Minnesota's Sensitive Lakeshore Identification Manual:
A Conservation Strategy for Minnesota's Lakeshores

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STATE OF MINNESOTA
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DIVISION OF ECOLOGICAL RESOURCES

Minnesota's Sensitive Lakeshore Identification Manual: A Conservation Strategy for Minnesota's Lakeshores

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Metric and English Units
In Minnesota, most of the statewide lake hydrologic data have been recorded in English units. Specifically, lake depth contour data, lake area and shoreline length measurements available from MnDNR are recorded in feet. Where feasible, conversions have been made. However, it would be difficult and time consuming to convert these data to metric, particularly for GIS data. As an example, standard lake depth data is available in five or ten feet increments and these data would not convert cleanly to metric (5, 10, 15, 20, 25 feet would be converted to 1.5, 3.0, 4.6, 6.1, 7.6 meters). Conversely, establishment of survey site locations in GIS and in-field navigation with GPS is primarily done using UTM (universal transverse mercator) coordinates (meters).

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SENSITIVE LAKESHORE IDENTIFICATION
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
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Chapter 1. An Introduction to Sensitive Lakeshores

This manual explains the survey protocol used to identify and map sensitive fish and wildlife shoreline habitat for Minnesota lakes. Sensitive areas are places that provide unique or critical ecological habitat, and they are important habitat for species of greatest conservation need in particular. The protocols in this manual are science-based, and they were developed to be objective, fair, and commonly repeatable with basic due diligence. The purpose of the survey protocol in this manual is to provide the framework for data collection and analysis such that reliable advice can be given to local governments who could use the information to maintain environmental conditions and protect habitat for species in greatest conservation need via shoreland ordinance.

The shoreline and near-shore areas are critical to the health and well-being of fish, wildlife, and native plants. Many fish and wildlife species, as well as many species of greatest conservation need, are highly dependent on naturally vegetated shorelines as habitat for feeding, resting, and mating and juvenile life stages. Development and land alteration in the immediate shoreland and on the shoreline may have significant negative impacts on these species, and shoreland ordinances regulate these activities.

For the purpose of this manual the following definitions are used:
Shoreland is defined as Minnesota Rule 6120, which for lakes is that land located within 1000 feet of the ordinary high water level. Some local governments use a distance of 1320 feet. The methods in this protocol use land located within 1320 feet of the ordinary high water level in order to buffer the state-defined shoreland area.

Shoreline is the edge of a body of water and, alternatively, used here with regard to fish and wildlife habitat to refer to the narrow band around the lake centered on the land-water interface.

Near-shore is the shallow aquatic areas of a lake within 680 feet of the shoreline.

Shore impact zone means land located between the ordinary high water level of a public water and a line parallel to it at a setback of 50 percent of the structure setback, but not less than 50 feet. This area serves as the primary shoreline buffer, and for the General Development lakes surveyed it is the first 50 feet landward.

Lakeshore is the area comprised of the shoreland, shoreline and the near-shore.

Need

Increases in shoreland development are changing lake ecosystems. Development pressure is increasing with more dwellings per lake each year in Minnesota (Kelly and Stinchfield 1998). Human habitation along the shore has a cumulative effect on fish and wildlife habitat, water quality, and biota of lake ecosystems (Engel and Pederson 1998, Ramstack et al. 2004). Christensen et al. (1996) found significantly less submerged woody habitat from fallen trees along developed shorelines in Wisconsin and Michigan, and predicted that recent losses in developed lakes will affect littoral communities for about two centuries. Meyer et al. (1997) concluded that housing development along shores of northern Wisconsin lakes dramatically altered native vegetation, especially shrubs, and reduced frog populations. Elias and Meyer (2003) found that the mean number of plant species and the percent of native species were both greater at undeveloped sites than along developed Wisconsin lakeshores for upland, shoreline, and shallow water areas. Jennings et al. (1996) noted changes in near-shore substrate composition in Wisconsin lakes due to human activity. In an Iowa lake, Byran and Scarnecchia (1992) found significant reductions in aquatic macrophyte abundance in developed compared with undeveloped shorelines. Jennings et al. (2003) also found that the amount of littoral wood remains and emergent and floating-leaf vegetation was lower at developed sites and lakes with greater development density. By comparing vegetation abundance along undeveloped and developed shorelines for 44 lakes in Minnesota, Radomski and Goeman (2001) estimated that 20 to 28 percent of the near-shore emergent and floating-leaf coverage was lost. Radomski (2006) determined that floating-leaf and emergent vegetative cover was significantly affected by development for the period from 1939 to 2003 for Minnesota lakes.

Alteration of natural littoral zone habitats has negative consequences to fish and wildlife. Littoral zone vegetation is important for amphibians, ducks, herons, and many species of greatest conservation need (Meyer et al. 1997; Lindsay et al. 2002; Woodford and Meyer 2003). Floating-leaf and emergent vegetation provides fish and wildlife with foraging areas and refuge from predators (Killgore et al. 1993; Casselman and Lewis 1996; Valley et al. 2004). Many fish depend on this habitat for some part or most of their life (Becker 1983). Emergent vegetation, such as hardstem bulrush, provides spawning habitat, cover, and colonization sites for aquatic invertebrates and protects shorelines from erosion by dampening wave energy. Numerous fish species use protected embayments and vegetative cover disproportionately to their availability (Wei et al. 2004). Human activities that change vegetative cover can alter ecological processes and energy flow within lakes, thereby reducing their ability to support diverse and healthy fish and wildlife populations (Schindler and Scheuerell 2002).

Lake shorelines often vary greatly with respect to their ecological characteristics and functions. Additional work is needed to identify and protect high priority near-shore habitats. The idea that more restrictive development standards in protected bays and areas where habitat exists for species of greatest conservation need seems reasonable and warranted given the substantial near-shore habitat losses estimated to date and the projected losses possible with further shoreland development. Greater protection of sensitive shorelands and the valued ecosystem services requires identification, mapping and designation of these places.

Cass County recently began a pilot project on several lakes – a project they have named Intra-Lake Land Use Reclassification. The county led a technical team of federal, state, and local resource managers to develop criteria for determining sensitive areas. The criteria were then incorporated into a GIS (Geographic Information Systems) algorithm to identify sensitive lakeshores. The county proposed specific development standards, including larger lot sizes and greater structure setbacks for new lots, for these areas. The county held public hearings on this approach for protecting significant fish and wildlife habitat. Cass County acknowledged that insufficient resources existed for extensive field verification and validation of county designated sensitive areas, and they asked the DNR for assistance before proceeding with any proposed zoning or ordinance changes. This manual was the result of this Cass County/State collaboration.

Minnesota's Comprehensive Wildlife Conservation Strategy (CWCS) identifies the "significant loss and degradation of habitat" as one of four major Management Challenges (DNR 2006). Managing emerging issues affecting species of greatest conservation need is listed a Priority Conservation Action and the loss and degradation of Minnesota's lakeshore is clearly an emerging issue. Species of greatest conservation need are animals whose populations are rare, declining or vulnerable to decline. They are also species whose populations are below levels desirable to ensure their long-term health and stability. Many species of greatest conservation need depend on lakeshores.

The Minnesota State Demographic Center has projected growth in many of the lake-rich counties to exceed 35 percent in the next 25 years. CWCS promotes habitat-based conservation, and there is a need to assess the amount and quality of key near-shore habitats and to map their locations in this subsection (Priority Conservation Actions for Surveys, subsection item 2a). Species of greatest conservation need in this subsection that may benefit from this project include, but are not limited to: American and least bitterns, red-necked and western grebes, black tern, common tern, common loon, bald eagle, marsh and sedge wrens, swamp sparrow, Virginia and yellow rails, least darter, pugnose shiner, longear sunfish and numerous invertebrate species. Other wildlife species of interest that are associated with shoreline and lake communities include osprey, great blue heron, and green and mink frogs.

Expected Results or Benefits

A sensitive area district concept and the allowance to reclassify isolated bay shorelands to a more restrictive class was incorporated into Minnesota's Alternative Shoreland Management Standards (version 1.0, December 12, 2005; a product of the Governor's Clean Water Initiative). Local governments can now create sensitive area districts along sensitive shores and reclassify bays on recreational development and general development classed lakes to provide greater protection to near-shore species of greatest conservation need. Assisting local governments on potential districting and reclassification is a valuable service and benefit, and this manual is an aid to provide those services and benefits.

Within the environmental review processes, determining where significant fish and wildlife habitat occurs and delineating sensitive areas would be helpful in regulating shoreland and public waters development including structures, bridges, culverts, water alterations, excavation, and destruction of aquatic plants. Appropriate aquatic plant management and shoreland development rules and regulations for sensitive areas may help promote healthy and balanced near-shore communities and protect habitat for species of greatest conservation need. Thus, a program to delineate these areas is anticipated to be beneficial to DNR processes and local government decision-making.

Assessing the amount and quality of key near-shore habitats and mapping their locations provides additional resources to support some of the Priority Conservation Actions outlined in the CWCS for this ecological subsection.

Summary of Approach
The first work in identifying sensitive lakeshores requires the review and compilation of the existing data. Sources of potential existing data on Minnesota lakes and lakeshore plant and animal communities include, but are not limited to:

1. DNR Fisheries Lake Surveys
2. DNR Wildlife Shallow Lakes Program Surveys
3. DNR Natural Heritage Information System
4. DNR Ecological Resources Lake Surveys
5. DNR Invasive Species Program surveys
6. DNR Volunteer Loon Watcher Surveys
7. DNR Bald Eagle and Osprey Nest Surveys
8. University of Minnesota / Bell Museum Herbarium
9. Published literature and agency reports
10. Aerial photography
11. National Wetland Inventory
12. National Cooperative Soil Survey

Available data are incorporated into a geographic information system (GIS), and these data are used in survey design and determination of unique or critical ecological areas.

The sensitive lakeshore protocol consists of three components: field surveying lakeshore habitats and their use by high priority animal species, identifying sensitive lakeshore habitats and developing an ecological model, and compiling and delivering information on sensitive lakeshores to various land and resource managers. This is the same general approach used by the Minnesota County Biological Survey.

The first component involves field surveys of the lake aquatic plant communities and the distribution of high priority animal species. The aquatic plant surveys are conducted lake-wide and occur at a number of different scales. Submerged habitats and near-shore areas are also sampled. High priority animal species include species of greatest conservation need as well as other animals whose habitat use represent a good proxy for species of greatest conservation need.

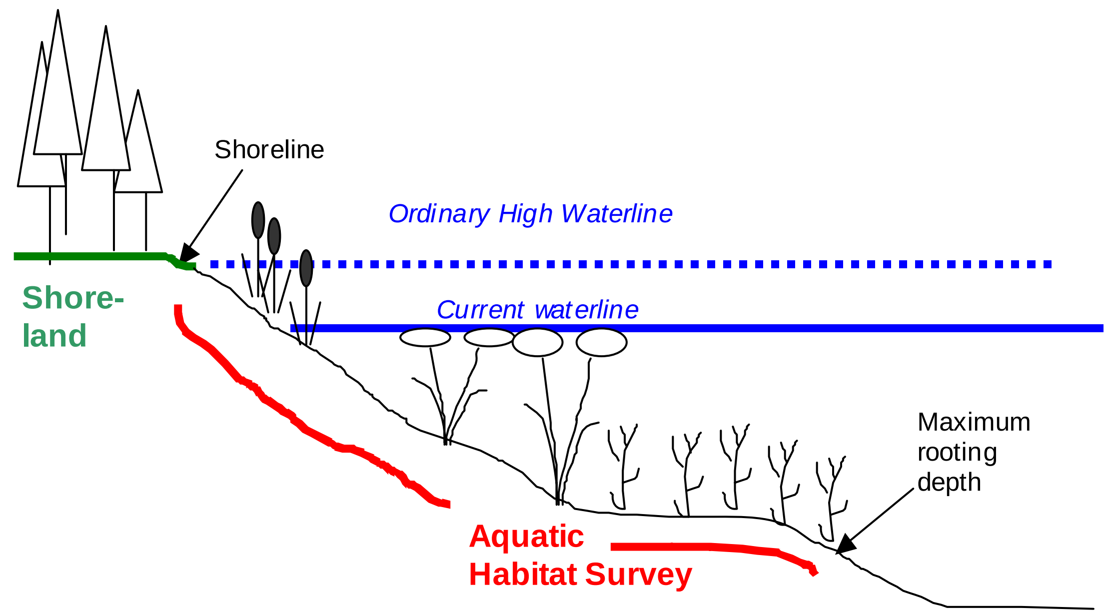
The second component involves the development of ecological models that objectively and consistently rank lakeshores for sensitive area designation. Objective methods deliver repeatable results that are relatively insensitive to the subjective interpretations of the individuals doing the ranking; in addition, consistent, fair rankings are more likely to stand up to scrutiny and can be used as the basis for regulatory action.

The final component of identifying sensitive lakeshore is to deliver advice to local governments and other groups who could use the information to maintain high quality environmental conditions and to protect habitat for species in greatest conservation need via shoreland ordinance.

Chapter 2. Aquatic Habitat Survey and Mapping

The Aquatic Habitat Survey describes the type, quantity and quality of the existing aquatic habitat, from the shoreline to the maximum depth of aquatic plant growth (Figure 1).

Figure 1. Lake zones included in the aquatic habitat survey (shoreline to maximum rooting depth).



The aquatic habitat surveys are conducted using a tiered survey approach. Survey components include:

1. Assessment of lake-wide vegetation community using the grid point-intercept method.
2. Delineation and description of emergent and floating-leaf plant beds.
3. Delineation and description of other unique aquatic plant areas.

The grid point-intercept method is a useful tool for lake-wide assessment of aquatic plant communities. However, it is not always adequate for assessment of near-shore vegetation, including emergent and floating-leaf beds. One problem with the grid survey methodology is that it may under sample near-shore, shallow sites where the habitat is often quite different. To compensate for this shortcoming, sampling protocol includes methods to delineate, map and describe emergent and floating-leaf habitat and other unique aquatic plant communities.

Sampling Timeline

Most vegetation sampling is conducted during peak growth and before plants senesce - July through early September. Lake-wide aquatic plant surveys are the first component and are conducted after significant plant growth is noted through July. In lakes with extensive wild rice

(*Zizania palustris*) stands, surveys may be conducted earlier (June) to minimize damage to wild rice. If curly-leaf pondweed (*Potamogeton crispus*) is an important part of a lake plant community, surveys may be conducted in May or June, before this species senesces. Surveys to delineate and describe emergent and floating-leaf stands and other unique plant areas are conducted in August and early September, and they may be conducted the year after the initial lake-wide aquatic plant assessment. Data management and analysis, which will rely on GIS, are conducted during non-field survey times.

