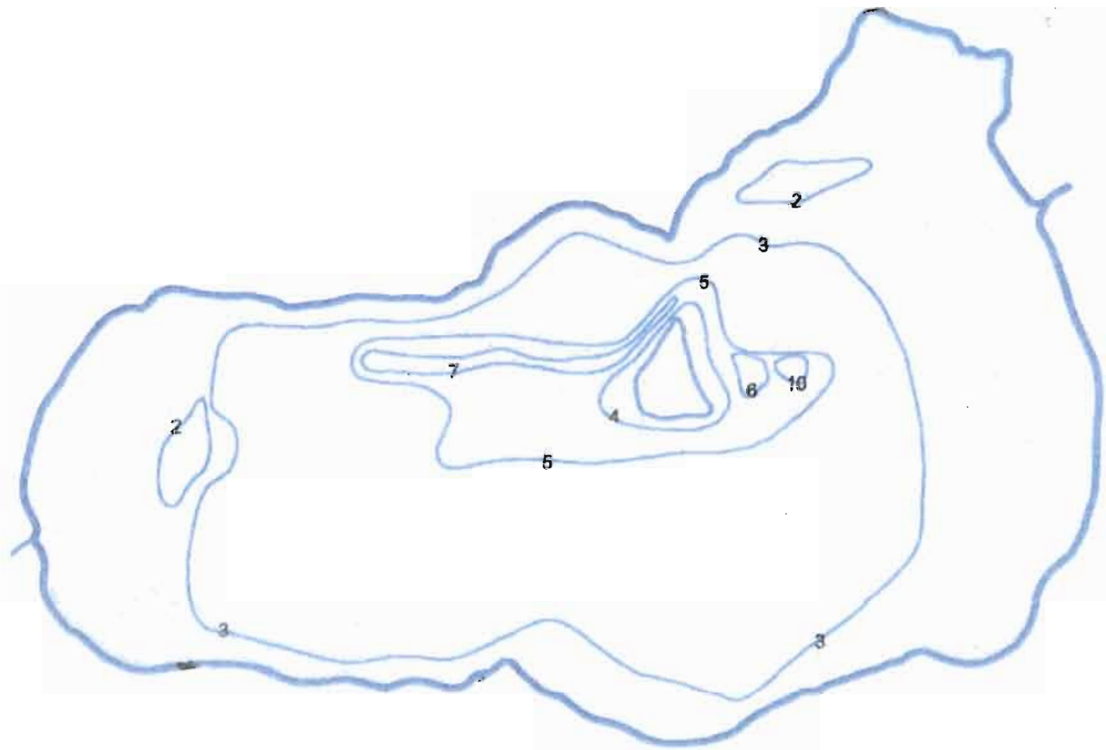
White Lake, Waupaca County, Wisconsin
Comprehensive Survey Results and Management Plan

January 4, 2003



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Abstract:

A comprehensive survey conducted on White Lake during 2002 found a lake containing a rich diversity of aquatic plants. This diversity of plants provided many of the fish, wildlife and water quality values found on the lake. Two exotic species found, Eurasian watermilfoil and purple loosestrife, and were identified as primary management concerns. A review of available management options was presented. A total of 555 acres of lakebed were estimated to be susceptible to Eurasian watermilfoil invasion. All physical and chemical parameters analyzed indicated good water quality. These parameters did not vary substantially with seasonal events. Nor had parameters changed markedly from those found during a 1991 survey. The good water quality was attributed to the diversity and abundance of aquatic plants and the characteristics of the watershed.

Wetlands in the White Lake watershed protect the lake from agricultural runoff. Phosphorus loading from the inlet creek was insignificant. Groundwater seepage was determined to be the main water source for the lake. Land uses in the watershed having the greatest potential to impact water quality were the residential areas along the north and south shores.

A concurrent DNR fishery survey found a fish community top heavy with predators – namely abundant, small northern pike. Other gamefish and panfish species were present limited numbers, but typically had above average sizes. Forage species were scarce. The main area of concern was high overwinter mortality on juvenile fish, which was likely due to heavy predation when fish crowded around aerators in winter. Other areas of concern were the presence of carp and limited spawning habitat for walleyes. Spawning and nursery habitat for other species was abundant, and was not considered to be a limiting factor in fish production.

Management recommendations included developing a long-term management program for Eurasian watermilfoil that utilized treatment with 2,4D herbicides. Lake monitoring and education were identified as critical components to the success of this program. Use of bio-control beetles was recommended for control of pl. Use of a mechanical weed harvester was recommended for control of nuisance native plants. Harvesting lanes were identified, and guidelines were established to protect spawning fish and emergent plant beds. Riparian property owners were given recommendations for maintaining lake water quality. It was also recommended that the Lake Associations commission a study that would monitor winter dissolved oxygen profiles to assess the impacts to the fishery, and provide technical details for expanding and upgrading the lake's aeration system.

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Acknowledgements

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A final thanks to the members of The White Lake Aeration – Conservation Club and the White Lake Preservation Association for working cooperatively toward the betterment of this unique and valuable natural resource.

Additional contributors: Andy Chikowski, Aquatic Biologists.

1.0 Introduction

White Lake, located in the town of Royalton, is the second largest waterbody in Waupaca County. This 1026-acre impoundment has a maximum depth of 12 feet. However, only 12% of the lake is greater than 4 feet deep. White Lake is part of a large wetland complex that drains into the South Branch of the Little Wolf River. Approximately half of the shoreline is upland and is developed with summer cottages and year-around homes. The lake contains a diverse variety of submergent aquatic plants plus extensive beds of emergent plants including wild rice (*Zizania aquatica*) and hardstem bulrush (*Scirpus acutus*). Thus the lake is an important resource for migratory waterfowl. During winter, an aeration system is operated in the deeper portions of the lake to maintain a fishery. Because of these features, White Lake is heavily utilized by anglers and waterfowlers.

Two organizations assist in the management of the lake, the White Lake Preservation Association and the White Lake Aeration Association. At present, the main management concerns for these associations include maintaining water quality, improving the fishery, managing the invasive exotic plants: Eurasian watermilfoil (*Myriophyllum spicatum*) and purple loosestrife (*Lythrum salicaria*), and managing native aquatic plants to maintain boating opportunities. In order to address these concerns, the two Lake Associations collaborated on a project to conduct a comprehensive study of the lake, and to develop a long-range management plan. The Lake Associations retained Aquatic Biologists, Inc. to conduct these studies and to assist with the development of a management plan. Financial assistance for this project was provide through the Wisconsin Department of Natural Resources' Lake Management Planning Grant Program.

This report presents the methods, results and conclusions of the comprehensive lake survey and outlines the management plans jointly adopted by the White Lake Preservation Association and the White Lake Aeration Association.

1.1 Project goals

The primary goal of this project was to gather information on the chemical, physical and biological characteristics of White Lake in order to facilitate informed decision-making in the development of a comprehensive management plan. Specific objectives of the project were to identify and prioritize current management needs, and to research management options for their applicability to White Lake. Strategies for achieving these objectives included:

1) surveying the aquatic plant community and researching plant management options
2) assessing physical and chemical water quality parameters throughout the season
3) developing nutrient and water budgets
4) analyzing watershed characteristics
5) assessing fishery characteristics, and
6) assessing fish habitats and improvement options.

1.2 Description of study area

White Lake is a natural waterbody formed in a glacial outwash plain. Historically, it has been characterized as a shallow, marsh-like lake. A large wetland area, predominantly swamp forest, occurs to the west of the lake basin. An intermittent creek drains from this wetland into the lake. An intermittent outlet creek drains into a large wetland complex that adjoins the northeast portion of the lake. The outlet creek drains into the South Branch of the Little Wolf River. The topography surrounding White Lake is generally level, with some moderate slopes occurring to the southwest of the lake. Upland soil types along the south shore are predominantly Plainfield loamy sands, which are characterized as excessively drained. Upland soil types along the north shore are predominantly Meehan and Roscommon loamy sands, which are characterized as poorly drained. Wetland soil types to the east and west of the lake are very poorly drained Seeleyville and Cathro/Markey mucks (USDA, 1984).

White Lake was historically an excellent waterfowl production area. In 1870 though, the lake was partially drained to create a cranberry marsh. In 1921 a fixed concrete dam with a four-foot head was constructed on the outlet creek. This dam was designed to restore and maintain lake water levels (IPS, 1991).

1.3 Management history

1.31 Programs

Since the impoundment of the lake in 1921, the major focus of lake management efforts have revolved around maintaining a fishery and maintaining boating opportunities. Because of the shallow, marsh-like nature of the lake, it has been prone to periodic winter fish kills, thus the lake has an extensive stocking history. In 1973 the White Lake Aeration Association installed an aeration system in the lake in order to alleviate the winterkill problem. An aeration system has been in operation every winter since. The White Lake Preservation Association began operation of a mechanical weed harvester in 1983 to maintain boating lanes in the lake. Because of the diverse opportunities on White Lake, the interests of anglers, boaters and waterfowlers have often been at odds.

1.32 Studies

In response to a controversy that developed between waterfowl hunters and anglers regarding water level management and the resultant loss of waterfowl habitat, the Wisconsin Department of Natural Resources conducted a macrophyte survey of the lake. This survey was conducted in 1989. Its purpose was to provide baseline data on the lake's aquatic plant community. This survey found an abundance of both submergent and emergent plant species, including two exotic species: Eurasian watermilfoil and purple loosestrife. Plant density and distribution was correlated with bottom substrate type. The report recommended exploring management options for control of exotic species.

In 1990 the White Lake Preservation Association retained IPS Environmental and Analytical Services to conduct a comprehensive survey of the lake and assist with development of a management plan. This study assessed water quality parameters and aquatic plant community characteristics, researched historical lake data and plant management techniques, and identified property owner activities that potentially influenced lake water quality. The study found good water quality and an aquatic plant community similar to that found in the earlier survey. The report outlined a weed harvesting plan and recommended activities for individual lakeshore property owners.

2.0 Methods

2.1 Aquatic Plant Survey

Field studies will included conducting line-transect surveys of both submergent and emergent aquatic plants throughout the lake, mapping the distribution emergent plant beds, and mapping the distribution of Eurasian watermilfoil. Other research included compiling information on the aquatic plants found and there ecological value to White Lake, reviewing the effectiveness and impacts of past plant management activities and exploring other applicable plant management techniques.

A line-transect survey was used to determine the distribution, percent frequency and composition of species encountered. Transects were established at 1000 foot intervals, and ran north - south (**Figure 1**). Transect tracking was facilitated with a hand-held GPS unit. Sampling plots were established along each transect at 1000 foot intervals. (GPS coordinates are given in **Appendix 1**.) Plots were established by estimating a 10-foot diameter circle around the anchored boat. The circular plot was then divided into four quarters, with each quarter representing a quadrant. Plants were collected in each quadrant with a tethered short-toothed rake. A total of 216 quadrants were sampled. From each rake haul, all plants collected were identified to *genus*, and to *species* whenever possible. Depth and bottom substrate were also noted for each sampling plot. Data were recorded separately for each transect.

The location and spatial arrangement of emergent plant beds and Eurasian watermilfoil beds was determined visually with the aid of landmarks, and with the use of a GPS unit, and recorded on a map. The areas of these beds were determined through acreage grid analysis.

2.2 Analysis of physical and chemical parameters

In-lake water sampling and monitoring was done from a single site – at the deepest point in the lake (**Figure 1**). Samples were collected one foot below the surface. Collections were made four times in 2002: April (spring turnover), June, August and October. All water samples not analyzed in the field were sent to the State Lab of Hygiene for analysis.

The following parameters were be monitored on each sampling date:

total phosphorus	dissolved oxygen profile
chlorophyll *a*	temperature profile
pH	Secchi depth
nitrate + nitrite	gauge height

After the spring turnover in April, the following additional parameters were monitored:

dissolved phosphorus	Kjeldahl nitrogen
ammonia	conductivity
color	chloride
alkalinity	total dissolved solids
total suspended solids	

At the inlet and below the spillway (**Figure 1**), the following parameters were monitored on each sampling date:

total phosphorus	flow
temperature	pH
nitrate + nitrite	velocity
dissolved oxygen	

From the data collected, nutrient and water budgets were calculated for the lake using formulas given in Ingram, et.al. (1966).

