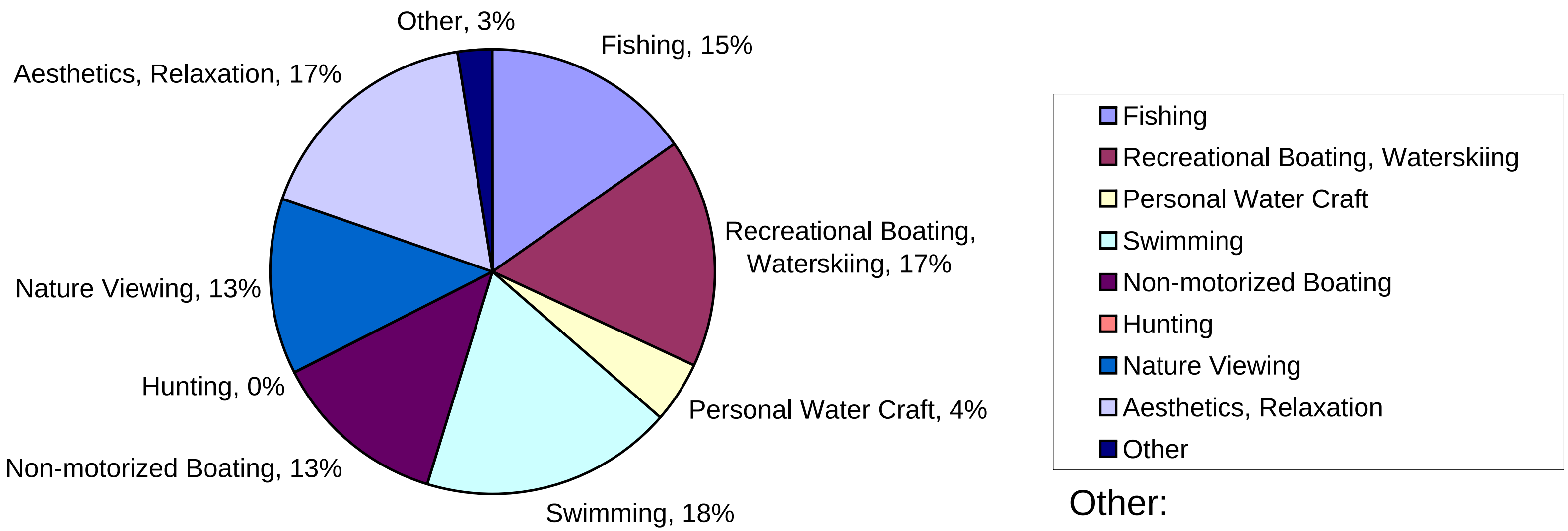



How often do you use Cedar Lake?
1 day - 2 days/month, 7%
3-9 days/month, 20%
10 or greater days/month, 73%
1 day - 2 days/month
3-9 days/month
10 or greater days/month

Activities most enjoyable by Cedar Lake users.



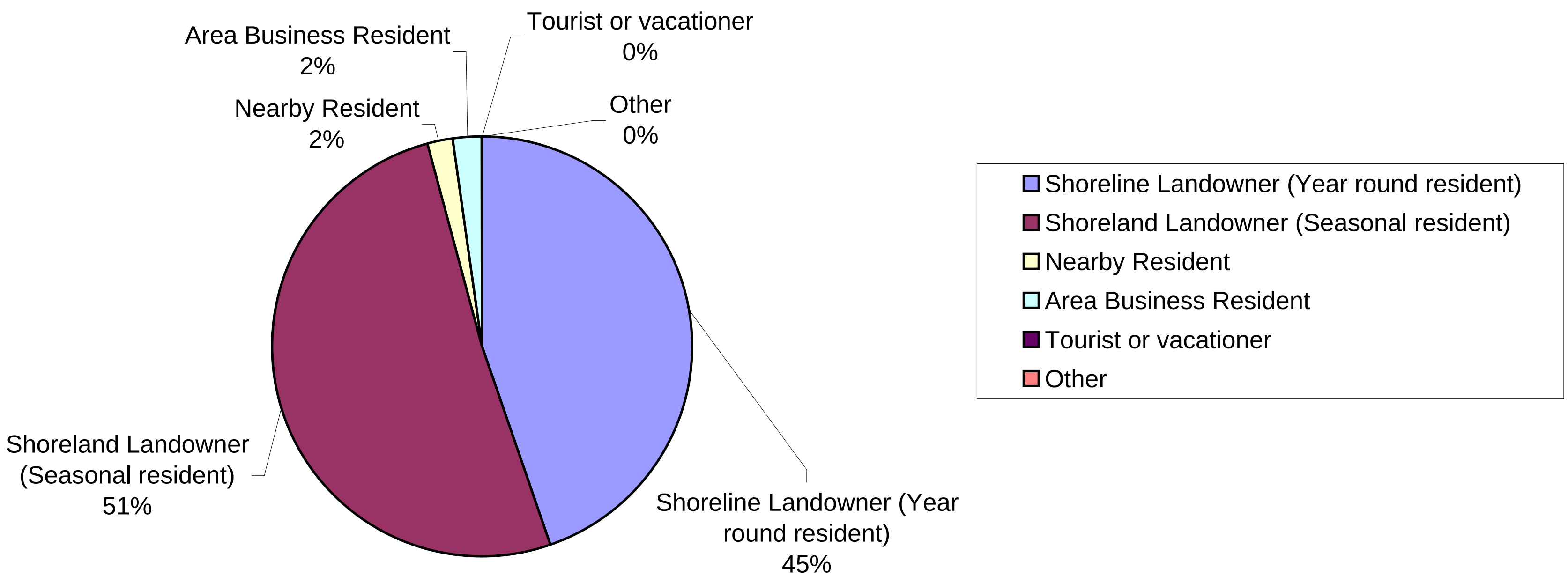
What recreational activity do you use Cedar Lake for?

