2002 SUMMARY REPORT
of
DIAMOND LAKE

Lake County, Illinois

Prepared by the

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EXECUTIVE SUMMARY

Diamond Lake is a 154-acre glacial lake in the Village of Mundelein. The lake receives drainage mostly from residential and urban land uses, but also from a small portion of agricultural land. The lake is popular with the area residents, as the Mundelein Park District offers access to the general public through their beach and a separate boat launch. In addition, two private homeowner's associations offer a total of two boat launches and three beaches for their association members. The lake drains to Indian Creek, which eventually flows to the Des Plaines River.

Since 1997, a decline in water quality has been noted, with a decrease in water clarity, and an increase in total phosphorus. Although total phosphorus increased, planktonic algal blooms were not determined to be a problem. However, the water clarity is fair to poor. The poor clarity is due to the turbidity in the water caused by suspended sediment rather than algae. The sediment is swept into the water column from the bottom by wind action, powerboats, and carp activities. Diamond Lake thermally stratifies during the summer, but approximately 69% of the water volume has an adequate supply of dissolved oxygen for aquatic life.

The Park District and some residents have expressed concerns about the aquatic plant populations in Diamond Lake that hinder recreational activities. The Mundelein Park District hires an aquatic herbicide applicator to annually treat the water skiing lane and the area near the beach for aquatic plants. However, aquatic plants covered only about 30% of the lake bottom during 2002, with the dominant species being Eurasian water milfoil, coontail and *Chara*. This amount of plant coverage does not seem to hinder recreation on Diamond Lake, as the boating area for skiing, tubing and jetskiing did not have plants that reached the surface. Although some localized areas near shore are thick with plants and can be difficult for boat passage, they are not the main ski areas and are shallow. In fact, further reduction of the amount of plant coverage in the lake could result in increased turbidity and algal growth, and reduce the available habitat for the fishery. To ease boating traffic through these plant infested areas, spot treatments could be done to create a boat/fish cruising lane through to the open water.

Ninety seven percent of the shoreline surrounding Diamond Lake is developed, with about 70% armored by either seawall or riprap. Therefore, very little of the total shoreline is experiencing erosion at this time. Of the shoreline that is eroding, 66% is turfgrass that has been mowed to the water's edge. Little of the shoreline harbors invasive shoreline plants.

The wildlife habitat offered around Diamond Lake is limited due to the suburban surroundings. Due to the highly developed shoreline, poor wildlife habitat exists. As a result, the wildlife species noted by staff while visiting Diamond Lake are those tolerant of suburban settings. IDNR fish surveys have noted a decline in the fishery since 1989. Concerns from IDNR staff written in the 2000 survey included the rapid increase in the yellow bass population, poor bluegill and largemouth bass populations, and limited aquatic plants for habitat.

LAKE IDENTIFICATION AND LOCATION

Diamond Lake is a 154-acre glacial lake in south central Lake County (T44N, R10E S36, R11E, S31), with a maximum depth of 25 feet. The lake has an average depth of 9.2 feet, with a volume of 1423 acre-feet[1], or 464 million gallons (see Appendix D). The length of shoreline is 5.9 miles. The Village of Mundelein borders the east and north shorelines. The remaining shoreline is unincorporated. The shoreline is primarily residential, and is 97% developed. Diamond Lake receives flow from two small tributaries along the west shoreline that drain residential and agricultural areas. The residential areas surrounding the lake and urban/commercial areas on the east side also contribute stormwater to the lake system. Diamond Lake was dammed in the 1950's with the installation of a spillway on the southeast shore. Eventually, the water flowing from Diamond Lake joins Indian Creek as it travels to the Des Plaines River.

BRIEF HISTORY OF DIAMOND LAKE

By the late 1960's the Mundelein Park District acquired a majority of the lake bottom. A few parcels on the far south end of the lake are still owned privately. Two homeowner's associations have private recreational areas on the lake. In the 1950's, aquatic plants were in nuisance proportions and the lake was dominated by small bluegill, pumpkinseed and yellow perch. Population surveys by the Illinois Department of Natural Resources[2] (IDNR) were conducted in 1989, 1997 and 2000. A decline in the fishery was noted in 1997, with dominant species being carp and yellow bass. The aquatic plants at that time were sparse. During the 2000 survey, IDNR staff noted a decrease in the number of fish collected but an increase in species diversity. During May through September of 1997, our Unit collected water quality samples from Diamond Lake. Water clarity was also measured during 2002 and in 1996 by a volunteer participating in the Illinois Environmental Protection Agency's (IEPA) Volunteer Lake Monitoring Program (VLMP). Other water quality data was gathered on September 1, 1992 for the IEPA's Lake Water Quality Assessment Program. These data will be discussed within the water quality section of this report. Our Unit also created a bathymetric map of the lake in 1997 (Appendix D).

In May of 1996 and February of 1997, the Lake County Public Works Department received complaints about sewage overflows from lift stations adjacent to the southern shore of Diamond Lake. In both instances, heavy rains caused high water flows to overload the lift stations. A rough estimate of 200,000 to 250,000 gallons bypassed the lift stations. Since these events, Lake County Public Works has upgraded parts of the systems in this area, and made several repairs. Their staff continues to monitor this area for problems and has plans to upgrade other portions of the system as needed.

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[1] One acre-foot is described as the amount of water that covers one acre, one foot deep.
[2] This agency was named the Illinois Department of Conservation at that time.

SUMMARY OF CURRENT AND HISTORICAL LAKE USES

Diamond Lake is used for boating, swimming, fishing, and aesthetics. The Mundelein Park District operates a licensed beach on the southeast shore that also offers picnicking, a playground and concessions. We collect water samples from this beach (and three other association beaches) for bacteria testing on a bimonthly basis from May through Labor Day. The Park District also owns Lewandowski Park on the northwest side of the lake that has a picnic shelter, a playground and a small parking lot. The park does not have a pier or launch for access to the lake from this point, but the Park District owns a boat launch on the east shore a few lots north of their beach. Motorized watercraft can be used from dawn until 10:00 p.m. The general public can purchase a yearly permit to use the launch. The Park District hires an aquatic herbicide applicator to treat the ski lane and near their beach (approximately 6 – 12 acres) annually with Reward®, an aquatic herbicide, to control Eurasian water milfoil. West Shore Park Homeowner's Association owns two parcels for their members' use that both stretch along the west shore in front of several homes. Both parcels have a small beach and a pier. The north parcel, Lake Terrace Beach, also has a swimming platform, and the south parcel, North Shore Park, includes a boat launch. The Oak Terrace Homeowner's Association has a park open to their members with a small beach and a boat launch at the southeast corner of the lake.

LIMNOLOGICAL DATA – WATER QUALITY

Water samples were collected each month, from May through September 2002, at the deepest location (see Figure 1). Samples were collected at 3 feet to represent water from the oxygenated zone, (epilimnion) and 20-21 feet to represent water from the anoxic zone, (hypolimnion). All samples were analyzed for a variety of parameters. The 2002 water quality data can be found in Table 1, Appendix A. The document, "Interpreting Your Water Quality Data" explains these parameters in detail. See Appendix B for water quality sampling and laboratory methods. Water clarity was also measured during 2002 and in 1996 by a volunteer participating in the Illinois Environmental Protection Agency's Volunteer Lake Monitoring Program (VLMP).

Thermal stratification occurs when a lake divides into an upper, warm water layer (epilimnion) and a lower, cold water layer (hypolimnion). When stratified, the epilimnetic and hypolimnetic waters do not mix, and the hypolimnion typically becomes anoxic (dissolved oxygen = 0 mg/l) by mid-summer in nutrient-enriched lakes. This is typical of deep lakes like Diamond Lake. This phenomenon is a natural occurrence in deep lakes and is not necessarily a bad thing if enough of the lake volume remains well oxygenated. A 5.0 mg/L concentration of dissolved oxygen (DO) is considered an amount adequate to support aquatic life, since some aquatic life forms suffer oxygen stress below this. Concentrations of DO of at least 5.0 mg/L in Diamond Lake were recorded throughout the water column in May in 2002. As the season progressed and the lake stratified, DO was less than 5.0 mg/L below at 12 feet deep in June,

10 feet deep in early and late August, and at 18 feet in September. The volume with adequate oxygen present in August represents nearly 69% of the total volume of water within the lake. Therefore, the amount of DO was sufficient for aquatic life in the majority of the lake volume during the 2002 sampling season. In May of 1997, DO was greater than 5.0 mg/L from the surface to the bottom. The depth at which DO was less than 5.0 mg/L was recorded at 14 feet deep in June and September, at 12 feet in July, and 16 feet in August. The lake had the least amount of DO in July, but still had nearly 77% of its total volume with DO concentrations of at least 5.0 mg/L.

When stratification occurred in Diamond Lake, oxygen was depleted in the hypolimnion, triggering chemical reactions at the sediment surface. These reactions, which commonly occur in most stratified lakes, result in the release of nutrients such as phosphorus and nitrogen from the sediment interface into the water column, known as internal loading. Typically, the hypolimnion is thermally isolated from the epilimnion during the summer, and nutrients build up in the bottom waters, reaching the sunlit surface waters of the epilimnion during fall turnover. Nutrients in high levels typically cause nuisance algal blooms that cloud the water, reducing the water clarity. Water clarity is usually the first thing people notice about a lake, and typifies the overall lake quality. The Illinois Department of Public Health suggests that a lake has clarity readings of at least 4 feet deep for swimming safety in order to see submerged objects. The Lake County median[3] clarity for 103 lakes throughout Lake County is 3.81 feet deep. The readings in Diamond Lake during 1997 averaged 5.1 feet deep. Between 1997 and 2002, the lake experienced a 48% decrease in water clarity, with a seasonal average of 3.43 feet deep. This decrease in water clarity can be explained by the 44% increase in total suspended solids (TSS) since 1997. TSS are composed of nonvolatile suspended solids (NVSS) such as non-organic materials such as clay or sediment particles, and volatile suspended solids (VSS) such as algae and other organic matter. In Diamond Lake, the calculated NVSS concentrations averaged 4.5 mg/L during 2002, which constitutes 76% of the TSS. Therefore, sediment is the major component that caused the low water clarity. The sediment may be disturbed from the bottom from motorized boating, wind action and carp activity. The clarity in Diamond Lake was also measured over the summers of 1996 and 2002 through the Illinois Environmental Protection Agency's Volunteer Lake Monitoring Program (VLMP). These readings were similar to the 1997 and 2002 LCHD readings, respectively.

Although planktonic algae was not a major reason for the low clarity readings during 2002, some algal growth was evident by the light green color noted in the water over the season. Total phosphorus (TP) is a key ingredient for algal growth, and in lakes across Lake County, the median TP concentration for epilimnetic samples is 0.056 mg/L. During 1997, Diamond Lake had an average TP concentration of 0.023 mg/L in the epilimnion. By 2002, the epilimnion had experienced a TP increase of nearly 61%, to 0.037 mg/L. Although lower than the Lake County median, these concentrations of

[3] This is the median value, or the point at which half of the lake samples have clarity readings less than this value, and the other half have greater values. Median and average values were calculated using results of lakes sampled by the LCHD from 1998 through 2002.

phosphorus in Diamond Lake supported algal growth in both years. The sample collected from the epilimnion in September of 1993 for the IEPA's Lake Water Quality Assessment Program was also analyzed for TP. This concentration was 0.022 mg/L, nearly matching the September, 1997 LCHD concentration of 0.018 mg/L. During 2002, TP concentrations in the hypolimnion had a seasonal average of 0.278 mg/L. This is more than 63% higher than the Lake County median for hypolimnetic waters (0.17 mg/L). The increase noted in epilimnetic TP concentrations since 1997 is a cause for concern. Sources of phosphorus to Diamond Lake include its watershed and internal loading from the sediment.

Aside from TP, the other nutrient critical for algae growth is nitrogen, which also increases in the hypolimnion over the summer in thermally stratified lakes. Both total Kjeldahl nitrogen (TKN), a measure of organic nitrogen, and ammonia nitrogen concentrations increased in the hypolimnion in Diamond Lake during 1997 and 2002, except for the month of September. In September, ammonia and TKN decreased in the hypolimnion as the lake began to destratify for fall turnover, and the hypolimnetic nitrogen was then distributed throughout the water column. During 1997, the average TKN concentration in the hypolimnion was 2.05 mg/L, which is close to the Lake County hypolimnetic median of 2.15 mg/L. This average increased slightly in 2002, when the average was 2.21 mg/L. Ammonia nitrogen (NH_3-N) is a nitrogen form readily available for use for algal growth. Ammonia nitrogen concentrations in Diamond Lake exhibited a similar seasonal pattern as the TKN concentrations in both years and were also close to the Lake County hypolimnetic median of 1.25 mg/L. In the epilimnion, ammonia is used for algal growth as quickly as it becomes available. Ammonia is converted to other nitrogen forms in the presence of dissolved oxygen, which was abundant in the epilimnion. For these reasons, the only epilimnetic sample in Diamond Lake with a detectable NH_3-N concentration during 2002 was in September, at 0.16 mg/L. In 1997, May was the only month in which NH_3-N was detected in the epilimnion, at 0.21 mg/L.

