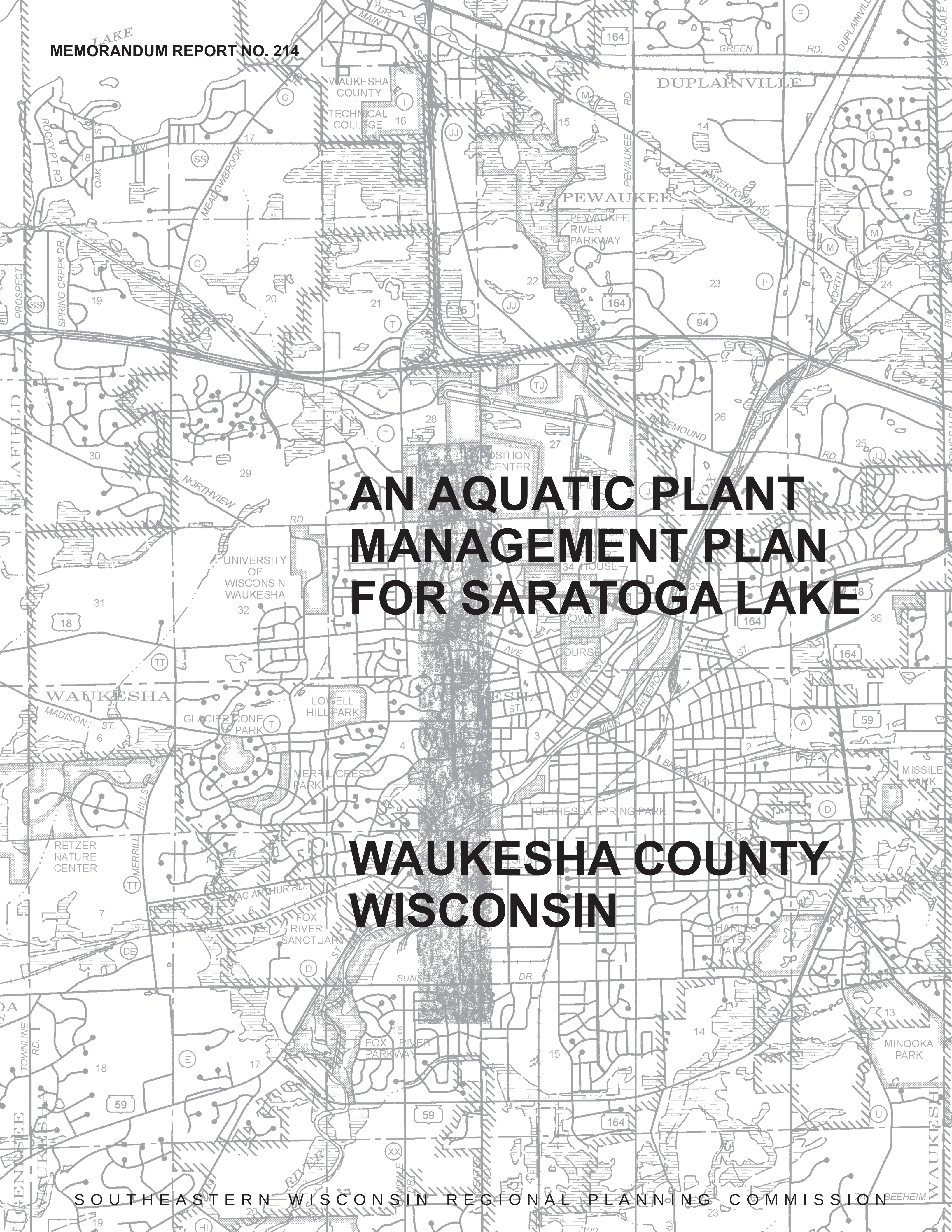
MEMORANDUM REPORT NO. 214



AN AQUATIC PLANT MANAGEMENT PLAN FOR SARATOGA LAKE

WAUKESHA COUNTY WISCONSIN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgement is due to Dr. Jeffrey A. Thornton, CLM, PH, former SEWRPC Principal Planner; Dr. Thomas M. Slawski, SEWRPC Principal Planner; Mr. Aaron W. Owens and Ms. Beverly A. Saunders, SEWRPC Planners; Mr. Edward J. Schmidt, SEWRPC GIS Planning Specialist; and Mr. Michael A. Borst, SEWRPC Research Aide, for their contributions to the conduct of this study and the preparation of this report.

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AN AQUATIC PLANT MANAGEMENT PLAN FOR SARATOGA LAKE WAUKESHA COUNTY, WISCONSIN

Prepared by the

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Chapter I

INTRODUCTION

Saratoga Lake, known locally as Barstow impoundment, is a 24-acre impoundment, located on the Fox (Illinois) River within U.S. Public Land Survey Section 35, Township 7 North, Range 19 East, and U.S. Public Land Survey Sections 1 and 2, Township 6 North, Range 19 East, City of Waukesha, Waukesha County, Wisconsin. The Lake is a recreational waterbody comprised of an impounded portion of the Fox River upstream of the dam located at Barstow Street in the City of Waukesha. Most of the frontage of Saratoga Lake is in public ownership. Frame Park and its environs are used for a river walk and various other recreational open space uses, including shoreline fishing and conduct of waterski shows during the summer months, and walking and jogging year-round. The park and its associated waterfront are popular public use areas for the City residents and their visitors.

The City of Waukesha staff who manage Frame Park and its facilities have become increasingly concerned about several lake-related issues, including decreased water clarity, heavy sediment deposition, increased growth of aquatic plants, and contamination of the lake waters by nonpoint source pollution. As a result, the City of Waukesha has determined to explore and quantify the magnitude of these concerns through the conduct of planning studies leading to the preparation of an aquatic plant management plan for Saratoga Lake. In this regard, it should be noted that an aquatic plant management plan does not, in and of itself, constitute a comprehensive lake management plan, but rather develops specific elements that can ultimately be incorporated into a comprehensive plan for the Lake.

BACKGROUND

This report represents part of the ongoing commitment of the City of Waukesha to sound planning with respect to Saratoga Lake. This planning program was designed as part of the ongoing program of lake-related information gathering, evaluation, and management being undertaken by the City in cooperation with other governmental and nongovernmental organizations and agencies, including the Wisconsin Department of Natural Resources (WDNR), Waukesha County, and the Southeastern Wisconsin Regional Planning Commission (SEWRPC).

AQUATIC PLANT MANAGEMENT PROGRAM GOALS AND OBJECTIVES

General aquatic plant management goals and objectives for Saratoga Lake were developed in consultation with the City of Waukesha. The agreed goals and objectives are to:

1. Protect and maintain public health, and promote public comfort, convenience, necessity, and welfare, in concert with the natural resource, through the environmentally sound management of native vegetation, fishes, and wildlife populations in and around Saratoga Lake;

2. Effectively control the quantity and density of aquatic plant growths in portions of the lake basin to better facilitate the conduct of water-related recreation, improve the aesthetic value of the resource to the community, and enhance the natural resource value of the waterbody;

3. Effectively maintain the water quality of Saratoga Lake to better facilitate the conduct of water-related recreation, improve the aesthetic value of the resource to the community, and enhance the resource value of the waterbody; and,

4. Promote a quality, water-based experience for residents and visitors to Saratoga Lake consistent with the policies and objectives of the WDNR as set forth in the regional water quality management plan.[1]

Specifically, this report sets forth various inventories of biota and abiotic factors currently and historically present within Saratoga Lake. The overall goal of this report is to formulate an aquatic plant management plan for Saratoga Lake that will encompass appropriate lake protection actions specifically suited to the current and forecast conditions prevailing in the Lake, including:

1. Identification of the range of possible management options that could be applied to Saratoga Lake, with varying levels and degrees of intervention including consideration of all forms of aquatic plant control as required pursuant to Chapters NR 107 and NR 109 of the *Wisconsin Administrative Code*, including the relevant provisions of Chapter NR 40 of the *Wisconsin Administrative Code*;

2. Determination of the technical feasibility of the options once a comprehensive list of possible management options has been identified, and selection of those options that have the best chance of being successful in meeting the desired use goals set by the community for further consideration by the related units of government and nongovernmental organizations; and,

3. Formulation of appropriate lake protection programs, including public information and education strategies and other possible actions necessary to address the identified problems and issues of concern.

Inventories, prepared by SEWRPC in cooperation with the City of Waukesha, include the results of field surveys conducted by the Commission staff during the summer of 2012, as well as data acquired by the WDNR and others in prior years. The aquatic plant surveys were conducted by Commission staff using the grid-based, point-intercept methodology currently being used by the WDNR for whole lake surveys.[2] The inventory and aquatic plant management plan elements presented in this report conform to the requirements and standards set forth in the relevant *Wisconsin Administrative Codes.*[3] Implementation of the recommended actions set forth herein should continue to serve as an important step in achieving the stated lake use objectives over time.

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[1]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *June 1979, as amended; see also SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

[2]*Wisconsin Department of Natural Resources, Publication No. PUB-SS-1068 2010,* Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry and Analysis, and Applications, *March 2010.*

[3]*This plan has been prepared pursuant to the standards and requirements set forth in the following chapters of the* Wisconsin Administrative Code*: Chapter NR 1, "Public Access Policy for Waterways;" Chapter NR 40, "Invasive Species Identification, Classification and Control;" Chapter NR 103, "Water Quality Standards for Wetlands;" Chapter NR 107, "Aquatic Plant Management;" and Chapter NR 109, "Aquatic Plants Introduction, Manual Removal and Mechanical Control Regulations."*

Chapter II

INVENTORY FINDINGS

INTRODUCTION

The physical characteristics of a lake and its watershed are important factors in any evaluation of existing and likely future water quality conditions and lake uses, including recreational uses. Characteristics, such as watershed topography, lake morphometry, and local hydrology, ultimately influence water quality conditions and the composition of plant and fish communities within a lake. Therefore, these characteristics must be considered in any type of lake management planning process. Accordingly, this chapter provides pertinent information on the physical characteristics of Saratoga Lake and its tributary area, land uses, and chemical and biological quality of the Lake, as well as recreational uses of and facilities provided by and around the Lake, and past and present management practices. The information presented in this chapter forms the basis upon which recommendations can be formulated.

WATERBODY CHARACTERISTICS

Saratoga Lake is located within the City of Waukesha, Waukesha County, Wisconsin, as shown on Map 1. The Wisconsin Department of Natural Resources (WDNR) has classified the Lake as a drainage, or through-flow, lake being both fed and drained by the Fox River. The Lake is formed by an impoundment on the Fox River at the Barstow Street, in the City of Waukesha. The Lake's water level is controlled artificially by a dam, leading to the local appellation of the Lake as the Barstow impoundment. However, for the purposes of this aquatic plant management plan, the waterbody will be referred to as Saratoga Lake.

The hydrographical characteristics of Saratoga Lake are set forth in Table 1. Saratoga Lake is aligned in approximately a northeast-southwest orientation and has a surface area of 24 acres, a volume of about 81.2 acre-feet, and a maximum depth of 4.5 feet.[1] The bathymetry of the Lake is shown on Map 2. This morphometry results in the Lake having an essentially riverine character, being dominated by the river flows, and strongly influenced by the rate at which waters flow through the waterbody. The rapid movement of water through the impoundment typically results in short water residence times, which in turn minimize the likelihood of development of algal blooms even under conditions of high-nutrient loading,[2] as discussed further below.

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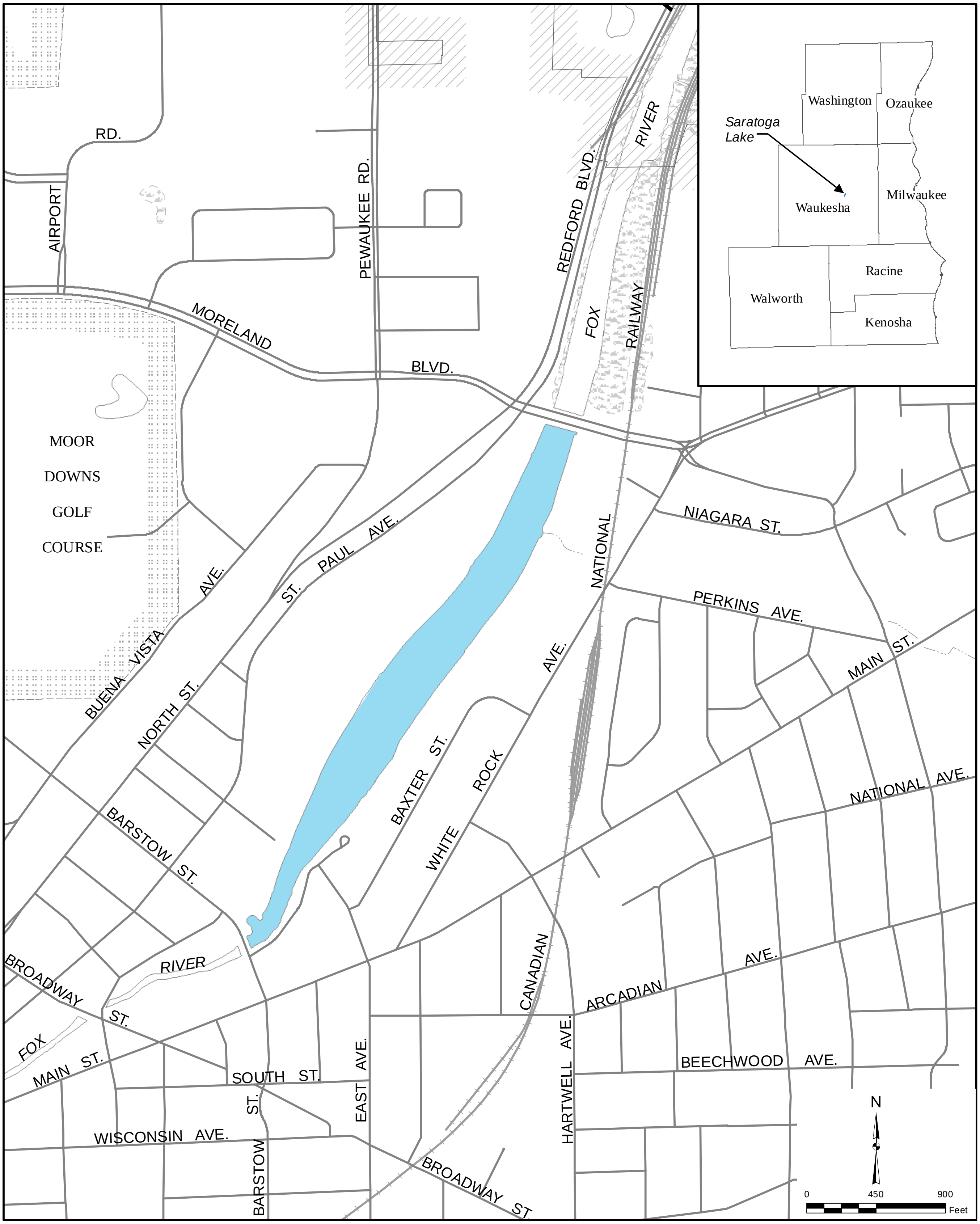
[1]*Measured by SEWRPC staff during the 2012 aquatic plant survey. The maximum depth of the Lake is reported by the WDNR to be 6.0 feet: Wisconsin Department of Natural Resources Publication No. PUB-FH-800 2005,* Wisconsin Lakes*, 2005. This difference represents recent siltation within the Lake.*

[2]*P.J. Dillon and W.B. Kirchner, "The Phosphorus Budget of Cameron Lake, Ontario: The Importance of Flushing Rate to the Degree of Eutrophy of Lakes,"* Limnology and Oceanography*, Volume 20, 1975, pages 28-39.*

Map 1

LOCATION OF SARATOGA LAKE



Source: SEWRPC.

Table 1

HYDROLOGY AND MORPHOMETRY OF SARATOGA LAKE

Parameter	Measurement
Size	
Surface Area of Lake	24 acres
Total Tributary Area[a]	79,302 acres
Lake Volume	81.2 acre-feet
Residence Time[b]	9 hours
Shape	
Length of Lake	0.7 miles
Width of Lake	0.06 mile
Length of Shoreline	1.7 miles
Shoreline Development Factor[c]	4.8
General Lake Orientation	NE-SW
Depth	
Maximum Depth	6 feet
Mean Depth	3 feet

[a] *The current measurement is based on elevation refinements made possible through SEWRPC digital terrain modeling analysis.*

[b] *Residence time is estimated as the time period required for a volume of water equivalent to the volume of the lake to enter the lake during years of normal precipitation.*

[c] *Shoreline development factor is the ratio of the shoreline length to the circumference of a circular lake of the same area.*

Source: Wisconsin Department of Natural Resources, U.S. Geological Survey, and SEWRPC.

Saratoga Lake has a residence time of 8.8 hours. Residence time, also known as *retention time* or *flushing rate*, refers to the average length of time that water remains in a lake. As noted, this can be a significant factor in determining the impact of contaminants, and nutrients, on a lake's water quality. Lakes with short duration retention times, such as flow-through lakes that are part of a river system, will flush nutrients and contaminants out of the lake fairly quickly. Lakes with very short retention times will flush nutrients out of the system so quickly that algal populations have insufficient time to thrive despite nutrient concentrations being sufficiently high to support large algal populations (although small populations of algae may still be present in more stagnant areas along the shoreline, as is the case with Saratoga Lake). Lakes with long retention times, such as in seepage lakes where there is no defined outflow and where surface runoff and direct precipitation are the primary inflows of water, tend to accumulate nutrients in their bottom sediments, gradually becoming more enriched over time as these nutrients are recycled within the lake waters. Average retention times can be as brief as a few days, as in the case of Saratoga Lake, or as long as many years. Lake Superior, for example, has a retention time of 500 years, the longest retention time of any Wisconsin lake. Most lakes in southeastern Wisconsin have retention times of about one year.

From a lake management perspective, efforts to control nutrient levels in a lake with a short retention time usually focus on limiting nutrient inflows to a lake. The rapid flushing times of such lakes can result in apparent water quality improvements within a relatively short period of time. Lakes with slower flushing rates usually respond to watershed protection at a much slower rate, with apparent improvement in water quality taking years to occur. Given the short retention time of only 8.8 hours, the degree to which the water quality in Saratoga Lake can be expected to improve and the time it will take to accomplish the improvement will depend on the degree to which nutrient and contaminant inputs to the Lake can be controlled and the amount of nutrient enrichment already deposited in the Lake's bottom sediments.

Saratoga Lake has a length of about 0.7 mile, a width of about 0.06 mile, and a shoreline length of about 1.7 miles. The Lake has a shoreline development factor of about 4.8, indicating that the shoreline length is nearly five times greater than that of a perfectly circular lake of the same area. Such a high value is usually the result of a highly irregular shoreline, such as would result from the existence of numerous bays and points. However, in the case of Saratoga Lake, the high shoreline development factor is a reflection of its greatly elongated shape being comprised, as it is, of the flooded portion of a riverine system.

Shoreline development factor is often related to the level of biological activity in a lake. The greater a lake's shoreline development factor, the greater is the likelihood that the lake will contain shallow, nearshore areas. The "littoral zone" (the shallow water area of a lake that extends out from the shoreline to the maximum depth of colonization of rooted aquatic plants) usually provides most of a lake's habitat suitable for plant and animal life. Consequently, lakes with larger littoral zones typically have a higher level of biological activity or production. In

Map 2

BATHYMETRIC MAP OF SARATOGA LAKE

DATE OF PHOTOGRAPHY: APRIL 2010

the case of Saratoga Lake, the shallow nature of the waterbody results in an abundance of littoral zone habitat; with a maximum depth of six feet, all of the lake bottom can be considered as littoral zone, or areas where aquatic plant growths can be anticipated.

Biological activity in a lake also can be influenced by other physical factors, such as lake-basin contours and bottom sediment composition. A preponderance of nearly flat bottom contours along with soft bottom sediments generally produces conditions consistent with high levels of biological activity. As shown on Map 2, Saratoga Lake is comprised mostly of shallow water with nearly flat bottom contours and soft bottom sediments, and, as a result, would be expected to have the ability to support abundant aquatic plant growths and a productive warm-water fishery.

TRIBUTARY AREA AND LAND USE CHARACTERISTICS

As shown on Map 3, the total area tributary to Saratoga Lake extends into the numerous upstream cities, villages, and towns that form the headwaters of the Fox River system. The total area which drains to Saratoga Lake is approximately 79,302 acres, or about 124 square miles, in areal extent. Table 2 provides a list of the various municipalities found within the tributary area of Saratoga Lake and the percent of the Lake's tributary area occupied by each municipality. These lands, in turn, also form the headwaters of the Illinois River, which ultimately drains into the Mississippi River.

Land Uses

Existing land uses within the area tributary to Saratoga Lake are nearly equally divided between urban land uses and rural land uses. Agriculture is the dominant rural land use; residential land use is the dominant urban use. Map 4 shows the existing land uses within the tributary area as of 2010; those uses also are summarized in Table 3.

Future changes in land use within the area tributary to the Lake may include further urban development, infilling of already platted lots, and possible redevelopment of existing properties. Under proposed year 2035 conditions, as shown on Map 5 and summarized in Table 3, urban land uses are expected to increase significantly, from about 50 percent of the land coverage in 2010 to about 64 percent of the land coverage in 2035. Agricultural uses are anticipated to decrease proportionately from about 25 percent of the land coverage in the year 2010, to about 10 percent of the land coverage under planned year 2035 conditions. These land use changes have the potential to modify the nature and delivery of nonpoint source contaminants to the Lake, with concomitant impacts on the aquatic plant communities within the waterbody.