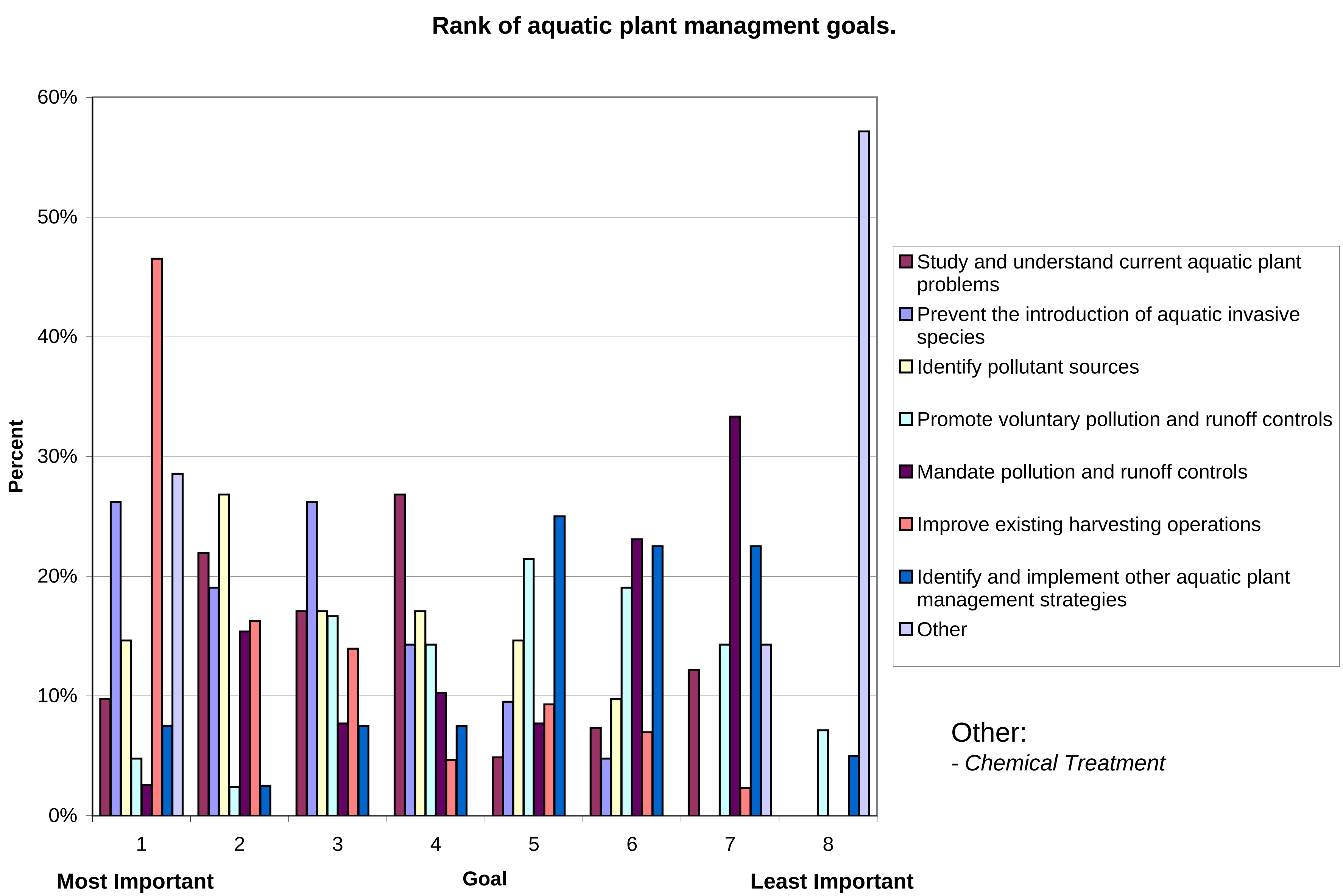


Other:

- Pontooning
- Family Fun Time
- Play with Family Pet

Respondant's affiliation with Cedar Lake.