The ratio of total nitrogen[4] (TN) to total phosphorus (TP) in a lake indicates if the lake is in shorter supply of nitrogen or phosphorus. Lakes with TN:TP ratios of more than 15:1 are usually limited by phosphorus. Those with ratios less than 10:1 are usually limited by nitrogen. Most lakes throughout Lake County are phosphorus limited. In 1997, the TN:TP ratio of Diamond Lake was 41:1, which means it is limited by phosphorus. The TN:TP ratio during 2002 was 32:1, indicating an increase in TP since 1997.

TP also plays a role in determining the trophic state index (TSI), which classifies lakes according to the overall level of nutrient enrichment. Using the total phosphorus concentration, the TSI can be calculated. The TSI falls within the range of one of four categories: hypereutrophic, eutrophic, mesotrophic and oligotrophic. Hypereutrophic lakes are those that have excessive nutrients, with nuisance algae growth reminiscent of "pea soup" and have a score greater than 70. Mesotrophic and oligotrophic lakes are those with low and poor nutrient levels, respectively. These are very clear lakes, with little or no plant and/or algae growth. Most lakes in Lake County are classified as eutrophic or nutrient rich, and are productive lakes in terms of aquatic plants and/or algae

[4] Total nitrogen consists of the organic forms of nitrogen plus nitrate nitrogen.

and fish. The trophic state of Diamond Lake in terms of its phosphorus concentration during 1997 was borderline mesotrophic with a score of 49. Lakes with a score of 50 or greater are eutrophic. By 2002, the increase in TP had changed the TSI to 56, and moved from mesotrophic to eutrophic. In 2002, Diamond Lake ranked #37 out of 103 Lake County lakes based on average total phosphorus concentrations (See Table 2 in Appendix A). Sources of phosphorus to Diamond Lake include its watershed and internal loading from the sediment.

The IEPA has assessment indices to classify Illinois lakes for their ability to support aquatic life, swimming, or recreational uses. The guidelines consider several aspects, such as water clarity, phosphorus concentrations (for the trophic state index) and aquatic plant coverage. Diamond Lake fully supports aquatic life according to these guidelines. However, the lake is slightly impaired for swimming uses because of the phosphorus concentrations. The lake was not considered impaired for swimming by high bacterial counts, however. Only a single beach closing occurred on Diamond Lake during 2002, which was at the Oak Terrace beach. The bacteria count dropped to very low numbers by the next day, and the beach was reopened. Although plants are not growing to the surface in the main boating area, recreational uses are considered impaired because of the amount of plant growth (estimated at 30% of the lake bottom). The amount of plant growth is considered a minimal impairment for aquatic life. The overall use support category for Diamond Lake is that of partial support.

Conductivity is a measurement of water's ability to conduct electricity via total dissolved solids (TDS) that are minerals and salts in the water column. Lakes with residential and/or urban land uses often have higher conductivity readings and higher total dissolved solids concentrations than lakes that are not surrounded by development because of the use of road salts. Stormwater runoff from impervious surfaces such as asphalt and concrete can deliver high concentrations of these salts to nearby lakes and ponds. The average conductivity reading in the epilimnion is 0.7570 milliSiemens/cm for Lake County lakes. During 1997, the conductivity readings in Diamond Lake were high, averaging 0.9072 milliSiemens/cm in the epilimnion. In the 2002 season, the conductivity readings were less, but were still higher than the Lake County average, with a seasonal average of 0.8374 milliSiemens/cm in the epilimnion. During both years, the conductivity readings decreased each month, which is typical of lakes that receive road salts through stormwater runoff. TDS concentrations in Diamond Lake were higher than the Lake County average during 1997 and 2002, and mimicked the pattern of the conductivity readings in those years. TDS samples collected during 2002 in the epilimnion averaged 458 mg/L, and decreased throughout the season. Like the conductivity readings in 1997, the TDS concentrations in 1997 were higher than those measured in 2002, averaging 497 mg/L.

Since most road salt used for de-icing is sodium chloride, calcium chloride, potassium chloride, magnesium chloride or ferrocyanide salts, the concentration of chlorides in each water sample based on conductivity readings can be calculated. The 2002 calculated seasonal average for chloride in Diamond Lake is 132 mg/L in the epilimnion. The 1997 seasonal average is calculated at 157 mg/L. The Illinois Environmental Protection

Agency (IEPA) standard for chloride is 500 mg/L. Once values exceed this standard the water body is deemed to be impaired, thus impacting aquatic life. However, in a study by Environment Canada (equivalent to our USEPA), it was estimated that 5% of aquatic species such as fish, zooplankton and benthic invertebrates would be affected at chloride concentrations of about 210 mg/l. Additionally, shifts in algae populations in lakes were associated with chloride concentrations as low as 12 mg/l.

During 2002, LCHD staff measured water elevation of the lake each month. Very little change occurred between measurements, with the largest drop in elevation of only 2.4 inches occurring between early and late August. Over the season, the change between elevation readings each month ranged from 0.5 inches to 2.4 inches. A rain gage operated by the Lake County Stormwater Management Commission near Diamond Lake recorded daily rainfall throughout the season. The largest rainfall recorded before an LCHD sampling date was 3.33 inches, but this fell on August 22, five days before the August 27 sampling date. One interesting note was that the water level on August 27 was still 2.4 inches lower than the August 1 measurement, even with the heavy rains on August 22. This was due to drought conditions earlier in the season.

LIMNOLOGICAL DATA – AQUATIC PLANT ASSESSMENT

Staff randomly sampled locations in Diamond Lake each month for aquatic plants, and identified eight species. Staff also identified one macroalgae, (*Chara*) and recorded shoreline plants. Table 3 lists the plants that were identified by their common and scientific names.

Table 4 in Appendix A lists the aquatic plant species and the frequency that they were found. The aquatic plant found most frequently throughout the season was Eurasian water milfoil, which was identified in 77% of all samples. Coontail was found in 58% of all samples. Chara was found in 22% of all samples. Depending on their life cycles, some plants were more prevalent in some months than others. For example, of the samples taken in May, Eurasian water milfoil was found in 74%, *Chara* in 48%, and coontail in 33% of the samples. However, the number of samples with *Chara* declined each month through September. The number of samples with coontail increased after the month of May. Coontail declined slightly in September, when 50% of the plant samples contained coontail. In early August, coontail was found in slightly more samples than Eurasian water milfoil. Eurasian water milfoil was found less often between May and early August, but was still the dominant plant throughout the season.

Aquatic plants will not photosynthesize in water depths with less than 1% of the available sunlight. Water clarity and depth are the major limiting factors in determining the maximum depth at which aquatic plants will grow in a lake. During May 2002, the 1% light level reached 10 feet deep. Coontail, a plant species tolerant of low light conditions, was growing at this depth in May, which was the deepest location at which any plants were found over the season. In June, the 1% light level reached down to 12 feet, although no plants were recorded at this depth. If plants were allowed to cover the bottom from the shoreline depths out to the 10-foot contour, Diamond Lake would have about 62% of the lake bottom covered with plants. However, staff noted some shallow areas, especially along the east shore, devoid of plant growth that had very hard or sandy substrates. Using ArcView, a geographic information software program, an estimation of the plant coverage for Diamond Lake in 2002 is 30% of the lake bottom. To maintain a healthy fishery, the Illinois Department of Natural Resources suggests plant coverage of 20% to 40% across the lake bottom.

The Mundelein Park District contracts with an aquatic herbicide applicator to control plants within the ski lane and an area near the Park District beach. In 2002, Diamond Lake was treated with 12.5 gallons of Reward® in late May, as well as approximately 20 pounds of copper sulfate, an algicide. Reward® is a non-selective contact herbicide, meaning it kills any plants that come in contact with it. Because the application rate of Reward® is 1-2 gallons per acre, the amount used in 2002 treated 6 – 12 acres. In 2001, 23 gallons of Reward® were used, and in 2000, 15 gallons of Reward® were applied. Although the ski lane and the area near the beach were not harboring dense plant beds after treatment, aquatic plants were thick in some localized areas of the lake during 2002, especially in the southwest and northeast corners of the lake. Spot treatments could be done in the southwest corner to create a boat or fish cruising lane. The plant bed of white water lilies in the northeast corner is close to only three houses. During 2002, access to the main part of the lake from these houses was not a problem. This plant bed should be left intact to provide for wildlife habitat. If this lily bed should expand in the future and begin to hinder boat traffic from these houses, a spot treatment could be done here also. Estimations of plant coverage before and after any aquatic herbicide treatment should be done annually and should be kept with the records of herbicide amounts that were used that year. Estimations can be done by using GPS (global positioning system) to locate the plant beds on a map of the lake. These maps would be helpful to refer to when planning for aquatic plant treatments in future years. This way, any changes in plant coverage can be tracked and the amount of herbicide can be adjusted if necessary.

Floristic quality index (FQI) is a measurement designed to evaluate the closeness of the flora (plants species) of an area to that with undisturbed conditions. It can be used to: 1) identify natural areas, 2) compare the quality of different sites or different locations within a single site, 3) monitor long term floristic trends, and 4) monitor habitat restoration efforts. Each floating and submersed aquatic plant in a lake is assigned a number between 1 and 10 (10 indicating the plant species most sensitive to disturbance). These numbers are then used to calculate the FQI. A high FQI number indicates that there are a large number of sensitive, high quality plant species present in the lake, and better plant diversity. Nonnative species are included in the FQI calculations for Lake County lakes. The FQI scores of 86 lakes measured from 2000 through 2002 range from 0 to 37.2, with an average of 14.2. Diamond Lake has a floristic quality of 16.3, indicating a slightly higher than average aquatic plant diversity.

Table 3. Aquatic and Shoreline Plants in Diamond Lake, May – September, 2002	
Aquatic Plants	
Coontail	*Ceratophyllum demersum*
Chara	*Chara*
Eurasian Water Milfoil	*Myriophyllum spicatum*
Slender Naiad	*Najas flexilis*
Spatterdock	*Nuphar variegata*
White Water Lily	*Nymphaea tuberosa*
Sago Pondweed	*Stuckinia pectinatus*
Eelgrass	*Vallisneria americana*
Water Stargrass	*Zosterella dubia*
Shoreline Plants	
Cattail	*Typha sp.*
Purple loosestrife	*Lythrum salicaria*
Buckthorn	*Rhamnus sp.*

LIMNOLOGICAL DATA - SHORELINE ASSESSMENT

In August 2002, LCHD staff assessed the shoreline of Diamond Lake. See Appendix B for a discussion of the methods used. Approximately 97 % (15,907 feet) of the shoreline is classified as developed. Figure 2 shows the three most common shoreline types around Diamond Lake: seawall (59% or 9,447 feet of the total shoreline), lawn (16% or 2,530 feet of the total shoreline) and riprap (13% or 2,029 feet of the total shoreline). The seawall and riprap represent a total of 72% (11,477 feet) of shoreline armored against erosion from wind and motorboat induced wave action. Because of this, only about 13% of the shoreline is eroding (Figure 3). About 3% (476 feet) of the shoreline is moderately eroding, and about 10 % (1,688 feet) is slightly eroding. None of the shoreline is severely eroding. Sixty-six percent of the eroding shoreline is manicured lawn mowed to the water's edge. Because turfgrass has a shallow root system of about 2-3 inches, it does not stabilize the shoreline against erosion. Native deep-rooted plants can stabilize the shoreline better (in addition to adding good wildlife habitat), but on a lakeshore continually battered by wind and motorboat waves, it may be difficult for native vegetation to become established and thrive. One resident on Diamond Lake successfully met this challenge by planting a variety of native vegetation behind a wood seawall, ensuring maximum protection against wave erosion, yet simultaneously offering good wildlife habitat. If people are concerned about being unable to approach the lake on their property after installing a buffer strip, a narrow path mowed to the shoreline will allow access and not interrupt the integrity of the buffer strip.

Staff also noted some areas with invasive, aggressive shoreline plants. Only about 13% (2,057 feet) of the total shoreline harbored these plant species (Figure 4). Purple loosestrife (*Lythrum salicaria*) and buckthorn (*Rhamnus sp.*) were noted. Although this is a small percentage, measures should be taken to remove these plants as they are aggressive, and can crowd out native, beneficial plants such as those used in buffer strips.