Population and Households

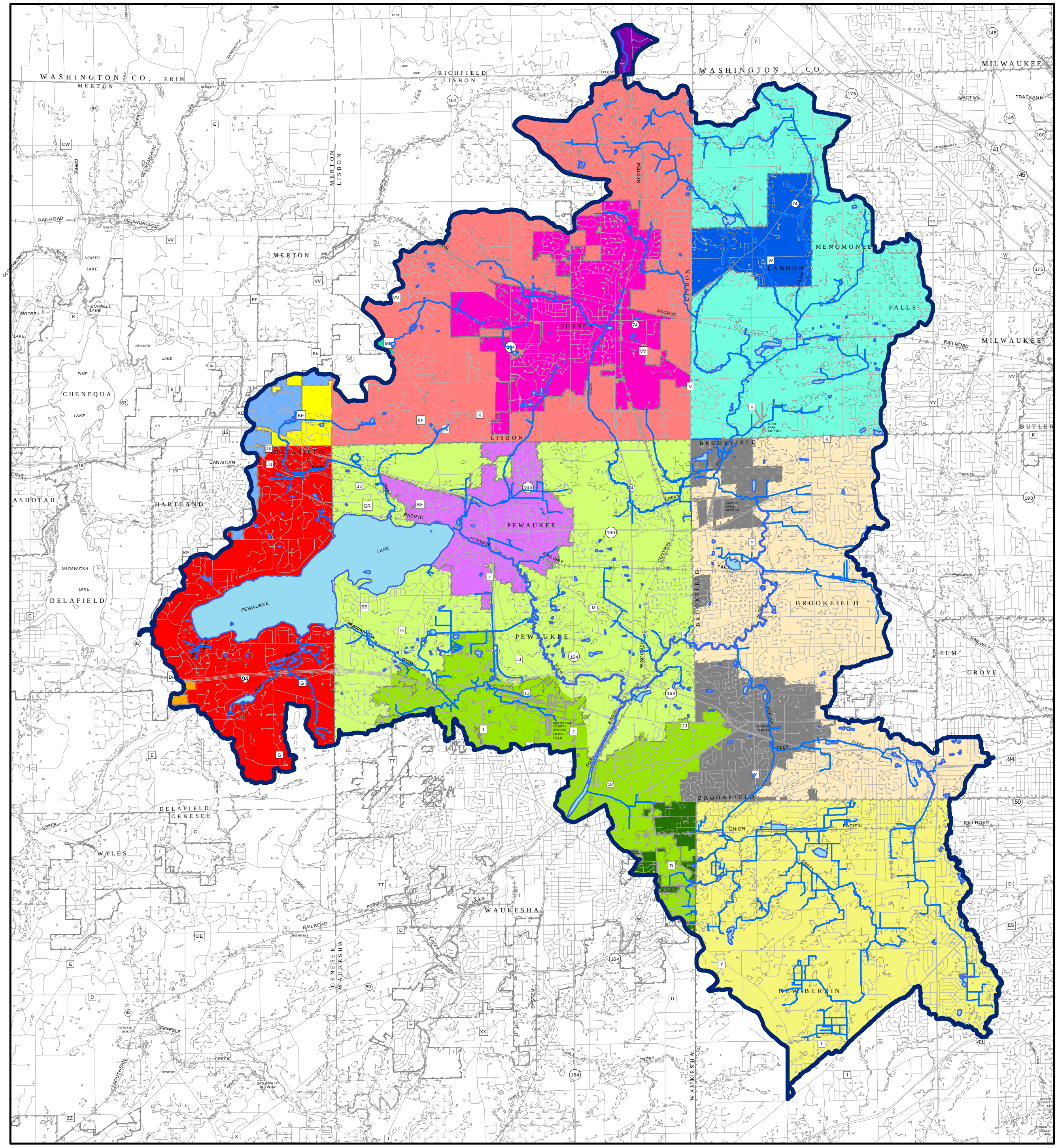
As shown in Table 4, the population and numbers of households within the area tributary to Saratoga Lake have generally increased since 1960. During that time, there were two decades of significantly greater rates of increase in population: the first occurred between 1960 and 1970, when the number of people increased by nearly 28 percent, from 58,087 persons to 74,275 persons, and the second occurred between 1990 and 2000, when the population showed an increase of over 23 percent, from 94,384 to 116,407 individuals. There were corresponding increases in the numbers of households during those same periods of 34.2 and 35.3 percent, respectively. It is interesting to note that the time between 1970 and 1980 actually showed the single greatest increase in the number of households, of over 41 percent.

SHORELINE PROTECTION AND EROSION CONTROL

Erosion of shorelines results in the loss of land, damage to shoreline infrastructure, and interference with lake access and use. Wind-wave action, ice movement, and wave action produced by motorized boat traffic and related activities against unprotected or under-protected shoreline are usually the primary causes of such erosion. Other factors that can influence shoreline erosion include: the maximum distance across open water ("fetch"), especially when the main axis of a lake is aligned with prevailing westerly winds common to southern Wisconsin; the degree of slope of the lake bottom adjacent to the shoreline; the shoreline bank height; the composition of the shoreline bank material (clay, rock, marl, peat, etc.); potential flank erosion generated by shoreline structures; the amount

Map 3

CIVIL DIVISION BOUNDARIES WITHIN THE AREA TRIBUTARY TO SARATOGA LAKE: 2012



- City of Brookfield
- City of Delafield
- City of New Berlin
- City of Pewaukee
- City of Waukesha
- Village of Hartland
- Village of Lannon
- Village of Merton
- Village of Pewaukee
- Village of Richfield
- Village of Sussex
- Village of Menomonee Falls
- Stream
- Town of Delafield
- Town of Lisbon
- Town of Waukesha
- Town of Merton
- Town of Brookfield
- Surface Water
- Saratoga Lake Drainage Area

N

0 0.5 1 1.5 Miles

0 5,000 10,000 Feet

Source: SEWRPC.

Table 2

AREAL EXTENT OF CIVIL DIVISIONS WITHIN THE AREA TRIBUTARY TO SARATOGA LAKE: 2012

Community	Civil Division Area (acres)	Percent of Tributary Area
City of Brookfield	9,016	11.3
City of Delafield	61	0.1
City of New Berlin	10,838	13.6
City of Pewaukee	13,454	16.8
City of Waukesha	4,914	6.2
Town of Brookfield	3,228	4.0
Town of Delafield	6,889	8.7
Town of Lisbon	10,332	13.0
Town of Merton	447	0.7
Town of Waukesha	478	0.8
Village of Hartland	657	0.9
Village of Lannon	1,593	2.0
Village of Menomonee Falls	9,464	11.9
Village of Merton	28	0.1
Village of Pewaukee	2,895	3.6
Village of Richfield	195	0.3
Village of Sussex	4,813	6.0
Total	79,302	100.0

Source: SEWRPC.

and types of vegetation growing on the shoreline bank and in the water adjacent to the shoreline; the stability of the shoreline bank (if the bank has been disturbed by human activities, such as tree removal, mowing, etc.); and, the geometry and orientation of the shore.

Shoreline Protection on Saratoga Lake

Often some kind of structure or material is installed along a lakeshore in order to provide protection from natural and artificial or human-induced erosive forces. Most such structures generally fall into one of three categories, regardless of material being used. These forms are: “bulkhead,” where a solid, *vertical* wall of some material, such as poured concrete, steel, or timber is erected; “revetment,” where a solid, *sloping* wall (frequently asphalt, as in the case of a roadway, or poured concrete) is used; and “riprap,” where a barrier of rocks and/or stones is placed along the shoreline. Natural or unprotected areas, and beaches or areas where the substrate is comprised of sand or pea gravel, are considered as separate categories. Some of the areas where no attempt has been made to provide any degree of artificial shoreline protection, such as where the shoreline of a wooded lot has been left unprotected, can develop the characteristics of a protected shoreline, becoming naturally “armored” by rock of glacial origin.

Placement of shoreline protection structures typically requires a permit from the State of Wisconsin, pursuant to authorities granted to the WDNR under Chapter 30 of the *Wisconsin Statutes*. The WDNR provides a helpful web site for assisting riparian owners to determine if a permit is needed for anticipated shoreline protection projects.[3] This web site also provides useful advice, as well as links that will assist the property owner in designing an appropriate shoreline protection project. Many local municipalities also have permitting requirements associated with shoreland areas.

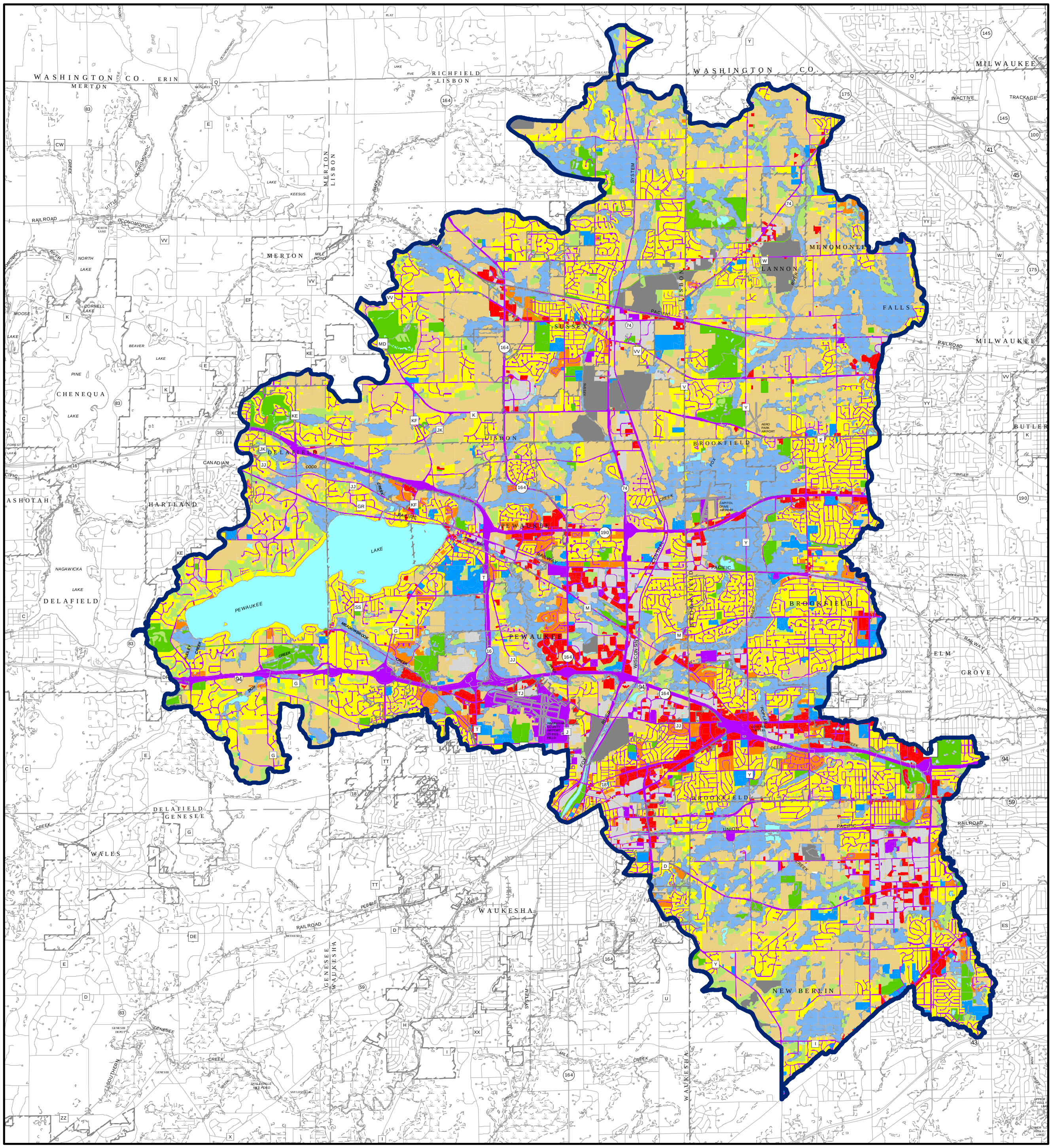
The “hard” artificial seawalls of stone, riprap, concrete, timbers, and steel, once considered “state-of-the-art” in shoreline protection, are now recognized as only part of the solution in protecting and restoring a lake’s water quality, wildlife habitat, recreational opportunities and scenic beauty. More recently, “soft” shoreline protection techniques involving a combination of materials, including native plantings, are not only increasingly required pursuant to Chapter NR 328 of the *Wisconsin Administrative Code*, but also increasingly popular as riparian owners have become aware of the value of, not only protecting their shorelines, but, at the same time, improving the viewshed and providing natural habitat for wildlife. More natural options for shoreline protection also enhance the aesthetics of a shoreline, providing for a great diversity of viewing opportunities and enhanced privacy for the landowner.

A survey of the shoreline protection methods in use on Saratoga Lake was conducted by Southeastern Wisconsin Regional Planning Commission (SEWRPC) staff during 2012. Observations made by SEWRPC staff during 2012 indicated that there were no significant buffer zones along the shoreline of Saratoga Lake. The results of that

[3]http://dnr.wi.gov/waterways/shoreline_habitat/shoreline.html

Map 4

LAND USE WITHIN THE AREA TRIBUTARY TO SARATOGA LAKE: 2010



SINGLE-FAMILY RESIDENTIAL	RECREATION
MULTI-FAMILY RESIDENTIAL	WETLANDS
COMMERCIAL	WOODLANDS
INDUSTRIAL	SURFACE WATER
TRANSPORTATION, COMMUNICATIONS, AND UTILITIES	AGRICULTURAL, UNUSED, AND OTHER OPEN LANDS
GOVERNMENT AND INSTITUTIONAL	EXTRACTIVE AND LANDFILL

STREAM

SARATOGA LAKE DRAINAGE AREA

N

0 0.5 1 1.5 Miles

0 5,000 10,000 Feet

Source: SEWRPC.

Table 3

EXISTING AND PLANNED LAND USE WITHIN THE TOTAL DRAINAGE AREA TRIBUTARY TO THE BARSTOW IMPOUNDMENT: 2010 AND 2035

Land Use Categories[a]	2010 Acres	2010 Percent of Total	2035 Acres	2035 Percent of Total
Urban				
Residential	19,614	24.7	25,351	32.0
Commercial	2,735	3.4	3,751	4.7
Industrial	2,662	3.3	3,858	4.9
Governmental and Institutional	1,630	2.1	2,268	2.9
Transportation, Communication, and Utilities	9,561	12.1	11,612	14.6
Recreational	2,753	3.5	3,555	4.5
Subtotal	38,955	49.1	50,395	63.6
Rural				
Agricultural and Other Open Lands	19,737	24.9	8,225	10.4
Wetlands	12,267	15.5	12,269	15.5
Woodlands	3,686	4.6	3,681	4.6
Water	3,188	4.0	3,188	4.0
Extractive	1,392	1.8	1,467	1.8
Landfill	77	0.1	77	0.1
Subtotal	40,347	50.9	28,907	36.4
Total	79,302	100.0	79,302	100.0

[a]*Parking included in associated use.*

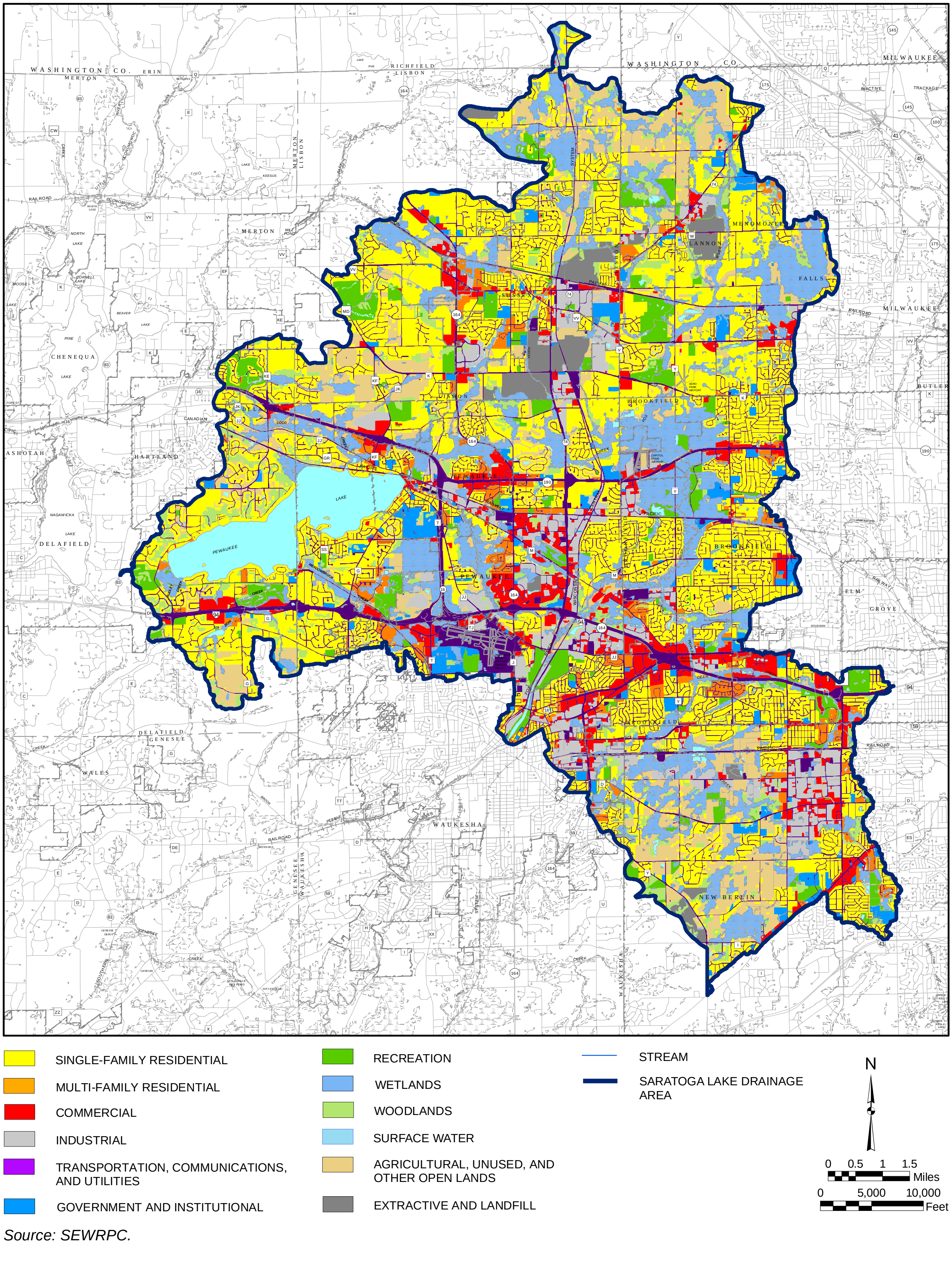
Source: SEWRPC.

survey are shown on Map 6. In general, the majority of the shoreline on Saratoga Lake was protected by the placement of large rocks, or “riprap,” with little or no natural, undisturbed shoreline observed. The size of the rock used and the spacing, or gaps, between the rocks, was somewhat atypical compared to the riprap protection commonly found on lakeshores in the Region. However, the natural plantings of vegetation along most of the shoreline together with the rocks, makes for a pleasing natural appearance overall and is likely to provide adequate protection, given the limited amount of boat traffic and wind-wave action experienced by the Lake.

The urban setting of Saratoga Lake and the fact that the Lake lies entirely within a city park, Frame Park, together with the recreational influences of the park location, tend to produce a waterbody with some features not often found in other lakes in the Region. For example, the unusual nature of the rock-protected shoreline has already been described. In addition, to accommodate anglers and others who desire more direct recreational access to the water’s edge than can be accomplished along the majority of the lake shoreline, several access points comprised of poured concrete steps, forming “tiered seating,” have been constructed. These “bulkhead” type structures (if, indeed, that term can be appropriately applied in this case) are not typical of shoreline structures commonly observed. In addition, the paved walking path around the waterbody and several fishing piers and boat livery form other uncommon features of lakeshores, while providing value to the public amenity. While most lakes in southeastern Wisconsin have some amount of undisturbed, or natural, shoreline, the urban and recreational open spaces surrounding Saratoga Lake, combined with the riverine nature of the Lake, have resulted in the absence of undisturbed natural shorelines around the Lake. Map 6 shows the location of the various shoreline protective and access structures found along the shoreline of Saratoga Lake.

Map 5

PLANNED LAND USE WITHIN THE AREA TRIBUTARY TO SARATOGA LAKE: 2035



Source: SEWRPC.

Table 4

POPULATION AND HOUSEHOLDS IN THE SARATOGA LAKE AREA: 1960-2010

Year	Population	Change from Previous Decade		Households (occupied housing units)	Change from Previous Decade	
		Number	Percent		Number	Percent
1960	58,087	- -	- -	14,912	- -	- -
1970	74,275	16,188	27.9	20,012	5,100	34.2
1980	87,632	13,357	18.0	28,317	8,305	41.5
1990	94,384	6,752	7.7	33,634	5,317	18.8
2000	116,407	22,023	23.3	45,517	11,883	35.3
2010	124,936	8,529	7.3	51,061	5,544	12.2

Source: U.S. Bureau of Census and SEWRPC.

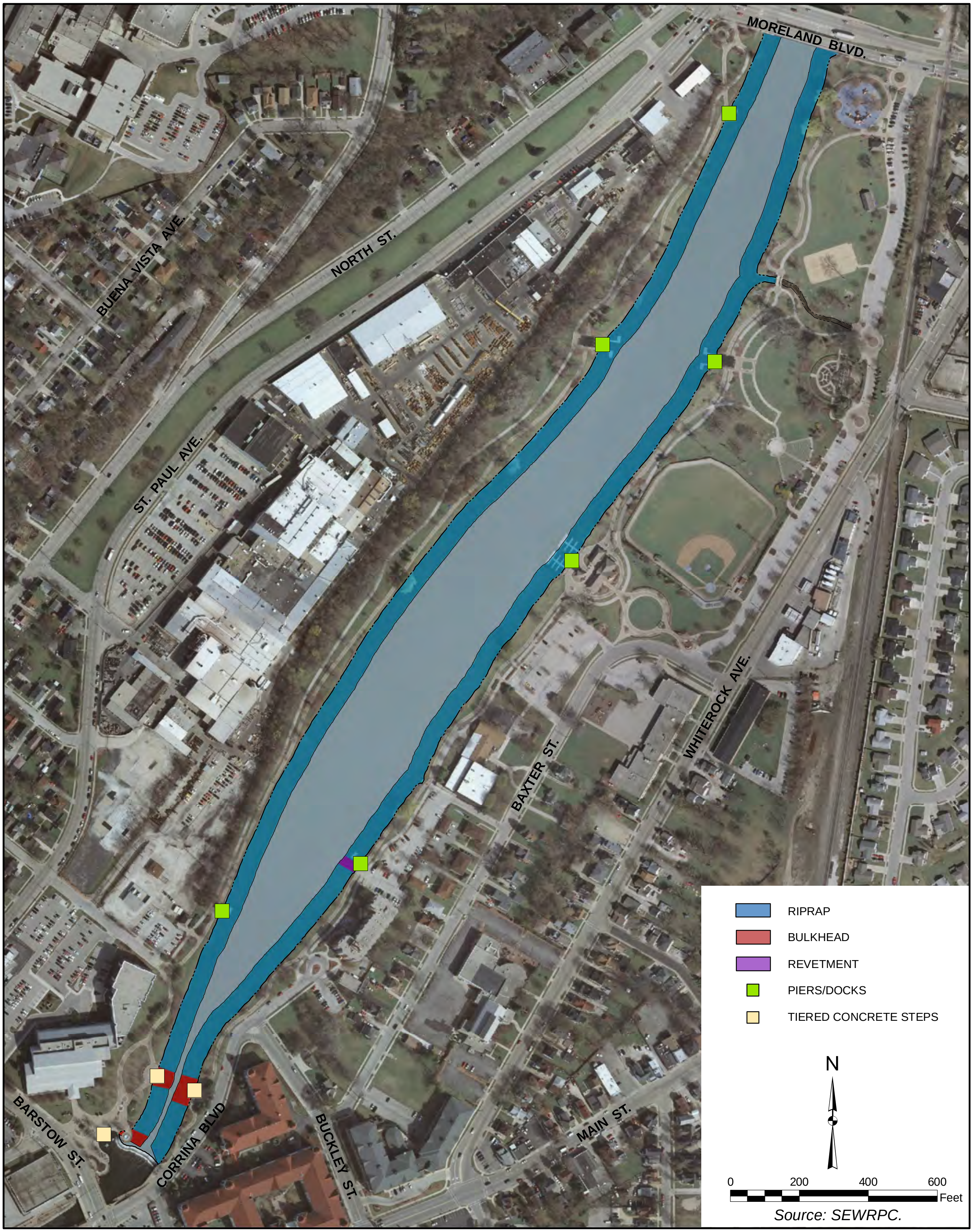
Erosion Potential of Saratoga Lake Shoreline Areas

The elongated shape of Saratoga Lake, arising as a function of its riverine nature, would tend to lessen the erosive effects of wind-wave action against either the eastern or western shorelines. Although the northeast-southwest orientation of Saratoga Lake generally aligns with the aforementioned prevailing westerly winds, the narrowness of the Lake, surrounding development that acts effectively as a windbreak, and consequent lack of open water span (or "fetch") would be likely to minimize the natural wind-wave action and erosive energy against the downwind shorelines of Saratoga Lake. This places Saratoga Lake generally within the category of low erosion intensity, using the erosion intensity score worksheet set forth in Section 328.08, Table 1, of the *Wisconsin Administrative Code*. Such a score would suggest that shoreline erosion control structures should be vegetative in nature.