Rank of aquatic plant managment goals.
60%
50%
40%
30%
20%
10%
0%
Percent
1
2
3
4
5
6
7
8
Most Important
Goal
Least Important
Study and understand current aquatic plant problems
Prevent the introduction of aquatic invasive species
Identify pollutant sources
Promote voluntary pollution and runoff controls
Mandate pollution and runoff controls
Improve existing harvesting operations
Identify and implement other aquatic plant management strategies
Other
Other:
- Chemical Treatment

APPENDIX C

SUMMARY OF AQUATIC PLANT MANAGEMENT ALTERNATIVES

Aquatic Plant Management

Aquatic plants are a critical component in an aquatic ecosystem. Any management of an ecosystem can have negative or even detrimental effects on the whole ecosystem. Therefore, the practice of managing aquatic plants should not be taken lightly. The concept of Aquatic Plant Management (APM) is highly variable since different aquatic resource users want different things. Ideal management to one individual may mean providing prime fish habitat, for another it may be to remove surface vegetation for boating. The practice of APM is also highly variable. There are numerous APM strategies designed to achieve different plant management goals. Some are effective on a small scale, but ineffective in larger situations. Others can only be used for specific plants or during certain times of the growing season. Of course, the types of plants that are to be managed will also help determine which APM alternatives are feasible. The following paragraphs discuss the APM methods used today. The discussion is largely adopted from *Managing Lakes and Rivers, North American Lake Management Society, 2001*, supplemented with other applicable current resources and references. The methods summarized here are largely for management of rooted aquatic plants, not algae. While some methods may also have effects on nuisance algae blooms, the focus is submergent rooted aquatic macrophytes. This information is provided to allow the user to gain a basic understanding of the APM method, it is not designed to an all-inclusive APM decision-making matrix. APM alternatives can be divided into the following categories: Physical Controls, Chemical Controls, and Biological Controls.

Physical Controls

Physical APM controls include various methods to prevent growth or remove part or all of the aquatic plant. Both manual and mechanical techniques are employed. Physical APM methods include:

- Hand pulling
- Hand cutting
- Bottom barriers
- Light limitation (dyes, covers)
- Mechanical harvesting
- Hydroraking/rototilling
- Suction Dredging
- Dredging
- Drawdown

Each of these methods are described below. The costs, benefits, and drawbacks of each APM strategy are provided.

Hand Pulling: This method involves digging out the entire unwanted plant including stems and roots with a hand tool such as a spade. This method is highly selective and suitable for shallow areas for removing invasive species that have not become well established. This technique is obviously not for use on large dense beds of nuisance aquatic plants. It is best used in areas less than 3 feet, but can be used in deeper areas with divers using scuba and snorkeling equipment. It can also be used in combination with the suction dredge method. In Wisconsin, hand pulling may be completed outside a designated sensitive area without a permit but is limited to 30 feet of shoreline frontage. Removal of exotic species is not limited to 30 feet.

Advantages: This technique results in immediate clearing of the water column of nuisance plants. When a selective technique is desired in a shallow, small area, hand pulling is a good choice. It is also useful in sensitive areas where disruption must be minimized.

Disadvantages: This method is labor intensive. Disturbing the substrate may affect fish habitat, increase turbidity, and may promote phosphorus re-suspension and subsequent algae blooms.

Costs: The costs are highly variable. There is practically no cost using volunteers or lakeshore landowners to remove unwanted plants, however, using divers to remove plants can get relatively expensive. Hand pulling labor can range from $400 to $800 per acre.

Hand Cutting: This is another manual method where the plants are cut below the water surface. Generally the roots are not removed. Tools such as rakes, scythes or other specialized tools are pulled through the plant beds by boat or several people. This method is not as selective as hand pulling. This method is well suited for small areas near docks and piers. Plant material must be removed from the water. In Wisconsin, hand cutting may be completed outside a designated sensitive area without a permit but is limited to 30 feet of shoreline frontage. Removal of exotic species is not limited to 30 feet.

Advantages: This technique results in immediate clearing of the water column of nuisance plants. Costs are minimal.

Disadvantages: This is also a fairly time consuming and labor intensive option. Since the technique does not remove the entire plant (leaves root system and part of plant), it may not result in long-term reductions in growth. This technique is not species specific and results in all aquatic plants being removed from the water column.

Costs: The costs range from minimal for volunteers using hand equipment up to over $1,000 for a hand-held mechanized cutting implement. Hand cutting labor can range from $400 to $800 per acre.

Bottom Barriers: A barrier material is applied over the lake bottom to prevent rooted aquatics from growing. Natural barriers such as clay, silt, and gravel can be used although eventually plants may root in these areas again. Artificial materials can also be used for bottom barriers and anchored to the substrate. Barrier materials include burlap, nylon, rubber, polyethylene, polypropylene, and fiberglass. Barriers include both solid and porous forms. A permit is required to place any fill or barrier structure on the substrate of a waterbody. This method is well suited for areas near docks, piers, and beaches. Periodic maintenance may be required to remove accumulated silt or rooting fragments from the barrier.

Advantages: This technique does not result in production of plant fragments. Properly installed, it can provide immediate and multiple year relief.