LIMNOLOGICAL DATA – WILDLIFE ASSESSMENT

Table 5 lists the wildlife species staff noted around Diamond Lake. Because the lake is in the middle of a residential setting with the majority of the shoreline as seawall, lawn or riprap, habitat for wildlife is limited. Enhancing habitat for terrestrial wildlife such as birds and small mammals can be accomplished through the addition of shoreline buffer zones, which are recommended as one aspect of shoreline protection. Most of the birds that were seen were those tolerant of residential settings. Staff did identify an osprey, which is an Illinois endangered species, flying over Diamond Lake. The sighting occurred in late September, and was an individual that was most likely migrating through the area.

Table 5. Wildlife species observed on Diamond Lake May – September, 2002

<u>*Birds*</u>	
*Osprey	*Pandion haliaetus*
Mute Swan	*Cygnus olor*
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhnchos*
Ring-billed Gull	*Larus delawarensis*
Caspian Tern	*Sterna caspia*
Great Blue Heron	*Ardea herodias*
Mourning Dove	*Zenaida macroura*
Red-bellied Woodpecker	*Melanerpes carolinus*
Purple Martin	*Progne subis*
Cliff Swallow	*Petrochelidon pyrrhonota*
Barn Swallow	*Hirundo rustica*
Tree Swallow	*Iridoprocne bicolor*
Bank Swallow	*Riparia riparia*
Chimney Swift	*Chaetura pelagica*
American Crow	*Corvus brachyrhynchos*
Blue Jay	*Cyanocitta cristata*
House Wren	*Troglodytes aedon*
American Robin	*Turdus migratorius*
House Sparrow	*Passer domesticus*
American Goldfinch	*Carduelis tristis*
Indigo Bunting	*Passerina cyanea*
Chipping Sparrow	*Spizella passerina*

* Endangered in Illinois

In May 2000, the IDNR conducted a fisheries survey throughout Diamond Lake. Twelve species of fish were identified, with a total of 225 fish collected. Yellow bass and yellow perch dominated the fishery. A decline in the bluegill, carp and bullhead populations were noted. The 1997 fisheries survey revealed 9 species, with a collection of 283 fish. It was noted in both surveys that yellow bass dominated the fishery, and bluegill had declined. The largemouth bass fishery was poor, even with stocking a total of 11,920 bass from 1994 through 1996. The poor bluegill and largemouth bass fisheries were attributed to the rapid population increase of yellow bass since 1989. Another concern was that IDNR staff noted very little plant growth during their 2000 fisheries survey. This survey was done in mid-May, which means some plants were still in early growth stages, but other plants should have been seen in larger populations. However, during 2002, as stated within the aquatic plant section above, Diamond Lake had plant coverage of about 30%, which is within the target range that is sufficient habitat for the fishery. The IDNR recommendations to the Mundelein Park District were as follows:

1. Maintain a reasonable amount of vegetation on the shoreline, near shore and in patches for nursery cover of small fish.

2. Reduce the number of channel catfish stocked to increase the general condition of the population. Channel catfish may not be targeted by fishermen enough to remove surplus fish, which may have lead to a stockpiling of the population and their poor condition.

3. Promote the harvest of carp and channel catfish.

4. Stock walleye at a rate of 15 to 25 fingerlings/acre (2355 to 3925 every other year) to develop and maintain a predatory presence and sport fishery.

The Park District did stock 3800 walleye in both 1999 and 2000.

EXISTING LAKE QUALITY PROBLEMS

- *Poor Water Clarity*

  Diamond Lake has low water clarity mainly due to sediment suspended in the water. Sources are from the watershed and sediment resuspension from the bottom by motorized watercraft, wind, wave and carp action.

- *Limited Wildlife Habitat*

  Because of the urban/residential setting, Diamond Lake has limited habitat to support wildlife. Improvements such as the addition of a buffer zone of native vegetation could be made around the lake to increase wildlife species diversity.

- *Shoreline Erosion*

  Although only 13% of the total shoreline around Diamond Lake is eroding, these shorelines will continue to erode if protective measures are not taken. Approximately 66% of the eroding shoreline is manicured lawn to the water's edge. Since turfgrass has very short root systems, it cannot withstand constant wave action, and under these circumstances are bound to erode. Reflecting waves from the nearby seawalls will also exacerbate the problem.

- *Excessive Aquatic Plants (Localized)*

  Although the ski lane was not subject to excessive plant beds during 2002, some localized plant beds in Diamond Lake could hinder boat traffic. Most notable was the southwest corner of the lake. To create a boat lane through the plants, a spot treatment could be done in this area. Further reduction of the plant coverage in the lake is not recommended, since the lake needs plant coverage between 20% and 40% of the lake bottom to support aquatic life. During 2002, Diamond Lake was within this range, with 30% plant coverage.

- *Invasive Shoreline Plant Species*

  Invasive shoreline plants are scattered around Diamond Lake, and not in large populations at this time. However, they can cause problems in large numbers. Their removal now would curtail their expansion.

POTENTIAL OBJECTIVES FOR DIAMOND LAKE MANAGEMENT PLAN

I. Illinois Volunteer Lake Monitoring Program
II. Shoreline Erosion Control
III. Enhance Aquatic Plant Management Plan
IV. Enhance Wildlife Habitat Conditions
V. Eliminate or Control Exotic Species

OPTIONS FOR ACHIEVING THE LAKE MANAGEMENT PLAN OBJECTIVES

Objective I: Illinois Volunteer Lake Monitoring Program

In 1981, the Illinois Volunteer Lake Monitoring Program (VLMP) was established by the Illinois Environmental Protection agency (Illinois EPA) to gather fundamental information on Illinois inland lakes, and to provide an educational program for citizens. Approximately 250 citizen volunteers sample 150-200 lakes (out of 3,041 lakes in Illinois) annually. The volunteers are primarily lakeshore residents, lake owners/managers, members of environmental groups, public water supply personnel, and citizens with interest in a particular lake. Diamond Lake was sampled only during 1996 and 2002. Continued monitoring of Diamond Lake through this program is recommended.

Objective II: Shoreline Erosion Control

Erosion is a potentially serious problem to lake shorelines and occurs as a result of wind, wave, or ice action or from overland rainwater runoff. While some erosion to shorelines is natural, human alteration of the environment can accelerate and exacerbate the problem. Erosion not only results in loss of shoreline, but also negatively influences the lake's overall water quality by contributing nutrients, sediment, and pollutants into the water. This effect is felt throughout the food chain since poor water quality negatively affects everything from microbial life to sight feeding fish and birds to people who want to use the lake for recreational purposes. The resulting increased amount of sediment will over time begin to fill in the lake, decreasing overall lake depth and volume and potentially impairing various recreational uses.

In the case of Diamond Lake, only 13% of the shoreline is eroding. Although this may not seem significant, most of the eroding shoreline is lawn that has been mowed to the water's edge. Because of its short root system, turfgrass will not withstand wave action, and will simply continue to erode. Replacing the lawn at the shoreline with a buffer strip containing native deep-rooted plants can not only help with erosion, but also add wildlife habitat. However, in areas that receive heavy wave action, riprap or a seawall may be the best option to curtail the erosion. If seawall or riprap are necessary or are already present, buffer plants can be planted behind the riprap or seawall to enhance wildlife habitat.

Option 1: No Action

Pros

There are no short-term costs to this option. However, extended periods of erosion may result in substantially higher costs to repair the shoreline in the future.

Eroding banks on steep slopes can provide some habitat for wildlife, particularly bird species (e.g. kingfishers and bank swallows) that need to burrow into exposed banks to nest. In addition, certain minerals and salts in the soils are exposed during the erosion process, which are utilized by various wildlife species.

Cons

Taking no action will most likely cause erosion to continue and subsequently may cause poor water quality due to high levels of sediment or nutrients entering a lake. This in turn may retard plant growth and provide additional nutrients for algal growth. A continual loss of shoreline is both aesthetically unpleasing and may potentially reduce property values. Since a shoreline is easier to protect than it is to rehabilitate, it is in the interest of the property owner to address the erosion issue immediately.

Costs

In the short-term, cost of this option is zero. However, long-term implications can be severe since prolonged erosion problems may be more costly to repair than if the problems were addressed earlier. As mentioned previously, long-term erosion may cause serious damage to shoreline property and in some cases lower property values.

<u>Option 2: Install a Steel or Vinyl Seawall</u>

Seawalls are designed to prevent shoreline erosion on lakes in a similar manner they are used along coastlines to prevent beach erosion or harbor siltation. Today, seawalls are generally constructed of steel, although in the past seawalls were made of concrete or wood (frequently old railroad ties). Concrete seawalls cracked or were undercut by wave action requiring routine maintenance. Wooden seawalls made of old railroad ties are not used anymore since the chemicals that made the ties rot-resistant could be harmful to aquatic organisms. A new type of construction material being used is vinyl or PVC. Vinyl seawalls are constructed of a lighter, more flexible material as compared to steel. Also, vinyl seawalls will not rust over time as steel will.

Pros

If installed properly and in the appropriate areas (i.e. shorelines with severe erosion) seawalls provide effective erosion control. Seawalls are made to last numerous years and have relatively low maintenance.

Cons

Seawalls are disadvantageous for several reasons. One of the main disadvantages is that they are expensive, since a professional contractor and heavy equipment are needed for installation. Any repair costs tend to be expensive as well. If any fill material is placed in the floodplain along the shoreline, compensatory storage may also be needed. Compensatory storage is the process of excavating in a portion of a property or floodplain to compensate for the filling in of another portion of the floodplain. Permits and surveys are needed whether replacing and old seawall or installing a new one (see costs below).

Wave deflection is another disadvantage to seawalls. Wave energy not absorbed by the shoreline is deflected back into the lake, potentially causing sediment disturbance and resuspension, which in turn may cause poor water clarity and problems with nuisance algae, which use the resuspended nutrients for growth. If seawalls are installed in areas near channels, velocity of run-off water or channel flow may be accelerated. This may lead to flooding during times of high rainfall and run-off, shoreline erosion in other areas of the lake, or a resuspension of sediment due to the agitation of the increased wave action or channel flow, all of which may contribute to poor water quality conditions throughout the lake. Plant growth may be limited due to poor water clarity, since the photosynthetic zone where light can penetrate, and thus utilized by plants, is reduced. Healthy plants are important to the lake's overall water clarity since they can help filter some of the incoming sediment, prevent resuspension of bottom sediment, and compete with algae for nutrients. However, excessive sediment in the water and high turbidity may overwhelm these benefits.

Finally, seawalls provide no habitat for fish or wildlife. Because there is no structure for fish, wildlife, or their prey, few animals use shorelines with seawalls. In addition, poor water clarity that may be caused by resuspension of sediment from deflected wave action contributes to poor fish and wildlife habitat, since sight feeding fish and birds (i.e. bass, herons, and kingfishers) are less successful at catching prey. This may contribute to a lake's poor fishery (i.e. stunted fish populations).

Costs

Depending on factors such as slope and shoreline access, cost of seawall installation ranges from $65-80 per linear foot for steel and $70-100 per linear foot for vinyl. Along Diamond Lake, approximately 476 feet of private shoreline is moderately eroding, and approximately 1688 feet is slightly eroding, including about 128 feet of Mundelein Park District property. The cost for a steel seawall at the Park District property would be $8,320-$10,240. Costs for a vinyl seawall would be $8,960-12,800. The remainder of the eroding shoreline is on private properties scattered around the lake. A licensed contractor installs both types of seawall. Additional costs may occur if the shoreline needs to be graded and backfilled, has a steep slope, or poor accessibility. Price does not include the necessary permits required. Additional costs will be incurred if compensatory storage is needed. Prior to the initiation of work, permits and/or surveys from the appropriate government agencies need to be obtained. For seawalls, a site development permit and a building permit are needed. Costs for permits and surveys can be $1,000-2,000 for installation of a seawall. Contact the Army Corps of Engineers, local municipality, or the Lake County Planning and Development Department.

Option 3: Install Rock Riprap or Gabions

Riprap is the term for using rocks to stabilize shorelines. Size of the rock depends on the severity of the erosion, distance to rock source, and aesthetic preferences. Generally, four to eight inch diameter rocks are used. Gabions are wire cages or baskets filled with rock. They provide similar protection as riprap, but are less prone to displacement. They can be stacked, like blocks, to provide erosion control for extremely steep slopes. Both riprap and gabions can be incorporated with other erosion control techniques such as plant buffer strips. If any plants will be growing on top of the riprap or gabions, fill will probably be needed to cover the rocks and provide an acceptable medium for plants to grow on. Prior to the initiation of work, permits and/or surveys from the appropriate government agencies need to be obtained (see costs below). Riprap may be the best option for some of the shoreline around Diamond Lake that receives heavy wave action. It would provide some habitat, as opposed to the lack of habitat offered by a seawall, and if installed properly, would hold up to fluctuating water levels. The riprap can be further enhanced by the addition of deep-rooted native vegetation upland of the rocks.