That said, the Badgerland Water Ski Show Team, in an undated application to the Waukesha Department of Parks, Recreation and Forestry has requested that a portion of the shoreline of Saratoga Lake be converted to revetment. Specifically, the Team has requested that "the proposed 10x80[feet] stage…be cement so it is permanent (similar to other parks in aerial views highlighted [in their letter]) and covered with padding and outdoor carpet with seasonal plantings to provide minimal impact to the surrounding park setting." City staff requested SEWRPC staff to evaluate the potential impacts of such a proposal on Saratoga Lake. A site inspection in April 2013 found that the rock riprap had been removed from the shoreline adjacent to the area proposed for placement of the stage, creating an unprotected portion of shoreland between areas protected by existing riprap. An immediate concern of creating such an unprotected portion of shoreline was the likelihood of differential erosion caused by the protected shoreline focusing wave energy onto the unprotected portion of the shoreline. In an effort to quantify the risk associated with this gap in the shoreland protection around Saratoga Lake, SEWRPC staff completed the Chapter NR 328 erosion intensity score worksheet, set forth in Section NR 328.08 of the *Wisconsin Administrative Code*. This worksheet suggested that the shoreline remained in a low energy condition, although the score allocated to this area by SEWRPC staff, of between 34 and 42, was approaching the moderate erosion intensity score of 48. A significant contribution to this score was attributable to boat wakes. Given the recent history of the riprap removal, there did not appear to any significant differential erosion at the time of the field visit, although such erosion would not be unexpected. Consequently, City staff are recommended to take periodic measurements from the side walk to the shoreland, in order to monitor and document such anticipated recession. Should such erosion occur, the erosion intensity score could well approach the level of moderate intensity that would indicate a structural approach to shoreland protection. For this reason, SEWRPC staff recommend a more robust form of shoreland protection be considered at this site.

Map 6

SHORELINE PROTECTION STRUCTURES ON SARATOGA LAKE: 2012



DATE OF PHOTOGRAPHY: APRIL 2010

It should be noted that any shoreland structural intervention would be subject to State of Wisconsin permitting requirements administered by the WDNR under Chapter 30 of the *Wisconsin Statutes*. The numbers and types of activities allowed under the general (statewide) permit are quite limited, with repair or replacement of riprap being limited to 300 linear feet and 100 linear feet, respectively, in any five-year period, and replacement of sand on a shoreline is limited to less than two cubic yards. It can be anticipated that any repair or replacement of the riprap that has been removed from the proposed stage site would be subject to an individual permit to be issued by the WDNR pursuant to their Chapter 30, *Wisconsin Statutes*, authorities. Such permits are unlikely to support placement of a "seawall" such as the concrete revetment proposed by the Badgerland Water Ski Show Team, as such structure obstruct the natural shoreland structure and ecological function, and the sand or pea gravel requirement to backfill the 800 square feet "beach" would be likely to exceed the two cubic yards. Consequently, it is recommended that consideration be given to a removable structure, such as a barge or floating pier that could be removed when the ski show is not in progress, and to replacement of the rock riprap along the lakeshore to minimize the erosive effects of the boat wakes within this confined waterway.

Buffer Areas

Buffer zones are those areas adjacent to the shorelines of waterbodies, such as lakes, rivers, and wetlands, that consist of a band of vegetation extending both above and below the Ordinary High Water Mark (OHWM), which demarcates the shore of a waterbody. Onshore buffer zones can be purposefully designed and populated with those plant species that help filter pollutants from runoff or may consist of undisturbed vegetation native to the shoreland area. When located along streambanks, vegetative buffers can lessen erosion, minimize downstream flooding, and help maintain stream baseflows. When planted with native species, restored vegetative buffers offer the additional advantages of improving the viewshed and attracting native wildlife. Offshore, such buffer zones can be comprised of shoreland plant species and aquatic plants that inhabit the nearshore area. Such plants provide shoreline protection by damping wave action, as well as providing a physical protection for the shoreline. Examples of shoreline protection alternatives are shown in Figure 2 in Chapter III of this report.

There is no one-size-fits-all buffer width adequate to protect water quality, wildlife habitat, and human needs. [4] As buffer areas become wider, their pollutant removal effectiveness (buffering) typically increases, but may reach a point of diminishing returns compared to the amount of land devoted to the buffer function. This consideration has resulted in a statewide minimum buffer width of 75 feet around lakes. Since buffer zones offer the additional advantage of providing habitat for native species, understanding habitat needs for wildlife species is an important consideration in designing riparian buffers. Based on the needs of many wildlife species found in southeastern Wisconsin, the minimum core habitat buffer width is about 400 feet and the optimal width for sustaining the majority of wildlife species is about 900 feet. For a number of reasons, 400- to 900-foot-wide buffers are not practical along the shorelines of many lakes, streams, and wetlands within southeastern Wisconsin, but can occur around undisturbed natural lakes or can be designed into a landscape regime in areas where agricultural lands are converted to urban land uses. Consequently, communities should develop guidelines that remain flexible to meeting site-specific needs, while also achieving the most benefits for water resources and wildlife. These determinations must be practical, being balanced with the needs of the riparian owners for water access, viewing opportunities, and property area considerations, among others.

Because of its urban setting, Saratoga Lake is particularly susceptible to runoff from local impervious (hard) surfaces. Asphalt, packed gravel and concrete roadways, parking lots, walkways, bikeways, and other hard surfaces within the Lake's drainage area, all interfere with the ground's ability to soak up rainwater. Such surfaces result in increased stormwater runoff that can carry a variety of materials and pollutants into the Lake. A typically sized lot along a lakeshore, with only 8 percent of its area covered by impervious surfaces, will produce approximately four times the amount of sediment runoff than would a lot with no impervious surfaces; that same

[4] *SEWRPC Publication,* Managing the Water's Edge: Making Natural Connections, *May 2010.*

lot with 20 percent impervious surfaces will generate five times the runoff volume, six times the phosphorus input and 18 times the sediment input as it would without impervious surfaces.[5] Impervious surfaces also affect fish populations. This is especially the case when those surfaces are within the first 150 feet of the shoreline. In a study of 47 streams in southeastern Wisconsin, it was found that when the number of fish species in a stream with between 8 and 12 percent impervious surfaces within its watershed was compared to the number of fish species in a stream with less than 8 percent impervious surfaces within its watershed, there was a decline in the numbers of fish species of over 40 percent; when the amount of impervious surfaces in the watershed rose to even slightly above the 12 percent threshold, the number of fish species decreased by nearly 74 percent.[6]

The use of shoreline buffer zones to enhance shoreline and water quality protection and to protect fish and other wildlife has been gaining support among those individuals and organizations charged with the protection of lakes and streams. Although neatly trimmed grass lawns along shorelines are popular, they offer limited benefits for water quality or wildlife habitat; the cumulative effects of many houses with such shorelines can negatively impact the natural ecological (and potentially the hydrological) structure and functioning of the adjacent streams, lakes, and wetlands. When combined with best practices stormwater management, environmentally friendly yard care, effective wastewater treatment, conservation farm methods, and appropriate use of fertilizers and other agrochemicals, vegetative buffer zones can effectively minimize impacts to our shared water resources.[7]

WATER QUALITY IN SARATOGA LAKE

Records of water quality for Saratoga Lake are few. The Water Division of the WDNR maintains the Surface Water Integrated Monitoring System (SWIMS) database that provides access to surface water quality and related data that are useful in evaluating water quality in many of the lakes in the Region. With regard to Saratoga Lake, the SWIMS database contained information collected variously from 12 sampling stations in and around the Lake intermittently from August of 1990 through February of 2010. These data, however, focused primarily on the levels of various heavy metals and other inorganic toxins rather than on those chemical and physical parameters commonly measured when assessing the overall water quality or “health” of a lake. In short, these data are beyond the scope of this aquatic plant management plan and are, therefore, not included in this report.

In the absence of lake water quality data, this report will, instead, provide general descriptions of those water quality parameters considered to be part of most standard water quality sampling protocols for lakes in the Region. As part of the recommendations that will be made later in this report, collection of these data by the City of Waukesha (or by the Friends of Frame Park) will be recommended. Many lake organizations in the Region currently monitor water quality through one of the various programs available to communities: the U.S. Geological Survey (USGS) offers a comprehensive annual sampling program utilizing USGS staff and facilities, while the University of Wisconsin–Extension (UWEX) offers support for the Citizen Lake Monitoring Network (CLMN) which utilizes local volunteers to collect water samples and send them to the State Laboratory of Hygiene (SLoH) for processing.

Principal Water Quality Factors

Water Clarity

Water clarity, or transparency, is often used as an indication of a lake’s water quality. Transparency can be affected by physical factors, such as water color and suspended particles, and by various biologic factors, including seasonal variations in planktonic algal populations living in a lake. Water clarity is measured typically

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[5]*University of Wisconsin–Extension Publication GWQ061 1-10-2012*, Impervious Surfaces – How They Impact Fish, Wildlife and Waterfront Property Values, *2012.*

[6]Ibid.

[7]Ibid.

with a Secchi disk, a black-and-white, eight-inch-diameter disk, which is lowered into the water until a depth is reached at which the disk is no longer visible. This depth is known as the "Secchi-disk reading." Such measurements provide a ready means of assessing water quality, and, hence, comprise an important part of the aforementioned CLMN program, in which citizen volunteers assist in lake water quality monitoring efforts, as well as the USGS monitoring program. In a study of 54 lakes in southeastern Wisconsin, the mean Secchi-disk measurement was about five feet.[8] Secchi-disk measurements for Saratoga Lake are likely to be less than this average, although the entire lake bottom is probably within the depth of 1 percent light penetration required for supporting aquatic plant growth and photosynthesis by these aquatic plants.

In addition to in-lake direct measurements of water clarity using a Secchi disk, transparency of many Wisconsin lakes has been measured using remote sensing technology. The Environmental Remote Sensing Center (ERSC), established in 1970 on the University of Wisconsin-Madison campus, was one of the first remote sensing facilities in the United States. Using data gathered by satellite remote sensing over a three-year period, the ERSC generated a map based on a mosaic of satellite images showing the estimated water clarity of the largest 8,000 lakes in Wisconsin. The WDNR, through its volunteer Self-Help Monitoring Program (now the CLMN), was able to gather water clarity measurements from about 800 lakes, or about 10 percent of Wisconsin's largest lakes. Of these, the satellite remote sensing technology utilized by ERSC was able to accurately estimate clarity, providing a basis for extrapolating water clarity estimates to the remaining 90 percent of lakes.

In the case of Saratoga Lake, measurements obtained from analysis of LANDSAT images taken on four separate dates between July 10, 2010, through September 28, 2010, indicated an average Secchi depth in the Lake of 3.4 feet, indicative of poor water quality. This depth also reflects the probable maximum depth of colonization by aquatic plants.[9]

It is of interest to note that, in a USGS report of 1993[10] dealing with water clarity in another southeastern Wisconsin lake, namely Hooker Lake in Kenosha County, it was suggested that the apparent high turbidity in Hooker Lake during July and August of 1992 might be the result of powerboating activities, wind action, and fish feeding and reproduction activities (presumably the sediment disturbing activities of carp and other bottom-dwelling species). In this case, the report suggested that perhaps chlorophyll-*a* concentrations might be a better measure of that Lake's water quality rather than Secchi depth. Regardless, a variety of living and nonliving factors can influence the water clarity of a lake. The overall shallow depth of Saratoga Lake could make loose bottom sediments particularly susceptible to disturbance by powerboating activities, or the activities of bottom-dwelling fish, for example.

In addition to fish, other living organisms in a lake can have an impact on water clarity. A species of mollusk, the zebra mussel (*Dreissena polymorpha*), has been shown to affect a lake's water clarity. This nonnative species of shellfish rapidly colonizes nearly any underwater surface, artificial or natural, and this behavior has caused the zebra mussel to become a costly nuisance to humans, as massive populations of the mollusk have led to the clogging of municipal water intake pipes and the fouling of underwater equipment. The animal also has been known to have negative impacts on native benthic organism populations by disrupting aquatic food chains, removing significant amounts of bacteria and smaller phytoplankton which serve as food for a variety of other

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[8]*R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* Limnological Characteristics of Wisconsin Lakes, *1983.*

[9]*D. E. Canfield, Jr., K. A. Langeland, S. B. Linda, and W. T. Haller, "Relations Between Water Transparency and Maximum Depth of Macrophyte Colonization in Lakes,"* Journal of Aquatic Plant Management, *Volume 23, 1985, pages 25-28.*

[10]*U.S. Geological Survey letter report from Stephen J. Field, biologist, to Geoffrey L. Wheeler, President, Hooker Lake Management District,* June 24, 1993.

aquatic organisms, including larval and juvenile fishes and many forms of zooplankton. Ironically, as a result of the filter feeding proclivities of these animals, many lakes have actually experienced improved water clarity. However, this improved water clarity, in turn, has resulted in increased growths of rooted aquatic plants, including Eurasian water milfoil (*Myriophyllum spicatum*), in some lakes.

A curious caveat to the interplay between zebra mussels, water clarity, Eurasian water milfoil and native aquatic plants have been observed within the Southeastern Wisconsin Region: zebra mussels have been observed attaching themselves to the stalks of the Eurasian water milfoil plants, dragging the stems out of the zone of light penetration due to the weight of the zebra mussel shells, and interfering with the competitive strategy of the Eurasian water milfoil plant which seeks to exploit the sunlight in the upper regions of a waterway. This has contributed in some cases to improved growths of beneficial native aquatic plants, while in other cases it has led to nuisance growths of filamentous algae, which tend to be too large to be ingested by the zebra mussels.

Regardless of the seemingly beneficial impacts of these animals, the overall effect is that, as zebra mussels and other invasive species spread to inland lakes and rivers, so do the environmental, aesthetic, and economic costs to water users. The WDNR does not currently list Saratoga Lake as having an established population of zebra mussels. However, zebra mussels have become established in many waterbodies in Waukesha County, including Pewaukee Lake and the Pewaukee River upstream of the Saratoga Lake. Consequently, their appearance in Saratoga Lake should be monitored and the WDNR should be immediately notified should this species be found in the Lake.

Dissolved Oxygen

Dissolved oxygen levels are one of the most critical factors affecting the living organisms of a lake ecosystem. Dissolved oxygen levels have not been recorded for Saratoga Lake. Generally, dissolved oxygen levels are higher at the surface of a lake, where there is an interchange between the water and atmosphere, stirring by wind action, and production of oxygen by plant photosynthesis. Dissolved oxygen levels are usually lowest near the bottom of a lake, where decomposer organisms and chemical oxidation processes deplete oxygen during the decay process. About 5.0 milligrams per liter (mg/l) of dissolved oxygen is considered the minimum level below which oxygen-consuming organisms, such as fish, become stressed. Fish are unlikely to survive when dissolved oxygen concentrations drop below 2.0 mg/l. Oxygen levels near a lake's surface are commonly in the 10 to 12 mg/l range in lakes in the Southeastern Wisconsin Region, but can reach levels approaching 0 mg/l in the bottom waters near the end of summer or during ice-bound conditions in late winter. Such low oxygen levels can happen as the result of a number of factors, primary among them being the natural process of lake stratification.

A lake becomes stratified when, in a layer of the lake's waters, either a thermal gradient (called a "thermocline") or a chemical gradient (called a "chemocline") develops that is of such an intensity that it acts as a barrier separating the upper waters of the lake from the lower waters, sometimes to the extent of preventing the two layers from mixing. To determine, then, if a lake stratifies, data is gathered to look for evidence of the formation of either a chemocline or a thermocline. The presence of a thermocline in a lake is generally detectable as a pronounced drop in water temperature (usually 10 to 15 degrees Fahrenheit) over a relatively small change in depth (usually about 10 feet). To detect a thermocline, measurements of water temperature are taken at regular depth intervals at the deepest part of a lake. The temperature-depth data can then be depicted graphically in what is known as a "profile," a thermocline will usually appear as a characteristic "S"-shaped portion of the profile curve. Due to Saratoga Lake's shallow depth and its riverine nature that produces a generally continual circulation of its water, it is unlikely that Saratoga Lake stratifies.

However, in those lakes that do stratify, when the surface supply of oxygen is cut off from the bottom waters, eventually**,** if there is not enough dissolved oxygen in the lower waters to meet the demands of bottom-dwelling aquatic life and decaying organic material, the dissolved oxygen levels in the bottom waters may be reduced to zero, a condition known as anoxia or anaerobiasis, and this can have a number of negative impacts on the organisms, especially fish, living in a lake. For example, where anoxia develops in the bottom waters of a lake, fish tend to move upward, nearer to the surface of the lake, where higher dissolved oxygen concentrations exist.

This upward migration, when combined with the warmer water temperatures found near a lake's surface, can select against some fish species that prefer the cooler water temperatures and their competitive success may be severely impaired. Additionally, when there is insufficient oxygen in the lower waters, fish can be susceptible to summer-kills. *Hypolimnetic* ("bottom water") *anoxia* is common in many of the lakes in southeastern Wisconsin. When this condition occurs during winter months when ice cover prevents oxygen from diffusing into surface waters and extended periods of heavy snow cover may effectively block sunlight from reaching oxygen-producing plants under the surface of a lake, it can lead to winter fish kills as dissolved oxygen stores are not sufficient to meet the total demand for oxygen. Neither summer- nor winterkills have been reported as an issue in Saratoga Lake.

In addition to biological consequences, the lack of dissolved oxygen at depth can enhance the development of chemoclines, or chemical gradients, with an inverse relationship to the dissolved oxygen concentration. For example, the exchange that can sometimes take place between the bottom sediments and water involving certain elements, such as phosphorus, iron, and manganese, is increased under anaerobic conditions, resulting in increased hypolimnetic concentrations of these elements. Under anaerobic conditions, changes in iron and manganese oxidation states enable the release of phosphorus from the iron and manganese complexes to which they were bound under aerobic conditions. This "internal loading" can affect water quality significantly if these nutrients and salts are then mixed into the epilimnion, especially during early summer, when these nutrients can become available for algal and rooted aquatic plant growth.

Total Phosphorus

Phosphorus is an element of fundamental importance to living things, both as a nutrient and as a major cellular constituent. Although it may be found in any of four major fractions, or forms, most data concerning phosphorus in fresh water lakes refers to *total phosphorus.* This is because total phosphorus concentrations include the phosphorus contained in plant and animal fragments suspended in the lake water, phosphorus bound to sediment particles, and phosphorus dissolved in the water column. Lakes rich in organic nutrients tend to have high total phosphorus concentrations.

Statewide standards for phosphorus concentrations in lakes were adopted during November 2010. The statewide phosphorus standard supersedes the regional guideline value of 20 micrograms per liter (μg/l) or less during spring turnover established by the regional water quality management plan.[11] A concentration of less than 20 μg/l is the level considered as necessary to limit algal and aquatic plant growths to levels consistent with recreational water use objectives, as well as water use objectives for maintaining a warmwater fishery and other aquatic life. Pursuant to Section NR 102.06, "Phosphorus," of the *Wisconsin Administrative Code*, Saratoga Lake is likely to be considered to be a nonstratified drainage lake, and, as such, would be subject to a 0.040 mg/l (40 μg/l) total phosphorus criterion, above which value the lake would be considered to be impaired with respect to phosphorus. Total phosphorus concentrations have not been measured for Saratoga Lake.

Seasonal gradients of phosphorus concentrations between the epilimnion and hypolimnion of a lake reflect the biogeochemistry of this growth element. When aquatic organisms die, they usually sink to the bottom of a lake, where they decompose. Phosphorus from these organisms is then either stored in the bottom sediments or re-released into the water column. Because phosphorus is not highly soluble in water, it readily forms insoluble precipitates with calcium, iron, and aluminum under aerobic conditions, and accumulates predominantly in the lake's bottom sediments. As described above, if the bottom waters become depleted of oxygen during stratification, certain chemical changes occur, including the change in the oxidation state of iron from the insoluble Fe^{3+} state to the more soluble Fe^{2+} state. The effect of these chemical changes is that phosphorus becomes soluble and is more readily released from the sediments in a process known as "internal loading." This process also occurs

[11] *See SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; and Volume Three,* Recommended Plan, *June 1979.*

under aerobic conditions, but generally at a slower rate than under anaerobic conditions. As the waters mix, this phosphorus may be widely dispersed throughout a lake waterbody and become available for algal growth. It is not possible to determine whether internal loading may be occurring in Saratoga Lake, due to the absence of adequate water quality data. However, the river-run nature and shallow character of Saratoga Lake would suggest that internal loading under anoxic conditions is likely to be minimal.

The magnitude of the release of phosphorus from bottom sediments during internal loading in a lake and its subsequent effects in contributing to algal growth in the surface waters of a lake may be moderated by a number of circumstances, including the rates of mixing during the spring and fall overturn events. Slow mixing generally results in any phosphorus released from the bottom waters of a lake being reprecipitated and, consequently, unavailable to aquatic plants.[12] On the other hand, rapid through flows of water, associated with low water residence times, can eliminate the sediment-water concentrations gradients, and result in water quality that is perceived to be better than would be indicated by a high concentration of phosphorus in either or both the water column or lake sediments.[13]

Chlorophyll-a

Chlorophyll-*a* is the major photosynthetic ("green") pigment in plants, including aquatic plants and algae. The amount of chlorophyll-*a* present in the water is an indication of the biomass, or amount of algae, in the water. The mean chlorophyll-*a* concentration for lakes in the Southeastern Wisconsin Region is about 43 μg/l, with a median concentration of about 10 μg/l.[14] Chlorophyll-*a* levels above 10 μg/l generally result in a green coloration of the water that may be severe enough to impair recreational activities, such as swimming or waterskiing.[15] Chlorophyll-*a* levels have not been measured for Saratoga Lake.

Other Water Quality Factors

Nitrogen

Nitrogen, especially in its reactive, or "organic" form, is an element that is essential to the growth of plants, both terrestrial and aquatic plants. Most organic nitrogen is the result of a process known as "nitrogen fixation" which occurs in certain symbiotic microbes found in the roots of some plants, especially legumes and rice. Primary natural sources of nitrogen in lakes include: precipitation falling directly on a lake's surface; nitrogen fixation processes occurring both in a lake's water and its sediments; and groundwater input and surface runoff. Man-made sources of organic nitrogen include livestock wastes; agricultural fertilizers, including lawn fertilizers; and human sewage. Additional amounts of reactive nitrogen will likely enter surface- and groundwater ecosystems in the future as greater amounts of nitrogen are used in the increased production of food needed to support a growing population. Because of its association with plant growth, nitrogen level in a lake is considered a key chemical parameter in monitoring the chemical makeup of lake ecosystems. Lakes in the southeast region have an average total nitrogen level of about 1.43 mg/l, the highest level of any region in the State.[16] Total nitrogen measurements have not been recorded for Saratoga Lake.