Disadvantages: This is a non-selective option, all plants beneath the barrier will be affected. Some materials are costly and installation is labor intensive. Other disadvantages include limited material durability, gas accumulation beneath the cover, or possible re-growth of plants from above or below the cover. Fish and invertebrate habitat is disrupted with this technique. Anchored barriers can be difficult to remove.

Costs: A 20 foot x 60 foot panel cost $265, while a 30 foot x 50 foot panel cost $375 (this does not include installation costs). Costs for materials vary from $0.15 per square foot ($ft^2$) to over $0.35/ ft^2. The costs for installation range from $0.25 to $0.50/ ft^2. Barriers can cost $20,000 to $50,000 per acre.

Light Limitation: Limiting the available light in the water column can prevent photosynthesis and plant growth. Dark colored dyes and surface covers have been used to accomplish light limitation. Dyes are effective in shallow water bodies where their concentration can be kept at a desired concentration and loss through dilution is less. This method is well suited for small, shallow water bodies with no outlets such as private ponds.

Surface covers can be a useful tool in small areas such as docks and beaches. While they can interfere with aquatic recreation, they can be timed to produce results and not affect summer recreation uses.

Advantages: Dyes are non-toxic to humans and aquatic organisms. No special equipment is required for application. Light limitation with dyes or covers method may be selective to shade tolerant species. In addition to submerged macrophyte control, it can also control the algae growth.

Disadvantages: The application of water column dyes is limited to shallow water bodies with no outlets. Repeated dye treatments may be necessary. The dyes may not control peripheral or shallow-water rooted plants. This technique must be initiated before aquatic plants start to grow. Covers inhibit gas exchange with the atmosphere.

Costs: Costs for a commercial dye and application range from $100 to $500 per acre.

Mechanical Harvesting: Mechanical harvesters are essentially cutters mounted on barges that cut aquatic plants at a desired depth. Maximum cutting depths range from 5 to 8 feet with a cutting width of 6.5 to 12 feet. Cut plant materials require collection and removal from the water. Conventional harvesters combine cutting, collecting, storing, and transporting cut vegetation into one piece of equipment. Transport barges and shoreline conveyors are also available to remove the cut vegetation. The cut plants must be removed from the water body. The equipment needs are dictated by severity of the aquatic plant problem. Contract harvesting services are available in lieu of purchasing used or new equipment. Trained staff will be necessary to operate a mechanical harvester. To achieve maximum removal of plant material, harvesting is usually completed during the summer months while submergent vegetation is growing to the surface. The duration of control is variable and re-growth of aquatic plants is common. Factors such as timing of harvest, water depth, depth of cut, and timing can influence the effectiveness of a harvesting operation. Harvesting is suited for large open areas with dense stands of exotic or nuisance plant species. Permits are now required in Wisconsin to use a mechanical harvester.

Advantages: Harvesting provides immediate visible results. Harvesting allows plant removal on a larger scale than other options. Harvesting provides flexible area control. In other words, the harvester can be moved to where it is needed and used to target problem areas. This technique has the added benefit of removing the plant material from the water body and therefore also eliminates a possible source of nutrients often released during fall decay of aquatic plants. While removal of nutrients through plant harvesting has not been quantified, it can be important in aquatic ecosystem with low nutrient inputs.

Disadvantages: Drawbacks of harvesting include: limited depth of operation, not selective within the application area, and expensive equipment costs.

Harvesting also creates plant fragments, which can be a concern since certain plants have the ability to reproduce from a plant fragment (e.g. Eurasian watermilfoil). Plant fragments may re-root and spread a problem plant to other areas. Harvesting can have negative effects on non-target plants, young of year fish, and invertebrates. The harvesting will require trained operators and maintenance of equipment. Also, a disposal site or landspreading program will be needed for harvested plants.

Costs: Costs for a harvesting operation are highly variable dependant on program scale. New harvesters range from $40,000 for small machines to over $100,000 for large, deluxe models. Costs vary considerably, depending on the model, size, and options chosen. Specially designed units are available, but may cost more. The equipment can last 10 to 15 years. A grant for ½ the equipment cost can be obtained from the Wisconsin Waterways Commission and a loan can be obtained for the remaining capital investment. Operation costs include insurance, fuel, spare parts, and payroll. Historical harvesting values have been reported at $200 up to $1,500 per acre. A survey of recent Wisconsin harvesting operations reported costs to be between $100/acre and $200/acre.

A used harvester can be purchased for $10,000 to $20,000. Maintenance costs are typically higher.

Contract harvesting costs approximately $125/per hour plus mobilization to the water body. Contractors can typically harvest ¼ to ½ acre per hour for an estimated cost of $250 to $500/per acre.

Hydroraking/rototilling: Hydroraking is the use of a boat or barge mounted machine with a rake that is lowered to the bottom and dragged. The tines of the rake rip out roots of aquatic plants. Rototilling, or rotovation, also rips out root masses but uses a mechanical rotating head with tines instead of a rake. Harvesting may need to be completed in conjunction with these methods to gather floating plant fragments. This application would best be used where nuisance populations are well established and prevention of stem fragments is not critical. A permit would be required for this type of aquatic plant management and would only be issued in limited cases of extreme infestations of nuisance vegetation. In Wisconsin, this method is not looked upon favorably or at all by the WDNR.