A. Lake-wide vegetation and near-shore substrate survey (grid point-intercept survey)

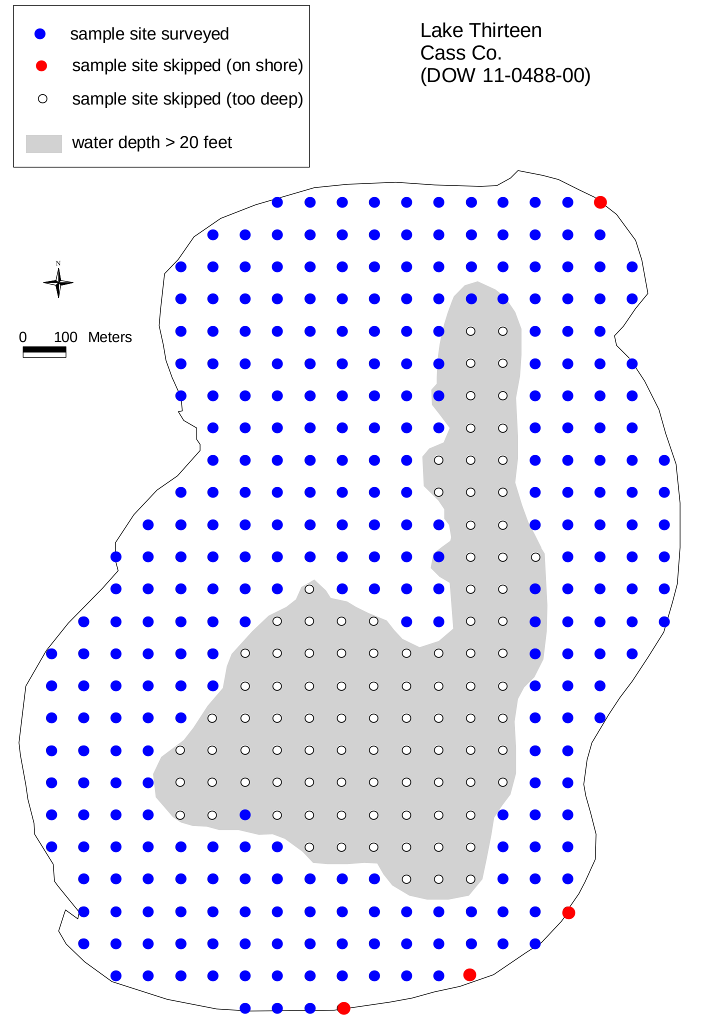
The goal of the lake-wide vegetation survey is to quantitatively assess the major plant species within the lake basin. Objectives include:

1. Record the aquatic plant species that occur in the lake
2. Estimate frequencies of occurrence of individual species
3. Estimate the percent of the lake occupied by rooted vegetation
4. Develop GIS-based, lake-wide distribution maps for the common species
5. Estimate the maximum depth of rooted vegetation
6. Describe the shoal water substrate types

The grid point-intercept method used here records frequency of occurrence (presence/absence) as the measure to estimate plant abundance and individual species abundance. The grid point-intercept vegetation survey method estimates plant frequency by determining the proportion of survey points that "hit" or intercept vegetation. Frequencies of individual species can also be estimated by recording the plant species when intercepted by a point.

The grid point-intercept vegetation survey methodology follows that of Madsen (1999), and the technique has been extensively used in Minnesota by the lead aquatic plant ecologist (Donna Perleberg), the Minnesota DNR Wildlife Shallow Lakes Program, and has been adopted by the Wisconsin DNR as their standard lake vegetation survey method (Jennifer Hauxwell, personal communication). In comparisons of several boat-based aquatic vegetation survey methods, the grid point-intercept method was found to provide the most rapid, repeatable, GIS-based method to assess lake-wide plant species abundance and associated depth data (Perleberg 2001a, Perleberg 2001b). Williams et al. (2008) recommended the point-intercept survey for whole-lake assessments where statistical comparisons are needed. Other boat-based methods (Jesson and Lound 1962, Yin et al. 2000) provide more site-specific detail, but require the boat to be anchored at each sample site, thus reducing the total number of sites that can be sampled per hour. Furthermore, because the grid point-intercept method collects frequency data only, other advantages include consistency in data collection between different surveyors, ability to monitor a variety of plant growth forms, opportunity to monitor at flexible times throughout the growing season, and uncomplicated data analysis (Nichols 1984, Elzinga et al. 2001). In addition, frequency data are recommended as an appropriate abundance estimate when studying long-term changes in communities (Nichols 1999). It may not be appropriate to estimate aerial coverage from these data because accuracy would be dependent on the resolution (spacing of points) of the survey (Williams et al. 2008).

Figure 2. Grid Point-Intercept Survey. Example of sample site locations, Lake Thirteen, Cass County.



In the grid point-intercept method, survey points are established throughout the littoral (or the vegetated) zone on a grid using GIS. While other aquatic vegetation survey methods may randomly assign survey points within a stratified area (Yin et al. 2000), a random systematic placement of survey points is more appropriate because lake-wide mapping is a primary objective. If a current depth contour map of the lake is available, points may be established within the littoral zone only. However, on many lakes, the exact area of the littoral zone is unknown and it is easier to establish sample points across the entire basin and once in the field skip points that occur in deep water. Once sampling has begun, surveyors may determine that little or no vegetation occurs beyond a certain depth, and skip survey points that occur beyond that depth (Figure 2). In most Minnesota lakes, it is recommended that surveyors sample to at least a depth of 20 feet (6 meters). If depth contour lines are well documented, a stratified sampling approach may be appropriate where a predetermined number of sample points are placed within a specific depth zone (ex. 200 points in the shore to 5 feet zone, 200 points in the 6 to 15 feet zone). However, for most Minnesota lakes, mapped depth contours only approximate the actual depths and a simple grid spacing of points is easier. It is important that the maximum depth sampled and the total number of surveyed sites be stated along with survey results.

Required sample size

The size of the littoral zone, the shape of the lake, and existing information about the plant community will determine the number of points and the grid resolution (see Appendix 1 for more information on the number of points necessary for appropriate sampling).

Within the littoral zone, a minimum of 250 points will be sampled on most lakes, to ensure that commonly occurring species (species occurring at frequencies of at least 40%) are adequately

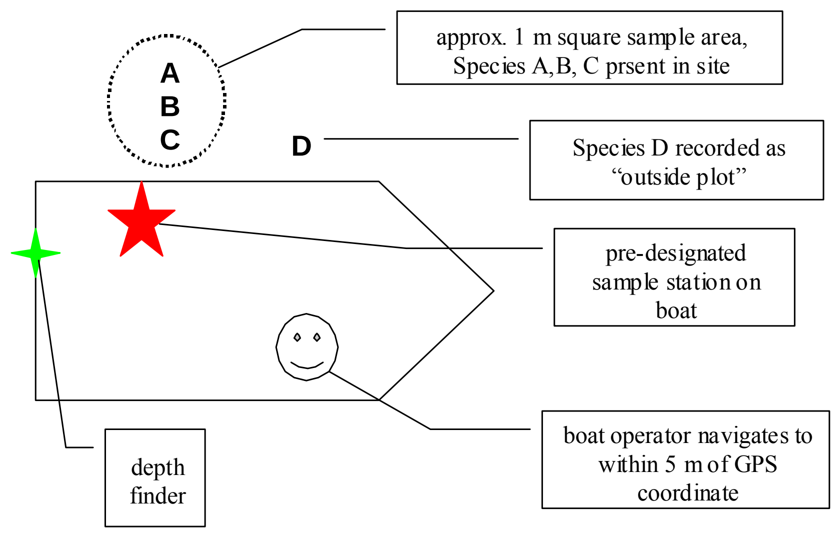
sampled with an error of 15% with 95% confidence. To date, the number of survey points sampled on Cass County lakes has ranged from 400 to 2,100, with a mean of 950.
A two-person crew can generally survey between 100 and 300 points per day (fewer points with increases in plant density or species richness).

Equipment
A checklist of required and recommended equipment is provided in Appendix 2, and the field data collection form is given in Appendix 3. Survey point waypoints are uploaded to handheld GPS units.

Field sampling
Sampling is conducted primarily from a boat (Figure 3) and GPS units are used to navigate to each sample point. The survey points are not intended to be permanent sampling locations and are not marked with permanent markers. Rather, the goal is to navigate to the approximate location of each sample point. Given the inherent inaccuracy of field-model GPS units, and the shifting movement of the boat due to wave action, surveyors are not always able to stop precisely on the survey point location. Surveyors are directed to navigate to within five meters of survey point coordinates shown on the GPS unit. The boat operator maintains the position of the boat without anchoring and sampling is conducted from a pre-designated side of the boat.

Survey points may be skipped under the following conditions:
1. Site location is on shore (sample station is permanently removed from database)
2. Site location is within a dense and/or shallow bed of emergent or floating-leaf vegetation and motoring into the site would likely destroy vegetation. (Surveyors record general observations about the site but do not include data in calculations.)
3. Site location occurs in water depths greater than maximum rooting depth of vegetation.
4. Access to site is prevented by dock, swim area, other boats.

Figure 3. Sampling at each point-intercept location.



Water depth

At each sampling point, water depth is recorded in one-foot increments using an electronic depth finder mounted at the stern of the boat or, in water depths less than eight feet (2.5 meters), with a measured stick at the pre-designated sample side on the boat (Figure 3).

Vegetation sampling – presence/absence

Plant species abundance is estimated by presence/absence, or frequency of individual species within the survey sites. All plant species found within an approximate one square meter sample site ("A, B, C:" in Figure 3) are identified and recorded. In shallow water, where vegetation is visible, it may be useful to use a plastic hoop to delineate the sample area (Figure 4). A double-headed, weighted garden rake attached to a rope is used to survey vegetation not visible from the surface (Figure 5). In depths where the lake bottom is not visible, or when wind prevents using the delineation hoop, surveyors attempt to drag the rake across an approximate one-meter square area.

Figure 4. Plastic hoop measuring 1 meter square in area (1.13 m diameter) used to delineate sample area in shallow water.

Plant taxonomy and nomenclature follow Crow and Hellquist (2000). Voucher specimens are collected for most plant species (Hellquist 1993). Any additional plant species found outside of the survey area ("D" in Figure 3) are recorded as present in the lake but are not included in estimates of species frequency.

Frequency of occurrence is calculated for each species as the number of sites in which a species occurred divided by the total number of sample sites. Frequency is calculated for the entire sampled area and also by water depth intervals.

Figure 5. Double-headed, weighted rake for submerged plant sampling.

Vegetation sampling – cover estimate

In addition to vegetation presence/absence data collected with the grid point-intercept method, lake managers are also often interested in "plant cover" as it relates to fish and wildlife habitat and recreational lake use. Plant cover can be defined as the vertical projection of vegetation from the ground as viewed from above and can be distinguished as basal cover and aerial or canopy cover (Elzinga et al. 2001). Surveyors also have the option of recording a coarse description of plant cover at each site but this is a qualitative estimation and is not used in statistical analyses. Recording cover can be difficult because:

1. The boat is not anchored and it can be difficult to maintain position long enough to record cover;
2. In low clarity and/or deep water, plant cover can not easily be viewed from the boat surface (Newman et a. 1998);
3. Cover estimations will vary between surveyors (Newman et a. 1998);
4. Cover may change throughout the time period of the survey (Nichols 1984).

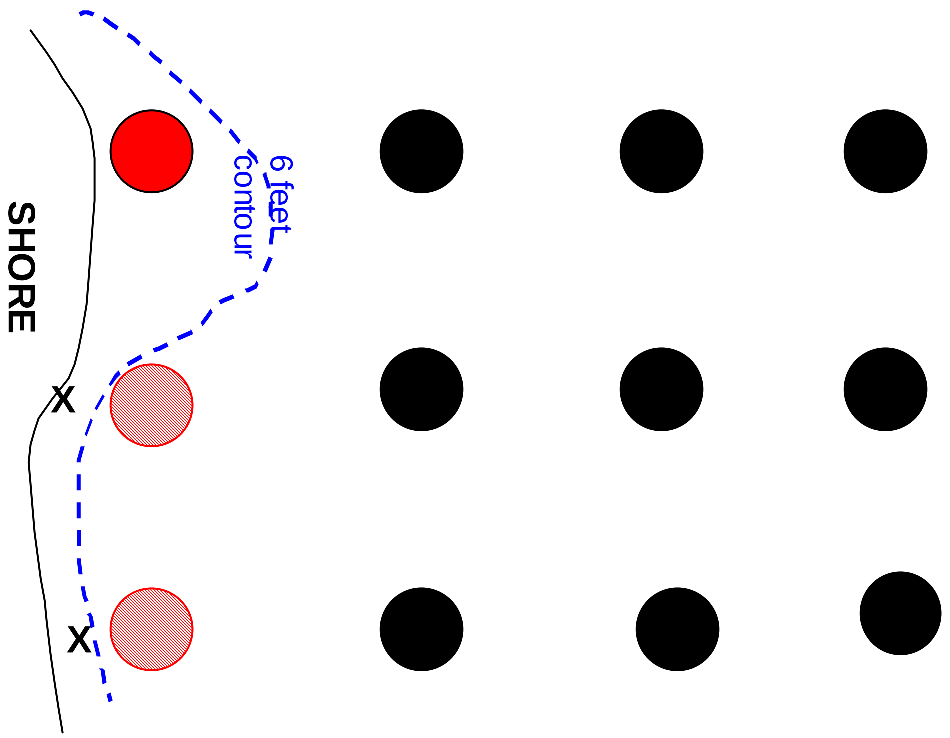
Nevertheless, it may sometimes be useful to have a general estimate of cover, for example, in lakes where non-native species management is a priority. In such cases, surveyors may elect to estimate cover for only the non-native species. If surveyors decide to include a cover estimate, it is recommended that they select only two or three categories for cover descriptions such as:
1. plant species matted at or near water surface vs. not matted
2. few plants collected on rake vs. rake full of vegetation

Substrate sampling
In water depths of six feet (two meters) and less, surveyors evaluate lake bottom substrate from the pre-designated sample station (Figure 2) by tapping a pole into the lake bottom; soft substrate can usually be brought to the surface on the pole or sampling rake for evaluation. Standard lake substrate classes are recorded following the Minnesota DNR Lake Survey Manual (DNR 1993). If several substrate types occur at a site, surveyors record the most common type.