Pros

Riprap and gabions can provide good shoreline erosion control. Rocks can absorb some of the wave energy while providing a more aesthetically pleasing appearance than seawalls. If installed properly, riprap and gabions will last for many years. Maintenance is relatively low, however, undercutting of the bank can cause sloughing of the riprap and subsequent shoreline. Areas with severe erosion problems may benefit from using riprap or gabions. In all cases, a filter fabric should be installed under the rocks to maximize its effectiveness.

Fish and wildlife habitat can be provided if large boulders are used. Crevices and spaces between the rocks can be used by a variety of animals and their prey. Small mammals, like shrews can inhabit these spaces in the rock above water and prey upon many invertebrate species, including many harmful garden and lawn pests. Also, small fish may utilize the structure underwater created by large boulders for foraging and hiding from predators.

Cons

A major disadvantage of riprap is the initial expense of installation and associated permits. Installation is expensive since a licensed contractor and heavy equipment are generally needed to conduct the work. Permits are required if replacing existing or installing new riprap or gabions and must be acquired prior to work beginning. If any fill material is placed in the floodplain along the shoreline, compensatory storage may also be needed. Compensatory storage is the process of excavating in a portion of a property or floodplain to compensate for the filling in of another portion of the floodplain.

While riprap and gabions absorb wave energy more effectively than seawalls, there is still some wave deflection that may cause resuspension of sediment and nutrients into the water column.

Small rock riprap is poor habitat for many fish and wildlife species, since it provides limited structure for fish and cover for wildlife. As noted earlier, some small fish and other animals will inhabit the rocks if boulders are used. Smaller riprap is more likely to wash away due to rising water levels or wave action. On the other hand, larger boulders are more expensive to haul in and install.

Riprap may be a concern in areas of high public usage since it is difficult and possibly dangerous to walk on due to the jagged and uneven rock edges. This may be a liability concern to property owners.

Costs

Cost and type of riprap used depend on several factors, but average cost for installation (rocks and filter fabric) is approximately $30-45 per linear foot. Costs for gabions are approximately $20-30 per linear foot, and approximately $60-100 per linear foot when filled with rocks. Along Diamond Lake, approximately 476 feet of private shoreline is moderately eroding, and approximately 1688 feet is slightly eroding, including about 128 feet of Mundelein Park District property. The cost for riprap at the Park District property would be about $3,840-$5,760. Because this area is only slightly eroding, and gabions are for areas that are eroding more severely, gabions would be excessive for this area. The remainder of the eroding shoreline is on private properties scattered around the lake. The steeper the slope and severity of erosion, the larger the boulders that will need to be used and thus, higher installation costs. In addition, costs will increase with poor shoreline accessibility and increased distance to rock source. Costs for permits and surveys can be $1,000-2,000 for installation of riprap or gabions, depending on the circumstances. Additional costs will be incurred if compensatory storage is needed. Contact the Army Corps of Engineers, local municipalities, and the Lake County Planning and Development Department.

Option 4: Create a Buffer Strip

Another effective method of controlling shoreline erosion is to create a buffer strip with existing or native vegetation. Native plants have deeper root systems than turfgrass and thus hold soil more effectively. Native plants also provide positive aesthetics and good wildlife habitat. Cost of creating a buffer strip is quite variable, depending on the current state of the vegetation and shoreline and whether vegetation is allowed to become established naturally or if the area needs to be graded and replanted. Allowing vegetation to naturally propagate the shoreline would be the most cost effective, depending on the severity of erosion and the composition of the current vegetation. Non-native plants or noxious weedy species may be present and should be controlled or eliminated.

Stabilizing the shoreline with vegetation is most effective on slopes no less than 2:1 to 3:1, horizontal to vertical, or flatter. Usually a buffer strip of at least 25 feet is recommended, however, wider strips (50 or even 100 feet) are recommended on steeper slopes or areas with severe erosion problems. Areas where erosion is severe or where slopes are greater than 3:1, additional erosion control techniques may have to be incorporated such as biologs, A-Jacks®, or riprap.

Buffer strips can be constructed in a variety of ways with various plant species. Generally, buffer strip vegetation consists of native terrestrial (land) species and emergent (at the land and water interface) species. Terrestrial vegetation such as native grasses and wildflowers can be used to create a buffer strip along lake shorelines. Table 6 in Appendix A gives some examples, seeding rates and costs of grasses and seed mixes that can be used to create buffer strips. Native plants and seeds can be purchased at regional nurseries or from catalogs. When purchasing seed mixes, care should be taken that native plant seeds are used. Some commercial seed mixes contain non-native or weedy species or may contain annual wildflowers that will have to be reseeded every year. If purchasing plants from a nursery or if a licensed contractor is installing plants, inquire about any guarantees they may have on plant survival. Finally, new plants should be protected from herbivory (e.g., geese and muskrats) by placing a wire cage over the plants for at least one year.

A technique that is sometimes implemented along shorelines is the use of willow posts, or live stakes, which are harvested cuttings from live willows (*Salix* spp.). They can be planted along the shoreline along with a cover crop or native seed mix. The willows will resprout and begin establishing a deep root structure that secures the soil. If the shoreline is highly erodible, willow posts may have to be used in conjunction with another erosion control technique such as biologs, A-Jacks ®, or riprap.

Emergent vegetation, or those plants that grow in shallow water and wet areas, can be used to control erosion more naturally than seawalls or riprap. Native emergent vegetation can be either hand planted or allowed to become established on its own over time. Some plants, such as native cattails (*Typha* sp.), quickly spread and help stabilize shorelines, however they can be aggressive and may pose a problem later. Other species, such as those listed in Table 6 in Appendix A should be considered for native plantings.

On Diamond Lake, the installation of buffer strips can be done behind riprap or seawall, and taller emergent plants added in the water front. If people are concerned about being unable to approach the lake on their property, a narrow, mowed path to the shoreline will allow access and not interrupt the integrity of the buffer strip. The newly planted vegetation will need protection from grazing wildlife until it is established.

Pros

Buffer strips can be one of the least expensive means to stabilize shorelines. If no permits or heavy equipment are needed (i.e. no significant earthmoving or filling is planned), the property owner can complete the work without the need of professional contractors. Once established (typically within 3 years), a buffer strip of native vegetation will require little maintenance and may actually reduce the overall maintenance of the property, since the buffer strip will not have to be continuously mowed, watered, or fertilized. Occasional high mowing (1-2 times per year) for specific plants or physically removing other weedy species may be needed.

The buffer strip will stabilize the soil with its deep root structure and help filter run-off from lawns and agricultural fields by trapping nutrients, pollutants, and sediment that would otherwise drain into the lake. This may have a positive impact on the lake's water quality since there will be less "food" for nuisance algae. Buffer strips can filter as much as 70-95% of sediment and 25-60% of nutrients and other pollutants from runoff.

Another benefit of a buffer strip is potential flood control protection. Buffer strips may slow the velocity of flood waters, thus preventing shoreline erosion. Native plants also can withstand fluctuating water levels more effectively than commercial turfgrass. Many plants can survive after being under water for several days, even weeks, while turfgrass is intolerant of wet conditions and usually dies after several days under water. This contributes to increased maintenance costs, since the turfgrass has to be either replanted or replaced with sod. Emergent vegetation can provide additional help in preserving shorelines and improving water quality by absorbing wave energy that might otherwise batter the shoreline. Calmer wave action will result in less shoreline erosion and resuspension of bottom sediment, which may result in potential improvements in water quality.

Many fish and wildlife species prefer the native shoreline vegetation habitat. This habitat is an asset to the lake's fishery since the emergent vegetation cover may be used for spawning, foraging, and hiding. Various wildlife species are even dependent upon shoreline vegetation for their existence. Certain birds, such as marsh wrens (*Cistothorus palustris*) and endangered yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) nest exclusively in emergent vegetation like cattails and bulrushes. Hosts of other wildlife like waterfowl, rails, herons, mink, and frogs to mention just a few, benefit from healthy stands of shoreline vegetation. Dragonflies, damselflies, and other beneficial invertebrates can be found thriving in vegetation along the shoreline as well. Two invertebrates of particular importance for lake management, the water-milfoil weevils (*Euhrychiopsis lecontei* and *Phytobius leucogaster*), which have been shown to naturally reduce stands of exotic Eurasian water-milfoil (*Myriophyllum spicatum*). Weevils need proper over wintering habitat such as leaf litter and mud which are typically found on naturalized shorelines or shores with good buffer strips. Many species of amphibians, birds, fish, mammals, reptiles, and invertebrates have suffered precipitous declines in recent years primarily due to habitat loss. Buffer strips may help many of these species and preserve the important diversity of life in and around lakes.

In addition to the benefits of increased fish and wildlife use, a buffer strip planted with a variety of native plants may provide a season long show of various colors from flowers, leaves, seeds, and stems. This is not only aesthetically pleasing to people, but also benefits wildlife and the overall health of the lake's ecosystem.

Cons

There are few disadvantages to native shoreline vegetation. Certain species (i.e. cattails) can be aggressive and may need to be controlled occasionally. If stands of shoreline vegetation become dense enough, access and visibility to the lake may be compromised to some degree. However, small paths could be cleared to provide lake access or smaller plants could be planted in these areas.

Costs

If minimal amount of site preparation is needed, costs can be approximately $10 per linear foot, plus labor. Cost of installing willow posts is approximately $15-20 per linear foot. Along Diamond Lake, approximately 476 feet of private shoreline is moderately eroding, and approximately 1688 feet is slightly eroding, including about 128 feet of Mundelein Park District property. The cost for a buffer strip at the Park District property would be about $1,280. Willow posts would cost about $1,920-$2,560. The labor that is needed can be completed by the property owner in most cases, although consultants can be used to provide technical advice where needed. This cost will be higher if the area needs to be graded. If grading is necessary, appropriate permits and surveys are needed. If filling is required, additional costs will be incurred if compensatory storage is needed. The permitting process is costly, running as high as $1,000-2,000 depending on the types of permits needed.

<u>Option 5: Install A-Jacks®</u>
A-Jacks® are made of two pieces of pre-cast concrete when fitted together resemble a child's playing jacks. These structures are installed along the shoreline and covered with soil and/or an erosion control product. Native vegetation is then planted on the backfilled area. They can be used in areas where severe erosion does not justify a buffer strip alone.

Pros
The advantage to A-Jacks® is that they are quite strong and require low maintenance once installed. In addition, once native vegetation becomes established the A-Jacks® can not be seen. They provide many of the advantages that both riprap and buffer strips have. Specifically, they absorb some of the wave energy and protect the existing shoreline from additional erosion. The added benefit of a buffer strip gives the A-Jacks® a more natural appearance, which may provide wildlife habitat and help filter run-off nutrients, sediment, and pollutants. Less run-off entering a lake may have a positive effect on water quality.

Cons
The disadvantage is that installation cost can be high since labor is intensive and requires some heavy equipment. A-Jacks® need to be pre-made and hauled in from the manufacturing site. These assemblies are not as common as riprap, thus only a limited number of contractors may be willing to do the installation.

Costs
The cost of installation is approximately $40 - 75 per linear foot, but does not include permits and surveys, which can cost $1,000 - 2,000 and must be obtained prior to any work implementation. Along Diamond Lake, approximately 476 feet of private shoreline is moderately eroding, and approximately 1688 feet is slightly eroding, including about 128 feet of Mundelein Park District property. The cost for A-Jacks® at the Park District property would be about $5,120 - 9,600. Additional costs will be incurred if compensatory storage is needed.

<u>Option 6: Install Biolog, Fiber Roll, or Straw Blanket with Plantings</u>
These products are long cylinders of compacted synthetic or natural fibers wrapped in mesh. The rolls are staked into shallow water. Once established, a buffer strip of native plants can be planted along side or on top of the roll (depending if rolls are made of synthetic or natural fibers). They are most effective in areas where plantings alone are not effective due to already severe erosion. In areas of severe erosion, other techniques may need to be employed or incorporated with these products.

Pros
Biologs, fiber rolls, and straw blankets provide erosion control that secure the shoreline in the short-term and allow native plants to establish which will eventually provide long-term shoreline stabilization. They are most often made of bio-degradable materials, which break down by the time the natural vegetation

becomes established (generally within 3 years). They provide additional strength to the shoreline, absorb wave energy, and effectively filter run-off from terrestrial sources. These factors help improve water quality in the lake by reducing the amount of nutrients available for algae growth and by reducing the sediment that flows into a lake.