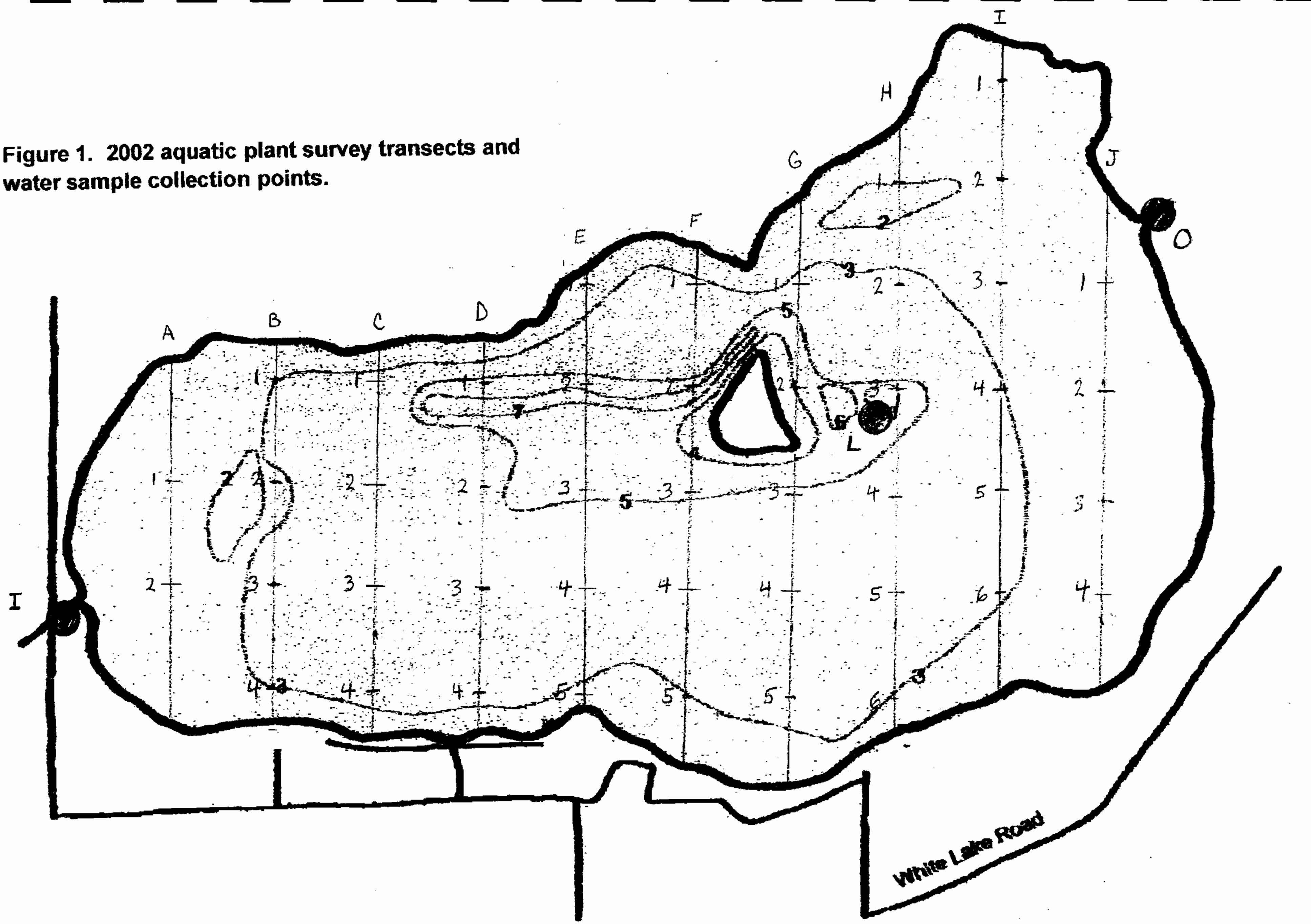
2.3 Watershed analysis

Watershed analyses included delineation of watershed boundaries, determinations of acreage and drainage patterns, identification of land uses and cover types, and identification of areas affecting water quality such as wetlands and eroded sites. Land use patterns, cover types and other biological and geological features found in the watershed were identified and mapped during ground surveys. The watershed boundary was extrapolated from USGS topographical maps. The total area of the watershed, and the area and percentage of different land-use types within the watershed boundary was calculated from acreage grid analysis.

2.4 Fishery / habitat assessment

ABI Staff assisted Department of Natural Resources personnel with netting and shocking activities during a concurrently run fish survey. During these surveys, fish species composition and characteristics were noted, along with spawning, nursery and foraging habitats. Separate surveys were done during peak centrarchid (sunfish family) spawning activity to further assess and document important spawning habitat. Other work included gathering of historical fish stocking data, and research and review of the habitat requirements and potential habitat improvement techniques for the species found in White Lake.

Figure 1. 2002 aquatic plant survey transects and water sample collection points.



3.0 Results and Discussion

3.1 Aquatic plants

3.11 Survey results

The results of the aquatic plant survey are shown in **Table 1**. A very high diversity of aquatic plants was found in White Lake. A total of 28 species were encountered, including 19 submergents, 4 emergents, four floating-leaf species and one specie of filamentous algae. Bushy pondweed (*Najas flexilis*) was most abundant, having been found at 56.3% of sample points (percent frequency) and comprising 22.6% of the plant species found (% composition). Large-leaf pondweed (*Potamogeton amplifolius*) was nearly as abundant at 51.7% frequency and 20.7% composition. The next most abundant species were elodea (*Elodea canadensis*) and white-stem pondweed (*P. praelongus*). The most abundant emergent species were wild rice and hardstem bulrush. The most abundant floating leaf plant was white water lily (*Nymphaea odorata*).

The 2002 plant survey data are compared to the data from the two earlier surveys in **Table 2**. These earlier surveys are not very comparable because different transects and a variety of collection methods were used. They were also much more limited in scope. The 1989 survey only assessed areas near the public boat launches and around the island. The 1991 survey was more extensive, but did not cover the east or west end of the lake where abundant emergent species were found. 18 species were found in the 1989 survey, while 20 species were found in the 1991 survey. The two surveys both found bushy pondweed and white-stem pondweed to be most abundant. Fern pondweed (*P. robinsii*) was the third most abundant plant in 1989, but was not found during 1991 or 2002. In all, nine species found in the earlier surveys were not found in the 2002 survey. Two exotic species, Eurasian watermilfoil and purple loosestrife, however were found in both earlier surveys.

Table 1. Results of aquatic plant survey conducted on White Lake during May 2002.

Species common name	scientific name	Percent Frequency	Percent Composition
Bushy Pondweed	*Najas flexilis*	56.3	22.6
Large Leaf Pondweed	*Potamogeton amplifolius*	51.7	20.7
Elodea	*Elodea canadensis*	21.0	8.4
White Stem Pondweed	*Potamogeton praelongus*	21.0	8.4
Wild Rice	*Zizania spp.*	14.8	5.9
Musk Grass	*Chara spp.*	13.1	5.2
Water Celery	*Valisneria americana*	12.5	5.0
Eurasian Watermilfoil	*Myriophyllum spicatum*	8.0	3.2
Flatstem Pondweed	*Potamogeton zosteriformis*	6.8	3.2
Northern Watermilfoil	*Myriophyllum sibericum*	5.1	2.1
White Water Lily	*Nymphaea odorata*	4.0	1.6
Hardstem Bulrush	*Scripus acutus*	3.4	1.4
Illinois Pondweed	*Potamogeton illinoensis*	3.4	1.4
Water Marigold	*Bidens beckii*	3.4	1.4
Bladderwort	*Utricularia vulgaris*	2.8	1.1
Coontail	*Ceratophyllum demersum*	2.8	1.1
Water Buttercup	*Ranunculus longirostris*	2.8	1.1
Needle Rush	*Eleocharis acicularis*	2.3	0.9
Pickerel Weed	*Pontederia cordata*	2.3	0.9
Various-leaved Watermilfoil	*Myriophyllum heterophyllum*	2.3	0.9
Floating Leaf Pondweed	*Potamogeton natans*	1.7	0.7
Spadderdock	*Nuphar variegata*	1.7	0.7
Elodea spp.	*Anacharis densa*	1.1	0.5
Filamentous algae	*Chlorophyceae*	1.1	0.5
Watersheild	*Brasenia schreberi*	1.1	0.5
Sago Pondweed	*Potamogeton pectinatus*	0.6	0.2
Water Stargrass	*Zosterella dubia*	0.6	0.2
Whorled Watermilfoil	*Myriophyllum verticillatum*	0.6	0.2
No Plants Found		8.0	

Table 2. A comparison of aquatic plant data from three surveys conducted on White Lake.

common name	scientific name	1989	1991	2002
Elodea spp.	*Anacharis densa*			1
Water Marigold	*Bidens beckii*			3
Water Shield	*Brasenia schreberi*			1
Coontail	*Ceratophyllum demersum*	12	4	3
Musk Grass	*Chara spp.*	40	8	13
Filamentous algae	*Chlorophyceae*	20	12	1
Needle Rush	*Eleocharis acicularis*			2
Elodea	*Elodea canadensis*	8	4	21
Small Duckweed	*Lemna minor*			
Purple Loosestrife	*Lythrum salicaria*	16		
Various-leaved Watermilfoil	*Myriophyllum heterophyllum*			2
Northern Watermilfoil	*Myriophyllum sibericum*			5
Eurasian Watermilfoil	*Myriophyllum spicatum*	16		8
Milfoil Species	*Myriophyllum spp.*		24	
Whorled Watermilfoil	*Myriophyllum verticillatum*			1
Bushy Pondweed	*Najas flexilis*	88	72	56
Nitella	*Nitella spp.*		16	
Spadderdock	*Nuphar variegata*		4	2
White Water Lily	*Nymphaea odorata*	4	32	4
Smartweed	*Polygonum amphibium*	4		
Pickerel Weed	*Pontedaria cordata*	28	40	2
Large Leaf Pondweed	*Potamogeton amplifolius*	32		52
Illinois Pondweed	*Potamogeton illinoiensis*		28	3
Floating-leaf Pondweed	*Potamogeton natans*			2
Sago Pondweed	*Potamogeton pectinatus*	32	12	1
White Stem Pondweed	*Potamogeton praelongus*	60	64	21
Small Pondweed	*Potamogeton pusillus*		4	
Clasping-Leaf Pondweed	*Potamogeton richardsonii*	28		
Fern Pondweed	*Potamogeton robinsii*	52		
Flatstem Pondweed	*Potamogeton zosteriformis*	16	12	7
Water Buttercup	*Ranunculus longirostris*			3
Hardstem Bulrush	*Scirpus acutus*	20	40	3
Narrow-Leaf Cattail	*Typha angustifolia*		4	
Broad-Leaf Cattail	*Typha latifolia*	20	8	
Bladderwort	*Utricularia vulgaris*			3
Water Celery	*Valisneria americana*		32	13
Horned Pondweed	*Zannichellia palustris*		4	
Wild Rice	*Zizania spp.*			15
Water Stargrass	*Zosterella dubia*			1
No Plants Found			4	8

3.12 Ecological values

The high diversity of aquatic plants found in White Lake is indicative of a healthy aquatic ecosystem. Many of the species found provide important spawning, nursery and foraging habitat for fish. Likewise, many of the species found provide critical food and shelter for a variety of wildlife. The diversity of aquatic plants found in White Lake is no doubt responsible for maintaining the lake's water quality. Aquatic plants capture sediments and nutrients that enter the system. The ability of rooted plants to utilize available phosphorus greatly limits the potential for algae blooms. Aquatic plants also stabilize bottom sediments preventing resuspesion from wave action. Plants species vary in their ability to provide these characteristics, thus maintaining a high aquatic plant diversity will be critical to protecting the lake's water quality. The description and ecological value of aquatic plants found in White Lake is given in **Table 3**.

3.13 Exotic species

Two exotic species were found during this survey, Eurasian watermilfoil and purple loosestrife. Purple loosestrife was not encountered along the transects because they only included plants growing in the water. Purple loosestrife, however was observed along extensive areas of shoreline. Control of these exotic species should be a primary lake management concern. Due to its aggressive growth and rapid dispersal, Eurasian watermilfoil represents a substantial threat to Wisconsin's Lakes. Because Eurasian watermilfoil grows quickly to the water's surface and forms dense canopies that block sunlight, it can displace nearly all native submergent species. This has been attributed to significant declines in the habitat diversity of lakes. The dense canopy and surface mat formations of mature Eurasian watermilfoil beds can greatly inhibit recreational values such as swimming boating and fishing. Eurasian watermilfoil has also been linked to declines in fishery quality, invertebrate abundance and water quality (Pullman, 1993).

Purple loosestrife can be found in a wide variety of habitats from shallow water to moist soils. Like Eurasian watermilfoil it is a very aggressive plant that can displace many native wetland plants including cattails (*Typha spp.*). Unlike cattails, purple loosestrife has little food or cover value for wildlife (Borman, et. al. 1997). When food and cover disappear, so do the species that depend on it.

3.14 Eurasian watermilfoil distribution

During the May 2002 survey, Eurasian watermilfoil was found at 8.0% of sample points, making it the 8th most abundant species in the lake. Eurasian watermilfoil was most abundant in the deep slot that runs west from the island. This continuous bed covered an area of 20.3 acres (**Figure 2**). Eurasian watermilfoil was also found in scattered clumps around the east end of the lake.

Eurasian watermilfoil is typically found in water depths of 3 to 12 feet (Borman, et. al. 1997), and prefers to grow in rich organic sediments. During the 2002 survey it was found growing entirely in muck bottom areas. In order to develop a predictive model for the potential spread of Eurasian watermilfoil, the percent frequency of plants by depth contour (**Table 4**) and the area and percent frequency of different bottom substrates by depth contour (**Table 5**) were calculated. Eurasian watermilfoil was found in all depth ranges. While there was no clear correlation between depth and Eurasian watermilfoil percent frequency, Eurasian watermilfoil was most abundant in depths greater than five feet (37.5% frequency).

Because Eurasian watermilfoil prefers water depths greater than three feet and prefers muck bottoms, we can assume that these portions of the lake are most susceptible to nuisance milfoil growth. From **Table 5** we find that a total of 586 acres of the lake have a depth of three feet or greater. At this depth 94.7 percent of the bottom substrate is muck. This equates to 555 acres of the lake that are at risk from Eurasian watermilfoil invasion. While Eurasian watermilfoil has existed in White Lake since at least 1989, it is probably safest to assume that it will continue to spread until it becomes the dominant plant species – as it has on virtually very other lake where it has been left unchecked.

Eurasian watermilfoil (top), the exotic threat, compared to northern watermilfoil, an important native plant.

Large-leaf pondweed, a common plant in White Lake.

Table 3. Description and ecological value of aquatic plants found in White Lake, May 2002.