Substrate Group	**Type**	**Code**	**Description**
Hard Bottom	Boulder	BO	Diameter over 10 inches
	Rubble	RU	Diameter 3 to 10 inches
	Gravel	GR	Diameter 1/8 to 3 inches
	Sand	SA	Diameter less than 1/8 inch
	Sand/Silt	SS	Sand bottom overlaid with thin layer of silt
Soft Bottom	Silt	SI	Fine material with little grittiness
	Marl	MR	Calcareous material
	Muck	MU	Decomposed organic material

Surveyors attempt to record a substrate description at the shore side of each row of points. If a sample site occurs near shore but in water depth greater than six feet, surveyors collect depth and vegetation data and then motor into shallower water and record the substrate type adjacent to the actual survey point (Figure 6).

Figure 6. Sampling near-shore substrates. (Red circle = Substrate sample recorded at sample site. Red-hatched circles = Too deep for substrate sample, "off-site substrate" recorded at "X", black circles = no substrate recorded)



B. Delineate and describe emergent and floating-leaf plant beds

Protocols are based on the procedures documented in the DNR draft Aquatic Vegetation Mapping Guidelines (DNR 2005) and may include a combination of aerial photo delineation and interpretation, field delineation, ground-truthing and site specific surveys. Large stands of emergent and floating-leaf vegetation are mapped. Mapping of small beds is resource intensive and imprecise using available GIS tools. Plant beds are characterized by the dominant genera or species and plant community descriptions may continue to be refined as more data are collected:

Survey Method	**Plant community type**	**Dominant plants**
Field delineation	Bulrush	*Scirpus* spp.
	Bulrush - mix	*Scirpus* spp.
	Spikerush	*Eleocharis* spp.
Aerial photos with field verification; descriptive detail will vary with survey effort	Cattail	*Typha* spp.
	Wild rice	*Zizania palustris*
	Wild rice - waterlily	*Zizania palustris*
	Mixed emergent	Various – *Equisetum* spp., *Eleocharis* spp., *Sagittaria* spp., *Sparganium* spp.

Survey Method	Plant community type	Dominant plants
	Waterlily	*Nymphaea odorata*
		Nuphar variegata
		Brasenia schreberi
		Various – *Sparganium* spp. (floating-leaf burreed), *Persicaria amphibian* (floating-leaf smartweed), *Potamogeton natans* (floating-leaf pondweed), etc.

Aerial Photo Delineation

Existing aerial photographs are used to map floating-leaf vegetation. The photo source, scale, and date are documented. Some issues associated with this method include difficulties in identifying vegetation beds from photos. This may result in missing small or floating-leaf vegetation beds altogether. Several photo sources are used, if possible, because different types of vegetation may appear differently on separate photos. The locations on the photo are only as accurate as the photo rectification.

Aerial photo delineated maps are field-checked. Using field surveys, species compositions of stands are verified. Changes in vegetation observed between different photo dates can also be confirmed.

Field Delineation

Field mapping focuses on bulrush (*Scirpus* spp.) beds, which are difficult to see on aerial photos. Existing data are used along with a reconnaissance survey to identify extensive bulrush stands for further quantification. Bulrush habitat is mapped and digitized using GPS (equipment check list is in Appendix 4).

Stem density is an important factor in assessing the overall habitat quality of an emergent plant stand. Emergent vegetation stem density in general, and bulrush stem density in particular, has been used to describe several types of waterfowl and shorebird nesting habitat (Custer 1993, Spautz and Nur 2002). Waterfowl studies may focus specifically on optimal ranges of bulrush stem densities for a particular bird species (Custer 1993). Bulrush also serves as habitat for many fish species (Becker 1983). Numerous factors may affect bulrush stem density including the species of bulrush present, competition from other plant species, water depth (Hunter et al. 2000), substrate type, substrate nutrient levels, herbivory (Lentz and Cipollini 1998), and disturbance by humans. Stem density varies within and among bulrush stands and the number of stems per square meter may range from less than one to more than 800 (Hall and Freeman 1994).

Estimating bulrush stem density can be difficult and surveyors often rely on visual estimates to describe stand density (DNR 2005). Bulrush stands have been described as “sparse”, “moderately dense”, or “dense” (DNR 2005) with no association to stem density counts, or with stem density counts that overlap (same mean count for sparse and moderate categories) (Morris 1999). Kantrud (1996) suggests that a "healthy" stand of soft-stem bulrush (*Scirpus validus*) would have a stem density range of 50 to 500. Field trials were conducted in 2006 to determine the feasibility of estimating bulrush stem density using plotless methods (Engeman et al. 1994). Survey methods were found to be labor intensive and difficult to reliably repeat. Therefore, stem density estimates of bulrush will not be included as a standard method in this protocol.

C. Identify areas of unique and rare aquatic plant species

Surveyors use information collected during the grid point-intercept survey and near-shore vegetation surveys to locate unique aquatic plant species. These species may include:

1. Rare (endangered, threatened, special concern) plant species

2. Plant species that are not listed as rare but are uncommon in the state or locally. These may include species that are proposed for rare listing.

3. Plants species with high coefficient of conservatism values. A coefficient of conservatism value, or C value, may range from 0 to 10 and represents an estimated probability that a plant is likely to occur in a landscape relatively unaltered from what is believed to be a pre-settlement condition (Nichols 1999, Bourdaghs et al. 2006.). Because the amount of information for each species differs, C values are subjectively assigned by biologists based on existing information and professional judgment. Nichols (1999) developed tentative C values for 128 Wisconsin lake plants based on their substrate preference, turbidity tolerance, rooting strength, primary reproductive means, and tolerance to water drawdowns. C values have now been established for most aquatic and wetland plant species native to Wisconsin (WDNR 2007) and Minnesota (Milburn et al. 2007). C values may vary from region to region (Swink and Wilhelm 1994, Herman et al. 1996) and values developed by Wisconsin are mostly applicable in Minnesota. Plant species with assigned C values of 9 and 10 will be included as "unique species". C values could vary regionally within the state (Nichols 1999), and it may be necessary to regionalize the selection process within Minnesota (e.g., for southern Minnesota lakes, species with C values of 7 or higher will be included as "unique species"). Tree species are not included in the unique plant survey.

4. Plant communities that provide unique habitat conditions within the specific lake (e.g., off-shore muskgrass (*Chara* spp.) bed that provides the only off-shore habitat; the only remaining waterlily bed on a lake).

Partial list of rare (special concern, threatened, or endangered) and unique plant species most likely to be found in lakes or along lakeshores can be found in Appendix 5.

Chapter 3. Near-shore Vegetation Surveys

These surveys are designed to characterize near-shore sites that contain unique habitat for native aquatic plant communities and high priority animal species. Based on information collected during the aquatic habitat and near-shore fish and other aquatic animal surveys, high priority shoreline sites are identified for detailed vegetation surveys. High priority near-shore sites will typically be undeveloped and may include:

1. Locations of animal species of greatest conservation need
2. Locations of rare and unique aquatic plant species
3. Intact, high quality aquatic/wetland plant communities

Near-shore vegetation surveys are conducted in August and early September, and they may be conducted the year after the initial lake-wide aquatic plant assessment.

Sampling plots are established and surveyed on selected shoreline areas of each lake. Existing data are used along with a reconnaissance survey to select areas to be surveyed. The goal of this survey is to quantitatively assess the type and quality of the existing shoreland plant communities that occur adjacent to potentially high quality in-lake habitat sites. Data collected are used to describe that specific area of the lake and are not considered to represent the plant community of the lake as a whole (Titus 1993).

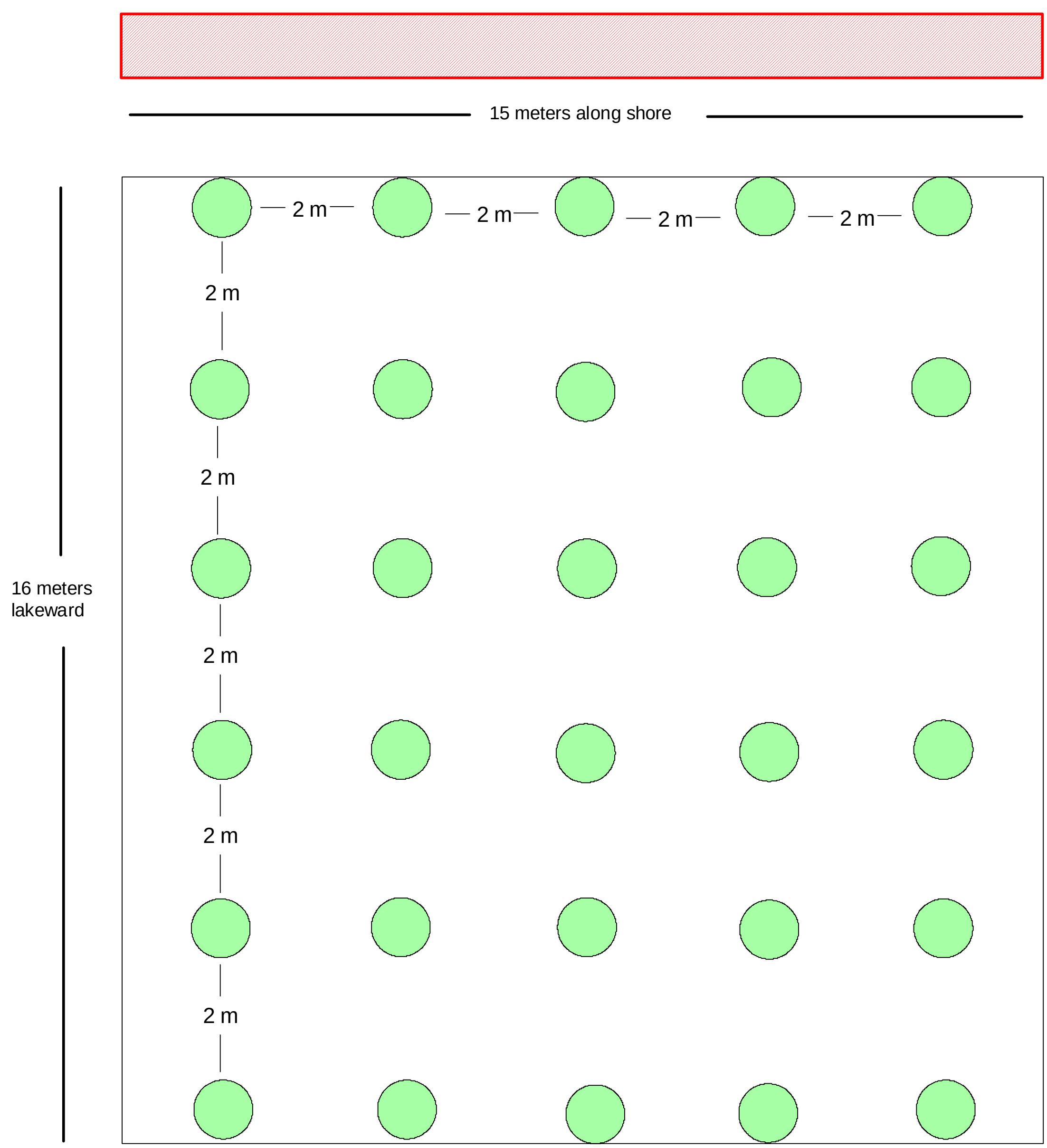
Objectives include:

1. Characterize the aquatic plant community
    a. Identify plant species present
    b. Estimate the amount of vegetation present
2. Characterize the lake bottom type
3. Estimate the amount of woody habitat within the area
4. Estimate the mean water depth within the area
5. Identify the emergent wetland and/or terrestrial plant species present along the shoreline

In-lake Vegetation Quadrates

Plots are approximately 240 square meters (0.06 acres) in area and typically extend 15 meters along shore and 16 meters lakeward; plots abut the shoreline (Figure 6). The actual plot dimensions may be adjusted to account for sites with steep drop-offs but the plot areas remain consistent. Aquatic sampling quadrates (1 m^2) are systematically placed every two meters along transect lines within the sampling plot.

Figure 6. Near-shore sample plot. Sampling within the plot includes:
A) a species list of shoreland plants from a 15 m^2 plot (1 m landward x 15 m along shore), and;
B) plant occurrence, water depth, and substrate type from 30 – 1 m^2 in-lake quadrates.



The transect line is anchored on shore with a plastic stake and at the deep-water edge with a pole (Figure 7). Surveyors determine if transect length and number need to be adjusted to ensure adequate coverage of the vegetation within the area.

Figure 7. Surveyors establish transect line of near-shore plot.

A circular plastic hoop is used to delineate the sample area (Figure 4). Circular plots have less edge per unit area than squares and rectangles (Elzinga et al. 2001) and have been used to delineate shallow sample sites of grid point-intercept surveys (Chapter 2). They are recommended here so that frequency data collected are comparable to the grid point-intercept data.

The hoop may be attached to a pole to help surveyors maintain their position at the sample station. Surveyors wade to most sample sites and if needed may use a float tube or boat for deeper water sites. In sites with flocculent substrate, a float tube is recommended to limit resuspension of bottom sediments which reduces visibility. A viewing scope or dive mask are recommended for viewing vegetation (Figure 8).

Figure 8. Surveyor views vegetation within quadrat along transect.

Within each 1 m^2 quadrate, the following are recorded:

1. Plant species abundance is estimated by presence/absence, or frequency of individual species within the survey sites. All plant species found within the 1-m2 quadrate are identified and recorded. Plant taxonomy and nomenclature follow Crow and Hellquist (2000). Voucher specimens are collected for most plant species (Hellquist 1993).

2. Substrate type is described using the classes listed in Chapter 2.

3. The presence of aquatic woody habitat is described as:
   a. Absent
   b. Small twigs or branches (< 6 inches diameter) present
   c. Tree limbs (6-10 inch diameter) present
   d. Trees (>10 inch diameter) present

4. Water depth is recorded using a measured pole. If water depth exceeds six feet, a boat mounted electronic depth finder may be used.

In 2007, surveyors conducted field trials to determine if additional measurements within each quadrate were feasible. They concluded that plant cover and plant height could not be consistently estimated and they are not included as part of this protocol.

Shoreline Vegetation Quadrate

In addition, one shoreline vegetation quadrate (one meter landward by fifteen meters along shore) is sampled at the vegetated zone of the land-water interface (Figure 9; first line of emergent vegetation adjacent to the lake). Trial surveys in 2006 found a 5 m^2 area to be a minimum sample size for identifying commonly occurring shoreland plant taxa, and in 2007, surveyors determined that a 15 m^2 area did not require significant additional survey time, so this dimension is used.