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[12]*See, for example, R.D. Robarts, P.J. Ashton, J.A. Thornton, H.J. Taussig, and L.M. Sephton, "Overturn in a hypertrophic, warm, monomictic impoundment (Hartbeespoort Dam, South Africa),"* Hydrobiologia*, Volume 97, 1982, pages 209-224.*

[13]*P.J. Dillon and W.B. Kirchner,* op. cit.*; see also Organization for Economic Cooperation and Development,* Eutrophication of Waters: Monitoring, Assessment and Control*, OECD, 1982.*

[14]*R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

[15]*J.R. Vallentyne, "The Process of Eutrophication and Criteria for Trophic State Determination," in* Modeling the Eutrophication Process—Proceedings of a Workshop at St. Petersburg, Florida*, November 19-21, 1969, pages 57-67.*

[16]*R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

Nitrogen-to-Phosphorus Ratios

Aquatic plants and algae require such nutrients as phosphorus and nitrogen for growth. In hard-water alkaline lakes, most of these nutrients are generally found in concentrations that exceed the needs of growing plants. However, in lakes where the supply of one or more of these nutrients is limited, plant growth is limited by the amount of the nutrient that is available in the least quantity relative to all of the others. The ratio (N:P) of total nitrogen (N) to total phosphorus (P) in lake water indicates which nutrient is the factor most likely to be limiting aquatic plant growth in a lake.[17] Where the N:P ratio is greater than 14:1, phosphorus is most likely to be the limiting nutrient. If the ratio is less than 10:1, nitrogen is most likely to be the limiting nutrient. The N:P ratios for Saratoga Lake cannot be determined due to the lack of adequate water quality data.

Alkalinity and pH

Alkalinity is generally reported as mg/l $CaCO_3$ equivalents and is a measure of a lake's ability to absorb and neutralize acidic loadings. A lake's alkalinity is often closely associated with the soils and bedrock of a lake's tributary area. Lakes in the southeastern part of the State traditionally have high alkalinity, reflective of the limestone and dolomite deposits that make up much of the underlying bedrock of lake tributary areas in this region; low alkalinity lakes are mostly confined to the northern regions of the State.[18] The mean value for lakes in the southeast region is 173 mg/l.[19] Alkalinity has not been measured recently in Saratoga Lake.

The pH is a logarithmic measure of hydrogen ion concentration on a scale of 0 to 14 standard units, with 7 indicating neutrality. A pH above 7 indicates basic (or alkaline) water, and a pH below 7 indicates acidic water. The pH of lake water influences many of the chemical and biological processes that occur there. Even though moderately low or high pH values may not directly harm fish or other organisms, pH values near the ends of the scale can have adverse effects on the organisms living in a lake. Additionally, under conditions of very low (acidic) pH, certain metals, such as aluminum, zinc, and mercury, can become soluble if present in a lake's bedrock or tributary area soils, leading to an increase in concentrations of such metals in a lake's waters with subsequent potentially harmful effects to, not only the fish, but also to those organisms, including humans, who consume them.[20]

As in the case of alkalinity, the chemical makeup of the underlying bedrock has a great influence on the pH of lake waters. In the case of lakes in the Southeastern Wisconsin Region, where the bedrock is comprised largely of limestone and dolomite, the pH typically is in the alkaline range above 7. In general, the pH for most natural waterbodies is within the range of about 6.0 to about 8.5.[21] Measurements of pH from lakes in southeastern Wisconsin averaged about 8.1, which, due to the underlying geology of the Region, were the highest recorded from any region in the State; by contrast, lakes in the northeast are slightly acidic with an average pH of about 6.9.[22] Other factors influencing pH include precipitation, as well as biological (algal) activity within a lake. Natural buffering of rainfall by carbon dioxide in the atmosphere and the carbonate system in a lake, its tributary streams and drainage area, all tend to moderate the pH level in other lakes in the Region. The pH for Saratoga Lake has not been determined.

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[17] *M.O. Allum, R.E. Gessner, and T.H. Gakstatter, U.S. Environmental Protection Agency Working Paper No. 900,* An Evaluation of the National Eutrophication Data, *1976.*

[18] *R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

[19] Ibid.

[20] *Byron Shaw, Lowell Klessig, Christine Mechenich,* Understanding Lake Data, *University of Wisconsin-Extension Publication No. G3582, 2004.*

[21] *Deborah Chapman,* Water Quality Assessments, second edition, *E&FN Spon, 1996.*

[22] *R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

Conductivity

The conductivity, or electrical conductivity (*EC*), of a lake's waters is a measure of how much resistance to electrical flow exists in the water. As the concentration of charged particles ("ions") in water increases, it's resistance to electrical flow diminishes. Therefore, EC indirectly estimates the amount of dissolved ions in the water. Several natural influences can affect a lake's conductivity. For example, just as in the cases of alkalinity and pH, high concentrations of limestone in the soils of a lake's watershed and basin can lead to a higher conductivity in the lake's waters due to the dissolution of carbonate minerals in the limestone. Another natural influencing factor of conductivity is the proportion of the watershed size to the lake basin size. The larger the watershed, the more soil contact water has as it drains to the lake. Other natural influences include such things as atmospheric deposition (in ocean coastal areas, ocean water increases the salt content of strong onshore winds and precipitation) and the concentration of dissolved salts through the process of evaporation of water from a lake's surface.

Increased conductivity in a lake's waters can also be attributed to anthropogenic or human influences. Such influences include: wastewater from sewage treatment plants and from onsite septic systems; urban runoff from roads, especially road salt used to clear road surfaces of ice and snow; animal wastes; and agricultural/lawn/garden runoff, primarily chemical fertilizers and pesticides. Consequently, abnormally high levels of conductivity in a lake's waters are often a signal of a potential pollution problem. Generally, conductivity measurements are expected to fall within a range of about two times a lake's hardness values.[23] In addition, top versus bottom measurements of conductivity generally reveal increased levels of conductivity at depth due to decomposition of bottom sediments and acidic conditions that allow certain materials to become more soluble.

Up until the late 1970s, conductivity was typically measured in units known as micromhos per centimeter (μmho/cm); after that time, the standard unit was changed to microSiemens/cm (μS/cm), where 1 μmho/cm = 1 μS/cm. Also, it is worth noting that, since increasing temperature creates an increase in electrical flow in an ionic solution, conductivity measurements are automatically compensated to a standard temperature of 25 degrees Celsius, such measurements being referred to as *specific conductivity.* Conductivity measurements have not been taken in Saratoga Lake.

There are a number of other chemical and physical parameters commonly measured when undertaking a comprehensive study of a lake's water quality, including turbidity, various cations (positively charged ionic substances, such as calcium, magnesium, and sodium, among others) and various anions (negatively charged ionic substances, such as chloride and sulfate).

For the purposes of this report on the current conditions of Saratoga Lake, since no comprehensive water quality data were available, this report focused on those principle water quality factors most commonly used when determining a lake's water quality that could be determined by other means, such as by remote sensing of water transparency as noted above or mathematical modeling.

Chloride

An important emerging issue in southeastern Wisconsin is the application of salts for snow and ice control on roads and other surfaces, and the use and discharge of salts in water softeners used to treat water for domestic supply. Chloride associated with these salts is a persistent constituent that is often transported by stormwater runoff and wastewater discharges. Stormwater and wastewater management practices do not treat or remove dissolved chloride in runoff. As a consequence, concentrations of dissolved chloride in both surface and ground waters throughout Southeastern Wisconsin are increasing, and while these concentrations currently remain below those levels necessary to cause significant changes in the plant and animal communities in the river system, special safeguards must be considered in order to avoid future adverse effects. Chloride values have not yet been monitored within Saratoga Lake.

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[23]*Byron Shaw, et al.*, op. cit.

POLLUTION LOADINGS AND SOURCES

Pollutant loads to a lake are generated by various natural processes and human activities that take place in the area tributary to a lake. These loads are transported to the lake through the atmosphere, across the land surface, and by way of inflowing streams. Pollutants transported by the atmosphere are deposited onto the surface of the lake as dry fallout and direct precipitation. Pollutants transported across the land surface enter the lake directly as surface runoff and, indirectly, as groundwater inflows, including drainage from onsite wastewater treatment systems. Pollutants transported by streams also enter a lake as surface water inflows.

In drainage lakes, like Saratoga Lake, pollutant loadings transported by precipitation falling directly onto the lake surface, runoff from the tributary areas immediately surrounding the Lake, and stream inflow, in the absence of identifiable or point source discharges from industries or wastewater treatment facilities, comprise the principal routes by which contaminants enter the waterbodies.[24] The presence of clearly identifiable inflowing watercourses to Saratoga Lake and to the upstream portions of the Fox River that are part of the tributary area of Saratoga Lake would suggest that the input of contaminants carried into the Lake by inflowing streams is deserving of consideration. Although groundwater contributes a significant amount of water to Saratoga Lake, groundwater is not usually a source of pollution to a lake. Currently, there are no significant point source pollutants which discharge directly into Saratoga Lake.[25] For this reason, the discussion that follows is based upon nonpoint source pollutant loadings to the Lake, which enter the lake through eight major outfalls in the Saratoga proper, including six municipal storm sewer systems along the eastern shore and two private storm sewers (permitted by WDNR) along the western shore.[26]

Nonpoint sources of water pollution include urban sources, such as runoff from residential, commercial, transportation, construction, and recreational activities; and rural sources, such as runoff from agricultural lands and onsite sewage disposal systems. Nonpoint sourced phosphorus, suspended solids, and urban-derived metals inputs to Saratoga Lake were estimated using the Wisconsin Lake Model Spreadsheet (WiLMS version 3.0),[27] and the unit area load-based (UAL) models developed for use within the Southeastern Wisconsin Region.[28] These two models operate on the general principal that, depending on land use (agricultural, residential, etc.), a given surface area of land within a lake's tributary area will deliver a predetermined mass of pollutants to a lake. Values predicted by these two models can then be compared to those observed at monitoring stations in a lake. This

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[24]*Sven-Olof Ryding and Walter Rast, "The Control of Eutrophication of Lakes and Reservoirs,"* Unesco Man and the Biosphere Series*, Volume 1, Parthenon Press, Carnforth, 1989; Jeffrey A. Thornton, Walter Rast, Marjorie M. Holland, Geza Jolankai, and Sven-Olof Ryding, "The Assessment and Control of Nonpoint Source Pollution of Aquatic Ecosystems,"* Unesco Man and the Biosphere Series*, Volume 23, Parthenon Press, Carnforth, 1999.*

[25]*Historically, drainage from the industrial areas on the eastern side of the City of Waukesha was conveyed into the Fox River upstream of Saratoga Lake, creating a legacy of contamination that is currently be investigated by the WDNR with the assistance of the Southeastern Wisconsin Fox River Commission. The ultimate goal of this investigation would be to remove or stabilize contaminated sediments to minimize downstream transport of contaminants within the Fox River. As of early 2013, these investigations were ongoing.*

[26]*WDNR Stormwater Staff.*

[27]*John C. Panuska and Jeff C. Kreider, Wisconsin Department of Natural Resources Publication No. PUBL-WR-363-94,* Wisconsin Lake Modeling Suite Program Documentation and User's Manual, Version 3.3 for Windows*, August 2002.*

[28]*SEWRPC Planning Report No. 30,* op. cit.

comparison serves two purposes: 1) the identification of potential water quality issues of concern, and 2) the indication of potential sources of water pollution not accounted for on the basis of land use.[29]

Phosphorus Loadings

Table 5 sets forth the estimated existing year 2010 phosphorus loads to Saratoga Lake from its tributary area, which were estimated based upon land use inventory data set forth in the regional land use plan.[30] It was estimated that, under year 2010 conditions, the total phosphorus load to Saratoga Lake from its tributary area was 33,547 pounds. Of the annual total phosphorus load, it was estimated that 18,817 pounds per year, or about 56 percent of the total loading, were contributed by runoff from rural lands, mostly agricultural lands, and 14,315 pounds per year, or about 43 percent, were contributed by runoff from urban lands, mostly from residential sources. About 415 pounds, or about 1 percent, were contributed by direct precipitation onto the lake surface.

Phosphorus release from the lake bottom sediments, or internal loading as discussed above, does not appear to have been a contributing factor to the total phosphorus loading to Saratoga Lake. Using the Organization for Economic Cooperation and Development (OECD) phosphorus loading model,[31] this phosphorus load would equate to an in-lake phosphorus concentration of about 150 μg/l. This concentration is the slightly higher than the total phosphorus concentration of 0.13 mg/l (= 130 μg/l) reported by the WDNR based on a sampling of the impoundment conducted during 1993. Nevertheless, this agreement provides some confidence that the OECD model could be used to predict the forecast in-lake total phosphorus concentration based on forecast phosphorus loadings. It should be noted that these concentrations greatly exceed the regional guideline of 20 μg/l set forth in the regional water quality management plan,[32] as well as the State phosphorus criterion of 40 μg/l established for nonstratified drainage lakes pursuant to Section NR 102.06(4)(b) of the *Wisconsin Administrative Code*.

Based upon the estimates set forth in the regional water quality management plan,[33] it was recommended that phosphorus loads in the area tributary to Saratoga Lake be reduced. Recommended reductions in total phosphorus loading of up to 50 percent from urban nonpoint sources and of up to 75 percent from rural nonpoint sources of contamination were recommended. To this end, the City of Waukesha, surrounding municipalities, and Waukesha County implemented an extensive campaign of community awareness creation as a major action to implement this recommendation since its inception.

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[29]*The forecast total phosphorus load to the Lake, generated through the WiLMS and UAL models, allows calculation of the likely in-lake average annual total phosphorus concentration which can be compared with the observed values reported in the USGS TSI or Level 2 CLMN datasets. Significant differences between forecast and observed values generally indicates the presence of an unidentified source; occasionally, such a difference can be ascribed to the fact that a lake may fall outside the range of typical lakes used to derive the mathematical relationships used in the WiLMS and UAL models.*

[30]*SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006.*

[31]*Organization for Economic Cooperation and Development,* Eutrophication of Waters: Monitoring, Assessment and Control, *OECD, 1982.*

[32]*SEWRPC Planning Report No. 30,* op. cit.

[33]*SEWRPC Planning Report No. 30, Volume Two,* op. cit.*; see also SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

Table 5

ESTIMATED ANNUAL POLLUTANT LOADINGS BY LAND USE CATEGORY WITHIN THE AREA TRIBUTARY TO SARATOGA LAKE: 2010 AND 2035

Land Use Category	Pollutant Loads: 2010			
	Sediment (tons)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)
Urban				
Residential	191.2	3,922.8	- -	196.1
Commercial	1,072.1	3,282.0	601.7	4,075.1
Industrial	1,000.9	3,114.5	585.6	3,966.4
Governmental	416.5	2,200.5	114.1	1,304.0
Transportation	45.4	1,051.7	- -	- -
Recreational	33.0	743.3	- -	- -
Subtotal	2,759.1	14,314.8	1,301.4	9,541.6
Rural				
Agricultural	4,440.8	16,973.8	- -	- -
Wetlands	22.7	490.7	- -	- -
Woodlands	6.8	147.4	- -	- -
Water	299.7	414.4	- -	- -
Open Lands	0.4	8.5	- -	- -
Extractive	313.2	1,197.1	- -	- -
Subtotal	5,083.6	19,231.9	- -	- -
Total	7,842.7	33,546.7	1,301.4	9,541.6

Land Use Category	Pollutant Loads: 2035			
	Sediment (tons)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)
Urban				
Residential	247.2	5,070.2	- -	253.5
Commercial	1,470.4	4,501.2	825.2	5,589.0
Industrial	1,450.6	4,513.8	848.8	5,748.4
Governmental	579.5	3,061.8	158.8	1,814.4
Transportation	55.1	1,277.3	- -	- -
Recreational	42.6	959.9	- -	- -
Subtotal	3,845.4	19,384.2	1,832.8	13,405.3
Rural				
Agricultural	350.6	7,073.5	- -	- -
Wetlands	22.7	490.7	- -	- -
Woodlands	6.8	147.2	- -	- -
Water	299.7	414.4	- -	- -
Extractive	330.4	1,270.1	- -	- -
Subtotal	1,010.2	9,395.9	- -	- -
Total	4,855.6	28,780.1	1,832.8	13,405.3

Source: SEWRPC.

Table 5 also shows the estimated phosphorus loads to Saratoga Lake from its tributary area under planned year 2035 conditions.[34] As a result of anticipated land use changes expected to occur through 2035, the annual total phosphorus load to the Lake is anticipated to diminish as agricultural activities within the area tributary to Saratoga Lake are replaced by urban residential land uses. The most likely annual total phosphorus load to the Lake under the planned conditions is estimated to be 28,780 pounds. Of the total annual forecast phosphorus load, 8,980 pounds per year, or about 32 percent of the total loading, are estimated to be contributed by runoff from rural land, and 19,385 pounds per year, or about 67 percent, from urban land. About 415 pounds, or about 1 percent, are expected to be contributed by direct precipitation onto the lake surface. Thus, it may be anticipated that not only will the amount of the phosphorus load decrease, but that the distribution of the sources of the phosphorus load to the Lake may change, with the amount of phosphorus being contributed from urban sources experiencing an increase from comprising about 43 percent of the total in 2010 to about 67 percent of the total in 2035, while the amount of phosphorus from agricultural sources will decrease from 56 percent of the total in 2010 to about 32 percent of the total in 2035. Despite this reduction in phosphorus loading, the forecast in-lake total phosphorus concentration is estimated to be 130 μg/l, or well in excess of regional guidelines and State criteria.

Sediment Loadings

The estimated sediment loadings to Saratoga Lake from its tributary area under existing year 2010 and planned year 2035 conditions and, as set forth in the adopted regional land use plan,[35] are shown in Table 5. A total annual sediment loading of 7,840 tons was estimated to be contributed to Saratoga Lake from its tributary area under year 2010 conditions, as shown in Table 5. Of the likely annual sediment load, it was estimated that 4,780 tons per year, or about 61 percent of the total loading, were contributed by runoff from rural lands, mostly from agricultural sources, and 2,760 tons, or about 35 percent, were contributed by urban lands. Approximately 300 tons, or about 4 percent of the annual sediment load, were contributed by atmospheric deposition onto the lake surface.

Under 2035 conditions, the annual sediment load to the Lake from its tributary area is anticipated to diminish. The most likely annual sediment load to the Lake under 2035 land use conditions is estimated to be 4,855 tons. Of this forecast sediment load anticipated for Saratoga Lake, 710 tons of sediment are estimated to be contributed to the Lake from rural sources and 3,845 tons from urban sources. Direct deposition of sediment onto the lake surface is expected to deliver about 300 tons of sediment per year through direct precipitation onto the lake surface.

Urban Heavy Metals Loadings

Urbanization brings with it increased use of metals and other materials that contribute pollutants to aquatic systems.[36] The majority of these metals become associated with sediment particles,[37] and are, consequently, likely to be encapsulated into the bottom sediments of a lake. Sediment samplings conducted by the WDNR over several years during the period from 1993 through 2008 confirm that concentrations of various contaminants in the sediments of Saratoga Lake frequently exceed the lowest effect level (LEL) thresholds set forth in State sediment quality guidelines.[38] These data are summarized in Table 6.

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[34]*SEWRPC Planning Report No. 48*, op. cit.

[35]Ibid.

[36]*Jeffrey A. Thornton, et al.,* op. cit.

[37]*Werner Stumm and James J. Morgan,* Aquatic Chemistry: An Introduction Emphasizing Chemical Equilibria in Natural Waters, *Wiley-Interscience, New York, 1970.*

[38]*Wisconsin Department of Natural Resources, unpublished report, "Inventory of Statewide Contaminated Sediment Sites and Development of a Prioritization System," June 1994.*

Table 6

SARATOGA LAKE SEDIMENT QUALITY DATA AND DRAFT STATE OF WISCONSIN SEDIMENT QUALITY CRITERIA: 1993 THROUGH 2008

Chemicals	Concentration in mg/kg						
	LEL	MEL	SEL	1993	1999	2007	2008
Arsenic (As)	6	33	85	- -	6-27	6	2
Cadmium (Cd)	1.1	5	9	- -	0.9-1.7	0.5	0.4
Chromium (Cr)	31	110	145	- -	24-54	23.6	35.9
Copper (Cu)	25	110	390	- -	21-450	46.8	67.4
Nickel (Ni)	31	50	75	- -	18-389	15	14
Lead (Pb)	31	110	250	- -	28-260	91	32
Zinc (Zn)	120	270	820	- -	310	- -	- -
PCBs (total)	0.07	3.3	26.4	0.05	<0.05-0.40	0.05	- -
Oil and Grease	1,000	- -	- -	- -	- -	1,470	1,230
Ammonia-Nitrogen	75	- -	- -	- -	- -	- -	0.3
Total Phosphorus	- -	- -	- -	- -	- -	1,650	- -

NOTE: LEL = Lowest Effect Level
MEL = Moderate Effect Level
SEL = Severe Effect Level

Source: Wisconsin Department of Natural Resources and SEWRPC.

The estimated loadings of copper and zinc likely to be contributed to Saratoga Lake from its tributary area under existing year 2010 land use conditions and forecast year 2035 conditions are shown in Table 5. During 2010, 1,300 pounds of copper and 9,540 pounds of zinc were estimated to be contributed annually to Saratoga Lake from its tributary area, all from urban lands. Under planned year 2035 conditions, as set forth in the adopted regional land use plan,[39] the annual heavy metal loads to the Lake are anticipated to increase to about 1,830 pounds of copper and 13,405 pounds of zinc per year.

TROPHIC STATUS

Lakes are commonly classified according to their degree of nutrient enrichment, or trophic status. The ability of a lake to support a variety of recreational activities and healthy fish and other aquatic life communities is often correlated to the degree of nutrient enrichment that has occurred. There are three terms generally used to describe the trophic status of a lake: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic lakes are nutrient-poor lakes. These lakes characteristically support relatively few aquatic plants and often do not contain very productive fisheries. Oligotrophic lakes may provide excellent opportunities for swimming, boating, and waterskiing. Because of the Region's naturally fertile soils and the intensive land use activities, there are relatively few oligotrophic lakes in southeastern Wisconsin.

Mesotrophic lakes are moderately fertile lakes which may support abundant aquatic plant growths and productive fisheries. However, nuisance growths of algae and macrophytes are usually not exhibited by mesotrophic lakes. These lakes may provide opportunities for all types of recreational activities, including boating, swimming, fishing, and waterskiing. Many lakes in southeastern Wisconsin are mesotrophic.

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[39]*SEWRPC Planning Report No. 48*, op. cit.

Eutrophic lakes are nutrient-rich lakes. These lakes often exhibit excessive aquatic macrophyte growths and/or experience frequent algae blooms. If the lakes are shallow, fish winterkills may be common. While portions of such lakes are not ideal for swimming and boating, eutrophic lakes may support very productive fisheries. Although some eutrophic lakes are present in the Region, severely eutrophic lakes are rare, especially since the regionwide implementation of recommendations put forth in the regional water quality management plan. Severely enriched lakes are sometimes referred to as being hypertrophic.

Several numeric "scales," based on one or more water quality indicators, have been developed to define the trophic condition of a lake. Because trophic state is actually a continuum from very nutrient poor to very nutrient rich, a numeric scale is useful for comparing lakes and for evaluating trends in water quality conditions. Care must be taken, however, that the particular scale used is appropriate for the lake to which it is applies. In this case, the Vollenweider-OECD open-boundary trophic classification system is not an appropriate mathematical tool given the very short water retention time of Saratoga Lake,[40] but the Carlson Trophic State Index (TSI),[41] with a variation known as the Wisconsin Trophic State Index value (WTSI), could be used as an assessment tool.[42] The WTSI is designed to account for the greater humic acid content—brown water color—present in Wisconsin lakes, in comparison to the clear water lakes of Ohio for which the Carlson TSI was developed. The WTSI has been adopted by the WDNR for use in lake management investigations. The WTSI values for Saratoga Lake were estimated on the basis of the averaged satellite measurements of water transparency of 3.4 feet, or 1.03 meters. Using these data, the WTSI value for Saratoga Lake was determined to be approximately 59.6, placing Saratoga Lake well within the eutrophic, or enriched, range.