Species	Description	Ecological Value
Bladderwort *(Utricularia vulgaris)*	Floating stems grow 2-3 meters long and are made up of finely divided leaf-like branches containing bladders that trap prey	Provide food and cover for fish; grow in very loose, soft sediment where other aquatic plants have a hard time establishing
Bushy Pondweed *(Najas flexilis)*	Submersed plant with a finely branched stem growing up to 1 meter; leaves are narrow, pointed, and grow in pairs	Very important food for many species of waterfowl and marsh birds; provides a good source of shelter and food for fish
Coontail *(Ceratophyllum demersum)*	As its name implies, it produces whorls of narrow, toothed leaves on a long trailing stem that often resembles the tail of a raccoon	Provide shelter for young fish and is home to insects which provide food for fish and waterfowl; captures a large amount of sediment and phosphorus which greatly helps water quality
Elodea *(Elodea canadensis)*	Made up of slender stems with small, lance shaped leaves that attach directly to the stem; leaves are in whorls of 2 or 3 and are more crowded toward the stem tip	Provide cover for fish and is home for many insects that fish feed upon
Eurasian Water milfoil *(Myriophyllum spicatum)*	Produces long spaghetti-like stems; leaves are feather-like, resemble bones on a fish spine, and are in whorls of 4-5; flower spike sticks out of the water with whorls of flowers	Being an exotic species with aggressive growth it has limited ecological value; growing in dense, nuisance levels it is also a threat to habitat diversity of lakes
Flat-stem Pondweed *(Potamogeton zosterformis)*	Emerges from a rhizome which has a strongly flattened stems; leaves are stiff with a prominent mid-vein and many fine parallel veins	Provides cover for fish and is home for many insects which are fed upon by fish
Floating-Leaf Pondweed *(Potamogeton natans)*	Stems emerge from red-spotted rhizomes; leaves are heart shaped at base and rest flat on the water's surface	Provides food for ducks, geese, muskrats, beaver, deer, and moose; offers shade and cover for fish
Hardstem Bulrush *(Scripus acutus)*	Made up of olive-colored cylindrical stems; prefer firm bottoms and emerge above waters surface in waters as deep as 6 feet	Provide important spawning, nursery, and foraging habitat for fish; food for many birds and muskrats; important plant for utilizing excess nutrients and improving water quality
Illinois Pondweed *(Potamogeton illinoensis)*	Stout stems emerge from a thick rhizome; leaves are lance-shaped to oval and often have a sharp tip	Excellent cover for fish and invertebrates; source of food for waterfowl, muskrats, beaver, and deer
Large-Leaf Pondweed *(Potamogeton amplifolius*	Stems are tough and emerge from a ridged black rhizome; leaves are large and broad with many veins; submerged leaves tend to be arched and slightly folded	Offers excellent shelter, shade, and foraging habitat for fish; its nutlets are valued for food by waterfowl
Musk Grass *(Chara spp.)*	A complex algae that resembles a higher plant; its is identified by its pungent, musk-like odor and whorls of toothed branched leaves	Provides shelter for young fish and is associated to black crappie spawning sites; helps stabilize bottom sediments and contributes to better water quality
Needle Rush *(Eleocharis acicularis)*	Produces slender short stems that emerge in tufts from a spreading rhizome; leaves are small and rest at the base of the stem; each stem has a small, single spikelet at its peak	Provide food for waterfowl and muskrats; home to many invertebrates

Table 3 continued. Description and ecological value of aquatic plants found in White Lake, May 2002

Species	Description	Ecological Value
Northern Watermilfoil *(Myriophyllum heterophyllum)*	Light colored stems with leaves divided like a feather; flower spike emerges above water level and is made up of whorls of red tinted flowers	Offers excellent foraging habitat for fish; food for waterfowl and provides a home for invertebrates
Pickerel Weed *(Pontederia cordata)*	Glossy, heart shaped leaves that emerge above the water surface; leaf blade made up of many fine, parallel veins; flower spike crowded by many small blue flowers	Home for many insects and fish; food for muskrats and waterfowl; serves as an important shoreline stabilizer against wave action
Sago Pondweed *(Potamogeton pectinatus)*	Stems emerge from slender rhizomes with many starchy tubers; leaves are sharp, thin, and resemble a pine needle; flowers emerge in small whorls	One of the most important foods for migrating waterfowl; important habitat for juvenile trout and other young fish
Spadderdock *(Nuphar variegata)*	Emerges from a spongy rhizome; leaves are heart shaped (10-25 cm long) with rounded lobes; flowers are round with 5-6 yellow sepals	Provide food for ducks, muskrats, beaver, and deer; provide cover and shade for fish and insects
Various-Leaved Watermilfoil *(Myriophyllum heterophyllum)*	Leaves are feather-like and arranged in whorls of 4-6; small red tinted flowers emerge above the water surface in a clustered spike	Offers shade, cover, and foraging habitat for fish; food for waterfowl and a home to many invertebrates
Water Buttercup *(Ranunculus longirostris)*	Branched stems emerge from buried rhizomes; leaves are alternate and are made up of many thread-like divisions; white flowers emerge just above the water's surface and contain 5 petals	Home for many invertebrates which serve as fish forage; food for ducks and upland game birds
Water Celery *(Valisneria americana)*	Made up of long ribbon-like leaves that emerge from a cluster; leaves tend to be mostly submersed with only leave tips trailing at water surface	Provides great habitat for fish and is relished by waterfowl, especially the canvasback
Water Marigold *(Bidens beckii)*	Stem made up of many thread-like divisions of leaves; emerge above waters surface and develop yellow daisy-like flowers	Flowers attract insects; offer cover and foraging habitat for fish; fruit utilized by waterfowl and shorebirds
Watersheild *(Brasenia schreberi)*	Stems are long and elastic; root stalk attaches to the middle of a single oval leaf; leaves are green on the top and purple on the underside; maroon flowers emerge slightly above the water's surface	Provides shade and cover for fish and invertebrates; consumed by waterfowl
Water Stargrass *(Zosterella dubia)*	Made up of slender branched stems; leaves are narrow and are alternately arranged; flowers are yellow, star-shaped, and single	Utilized by waterfowl for food and provides cover for fish
White-Stem Pondweed *(Potamogeton praelongus)*	Long zigzag stems up to 2-3 meters; leaves clasp the stem and are oval shaped with a cupped, boat shaped tip.	Good food producer for waterfowl and furbearers; important habitat for musky and trout
White Water Lily *(Nymphaea odorata)*	Develop round reddish floating pads; large white flowers with yellow stamens float on the water surface	Important cover for fish, especially largemouth bass; food for muskrats, beaver, waterfowl, and moose
Whorled Watermilfoil *(Myriophyllum verticillatum)*	Leaves are feather-like and attach directly to a greenish-brown stem; flower bracts tend to be lobed	Provides invertebrate habitat and is utilized by fish for foraging and cover
Wild Rice *(Zizania aquatica)*	Tall, shallow rooted emergent; leaves are narrow and pointed; flowers form clusters of rod shaped grain at its tip	Relished for food by waterfowl, sora rails, black birds, and muskrats; provide cover for fish and spawning sites for musky and pike

Figure 2. Distribution of Eurasian watermilfoil in White Lake as of July, 2002.

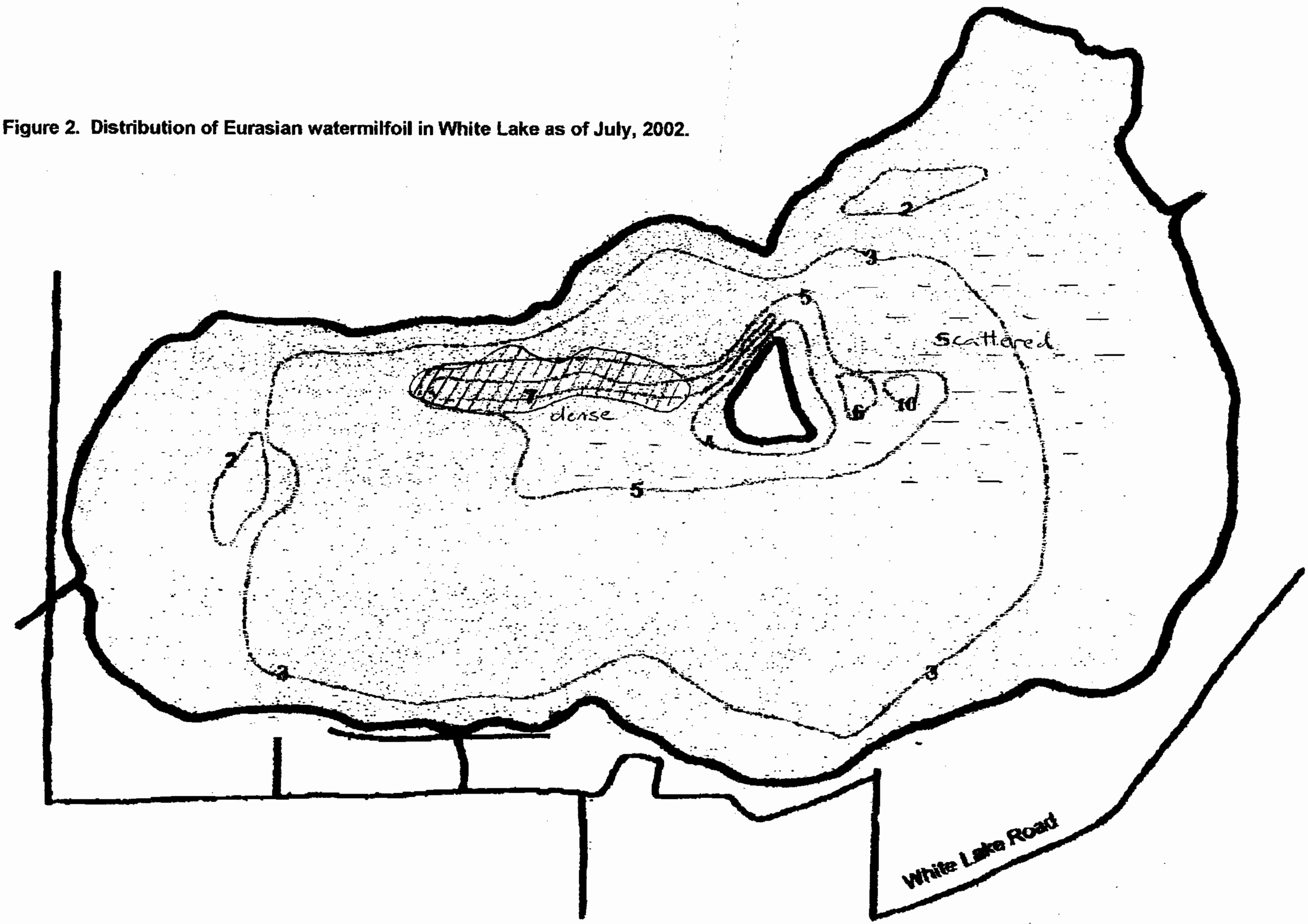


Table 4. Aquatic plant percent frequency by depth from the 2002 White Lake survey.

Species common name	scientific name	Depth Contour (feet) / Percent Frequency 0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	5.0 +
Bladderwort	*Utricularia vulgaris*	20.0	6.3			
Bushy Pondweed	*Najas flexilis*	15.0	37.5	67.6	61	50
Coontail	*Ceratophyllum demersum*	20.0			1.6	
Elodea	*Elodea canadensis*	30.0	31.3	25	9.4	37.5
Elodea spp.	*Anacharis densa*		12.5			
Eurasian Watermilfoil	*Myriophyllum spicatum*	15.0	18.8	5.9	1.6	37.5
Filamentous algae	*Chlorophyceae*	10.0				
Flatstem Pondweeed	*Potamogeton zosteriformis*	20.0	6.3	8.8	4.7	
Floating Leaf Pondweed	*Potamogeton natans L.*	5.0	12.5			
Hardstem Bulrush	*Scripus acutus*	5.0	12.5	2.9	1.6	
Illinois Pondweed	*Potamogeton illinoensis*	5.0	12.5		6.3	
Large Leaf Pondweed	*Potamogeton amplifolius*		12.5	4.4	6.3	
Musk Grass	*Chara spp.*	35.0	12.5	14.7	6.3	
Needle Rush	*Eleocharis acicularis*	10.0		2.9		
Northern Watermilfoil	*Myriophyllum sibericum*		12.5	4.4	6.3	
Pickerel Weed	*Pontederia cordata L.*	20.0				
Sago Pondweed	*Potamogeton pectinatus*			1.5		
Spadderdock	*Nuphar variegata*	15.0				
Various-leaved Watermilfoil	*Myriophyllum heterophyllum*	15.0		1.5		
Water Buttercup	*Ranunculus longirostris*		12.5	2.9	1.6	
Water Celery	*Valisneria americana*	30.0	18.8	11.8	6.3	12.5
Water Marigold	*Bidens beckii*	5.0		4.4	3.1	
Watersheild	*Brasenia schreberi*	10.0				
Water Stargrass	*Zosterella dubia*		6.3			
White Stem Pondweed	*Potamogeton praelongus*			23.5	28.1	37.5
White Water Lily	*Nymphaea odorata*	30.0	6.3			
Whorled Watermilfoil	*Myriophyllum verticillatum*				1.6	
Wild Rice	*Zizania spp.*	55.0	50.0	7.4	3.1	

Table 5. Percent frequency of bottom substrates by depth contour from the 2002 White Lake Survey.

	Depth contour (feet) / Percent Compostion				
Substrate	**0-1.9**	**2.0-2.9**	**3.0-3.9**	**4.0-4.9**	**5.0 +**
Area (acres)	*238*	*201*	*461*	*106*	*20*
Muck	60	75	100	79	50
Sand	20	25		14	50
Muck/Sand					
Muck/Bog	20			7	

3.15 Management options

Aquatic plant management needs for White Lake fall into three categories: 1) exotic species control, which will be directed at drastically reducing or eliminating target plants; 2) control of native species to improve navigation, which will be directed at reducing plants in selected areas while maintaining ecological values; and 3) control of plants along individual property frontages, which will be directed reducing or removing plants from small areas along shore to provide swimming or boat-mooring areas. Each of these categories will require a different management approach. Options for each category are discussed in the following paragraphs.