Surveyors record all species within the shoreline quadrate. Taxa are identified to the lowest taxonomic level possible. When necessary, difficult to identify taxa are collected for identification verification. Nomenclature follows the most current draft of MNTAXA (list of all plant species known in Minnesota; MNDNR 2003). A photo of each shoreline quadrate is taken. A checklist of required equipment is listed in Appendix 6, and the field data collection forms are provided in Appendices 7 and 8.

Figure 9. Shoreline vegetation quadrat. Blue line indicates shore/and interface. Surveyor lays out 15 m plot edge.

Chapter 4. Aquatic Frog Calling Survey

An aquatic frog survey is conducted from mid June to mid July. The methodology follows the Minnesota Frog and Toad Calling Survey (MFTCS) protocol, which was an outgrowth of the North American Amphibian Monitoring Program. Information on MFTCS can be found at: http://www.dnr.state.mn.us/volunteering/frogtoad_survey/index.html

Several life-cycle characteristics make mink frogs (*Rana septentrionalis*) and green frogs (*Rana clamitans*) ideal indicator species of lakeshore habitats. First, mink and green frogs are shoreline-dependent species that inhabit nearly all types of permanent water in this region. Adult male frogs are easily surveyed by auditory detection. They establish and defend distinct territories, and tend to remain along the periphery of lakes and ponds throughout the summer breeding season or in areas of shallow water with emergent vegetation. Green frogs breed from late May to mid-August and mink frogs begin their calling in late May with the breeding season extending from late June to early August (Breckenridge 1944), so a summer calling survey is an effective technique to determine presence and abundance.

Objectives of the aquatic frog calling survey include:

1. Determine index of abundance for all frogs and toads
2. Estimate actual abundance of mink frogs and green frogs
3. Develop distribution maps for mink frogs and green frogs

Figure 10. Sampling stations every 400 meters along shore.

The entire shoreline of each lake is surveyed. Listening stations are established using GIS to generate evenly spaced points every 400 meters around the lake. Shoreline length determines the total number of stations (Figure 10), and a minimum of 100 stations will be established on each large lake.

Surveys are conducted between sunset and 1:00 AM, and if conditions deteriorate such that rain showers or breezy conditions substantially affect hearing ability, a survey is stopped. At each listening station, a biologist listens for several minutes for frog and toad calls. An estimate of the abundance of frogs and a calling index is recorded for both mink and green frogs. The calling intensity of all other amphibian species heard is also recorded. The field datasheet used for the survey is provided in Appendix 9.

The abundance of green and mink frogs at each station is classed as:
1. 1-9 individuals
2. 10-20 individuals
3. 20-100 individuals
4. > 100 individuals.

The call index value for each amphibian species heard is recorded according to the following:
1. individuals can be counted (silence between calls)
2. calls of individuals can be distinguished, but some overlap of calls
3. full chorus (calls constant, continuous, and overlapping).

Chapter 5. Near-shore Fish and Other Aquatic Animal Survey

The purpose of this survey is to identify critical areas for aquatic animals and map locations where sensitive indicator species are present. Specific objectives include:

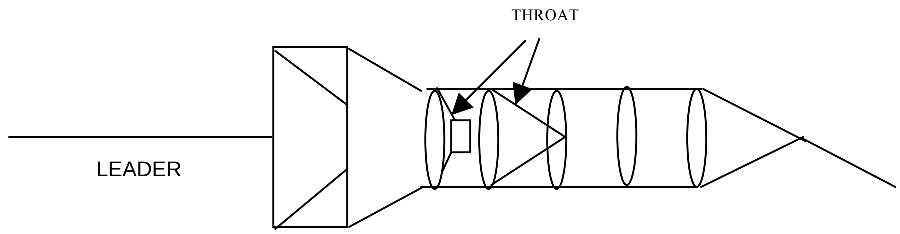
1. Record presence and abundance of fish species of greatest conservation need
2. Record presence and abundance of fish proxy species
3. Develop distribution maps for species of greatest conservation need and proxy species
4. Identify habitat (substrate and aquatic vegetation biovolume) associated with presence of species of greatest conservation need and proxy species
5. Identify near-shore fish assemblages
6. Document presence of other aquatic species (frogs, turtles)

Fish species of greatest conservation need include pugnose shiner (*Notropis anogenus*), least darter (*Etheostoma microperca*), and longear sunfish (*Lepomis megalotis*). These fish are associated with large, near-shore stands of muskgrass or aquatic macrophytes, as are the proxy species for these sensitive indicator species, which include blackchin shiner (*Notropis heterodon*), blacknose shiner (*Notropis heterolepis*), and banded killifish (*Fundulus diaphanus*). These fish species are intolerant to disturbance and may require large undisturbed patches of near-shore vegetation. They are often only present in undisturbed lakes, and they have been extirpated from lakes where watershed and lakeshore development has occurred (Clady 1976, Lyons 1989).

Near-shore aquatic animal surveys are conducted in the summer using a systematic random or stratified random sampling design with fish collection methods that generally follow Minnesota's lake near-shore fish sampling protocol (Drake and Pereira 2002, Drake and Valley 2006). For each lake, points used during the aquatic frog calling survey are also used for near-shore aquatic vertebrate sampling stations. Sampling is conducted within a 50-foot (15 meter) radius of the sampling station. The number of stations will be dependent on the size of the lake, and whether any stratification is used.

Near-shore fish assemblages are sampled using shoreline seining, backpack electrofishing, and trapnets. Within each near-shore sampling area, all sampling gear will be used, if possible. Trap nets have a 12.2-m lead approximately 1.1 m deep with two 1.5-m by 0.8-m frames and six 0.76-m hoops with a 18-cm square throat; all mesh is 6.4-mm nylon (Figure 11). The nets are oriented perpendicular to shore with the leader on or near the shore. Nets are set overnight and pulled the next day. For seining and electrofishing effort at sampling stations, the survey crew alternates gear used first. Two shocking passes are conducted at each station, one near the shoreline and one at a depth of approximately 30 to 40 inches (75–100 cm). Electrofishing crews consist of two members, one to carry and operate the backpack electroshocker and one to collect fish. The seine used is 15.2-m long with a bag, and all mesh is 3.2-mm nylon. The seine is set at the shoreline and perpendicular out to the length of the seine or the maximum wadable depth, and the offshore end of the seine is arced back to shore. For each gear, species are identified and counted. In places with excessive vegetation, depth, or extremely soft bottom, seining or trapnetting may not be conducted. However, in these situations, electrofishing is conducted, and often, from a boat.

Figure 11. Diagram of a trapnet.



Standard near-shore lake substrate classes are recorded for each sampling station following DNR Fisheries Lake Manual (DNR 1993) (see Chapter 2). In addition, an estimate of aquatic vegetation biovolume is recorded for the seine haul area (i.e., a 15 m^2 area abutting the shore). This estimate represents the volume of a sampling area that contains submerged aquatic vegetation. Seining, electrofishing and trapnet data are pooled by station, each station representing one unit of sampling effort.

Chapter 6. Bird Survey

Birds use a wide variety of lakeshore habitats. Many birds use specific habitat types or require a combination of habitats for their life cycles; some of these habitats are rare or limited in size and distribution, thus limiting the range of the bird species. Lakeshore habitats used by birds include trees and forested areas, shrub swamps, aquatic emergent vegetation such as bulrush and cattail marshes, rocky reefs and islands, mud flats, the water/land interface of the shoreline, the water surface and under the water.

Information on birds is collected in two phases. The first phase is to search existing databases for historical records of nesting and for occurrences of rare species. This data collection takes place before the field season begins. Special efforts are made to search during the field season for species that had historical records. The second phase of the project is field surveys for all bird species utilizing lake shorelines. Field surveys take place during the nesting season, when birds are most vocal. Methods include point-counts, call-playback surveys for secretive marsh species, and general observations of rare species observed.

Although all bird species are noted and recorded, surveyors focus on bird species of greatest conservation need (SGCN). A second list of species is also given special note. These species are dependent on specific aquatic habitats, represent SGCN proxy species, or are suffering declines in Minnesota.

Bird Species of Greatest Conservation Need
These species are likely to be found near central Minnesota lakeshores. Species are listed in AOU order.

American Black Duck (*Anas rubripes*)
Common Loon (*Gavia immer*)
Red-necked Grebe (*Podiceps grisegena*)
American White Pelican (*Pelecanus erythrorhynchos*)
American Bittern (*Botaurus lentiginosus*)
Least Bittern (*Ixobrychus exilis*)
Bald Eagle (*Haliaeetus leucocephalus*)
Red-shouldered Hawk (*Buteo lineatus*)
Yellow Rail (*Coturnicops noveboracensis*)
Virginia Rail (*Rallus limicola*)
Common Tern (*Sterna hirundo*)

Forster's Tern (*Sterna forsteri*)
Black Tern (*Chlidonias niger*)
Common Nighthawk (*Chordeiles minor*)
Yellow-bellied Sapsucker (*Sphyrapicus varius*)
Eastern Wood-Pewee (*Contopus virens*)
Least Flycatcher (*Empidonax minimus*)
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)
Sedge Wren (*Cistothorus platensis*)
Marsh Wren (*Cistothorus palustris*)
Veery (*Catharus fuscescens*)
Golden-winged Warbler (*Vermivora chrysoptera*)
Ovenbird (*Seiurus aurocapilla*)
Swamp Sparrow (*Melospiza georgiana*)
White-throated Sparrow (*Zonatrichia albicollis*)
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)

Other Bird Species of Interest

Great Blue Heron (*Ardea herodias*)
Green Heron (*Butorides virescens*)
Osprey (*Pandion haliaetus*)
Sora (*Porzana carolina*)
Spotted Sandpiper (*Actitis macularia*)
Caspian Tern (*Sterna caspia*)
Alder Flycatcher (*Empidonax alnorum*)
Purple Martin (*Progne subis*)

Database Searches for Historical Information

This information search focuses on past records of species that have been entered in DNR databases such as the DNR Natural Heritage Database Information System, DNR Volunteer Loon Watcher Surveys, DNR Eagle Nest Records, and DNR Osprey Nest Records. Bird species of focus include the common loon, red-necked grebe, bald eagle, osprey, black tern and other colonial nesting waterbird species.

Field Surveys

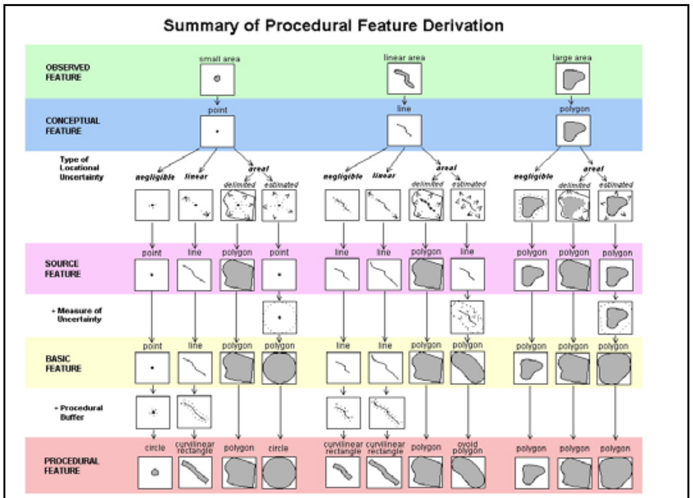
Three types of field data are collected on birds—point counts, call-playback surveys targeting marsh birds, and general field observations. All birds heard or seen while conducting the surveys or while working on the lake or along the shoreline during the nesting season, defined as the last week of May through the first week of July, are recorded.

Morning point counts for birds are conducted between sunrise and 10:00 AM at the same sample stations used for frog surveys (see Chapter 5). The entire shoreline is surveyed by boat with points at 400-meter intervals. The boat is stopped when the GPS point is reached and the boat is positioned 20 –50 meters from shore (depending on water depth). A timer is set for 5 minutes and all birds heard or seen are recorded. Relatively calm conditions are required in order to hear the birds along the shoreline, so surveys require positioning the boat out of the wind (protected side of lake) or conducting surveys only when wind speeds are less than 6 mph. If noise from sources such as waves along the shoreline, wind, or road construction negatively affects the ability to hear birdsong, the survey is cancelled for that day.

Marsh birds are notoriously secretive and are not often recorded on passive-listening point counts. Call-playback surveys done in the evening, before sunset, are a better method to discover the presence of birds such as rails. The survey methodology used is modified from “Standardized North American Marsh Bird Monitoring Protocols” (Conway 2005), and uses calls from species expected to be found in the local lakeshore/marsh habitats. Surveys are not conducted from pre-determined sampling stations, but at locations where there is significant marsh habitat. The surveys are done from a boat. The survey begins with five minutes of passive listening, which is followed by 30 seconds of call-playback, then a shorter period of listening. This call-playback sequence is repeated three times. Species targeted with this method include American bittern, least bittern, Virginia rail and sora. If suitable habitat for yellow rails is found, surveys are conducted after dark using their distinctive call.

General field observations are also recorded while surveyors are in transit between points or conducting other work on the lake. These observations include notes on feeding areas, roosting/resting sites, and nest areas, especially for birds that are SGCNs or other species of interest. A bird checklist is kept to record all species observed on the lakeshore or in the water for each study lake so that a species list can be compiled at the end of the field season. A sample field data collection form is provided in Appendix 10.

Chapter 7. Ecological Models to Delineate Sensitive Lakeshore



Source: NatureServe 2002

Ecological models are used to assist in the determination of sensitive areas. This approach is based on ecologically based guidelines for land use (Dale et al. 2000) and is consistent with research on identifying important green infrastructure (Benedict and McMahon 2006). Two modeling approaches are used. First, an ecological model based on documented lakeshore plant and animal communities and hydrological conditions is used to identify sensitive lakeshore. Examples of such an approach on a coarser scale include the Regionally Significant Ecological Area Assessment by the DNR for the seven-county metropolitan area completed in 2003 and the sensitive natural area assessment for the 17-county central region (AMEREGIS & DNR 2006). The benefit of this approach is that criteria come from the science-based surveys (variables include species presence, biological diversity, and habitat size and quality), and the value (or model score) of the shoreline with regard to fish and wildlife habitat is objectively assessed. Second, predictive models are used to identify lakeshore in need of restoration where sensitive indicator species are not present or are in very low abundance. These statistical models use logistic regressions or spatial analyses on hydrological, morphological and aquatic vegetation variables.