AQUATIC PLANTS IN SARATOGA LAKE

Aquatic plants include larger plants, or macrophytes, and microscopic algae, or phytoplankton. These plants form an integral part of the aquatic food web, converting inorganic nutrients present in the water and sediments into organic compounds that are directly available as food to other aquatic organisms. In this process, known as photosynthesis, plants utilize energy from sunlight and release into the water the oxygen required by many other aquatic life forms.

Aquatic Plant Survey

To document the types, distribution, and relative abundance of aquatic macrophytes in Saratoga Lake, an aquatic plant survey was conducted in early October 2012 by SEWRPC staff utilizing the WDNR grid-based point-intercept methodology.[43] A list of aquatic plant species observed in the 2012 survey is presented in Table 7. The ecological significance of each plant listed in Table 7 is set forth in Table 8. Map 7 shows the various plant communities observed at each sampling site. Representative illustrations of these aquatic plants can be found in Appendix A.

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[40]*H. Olem and G. Flock, U.S. Environmental Protection Agency Report EPA-440/4-90-006,* The Lake and Reservoir Restoration Guidance Manual, Second Edition, *Washington, D.C., August 1990.*

[41]*R.E. Carlson, "A Trophic State Index for Lakes,"* Limnology and Oceanography, *Vol. 22, No. 2, 1977.*

[42]*R.A. Lillie, S. Graham, and P. Rasmussen, "Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes,"* Research and Management Findings, *Wisconsin Department of Natural Resources Publication No. PUBL-RS-735 93, May 1993.*

[43]*Wisconsin Department of Natural Resources, Publication No. PUB-SS-1068 2010,* Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry and Analysis, and Applications, *March 2010.*

Table 7

AQUATIC PLANT SPECIES OBSERVED IN SARATOGA LAKE: 2012

Aquatic Plant Species	Abundance Score	Frequency of Occurrence	Relative Density	Importance Value
Ceratophyllum demersum (coontail)	163	73.7	2.3	171.6
Elodea canadensis (waterweed)	43	25.3	1.8	45.3
Lemna minor (duckweed)	112	64.2	1.8	117.9
Myriophyllum spicatum (Eurasian water milfoil)	114	53.7	2.2	120.0
Myriophyllum sibiricum (native milfoil)	1	1.1	1.0	1.1
Potamogeton crispus (curly-leaf pondweed)	4	3.2	1.3	4.2
Potamogeton foliosis (leafy pondweed)	1	1.1	1.0	1.1
Potamogeton zosteriformis (flat-stem pondweed)	50	33.7	1.6	52.6
Stuckenia pectinata (Sago pondweed)	2	1.1	2.0	2.1
Vallisneria americana (eel-grass/wild celery)	1	1.1	1.0	1.1
Zosterella dubia (water stargrass)	10	4.2	2.5	10.5

NOTES: There were 95 sites sampled.

Abundance Score = A subjective assessment of the abundance of a species at a site on a scale of 1 to 5, with 5 = greatest abundance

Frequency of Occurrence = The number of occurrences of a species divided by the number of samples with vegetation, expressed as a percentage

Relative Density = The sum of the density ratings for a species divided by the number of sampling points with vegetation.

Importance Value = The product of the relative frequency and the average density, expressed as a percentage.

Source: Aron and Associates, and SEWRPC.

The 2012 survey identified 11 plant species, 10 of which were submerged species, including four species of pondweed. The one nonsubmerged species was duckweed (*Lemna minor*), which was the second most commonly observed plant reported. The dominant submerged aquatic plant in Saratoga Lake at the time of the 2012 survey was coontail (*Ceratophylum demersum*). This is a relatively common native aquatic plant and is dominant in many of the Region's lakes. The second most common submerged plant species was a nonnative plant: Eurasian water milfoil (*Myriophyllum spicatum*), which is further discussed below. Other submerged aquatic plant species identified in the 2012 survey included three native species of pondweed, one nonnative pondweed, plus waterweed (*Elodea canadensis*), eel-grass (*Vallisneria americana*), and water stargrass (*Zosterella dubia*).

Aquatic Plant Species of Special Significance

Native Aquatic Plants

Native aquatic plant species are specially adapted to local environments. Native wildlife, from insects through mammals, is similarly adapted to the local environment, a significant part of which is comprised of the plants. Many kinds of wildlife depend exclusively on the presence of specific plant species for survival.

In southeastern Wisconsin lakes, there are several submerged aquatic plant species of special importance: large-leaf pondweed (*Potamogeton amplifolius*), white-stem pondweed (*Potamogeton praelongus*), and the macro-alga muskgrass (*Chara vulgaris*). These are important native aquatic plants upon which fish and wildlife depend:

Table 8

POSITIVE ECOLOGICAL SIGNIFICANCE OF AQUATIC PLANT SPECIES PRESENT IN SARATOGA LAKE: 2012

Aquatic Plant Species Present	Ecological Significance
Ceratophyllum demersum (coontail)	Provides good shelter for young fish; supports insects valuable as food for fish and ducklings; native
Elodea canadensis (waterweed)	Provides shelter and support for insects which are valuable as fish food; native
Lemna minor (duckweed)	A valuable food source for waterfowl; also consumed by muskrat, beaver, fish; provides shade and cover for fish and invertebrates; native
Myriophyllum spicatum (Eurasian water milfoil)	None known; nonnative
Myriophyllum sibiricum (whorled, or native, milfoil)	Fruit and foliage eaten by waterfowl; provides cover and forage opportunities for fish; native
Potamogeton crispus (curly-leaf pondweed)	Nonnative
Potamogeton foliosis (leafy pondweed)	The fruit is an important food source for waterfowl; the stem and leaves supply food for muskrat, beaver, deer, and moose and provide forage and cover for fish; native
Potamogeton zosteriformis (flat-stem pondweed)	Provides some food for ducks; native
Stuckenia pectinata (Sago pondweed)	A top food source for waterfowl; native
Vallisneria americana (eel-grass/wild celery)	Provides good shade and shelter, supports insects, and is valuable fish food; native
Zosterella dubia (water stargrass)	Locally important food source for waterfowl and forage for fish; native

NOTE: Information obtained from *A Manual of Aquatic Plants* by Norman C. Fassett, University of Wisconsin Press; *Guide to Wisconsin Aquatic Plants*, Wisconsin Department of Natural Resources; and *Through the Looking Glass...A Field Guide to Aquatic Plants*, Wisconsin Lakes Partnership, University of Wisconsin-Extension.

Source: SEWRPC.

- Large-leaf pondweed is well known to anglers since, due to its large leaf size and plant spacing, it has superior qualities as fish habitat.

- White-stem pondweed is of special importance among the pondweeds that occur in the Region because of its sensitivity to changes in water quality and intolerance of turbidity. It is considered a valuable water quality indicator species.

- Although muskgrass lacks a root system, it is an effective bottom sediment stabilizer, benefiting water quality, and is a favored waterfowl food source. It is prevalent in the plant communities of many lakes in the Region, and frequently is seen as an indicator of good water quality in a lake.[44] Muskgrass also is implicated in maintaining water quality conditions that assist native aquatic plant species to successfully outcompete nonnative aquatic plant species.

During the 2012 aquatic plant survey, none of these species was observed in Saratoga Lake. The frequency and distribution of the four most common native aquatic plants in Saratoga Lake (coontail, duckweed, flat-stem pondweed and waterweed, respectively) are represented on Maps B-1 through B-4 in Appendix B.

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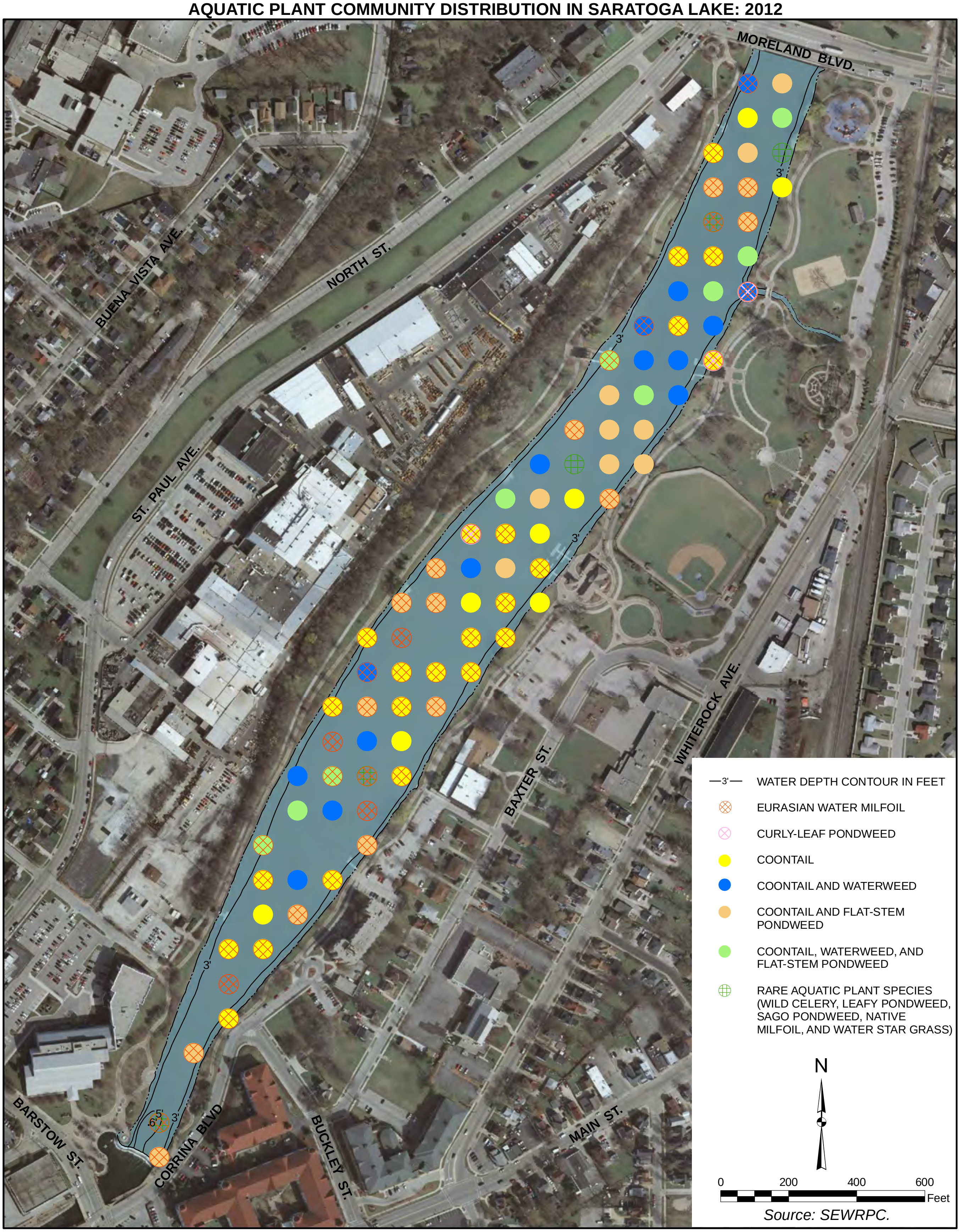
[44]*In general, hardwater lakes are dominated by aquatic plants, such as Elodea and Chara. Hardwater lakes are associated with watersheds rich in carbonate minerals, such as dolomite, and typically have high alkalinity values. See Peter K. Hepler, "Calcium: A Central Regulator of Plant Growth and Development,"* The Plant Cell, *Volume 17, August 2005, pages 2142-2155.*

Map 7

AQUATIC PLANT COMMUNITY DISTRIBUTION IN SARATOGA LAKE: 2012



DATE OF PHOTOGRAPHY: APRIL 2010

Aquatic Invasive Species

The WDNR lists the following three aquatic invasive species as being detrimental to the ecological health of the Lake. These are declared nuisance species as identified in Chapters NR 40 and NR 109 of the *Wisconsin Administrative Code*: Eurasian water milfoil, curly-leaf pondweed (*Potamogeton crispus*), and purple loosestrife (*Lythrum salicaria*). Two of these species, Eurasian water milfoil and curly-leaf pondweed, were recorded during the 2012 aquatic plant survey at Saratoga Lake. Purple loosestrife, which is becoming more widespread in wetlands and shorelands throughout the Region, although not recorded on the 2012 survey of Saratoga Lake, was observed in small numbers by SEWRPC staff. A fourth invasive organism, zebra mussel, has already been noted above and was not reported as being present in Saratoga Lake.

Eurasian Water Milfoil

Eurasian water milfoil is one of eight milfoil species found in Wisconsin and the only one known to be exotic, or nonnative. Because of its nonnative nature, Eurasian water milfoil has few natural enemies that can inhibit its growth, which can be explosive under suitable conditions. The plant exhibits this characteristic growth pattern in lakes with organic-rich sediments, or where the lake bottom has been disturbed, e.g., it frequently has been reported as a colonizing species following dredging. Unless its growth is anticipated and controlled, Eurasian water milfoil populations can displace native plant species and interfere with the aesthetic and recreational use of the waterbodies. This plant has been known to cause severe recreational use problems in Wisconsin Lakes.

Eurasian water milfoil reproduces by the rooting of plant fragments. Consequently, some recreational uses of lakes can result in the expansion of Eurasian water milfoil communities. For example, when boat propellers fragment Eurasian water milfoil plants, these fragments, as well as fragments that occur for other reasons, such as wind-induced turbulence or fragmentation of the plant by fishes, are able to generate new root systems, allowing the plant to colonize new sites. The fragments also can cling to boats, trailers, motors, and/or bait buckets, and can stay alive for weeks contributing to the transfer of milfoil to other lakes. For this reason, it is very important to remove all vegetation from boats, trailers, and other equipment prior to launching into waterbodies.

Eurasian water milfoil was the second most common submerged plant species observed in the 2012 survey of Saratoga Lake. Map 8 shows the distribution of this plant species in relation to other plants in the Lake.

Curly-Leaf Pondweed

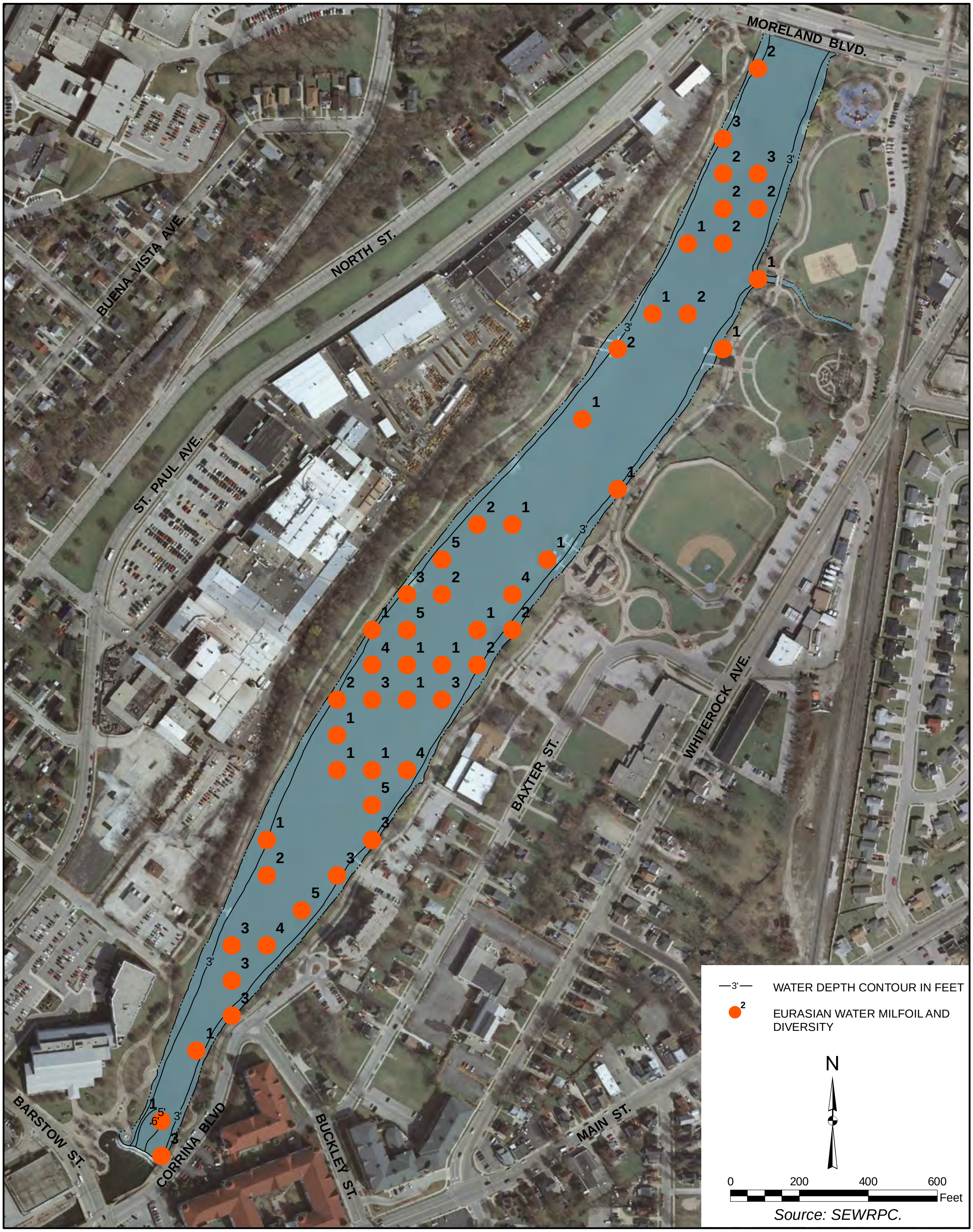
Curly-leaf pondweed is a plant that thrives in cool water and exhibits a peculiar split-season growth cycle that helps give it a competitive advantage over native plants and makes management of this species difficult. In late summer, the plant produces specialized over-wintering structures, or "turions" and the main body of the plant dies off and drops to the bottom where the turions lie dormant until the cooler fall water temperatures trigger the turions to germinate. Over the winter, the turions produce winter foliage that thrives under the ice. In spring, when water temperatures begin to rise again, the plant has a head start on the growth of native plants and quickly grows to full size, producing flowers and fruit earlier than its native competitors. Because it can grow in more turbid waters than many native plants, protecting or improving water quality is an effective method of control of this species; clearer waters in a lake can help native plants compete more effectively with curly-leaf pondweed. Map 9 shows the distribution of curly-leaf pondweed in Saratoga Lake in 2012, however, it is important to note that curly-leaf pondweed, as a general rule, is most prevalent in the spring in the Southeastern Wisconsin Region. As this survey was completed in October 2012, it is, therefore, possible that this survey did not fully capture the prevalence of curly-leaf pondweed in Saratoga Lake.

Purple Loosestrife

Purple loosestrife is a wetland perennial plant native to Europe and Asia. The plant can grow to three to seven feet in height and produces a bright purple flower spike in late summer, where it can easily be identified growing along shorelands among native plants, such as cattails. It is a hardy plant: even if the stems are clipped, trampled or buried, they can take root and produce new plants. As is the case with most nonnative species, lack of natural controls (insects and diseases) often leads to prolific reproduction that has allowed purple loosestrife to invade many of our wetlands to the extent that native vegetation is under threat of near total exclusion. Such species

Map 8

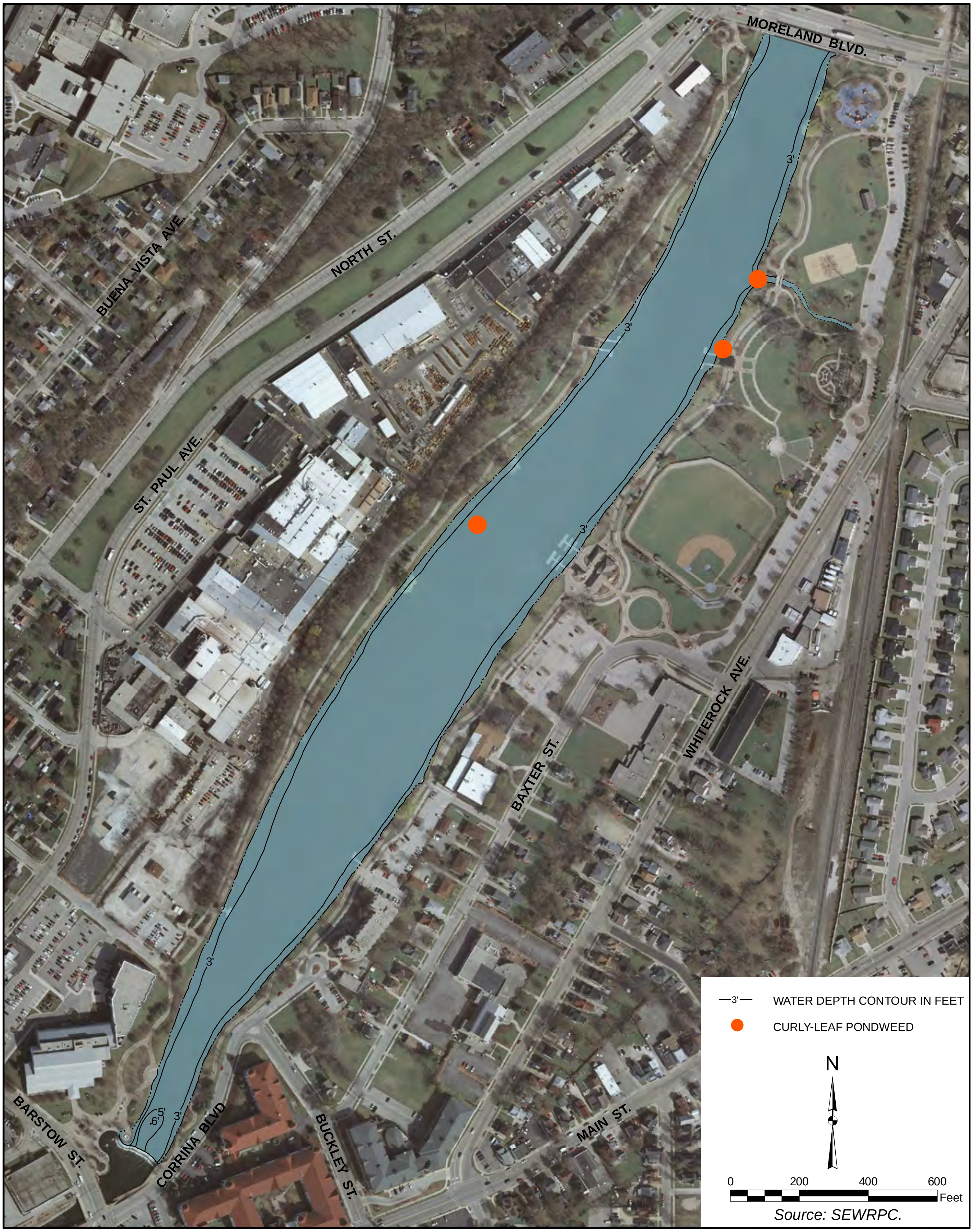
EURASIAN WATER MILFOIL DISTRIBUTION IN SARATOGA LAKE: 2012



DATE OF PHOTOGRAPHY: APRIL 2010

Map 9

CURLY-LEAF PONDWEED DISTRIBUTION IN SARATOGA LAKE: 2012



DATE OF PHOTOGRAPHY: APRIL 2010

replacement can have profound detrimental effects on native wildlife adapted to, and dependent upon, native vegetation for survival. Control is usually attempted by cutting and bagging the tops of the plant during flowering and treating the cut stem with chemical herbicide (if used near water, use of an aquatic herbicide may require a WDNR permit pursuant to Chapter NR 107 of the *Wisconsin Administrative Code*); bio-control utilizing *Galerucella* beetles has also been successful in many parts of the State in controlling purple loosestrife populations.