3.151 exotic species control

While the two invasive exotics found during the White Lake surveys, Eurasian watermilfoil and purple loosestrife, may be equally detrimental to the ecosystem, Eurasian watermilfoil typically receives far more management attention due to its impacts on boating, swimming and fishing.

Three main methods are commonly used to control Eurasian watermilfoil in Wisconsin: mechanical weed harvesting, biological controls and herbicides. DNR permits are required for any herbicide treatments and for any large-scale mechanical harvesting. Boat-mounted mechanical weed harvesters are usually used in lakes that have historically used harvesters, and in situations where lake management units have done insufficient planning to receive permits for herbicide use. Mechanical harvest is not a recommended control method for Eurasian watermilfoil, however. Eurasian watermilfoil can reproduce by fragmentation (Borman, et. al. 1997), and the free-floating plant matter left from cutting operations can accelerate dispersal of the plant. In some cases, mechanical cutting of a small milfoil bed has resulted in the rapid spreading of the plant throughout an entire lake. Fragments left from cutting operations are also readily picked up by boats and trailers and are more easily spread to neighboring lakes. Another disadvantage is that cutting does not typically kill plants. Nor is there evidence to suggest that cutting can induce a shift back to native species. Mechanical harvest of Eurasian watermilfoil is usually done on an ever-increasing annual basis. Given these considerations, using the mechanical weed harvester in Eurasian watermilfoil beds should be avoided.

There has been considerable research on biological vectors, such as insects, and their ability to affect a decline in Eurasian watermilfoil populations. Of these, the milfoil weevil has received the most attention. Native milfoil weevil populations have been associated with declines in Eurasian watermilfoil in natural lakes in Vermont (Creed and Sheldon, 1995), New York (Johnson, et. al., 2000) and Wisconsin (Lilie, 2000). However there is scant evidence that *stocked* weevils can produce a decline in Eurasian watermilfoil density. A twelve lake study called "The Wisconsin Milfoil Weevil Project" (Jester, et. al. 1999) conducted by the University of Wisconsin, Stevens Point in conjunction with the Wisconsin Department of Natural Resources researched the efficacy of weevil stocking. This report concluded that milfoil weevil densities were not elevated, and that Eurasian watermilfoil was unaffected by weevil stocking in any of the study lakes.

There have been numerous reasons given for the lack of success of weevil stocking as a management option, including calcium carbonate deposits on plants (Jester, et. al. 1999), poor over-wintering habitat (Newman, et, al. 2001), high pH (C. Kendziorski, 2001) and sunfish predation (Newman, pers. comm.). Perhaps the most compelling reason why weevil stocking has been unsuccessful may be that weevil populations are already at carrying capacity in many lakes. Recent studies in Wisconsin indicate that milfoil weevils are widely distributed throughout Wisconsin's lakes (Jester, et. al. 1997).

One reason that native weevil populations may be able to impact Eurasian watermilfoil in some lakes but not others may have to do with a lake's surface are and its wind fetch. Recent studies conducted by Aquatic Biologists, Inc. staff (as yet unpublished) concluded that a relationship might exist between wind energy and the ability of milfoil weevils to affect a decline in Eurasian watermilfoil. It appears that lakes must be large enough (300 acres +) to generate sufficient wave action before milfoil stems burrowed by weevils will collapse. Thus weevils may be able to impact milfoil in White Lake due to it large surface area. If a naturally occurring weevil population does not exist in White Lake, weevil stocking may yet be a viable management option. However this option should be considered a last resort only if milfoil becomes too widespread to manage with other means. On those lakes where weevils have been able to impact Eurasian watermilfoil, the density may have been reduced enough to allow native species to survive, thus maintaining ecological values, but the milfoil is still generally considered to be at nuisance levels by lake users (Sheldon, 1995).

Herbicides have been the most widely used and most successful tools for controlling Eurasian watermilfoil. The two herbicide groups most commonly employed are fluridone (Avast®, Sonar®) and 2,4D (Aquacide®, Aquakleen®, Navigate®, Weedar 64®). Whole-lake Sonar® treatments have been done on several Wisconsin Lakes. While initial results were encouraging (species selectivity, 95-100% initial control), continued monitoring found that desired long-term control was not achieved (Cason, 2002). 2,4D herbicides, on the other hand, have been used on hundreds of Wisconsin Lakes with good success.

The E.P.A. lists 2,4D as a Class D herbicide, which means that there is no data to support that it is harmful to humans. The E.P.A. product label lists no water use restrictions for swimming or fish consumption following treatment with 2,4D either (**Appendix 2**). 2,4D is a biodegradable organic herbicide that does not persist in the environment in any form. Applied correctly at prescribed rates, 2,4D is highly selective to Eurasian watermilfoil. 2,4D has been used on thousands of lakes throughout North America. To date 2,4D treatments have been the single most effective Eurasian watermilfoil control program. In fact, the number of lakes in Michigan having Eurasian watermilfoil problems has actually declined as a result of 2,4D use (Pullman, 1993). The greatest disadvantage of 2,4D treatments is that they rarely produce 100% control. As a granular formulation, the product tends to work only where applied. Unnoticed and untreated plants may eventually grow to dense beds if left unchecked. Factors such as pH and plant maturity may also reduce treatment efficacy. Several follow-up treatments, in-season or on subsequent years, may be needed to reduce Eurasian watermilfoil to target levels. While there are no panaceas for Eurasian watermilfoil control, available evidence suggests that 2,4D treatments will be the most viable control option for White Lake.

There are several methods that are commonly used for purple loosestrife control: digging and hand pulling, cutting, herbicide treatments and biological controls. Digging and hand pulling are most effective for small infestations. Individual property owners are encouraged to use this method if they are able. Cutting involves removal and destruction of flowers and seed heads to inhibit plant propagation. Since cut plants tend to re-grow and since seeds present in the soils can sprout new plants, this method will need to be done for a number of years before desired control is achieved. Herbicide treatments are the easiest and most economical of methods. The most commonly used herbicide is glyphosate (Eagre®, Rodeo®). This product rapidly biodegrades upon contact with soil or water. There are no water use restrictions following treatment. Because it is non-selective, each individual plant must be sprayed, as opposed to broadcast applications. Glyphosate is extremely effective in controlling purple loosestrife. It is also a low cost treatment. The recently approved herbicide, triclopyr (Renovate®), may be considered the tool of choice for purple loosestrife control (Baumann, et.al., 2000). This herbicide is as effective as glyphosate, but is more selective to purple loosestrife, and can be applied at a lower cost.

The biggest disadvantage of herbicide treatments though, is that seeds in the soil will sprout new plants, requiring annual treatments for a number of years before desired control is achieved. Biological controls using several species of beetles and a weevil from Europe, by far show the most promise for long-term control of purple loosestrife (WDNR PUB-WT-276 2001). Studies have shown that these insects are entirely selective to purple loosestrife and have been effective in reducing purple loosestrife to levels where native plants can regenerate. The Wisconsin Department of Natural Resources offers two options for using beetles as a biological control agent. Beetles can be purchased outright, or beetle rearing kits can be supplied to organizations willing to raise their own. This biological control option would be well suited for White Lake given its heavy purple loosestrife infestation, and should be given top consideration as a management option.

3.152 control of native plants for navigation

Native macrophytes in shallow, fertile lakes may commonly grow to densities where boating uses are impaired. White Lake has had a history of nuisance aquatic plant growth. However these same plants are responsible for the lake's water quality as well as the hunting and fishing opportunities available on the lake. Therefore management activities directed at controlling native plants should have a minimal impact. The most effective way of ensuring this is to limit plant control activities to high-use areas, such as designated boating lanes.

Two methods are commonly used to maintain boating lanes: herbicide treatments and mechanical weed harvesting. Non-selective herbicide treatments typical kill all species in the treatment area. This method is usually much less costly than weed harvesting, however it is less precise. Herbicide drift may impact plants outside the target area, or may dilute products to ineffective levels. Anti-drift agents, such as PolyAn®, may reduce this problem, but on large, wind-swept lakes, such as White Lake, it may still be a concern. Mechanical harvesting, on the other hand, has the advantage of precision control. It also does not kill plants, but simply mows them; thus ecological impacts are minimized. Given these considerations, use of the mechanical weed harvester should continue as the method for maintaining navigation lanes on the lake.

3.152 plant control along individual frontages

Many lakeshore property owners want swimming areas that are free of vegetation along their frontage, or reduced aquatic plant growth in boat mooring areas. This is certainly understandable, as boating and swimming are reasons why many people own lakefront property. However, lakeshore property owners should be aware that near-shore aquatic plants are often critical habitat for fish and wildlife, and play an important role in stabilizing banks and preventing erosion. Therefore human disturbances of these habitats should be minimized.

State statues have provisions allowing riparian property owners to manage aquatic plants along their frontage. The three most commonly used methods are herbicides, benthic barriers and manual removal. Property owners must acquire DNR permits before any herbicides or algaecides are applied to their lake frontage. All liquid herbicides must be applied by certified aquatic pesticide applicators. Treatment areas for native plants shall not exceed 50 feet in width by 150 feet in length. Herbicide treatments are the most costly method for individual frontages. It is also difficult to effectively treat small sites with herbicides due to product dilution and drift. These considerations make herbicide treatments the least desirable option.

Benthic barriers or bottom screens smother plants and prevent them from resprouting. DNR permits are required before placing these types of structures on lakebeds. The use of benthic barriers is made less desirable by the fact that it is a very high maintenance option. Barriers require regular removal and cleaning or else plants will quickly take root in the sediments that collect on top of them.

Physical removal of plants is usually done with the aid of hand cutters and rakes. While this method is labor intensive, it is the least expensive, most convenient, most precise and often most effective method. Recent administrative rule changes allow riparian property owners to manually remove aquatic plants in 35 foot wide path extending from shore without a permit. These characteristics make this the preferred plant management option for individual property owners.

3.2 Water quality parameters

While a number of parameters may be tested to evaluate the water quality of a lake, the three most commonly assessed parameters are chlorophyll *a* concentration, total phosphorus and Secchi disc depth. Another important parameter that can be used to assess the trophic state or relative age of a lake is dissolve oxygen concentration. While no single parameter can provide reliable gauge of lake water quality, taken collectively over time, these parameters form an accurate basis for comparative analysis. The results of these tests taken through the 2002 season are shown in **Table 6**.

3.21 Chlorophyll *a*

Chlorophyll is a pigment found in all plants. It is the only pigment that can convert light to chemical energy in photosynthesis. Chlorophyll *a* concentrations are often used to gauge algal abundance. Because algal abundance is often related to nutrient inputs in a lake, chlorophyll *a* can be a good indicator of water quality. Average chlorophyll *a* readings were low for White Lake, indicating that the bulk of plant biomass was tied up in macrophytes. These values are quite good considering the morphological characteristics of the lake. **Figure 3** ranks White Lake on a chlorophyll *a* water quality index. White Lake ranked in the "good" range.

3.22 Secchi disc depth

A Secchi disc is an eight-inch diameter black and white plate that is lowered into the water on a calibrated cord. The depth at which the disc is last visible is used as the standard measure of water clarity. Water clarity is often a function of suspended solids and/or phytoplankton density, and is thus often related to water quality. Secchi disc readings were fairly stable throughout the season on White Lake. White Lake ranks in the "fair" range on the Secchi disc depth water quality index shown in **Figure 4**. Theses results are not surprising considering the large wind fetch and shallow waters that make White Lake more susceptible to sediment resuspesion. Without abundant macrophyte growth, White Lake would no doubt rank in the "very poor" range.