A. Models based on habitat, plant and animal occurrences

The following 15 attributes, based on the major conservation principles listed below, were used to identify sensitive lakeshores:

1. Hydric soils
2. Near-shore substrate
3. Wetlands
4. Near-shore plant frequency
5. Near-shore aquatic plant community richness
6. Presence of rare and other unique plant species in the near-shore area
7. Presence of extensive emergent and floating-leaf vegetation beds
8. Presence of aquatic frogs
9. Loon nesting areas
10. Shoreline bird species richness
11. Presence of bird species of greatest conservation need (exclusive of loon and bald eagle nests)

12. Near-shore aquatic vertebrate richness (fish, frogs, turtles)
13. Presence of fish species of greatest conservation need or their proxy species
14. Natural rare features as documented in the DNR's Natural Heritage Information System
15. Size and shape of natural areas

Conservation principles

The ecological models are based on the following conservation principles:

1. Wetlands and littoral areas provide important habitat and services

Shallow water areas, wetlands, bogs and fens often provide critical habitat. Near-shore areas, which are rich in aquatic plant diversity and abundance, represent prime habitat for a variety of fish and wildlife. Aquatic plants in these near-shore areas tend to serve a variety of functions, such as absorbing nutrients that reduce water quality, reducing erosion from waves, and providing food and habitat for fish and wildlife. Wetlands are especially critical habitats for wildlife. Many wildlife species in Minnesota inhabit or are attracted to wetlands, and wetlands are the principal habitat for many waterfowl and waterbird species. The loss of natural wetlands around lakes and in their drainage basins is a causal factor in the deterioration of many lakes. Wetlands filter nutrients and runoff sediments that may impair water quality, recharge groundwater, and reduce runoff discharge that could cause erosion and flooding.

2. Wetlands and productive littoral areas are vulnerable to development

Shallow bays are particularly vulnerable to water surface use. Boat traffic on shallow lakes can result in an increase in phosphorus concentrations due to sediment resuspension. This phosphorus can then stimulate growth of attached or planktonic algae, thereby degrading or eliminating important aquatic plant communities. In addition, boat traffic on shallow lakes and in littoral areas can damage or destroy aquatic macrophytes.

3. Shoreland and shorelines are often heterogeneous with critical habitat clustered

Shorelines are often comprised of a mix of windswept open areas and protected bays. Bays, because they are protected to some degree from wind and waves, often contain abundant vegetation. For example, they may contain a large portion of the valuable floating-leaf and emergent plant stands for a lake. Numerous fish species use these protected bays, wetland fringes, and the associated vegetative cover disproportionately to their availability. Fish prefer wetland embayment areas because they generally warm up faster in the spring, the presence of emergent and floating-leaf vegetation provides cover, and productivity is higher in these areas. In addition, such areas are often used for fish spawning and nursery grounds. Loons also prefer to nest in specific areas, such as on vegetated hummocks, small islands, or masses of emergent vegetation.

Conservation of these shoreland areas containing critical habitat may maintain regional and lake-specific diversity of plants and wildlife.

4. The size and shape of an area is important

Fragmentation of habitat is the leading threat to biodiversity. Wildlife dispersal and travel generally occurs across wide swaths of land, not narrow corridors. To allow the flow of species across wide areas, large natural areas are needed. When natural areas are fragmented into numerous small and irregular shaped pieces (patches), the plants and animals found on the site, and the interactions that take place between plants and animals (e.g., predator and prey relationships) change. Habitat islands are vulnerable to loss of species.

The larger a natural area is, the more likely it will support populations of native plants and animals. Fish species of greatest conservation need (pugnose shiner, least darter, and longear sunfish) are intolerant to disturbance and may require large undisturbed patches of near-shore vegetation. Fragmentation of vegetation often results in a reduction in the nest success of some bird species. Small, irregularly shaped areas have a greater proportion of edge area than interior area. Birds forced to nest in the edges may have a greater risk of losing offspring to predators (crows, grackles, brown-headed cowbirds).

Edges do provide important habitat for many plants and animals and often have a high number of species. This is in part because fragmentation of vegetation often increases the occurrence of invasive, non-native plants and animals that inhabit edge habitats. Over time, invasive non-natives often out-compete native species, leading to decreased species diversity at the landscape scale.

5. Adjacent land use affects natural areas

Strategic conservation requires an integrated landscape approach that considers the influence of neighboring areas. Local changes can have broad-scale impacts on lake and river ecosystems. The introduction of non-native plant species into forests and lakeshores from urban gardens, trampling of vegetation from heavy pedestrian or recreational use, and increased salinity of wetlands from road salts are several ways that adjacent urban, suburban, and agricultural land uses adversely impact natural areas.

Extensive development introduces new predators and may increase predator populations. Wildlife impacts include increased mortality from cat predation, car kills, killing of wildlife (snakes and bats) by landowners due to misperceptions/fear, and reduced reproductive success if breeding is disrupted by human activities.

6. The connectivity of habitats and vegetation is important

Linkage is essential for natural systems to function properly. The loss of connectivity through the addition of impervious surfaces such as roads and buildings often fragments landscapes. Fragmentation changes how plants, animals, wind and water move across the landscape.

Habitat connectivity may allow an animal to relocate when habitat is lost or degraded due to natural or human disturbance. Movement allows individuals from different populations to breed, which maintains genetic diversity in the population. Some animals have different vegetation requirements during different stages of their life cycle. For example, Blanding's turtles require large wetland complexes for over-wintering and dry, sandy soil grasslands for breeding. An animal's risk of being killed (increased predation, road strikes) during movement increases in fragmented landscapes. Lake, stream and wetland habitat quality is dependent on maintaining vegetated riparian and lakeshore zones, and connectivity to upland vegetation.

7. Species diversity is important
Diversity of both plant and animal species is critical to maintaining the health of an ecosystem. Diversity allows an ecosystem to adapt to varying conditions. Recent ecological research shows that a plot of land with many plant species is more productive and resistant to drought, pests, and other stresses than a plot with only a few species. Diverse habitats are fundamental in allowing an area to have high plant and animal diversity.

Many human activities cause changes in the environment that lead to lower species diversity and decreased ecological resiliency. Examples include excess nitrogen from pollutants, the introduction of invasive non-native species, and the disruption of natural processes such as natural water flow. These disruptions often lead to the elimination of many native species and the promotion of just a few species. These disturbed areas then are less able to tolerate outbreaks of pests and diseases and large-scale changes such as climate change.

Ecological Model Details

A GIS ecological model is used to identify sensitive lakeshore. The goal is to recognize potential shoreland and near-shore areas that contain important environmental features. The ability to identify sensitive areas is dependent on field surveys, which provide reliable information on the elements of biodiversity, how natural resource elements are connected, and their condition. There are several shortcomings with this general approach to identify sensitive lakeshore. For example, the minimum required size of a habitat patch needed for a given organism is quite variable. In addition, habitat variation exists over a range of spatial scales, and the size of the sampling unit used in the various surveys may not be optimal for ecological considerations. However, spatial dependence of neighboring points or nearby sample points is often a reasonable assumption in lakes, and the shoreland development policies necessitate that GIS analytical units constitute groupings of adjacent sampling points.

Environmental decision-making is complex and often based on multiple lines of evidence. Integrating the information from these multiple lines of evidence is rarely a simple process. The identification of sensitive lakeshore used here is an objective, repeatable and quantitative approach to the combination of multiple lines of evidence through calculation of weight of evidence (*weight of evidence* as used in this manual relates to an interpretative methodology).

The model has several components. First, spatial data layers of soils, wetlands, rare features, plant communities, and fish and wildlife habitat are overlaid with a spatial layer of shoreland areas. Priority rankings for shoreland segments or plots are based on an overlapping moving window that follows the shoreline. An overlapping window technique allows the value of connectivity to be automatically included in the rankings. The size of the window used in the analysis is dependent on the lake size since the optimal window size varies by survey designs (e.g., for moderately sized lakes, a 2000 feet long (1320 feet landward, 680 feet lakeward) by 500 feet wide window, with 250 feet overlap is used, whereas for large lakes this window size is increased). In this framework, shorelands are rated based on the cumulative score of the spatial data layers to provide resource conservation priorities.

Attributes from field surveys are summarized by polygons according to the elements occurrence (EO) data standard (NatureServe 2002). Substrate and aquatic plant data are given a negligible locational uncertainty type (areal estimated type with a 25 m radius). Unique plant communities and emergent and floating-leaf stands are of the areal delimited type (assuming negligible uncertainty). Frog and bird surveys and loon nesting area polygons are of the areal estimated type with a 200m radius. Fish and other aquatic vertebrate survey polygons are of the areal estimated type with a 50m radius. The Natural Heritage Information System also uses this EO data standard.

Model Attributes

The following matrix is used to assign scores for shoreland segments:

Attribute	GIS Data Type	Score	Criteria of Plot
Hydric Soils	Polygons from Cass County Soil Survey	3	> 25% of analysis window is hydric soils
		2	12.5-25% hydric soils
		1	< 12.5% hydric soils
		0	No hydric soils observed
Near-shore Substrate	Points from surveys (converted to a circle procedural feature based on measure uncertainty)	3	Frequency of occurrence is > 50% soft substrate (muck, marl or silt) (i.e., at least 50% of points within analysis window consisting of soft substrate)
		2	Frequency of occurrence is 25-50% soft substrate
		1	Frequency of occurrence < 25% soft substrate
		0	No soft substrate observed
Wetlands	Polygons from the National Wetland Inventory	3	> 25% of analysis window is in wetlands
		2	12.5-25% is in wetlands
		1	< 12.5% is in wetlands
		0	No wetlands recorded
Near-shore Plant Occurrence	Points from the Aquatic Plant Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Frequency of occurrence is > 75% (>75% of points within the analysis window contained vegetation)
		2	Frequency of occurrence is 25-75%
		1	Frequency of occurrence < 25%
		0	No vegetation observed
Aquatic Plant Richness	Points from the Aquatic Plant Surveys (converted to a circle procedural feature based on measure	3	Total number of plant taxa within analysis window > 10
		2	Total number of plant taxa 5-10
		1	Total number of plant taxa 1-4

Attribute	GIS Data Type	Score	Criteria of Plot
	uncertainty)	0	No vegetation observed
Unique and Rare Plant Species	Points determined from the Aquatic Plant Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Presence of 2 or more unique or rare plant species within analysis window
		2	Presence of 1 unique plant species
		0	No unique plant species observed
Presence of Emergent and Floating-leaf Plants Beds	Polygons based on stand locations determined with the Aquatic Plant and Remote Sensing Surveys	3	Emergent and/or floating-leaf plant stands occupy > 25% of the aquatic part of the analysis window
		2	Stands occupy 5-25%
		1	Present but occupies < 5%
		0	No emergent or floating-leaf plant bed observed
Frog Areas	Polygons based on Frog Surveys	3	Presence of both green and mink frogs within analysis window
		2	Presence of green or mink frogs
		0	Neither species observed
Loon Nesting Areas	Polygons based on Loon Watcher Surveys and Bird Surveys	3	Presence of natural loon nest within analysis window
		2	Presence of loon nest on artificial platform
		0	No loon nesting observed
Shoreline Bird Richness	Points from the Bird Surveys (converted to a circle procedural feature based on measure uncertainty)	3	Total number of bird species within analysis window > 18
		2	Total number of bird species 8-18
		1	Total number of bird species 1-7
		0	No bird species observed
Birds Species of Greatest Conservation Need (SGCN)	Polygons based on bird surveys	3	Presence of 3 or more SGCNs within analysis window
		2	Presence of 2 SGCNs
		1	Presence of 1 SGCN
		0	No SGCNs observed
Aquatic Animal Vertebrate Richness (fish, frogs, turtles)	Polygons based on Aquatic Vertebrate Survey	3	Total number of aquatic vertebrate species within analysis window > 10
		2	Total number of aquatic vertebrate species 5-10
		1	Total number of aquatic vertebrate species 1-4

Attribute	GIS Data Type	Score	Criteria of Plot
		0	No aquatic vertebrates observed
Fish Species of Greatest Conservation Need (SGCN) and their proxies	Polygons based on field observations and surveys	3	Presence of one or more SGCNs within analysis window
		2	Presence of one or more proxy species
		0	SGCNs or proxies not present
Other Rare Features	Polygons from the Natural Heritage Information System	3	Presence of multiple Natural Heritage Features within analysis window
		2	Presence of a Natural Heritage Feature
		0	No Natural Heritage Feature recorded
Size and shape of natural areas	Polygons based on DNR lake map interpretation	3	Protected or isolated bay within analysis window
		2	Non-protected or non-isolated bay within analysis window
		0	No distinctive bays

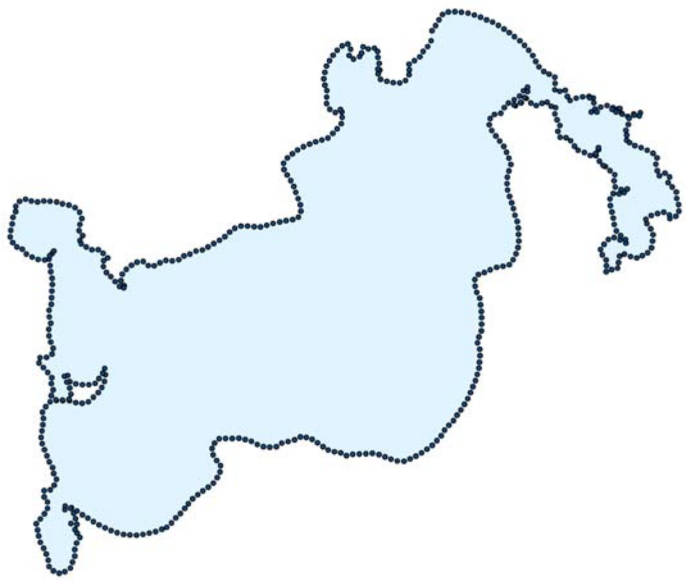
The Sensitivity Index is the cumulative score of the 15 attributes. Once a Sensitivity Index has been developed for a lake, clusters of points with similar values are identified using GIS. Cluster analysis uses ArcMap Hot Spot algorithms with a fixed Euclidean distance search radius of 2000 feet (609 m). The mapped calculated z-scores where Sensitivity Index values are statistically significant (> 1.96) indicate the most probable highly sensitive shoreland. These areas are then buffered by ¼ mile, resulting in discrete potential sensitive shoreland areas or resource protection districts.