Aquatic Plant Diversity in Saratoga Lake

A key aspect of the ability of an ecosystem, such as a lake, to maintain its ecological integrity is through "biological diversity." Conserving the biological diversity, or biodiversity, of an ecosystem helps not only to sustain the system, but preserves a spectrum of options for future decisions regarding the management of that system.

The presence of a highly diverse plant community, especially one containing a variety of pondweeds, is generally considered to be indicative of a healthy lake and good habitat for fishes and aquatic life. For example, nearby Little Muskego Lake in a survey conducted in 2007 was observed to contain 18 submerged plant species, nine of which were pondweeds.[45] Additionally, Pell Lake has been reported to have 13 species of submersed aquatic plants;[46] Lake Mary has been reported to have 15 species;[47] Elizabeth Lake, 18 species;[48] and Geneva Lake, 20 species.[49] With an aquatic plant community comprised of only 11 plant species, Saratoga Lake in 2012 would be considered to have a somewhat limited diversity of aquatic species. Map 10 indicates the diversity of plant species observed at each sampling site.

Aquatic plants in lakes and waterways have specific requirements for sunlight and substrate, and, consequently, plant communities vary with depth, water quality, and other "drivers" that affect the ability of the plants to succeed in a specific locality. For these reasons, some areas of a lake may contain plant communities with very little diversity, e.g., communities with five or fewer species, while other areas can be extremely diverse. In Saratoga Lake, given the few species of aquatic plants comprising the Lake's flora, can be considered as having poor diversity.

Changes in the Aquatic Plant Communities in Saratoga Lake

Aquatic plant communities do undergo cyclical and periodic changes which reflect, in part, changing climatic conditions on an interannual scale and, in part, the evolution of the aquatic plant community in response to long-term changes in a lake's "hydroclimate." These latter changes include factors, such as long-term trends in nutrient loading, sedimentation rates, and recreational use patterns. The former, interannual changes may occur over a period of three to seven years, and may be temporary; the latter, evolutionary changes may occur over a decadal

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[45]*SEWRPC Memorandum Report No. 155, 2nd Edition,* An Aquatic Plant Management Plan for Little Muskego Lake, Waukesha County, Wisconsin, *February 2009.*

[46]*SEWRPC Memorandum Report No. 158,* A Lake Protection and Recreational Use Plan for Pell Lake, Walworth County, Wisconsin, *May 2006.*

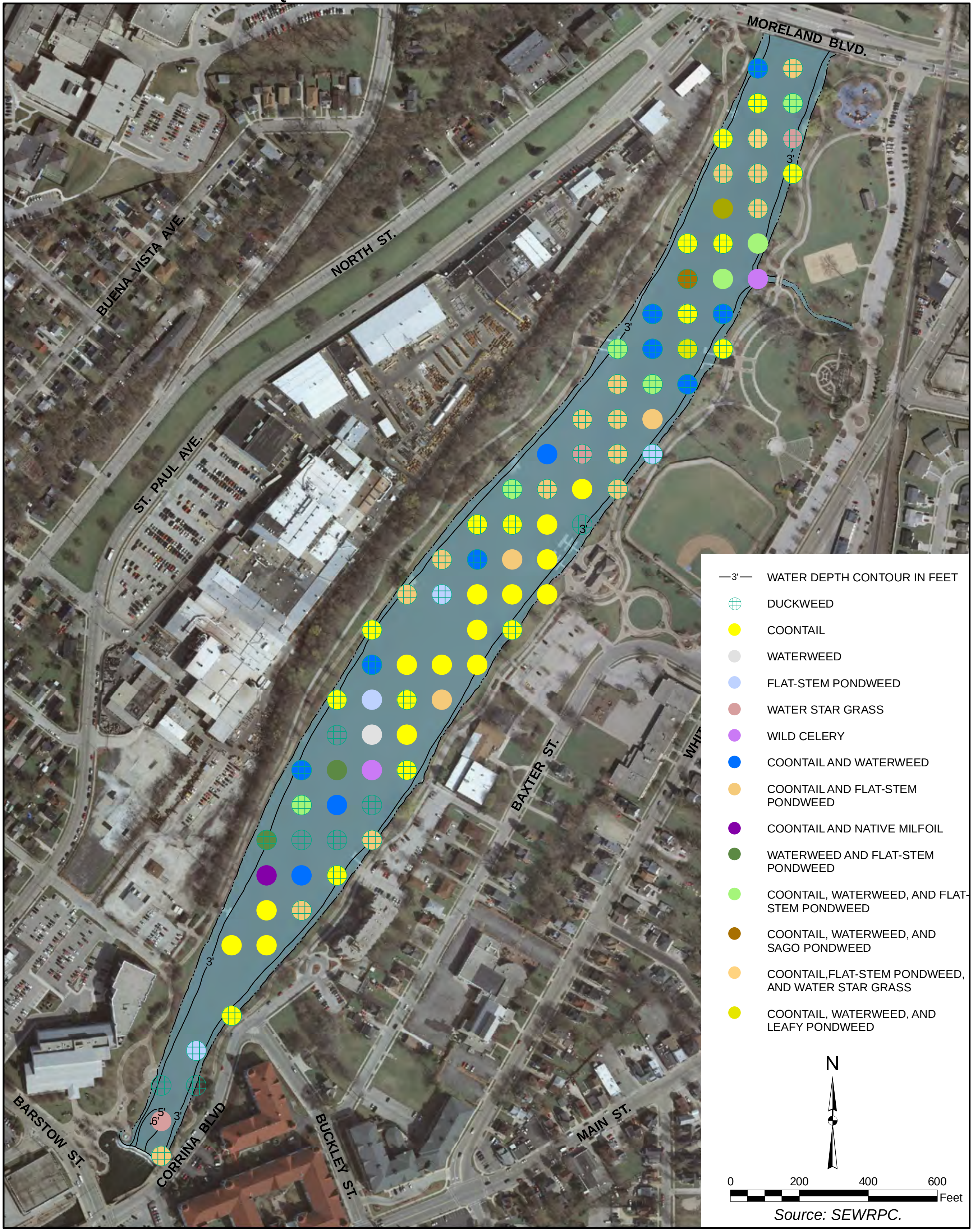
[47]*SEWRPC Community Assistance Planning Report No. 302,* A Lake Management Plan for Elizabeth Lake and Lake Mary, Kenosha County, Wisconsin, *Volume One*, Inventory Findings, *July 2009.*

[48]Ibid.

[49]*SEWRPC Community Assistance Planning Report No. 60, 2nd Edition,* A Lake Management Plan for Geneva Lake, Walworth County, Wisconsin, *May 2008.*

Map 10

AQUATIC PLANT DIVERSITY IN SARATOGA LAKE: 2012



DATE OF PHOTOGRAPHY: APRIL 2010

period or longer and are longer-lasting. Some species, such as the pondweeds noted above, exhibit distinct seasonality, with individual species having well-defined growing periods that reflect water temperature, insolation, and other factors. In addition, the changes in aquatic plant populations in a lake may reflect the results of aquatic management practices and/or may reflect a natural periodicity experienced by a species. Such periodicity, especially in Eurasian water milfoil populations, has been observed elsewhere in southeastern Wisconsin, and potentially reflects the influences of a combination of stressors. These stressors include biological factors, such as the activities of naturally occurring Eurasian water milfoil weevils, as well as climatic and limnological factors, such as insolation, water temperature, and lake circulation patterns. Due to the lack of empirical data concerning the plant communities in Saratoga Lake over time, it is impossible to draw any conclusions regarding the types or degree of changes that may be occurring in these communities.

Past and Present Aquatic Plant Management Practices in Saratoga Lake

Records of aquatic plant management efforts on Wisconsin lakes were first maintained by the WDNR beginning in 1950. Prior to 1950, aquatic plant management interventions are likely, but were not recorded. Currently, all forms of aquatic plant management are subject to permitting by the WDNR pursuant to authorities granted the Department under Chapters NR 107 and NR 109 of the *Wisconsin Administrative Code*. Recent aquatic plant management activities have focused on mechanical harvesting utilizing equipment that has been rented by the City of Waukesha. There are no records of chemical herbicide use for the management of aquatic plants on Saratoga Lake.

The City of Waukesha historically has harvested about 12 acres of Saratoga Lake, within an area extending south from the Moreland Road bridge to the boat launch site near Schuetze Recreational Center. The shallow water depths near the Moreland Road bridge, where depths are approximately two feet, limit harvesting in that area and further upstream. The volume of aquatic plant material harvested by the City from Saratoga Lake during the period from 2004 through 2012 is shown in Table 9.

FISH AND WILDLIFE

Fish and Fisheries

In 1963, the fishery of Saratoga Lake consisted largely of panfish and northern pike, with channel catfish and smallmouth bass present in lesser abundance.[50] As of 2005, the WDNR reported that, in Saratoga Lake, northern pike, largemouth bass, and panfish are present.[51]

A fish survey conducted in 1978 reported the fishery to consist of yellow perch, northern pike, white sucker, pumpkinseed, common carp, creek chub, rainbow darter, johnny darter, largescale stoneroller, striped shiner, common shiner, black crappie, spottail shiner, yellow bullhead, black bullhead, and rock bass.[52] There were no observations of any State-designated, special-concern species or threatened species in Saratoga Lake.[53]

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[50]*Wisconsin Conservation Department,* Surface Water Resources of Waukesha County, *1963.*

[51]*Wisconsin Department of Natural Resources Publication No. PUB-FH-800 2005,* op. cit.

[52]*D. Fago, Wisconsin Department of Natural Resources Research Report No. 148,* Retrieval and Analysis System Used in Wisconsin's Statewide Fish Distribution Survey, Second Edition, *December 1988.*

[53]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997.*

Table 9

VOLUME OF AQUATIC PLANT MATERIALS HARVESTED FROM SARATOGA LAKE

Year	Volume of Harvested Plants (cubic yards)
2004	20.0
2005	24.4
2006	24.4
2007	- -
2008	55.2
2009	200.0
2010	200.0
2011	90.0
2012	34.0

Source: City of Waukesha, and SEWRPC.

Amphibians, Reptiles, Birds, and Mammals

Amphibians and reptiles are vital components of the Saratoga Lake ecosystem, and include frogs, toads, and salamanders; and turtles and snakes, respectively. About 14 species of amphibians and 16 species of reptiles would normally be expected to be present in the Lake's tributary area.[54] The tributary area also supports a significant population of waterfowl, including mallards, wood duck, and blue-winged teal. During the migration seasons a greater variety of waterfowl may be present and in greater numbers.

With respect to wildlife, most of the wildlife remaining in and around the shorelands of the Lake are urban-tolerant species: smaller animals and waterfowl would be expected to inhabit the lakeshore areas; muskrats, beaver, grey and fox squirrels, and cottontail rabbits are likely to be abundant and widely distributed in the immediate riparian areas; and larger mammals, such as the whitetail deer, are likely to be confined to the larger wooded areas and the open meadows found within the tributary area of the Lake. The remaining undeveloped areas provide the best-quality cover for many wildlife species.

ENVIRONMENTALLY SIGNIFICANT AREAS

Because of its size and location, the Saratoga Lake tributary area contains numerous natural areas of varying sizes, some of which have significant ecological importance. Map 11 shows the locations of such environmentally significant areas. There are no environmentally significant lands immediately adjacent to the Lake, however, largely due to the historically disturbed urban landscape within which the Lake is located.

WDNR-Designated Sensitive Areas

The WDNR, pursuant to authorities granted under Chapter 30 of the *Wisconsin Statutes* and Chapter NR 107 of the *Wisconsin Administrative Code*, can designate environmentally sensitive areas within lakes. These areas have special biological, historical, geological, ecological, or archaeological significance, "offering critical or unique fish and wildlife habitat, including seasonal or life-stage requirements, or offering water quality or erosion control benefits of the body of water." Saratoga Lake does not contain any such designated sensitive areas.

SEWRPC-Designated Critical Species Habitat

As part of its regional planning program, and as a logical extension of its environmental corridor concept expounded through the regional, county-, and local-level land use plans for southeastern Wisconsin,[55] SEWRPC has identified natural areas and critical species habitat areas within the Southeastern Wisconsin Region.[56] These areas reflect the attributes of the landscape necessary to protect and preserve the ambience, natural beauty, and

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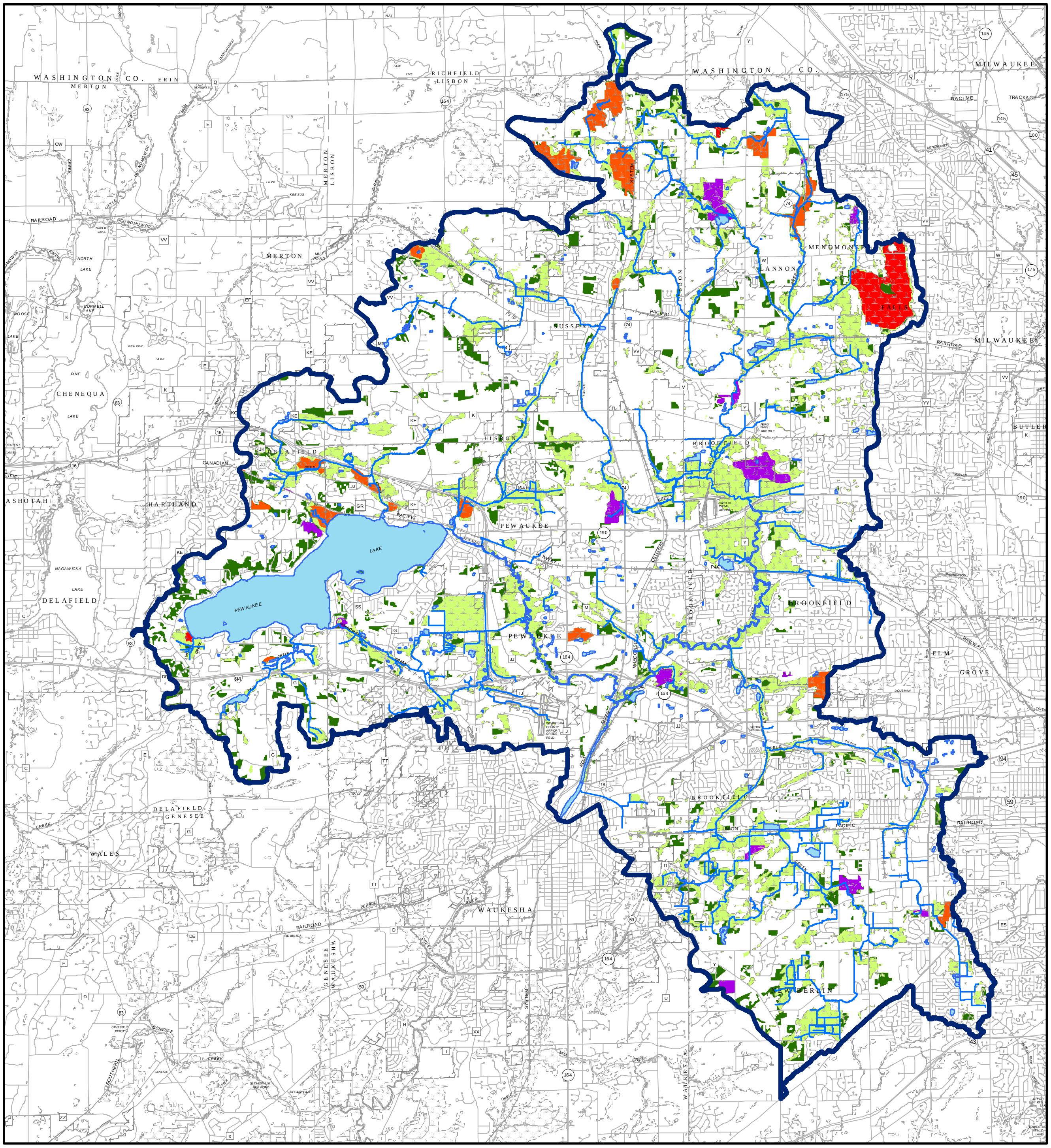
[54]Ibid.

[55]*See SEWRPC Planning Report No. 7,* The Regional Land Use-Transportation Study, *1965, and subsequent editions; see also Bruce P. Rubin and Gerald H. Emmerich, Jr., "Refining the Delineation of Environmental Corridors in Southeastern Wisconsin,"* SEWRPC Technical Record, *Volume 4, Number 2, March 1981.*

[56]*SEWRPC Planning Report No. 42,* op cit.

Map 11

ENVIRONMENTALLY SIGNIFICANT AREAS WITHIN THE AREA TRIBUTARY TO SARATOGA LAKE



NATURAL AREA OF COUNTYWIDE OR REGIONAL SIGNIFICANCE (NA-2)

NATURAL AREA OF LOCAL SIGNIFICANCE (NA-3)

CRITICAL SPECIES HABITAT

WOODLANDS

WETLANDS

SURFACE WATER

STREAM

SARATOGA LAKE DRAINAGE AREA

N

0 0.5 1 1.5 Miles

0 5,000 10,000 Feet

Source: SEWRPC.

biological diversity of southeastern Wisconsin that are essential to maintain the public health and welfare, support and sustain economic development, and provide continuing choices and opportunities for future generations. Areas identified as critical species habitat and/or natural areas were designated as being of local significance, Regional significance, or State or national significance. The lands surrounding Saratoga Lake do not contain any SEWRPC-designated critical species habitat or natural areas, although the greater tributary area that drains to Saratoga Lake does contain numerous such areas.

Woodlands and Wetlands

Woodlands in southeastern Wisconsin are defined as those areas containing 17 or more trees per acre which have at least a four-inch-diameter at breast height, that is, at a height of 4.5 feet above ground. The area tributary to Saratoga Lake contains numerous woodlands within its boundary, as shown in Map 11. However, if urban development continues within the tributary area, much of the remaining woodland cover may be expected to be lost, primarily as a consequence of increasing urban density development.

Wetlands perform a variety of valuable functions in natural communities, including: serving as stormwater and floodwater storage and retention—a function particularly important in riverine communities, such as the Fox River—aiding in the moderation of water level fluctuations; participating in important groundwater-wetland water exchange; and providing filtration and storage of sediments, nutrients, or toxic substances that would otherwise adversely impact water quality. Map 11 shows the locations of wetland areas located within the tributary area of Saratoga Lake. The amount and distribution of these wetlands should remain relatively stable if the recommendations contained in the regional land use plan are followed. Wetlands in excess of two acres in area are protected from development under various State and Federal wetland preservation laws.

ENVIRONMENTAL CORRIDORS AND ISOLATED NATURAL FEATURES

Environmental Corridors

One of the most important tasks undertaken by SEWRPC as part of its work program was the identification and delineation of those areas of the Region having high concentrations of natural, recreational, historic, aesthetic, and scenic resources which should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base *per se*, are closely related to, or centered on, that base and, therefore, are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are: 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

The delineation of these 12 natural resource and natural resource-related elements on a map results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by SEWRPC. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are, by definition, at least 400 acres in size, two miles in length, and 200 feet in width. The primary environmental corridors delineated by SEWRPC within the tributary area to Saratoga Lake are, in some cases, contiguous with environmental corridors and isolated natural resource areas lying outside the lake tributary area boundary and, consequently, do meet these size and natural resource element criteria.

It is important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of one element of the total environment may lead to a chain reaction of deterioration and destruction. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater.

Groundwater serves as a source of domestic, municipal, and industrial water supply and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes may not, in-and-of-itself, be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the Saratoga Lake tributary area, thus, becomes apparent.

In the portion of the southeastern Wisconsin area tributary to Saratoga Lake, the streambanks and lakeshores located within the environmental corridors should be candidates for immediate protection through proper zoning or through public ownership. Of the areas not already publicly owned, the remaining areas of natural shoreline, and riparian wetland areas, are perhaps the most sensitive areas in need of greatest protection.

Primary Environmental Corridors

The primary environmental corridors in southeastern Wisconsin generally lay along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. As shown on Map 12, the primary environmental corridors, as of 2005, encompassed about 12,943 acres, or about 16 percent of the Saratoga Lake tributary area. Primary environmental corridors may be subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems, as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clearwater into sanitary sewerage systems. The preservation of such corridors, thus, is one of the major ways in which the water quality of Saratoga Lake can be maintained and, perhaps, improved.

Secondary Environmental Corridors

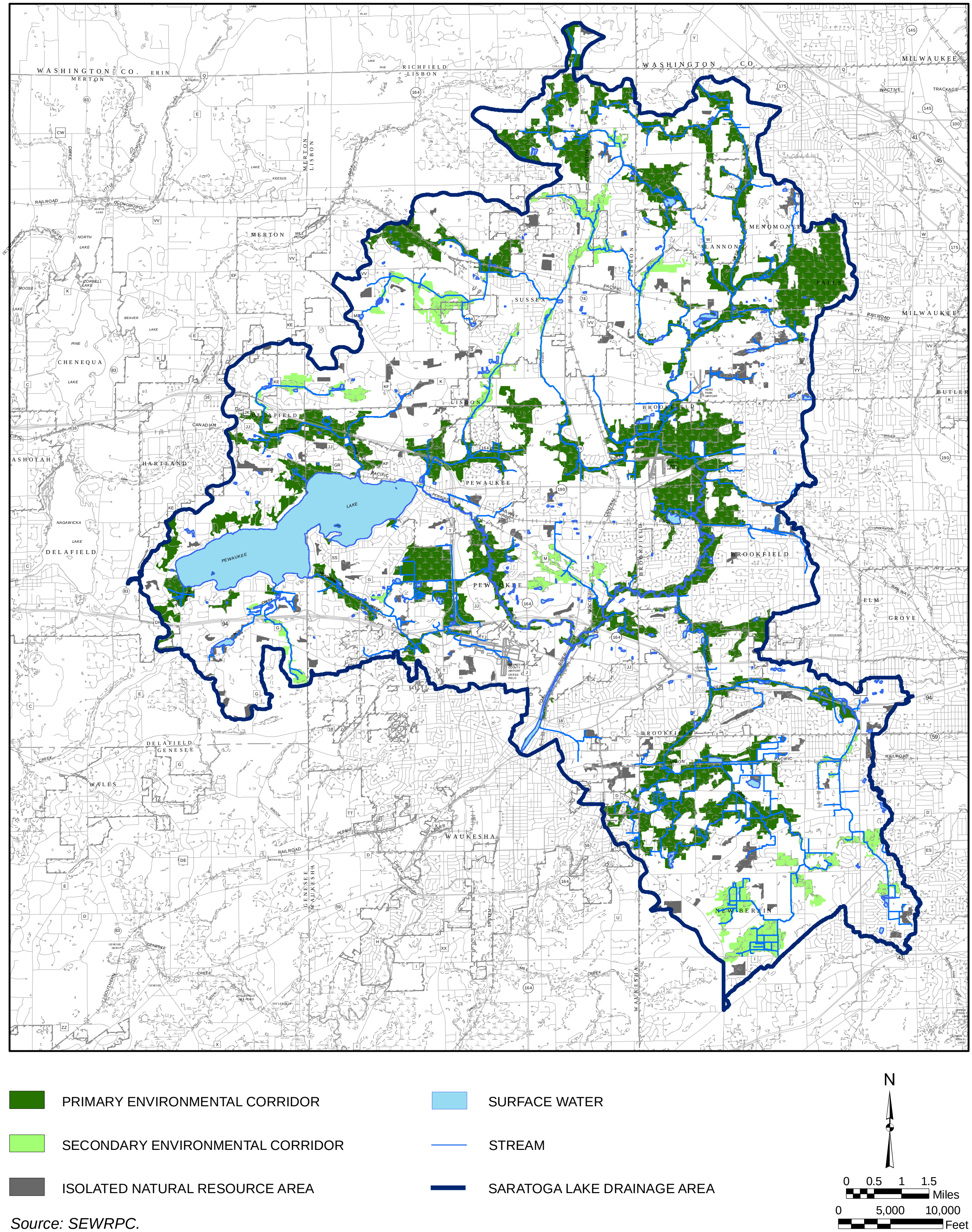
Secondary environmental corridors are located generally along intermittent streams or serve as links between segments of primary environmental corridors. Secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses, and facilitate surface water drainage, maintain “pockets” of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species. As shown on Map 12, secondary environmental corridors, as of 2005, encompassed about 2,762 acres, or about 3.5 percent of the total tributary area.