Advantages: These methods have the potential for significant reductions in aquatic plant growth. These methods can remove the plant stems and roots, resulting in thorough plant disruption. Hydroraking/rototilling can be completed in "off season" months avoiding interference with summer recreation activities.

Disadvantages: Hydroraking/rototilling are not selective and may destroy substrate habitat important to fish and invertebrates. Suspension of sediments will increase turbidity and release nutrients trapped in bottom sediments into the water column potentially causing algal blooms. These methods can cause floating plant and root fragments, which may re-root and spread the problem. Hydroraking/rototilling are expensive and not likely to be permitted by regulatory agencies.

Costs: Bottom tillage costs vary according to equipment, treatment scale, and plant density. For soft vegetation costs can range from $2,000 to $4,000 per acre. For dense, rooted masses, costs can be up to $10,000 per acre. Contract bottom tillage reportedly ranges from $1,200 to $1,700 per acre (Washington Department of Ecology, 1994).

Suction Dredging: Suction dredging uses a small boat or barge with portable dredges and suction heads. Scuba divers operate the suction dredge and can target removal of whole plants, seeds, and roots. This method may be applied in conjunction with hand cutting where divers dislodge the plants. The plant/sediment slurry is hydraulically pumped to the barge through hoses carried by the diver. Its effectiveness is dependent on sediment composition, density of aquatic plants, and underwater visibility. Suction dredging may be best suited for localized infestations of low plant density where fragmentation must be controlled. A permit will be required for this activity.

Advantages: Diver suction dredging is species –selective. Disruption of sediments can be minimized. These methods can remove the plant stems and roots, resulting in thorough plant disruption and potential longer term control. Fragmentation of plants is minimized. This activity can be completed near and around obstacles such as piers or marinas where a harvester could not operate.

Disadvantages: Diver suction dredging is labor intensive and costly. Upland disposal of dredged slurry can require additional equipment and costs. Increased turbidity in the area of treatment can be a problem. Release of nutrients and other pollutants can also be a problem.

Costs: Suction dredging costs can be variable depending on equipment and transport requirements for slurry. Costs range from $5,000 per acre to $10,000 per acre.

Dredging

Sediment removal through dredging can work as a plant control technique by limiting light through increased water depth or removing soft sediments that are a preferred habitat to nuisance rooted plants. Soft sediment removal is accomplished with drag lines, bucket dredges, long reach backhoes, or other specialized dredging equipment. Dredging has had mixed results in controlling aquatic plant, however it can be highly effective in appropriate situations. Dredging is most often applied in a major restructuring of a severely degraded system. Generally, dredging is an activity associated with other restoration efforts. Comprehensive pre-planning will be necessary for these techniques and a dredging permit would be required.

Advantages: Dredging can remove nutrient reserves which result in nuisance rooted aquatic plant growth. Dredging, when completed, can also actually improve substrate and habitat for more desirable species of aquatic plants, fish, and invertebrates. It allows the complete renovation of an aquatic ecosytem. This method has the potential for significant reductions in aquatic plant growth. These methods can be completed in "off season" months avoiding interference with summer recreation activities.

Disadvantages: Dredging can temporarily destroy important fish and invertebrate habitat. Suspension of sediments usually increases turbidity significantly and can possibly releases nutrients causing algae blooms. Dredging is extremely expensive and requires significant planning. Dredged materials may contain toxic materials (metals, PCBs). Dredged material transportation and disposal of toxic materials are additional management considerations and are potentially expensive. It could be difficult and costly to secure regulatory permits and approvals.

Costs: Dredging costs depend upon the scale of the project and many other factors. It is generally an extremely expensive option.

Drawdown: Water level drawdown exposes the plants and root systems to prolonged freezing and drying to kill the plants. It can be completed any time of the year, however is generally more effective in winter, exposing the lake bed to freezing temperatures. If there is a water level control structure capable of drawdown, it can be an in-expensive way to control some aquatic plants. Aquatic plants vary in their susceptibility to drawdown, therefore, accurate identification of problem species is important. Drawdown is often used for other purposes of improving waterfowl habitat or fishery management, but sometimes has the added benefit of nuisance rooted aquatic plant control. This method can be used in conjunction with a dredging project to excavate nutrient-rich sediments. This method is best suited for use on reservoirs or shallow man-made lakes. A drawdown would require regulatory permits and approvals.

Advantages: A drawdown can result in compaction of certain types of sediments and can be used to facilitate other lake management activities such as dam repair, bottom barrier, or dredging projects. Drawdown can significantly impact populations of aquatic plants that propagate vegetatively. It is inexpensive.