It is expected that the conservation principles and this ecological model will have a greater propensity to identify the most highly sensitive lakeshores to be shorelands associated with bays or sheltered areas of the lake characterized by quiet water and abundant vegetation. However, sections of the shoreline with high wind and wave exposure (i.e., high-energy shorelines) may also be sensitive. Although many of the animal species surveyed (e.g., frogs, bird and fish species of greatest conservation need) prefer the protected, vegetation-rich areas such as bays, other species inhabit the windswept shorelines. These high-energy shorelines often have vegetation communities and substrates that differ significantly from the bays. Waves may uproot or fragment plants, or affect plant growth and reproduction (Doyle 2001). Waves can also transport sediments, altering the substrate composition. Silt may be suspended and removed from an area, leaving a sandy or gravelly bottom. Because walleye typically require silt-free substrates for spawning (Newburg 1975), they may inhabit these shores during spawning. There is a positive association between wind-wave power and walleye, and walleye may be also attracted to high-energy areas where smaller prey species are vulnerable due to wave action (Cross and McInerny 2006). Certain shorebirds, such as sandpipers and plovers, use the sandy beaches of high-energy shorelines for feeding and even nesting. Because these high-energy shorelines provide habitat for several animal species, they may have sufficient diversity to receive a high species richness score. The presence of rare features, wetlands, and hydric soils around these sections of shoreline may also enable these areas to obtain high scores in the ecological model.

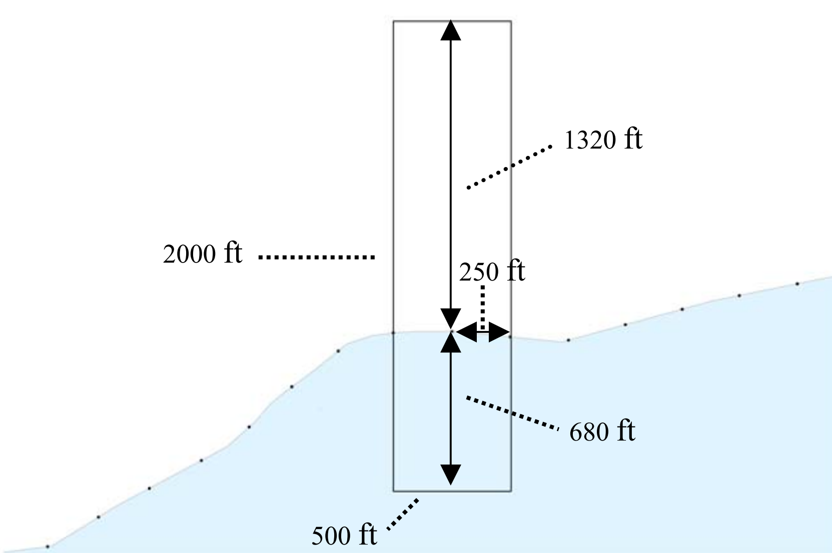
GIS Steps of Ecological Model

The following nine steps are used to create a sensitive lakeshore map:

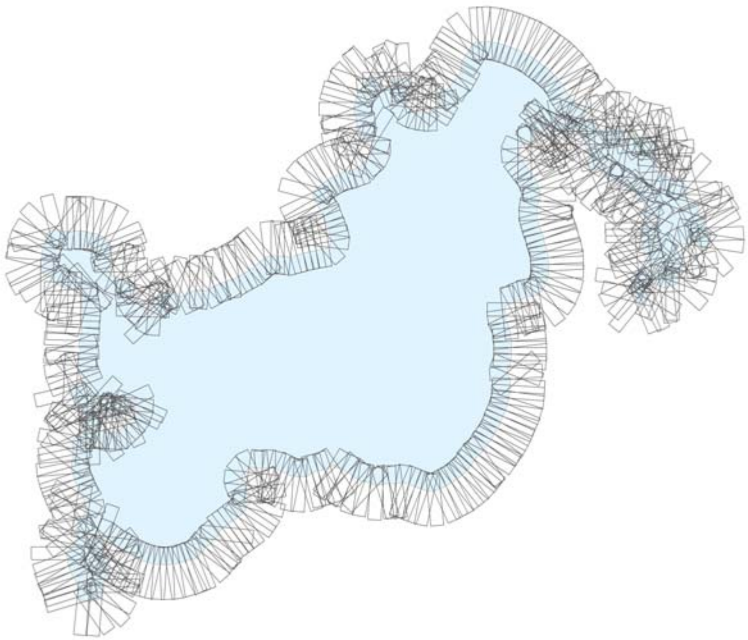
1. Create points every 250 ft along the shoreline.



2. Create window around each point with following specifications (this will vary depending on lake size).



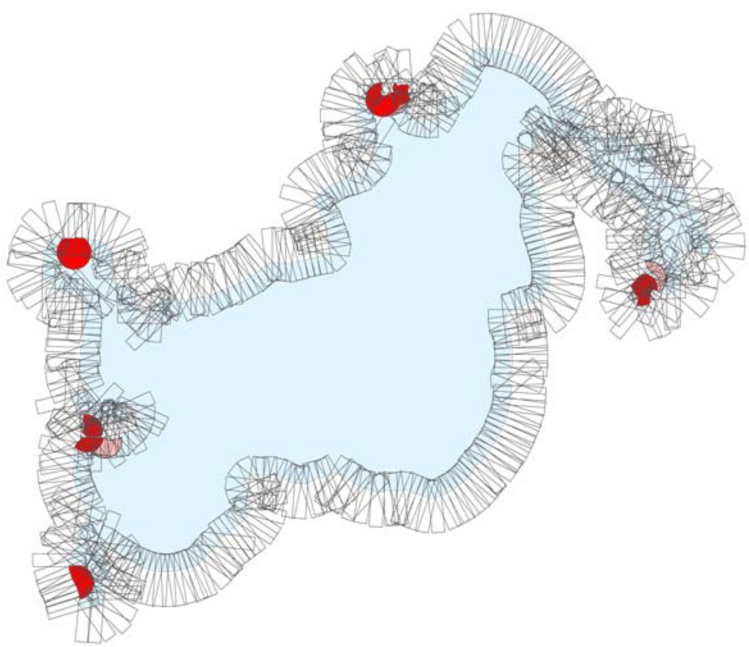
All points around with window around points



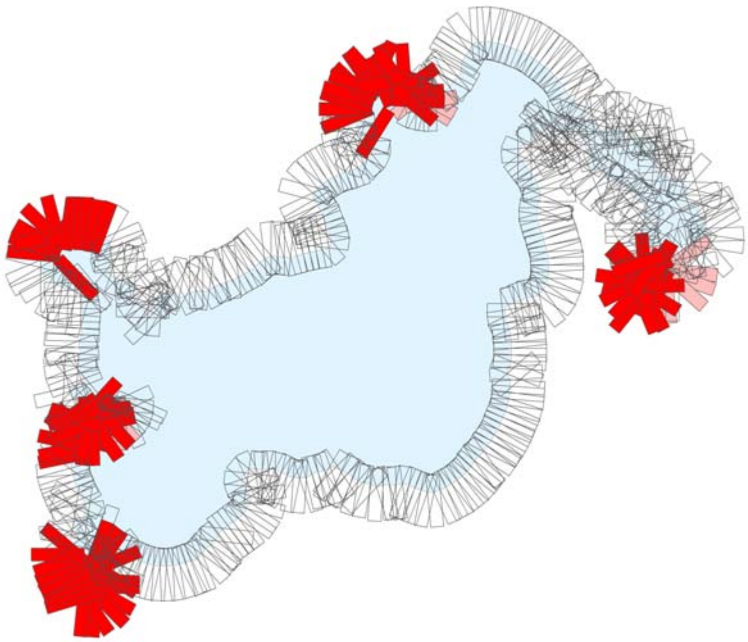
Zoom in of windows on shoreline

3. Input data layer. Example below is for loon nests where red is a natural nest and pink is a platform nest. The nest sites are buffered to 200m and limited to the water.

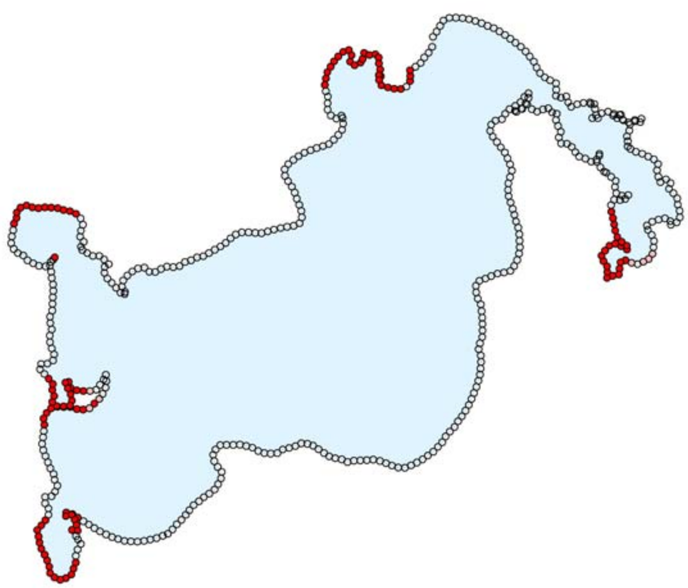
4. Perform a spatial join between the windows and loon nest sites to assign each window a loon nest value. Natural nests are assigned a value of 3 and platform nests are assigned a value of 2 (see Model Attributes matrix). If multiple loon nests occur within one window, the window is assigned the highest score.



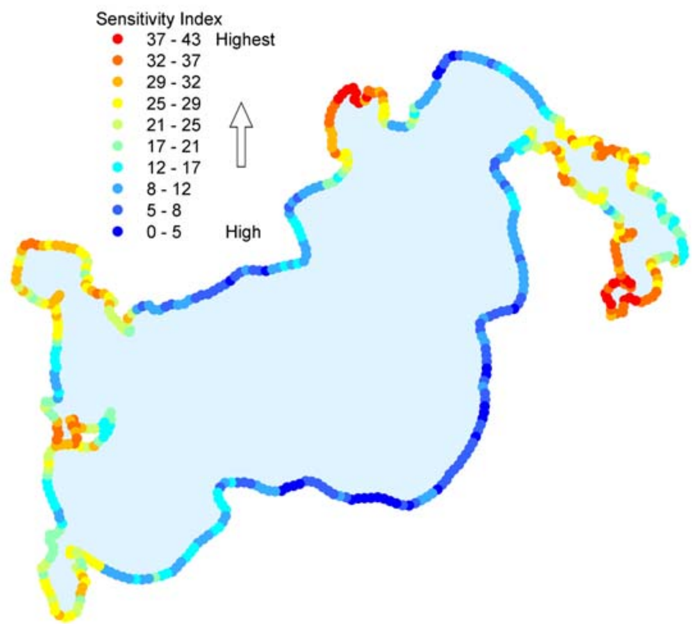
results in:



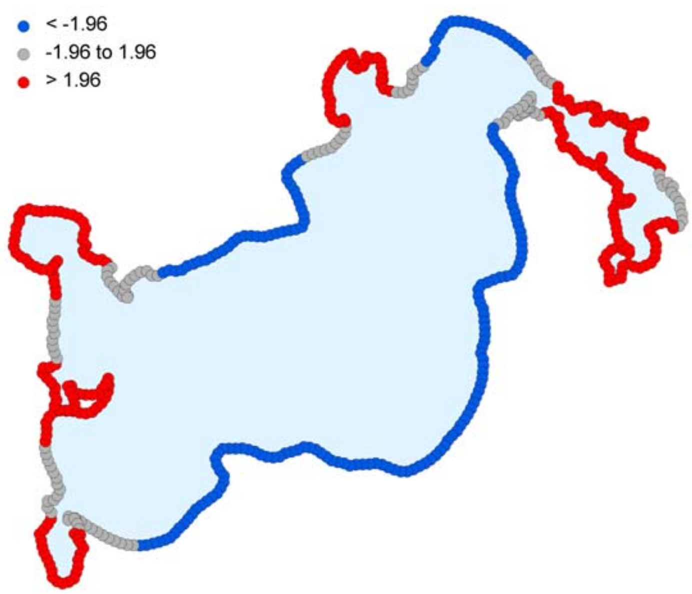
5. Perform a spatial join between the “loon coded” windows and the original 250 ft points. Each point is therefore assigned the same value as its corresponding window.



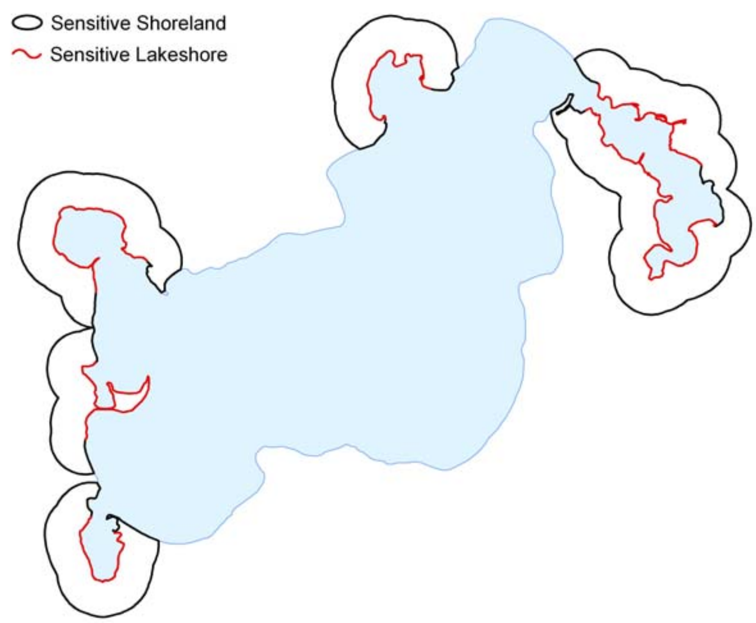
6. Repeat this on all layers. The Sensitivity Index is the cumulative score. Red/orange colors represent points with the highest cumulative scores (highest sensitivity), whereas green/blue scores represent points with lower cumulative scores (high sensitivity).