Cons

These products may not be as effective on highly erodible shorelines or in areas with steep slopes, as wave action may be severe enough to displace or undercut these products. On steep shorelines grading may be necessary to obtain a 2:1 or 3:1 slope or additional erosion control products may be needed. If grading or filling is needed, the appropriate permits and surveys will have to be obtained.

Costs

Costs range from $25 to $35 per linear foot of shoreline, including plantings. This does not include grading, or the necessary permits and surveys, which may cost $1,000 – 2,000 depending on the type of earthmoving that is being done. Along Diamond Lake, approximately 476 feet of private shoreline is moderately eroding, and approximately 1688 feet is slightly eroding, including about 128 feet of Mundelein Park District property. The costs for the Park District property would be about $3,200 – 4,480. Additional costs may be incurred if compensatory storage is needed.

Objective III: Enhance Aquatic Plant Management Plan

All aquatic plant management techniques have both positive and negative characteristics. If used properly, they can all be beneficial to a lake's well being. If misused or abused, they all share similar outcomes - negative impacts to the lake. Putting together a good aquatic plant management plan should not be rushed. Plans should consist of a realistic set of goals well thought out before implementation. The plan should be based on the management goals of the lake and involve usage issues, habitat maintenance/restoration, and limitations of the lake. For an aquatic plant management plan to achieve long term success, follow up is critical. A good aquatic plant management plan considers both the short and long-term needs of the lake. The management of the lake's vegetation does not end once the nuisance vegetation has been reduced/eliminated. It is critical to continually monitor problematic areas for regrowth and remove as necessary. An association or property owner should not always expect immediate results. A quick fix of the vegetation problems may not always be in the best interest of the lake. Sometimes the best solutions take several seasons to properly solve the problem. The management options covered below are commonly used techniques that are coming into wider acceptance and have been used in Lake County. There are other plant management options that are not covered below as they are not very effective, unreliable, or are too experimental to be widely used.

During 2002, Diamond Lake had an estimated plant coverage of 30%, which is ideal for providing for a healthy fishery. The Park District hires an aquatic herbicide applicator to treat the ski lane and near their beach (approximately 6 – 12 acres) annually with Reward®, an aquatic herbicide, to control Eurasian water milfoil. The main boating area did not have plants to the surface after treatment during 2002. However, the southwest corner of the lake had a heavy Eurasian water milfoil bed that hindered boat traffic to the main part of the lake. To ease boat travel and provide for a fish cruising lane, a path could be created through this plant growth. Although it is Eurasian water milfoil, complete removal of this plant bed is **not** recommended, since some habitat is required by aquatic life. Also, the total loss of plants in this shallow area would result in an increase in turbidity from sediment that could easily be swept into the water column by wind, wave and carp action. An area in the northeast corner had a thick plant bed of white water lilies, but its location was not causing a hindrance to boat traffic from the three houses nearby.

<u>Option 1: No Action</u>

If the lake is dominated by *native*, *non-invasive* species, the no action option could be ideal. Under these circumstances native plant populations could flourish and keep nuisance plants from becoming problematic. However, if a no action aquatic plant management plan in a lake with non-native, invasive species, nothing would be done to control the aquatic plant population of the lake regardless of the type and extent of the vegetation. Nuisance vegetation could continue to grow until epidemic proportions are reached. Growth limitations of the plant and the characteristics of the lake itself (light penetration, lake morphology, substrate type, etc.) will dictate the extent of infestation. Rooted plants, such as curly leaf pondweed (*Potamogeton crispus*) and elodea (*Elodea* *canadensis*), will be bound by physical factors such as substrate type and light availability. Plants such as Eurasian water milfoil and coontail, which can grow unrooted at the surface regardless of water depth, could grow to cover 100% of the water's surface. This could cause major inhibition of the lakes recreational uses and impact fish and other aquatic organisms adversely.

Pros

There are positive aspects associated with the no action option for plant management. The first, and most obvious, is that there is no cost. However, if an active management plan for vegetation control were eventually needed, the cost would be substantially higher than if no action had been taken in the first place. Another benefit of this option would be the lack of environmental manipulation. Under the no action option, no chemicals, mechanical alteration, or introduction of any organisms would take place. This is important since studies have shown that nuisance plants are more likely to invade disrupted areas. If the lake contains native, non-invasive plant species, expansion of the native plant population would increase the overall biodiversity and health of the lake. Habitat, breeding areas, and food source availability would greatly improve. Use of the lake would continue as normal and in some cases might improve (fishing) if native plants keep "weedy" plants under control.

An additional benefit of the no action option is the possible improvement in water quality. Turbidity could decrease and clarity should increase due to sediment stabilization by the plant's roots. Algal blooms could be reduced due to decreased resource availability and sediment stabilization. However, the occurrence of filamentous algae may increase/remain stable due to their surface growth habitat. The lake's fishery could improve due to habitat availability, which in turn would have numerous positive effects on the rest of the lake's ecosystem.

Cons

Under the no action option, if nuisance vegetation is dominant in the lake and were uninhibited and able to reach epidemic proportions, there will be many negative impacts on the lake. By their weedy nature, the nuisance plants would out-compete the more desirable native plants. This could eventually, drastically reduce or even eliminate the native plant population of the lake and reduce the lake's biodiversity. The fishery of the lake may become stunted due the to lack of quality forage fish habitat and reduced predation. Predation will decrease due to the difficulty of finding prey in the dense stands of vegetation. This will cause an explosion in the small fish population and with food resources not increasing, growth of fish will be reduced. Decreased dissolved oxygen levels, due to high biological oxygen demand from the excessive vegetation, will also have negative impacts on the aquatic life. Wildlife populations will also be negatively impacted by these dense stands of vegetation. Birds and waterfowl will have difficulty finding quality plants for food or in locating prey within the dense plant stands.

Water quality could also be negatively impacted with the implementation of the no action option. Deposition of large amounts of organic matter and release of nutrients upon the death of the massive stands of vegetation is a probable outcome of the no action option. These dead plants will contribute to the sediment load of the lake and could accelerate its filling in. The large nutrient release when the plants die back in the fall could lead to lake-wide algae blooms and an overall increase of the internal nutrient load. In addition, the decomposition of the massive amounts of vegetation will lead to a depletion of the lakes dissolved oxygen. This can cause fish stress, and eventually, if the stress is frequent or severe enough, fish kills. All of the impacts above could in turn have negative impacts on numerous aspects of the lake's ecosystem.

In addition to the ecological impacts, many physical uses of the lake will be negatively impacted. Boating could be nearly impossible without becoming entangled in thick stands of plants. Swimming could also become increasingly difficult due to thick vegetation that would develop at beaches. Fishing could become more and more exasperating due in part to the thick vegetation and also because of stunted fish population. In addition, the aesthetics of the lake will also decline due to large areas of the lake covered by tangled mats of vegetation and the odors that will develop when they decay. The combination of the above events could cause property values on the lake to suffer. Property values on lakes with weedy plant/algae problems have been shown to decrease by as much as 15-20%.

Costs
No cost will be incurred by implementing the no action management option. However, if in the future a management plan was initiated, costs might be significantly higher since a no action plan was originally followed.

Option 2: Aquatic Herbicides
Aquatic herbicides are the most common method to control nuisance vegetation/algae. When used properly, they can provide selective and reliable control. Products can not be licensed for use in aquatic situations unless there is less than a 1 in 1,000,000 chance of any negative effects on human health, wildlife, and the environment. Aquatic herbicides are not allowed to be environmentally persistent, bioaccumulate, or have any bioavailability. Prior to herbicide application, licensed applicators should evaluate the lake's vegetation and, along with the lake's management plan, choose the appropriate herbicide and treatment areas, and apply the herbicides during appropriate conditions (i.e., low wind speed, DO concentration, temperature).

There are two groups of herbicides: contact and systemic. Contact herbicides, like their name indicates, kill on contact. These herbicides affect only the above ground portion of the plant that they come into contact with and therefore do not kill the root system. An example of a contact herbicide is diquat. Systemic herbicides are taken up by the plant and disrupt cellular processes, which in turn cause plant death. These herbicides kill both the above ground portions of the plant as well as the root system. An example of a systemic herbicide is fluridone. Both types of herbicides are available in liquid or granular forms. Liquid forms are concentrated and need to be mixed into water to obtain the desired concentration. The solution is then sprayed on the water's surface or injected into the water in the treatment areas. Granular herbicides are broadcast in a known rate over the treatment area where they sink to the bottom. Some granular products slowly release the herbicide, which is then taken up by the plant. These are referred to as SRP formulations (Slow Release Pellet). Other granular herbicides come in crystal form and dissolve as they come in contact with water. This is typical of herbicides such as copper sulfate. Many herbicides come in both liquid and granular forms to fit the management needs of the lake. Herbicide applications can either be done as whole lake treatments or as more selective spot treatments. Multiple herbicides are often mixed and applied together. This is called a tank mix. This is done to save time, energy, and cost.

Aquatic herbicides are best used on actively growing plants to ensure optimal herbicide uptake. For this reason, herbicides are normally applied mid to late spring when water temperatures are above 60^0F. This is the time of year when the plants are most actively growing and before seed/vegetative propagule formation. Follow up applications should be done as needed. When choosing an aquatic herbicide it is important to know what plants are present, which ones are problematic, which plants are beneficial, and how a particular herbicide will act upon these plants. The herbicide label is very important and should always be read before use. There may be more than one herbicide for a given plant. As with other management options, proper usage is the key to their effectiveness, benefits, and disadvantages.

The Mundelein Park District contracts with an aquatic herbicide applicator to control plants within the ski lane and an area near the Park District beach. In 2002, Diamond Lake was treated with 12.5 gallons of Reward® in late May, as well as approximately 20 pounds of copper sulfate, an algicide. Reward® is a non-selective contact herbicide, meaning it kills any plants that come in contact with it. Because the application rate of Reward® is 1-2 gallons per acre, the amount used in 2002 treated 6 – 12 acres. This treatment did not affect the plant bed in the southwest corner of the lake. To create a boat lane through the plant bed at this location, treatments should occur early in the spring (April or May). If herbicides are used, systemic herbicides like 2,4-D granular (Aquacide®, Aqua-Kleen®, Navigate®, or Weedar 64®) could be used. 2,4-D is very effective for use in spot treatments, and is not environmentally persistent. Reward®, which was used to treat the ski lane, could also be used to create the boat/fish cruising lane at the southwest corner of the lake.

Pros

When used properly, aquatic herbicides can be a powerful tool in management of excessive vegetation. Often, aquatic herbicide treatments can be more cost effective in the long run compared to other management techniques. A properly implemented plan can often provide season long control with minimal applications. Ecologically, herbicides can be a better management option than using mechanical harvesting or grass carp. When properly applied, aquatic herbicides may be selective for nuisance plants such as Eurasian water milfoil but allow desirable plants such as American pondweed (*Potamogeton nodosus*) to remain. This removes the problematic vegetation and allows native and more desirable plants to remain and flourish with minimal manipulation.

The fisheries and waterfowl populations of the lake would benefit greatly due to an increase in quality habitat and food supply. Dense stands of plants would be thinned out and improve spawning habitat and food source availability for fish. Waterfowl population would greatly benefit from increases in quality food sources, such as large-leaf pondweed (*Potamogeton amplifolius*). Another environmental benefit of using aquatic herbicides over other management options is that they are organism specific. The metabolic pathways by which herbicides kill plants are plant specific, which humans and other organisms do not carry out. Organisms such as fish, birds, mussels, and zooplankton are generally unaffected.

By implementing a good management plan with aquatic herbicides, usage opportunities of the lake would increase. Activities such as boating and swimming would improve due to the removal of dense stands of vegetation. The quality of fishing may improve because of improved habitat. In addition to increased usage opportunities, the overall aesthetics of the lake would improve, potentially increasing property values on the lake.

Cons

The most obvious drawback of using aquatic herbicides is the input of chemicals into the lake. Even though the United States Environmental Protection Agency (USEPA) approved these chemicals for use, human error can make them unsafe and bring about undesired outcomes. If not properly used, aquatic herbicides can remove too much vegetation from the lake. This could drastically alter biodiversity and ecological. Total or over-removal of plants can cause a variety of problems lake-wide. The fishery of the lake may decline and/or become stunted due to predation issues related to decreased water clarity. Other wildlife, such as waterfowl, which commonly forage on aquatic plants, would also be negatively impacted by the decrease in food supply.