3.23 Total Phosphorus

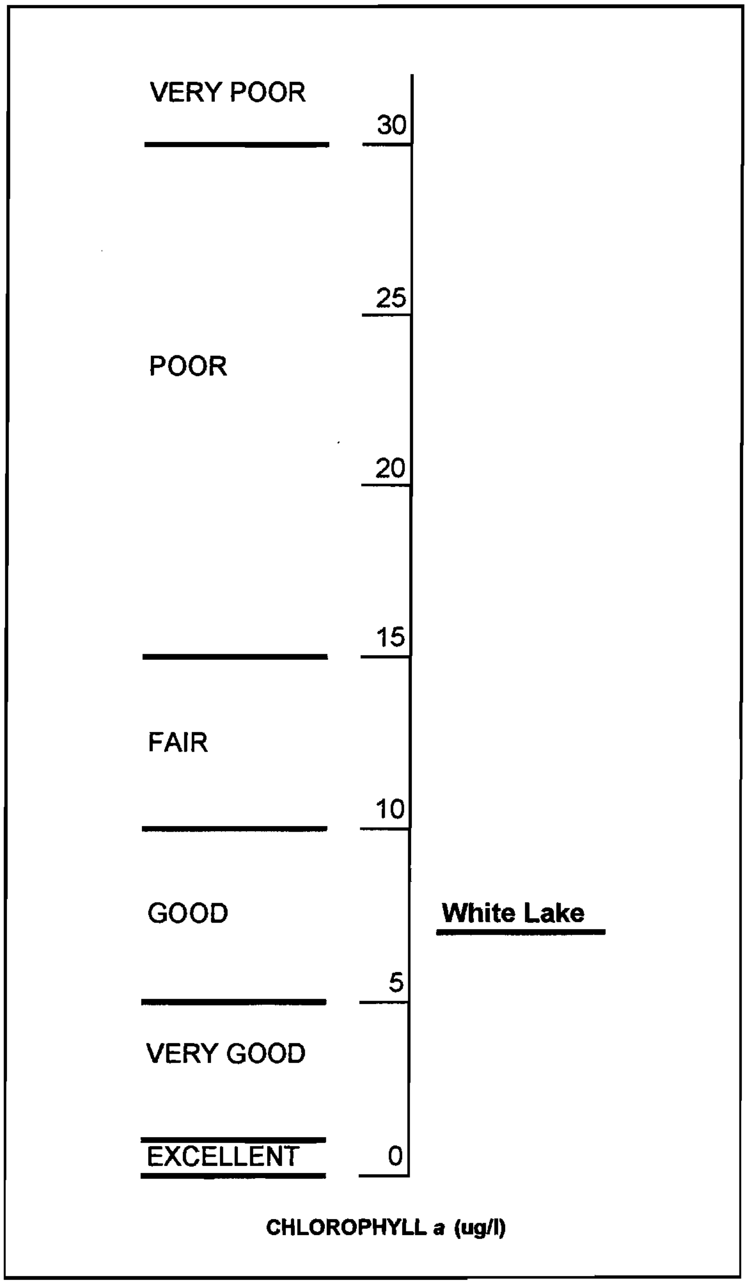
Phosphorus is the most common growth-limiting element for aquatic plants. Results indicate that it is indeed the limiting factor in plant growth in White Lake. Total phosphorus is a measure of available phosphorus plus phosphorus tied up in living cells. Results indicate that little phosphorus was available for algae growth. Again, this is

Table 6. 2002 White Lake survey water analysis data collected one foot below the surface over the deepest point of the lake.

				sample date		
parameter	unit	19-Apr-02	3-Jun-02	8-Aug-02	4-Nov-02	Average Value
alkalinity	mg/l	97				97
chloride	mg/l	9.5				9.5
chlorophyll *a*	ug/l	L.A.	L.A.	3.72	9.63	6.68
color	s.u.	15				15
conductivity	um/cm	234				234
dissolved oxygen - bottom	mg/l	2.0	1.5	0.2	1.7	1.4
dissolved oxygen - surface	mg/l	8.7	7.9	8.9	12.4	9.5
ammonia as N	ug/l	36				36
Kjeldahl nitrogen	ug/l	970				970
nitrate + nitrite as N	ug/l	34	N.D.	N.D.	N.D.	8.5
total phosphorus	ug/l	26	20	23	18	22
dissolved phosphorus	ug/l	N.D.				N.D.
nitrogen / phosphorus ratio		39 / 1				45 / 1
pH, field	s.u.	8.4	8.3	9.4	8.2	8.6
pH, lab	s.u.	8.09		9.26		8.68
secchi disc depth	ft.	6.0	8.2	7.7	6.2	7.0
temperature - bottom	C	17.6	15.5	23.2	3.1	14.9
temperature - surface	C	17.7	15.4	23.6	3.3	15.0
total dissolved solids	mg/l	132				132
total suspended solids	mg/l	4				4
weather conditions		windy	after heavy rain	calm	calm	
air temperature	C	12.1	14.8	20.9	3.3	12.8
cloud cover	%	90	100	0	0	48
gauge height	ft.	5.59	5.56	5.00	5.00	5.29

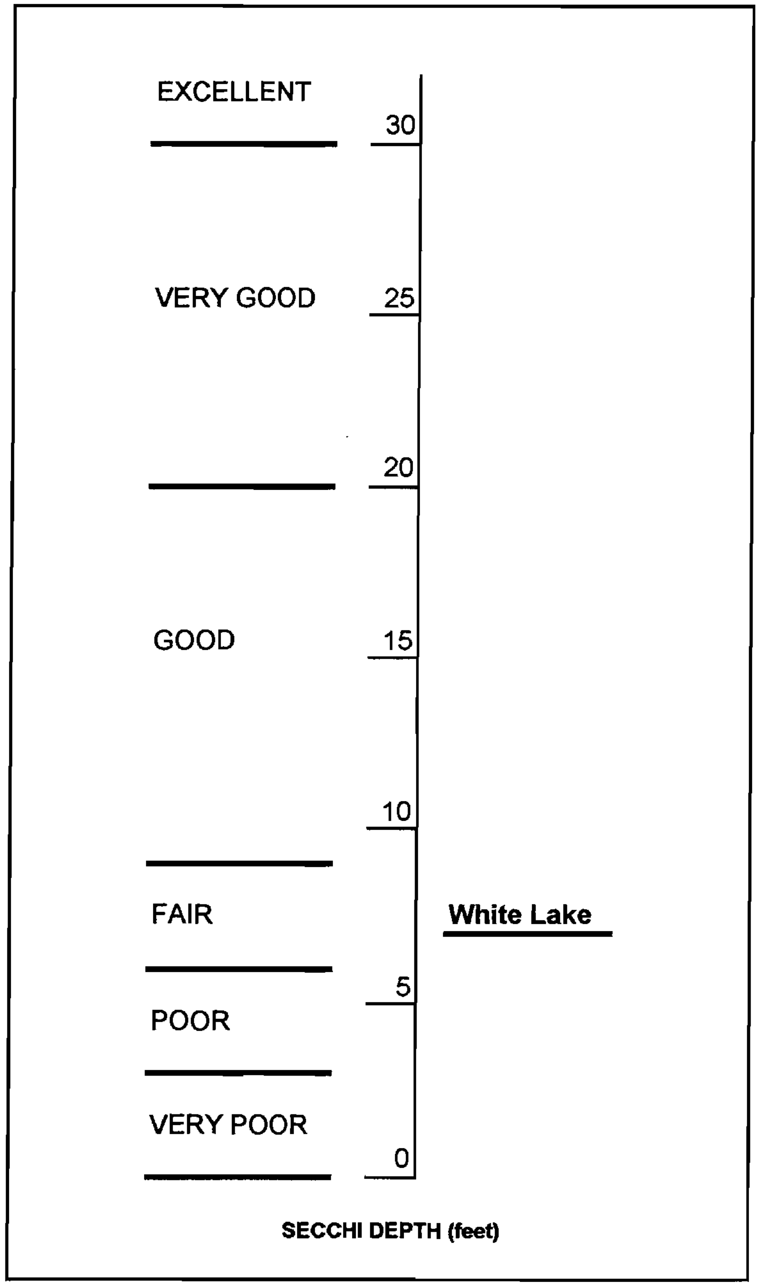
N.D. = not detected, concentration below limit of detection
L.A. = laboratory accident, test not performed.

Figure 3. Chlorophyll *a* water quality index.



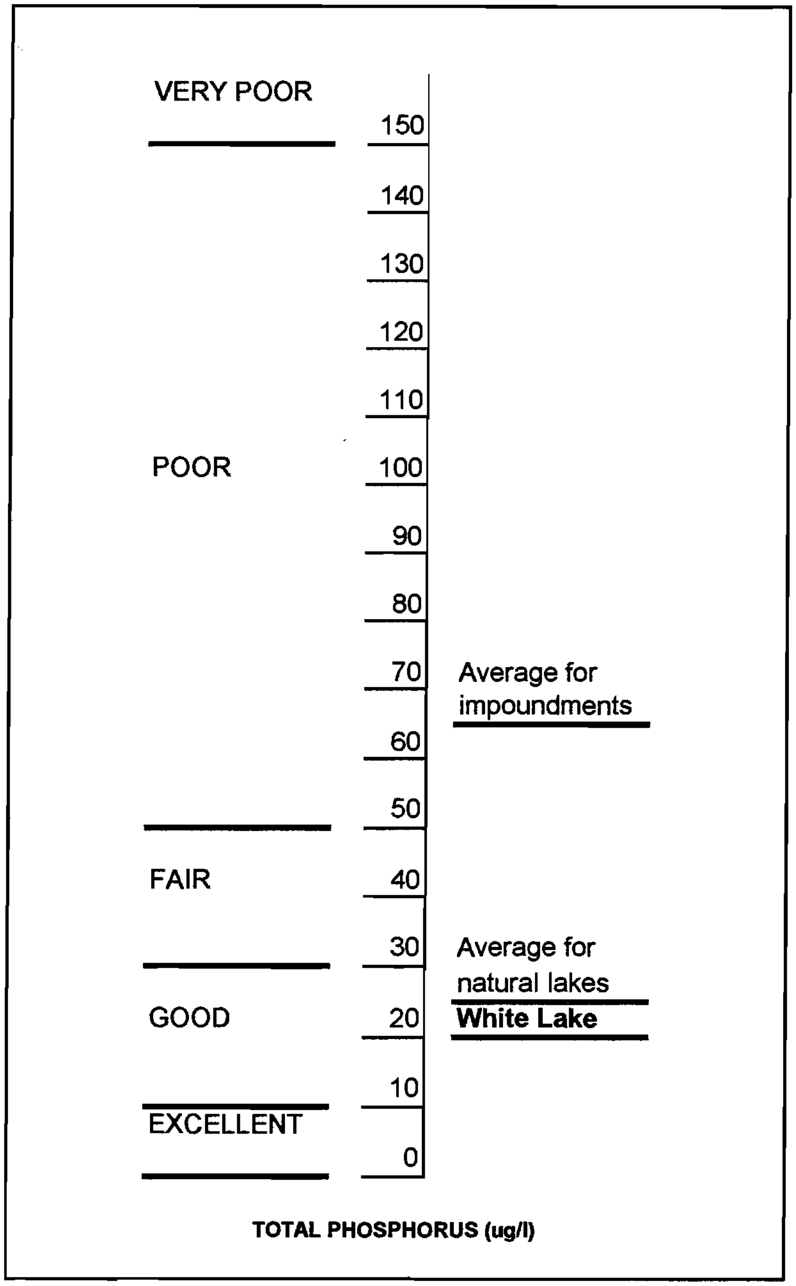
Adapted from Shaw, et. al. (2000).

Figure 4. Secchi disc depth water quality index.



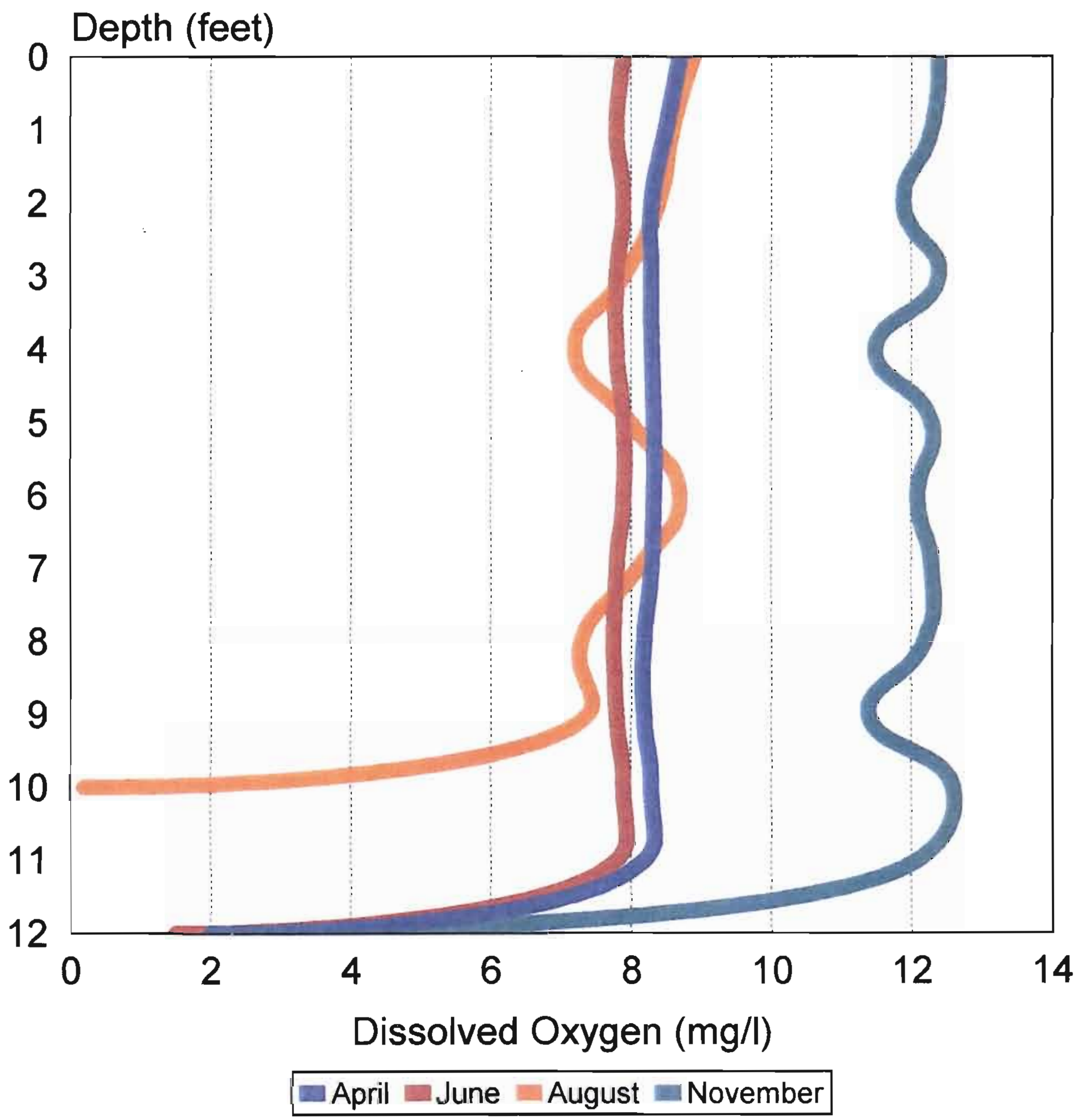
Adapted from Shaw, et. al. (2000).