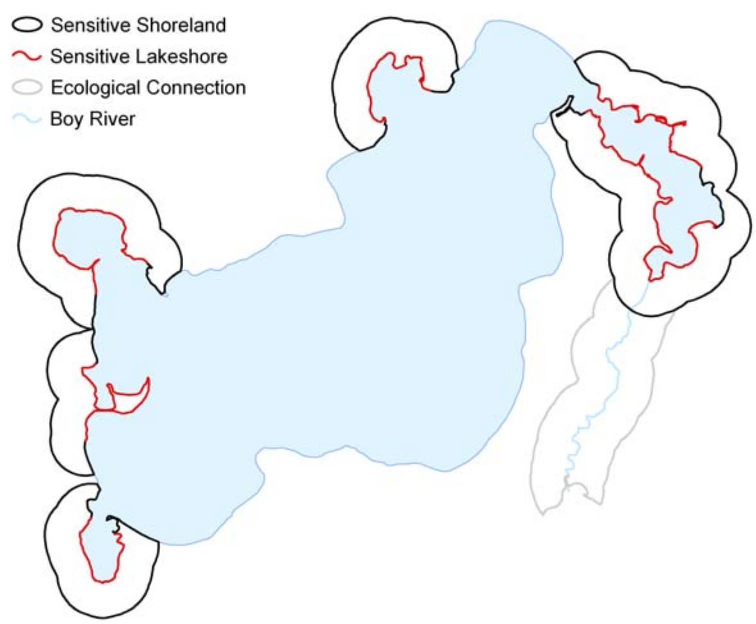
7. Perform cluster analysis on Sensitivity Index layer to obtain distinct segments of sensitive shoreland. Red areas represent highly sensitive shoreland.



8. Create buffers around highly sensitive shoreland to generate potential resource protection areas.



9. Finally, shorelands of inlets or outlets in potential sensitive lakeshore and other ecological connections will also be forwarded to the local government for consideration of sensitive area districting and public water reclassification, as water quality protection and connectivity of these areas for fish and wildlife is important.



A final report is assembled for each lake that summarizes the various surveys and the results of the ecological model. The final step is to provide the locations and maps of sensitive shorelines to the local government.

B. Predictive models for prompt, timely delineations and those for degraded areas

TO BE COMPLETED AFTER ACQUISITION OF SUITABLE DATASETS and as other research becomes available. Existing predictive models will also be refined. Cass County's GIS model to identify potential sensitive lakeshore will also be explored as a means to identify near-shore survey sites. The GIS model currently ranks shoreline segments as to sensitivity based on whether distance to the edge of the littoral area exceeds 650 feet (200 meters), presence of wetlands near-shore, whether the shoreline is part of an isolated bay, documented presence of threatened, endangered or special concern plants and animals (from the Natural Heritage Information System), and whether the shoreline segment was near an inlet or outlet. This model may be updated and replaced with a statistical modeling approach that uses binary logistic regression. Various statistical models could then be tested as to their efficacy to filter locations for detailed near-shore surveys. Fetch may also be included in such an analysis.

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Appendices

1. Grid point-intercept vegetation survey – required sample size
2. Grid point-intercept vegetation survey – equipment checklist
3. Grid point-intercept vegetation survey – field data collection form
4. Aquatic plant bed (e.g., bulrush) field delineation – equipment checklist
5. Partial list of rare (SPC-special concern, THR-threatened, END-endangered) and unique plant species most likely to be found in lakes or along lakeshores
6. Near-shore vegetation survey – equipment checklist
7. Near-shore vegetation survey (shoreline) – field data collection form
8. Near-shore vegetation survey (in-lake) – field data collection form
9. Aquatic frog calling survey – field data collection form
10. Bird survey – field data collection form

Appendix 1. Grid point-intercept vegetation survey: required sample size

The number of sample points required to reliably estimate species frequencies is not dependent on lake size (Newman et al. 1998) and required sample size can be calculated using the formula:

$N = (t/D)^2 * (1-p)/p$, where:

- N= required sample size
- t = appropriate value from t distribution table (1.96 for 95% confidence interval)
- P = estimate of frequency of occurrence
- D = error as a fraction of p (i.e. 0.1 to estimate p within 10%)

Newman et al. (1998) recommended that for data collected using the Jesson-Lound (1962) method, 40 to 100 samples per lake were adequate and found that sample sizes greater than 100-200 did not yield much additional precision or accuracy for frequencies of "common" species. His analysis was based on data collected using a method in which sample area (and thus resulting frequency estimate) was greater than that used in the point-intercept method. Required sample size may need to be increased for point intercept surveys.

Nichols (1984) agreed that the most common species should be used for calculating the adequacy of the sample and added that it may be appropriate to accept a greater error (for example 15% error instead of 10%) in order to reduce sampling effort. For many Minnesota lakes where point intercept surveys have been conducted, the "common" or most abundant species occurred with frequencies between 15% and 40% (within the zone from shore to 20 feet) (Perleberg, unpublished data).

Binomial distribution occurrence	Required sample size (20% error)	Required sample size (15% error)	Required sample size (10% error)
0.90	11	20	44
0.80	25	45	100
0.70	43	76	171
0.60	67	119	267
0.50	100	178	400
0.40	150	267	600
0.30	233	415	933
0.20	400	712	1600
0.10	900	1602	3600

Newman et al. (1998) found that required sample size is independent of lake size but we consider lake size here because we are also interested in vegetation mapping. For mapping purposes, on most lakes, sample points will be placed 213 feet (65 meters) apart, which will result in approximately one sample point per littoral acre. The minimum distance between survey points is determined by the accuracy of the GPS (Global Position System); with current GPS technology, a minimum distance of 98 feet (30 meters) is recommended to avoid

Appendix 1. (continued) . Grid point-intercept vegetation survey: required sample size

overlap of sampling locations.

Littoral zone width will influence sample point spacing and on lakes with narrow littoral zones points will be spaced closer together. For example, Roosevelt Lake in Cass County has a 390-acre littoral zone that, in many areas, is less than 50 meters in width. If lake littoral area alone were used to determine sample number, most points would not occur within the vegetated zone. Therefore, sample points were spaced 40 meters apart on this lake.

Recommended sample size and grid spacing

Lake littoral zone area (acres)	Maximum distance between survey points		Sampling density	Example lakes
	feet	meters		
>2,500	656	200	1 point per 10 acres	Leech, Cass, Gull
1001-2500	492	150	1 point per 6 acres	Boy, Woman, Ten Mile
250-1000	213	65	1 point per acre	Washburn, Alexander
<250	98-197	30-60	1-5 points per acre	Thunder, Deep Portage

General plant abundance and distribution are also considered when determining sample spacing. While the physical littoral zone may extend to 15 feet and deeper, vegetation on many lakes may be restricted to shallower depths. In these situations, sample points should be concentrated within the actual vegetated zone.

Appendix 2. Grid point-intercept Vegetation Survey equipment checklist

Point Intercept Field Equipment Checklist

BOAT and accessories

	Motorized boat (or canoe)
	Gas
	Tool Kit
	Fire Extinguisher
	First Aid Kit
	Life Jackets
	Seat Cushion
	Trolling motor
	Push pole
	Anchor

SAMPLING EQUIPMENT

	Telescoping pole marked in feet to measure water depth and test substrate
	Double-headed, weighted rake attached to 30+ feet of rope
	Plastic hoop measuring
	1 meter square in area
	View tube
	Secchi disc

ELECTRONICS

	Depth finder
	GPS with survey points downloaded
	12 volt adapter for GPS
	field computer
	Camera
	Cell phone
	Batteries
	Waterproof case for electronics

PLANT SAMPLES

	Cooler
	Ice
	Ziploc bags
	Waterproof markers
	Plant field guides

PAPERWORK

	Clipboard
	Lake Contour Map
	Map of survey points
	Field data sheets
	Aerial photo of lake
	pencils

PERSONAL GEAR

	Polarized sunglasses
	Rain wear
	Chest or hip waders
	Wide-brimmed hat
	Suncreen
	Bug repellant
	Lunch, water
	Hand towels

Appendix 3. Grid point-intercept Vegetation Survey field data collection form.

__________ ________ **Lake(____________County)** DOW# ____-_______-_____ DATE:____________2007

SURVEYORS: ____ MNDNR Eco Vegetation Survey

		Site number →														
	CODE	**DEPTH (ft) →**														
NO SURVEY - (SH = on shore, D= too deep)																
	EMT	**No vegetation found**														
Utricularia vulgaris	**UV**	**Bladderwort**														
Najas flexilis	NF	Bushy pondweed*														
Ranunculus sp.	R	Buttercup														
Elodea canadensis	EC	**Canada waterweed**														
V. americana	VA	Celery														
Chara sp.	C	Chara														
P. richardsonii	POR	**Clasping leaf**														
C. demersum	CD	Coontail														
P. crispus	PC	Curly-leaf pondwd														
P. zosteriformis	PZ	**Flat-stem pondwd**														
P. illinoensis	PI	Illinois pondweed														
P. amplifolius	PA	Large-leaf pondwd														
M. beckii	MB	**Marigold**														
Potamogeton sp.	POSN	Narrowleaf pondwd														
M. sibiricum	MS	Northern milfoil														
P. robbinsii	PR	Robbin's pondweed														
S. pectinata	PP	**Sago pondweed**														
Zosterella dubia	HD	Star grass														
P. gramineus	PG	Variable pondweed														
P. praelongus	POP	White-stem pondwd														
P. natans	PN	Floating-leaf pondwd														
Nymphaea odorata	NO	**White waterlily**														
Nuphar variegata	NV	Yellow waterlily														
Brasenica schreberi	BRS	Watershield														
Sagittaria sp.	SAS	**Arrowhead**														
Scirpus sp.	SCS	Bulrush														
Phragmites australis	PHAU	Cane														
Typha sp.	TS	**Cattail**														
Eleocharis sp.	ELSP	Spikerush														
Zizania aquatica	ZIP	Wild Rice														
sediment (BO, RB, GR, SA, SI, MR, MU)																

pg ___ of ____

X = species present in 1m2 sample area / X with circle = matted plants / 0 = found in lake but not in survey point

Appendix. 4. Aquatic plant bed delineation equipment checklist

Field Equipment Checklist
Aquatic plant bed GPS delineation

BOAT and accessories

	Motorized boat (or canoe)
	Gas
	Tool Kit
	Fire Extinguisher
	First Aid Kit
	Life Jackets
	Seat Cushion
	Trolling motor
	Push pole
	Anchor

ELECTRONICS

	Depth finder
	GPS
	12 volt adapter for GPS
	field computer
	Camera
	Cell phone
	Batteries
	Waterproof case for electronics

PLANT SAMPLES

	Cooler
	Ice
	Ziploc bags
	Waterproof markers
	Plant field guides

PAPERWORK

	Clipboard
	Lake Contour Map
	draft map with photo-interpretation notes
	Aerial photo of lake
	pencils

PERSONAL GEAR

	Polarized sunglasses
	Rain wear
	Chest or hip waders
	Wide-brimmed hat
	Suncreen
	Bug repellant
	Lunch, water
	Hand towels

Appendix 5. Partial list of rare (SPC-special concern, THR-threatened, END-endangered; * = proposed) and unique plant species most likely to be found in lakes or along lakeshores.

Life Form	Scientific name	Common Name	C value		MN Rare Status
			WI[1]	MN [2]	
Shrub	*Andromeda glaucophylla*	Bog rosemary	10	9	none
	Cephalanthus occidentalis	Buttonbush	9	7	*SPC
	Chamaedaphne calyculata	Leatherleaf	9	8	none
	Decodon verticillatus	Waterwillow	7	8	THR *SPC
	Kalmia polifolia	Bog laurel	10	9	none
	Myrica gale	Sweet Gale	9	8	none
Wetland emergents	*Arethusa bulbosa*	Dragon's mouth	10	10	none
	Carex lasiocarpa	Narrow-leaved wooly sedge	9	7	none
	Carex oligosperma	Few-seeded sedge	10	8	none
	Carex rostrata	Beaked sedge	10	8	none
	Cypripedium arietinum	Ram's head lady's slipper	10	9	THR
	Cypripedium candidum	Small white lady's slipper	10	10	SPC
	Cypripedium parviflorum	Yellow lady's slipper	9	8	none
	Cypripedium reginae	Showy lady's slipper	9	8	none
	Drosera anglica	English sundew	10	10	SPC
	Drosera linearis	Slender-leaved sundew	10	10	SPC
	Eriophorum angustifolium	Narrow-leaved cottongrass	9	8	none
	Menyanthes trifoliata	Bog buckbean	10	9	none
	Sarracenia purpurea	Pitcher plant	10	9	none
	Scheuchzeria palustris	Arrowgrass	10	9	none
	Triglochin maritima	Greater arrowgrass	10	10	none
	Xyris montana	Yellow-eyed grass	10	10	SPC
Lakeshore emergents	*Cladium mariscoides*	Twig rush	10	10	SPC
	Dulichium arundinaceum	Three-way sedge	9	8	none
	Eleocharis flavescens var. olivacea	Olive-colored spike rush	8	9	THR /*END
	Eleocharis quinquiflora	Few-flowered spike rush	8	9	SPC
	Eleocharis robbinsii	Robbins' spike rush	10	10	*THR
	Fimbristylis autumnalis	Autumn fimbristylis	8	6	SPC
	Heteranthera limosella	Mud plantain	N/A	7	THR
	Lobelia dortmanna	Water lobelia	10	10	none
	Rhynchospora fusca	Sooty-colored beak rush	10	9	SPC
	Sagittaria brevirostra	Midwestern arrowhead	9	9	none
	Sagittaria cristata	Crested arrowhead	9	8	none
	Sagittaria graminea	Grass-leaved arrowhead	9	8	none
	Scirpus heterochaetus	Slender bulrush	10	8	none
	Scirpus torreyi	Torrey's bulrush	9	8	none
	Sparganium glomeratum	Clustered burreed	8	7	SPC

1 .Wisconsin Floristic quality assessment. Wisconsin State Herbarium. http://www.botany.wisc.edu/wisflora/FloristicR.asp

2 .Milburn, S.A., M. Bourdaghs, and J.J. Husveth. 2007. Floristic quality assessment for Minnesota wetlands. Minnesota Pollution Control Agency. St. Paul, MN.

Appendix 5. (Continued)
Partial list of rare (SPC-special concern, THR-threatened, END-endangered; * = proposed) and unique plant species most likely to be found in lakes or along lakeshores.

Life Form	**Scientific name**	**Common Name**	**C value**		**MN Rare Status**
			WI[1]	**MN [2]**	
Floating-leaved	*Caltha natans*	Floating-leaf marsh marigold	10	9	END
	Nuphar microphylla	Small yellow waterlily	9	9	none
	Nuphar X rubrodisca	Intermediate yellow waterlily	9	9	none
	Caltha natans	Floating-leaf marsh marigold	10	9	END
	Nuphar microphylla	Small yellow waterlily	9	9	none
	Nuphar X rubrodisca	Intermediate yellow waterlily	9	9	none
	Nymphaea leibergii	Very small white waterlily	N/A	10	THR
	Sparganium angustifolium	Narrow-leaved burreed	9	8	none
	Sparganium fluctuans	Floating-leaved burreed	10	8	none
	Sparganium natans	Least burreed	10	9	none

1 Wisconsin Floristic quality assessment. Wisconsin State Herbarium.
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Appendix 5. (Continued)
Partial list of rare (SPC-special concern, THR-threatened, END-endangered;
* = proposed) and unique plant species most likely to be found in lakes or along lakeshores.