Disadvantages: This method is limited to situations with a water level control structure. Pumps can be used to de-water further if groundwater seepage is not significant. This technique may also result in the removal of beneficial plant species. Drawdowns can decrease bottom dwelling invertebrates and overwintering reptiles and amphibians. Drawdowns can affect adjacent wetlands, alter downstream flows, and potentially impair well production. Drawdowns and any water level manipulation are often highly controversial since shoreline landowners access and public recreation are limited during the drawdown. Fish populations are vulnerable during a drawdown due to over-harvesting by fisherman in decreased water volumes.

Costs: If a suitable outlet structure is available then costs should be minimal. If dewatering pumps would be required or additional management projects such as dredging are completed, additional costs would be incurred. Other costs would include recreational losses and perhaps loss in tourism revenue.

Chemical Controls

Using chemical herbicides to kill nuisance aquatic plants is the oldest APM method. However, past pesticides uses being linked to environmental or human health problems have led to public wariness of chemicals in the environment. Current pesticide registration procedures are more stringent than in the past. While no chemical pesticide can be considered 100 percent safe, federal pesticide regulations are based on the premise that if a chemical is used according to its label instructions it will not cause adverse environmental or human health effects.

Chemical herbicides for aquatic plants can be divided into two categories, systemic and contact herbicides. Systemic herbicides are absorbed by the plant, translocated throughout the plant, and are capable of killing the entire plant, including the roots and shoots. Contact herbicides kill the plant surface in which in comes in contact, leaving roots capable of re-growth. Aquatic herbicides exist under various trade names, causing some confusion. Aquatic herbicides include the following:

- Endothall Based Herbicide
- Diquat Based Herbicide
- Fluridone Based Herbicide
- 2-4 D Based Herbicide
- Glyophosate Based Herbicide
- Triclopyr Based Herbicide
- Phosphorus Precipitation

Each of these methods are described below. The costs, benefits, and drawbacks of each chemical APM alternative are provided.

Endothall Based Herbicide: Endothall is a contact herbicide, attacking a wide range of plants at the point of contact. The chemical is not readily transferred to other plant tissue, therefore regrowth can be expected and repeated treatments may be needed. It is sold in liquid and granular forms under the trade names of Aquathol® or Hydrothol®. Hydrothol is also an algaecide. Most endothall products break down easily and do not remain in the aquatic environment. Endothall products can result in plant reductions for a few weeks to several months. Multi-season effectiveness is not typical. A permit is required for use of this herbicide.

Advantages: Endothall products work quickly and exhibit moderate to highly effective control of floating and submersed species. This herbicide has limited toxicity to fish at recommended doses.

Disadvantages: The entire plant is not killed when using endothall. Endothall is non-selective in the treatment area. High concentrations can kill fish easily. Water use restrictions (time delays) are necessary for recreation, irrigation, and fish consumption after application.

Costs: Costs vary with treatment area and dosage. Average costs for chemical application range between $400 and $700 per acre.

Diquat Based Herbicide: Diquat is a fast-acting contact herbicide effective on a broad spectrum of aquatic plants. It is sold under the trade name Reward®. Diluted forms of this product are also sold as private label products. Since Diquat binds to sediments readily, its effectiveness is reduced by turbid water. Multi-season effectiveness is not typical. A permit is required for use of this herbicide.

Advantages: Diquat works quickly and exhibit moderate to highly effective control of floating and submersed species. This herbicide has limited toxicity to fish at recommended doses.

Disadvantages: The entire plant is not killed when using diquat. Diquat is non-selective in the treatment area. Diquat can be inactivated by suspended sediments. Diquat is sometimes toxic to zooplankton at the recommended dose. Limited water used restrictions (water supply, agriculture, and contact recreation) are required after application.

Costs: Costs vary with treatment area and dosage. A general cost estimate for treatment is between $200 and $500 per acre.

Fluoridone Based Herbicide: Fluoridone is a slow-acting systemic herbicide, which is effectively absorbed and translocated by both plant roots and stems. Sonar® and Avast!® is the trade name and it is sold in liquid or granular form. Fluoridone requires a longer contact time and demonstrates delayed toxicity to target plants. Eurasian watermilfoil is more sensitive to fluoridone than other aquatic plants. This allows a semi-selective approach when low enough doses are used. Since the roots are also killed, multi-season effectiveness can be achieved. It is best applied during the early growth phase of the plants. A permit and extensive planning is required for use of this herbicide.

Advantages: Fluoridone is capable of killing roots, therefore producing a longer lasting effect than other herbicides. A variety of emergent and submersed aquatics are susceptible to this herbicide. Fluoridine can be used selectively, based on concentration. A gradual killing of target plants limits severe oxygen depletion from dead plant material. It has demonstrated low toxicity to aquatic fauna such as fish and invertebrates. 3 to 5 year control has been demonstrated. Extensive testing has shown that, when used according to label instructions, it does not pose negative health affects.

Disadvantages: Fluoridine is a very slow-acting herbicide sometimes taking up to several months for visible effects. It requires a long contact time. Fluoridine is extremely soluble and mixable, therefore, not effective in flowing water situations or for treating a select area in a large open lake. Impacts on non-target plants are possible at higher doses. Time delays are necessary on use of the water (water supply, irrigation, and contact recreation) after application.