Figure 5. Total phosphorus water quality index.



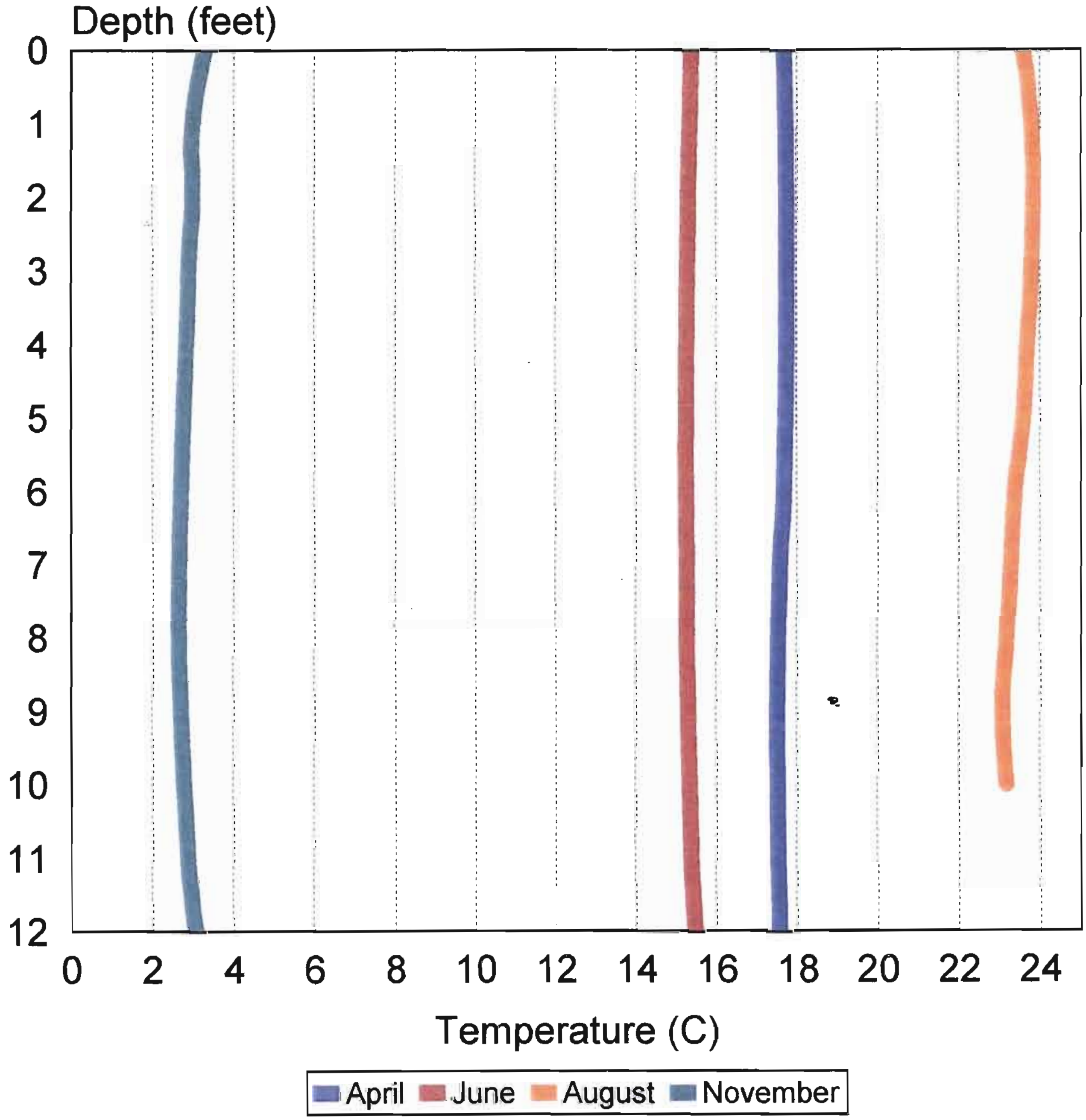
Adapted from Shaw, et. al. (2000).

Figure 6. White Lake 2002 dissolved oxygen profiles.



note: August reading was taken at 10 ft. depth

Figure 7. White Lake 2002 temperature profiles.



note: August reading was taken at 10 ft. depth directly related to the abundant macrophyte growth found in the lake. White lake ranks above average for natural lakes and well above average for impoundments (**Figure 5**).

3.24 Dissolved oxygen and temperature

Dissolved oxygen and temperature data are taken together, as dissolved oxygen saturation concentrations are inversely related to temperature. Seasonal profiles for these two parameters taken from White Lake are shown in **Figures 6** and **7**. This inverse relationship is apparent in the November readings when water temperatures were at their coolest and dissolved oxygen readings were at their highest.

In most cases, more productive lakes will have a greater oxygen deficit in the depths than less productive lakes. Therefore the productivity of a lake can often be estimated from the nature of its oxygen curve (Ruttner, 1953). There was a distinct oxycline apparent on each sampling date. The very bottom layer of the water column was nearly devoid of oxygen in each case. This is evidence of White Lake's productivity. The oxygen deficit in the depths is due to a rich layer of organic sediment and a correspondingly high bacterial oxygen demand. The fact that this oxycline remained near the bottom throughout the season is most likely a function of the lake's shallowness and wind fetch. Wave action and atmospheric diffusion were probably able to maintain oxygen throughout the season. When the lake is covered with ice though, it will no-doubt continue to be at considerable risk from low dissolved oxygen levels.

3.3 Water chemistry analysis

Along with the parameters discussed in section 3.2, eleven additional water chemistry parameters were tested during April after the spring turnover. The results of these analyses are given in **Table 6**. Averaged results from the 2002 are compared to water chemistry analysis results from the 1991 survey in **Tables 7** and **8.** A description of each parameter and the implications of the results found for White Lake are discussed in the following paragraphs.

3.31 Phosphorus

Phosphorus has been found to be the nutrient that limits plant and algae growth in more than 80% of Wisconsin lakes. As phosphorus levels increase, so does plant productivity. Failing septic systems, detergents, lawn and crop fertilizers soil erosion and feedlot runoff are all major sources of phosphorus found in lakes. Phosphorus analysis done in White Lake included total phosphorus and dissolved phosphorus. Dissolved phosphorus is phosphorus that is in solution in the water column that is readily available for plant growth. Total phosphorus is dissolved phosphorus plus the phosphorus found in living cells, such as algae, that are suspended in the water column. Total phosphorus therefore, is more often a better estimator of lake productivity.

As shown in **Figure 5**, total phosphorus concentrations were considered good for White Lake. Concentrations did not vary considerably throughout the season, nor had they changed much from the 1991 survey.

3.32 Nitrogen

Next to phosphorus, nitrogen is the nutrient most likely to contribute to excessive weed and algae growth. Nitrogen can enter lakes from groundwater, surface runoff and precipitation. In drainage lakes though, nitrogen concentrations most often correspond to local land uses. Nitrogen analyses for White Lake included ammonia, nitrate + nitrite and Kjeldahl nitrogen, which is organic nitrogen plus ammonia. Total nitrogen is determined by adding nitrate + nitrite to Kjeldahl nitrogen. When the ratio of total nitrogen to total phosphorus is less than 15:1, a lake is considered nitrogen limited. When this occurs, additions of nitrogen to the lake can lead to increases plant productivity.

The nitrogen : phosphorus ratio found for White Lake was 45:1 in 2002 and 62:1 in 1991, indicating that the lake is clearly phosphorus limited. Thus, nitrogen concentrations are not a concern for White Lake.

3.33 pH

pH is the negative logarithm of the H+ (hydrogen ion) concentration. The product of H+ and OH- (hydroxyl) ions present in water is a constant. This constant is known as the dissociation constant of water. Theoretically, pure water has equal concentrations of H+ and OH- and is neutral in reaction. Neutral water has a pH of 7. When OH- becomes greater than H+, pH rises and water is considered basic or alkaline. When H+ becomes greater than OH-, water is considered acidic. Since pH is a logarithmic scale, an increase of 1.0 in pH equals a ten-fold increase in OH- concentration. Thus water with a pH of 9 is 100 times more alkaline than water with a pH of 7.

The pH of lakes is affected by many factors: Rainwater is acidic and can lower pH. However this reaction is often buffered by calcium bicarbonate. Plant productivity will raise pH. Calcium bicarbonate is actively broken down by plants in the reactions of photosynthesis. The release of OH- from this reaction raises pH (Ruttner, 1953).

Extremes in pH can have negative effects on aquatic life. In Wisconsin, most pH – related problems with lakes are due to low pH. Low pH can inhibit fish spawning and even cause fish kills. Low pH can also lead to the precipitation of mercury, zinc and aluminum from bedrock. These metals can cause health problems for fish and animals that feed upon them, notably: loons, eagles and humans (Shaw, et.al., 2000). Fortunately the pH found for White Lake is high, and these are not concerns. The high pH found in White Lake is partly the result of local geology, as area lakes tend to be alkaline, and partly the result of plant productivity. From the results shown in **Table 6** we see that pH is directly related to water temperature – as is plant growth. PH in spring is 8.4, but dips to 8.3 during an unseasonably cold June. PH then rises to 9.4 in August when water temperature and plant growth are at their peak, and then drops back to 8.2 in November as water cools and plant productivity diminishes. Because the pH of White Lake had not changed markedly from 1991, it can be inferred that plant productivity had not increased either.

3.34 Alkalinity

Alkalinity is a measure of the calcium carbonate concentration of water. In reactions where acid is added to water containing calcium bicarbonate in solution, bicarbonates combine with hydrogen ions thereby limiting changes in pH. Not until additions of acids have exhausted available carbonates will pH values drop sharply. This buffering capacity is very important for organisms in aquatic environments in its ability to prevent major fluctuations in pH. Not surprisingly, alkaline lakes tend to have a greater abundance of aquatic life than acidic lakes.

Lakes that have an alkalinity of 10 mg/l or less are considered moderately to highly susceptible to acid rain. With an alkalinity of 97 mg/l, White Lake is considered non-sensitive to acid rain.

3.35 Chloride

While chloride ions are essential for plant photosynthesis, free chlorine is highly toxic to living cells. Chlorine kills by oxidation of cell membranes, but the process quickly converts it to harmless chloride ions. Thus chloride concentration is used to identify chlorinated waste discharges in lakes. Other sources of chloride are septic effluent, feedlot runoff, lawn fertilizers and road salts. Elevated levels of chloride indicate that these sources may be affecting the lake.

Chloride occurs naturally in the surface waters of Wisconsin. At typical concentrations it is not harmful to aquatic life. Typical values for Waupaca County Lakes are 3 – 10 mg/l. at 9.5 mg/l, White Lake falls within this range.

3.36 Color, dissolved solids

Color is a measure of dissolved organic compounds present in water. It is measured in a laboratory from filtered samples and expressed as standardized units (s.u.). Sources of water color commonly include byproducts of algae blooms and tannins leached from bogs. Highly colored water limits the depth at which photosynthesis can take place. Thus color is an important parameter that can affect lake productivity. The color value for White Lake, 15 units, was very low, however.

3.37 Suspended solids

Suspended solids are a measure of a lake's turbidity. Suspended solids can include clay particle and decaying plant matter as well as living organisms such as zooplankton and phytoplankton. More productive lakes and lakes having large watersheds with erodeable soils tend to have higher concentrations of suspended solids. Suspended solids and dissolved solids affect Secchi disc depth, and are thus determinants for a major water quality parameter. Suspended solids concentrations for White Lake were very low.

3.38 Conductivity

The ability of water to conduct an electrical current is called conductivity. Conductivity is dependant upon the concentration of inorganic compounds suspended in the water column. Like chloride, conductivity can be used to determine if human activities are influencing water quality. A general guideline is that conductivity should be about two times the hardness of water. Higher concentrations may indicate sources of pollution. The conductivity of White Lake was 2.4 times the hardness, and is thus not an area of concern.

3.4 Water and nutrient budgets

Total phosphorus concentration, velocity, flow and other parameters were determined for the White Lake inlet creek (**Table 9**) and the outlet creek (**Table 10**) in order to calculate water and phosphorus budgets. Lake volume and mean depth were calculated from transect data (**Appendix 1**). Water recharge /discharge rates were based on an estimated 120 days of flow / year. Annual precipitation was based on USDA records for Waupaca County. The following results were obtained:

Lake area	1026 acres
Mean depth	3.5 feet
Lake volume	3591 acre-feet
Water volume entering lake from inlet creek	1524.1 acre-feet
Water volume leaving lake from outlet creek	5377.3 acre-feet
Water volume entering lake from precipitation	2698.4 acre-feet
Total phosphorus entering lake from inlet creek	640.1 lbs / year
Total phosphorus leaving lake from outlet creek	645.3 lbs / year

It can be assumed that three sources of water contribute to White Lake: surface water inflow (inlet creek), precipitation and groundwater recharge. It can also be assumed that there are three main sources of water loss for White Lake: surface water drainage (outlet creek), evaporation, and groundwater discharge. The unknown variables are groundwater flow and volume and evaporation rates. Groundwater impacts are difficult to estimate. Evaporation is nearly impossible to calculate. It can be assumed however, that water input approximately equals water output. Or else White Lake would not exist.

We know that at least 4222.5 acre-ft are entering the lake via surface water and precipitation, and that 5377.3 acre-ft are leaving via the outlet creek. Assuming 0% evaporative loss, we can then determine that at least 1154.8 acre-ft of water enter the lake via groundwater. However evaporation is most certainly an important factor in the water budgets of such a large, shallow lake. If we assume only a 1% daily evaporation rate for the 240 days per year when White Lake is free of ice, we then have and evaporative loss of 8618.4 acre-ft / year. Based on this evaporation rate, groundwater would need to contribute at least 9773.2 acre-ft / year. Thus while exact numbers are not possible, we can infer that groundwater is the primary water source for White Lake.