Life Form	Scientific name	Common Name	C value		MN Rare Status
			WI[1]	MN [2]	
Submerged	*Callitriche hermaphroditica*	Northern water starwort	9	8	none
	Callitriche heterophylla	Large water starwort	9	8	SPC
	Ceratophyllum echinatum	Hornwort	10	10	none
	Crassula aquatica	Pygmy waterweed	N/A	5	THR /*END
	Elatine minima	Small waterwort	9	9	none
	Elatine triandra	Three-stamened waterwort	9	9	*THR
	Eriocaulon aquaticum	Pipewort	9	9	none
	Hippuris vulgaris	Marestail	10	9	none
	Littorella uniflora	American shore plantain	10	10	SPC
	Myriophyllum alterniflorum	Alternate-leaved water milfoil	10	10	none
	Myriophyllum tenellum	Leafless water milfoil	10	9	none
	Najas gracillima	Slender water naiad	7	10	SPC
	Najas guadalupensis	Southern naiad	N/A	8	*SPC
	Najas marina	Sea naiad	N/A	4	SPC
	Potamogeton alpinus	Alpine pondweed	9	9	none
	Potamogeton bicupulatus	Two-cupped pondweed	9	10	END
	Potamogeton confervoides	Algal-leaved pondweed	10	N/a	none
	Potamogeton diversifolius	Diverse-leaved pondweed	9	10	END
	Potamogeton hillii	Hill's pondweed	9	N/a	none
	Potamogeton oakesianus	Oakes' pondweed	10	10	*END
	Potamogeton obtusifolius	Blunt-leaved pondweed	9	8	none
	Potamogeton pulcher	Beautiful pondweed	10	N/a	*END
	Potamogeton vaseyi	Vasey's pondweed	10	10	SPC
	Ranunculus flammula	Creeping water buttercup	9	7	none
	Ranunculus gmelini	Yellow water crowfoot	10	6	*SPC
	Ruppia cirrhosa	Wigeon grass	8	6	SPC
	Scirpus subterminalis	Water bulrush	9	9	none
	Stuckenia vaginata	Large-sheathed pondweed	9	9	SPC /*END
	Subularia aquatica	Awlwort	10	10	THR
	Utricularia gemniscapa	Twin-scaped bladderwort	9	10	*END
	Utricularia gibba	Humped bladderwort	9	9	none
	Utricularia intermedia	Flat-leaved bladderwort	9	8	none
	Utricularia minor	Lesser bladderwort	10	8	none
	Utricularia purpurea	Purple-flowered bladderwort	9	10	SPC /* END
	Utricularia resupinata	Lavender-flowered bladderwort	9	10	SPC /* END

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2 Milburn, S.A., M. Bourdaghs, and J.J. Husveth. 2007. Floristic quality assessment for Minnesota wetlands. Minnesota Pollution Control Agency. St. Paul, MN.

Appendix 6. Near-shore Vegetation Survey equipment checklist

Near shore vegetation sampling - Equipment Checklist

(italics indicates optional gear)

BOAT and accessories

	Motorized boat (or canoe)
	Gas
	Tool Kit
	Fire Extinguisher
	First Aid Kit
	Seat Cushion
	Trolling motor
	Push pole
	Anchor
	Depth finder

FLOAT TUBES

	float tubes
	fins
	air pump
	ziploc bags in storage pocket

SAMPLING EQUIPMENT

	Circular plastic hoop (1.13 m diam)
	View tube or snorkel and mask
	Pole marked in 0.25 ft increments
	15 meter shore rope (knot at 1m, 4m, 7m, 10m, 13m)
	16 meter lakeward rope marked at 1m, 4m, 7m, 10m, 13m, 16m
	stakes for shoreland rope (2-3 per boat)
	weighted garden hook on 10 ft of light rope
	plastic dumbell buoys

ELECTRONICS

	GPS with shoreland survey plot uploaded
	12 volt adapter for GPS
	Spare Batteries for gps
	field computer and 12 volt adapter
	Camera
	Cell phone

PLANT SAMPLES

	Cooler
	Ice
	Ziploc bags (jumbo)
	Waterproof markers
	Plant field guides

PAPERWORK

	Clipboard
	Lake Contour Map
	Map of survey points
	Field data sheets
	Aerial photo of lake
	pencils

PERSONAL GEAR

	LIFE JACKETS
	CHEST WADERS
	Polarized sunglasses
	Rain wear
	Chest or hip waders
	Suncreen
	Bug repellant
	Lunch, water

Appendix 7. Near-shore Vegetation Survey (shoreline) field data collection form.

SHORELINE VEGETATION PLOT (1m by 15 m) **PG 1 of 2**

Lake ___________________________ Plot # _______ DATE ___________ 2007

photos taken ____________ Surveyors _____________________________

			plot	riparian zone
tree cover >25%	upland	Fire-Dependent Forest (Pines)		
		Mesic Hardwood Forest (Hardwoods)		
	wetland	Wet Forest (Cedar / Ash)		
		Forest Peatland (Spruce / Tamarack)		
tree cover <25%	wetland	Open Peatland (shrubs / sedges)		
		Alder Swamp		
		Wet Meadow (wide sedges)		
		Cattail Marsh		

GPS COORD

X Coord	
Y Coord	

	Common name	Scientific name	CC	inside plot	collected
Trees	Red Maple	Acer rubrum			
	Sugar Maple	Acer saccharum			
	Paper Birch	Betula papyrifera			
	Jack Pine	Pinus banksiana			
	Red Pine	Pinus resinosa			
	White Pine	Pinus strobus			
	Basswood	Tilia americana			
	Aspen	Populus sp.			
Shrubs	Alder	Alnus incana			
	Juneberry	Amelanchier sp.			
	Bog birch	Betula glandulifera			
	Red-osier dogwood	Cornus stolonifera			
	Dogwood	Cornus sp.			
	Hazelnut	Corylus sp.			
	Bush honeysuckle	Diervilla lonicera			
	Honeysuckle	Lonicera sp.			
	Pin cherry	Prunus pensylvanica			
	Black cherry	Prunus serotina			
	Choke cherry	Prunus virginiana			
	Raspberry	Rubus sp.			
	Gooseberry	Ribes sp.			
	Wild rose	Rosa sp.			
	Staghorn sumac	Rhus typhina			
	Smooth sumac	Rhus glabra			
	Sandbar willow	Salix cf. gracillima			
	Bebb's willow	Salix cf. bebbia			
	Steeple-bush	Spiraea sp.			
	Arrow-wood	Viburnum sp.			
Vines	Virginia creeper	Parthenocissus spp.			
	Poison ivy	Rhus toxicodendra			
	Wild grapes	Vitis			

	Common name	Scientific name	CC	inside plot	collected
Bog Shrubs	Bog Rosemary	Andromeda glaucophylla			
	Leather leaf	Chamaedaphne calyculata			
	Bog Laurel	Kalmia polifolia			
	Labrodor Tea	Ledum groenlandicum			
Sedges and Rushes	fine-leaved sedges	Carex lasiocarpa			
		Carex oligosperma			
	wide-leaved sedges	Carex aquatilis			
		Carex hystricina			
		Carex lacustris			
		Carex stricta			
	Nut grass	Cyperus sp.			
	Three-way sedge	Dulichium arundinaceum			
	Spike-rush	Eleocharis sp.			
	Cotton-grass	Eriophorum sp.			
	Rush	Juncus sp.			
	Bulrush	Scirpus sp.			
Grasses	Canada bluejoint	Calamagrostis canadensis			
	Wild rye	Elymus sp.			
	Rice cut grass	Leersia oryzopsis			
	Manna grass	Glyceria canadensis			
	Reed canary grass	Phalaris arundinaceae			
	Giant cane	Phragmites australis			
	bluegrass	Poa sp.			
	TURF GRASS				

Appendix 8. Near-shore Vegetation Survey (In-lake) field data collection form.

NEARSHORE INLAKE VEGETATION PLOTS LAKE: ___________________________ DOW: ________________

Surveyors: _________________________________ DATE ________________2007

MACROPLOT # ________________________

UTM Coords: X: ________________________ Y: ___________________________

woody debri - 0 = none
1 = small sticks
2 = branches
3 = trees

Quadrat number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Water DEPTH (cm)																														
sediment (BO, RB, GR, SA, SI, MR,																														
woody debri																														
EMT **No vegetation**																														
PLANT TAXA																														

Appendix 9. Aquatic Frog Calling Survey field data collection form.

Frog & Toad Calling Survey

Run survey after dark until 1:00 a.m., when wind velocity is less than 12 mph. Listen approximately 3-5 minutes at each stop and record the number of mink and green frogs and an *Index Value* for all species heard.

Lake:_________ ____________________Date:______________Observers:_________________________Start/End Time:_______________________

Attribute:	**Survey Point Number**																								
Water Temp																									
Air Temp																									
Wind Code																									
Sky Code																									
Moon Visible (Y/N)																									
Distracting Noise (Y/N)																									
√-only from adjacent pts																									
Mink Frogs (count)																									
Green Frogs (count)																									
Index Values:																									
Wood Frog																									
Western Chorus Frog																									
Spring Peeper																									
Northern Leopard Frog																									
Pickerel Frog																									
American Toad																									
Gray Tree frog																									
CopeÕs Gray Treefrog																									
Northern Cricket Frog																									
Mink Frog																									
Green Frog																									
Bull Frog																									
Canadian Toad																									
Great Plains Toad																									

Appendix 9. Continued. Aquatic Frog Calling Survey field data collection form.

Index Values:
1=individuals can be counted (silence between calls)
2=calls of individuals can be distinguished, but some overlap of calls
3=full chorus (calls constant, continuous, and overlapping).

Wind Codes:
0 - Calm (less than 1 mph; smoke rises vertically)
1 - Light Air (1-3 mph; smoke drifts in direction of wind)
2 - Light Breeze (4-7 mph; leaves rustle)
3 - Gentle Breeze (8-12 mph; leaves and small twigs in constant motion; extends light flag)
4 - Moderate Breeze (13-18 mph; moves thin branches) ---- Do not conduct survey, unless in Great Plains!
5 - Fresh Breeze (>18 mph; small trees begin to sway) ---- Do not conduct any survey!

Sky Codes:
0 - Clear or only a few clouds
1 - Partly cloudy or variable
2 - Broken clouds or overcast
3 - Fog
4 - Drizzle or light rain (not affecting hearing)
5 - Snow
6 - Showers (affecting hearing ability) ---- Do not conduct survey!

Count Codes:
Any number <10
10-20 (A)
20-100 (B)
100+ (C)

Frogs and Toads of Minnesota

Wood Frog	Duck-like call; hoarse clacking sound, quack of duck
Western Chorus Frog	Clicking sound; thumb on comb; ŌprpeepÕ
Spring Peeper	High pitch peep or ping; high, piping whistle
Northern Leopard Frog	Low snore with grunts and squeaks; long snore with clucking grunts
Pickerel Frog	Low pitch snore; steady, low pitched snore, 1-2 sec.
American Toad	High trill; long, musical trill
Gray Treefrog	Musical trill
CopeÕs Gray Treefrog	Fast metallic trill
Northern Cricket Frog	Glick, glick; similar to ball bearings; rattle or metal clicker
Mink Frog	Knock, knock, knock; blurred and deep, Ōcut-cut-cutÉ; rapid hammering
Green Frogs	Plucked banjo string; ŌcÕtungÕ
Bull Frog	Deep baritone; Ōjug-a-rumÕ; humming bass notes
Canadian Toad	Similar to American Toad except trill length shorter (2-9 sec)
Great Plains Toad	Harsh pulsating mechanical trill

Appendix 10. Bird Survey field data collection form.

Morning survey: Sunrise-10 a.m. (weather permi **Evening survey:**
Survey points: 5-10 minutes per point
Birds: all heard or seen at point near shoreline (ex: flyovers, loons only when nesting)

Name of lake: ___________________________ **Township:** ______________________

Date: ___________________________ **Start time:** _________ **End time:** __________

Observers: _________________________

Survey Pt. #																		
Air temp																		
Wind code (0-5)																		
Sky code (0-6)																		
Distract. noise (Y/N)																		
Species																		
Mallard																		
Common Goldeneye																		
Common Merganser																		
Hooded Merganser																		
Common Loon																		
Red-necked Grebe																		
American Bittern																		
Least Bittern																		
Great Blue Heron																		
Green Heron																		
Osprey																		
Bald Eagle																		
Yellow Rail																		
Virginia Rail																		
Sora																		
Spotted Sandpiper																		
Ring-billed Gull																		
Caspian Tern																		
Common Tern																		
Forster's Tern																		
Black Tern																		
Common Nighthawk																		
Red-bellied Woodpkr																		
Downy Woodpecker																		
Hairy Woodpecker																		
Northern Flicker																		
Pileated Woodpecker																		
Eastern Phoebe																		
Great Crested Flycatchr																		
Eastern Kingbird																		
Red-eyed Vireo																		
Blue Jay																		
American Crow																		
Tree Swallow																		
Barn Swallow																		
Black-capped Chickad.																		
Red-breasted Nuthch																		
Survey Pt. #																		
White-breasted Nuthch																		
House Wren																		
Sedge Wren																		
Marsh Wren																		
American Robin																		
Nashville Warbler																		
Yellow Warbler																		
Chestnut-sided Wblr.																		
Blk-throated grn Wblr.																		
Blk-&-whi Warbler																		
American Redstart																		
Ovenbird																		
Common Yellowthroat																		
Scarlet Tanager																		
Chipping Sparrow																		
Song Sparrow																		
Swamp Sparrow																		
Rose-breasted Grosbk																		
Red-winged blackbird																		
Common Grackle																		
Brown-headed Cowbird																		
Baltimore Oriole																		
Pine Siskin																		
American Goldfinch																		

Wind Code:
0 - Calm (less than 1 mph; smoke rises vertically)
1 - Light Air (1-3 mph; smoke drifts in direction of wind)
2 - Light Breeze (4-7 mph; leaves rustle)
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1 - Partly cloudy or var
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4 - Drizzle or light rain (not affecting hearing)
5 - Snow
6 - Showers (affecting hearing ability)

Notes____