Isolated Natural Resource Areas

In addition to the primary environmental corridors, other small concentrations of natural resource base elements exist within the Saratoga Lake tributary area. These concentrations are isolated from the environmental corridors by urban development or agricultural lands and, although separated from the environmental corridor network, have important natural values. These isolated natural resource areas may provide the only available wildlife habitat in a localized area, provide good locations for local parks and nature study areas, and lend a desirable aesthetic character and diversity to the area. Important isolated natural resource features include a variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource features should also be protected and preserved in a natural state whenever possible. Such isolated areas five or more acres in size within the area tributary to Saratoga Lake also are shown on Map 12 and total about 1,767 acres, or about 2 percent of the total tributary area.

Map 12

ENVIRONMENTAL CORRIDORS WITHIN THE AREA TRIBUTARY TO SARATOGA LAKE: 2005



Source: SEWRPC.

RECREATIONAL USES AND FACILITIES

Saratoga Lake is used year-round for a variety of active recreational purposes, as well as a visual amenity. The entire shoreline of Saratoga Lake is in public ownership, being contained within Frame Park, which is owned and maintained by the City of Waukesha. The eastern and western riverine shorelines of the Lake each contain a river walk trail and a separate paved bicycle trail. The eastern shorelands of the park contain numerous recreational facilities, including: the Schuetze Recreation Center and Rotary Building, both used for recreational programs and community rentals; a lighted and fenced baseball field; sand volleyball courts; two playground areas; a picnic shelter; a formal garden area; restroom facilities; lighted parking; the High Roller Riverside pavilion, which offers refreshments and boat rentals; and a boat ramp for limited access to the Fox River. There are floating docks on both the eastern and western shorelines for anglers to gain access to the water, as well as poured concrete tiered seating that extends to the water's edge on both shores near the southern end of the Lake. The area immediately downstream of the Barstow Street dam forms the Barstow Plaza that contains extensive informal seating areas, a large lagoon area with tiered seating and access to the water's edge, and the dam has been lighted to improve the aesthetics of the area. Map 6 shows the locations of various water-access points available on Saratoga Lake. On-water recreational uses include fishing, canoeing, and kayaking during the summer months; popular on-shore recreational uses include walking, cycling, bird watching, picnicking, and utilizing the open areas and park facilities provided by the City in Frame Park. Public boating access to Saratoga Lake is limited to carry-in access for car-top boats, although a paddle boat and bicycle rental facility operates within Frame Park providing greater access opportunities. Given the small surface area of Saratoga, this level of public recreational boating access is likely to meet the standards set forth in Chapter NR 1 of the *Wisconsin Administrative Code*.

LOCAL ORDINANCES

As shown in Table 10, the City of Waukesha has adopted ordinances in regard to general zoning, floodland zoning, shoreland zoning, and construction site erosion control and stormwater management. Recreational boating activities on Saratoga Lake are currently regulated by the City boating ordinance.

Table 10

LAND USE REGULATIONS WITHIN THE AREA TRIBUTARY TO SARATOGA LAKE IN WAUKESHA COUNTY BY CIVIL DIVISION

Community	Type of Ordinance				
	General Zoning	Floodland Zoning	Shoreland or Shoreland-Wetland Zoning	Subdivision Control	Construction Site Erosion Control and Stormwater Management
Washington County	None	Adopted	Adopted	Adopted	Adopted
Village of Richfield	Adopted	County ordinance	County ordinance	Adopted	Adopted
Waukesha County	Adopted	Adopted	Adopted and WDNR approved	Floodland and shoreland only	Adopted
City of Brookfield	Adopted	Adopted	Adopted and WDNR approved	Adopted	Adopted
City of Delafield	Adopted	Adopted	Adopted	Adopted	Adopted
City of New Berlin	Adopted	Adopted	Adopted	Adopted	- -[a]
City of Pewaukee	Adopted	Adopted	Adopted	Adopted	Adopted
City of Waukesha	Adopted	Adopted	Adopted and WDNR approved	Adopted	Adopted
Town of Brookfield	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Delafield	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Lisbon	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Merton	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Waukesha	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Village of Hartland	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Lannon	Adopted	Adopted	None	Adopted	Adopted
Village of Menomonee Falls	Adopted	Adopted	Adopted and WDNR approved	Adopted	Adopted
Village of Merton	Adopted	Adopted	Adopted	Adopted	County ordinance
Village of Pewaukee	Adopted	Adopted	None	Adopted	County ordinance
Village of Sussex	Adopted	Adopted	Adopted and WDNR approved	Adopted	Adopted

[a]*Erosion control and stormwater management standards are built into other ordinances.*

Source: SEWRPC.

Chapter III

ALTERNATIVE AND RECOMMENDED AQUATIC PLANT MANAGEMENT PRACTICES

INTRODUCTION

Saratoga Lake contains an aquatic plant community of limited diversity, but capable of supporting a warmwater fishery. The Lake suffers impairment of recreational opportunities and other lake-oriented activities due to limited water depths and an overabundance of aquatic macrophytes. In those areas of the Lake where Eurasian water milfoil (*Myriophyllum spicatum*) is abundant, certain recreational uses are limited, the aesthetic quality of the Lake is impaired, and in-lake habitat degraded. This plant primarily interferes with recreational boating activities by encumbering propellers, clogging cooling water intakes, snagging paddles, and slowing watercraft by wrapping around control surfaces. The plant also causes concern among swimmers who can become entangled within the plant stalks. Thus, without control measures, these areas can become problematic for navigation, fishing, and swimming. Native aquatic plants pose fewer potential problems for navigation, swimming, and fisheries, and generally have attributes that sustain a healthy fishery. Many native aquatic plants provide fish habitat and food resources, and offer shelter for juvenile fishes and young-of-the-year fish.

In this chapter, alternative and recommended actions for addressing the issues of concerns described in Chapters I and II of this report, are presented. These alternatives are focused primarily on those measures which can be implemented by the City of Waukesha, with lesser emphasis given to those measures which are applicable to other agencies having jurisdiction within the area tributary to the Lake. As noted in Chapter II of this report, recent aquatic plant management measures on Saratoga Lake can be categorized as primarily based on mechanical harvesting to manage nuisance levels of aquatic plant growth in the Lake.

AQUATIC PLANT MANAGEMENT MEASURES

The goal of the aquatic plant management program being implemented in Saratoga Lake by the City of Waukesha is to promote the multiple-purpose use of Saratoga Lake in a manner consistent with the maintenance of the integrity of the Lake's ecosystem. The following objectives were developed in consultation with the City of Waukesha. The objectives are to:

- Effectively control the quantity and density of aquatic plant growths in portions of Saratoga Lake to improve the water-related recreation opportunities, to improve the aesthetic value of the resource to the community, and to enhance the resource value of the waterbody;

- Manage the Lake in an environmentally sound manner, pursuant to the standards and requirements set forth in Chapters NR 103, "Water Quality Standards for Wetlands," NR 107, "Aquatic Plant Management," and NR 109, "Aquatic Plants: Introduction, Manual Removal & Mechanical Control Regulations," of the *Wisconsin Administrative Code,* to preserve and enhance the water quality and biotic communities, their habitats, and essential structure and function in the waterbody and adjacent areas;

- Protect and maintain public health and to promote public comfort, convenience, and welfare in concert with the natural resource through the environmentally sound management of native vegetation, fishes, and wildlife in, and around, Saratoga Lake; and

- Promote a quality water-based experience for visitors to Saratoga Lake consistent with the policies and practices of the Wisconsin Department of Natural Resources (WDNR), as set forth in the regional water quality management plan, SEWRPC Planning Report No. 30, *A Regional Water Quality Management Plan for Southeastern Wisconsin—2000*, as amended.

The shoreland and aquatic macrophyte management elements of this plan consider alternative management measures consistent with the provisions of Chapters NR 103, NR 107, and NR 109 of the *Wisconsin Administrative Code.* Further, the alternative aquatic plant management measures are consistent with the requirements of Chapter NR 7 of the *Wisconsin Administrative Code* governing recreational boating facilities, and with the public recreational boating access requirements set forth under Chapter NR 1 of the *Wisconsin Administrative Code.* Finally, the recommendations set forth herein acknowledge the goals of Chapter NR 40 of the *Wisconsin Administrative Code*, insofar as they relate to limiting the occurrence and spread of nonnative and invasive aquatic organisms.

Array of Management Measures

Aquatic plant management measures can be classed into four groups: ***physical measures***, which include lake-bottom coverings and water level management; ***biological measures***, which include the use of various organisms, including herbivorous insects and plantings of aquatic plants; ***manual*** and ***mechanical measures***, which include harvesting and removal of aquatic plants; and ***chemical measures***, which include the use of aquatic herbicides. All control measures are stringently regulated and require a State of Wisconsin permit. Chemical controls are regulated under Chapter NR 107 of the *Wisconsin Administrative Code,* and other aquatic plant management practices, with the exception of the placement of bottom covers, are regulated under Chapter NR 109 of the *Wisconsin Administrative Code*. Placement of bottom covers, a physical measure, also requires a WDNR permit under Chapter 30 of the *Wisconsin Statutes*. Costs range from minimal for manual removal of plants using rakes and hand-pulling, to upwards of $75,000 for the purchase of a mechanical plant harvester, for which the operational costs can approach $2,500 to $25,000 per year, depending on staffing and operation policies.

Physical Measures

Physical measures include a range of interventions aimed at physically obstructing the growth of aquatic plants by interfering with access by the plants to sunlight or other necessary growth substances. Lake bottom covers and light screens provide limited control of rooted plants by creating a physical barrier which reduces or eliminates the sunlight available to the plants. Sand and gravel are usually widely available and relatively inexpensive to use as cover materials, but plants readily recolonize areas so covered in about a year. In addition, sand blankets can act to smother developing fish eggs. Synthetic materials, such as polyethylene, polypropylene, fiberglass, and nylon, can provide relief from rooted plants for several years. However, such materials, known as bottom screens, or barriers, generally have to be placed and removed annually. Such barriers also are susceptible to disturbance by watercraft propellers or the buildup of gases from decaying plant biomass trapped under the barriers. Other physical alternatives include the use of dyes to reduce the penetration of sunlight into a lake to limit the growth of bottom-dwelling aquatic plants and algae, and the use of flocculent aids to adsorb nutrients and other growth substances limiting their availability to aquatic plants. An example of the latter type of control agent is the use of alum, or aluminum sulphate. The aluminum binds the phosphorus present in the water column and surfacial sediments so that this growth nutrient is no longer available in sufficient quantity to sustain plant growth.

In the case of Saratoga Lake, however, the application of physical aquatic plant management measures to control aquatic plant growth does not appear to be warranted. Thus, such measures are not considered for Saratoga Lake.

The deepening of waterbodies by dredging, while typically focused on navigational and hydrological considerations, also may provide opportunities for aquatic plant management. Modifying the depth contours of a lake may change the ability of aquatic plants to access nutrient-rich substrates, sunlight, and hydroclimate conditions suitable for growth. While dredging creates opportunities for colonizing species of aquatic plants to spread, most commonly increasing the area available for Eurasian water milfoil growth, dredging also can alter the physical habitat so that aquatic plant growth can be discouraged. In the case of Saratoga Lake, historical industrial discharges into the waterways draining to the impoundment may place significant constraints on the removal of the extensive volumes of unconsolidated sediment accumulated within the Lake. As noted in Chapter II, much of the sediment has concentrations of heavy metals and poly-chlorinated biphenyls (PCBs) that exceed the Lowest Effect Level criteria set forth in the WDNR draft sediment quality criteria report.[1] This condition may limit the options for disposal of dredged materials. Nevertheless, dredging should be considered a viable management measure, not only for managing aquatic plants in Saratoga Lake, but also for enhancing the recreational value of the impoundment. It should be noted that investigations preliminary to development of a dredging plan were underway at the time of writing.

Biological Measures

Biological measures utilize natural predators or grazing behaviors to control aquatic plants. Biological controls offer an alternative approach to other methods of controlling nuisance plants, particularly purple loosestrife (*Lythrum salicaria*), an invasive shoreland wetland plant, and Eurasian water milfoil. Classic biological control techniques have been successfully used to control both nuisance plants with herbivorous insects.[2] Recent evidence shows that *Galerucella pucilla* and *Galerucella calmariensis*, beetle species, and *Hylobius transversovittatus* and *Nanophyes brevis*, weevil species, have potential as biological control agents for purple loosestrife.[3] Extensive field trials conducted by the WDNR in southeastern Wisconsin since 1999 have indicated that these insects can provide effective management of large infestations of purple loosestrife. In contrast, the few studies of Eurasian water milfoil control utilizing *Eurhychiopsis lecontei*, an aquatic weevil species, have resulted in variable levels of control, with little control being achieved on those lakes having extensive motorized boating traffic. The use of *Eurhychiopsis lecontei* as a means of aquatic plant management control, may be a viable option for use on Saratoga Lake at this time, given the limited use of motorized watercraft on the Lake. That said, the use of biological control mechanisms may not be warranted due to the riverine character of the impoundment which may lead to the weevils being washed out of the Lake. Given this consideration, the use of biological control measures to manage in-lake aquatic plant communities is not considered viable at this time. Thus, such measures are not considered for Saratoga Lake.

The use of grass carp, *Ctenopharyngodon idella*, an alternative biological control used elsewhere in the United States, is not permitted in Wisconsin. This voracious herbivore has been shown to denude lakes and ponds of

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[1]*Wisconsin Department of Natural Resources, unpublished report, "Inventory of Statewide Contaminated Sediment Sites and Development of a Prioritization System," June 1994.*

[2]*B. Moorman, "A Battle with Purple Loosestrife: A Beginner's Experience with Biological Control,"* Lake Line, *Vol. 17, No. 3, September 1997, pages 20-21, 34-3; see also, C.B. Huffacker, D.L. Dahlsen, D.H. Janzen, and G.G. Kennedy,* Insect Influences in the Regulation of Plant Population and Communities, *1984, pages 659-696; and C.B. Huffacker and R.L. Rabb, editors,* Ecological Entomology, *John Wiley, New York, New York, USA.*

[3]*Sally P. Sheldon, "The Potential for Biological Control of Eurasian Water Milfoil (*Myriophyllum spicatum*) 1990-1995 Final Report," Department of Biology Middlebury College, February 1995.*

aquatic vegetation, exposing lake bottom sediments to wind erosion and increasing turbidity in lakes and ponds, and enhancing the likelihood of occurrence of nuisance algal blooms.[4]

A variation on the theme of biological control is the introduction of aquatic plants into a waterbody as a means of encouraging or stimulating the growth of desirable native aquatic plant species in a lake. While few projects of this nature have been undertaken in the Southeastern Wisconsin Region, the Lac La Belle Management District, in partnership with the WDNR and University of Wisconsin-Milwaukee, attempted to supplement the aquatic plant community of Lac La Belle by selectively planting pondweeds (*Potamogeton* spp.).[5] Several hundred pondweeds were transplanted into Lac La Belle, and while there is some evidence that a few of these transplants were successful, the net outcome of the project was disappointing. Few of the introduced plants were observed in subsequent years.[6] Given the extensive aquatic plant community present in Saratoga Lake, supplemental plantings are not considered to be a viable aquatic plant management option.

Manual and Mechanical Measures

The physical removal of specific types of vegetation by selective harvesting of plants provides a highly effective means of controlling the growths of nuisance aquatic plant species, including purple loosestrife and Eurasian water milfoil. Pursuant to Chapter NR 109 of the *Wisconsin Administrative Code*, manual harvesting of aquatic plants within a 30-foot-wide corridor along the shoreline would be allowed without a WDNR permit, provided the plant material is removed from a lake. Any other manual harvesting would require a State permit, unless employed in the control of designated nonnative invasive species, such as Eurasian water milfoil or curly-leaf pondweed.

In the shoreland area, where purple loosestrife may be expected to occur, bagging and cutting loosestrife plants prior to the application of chemical herbicides to the cut ends of the stems, can be an effective control measure for small infestations of this plant. Loosestrife management programs, however, should be followed by an annual monitoring and control program for up to 10 years following the initial control program to manage the regrowth of the plant from seeds. Manual removal of such plants is recommended for isolated stands of purple loosestrife. For larger stands, as noted above, biological control agents form an effective management tool.

In the nearshore area, specially designed rakes are available to assist in the manual removal of nuisance aquatic plants, such as Eurasian water milfoil. The use of such rakes also provides a safe and convenient method of controlling aquatic plants in deeper nearshore waters around piers and docks. The advantage of the rakes is that they are relatively inexpensive, easy and quick to use, and immediately remove the plant material from a lake. Removal of the plants from a lake avoids the accumulation of organic matter on the lake bottom, which adds to the nutrient pool that favors further plant growth. State permitting requirements for manual aquatic plant harvesting mandate that the harvested material be removed from a lake. Hand-pulling of stems, where they occur in isolated stands, also provides an alternative means of controlling plants, such as Eurasian water milfoil, in a lake, and purple loosestrife, on the lakeshore. Manual removal of Eurasian water milfoil is considered a

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[4]*C. Holdren, W. Jones and J. Taggart,* Managing Lakes and Reservoirs, *Third Edition, North American Lake Management Society, Terrene Institute, and U.S. Environmental Protection Agency, 2001.*

[5]*Donald H. Les and Glenn Guntenpergen, "Laboratory Growth Experiments for Selected Aquatic Plants, Final Report, July 1989-June 1990 (Year 1),"* Report to the Wisconsin Department of Natural Resources, *June 1990; Wisconsin Department of Natural Resources,* Environmental Assessment: Improvement of the Water Quality and Fisheries Habitat of Lac La Belle [sic] and the Lower Oconomowoc River, s.d.

[6]*At the 2003 annual meeting of the Lac La Belle Management District, a citizen reported observing a herbicide application in the vicinity of the planted area of the Lake. Such an application might explain the observed lack of success of this management measure. See SEWRPC Community Assistance Planning Report No. 47, 2nd Edition,* A Water Quality Management Plan for Lac La Belle, Waukesha County, Wisconsin, *May 2007.*

viable option in Saratoga Lake, where practicable and feasible, especially in the nearshore areas around the piers and docks.

Aquatic macrophytes also may be harvested mechanically with specialized equipment consisting of a cutting apparatus, which cuts up to about five feet below the water surface, and a conveyor system that picks up the cut plants. Mechanical harvesting can be a practical and efficient means of controlling plant growth, as it removes the plant biomass and nutrients from a lake. Mechanical harvesting is particularly effective as a measure to control large-scale growths of aquatic plants. Narrow channels can be harvested to provide navigational access and "cruising lanes" for predator fish to migrate into the macrophyte beds to feed on smaller fish. The harvesting of water lilies and other emergent native plants should be avoided.

"Clear cutting" aquatic plants and denuding the lake bottom of flora, using either manual or mechanical harvesting, should be avoided. However, top cutting of plants, such as Eurasian water milfoil, using mechanical harvesters, as shown in Figure 1, has proven to be beneficial in some lakes as a means of minimizing the competitive advantage of the Eurasian water milfoil plant and encouraging native aquatic plant growths.[7]

An advantage of mechanical aquatic plant harvesting is that the harvester typically leaves enough plant material in a lake to provide shelter for fish and other aquatic organisms, and to stabilize lake bottom sediments. Aquatic plant harvesting also has been shown to facilitate the growth of native aquatic plants in harvested areas by allowing light penetration to the lakebed.[8] Many native aquatic plants are low-growing species that are less likely to interfere with human recreational and aesthetic uses of a lake. By removing the competitive advantage created by the growth strategy of Eurasian water milfoil, and allowing sunlight to penetrate to the lakebed, native plants have an opportunity to resurge.[9]

Repeated harvesting and removal of aquatic plants from a lake system also has proven to be an effective means of encouraging native plant growth.[10] While the occurrence and abundance of aquatic plants reflects season and opportunity for growth, repeated harvesting can provide additional opportunities for the growths of native aquatic plants. Harvesting combined with the collection of floating plant fragments, especially along shorelines, removes both the fragments of plants, such as Eurasian water milfoil, which are capable of rerooting and regrowth in new areas of a lake, as well as the organic material that can contribute to the build-up of "muck" on the lake bottom.[11] If done correctly and carefully, harvesting has been shown to be of benefit in ultimately reducing the regrowth of nuisance plants.