Using these figures, we can also estimate the retention time of the lake. Retention time, also known as residence time, is the average length of time that water resides in a lake. Retention time is determined by dividing the volume of water leaving the lake by the

Table 7. A comparison of averaged water quality parameters from White Lake between 1991 and 2002. Data collected one foot below the surface over the deepest point of the lake.

parameter	unit	1991	2002
alkalinity	mg/l	95	97
chlorophyll *a*	ug/l	5	6.68
conductivity	um/cm	193	234
dissolved oxygen - bottom	mg/l	6.1	1.4
dissolved oxygen - surface	mg/l	7.5	9.5
ammonia as N	ug/l	43	36
Kjeldahl nitrogen	ug/l	1067	970
nitrate + nitrite as N	ug/l	4	9
total phosphorus	ug/l	18	22
dissolved phosphorus	ug/l	3	N.D.
nitrogen / phosphorus ratio		62.4 / 1	45 / 1
pH, field	s.u.	8.7	8.6
pH, lab	s.u.	8.20	8.68
secchi disc depth	ft.	8.5	7.0
temperature - bottom	C	16.9	14.9
temperature - surface	C	17.9	15.0

N.D. = not detected, concentration below limit of detection

Table 8. A comparison of averaged water quality parameters from the White Lake inlet between 1991 and 2002.

parameter	unit	1991	2002
dissolved oxygen	mg/l	4.5	5.7
nitrate + nitrite as N	ug/l	11	N.D.
total phosphorus	ug/l	120	80
pH, field	s.u.	7.6	7.3
temperature	C	23.6	13.0

N.D. = not detected, concentration below limit of detection

Table 9. 2002 White Lake survey water analysis data collected from the inlet creek below the road culvert.

		sample date				
parameter	unit	19-Apr-02	3-Jun-02	8-Aug-02	4-Nov-02	Average Value
dissolved oxygen	mg/l	10.3	4.2	1.8	6.6	5.7
nitrate + nitrite as N	ug/l	N.D.	N.D.	N.D.	N.D.	N.D.
total phosphorus	ug/l	82	73	118	46	80
pH, field	s.u.	7.6	7.2	7.3	7.2	7.3
temperature	C	15.4	11.8	19.9	4.8	13.0
velocity	ft./s	1.7	0.9	0	0	0.7
flow	cfs	8.1	4.7	0	0	3.2
weather conditions		windy	after heavy rain	calm	calm	
air temperature	C	12.1	14.8	20.9	3.3	12.8
cloud cover	%	90	100	0	0	48

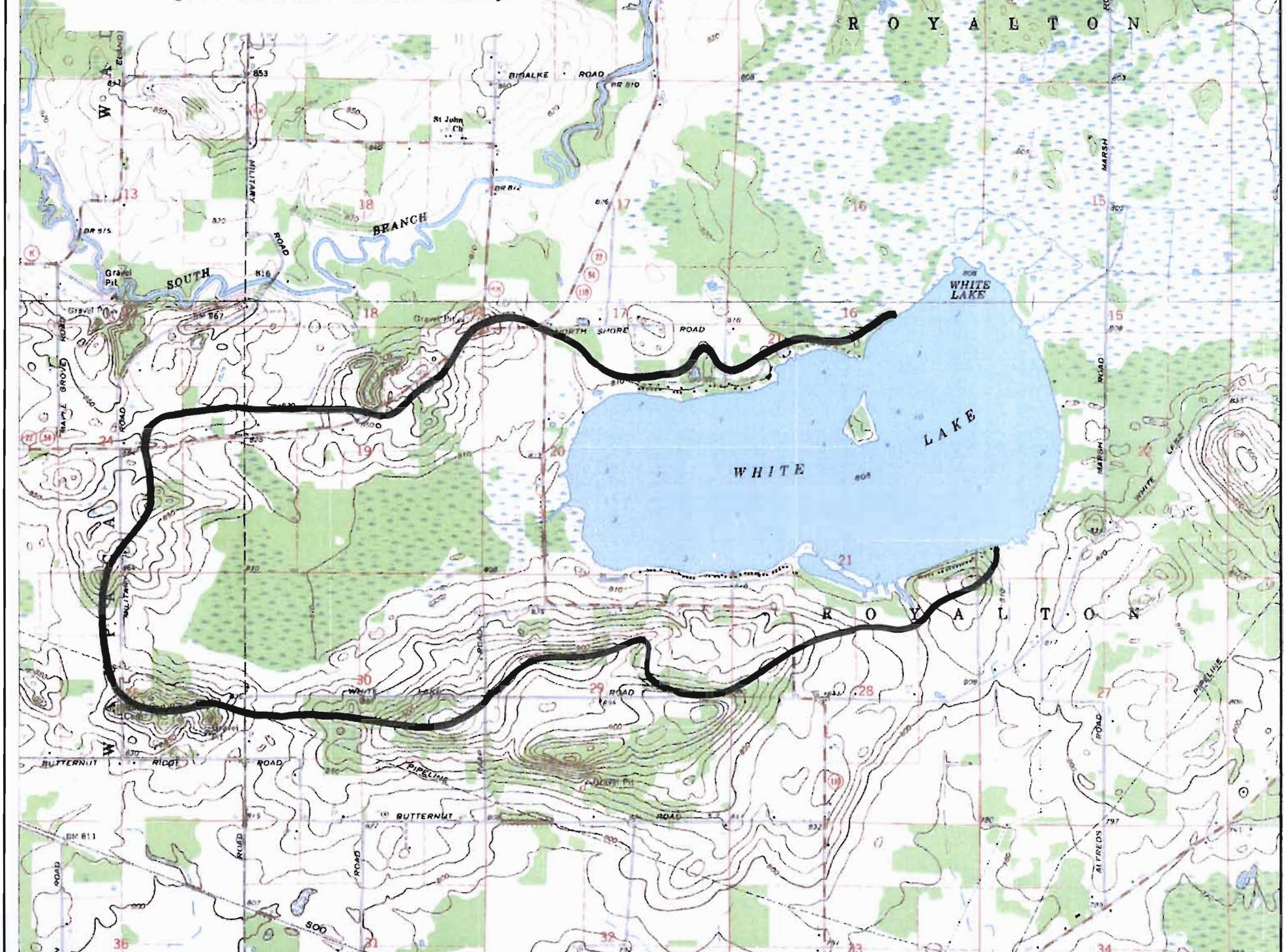
N.D. = not detected, concentration below limit of detection

Table 10. 2002 White Lake survey water analysis data collected from the outlet creek below the spillway.

		sample date				
parameter	unit	19-Apr-02	3-Jun-02	8-Aug-02	4-Nov-02	Average Value
dissolved oxygen	mg/l	8.7	8.1	3	5.5	6.3
nitrate + nitrite as N	ug/l	19	N.D.	69	N.D.	22
total phosphorus	ug/l	28	19	122	153	81
pH, field	s.u.	8.1	8.1	7.6	7.3	7.8
temperature	C	16.9	15.1	22.2	5.0	14.8
velocity	ft./s	11.2	3.9	0	0	3.8
flow	cfs	33.6	11.6	0	0	11.3
weather conditions		windy	after heavy rain	calm	calm	
air temperature	C	12.1	14.8	20.9	3.3	12.8
cloud cover	%	90	100	0	0	48

N.D. = not detected, concentration below limit of detection

Figure 8. White Lake watershed boundary.



total lake volume. The retention time for White Lake then, would be 94 days or less. In other words, the volume of White Lake turns over at least 3.9 times per year.

Phosphorus inputs in a lake are derived from primarily the watershed. Surface waters are the primary vehicles for phosphorus loading. Less common sources of phosphorus loading are groundwater (including septic leachate) and precipitation. Since phosphorus entering the lake via the inlet creek nearly equals the phosphorus exiting the lake via the outlet creek, phosphorus loading from the watershed does not appear to be a concern.

3.5 Watershed analysis

The total watershed area for White Lake was determined to be 1869 acres, or 2.92 square miles. The majority of the watershed is located in a valley to the west of the lake. The gradual slopes surrounding this valley drain into a swamp forest. This swamp forest in turn, is drained by the intermittent creek that feeds into White Lake (**Figure 8**). The following land uses and cover types and their acreage were determined for the White Lake watershed:

Upland forest	674 acres	(36.1%)
Crop land	546 acres	(29.2%)
Swamp forest	439 acres	(23.5%)
CRP	85 acres	(4.5%)
Residential	68 acres	(3.6%)
Pasture land	37 acres	(2.0%)
Shrub carr	20 acres	(1.1%)

It has been said that a lake is a product of its watershed. The excellent water quality found in White Lake then, may have a lot to do with characteristics of the watershed. While 31.2% of the watershed is used for agriculture, most of the surface water that drains from this land is filtered through swamp forest and shrub carr (shrub swamp) before entering the lake. These wetland habitats act as a buffer that captures nutrients and sediments before they can affect the lake. Without these natural filters, much of the water quality and fish and wildlife values of the lake would be lost. The 68 acres of residential land in the watershed occur primarily along the north and south shores of the lake. These areas have the greatest potential to impact water quality.

3.6 Fishery assessment

3.61 Fish community characteristics

The fishery surveys conducted by the Department of Natural Resources during 2002 included spring fyke netting, summer mini-fyke netting and fall boom-shocking. The preliminary results of these surveys are combined and presented in **Table 11**. The most abundant fish encountered was northern pike *(Esox lucius)*. In fact, northern pike outnumbered all panfish species combined. While a few large pike were caught, the vast majority were small and averaged only 17.1 inches long. Largemouth bass *(Micropterus salmoides)* were present in fair numbers and achieved good sizes (up to 20.0 inches). Panfish species, including bluegill *(Lepomis macrochirus)*, pumpkinseed *(L. gibbosus)*, black crappie *(Pomoxis nigromaculatus)* and yellow perch *(Perca flavescens)*, were present in low numbers but achieved above average sizes. Walleye *(Stizostedion vitreum)* were also present in low numbers but achieved good sizes. Of interest were several small walleye that were captured. These juvenile fish did not correspond to any recent stocking efforts and may be the result of natural reproduction.

One of the most striking findings of this survey was that important forage species, such as minnow (Cyprinidae) and suckers (Catostomidae), were scarce to absent. Four carp *(Cyprinus carpio)* were captured during the survey. This species had been the target of a massive eradication effort in the past. Should a resurgence of carp occur in White Lake, serious negative environmental impacts could result. The only positive of the overabundant northern pike may be that they are preventing carp from regaining a foothold.

Perhaps the most significant finding was that juvenile fish of all species were plentiful in the summer and fall surveys but were scarce in the spring survey. This suggests that juvenile fish experienced high over-winter mortality. This is most likely the result of predation. A likely scenario is that low winter dissolved oxygen levels forced all fish to congregate around the aerators. With all of these juvenile fish in close confinement with an overabundant predator population, heavy mortality is sure to result.

3.62 Habitat assessment

Fish habitat assessments were done throughout the season in order to identify habitats used for spawning and nursery areas by the different fish species. Primary fish spawning areas are identified in **Figure 9**. There was an abundance of good spawning habitat for bluegill, pumkinseed and largemouth bass. These were primarily the hard-bottomed areas along the developed shores, but also included areas around the island and in bulrush beds. Crappie and perch spawned in the protected channels along the south shore. These channels contained chara beds and abundant submerged wood. Northern pike spawned in emergent vegetation, primarily along the northeast corner of the lake. Walleyes attempted to spawn around the island and along a rocky area off of the south shore.

The expansive beds of emergent vegetation on west and northeast ends of the lake provided outstanding nursery areas for a number of juvenile fish species. Juvenile bluegill, yellow perch, largemouth bass and northern pike were all observed in abundance in these areas.

White Lake clearly has an abundance of quality fish habitat. Spawning and nursery habitat are not limiting the abundance of most species. The one exception may be walleye. Walleye prefer wind-swept rocky shorelines as spawning habitat. This type of habitat is limited in White Lake.

A literature review of spawning, rearing and foraging habitat requirements, habitat improvement techniques and important water quality parameters was done for the fish species encountered in White Lake. The results are shown in **Table 12**.