Another problem associated with removing too much vegetation is the loss of sediment stabilization by plants, which can lead to increased turbidity and resuspension of nutrients. The increase in turbidity can cause a decrease in light penetration, which can further aggravate the aquatic plant community. The resuspension of nutrients will contribute to the overall nutrient load of the lake, which can lead to an increased frequency of noxious algal blooms. Furthermore, the removal of aquatic vegetation, which competes with algae for resources, can directly contribute to an increase in blooms.

After the initial removal, there is a possibility for regrowth of vegetation. Upon regrowth, weedy plants such as Eurasian water milfoil and coontail quickly reestablish, form dense stands, and prevent the growth of desirable species. This causes a decrease in plant biodiveristy. Additionally, these dense stands of nuisance vegetation can lead to an overpopulation of stunted fish due to a decrease in predation of forage species by predatory fish. This disruption in the fisheries can have negative impacts throughout the ecosystem from zooplankton to higher organisms such as waterfowl and other wildlife. Additionally, some herbicides have use restrictions regarding their use in relation to fish, swimming, irrigation, etc.

Over-removal, and possible regrowth of nuisance vegetation that may follow will drastically impair recreational use of the lake. Swimming could be adversely affected due to the likelihood of increased algal blooms. Swimmers may become entangled in large mats of filamentous algae. Blooms of planktonic species, such as blue-green algae, can produce harmful toxins as well produce noxious odors. If regrowth of nuisance vegetation were to occur, motors could become entangled making boating difficult. Fishing would also be negatively impacted due to the decreased health of the lake's fishery. The overall appearance of the lake would also suffer due to an increase in unsightly algal blooms and massive stands of vegetation. This in turn could have an unwanted effect on property values. Studies have shown that problematic algal blooms can decrease property values by 15-20%.

Costs

Granular 2,4-D spot treatment cost approximately $350-425/surface acre. Costs for the use of Reward® is approximately $425 per surface acre. If a boat lane were created in the southwest corner of the lake (See Appendix E for map) covering about 3.6 acres, the cost would be approximately $1,260-1,530 for 2,4-D and approximately $1,530 for Reward®.

<u>Option 3: Hand Removal</u>

Hand removal of excessive aquatic vegetation is a commonly used management technique. Hand removal is normally used in small ponds/lakes and limited areas for selective vegetation removal. Areas surrounding piers and beaches are commonly targeted areas. Typically tools such as rakes and cutting bars are used to remove vegetation. These are easily obtainable through many outdoor supply catalogs or over the internet. Some rakes are equipped with tines as well as cutting edges. Tools can also be hand made by drilling a hole in the handle of a heavy-duty garden rake and tying it to a length of rope. Weights may be needed in order to provide forceful contact with the plants. In many instances, homeowners on lakes with near shore vegetation problems simply cut swaths through the weeds to create pathways to open water. Due to the limited amount of biomass removed, harvested plant material is often used as fertilizer and compost in gardens.

This technique could be used in Diamond Lake to eliminate small patches of nuisance vegetation, such as around piers or small beaches.

Pros

Hand removal is a quick, inexpensive, and selective way to remove nuisance vegetation. Hand removal is an activity in which all lake residents could participate. The work involved in removing plants can provide a rewarding sense of accomplishment. By removing excess vegetation, use of beaches and piers would be improved. Many of the improved water quality benefits of a well-executed herbicide program or harvesting program are also shared by hand removal. Wildlife habitat, such as fish spawning beds, could be greatly improved. This in turn would benefit other portions of the lake's ecosystem.

Cons
There are few negative attributes to hand removal. One negative implication is labor. Depending on the extent of infestation, removal of large amount, of vegetation can be quite tiresome. Another drawback can be disposal. Finding a site for numerous residents to dispose of large quantities of harvested vegetation can sometimes be problematic. However, individual homeowners would be removing limited quantities of plant material so there would not be much to dispose of. Another drawback is possible nonselective removal by hand harvesting. By throwing a rake blindly into the depths, it is impossible to determine what plants are removed and which ones are not until the rake is pulled up. Even in shallow depths, untrained persons might mistakenly remove desirable vegetation and/or disrupt valuable habitat (fish spawning beds). Over removal could also be a problem but is not normally a concern with hand removal.

Costs
Plant removal rakes can range in price from $50-150 and cutting tools commonly range in price from $50-200. Both are available from numerous catalogs and from the internet. A homemade rake would cost about $20-40.

Option 4: Water Milfoil Weevil

Euhrychiopsis lecontei (*E. lecontei*) is a biological control organism used to control Eurasian water milfoil (EWM). *E. lecontei* is a native weevil, which feeds exclusively on milfoil species. It was originally discovered while investigating declines of EWM in a Vermont lake in the early 1990s. It was discovered in northeastern Illinois lakes by 1995. Another weevil, *Phytobius leucogaster*, also feeds on EWM but does not cause as much damage as *E. lecontei*. Therefore, *E. lecontei* is stocked as a biocontrol and is commonly referred to as the Eurasian water milfoil weevil. Currently, the LCHD-Lakes Management Unit has documented weevils (*E. lecontei* and/or *P. leucogaster*) in 16 Lake County lakes. Many of these lakes have seen declines in EWM densities in recent years. It is highly likely that *E. lecontei* and/or *P. leucogaster* occurs in all lakes in Lake County that have excessive EWM growth.

Weevils are stocked in known quantities to achieve a density of 1-4 weevils per stem. As weevil populations expand, EWM populations may decline. After EWM declines, weevil populations decline and do not feed on any other aquatic plants and die back. When EWM starts to grow again in the spring, the weevil populations respond by keeping the increasing milfoil under control before it becomes a problem. Once the weevil is established, EWM should no longer reach nuisance proportions and begins to become less dense. Best results are achieved in lakes that have shallow EWM infestations in areas where it is undisturbed by recreational and management actives. Weevils need proper overwintering habitat such as leaf litter and mud, which are typically found on naturalized shorelines or shores with good buffer strips. Additionally, water temperatures need to be 68-70^{o}F for maximum weevil activity. For this reason, weevils are typically stocked in late spring/early summer. Currently only one company, EnviroScience Inc., has a stocking program (called the MiddFoil® process). The program includes evaluation of EWM densities of current weevil populations (if any), stocking, monitoring, and restocking as needed.

Controlling Eurasian water milfoil on Diamond Lake through the use of the weevils is not recommended at this time. The highly developed, manicured shorelines of Diamond Lake are not suitable habitat for weevil overwintering. Furthermore, weevils do not work well in areas where plants are continuously disturbed by activities such as powerboats and swimming, harvesting or herbicide use. Because these activities are prevalent in Diamond Lake, it would be unlikely that a weevil stocking program would be successful.

Pros

The milfoil weevil can provide long-term control of EWM. Typically, by the end of June EWM stands are starting to decline due to weevil damage. In many situations, EWM beds might not reach the surface before weevil damage causes declines. *E. lecontei* is also a selective means to control EWM. Studies have shown that *E. lecontei* has a strong preference for EWM and the only other plant it possibly will feed on is northern water milfoil. Since milfoil weevils are found to naturally occur in several lakes in Lake County, weevil stocking would be an augmentation rather than an introduction, making it a more natural control option.

If control with milfoil weevils were successful, the quality of the lake would be improved. Native plants could then start to recolonize. Fisheries of the lake would improve due to more balanced predation and higher quality habitat. Waterfowl would benefit due to increased food sources and availability of prey. Recreational activities such as fishing, swimming, and boating would be easier and more enjoyable with the removal of inhibiting stands of EWM.

Cons

Use of milfoil weevils does have some drawbacks. Control using the weevil has been inconsistent in many cases. EWM has been reduced one year, only to be unaffected the next. Reasons for these inconsistencies are under investigation. One possible explanation is lack of suitable overwintering habitat. The highly developed, manicured shorelines of many lakes in the County are not suitable habitat for weevil overwintering. This is one reason the weevils may not do well on Diamond Lake. Another possible explanation is cooler than normal summer water temperatures. Studies have shown that cooler water temperatures reduce weevil feeding and egg production.

Milfoil control using weevils may not work well on plants in deep water. Plants are able to compensate for weevil damage on upper portions of the plant by increasing growth on lower portions where weevil does not feed. Furthermore, weevils do not work well in areas where plants are continuously disturbed by activities such as powerboats and swimming, harvesting or herbicide use. Because these activities are prevalent in Diamond Lake, it would be unlikely that a weevil stocking program would be successful. In areas where weevils are to be stocked, activity should be reduced as much as possible. This may either limit the extent to which the weevils can be used or limit recreational use of the lake. The reasons for weevil success or failure in controlling EWM are still being researched and there are no definite answers at this time. Research has shown that approximately 1-2 weevils per stem are needed in order to see significant damage and decline of an EWM bed.

One of the most prohibitive aspects to weevil use is price. Typically weevils are stocked to achieve a density of 1-4 weevils per stem. This translates to 500-3000 weevils per acre. At a cost of $1 per weevil plus labor, an EWM management program using weevils can be expensive. Additionally, there is no guarantee that weevils will provide long term control or even produce any results at all.

Costs

EnviroScience, Inc.
3781 Darrow Road
Stow, Ohio 44224
1(800) 940-4025

Weevils are sold in units of 1000 bugs/unit and stocking rates must be at least 1 unit/stocked area. Normally there is a minimum purchase of 5-10 units. The cost of the weevils does not include the labor involved in initial surveys, stocking, and monitoring, which typically run an additionally $3,500-$4,500.

Option 5 – Mechanical Harvesting

Mechanical harvesting involves the cutting and removal of nuisance aquatic vegetation by large specialized boats with underwater cutting bars. Plants are cut below the water at a level that will restore use of the lake. Typically, problematic areas are harvested and other areas are left alone. However, some management plans call for more wide spread harvesting, especially when nuisance plants such as Eurasian watermilfoil become widespread. Harvesting could be used to create a boat lane in the southwest corner. However, it would not be cost-effective to purchase this equipment for such a small area, and it would probably be easier to find a consultant who uses aquatic herbicides than one who uses a harvester.

Pros

Mechanical harvesting can be a selective means to reduce nuisance vegetation stands in a lake. Typically, the plants are cut low restore recreational use and to ensure the plants do not grow back quickly. This practice normally improves habitat for fish and other aquatic organisms. Some plant species such as curlyleaf pondweed, if harvested at the right time, do not grow back to nuisance proportions after harvesting. The plant clippings are high in nutrients and can be used as fertilizer or compost. Additionally, use of the lake is uninterrupted while harvesting is occurring.

By removing large quantities of plant biomass the overall quality of the lake will improve in many ways. The decrease in vegetative biomass will reduce the oxygen demand on the lake. Some nuisance vegetation such as coontail has extremely high oxygen demands. Dense stands of these plants can quickly drain a lake of DO. This will cause increased dissolved oxygen levels. Additionally, a decrease in plant density will improve the fisheries of the lake by creating better opportunities for predation, which is essential in creating a balanced fish population. By removing nuisance vegetation, recreational uses of the lake will improve. The quality of activities such as boating, swimming, and fishing would greatly improve. The paths cut by the harvester will open fishing areas. By removing dense stands of vegetation the possibility of entanglement will decrease there by increasing opportunities for boating and swimming.

Cons

Once widespread, mechanical harvesting is becoming a less attractive management technique due to a variety of reasons. Many applicators that used to regularly employ mechanical harvesting no longer use or even offer this service due to low public demand. In addition to low public demand, high initial investment, extensive maintenance, and high operational costs have also led to decreased use. Since many applicators no longer offer harvesting services, a lake association would have to purchase and maintain their own harvester. Many associations do not have the financial resources to cover the maintenance cost involved with owning a harvester let alone buying a harvester, which can range in price from $50,000-150,000. Beside the financial limitations there are also physical limitations. Mechanical harvesters cannot be used in less than 3-4 ft of water and can not maneuver well in tight places. The harvested plant material must be disposed of to a place that can accommodate large quantities of plants and ensure the plants will not be washed back into the lake. Fish, clams, and other aquatic organisms are commonly caught in the harvester and injured or even removed from the lake in the harvesting process.

After the initial removal, there is a possibility for regrowth of the vegetation. Upon regrowth, weedy plants such as Eurasian watermilfoil and coontail quickly become reestablished, form dense stands, and prevent the growth of desirable species. This causes a decrease in plant biodiveristy. Additionally, these dense stands of nuisance vegetation will lead to an over population of stunted fish due to a decrease in predation of forage species by predatory fish. This disruption in the fisheries will have negative impacts throughout the ecosystem from zooplankton to higher organisms such as waterfowl.