Costs: Costs vary with treatment area and dosage. Treatment costs range from $500 to $2,000 per acre.

2,4-D Based Herbicide: 2,4-D based herbicides are sold in liquid or granular forms under various trade names. Common granular forms are sold under the trade names Navigate® and Aqua Kleen®. Common liquid forms include DMA 4® and Weedar 64®. 2,4-D is a systemic herbicide that affects broad leaf plants. It has been demonstrated effective against Eurasian watermilfoil, but it may not work on many aquatic plants. Since the roots are also killed, multi-season effectiveness may be achieved. It is best applied during the early growth phase of the plants. Visible results are evident within 10 to 14 days. A permit is required for use of this herbicide.

Advantages: 2,4-D is capable of killing roots, therefore producing a longer lasting effect than some other herbicides. It is fairly fast and somewhat selective, based on application timing and concentration. 2,4-D containing products are moderately to highly effective on a few emergent, floating, or submersed plants.

Disadvantages: 2,4-D can have variable toxicity effects to aquatic fauna, depending on formulation and water chemistry. 2,4-D lasts only a short time in water, but can be detected in sediments for months after application. Time delays are necessary on use of the water (agriculture and contact recreation) after application. The label does not permit use of this product in water used for drinking, irrigation, or livestock watering.

Costs: Costs vary with treatment area and dosage. Treatment costs range from $300 to $800 per acre.

Glyophosate Based Herbicide: Glyophosate has been categorized as both a contact and a systemic herbicide. It is applied as a liquid spray and is sold under the trade name Rodeo® or Pondmaster®. It is a non-selective, broad based herbicide effective against emergent or floating leaved plants, but not submergents. It's effectiveness can be reduced by rain. A permit is required for use of this herbicide.

Advantages: Glyophoshate is moderately to highly effective against emergent and floating-leaf plants resulting in rapid plant destruction. Since it is applied by spraying plants above the surface, the applicator can apply it selectively to target plants. Glyophosate dissipates quickly from natural waters, has a low toxicity to aquatic fauna, and carries no restrictions or time delays for swimming, fishing, or irrigation.

Disadvantages: Glyophoshate is non-selective in the treatment area. Wind can dissipate the product during the application reducing it's effectiveness and cause damage to non-target organisms. Therefore, spray application should only be completed when wind drift is not a problem. This compound is highly corrosive, therefore storage precautions are necessary.

Costs: Costs average $500 to $1,000 per acre depending on the scale of treatment.

Triclopyr Based Herbicide: Triclopyr is a systemic herbicide. It is registered for experimental aquatic use in selected areas only. It is applied as a liquid spray or injected into the subsurface as a liquid. Triclopyr is sold under the trade name Renovate® or Restorate®. Triclopyr has shown to be an effective control to many floating and submersed plants. It has been demonstrated to be highly effective against Eurasian watermilfoil, having little effect on valued native plants such as pondweeds. Triclopyr is most effective when applied during the active growth period of younger plants.

Advantages: This herbicide is fast acting. Triclopyr can be used selectively since it appears more effective against dicot plant species, including several difficult nuisance plants. Testing has demonstrated low toxicity to aquatic fauna.

Disadvantages: At higher doses, there are possible impacts to non-target species. Some forms of this herbicide are experimental for aquatic use and restrictions on use of the treated water are not yet certain.

Biological Controls

There has been recent interest in using biological technologies to control aquatic plants. This concept stems from a desire to use a "natural" control and reduce expenses related to equipment and/or chemicals. While use of biological controls is in its infancy, potentially useful technologies have been identified and show promise for integration with physical and chemical APM strategies. Several biological controls that are in use or are under experimentation include the following:

- Herbivorous Fish
- Herbivorous Insects
- Plant Pathogens
- Native Plants

Each of these methods are described below. The costs, benefits, and drawbacks of each biologic APM method are provided.

Herbivorous Fish: A herbivorous fish such as the non-native grass carp can consume large quantities of aquatic plants. These fish have high growth rates and a wide range of plant food preferences. Stocking rates and effectiveness will depend on many factors including climate, water temperature, type and extent of aquatic plants, and other site-specific issues. Sterile (triploid) fish have been developed resulting in no reproduction of the grass carp and population control. This technology has demonstrated mixed results and is most appropriately used for lake-wide, low intensity control of submersed plants. Some states do not allow stocking of herbivorous fish. In Wisconsin, stocking of grass carp is prohibited.

Advantages: This technology can provide multiple years of aquatic plant control from a single stocking. Compared to other long-term aquatic plant control techniques such as bottom tillage or bottom barriers, costs may be relatively low.

Disadvantages: Sterile grass carp exhibit distinct food preferences, limiting their applicability. Grass carp may feed selectively on the preferred plants, while less preferred plants, including milfoil, may increase. The effects of using grass carp may not be immediate. Overstocking may result in an impact on non-target plants or eradication of beneficial plants, altering lake habitat. Using grass carp may result in algae blooms and increased turbidity. If precautions are not taken (i.e. inlet and outlet control structures to prevent fish migration) the fish may migrate and have adverse effects on non-target vegetation.