3.63 Stocking history

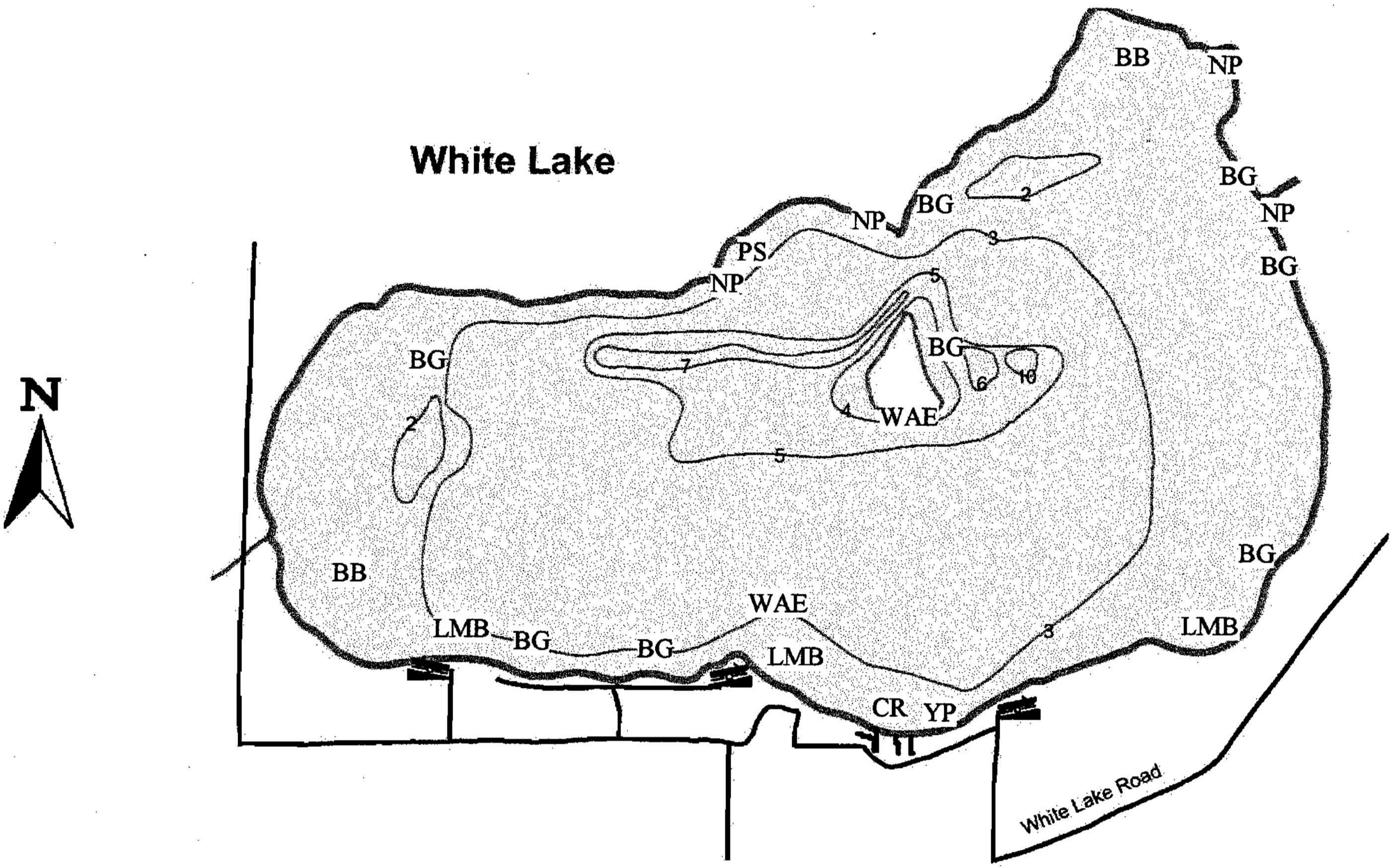
Because White Lake has had a history of winter fish kills and limited recruitment of juvenile fish into adult stock, it has an extensive stocking history. The stocking history from 1934 to 1990 is presented in **Table 13**. At least 10 different species were stocked. The most common were northern pike and walleye. Of these species stocked, smallmouth bass *(Micropterus dolomieui)*, golden shiner *(Notomegonus crysoluecas)*, white sucker *(Catostomas commersoni)* and fathead minnow *(Pimephales promelas)*, did not appear to maintain self-sustaining populations.

Table 11. Preliminary results of the 2002 fishery survey conducted on White Lake.

Species			Length (inches)		
Common Name	**Scientific Name**	**Total Catch***	**Min.**	**Max.**	**Ave.**
Northern Pike	*Esox lucius*	3241	9.9	35.0	17.1
Bluegill	*Lepomis macrochirus*	1998	0.5	10.2	7.5
Largemouth Bass	*Micropterus salmoides*	834	5.4	20.0	16.0
Yellow Perch	*Perca flavescens*	520	2.5	13.3	9.9
Pumpkinseed	*Lepomis gibbosus*	294	0.5	8.5	7.3
Brown Bullhead	*Ictalurus nebulosus*	228	12.6	14.0	13.4
Walleye	*Stizostedion vitreum*	165	8.8	26.2	18.7
Black Crappie	*Pomoxis nigromaculatus*	34	7.7	12.2	10.3
Yellow Bullhead	*Lepomis natalis*	18			
Common Carp	*Cyprinus carpio*	4			
Central Mudminnow	*Umbra limi*	2			
Green Sunfish	*Lepomis cyanellus*	2			
Common Shiner	*Notropis cornutus*	1			
Emerald Shiner	*Notropis atherinoides*	1			
Golden Shiner	*Notomegonus crysoleucas*	1			

* Total catch includes fyke netting, boom-shocking and mini-fyke netting.

Figure 9. Map of fish spawning areas.



BB = brown bullhead
BG = bluegill
CR = black crappie
LMB = largemouth bass

NP = northern pike
PS = pumkinseed
WAE = walleye

4.0 Conclusions

4.1 Summary of survey findings

White Lake was found to contain a rich diversity of aquatic plants. This diversity of plants provides many of the fish, wildlife and water quality values found on the lake. Areas of concern include control of two exotic species found: Eurasian watermilfoil and pl, and management of dense beds of native plants to maintain boating access. All physical and chemical parameters analyzed indicated good water quality. These parameters did not vary substantially with seasonal events. Nor had parameters changed markedly from those found during the 1991 survey. The good water quality was attributed to the diversity and abundance of aquatic plants and the characteristics of the watershed.

Wetlands in the White Lake watershed protect the lake from agricultural runoff. Phosphorus loading from the inlet creek was insignificant. Groundwater seepage was determined to be the main water source for the lake. Land uses in the watershed having the greatest potential to impact water quality were the residential areas along the north and south shores.

The DNR fishery survey conducted on the lake found a fish community top heavy with predators – namely abundant, small northern pike. Other gamefish and panfish species were present limited numbers, but typically had above average sizes. Forage species were scarce. The main area of concern was high overwinter mortality on juvenile fish, which was likely due to heavy predation when fish crowded around aerators in winter. Other areas of concern were the presence of carp and limited spawning habitat for walleyes. Spawning and nursery habitat for other species was abundant, and was not considered to be a limiting factor in fish production.

4.2 Management plans

4.21 Eurasian watermilfoil control

Spreading of Eurasian watermilfoil probably represents the single greatest threat to White Lake. Because this plant was found in scattered areas around the lake, controlling this species will be problematic. At a minimum the lake associations should contract treatment of the dense Eurasian watermilfoil beds in 2003. Ideally all Eurasian watermilfoil found will be treated. Treatments should be done using a granular formulation of 2,4D. Retreatments should be done as needed. Weed harvesting activities should be directed away from any Eurasian watermilfoil beds, as cutting may aid in the dispersal of the plant. Given the large size of the lake and the abundance of suitable habitat for Eurasian watermilfoil, the most practical approach may be to survey the lake each year so that any substantial beds of Eurasian watermilfoil that appear can be identified and treated as quickly as possible. In this manner, it may be possible to prevent Eurasian watermilfoil from taking over the lake and dominating the plant community. DNR permits will be required for all herbicide treatments.

The success of this treatment plan will rely upon active milfoil monitoring. Lake volunteers will need to be trained to identify Eurasian watermilfoil and map plant beds. Formal plant surveys that duplicate the methods of the 2002 survey should be conducted at three-year intervals for the purpose of monitoring program effectiveness and impact to native plants.

Education will also be an important component of a successful milfoil control program. Lake users should be instructed on the potential impacts of Eurasian watermilfoil, identification of the plant, and the importance of cleaning weeds from boats and trailers. These educational programs should be incorporated into association gatherings and events. The associations should seek assistance from the DNR in developing educational programs.

The associations may wish to seek financial assistance through the Waterways Commission grant program to conduct treatments. The associations may also wish to seek funding for further lake monitoring through small scale Lake Management Planning Grants. Grant information is available on the WDNR website: www.dnr.state.wi.us/org.

4.22 Purple loosestrife control

To control purple loosestrife, the Lake Associations should purchase bio-control beetles outright, or sponsor groups, such as school classes, scout troops, and 4H clubs, who would be willing to rear bio-control beetles. Rearing beetles would be the best management option for the lake. To purchase beetles or starter kits, Contact:

Brock Woods
DNR Research Center
1350 Femrite Dr.
Monona, WI 53716
(608) 221-6349

For individual property owners wanting to control smaller areas of pl, herbicide treatments using triclopyr or glyphosate should be contracted. DNR permits are required for pl control, but permit fees are waived.

4.23 Weed harvesting

Mechanical weed harvesting should continue as the primary method of maintaining boating access through dense beds of native submergent plants. Weed harvesting should be done in boating lanes and should not exceed those areas identified in **Figure 10**. The harvesting path should not exceed 200 feet in width. Harvesting paths should steer clear of any emergent plant beds. Harvesting paths should also remain at least 150 feet from shore, or harvesting should be done after June 30th, to avoid damaging fish spawning beds. Marker buoys should be placed in the lake to identify boating lanes and facilitate weed-harvesting operations.

Impending rule changes will impact weed-harvesting activities on lakes. Permits and record keeping will be required. Complete details are given in **Appendix 2**.

4.24 Lakeshore homeowner responsibilities

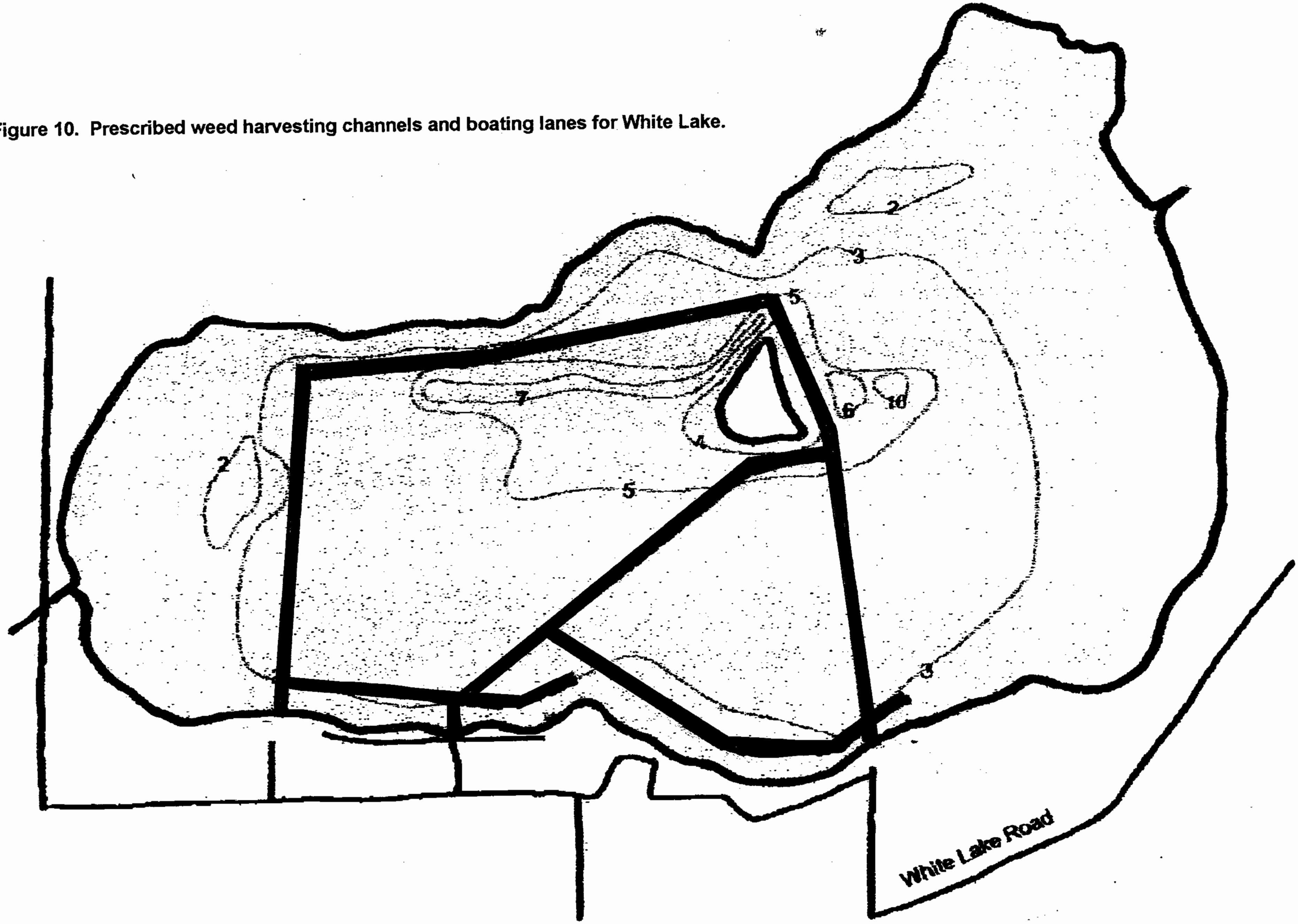
Because residential areas have been identified as areas with the greatest potential to impact water quality, the future of White Lake's water quality depends on the responsible actions of riparian property owners. Lakeshore homeowners should make sure that septic systems are up to date and functioning properly. If lawn fertilizers are used, they should contain "zero phosphorus". Property owners should also maintain buffer strips of unmowed vegetation, plant shoreline vegetation, or construct appropriate bank revetments to stabilize shorelines and prevent erosion. An excellent reference for shoreline habitat restoration is *Lakescaping for Wildlife and Water Quality* (Hederson, et. al.).

4.25 Fish habitat improvement

The Lake Associations should commission a study of White Lake's winter oxygen profiles in order to assess extent and impacts of low dissolved oxygen on fish distribution. This study should also explore options and provide technical details for upgrading and expanding the lake's aeration system.

Lake Association members should support the recommendations of area DNR fisheries biologist, as indicated by the final results of the DNR fishery survey. Particularly with regard to fish stocking, as this activity may have negative consequences in an unbalanced fishery.

Figure 10. Prescribed weed harvesting channels and boating lanes for White Lake.



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