The total removal or over removal of plants by mechanical harvesting can cause a variety of problems in the lake. One problem is the loss of sediment stabilization by the plants, which can lead to increased turbidity and resuspension of nutrients. The increase in turbidity can cause a decrease in light penetration, which can further aggravate the aquatic plant community. The resuspension of nutrients will also contribute to overall nutrient load of the lake, which can lead to increased frequency of algal blooms. Furthermore, the removal of aquatic vegetation, which competes for nutrients with algae, can directly contribute to an increase in algal blooms. The fisheries of the lake could decline to due to decreased predation caused by an inability to locate prey due to decreased water clarity. This could result in stunting of the fish population. Other organisms, such as waterfowl, which commonly forage on aquatic plants, would also be negatively impacted by the decrease in vegetation.

Another problem associated with mechanical harvesting is that it is a nonselective process. In the areas where harvesting is being conducted, all the plants are removed from that area. After the initial removal, regrowth of desirable plants does not typically occur in these harvested are. Due to their weedy nature plants such as Eurasian watermilfoil, which are able to grow more quickly than native plants and have a tolerance to being cut, become more established in the harvested areas. This will create a monoculture of nuisance vegetation. This causes an overall decrease in plant biodiversity, which can have detrimental effects to the entire ecosystem. Depending on the plant species, frequent harvesting might be required (typically 2-4 times per season). Along with this increased frequency come increased operational costs (labor, gas, maintenance, etc.). In addition to spreading in harvested areas, nuisance plants such as coontail and Eurasian watermilfoil can spread by vegetative fragments that may escape collection during the harvesting process and spread to uninfested parts of the lake. In addition to the release of plant fragments, as the plants are cut removed there is a possibility of plant associated nutrients being released into the lake. This could cause an increase in algal blooms whenever harvesting in conducted.

Cost

Depending on the type of the harvester (cutting width, payload capacity, hull material, HP of the motor, trailer options, etc) prices can range from 50,000 to 150,000. Operational and maintenance cost can typically range from $161.00-445.00/acre.

Objective IV: Enhance Wildlife Habitat Conditions

The key to increasing wildlife species in and around a lake can be summed up in one word: habitat. Wildlife needs the same four things all living creatures need: food, water, shelter, and a place to raise their young. Since each wildlife species has specific habitat requirements, which fulfill these four basic needs, providing a variety of habitats will increase the chance that wildlife species may use an area. Groups of wildlife are often associated with the types of habitats they use. For example, grassland habitats may attract wildlife such as northern harriers, bobolinks, meadowlarks, meadow voles, and leopard frogs. Marsh habitats may attract yellow-headed blackbirds and sora rails, while manicured residential lawns attract house sparrows and gray squirrels. Thus, in order to attract a variety of wildlife, a mix of habitats are needed. In most cases quality is more important than quantity (i.e., five 0.1-acre plots of different habitats may not attract as many wildlife species than one 0.5 acre of one habitat type).

It is important to understand that the natural world is constantly changing. Habitats change or naturally succeed to other types of habitats. For example, grasses may be succeeded by shrub or shade intolerant tree species (e.g., willows, locust, and cottonwood). The point at which one habitat changes to another is rarely clear, since these changes usually occur over long periods of time, except in the case of dramatic events such as fire or flood.

In all cases, the best wildlife habitats are ones consisting of native plants. Unfortunately, non-native plants dominate many of our lake shorelines. Many of them escaped from gardens and landscaped yards (i.e., purple loosestrife) while others were introduced at some point to solve a problem (i.e., reed canary grass for erosion control). Wildlife species prefer native plants for food, shelter, and raising their young. In fact, one study showed that plant and animal diversity was 500% higher along naturalized shorelines compared to shorelines with conventional lawns (University of Wisconsin – Extension, 1999).

At Diamond Lake, installing native vegetation along the shoreline can improve wildlife habitat. This can be done by replacing lawn with a native buffer strip, or by planting similar plants above the riprap or seawall, or by planting emergent species in the water near the shore.

Option 1: No Action

This option means that the current land use activities will continue. No additional techniques will be implemented. Allowing a field to go fallow or not mowing a manicured lawn would be considered an action.

Pros

Taking no action may maintain the current habitat conditions and wildlife species present, depending on environmental conditions and pending land use actions. If all things remain constant there will be little to no effect on lake water quality and other lake uses.

Cons
If environmental conditions change or substantial land use actions occur (i.e., development) wildlife use of the area may change. For example, if a new housing development with manicured lawns and roads is built next to an undeveloped property, there will probably be a change in wildlife present.

Conditions in the lake (i.e., siltation or nutrient loading) may also change the composition of aquatic plant and invertebrate communities and thus influence biodiversity. Siltation and nutrient loading will likely decrease water clarity, increase turbidity, increase algal growth (due to nutrient availability), and decrease habitat for fish and wildlife.

Costs
The financial cost of this option may be zero. However, due to continual loss of habitats many wildlife species have suffered drastic declines in recent years. The loss of habitat affects the overall health and biodiversity of the lake's ecosystems.

<u>Option 2: Increase Habitat Cover</u>
The buffer strip of native vegetation to combat shoreline erosion as suggested in Objective II would also increase the wildlife habitat around the lake. Allow native plants to grow or plant native vegetation along shorelines, including emergent vegetation such as cattails, rushes, and bulrushes (see Table 6 in Appendix A for costs and seeding rates). This will provide cover from predators and provide nesting structure for many wildlife species and their prey. It is important to control or eliminate non-native plants such as buckthorn, purple loosestrife, garlic mustard, and reed canary grass, since these species outcompete native plants and provide little value for wildlife.

Occasionally high mowing (with the mower set at its highest setting – not less than 6 inches) may have to be done for specific plants, particularly if the area is newly established, since competition from weedy and exotic species is highest in the first couple years. If mowing, do not mow the buffer strip until after July 15 of each year. This will allow nesting birds to complete their breeding cycle.

Brush piles make excellent wildlife habitat. They provide cover as well as food resources for many species. Brush piles are easy to create and will last for several years. They should be place at least 10 feet away from the shoreline to prevent any debris from washing into the lake.

Trees that have fallen on the ground or into the water are beneficial by harboring food and providing cover for many wildlife species. In a lake, fallen trees provide excellent cover for fish, basking sites for turtles, and perches for herons and egrets.

Increasing habitat cover should not be limited to the terrestrial environment. Native aquatic vegetation, particularly along the shoreline, can provide cover for fish and other wildlife.

Pros

Increased cover will lead to increased use by wildlife. Since cover is one of the most important elements required by most species, providing cover will increase the chances of wildlife using the shoreline. Once cover is established, wildlife usually have little problem finding food, since many of the same plants that provide cover also supply the food the wildlife eat, either directly (seeds, fruit, roots, or leaves) or indirectly (prey attracted to the plants).

Additional benefits of leaving a buffer include: stabilizing shorelines, reducing runoff which may lead to better water quality, and deterring nuisance Canada geese. Shorelines with erosion problems can benefit from a buffer zone because native plants have deeper root structures and hold the soil more effectively than conventional turfgrass. Buffers also absorb much of the wave energy that batters the shoreline. Water quality may be improved by the filtering of nutrients, sediment, and pollutants in run-off. This has a “domino effect” since less run-off flowing into a lake means less nutrient availability for nuisance algae, and less sediment means less turbidity, which leads to better water quality. All this is beneficial for fish and wildlife, such as sight-feeders like bass and herons, as well as people who use the lake for recreation. Finally, a buffer strip along the shoreline can serve as a deterrent to Canada geese from using a shoreline. Canada geese like flat, open areas with a wide field of vision. Ideal habitat for them is areas that have short grass up to the edge of the lake. If a buffer is allowed to grow tall, geese may choose to move elsewhere.

Cons

There are few disadvantages to this option. However, if vegetation is allowed to grow, lake access and visibility may be limited. If this occurs, a small path can be made to the shoreline. Composition and density of aquatic and shoreline vegetation are important. If vegetation consists of non-native species such as or Eurasian water milfoil or purple loosestrife, or in excess amounts, undesirable conditions may result. A shoreline with excess exotic plant growth may result in a poor fishery (exhibited by stunted fish) and poor recreation opportunities (i.e., boating, swimming, or wildlife viewing).

Costs

The cost of this option would be minimal. The purchase of native plants can vary depending upon species and quantity. Based upon 100 feet of shoreline, a 25-foot buffer planted with a native forb and grass seed mix would cost between $165-270 (2500 sq. ft. would require 2.5, 1000 sq. ft. seed mix packages at $66-108 per package). This does not include labor that would be needed to prepare the site for planting and follow-up maintenance. This cost can be reduced or minimized if native plants are allowed to grow. However, additional time and labor may be needed to insure other exotic species, such as buckthorn, reed canary grass, and purple loosestrife, do not become established.

Option 4: Increase Natural Food Supply

Habitats with a diversity of native plants will provide an ample food supply for wildlife. Food comes in a variety of forms, from seeds to leaves or roots to invertebrates that live on or are attracted to the plants. Plants found in Table 6 in Appendix A should be planted or allowed to grow. In addition, encourage native aquatic vegetation, such as water lily(*Nuphar* spp. and *Nymphaea tuberosa*), sago pondweed (*Stuckenia pectinatus*), largeleaf pondweed (*Potamogeton amplifolius)*, and wild celery (*Vallisneria americana*) to grow. Aquatic plants such as these are particularly important to waterfowl in the spring and fall, as they replenish energy reserves lost during migration.

Providing a natural food source in and around a lake starts with good water quality. Water quality is important to all life forms in a lake. If there is good water quality, the fishery benefits and subsequently so does the wildlife (and people) who prey on the fish. Insect populations in the area, including beneficial predatory insects, such as dragonflies, thrive in lakes with good water quality.

Dead or dying plant material can be a source of food for wildlife. A dead standing or fallen tree will harbor good populations of insects for woodpeckers, while a pile of brush may provide insects for several species of songbirds such as warblers and flycatchers.

Supplying natural foods artificially (i.e., birdfeeders, nectar feeders, corn cobs, etc.) will attract wildlife and in most cases does not harm the animals. However, "people food" such as bread should be avoided. Care should be given to maintain clean feeders and birdbaths to minimize disease outbreaks.

Pros

Providing food for wildlife will increase the likelihood they will use the area. Providing wildlife with natural food sources has many benefits. Wildlife attracted to a lake can serve the lake and its residents well, since many wildlife species (i.e., many birds, bats, and other insects) are predators of nuisance insects such as mosquitoes, biting flies, and garden and yard pests (such as certain moths and beetles). Effective natural insect control eliminates the need for chemical treatments or use of electrical "bug zappers" that have limited effect on nuisance insects.

Migrating wildlife can be attracted with a natural food supply, primarily from seeds, but also from insects, aquatic plants or small fish. In fact, most migrating birds are dependent on food sources along their migration routes to replenish lost energy reserves. This may present an opportunity to view various species that would otherwise not be seen during the summer or winter.

Cons

Feeding wildlife can have adverse consequences if populations become dependent on hand-outs or populations of wildlife exceed healthy numbers. This frequently happens when people feed waterfowl like Canada geese or mallard ducks. Feeding these waterfowl can lead to a domestication of these animals. As a result, these birds do not migrate and can contribute to numerous problems, such as excess feces, which are both a nuisance to property owners and a significant contribution to the lake's nutrient load. Waterfowl feces are particularly high in phosphorus. Since phosphorus is generally the limiting factor for nuisance algae growth in many lakes in the Midwest, the addition of large amounts of this nutrient from waterfowl may exacerbate a lake's excessive algae problem. In addition, high populations of birds in an area can increase the risk of disease for not only the resident birds, but also wild bird populations that visit the area.

Finally, tall plants along the shoreline may limit lake access or visibility for property owners. If this occurs, a path leading to the lake could be created or shorter plants may be used in the viewing area.

Costs

The costs of this option are minimal. The purchase of native plants and food and the time and labor required to plant and maintain would be the limit of the expense.

Option 5: Increase Nest Availability

Wildlife are attracted by habitats that serve as a place to raise their young. Habitats can vary from open grasslands to closed woodlands. The installation of the buffer strip as suggested above in Option 2 of this section will assist in this endeavor.

Standing dead or dying trees provide excellent habitat for a variety of wildlife species. Birds such as swallows, woodpeckers, and some waterfowl need dead trees to nest in. Generally, a cavity created and used by a woodpecker (e.g., red-headed or downy woodpecker, or common flicker) in one year, will in subsequent years be used by species like tree swallows or chickadees. Over time, older cavities may be large enough for waterfowl, like wood ducks, or mammals (e.g., flying squirrels) to use. Standing dead trees are also favored habitat for nesting wading birds, such as great blue herons, night herons, and double-crested cormorants, which build stick nests on limbs. For these birds, dead trees in groups or clumps are preferred as most herons and cormorants are colonial nesters.