Costs: Costs can range from $50/acre to over $2,000/acre, at stocking rates of 5 fish/acre to 200 fish/acre.

Herbivorous Insects: Non-native and native insect species have been used to control rooted plants. Using herbivorous insects is intended to selectively control target species. These aquatic larvae of moths, beetles, and thrips use specific host aquatic plants. Several non-native species have been imported under USDA approval and used in integrated pest management programs, a combination of biological, chemical, and mechanical controls.

These non-native insects are being used in southern states to control nuisance plant species and appear climate-limited, their northern range being Georgia and North Carolina. While successes have been demonstrated, non-native species have not established themselves for solving biological problems, sometimes creating as many problems as they solve. Therefore, government agencies prefer alternative controls.

Native insects such as the larvae of midgeflies, caddisflies, beetles, and moths may be successful APM controls in northern states. Recently however, the native aquatic weevil *Euhrychiopsis lecontei* has received the most attention. This weevil has been associated with native northern water milfoil. The weevil can switch plant hosts and feed on Eurasian watermilfoil, destroying it's growth points. While the milfoil weevil is gaining popularity, it is still experimental.

Advantages: Herbivorous insects are expected to have no negative effects on non-target species. The insects have shown promise for long term control when used as part of integrated aquatic plant management programs. The milfoil weevils do not use non-milfoil plants as hosts.

Disadvantages: Natural predator prey cycles indicate that incomplete control is likely. An oscillating cycle of control and re-growth is more likely. Fish predation may complicate controls. Large numbers of milfoil weevils may be required for a dense stand and can be expensive. The weevil leaves the water during the winter, may not return to the water in the spring, and are subject to bird predation in their terrestrial habitat. Application is manual and extremely time consuming. Introducing any species, especially non-native ones, into an aquatic ecosystem may have undesirable effects. Therefore, it is extremely important to understand the life cycles of the insects and the host plants.

Costs: Reported costs of herbivorous insects rang from $300/acre to $3,000/acre.

Specifically, the native milfoil weevils cost approximately $1.00 per weevil. It is generally considered appropriate to use 5 to 7 weevils per stem. Dense stands of milfoil may contain 1 to 2 million stems per acre. Therefore, costs of this new technology are currently prohibitive.

Plant Pathogens: Using a plant pathogen to control nuisance aquatic plants has been studied for many years, however, plant pathogens still remain largely experimental. Fungi are the most common pathogens, while bacteria and viruses have also been used. There is potential for highly specific plant applications.

Advantages: Plant pathogens may be highly species specific. They may provide substantial control of a nuisance species.

Disadvantages: Pathogens are experimental. The effectiveness and longevity of control is not well understood. Possible side effects are also unknown.

Costs: These techniques are experimental therefore a supply of specific products and costs are not established.

Native Plants: This method involves removing the nuisance plant species through chemical or physical means and re-introducing seeds, cuttings, or whole plants of desirable species. Success has been variable. When using seeds, they need to be planted early enough to encourage the full growth and subsequent seed production of those plants. Transplanting mature plants may be a better way to establish seed producing populations of desirable aquatics. Recognizing that a healthy, native, desirable plant community may be resistant to infestations of nuisance species, planting native plants should be encouraged as an APM alternative. Non-native plants can not be translocated.

Advantages: This alternative can restore native plant communities. It can be used to supplement other methods and potentially prevent future needs for costly repeat APM treatments.

Disadvantages: While this appears to be a desirable practice, it is experimental at this time and there are not many well documented successes. Nuisance species may eventually again invade the areas of native plantings. Careful planning is required to ensure that the introduced species do not themselves become nuisances. Hand planting aquatic plants is labor intensive.

Costs: Costs can be highly variable depending on the selected native species, numbers of plants ordered, and the nearest dealer location.

Aquatic Plant Prevention

The phrase "an ounce of prevention is worth a pound of cure" certainly holds true for APM. Prevention is the best way to avoid nuisance aquatic plant growth. Prevention of the spread of invasive aquatic plants must also be achieved. Inspecting boats, trailers, and live wells for live aquatic plant material is the best way to prevent nuisance aquatic plants from entering a new aquatic ecosystem. Protecting the desirable native plant communities is also important in maintaining a healthy aquatic ecosystem and preventing the spread of nuisance aquatics once they are present.

Prolific growth of nuisance aquatic plants can be prevented by limiting nutrient (i.e. phosphorus) inputs to the water body. Aeration or phosphorus precipitation can achieve controls of in-lake cycling of phosphorus, however, if there are additional outside sources of nutrients, these methods will be largely ineffective in controlling algae blooms or intense aquatic macrophyte infestations. Watershed management activities to control nutrient laden storm water runoff are critical to controlling excessive nutrient loading to the water bodies. Nutrient loading can be prevented/minimized by the following:

- Shoreline buffers
- Using non-phosphorus fertilizers on lawns
- Settling basins for storm water effluents