In addition to allowing dead and dying trees to remain, erecting bird boxes will increase nesting sites for many bird species. Box sizes should vary to accommodate various species. Swallows, bluebirds, and other cavity nesting birds can be attracted to the area using small artificial nest boxes. Larger boxes will attract species such as wood ducks, flickers, and owls. A colony of purple martins can be attracted with a purple martin house, which has multiple cavity holes, placed in an open area near water.

Bat houses are also recommended for any area close to water. Bats are voracious predators of insects and are naturally attracted to bodies of water. They can be enticed into roosting in the area by the placement of bat boxes. Boxes should be constructed of rough non-treated lumber and placed >10 feet high in a sunny location.

Pros

Providing places were wildlife can rear their young has many benefits. Watching wildlife raise their young can be an excellent educational tool for both young and old.

The presence of certain wildlife species can help in controlling nuisance insects like mosquitoes, biting flies, and garden and yard pests. This eliminates the need for chemical treatments or electric "bug zappers" for pest control.

Various wildlife species populations have dramatically declined in recent years. Since, the overall health of ecosystems depend, in part, on the role of many of these species, providing sites for wildlife to raise their young will benefit not only the animals themselves, but the entire lake ecosystem.

Cons

Providing sites for wildlife to raise their young have few disadvantages. Safety precautions should be taken with leaving dead and dying trees due to the potential of falling limbs. Safety is also important when around wildlife with young, since many animals are protective of their young. Most actions by adult animals are simply threats and are rarely carried out as attacks.

Parental wildlife may chase off other animals of its own species or even other species. This may limit the number of animals in the area for the duration of the breeding season.

Costs

The costs of leaving dead and dying trees are minimal. The costs of installing the bird and bat boxes vary. Bird boxes can range in price from $10-100. Purple martin houses can cost $50-150. Bat boxes range in price from $15-50. These prices do not include mounting poles or installation.

Objective V: Eliminate or Control Exotic Species

Numerous exotic plant species have been introduced into our local ecosystems. Some of these plants are aggressive, quickly out-competing native vegetation and flourishing in an environment where few natural predators exist. Plants such as purple loosestrife (*Lythrum salicaria*), buckthorn (*Rhamnus cathartica*), and reed canary grass (*Phalaris arundinacea*) are three examples. The outcome is a loss of plant and animal diversity. This section will address terrestrial shoreline exotic species.

Purple loosestrife is responsible for the "sea of purple" seen along roadsides and in wetlands during summer. It can quickly dominate a wetland or shoreline. Due in part to an extensive root system, large seed production (estimates range from 100,000 to 2.7 million seeds per plant), and high seed germination rate, purple loosestrife spreads quickly. Buckthorn is an aggressive shrub species that grows along lake shorelines as well as most upland habitats. It shades out other plants and is quick to become established on disturbed soils. Reed canary grass is an aggressive plant that if left unchecked will dominate an area, particularly a wetland or shoreline, in a short period of time. Since it begins growing early in the spring, it quickly out-competes native vegetation that begins growth later in the year. Control of purple loosestrife, buckthorn, and reed canary grass are discussed below. However, these control measures can be similarly applied to other exotic species such as garlic mustard (*Allilaria officianalis*) or honeysuckle (*Lonicera* spp.) as well as some aggressive native species, such as box elder (*Acer negundo*).

Presence of exotic species along a lakeshore is by no means a death sentence for the lake or other plant and animal life. If controlled, many exotic species can perform many of the original functions that they were brought here for. For example, reed canary grass was imported for its erosion control properties. It still contributes to this objective (offering better erosion control than commercial turfgrass), but needs to be isolated and kept in control. Many exotics are the result of garden or ornamental plants escaping into the wild. One isolated plant along a shoreline will probably not create a problem by itself. However, problems arise when plants are left to spread, many times to the point where treatment is difficult or cost prohibitive. A monitoring program should be established, problem areas identified, and control measures taken when appropriate. This is particularly important in remote areas of lake shorelines where the spread of exotic species may go unnoticed for some time.

Some areas of the shoreline around Diamond Lake have scattered invasive plants such as purple loosestrife and buckthorn shrubs. Because these plants have a tendency to germinate and thrive in disturbed areas, they could become a problem in the beginning stages of shoreline stabilization projects. Periodic checks should be conducted to identify and remove unwanted invasive plants while they are young, and easily removed.

<u>Option 1: No Action</u>
No control will likely result in the expansion of the exotic species and the decline of native species. This option is not recommended if possible.

Pros
There are few advantages with this option. Some of the reasons exotics were brought into this country are no longer used or have limited use. However, in some cases having an exotic species growing along a shoreline may actually be preferable if the alternative plant is commercial turfgrass. Since turfgrass has shallow roots and is prone to erosion along shorelines, exotics like reed canary grass or common reed (*Phragmites australis*) will control erosion more effectively. Native plants should take precedent over exotics when possible. Table 6 in Appendix A lists several native plants that can be planted along shorelines.

Cons
Native plant and wildlife diversity will be lost as stands of exotic species expand. Exotic species are not under the same stresses (particularly diseases and predators) as native plants and thus can out-compete the natives for nutrients, space, and light. Few wildlife species use areas where exotic plants dominate. This happens because many wildlife species either have not adapted with the plants and do not view them as a food resource, the plants are not digestible to the animal, or their primary food supply (i.e., insects) are not attracted to the plants. The result is a monoculture of exotic plants with limited biodiversity.

Recreational activities, especially wildlife viewing, may be hampered by such monocultures. Access to lake shorelines may be impaired due to dense stands of non-native plants. Other recreational activities, such as swimming and boating, may not be affected.

Costs
Costs with this option are zero initially, however, when control is eventually needed, costs will be substantially more than if action was taken immediately. Additionally, the eventual loss of ecological diversity is difficult to calculate financially.

Option 2: Biological Control

Biological control (bio-control) is a means of using natural relationships already in place to limit, stop, or reverse an exotic species' expansion. In most cases, insects that prey upon the exotic plants in its native ecosystem are imported. Since there is a danger of bringing another exotic species into the ecosystem, state and federal agencies require testing before any bio-control species are released or made available for purchase.

Recently two beetles (*Galerucella pusilla* and *G. calmariensis*) and two weevils (*Hylobius transversovittatus* and *Nanophyes marmoratus*) have offered some hope to control purple loosestrife by natural means. These insects feed on either the leaves or juices of purple loosestrife, eventually weakening or killing the plant. In large stands of loosestrife, the beetles and weevils naturally reproduce and in many locations, significantly retard plant densities. The insects are host specific, meaning that they will attack no other plant but purple loosestrife. Currently, the beetles have proven to be most effective and are available for purchase. There are no designated stocking rate recommendations, since using bio-control insects are seen as an inoculation and it may take 3-5 years for beetle populations to increase to levels that will cause significant damage. Depending on the size of the infested area, it may take 1,000 or more adult beetles per acre to cause significant damage.

Because the purple loosestrife is scattered around Diamond Lake and not in large enough densities, their control by this method may not be efficient at this time.

Pros

Control of exotics by a natural mechanism is preferable to chemical treatments. Insects, being part of the same ecological system as the exotic (i.e., the beetles and weevils and the purple loosestrife) are more likely to provide long-term control. Chemical treatments are usually non-selective while bio-control measures target specific plant species. This technique is beneficial to the ecosystem since it preserves, even promotes, biodiversity. As the exotic dies back, native vegetation can reestablish the area.

Cons

Few exotics can be controlled using biological means. Currently, there are no bio-control techniques for plants such as buckthorn, reed canary grass, or a host of other exotics. One of the major disadvantages of using bio-control is the costs and labor associated with it.

Use of biological mechanisms to control plants such as purple loosestrife is still under debate. Similar to purple loosestrife, the beetles and weevils that control it are not native to North America. Due to the poor historical record of introducing non-native species, even to control other non-native species, this technique has its critics.

Costs

The New York Department of Natural Resources at Cornell University (607-255-2821) sells overwintering adult beetles (which will lay eggs the year of release) for $2 per beetle and new generation beetles (which will lay eggs beginning the following year) at $0.25 per beetle. Some beetles may be available for free by contacting the Illinois Natural History Survey (217-333-6846).

Option 3: Control by Hand

Controlling exotic plants by hand removal is most effective on small areas (< 1 acre) and if done prior to heavy infestation. Some exotics, such as purple loosestrife and reed canary grass, can be controlled to some degree by digging, cutting, or mowing if done early and often during the year. Digging may be required to ensure the entire root mass is removed. Spring or summer is the best time to cut or mow, since late summer and fall is when many of the plant seeds disperse. Proper disposal of excavated plants is important since seeds may persist and germinate even after several years. Once exotic plants are removed, the disturbed ground should be planted with native vegetation and closely monitored. Many exotic species, such as purple loosestrife, buckthorn, and garlic mustard are proficient at colonizing disturbed sites.

Because the invasive plants are scattered around Diamond Lake, this may prove to be an efficient method for their control.

Pros
Removal of exotics by hand eliminates the need for chemical treatments. Costs are low if stands of plants are not too large already. Once removed, control is simple with yearly maintenance. Control or elimination of exotics preserves the ecosystem's biodiversity. This will have positive impacts on plant and wildlife presence as well as some recreational activities.

Cons
This option may be labor intensive or prohibitive if the exotic plant is already well established. Costs may be high if large numbers of people are needed to remove plants. Soil disturbance may introduce additional problems such as providing a seedbed for other non-native plants that quickly establish disturbed sites, or cause soil-laden run-off to flow into nearby lakes or streams. In addition, a well-established stand of an exotic like purple loosestrife or reed canary grass may require several years of intense removal to control or eliminate.

Costs
Cost for this option is primarily in tools, labor, and proper plant disposal.

Option 4: Herbicide Treatment
Chemical treatments can be effective at controlling exotic plant species. However, chemical treatment works best on individual plants or small areas already infested with the plant. In some areas where individual spot treatments are prohibitive or unpractical (i.e., large expanses of a wetland or woodland), chemical treatments may not be an option due to the fact that in order to chemically treat the area a broadcast application would be needed. Since many of the herbicides that are used are not selective, meaning they kill all plants they contact; this may be unacceptable if native plants are found in the proposed treatment area.

Herbicides are commonly used to control nuisance shoreline vegetation such as buckthorn and purple loosestrife. Herbicides are applied to green foliage or cut stems. Products are applied by either spraying or wicking (wiping) solution on plant surfaces. Spraying is used when large patches of undesirable vegetation are targeted. Herbicides are sprayed on growing foliage using a hand-held or backpack sprayer. Wicking is used when selected plants are to be removed from a group of plants. The herbicide solution is wiped on foliage, bark, or cut stems using a herbicide soaked device. Trees are normally treated by cutting a ring in the bark (called girdling). Herbicides are applied onto the ring at high concentrations. Other devices inject the herbicide through the bark. It is best to apply herbicides when plants are actively growing, such as in the late spring/early summer, but before formation of seed heads. Herbicides are often used in conjunction with other methods, such as cutting or mowing, to achieve the best results. Proper use of these products is critical to their success. Always read and follow label directions.

Because the invasive plants are scattered around Diamond Lake, this may prove to be an efficient method for their control.

Pros
Herbicides provide a fast and effective way to control or eliminate nuisance vegetation. Unlike other control methods, herbicides kill the root of the plant, which prevents regrowth. If applied properly, herbicides can be selective. This allows for removal of selected plants within a mix of desirable and undesirable plants.

Cons
Since most herbicides are non-selective, they are not suitable for broadcast application. Thus, chemical treatment of large stands of exotic species may not be practical. Native species are likely to be killed inadvertently and replaced by other non-native species. Off target injury/death may result from the improper use of herbicides. If herbicides are applied in windy conditions, chemicals may drift onto desirable vegetation. Care must also be taken when wicking herbicides as not to drip on to non-targeted vegetation such as native grasses and wildflowers. Another drawback to herbicide use relates to their ecological soundness and the public perception of them. Costs may also be prohibitive if plant stands are large. Depending on the device, cost of the application equipment can be high.

Costs
Two common herbicides, triclopyr (sold as Garlon ™) and glyphosate (sold as Rodeo®, Round-up™, Eagre™, or AquaPro™), cost approximately $100 and $65 per gallon, respectively. Only Rodeo® is approved for water use. A Hydrohatchet®, a hatchet that injects herbicide through the bark, is about $300.00. Another injecting device, E-Z Ject® is $450.00. Hand-held and backpack sprayers costs from $25-$45 and $80-150, respectively. Wicking devices are $30-40.

APPENDIX E: POSSIBLE HERBICIDE TREATMENT LOCATION FOR CREATION OF A BOAT LANE