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[7]*See SEWRPC Memorandum Report No. 143,* An Aquatic Plant Management Plan for the Lauderdale Lakes, Walworth County, Wisconsin*, August 2001.*

[8]*See SEWRPC Memorandum Report No. 143, 2nd Edition,* An Aquatic Plan Management Plan for the Lauderdale Lakes, Walworth County, Wisconsin*, July 2010, Appendix D, "Eurasian Water Milfoil Management in Mill Lake: 2002."*

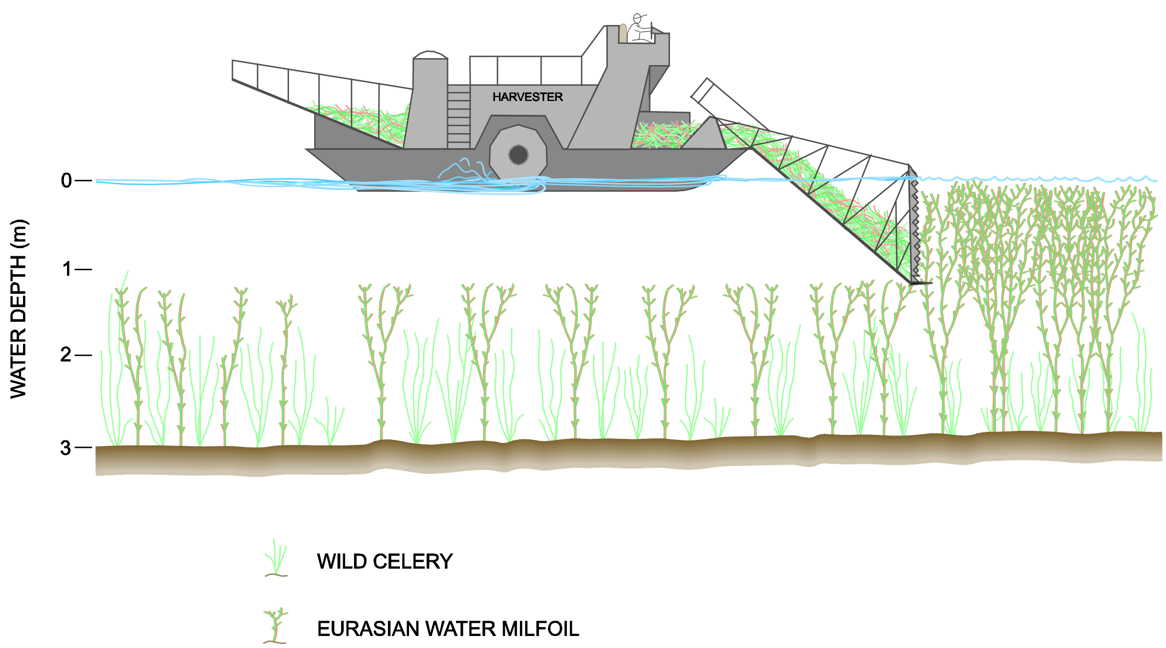
[9]*In the case of the Lauderdale Lakes, documented in SEWRPC Memorandum Report No. 143, 2nd Edition,* op. cit.*, the aquatic plant community of Sterlingworth Bay went from a virtual monoculture of Eurasian water milfoil to a mixed community comprised of pondweeds, Chara, eel-grass, Elodea, and coontail. Cutting of the Eurasian water milfoil canopy was required at three-week intervals to sustain the resurgence of native aquatic plants.*

[10]*SEWRPC Community Assistance Planning Report No. 58, 2nd Edition,* A Lake Management Plan for Pewaukee Lake, Waukesha County, Wisconsin*, May 2003.*

[11]*This is especially important in the case of nonnative aquatic plants, such as Eurasian water milfoil, that prefer rooting in organic rich, mucky sediments.*

Figure 1

PLANT CANOPY REMOVAL WITH AN AQUATIC PLANT HARVESTER



NOTE: Selective cutting or seasonal harvesting can be done by aquatic plant harvesters. Removing the canopy of Eurasian water milfoil may allow native species to reemerge.

Source: Wisconsin Department of Natural Resources and SEWRPC.

One disadvantage of mechanical harvesting is that the fragmentation of plants and, thus, contributing unintentionally to the spread of those plants that utilize fragmentation as a means of propagation, as is the case with Eurasian water milfoil. Harvesting may also disturb bottom sediments in shallower areas where such sediments are only loosely consolidated, thereby increasing turbidity and resulting in deleterious effects, including the smothering of fish breeding habitat and nesting sites. Disrupting the bottom sediments also could increase the risk that an exotic species, such as Eurasian water milfoil, may colonize the disturbed area, since this is a species that tends to thrive under disturbed bottom conditions. To this end, most WDNR-issued permits do not allow harvesting in areas having a water depth of less than three feet. Given the very shallow water depths in Saratoga Lake, opportunities for mechanical harvesting of the nuisance aquatic plants are limited. However, given the historic use of such measures, continued use in those areas where such harvesting is possible remains a viable management option. Continued, and potentially increased, manual harvesting is, therefore, considered to be a viable option for control of invasive aquatic plants in Saratoga Lake.

Chemical Measures

Chemical control measures include the use of herbicides as a short-term method of controlling heavy growths of nuisance aquatic plants. Chemical herbicides are generally applied to the growing plants in either a liquid or granular form. The advantages of using chemical herbicides to control aquatic macrophytes growth are their relatively low-cost and their ease, speed, and convenience of application. The disadvantages associated with chemical control include unknown long-term effects on fish, fish food sources, and humans; a risk of increased algal blooms due to the eradication of macrophyte competitors; an increase in organic matter in the sediments, possibly leading to increased plant growth, as well as anoxic conditions which can cause fish kills; adverse effects on desirable aquatic organisms; loss of desirable fish habitat and food sources; and finally, a need to repeat the treatment the following summer due to existing seed banks and/or plant fragments. Widespread chemical treatments also can provide an advantage to less desirable, invasive, introduced plant species to the extent that such treatments may produce conditions in which nonnative species can out-compete the more beneficial, native aquatic plant species. Hence, the large-scale use of chemical herbicides is seldom a feasible management option. In the case of Saratoga Lake, large-scale or widespread chemical treatment, therefore, is not considered a viable aquatic plant management option. Limited chemical control is often a viable technique for the control of the relatively small-scale infestations of aquatic plants, such as Eurasian water milfoil, or shoreland plants, such as purple loosestrife. This is especially true in the vicinity of piers and docks where other methods may be difficult to implement.

To minimize the possible impacts of deoxygenation, loss of desirable plant species, and contribution of organic matter to the sediments, early spring or late fall applications should be considered.[12] Such applications also minimize the concentrations and amounts of chemicals used, due to the facts that colder water temperatures enhance the herbicidal effects, while the application of chemical herbicides during the periods when most native aquatic plant species are dormant limits the potential for collateral damage. Use of chemical herbicides in aquatic environments is stringently regulated and requires a WDNR permit and WDNR staff oversight during applications.

Measures to control curly-leaf pondweed are not recommended, unless the growths of this plant continue into the recreational boating season. That being said, the use of early spring chemical controls targeting growths of Eurasian water milfoil and purple loosestrife in, and around, the Lake, especially in those near shoreline areas where mechanical harvesting would not be deemed viable, is considered a viable option for Saratoga Lake. Special consideration would, however, need to be placed on the timing of any future herbicide application, due to the fact that the very short residence time in the Lake may prevent sufficient contact times for herbicides, thereby, reducing or eliminating their effectiveness. Any future herbicide application must, therefore, include review of the hydrological regime in the upper Fox River watershed to minimize the risk of wash-out of the chemical herbicide.

Recommended Management Measures

The most-effective plans for managing aquatic plants rely on a combination of methods and techniques, such as those described above. Therefore, to enhance the recreational uses of Saratoga Lake, while maintaining the quality and diversity of the biological communities, the following recommendations are made:

- It is recommended that the use of chemical herbicides be considered for controlling nuisance growths of exotic species, particularly Eurasian water milfoil and purple loosestrife, in areas where it is deemed necessary and effective. Choosing these areas should take into account residence time and the contact time necessary for chemical treatment to be effective. Any such chemical application must be completed by licensed applicators. Early spring applications are recommended, subject to State permitting requirements, to maximize their effectiveness on nonnative plant species, while minimizing impacts on native plant species. Early spring applications can serve as a preventative measure to minimize the development of nuisance conditions. Use of chemical herbicides should be evaluated annually and the herbicide applied only on an as-needed basis. Only herbicides that selectively control Eurasian water milfoil, such as 2,4-D and endothall, should be used. Use of granular formulations would be recommended, given the hydrological conditions in the impoundment, as such

[12]*It should be noted that, at the time of writing, late fall herbicide treatments are considered to be experimental in Wisconsin and will not typically be permitted by the Wisconsin Department of Natural Resources at this time, pending further research into the use of such treatments. It also is noted that many aquatic plants become dormant during the late fall and winter, die back, and do not meet the nuisance standards established pursuant to Chapter NR 107 of the* Wisconsin Administrative Code *as the basis for the application of aquatic herbicides. Consequently, late fall applications of herbicides are not recommended.*

formulations would be less susceptible to wash-out during high flow events. For the control of purple loosestrife, the use of glyphosate could be considered for application to the cut stems of the plants after the seed heads have been bagged and cut.

- The use of algicides, such as Cutrine Plus, is not recommended at this time, because there are few significant, recurring filamentous algal or planktonic algal problems in Saratoga Lake, and valuable macroscopic algae, such as *Chara* and *Nitella*, are killed by this product. Should the control of the targeted nonnative rooted aquatic plant species result in extensive growths of algae in the Lake, use of chemical control measures would be warranted.

- Mechanical harvesting remains a viable method for the management of aquatic plant communities in Saratoga Lake where water depths allow use of an aquatic plant harvester.[13] It is, therefore, recommended that mechanical harvesting efforts in suitable areas should be continued and potentially increased in preparation for recreational activities. “Clear cutting,” or denuding, of the lake bottom of vegetation, is to be avoided as the root systems and low-growing aquatic plants present in the Lake, which tend to be dominated by native aquatic plants, provide for the stabilization of lake bottom sediments, benefitting water clarity, as well as habitat for fish and other aquatic organisms valued by the Saratoga Lake community.

- Manual harvesting around piers and docks is the recommended means of controlling nonnative nuisance species of plants in those areas. In this regard, the City of Waukesha could consider purchasing several specialty rakes designed for the removal of vegetation from shoreline property. Although the rakes do not require a permit for use along a 30-foot-width of shoreline, State requirements for manual aquatic plant harvesting mandate that the harvested material be removed from a lake. In the case of Saratoga Lake, given the extensive shoreland area within which aquatic plant harvesting could be considered, use of manual harvesting should be included in the City of Waukesha aquatic plant management permit application made under Chapter NR 109 of the *Wisconsin Administrative Code*. Where feasible and practicable, hand-pulling of stems, where they occur in isolated stands, also is recommended as an alternative means of controlling Eurasian water milfoil and purple loosestrife. Manual control also should target nonnative species.

- It also is recommended that the City of Waukesha consider the conduct of in-lake aquatic plant surveys at about three- to five-year intervals, depending upon the observed degree of change in the aquatic plant communities. In addition, information on the aquatic plant control program should be recorded and should include descriptions of major areas of nuisance plant growth and areas chemically treated.

- Additional periodic monitoring of the aquatic plant community is recommended for the early detection and control of future-designated nonnative species that may occur. Such control could be effected with the assistance of funds provided under the Chapter NR 198 aquatic invasive species control grant program and should be undertaken as soon as possible, once the presence of a nonnative, invasive species is observed and confirmed, reducing the risk of spread from waters where they are present and restoring native aquatic communities. Control of currently designated invasive species, designated pursuant to Chapters NR 40 and NR 109 of the *Wisconsin Administrative Code*,

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[13] *“Top chopping” techniques recommended for the control of Eurasian water milfoil can be effective; however, in Saratoga Lake, the depths of the waterbody are such as to make any harvesting problematical. The maximum depth reported by SEWRPC staff of 4.5 feet is only slightly greater than the three-foot depth recommended by the WDNR as the minimum depth in which to operate an aquatic plant harvester.*

using appropriate control measures,[14] is recommended throughout the Lake. Such control also could be effected with the assistance of funds provided under the Chapter NR 198, aquatic invasive species control grant program, for the control of established populations of invasive aquatic plant species.

- Consideration of the use of informational signage and similar outreach materials should be given to the aquatic plant management program by the City of Waukesha. Not only should such signage alert waterbody users to the nature and danger of nonnative aquatic plants, the informational materials could highlight positive aspects of the City's management program, including measures, such as shoreland buffers, use of native shoreland plantings, and similar environmentally friendly actions.

The recommended aquatic plant management plan for Saratoga Lake is set forth in Map 13. As recommended, it is proposed that aquatic plant management activities be restricted in certain ecologically valuable areas of the Lake. Aquatic plant management operations will be concentrated in the main basin of the Lake and near the boating access ramp, as well as in the principal boating and fishing areas. No environmentally sensitive areas have been identified by the WDNR in the Lake, pursuant to their Chapter NR 107 authorities.

ANCILLARY PLAN RECOMMENDATIONS

Water Quality Management

Water quality is a descriptor of the overall health of a waterbody. The importance of good water quality can hardly be underestimated, as it impacts nearly every facet of the natural balances and relationships that exist in a lake between the myriad of abiotic and biotic elements present. Water quality is comprised of a number of physical, chemical, and biological components which collectively create the in-lake conditions observed by lake residents and lake users. Because of the importance water quality plays in the functioning of a lake ecosystem, careful monitoring of this lake element represents a fundamental tool in the ongoing practice of lake management. Lake water quality monitoring, whether of a single parameter, such as water clarity, or multiple parameters, such as those included in the Trophic State Index determination, e.g., the concentrations of chlorophyll-*a* and total phosphorus, provide the quantitative basis necessary to identify and address water quality concerns at an early stage, when interventions need not be as drastic or costly, as may be the case if such problems are allowed to fully develop. For this reason, enrolling a volunteer monitor in the University of Wisconsin-Extension (UWEX) Citizen Lake Monitoring Network (CLMN) program is recommended.

The UWEX CLMN program, formerly the WDNR Self-Help Monitoring Program, trains volunteers enrolled in this program to gather data on water clarity at regular intervals through the use of a Secchi disk. Because poor water quality tends to result in reduced water clarity, Secchi-disk measurements are generally considered to be one of the key parameters in determining the overall quality of lake water and its associated trophic status. Secchi-disk measurement data are added to the WDNR-sponsored Surface Water Information Management System, or SWIMS data base, containing lake water quality information for many lakes in Wisconsin. These data, in turn, are accessible online through the WDNR website.

The UWEX also offers an Expanded Self-Help Monitoring Program (Level II) that involves collecting data on several key physical and chemical parameters in addition to the Secchi-disk measurements. Under this program, samples of lake water are collected by volunteers at regular intervals and analyzed by the State Laboratory of Hygiene. Data collection is more extensive and, consequently, places more of a burden on volunteers.

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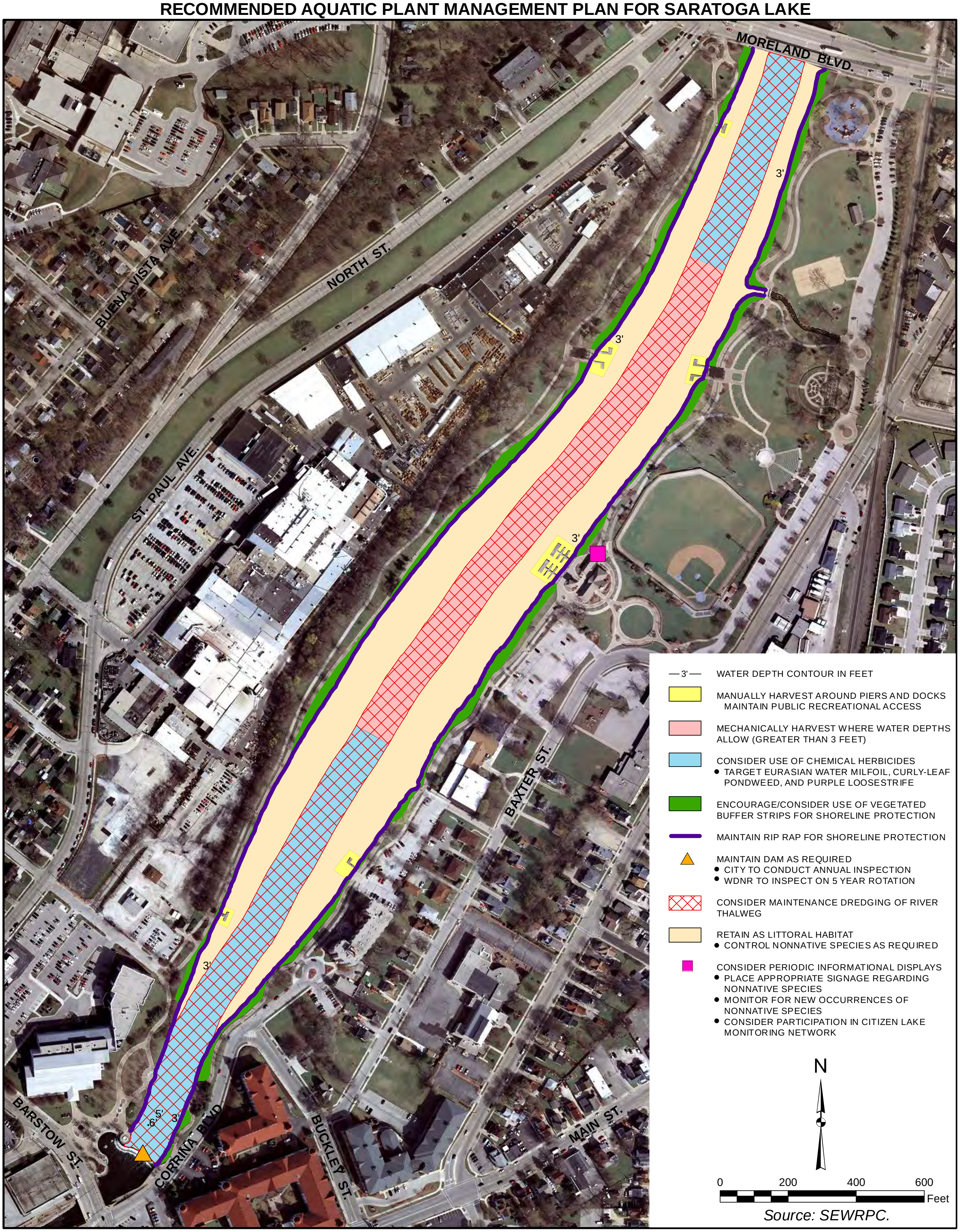
[14]*Appropriate control measures include, but are not limited to, any permitted aquatic plant management measure, placement of signage, and use of buoys to isolate affected areas of the Lake. Such measures, as may be appropriate, should be determined in consultation with WDNR staff and conducted in accordance with required permits under Chapters NR 107, "Aquatic Plant Management," NR 109, "Aquatic Plants: Introduction, Manual Removal & Mechanical Control Regulations," and NR 198, "Aquatic Invasive Species Control Grants," among others, of the* Wisconsin Administrative Code.

Map 13

RECOMMENDED AQUATIC PLANT MANAGEMENT PLAN FOR SARATOGA LAKE



DATE OF PHOTOGRAPHY: APRIL 2010

The basic UWEX CLMN program is available at no charge, but does require volunteers to be committed to taking Secchi-disk measurements at regular intervals—preferably weekly—throughout the spring, summer, and fall. The Expanded Self-Help Program requires additional commitment by volunteers to take a more-extensive array of measurements and samples for analysis, also on a regular basis. As with any volunteer-collected data, despite the implementation of standardized field protocols, individual variations in levels of expertise, due to background and experiential differences, can lead to variations in data and measurements from lake-to-lake and from year-to-year for the same lake, especially when volunteer participation changes.

Shoreline Protection

Shoreline protection measures refer to a group of management measures designed to reduce and minimize shoreline loss due to erosion by waves, ice, or related action of the water. Currently, the shoreline of Saratoga Lake is well protected by a variety of protection structures, including mainly riprap and a few areas with poured concrete tiered seating (a type of vertical wall bulkhead). Riprap was the most commonly occurring type of protection structure and bulkhead was the least common type. Where structural management measures were installed, most of the observed shoreline protection measures were in a good state-of-repair and no severe erosion-related problems were observed. Monitoring of shoreline vegetation for early detection and control of purple loosestrife and ongoing maintenance of shoreline protection structures is recommended.

Factors affecting the choice of shoreline protection method include: cost; shoreline bank height, vegetation, stability, and composition; shoreline geometry and geographic orientation; lake bottom contour and vegetation immediately adjacent to the stretch of shoreline under consideration; proximity to boat channels; possible influence of adjacent structures in producing flank erosion; and amount of open water (or "fetch") over which wind can act to produce wave action directly into the shoreline under consideration. A worksheet is provided as Table 1 within Section NR 328.08 of the *Wisconsin Administrative Code* in order to assist property owners who wish to install or modify existing shoreline protection structures. As noted in Chapter II, Saratoga Lake scores as a waterbody of low- to moderate-energy erosion intensity, with boat wake waves playing a major role in determining the severity of wake-related erosion intensity.

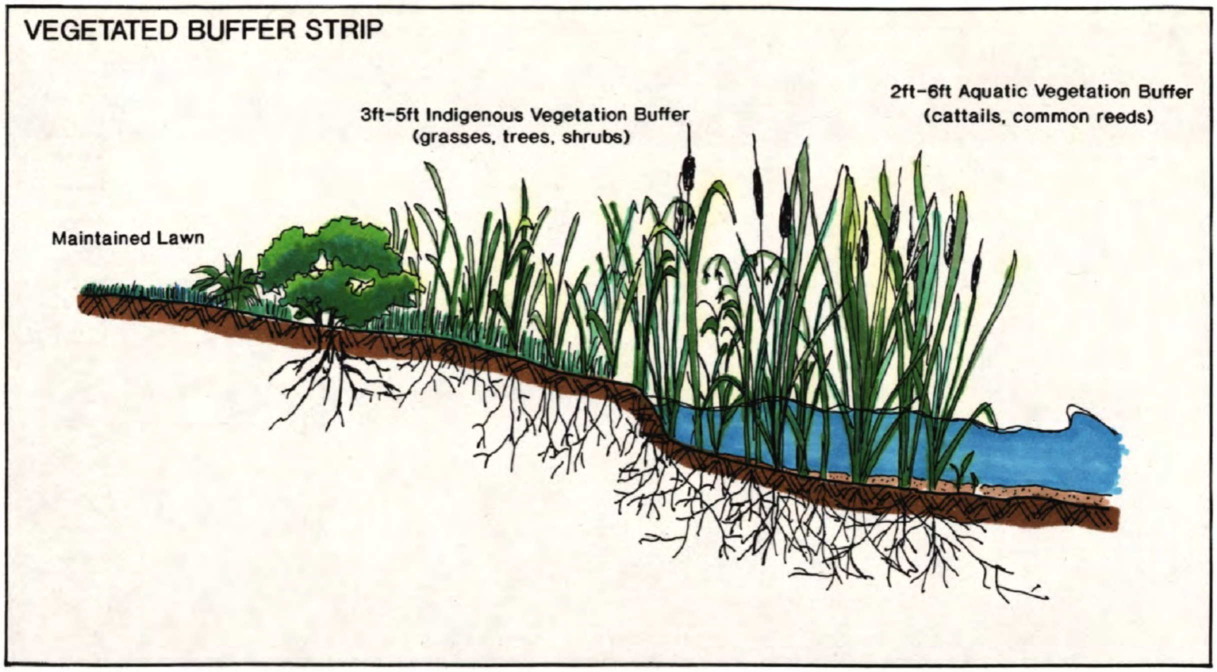
The use of such natural shorescaping techniques is generally required pursuant to Chapter NR 328 of the *Wisconsin Administrative Code*, except in moderate- to high-energy shorelines where more-robust structural approaches, such as placement of rock riprap, may be permitted. Maintenance of a vegetated buffer strip immediately adjacent to a lake is the simplest, least costly, and most natural method of reducing shoreline erosion. The area to be occupied by such vegetated buffer strips is influenced by whether the target shoreline includes developed or undeveloped areas. Along developed areas, this technique employs natural vegetation, rather than maintained lawns, in the first five to 10 feet back from the waterline and the establishment of emergent aquatic vegetation from the waterline out to two to six feet lakeward. Along undeveloped areas, the WDNR recommends shoreland buffers extend from the water's edge onto land at least 35 to 50 feet, contain three layers of flora, herbaceous, shrub, and tree, found in natural Wisconsin lakeshores, and not be mowed except for a viewing access corridor.[15] The use of vegetative buffer strips, as shown in Figure 2, is recommended, especially along those portions of the shoreline which do not experience active recreational uses. To this end, it is recognized that public safety concerns also need to be recognized in this public park and use of tall growing plants, for example, should be avoided, as such plants can provide cover for persons engaged in illegal activities.

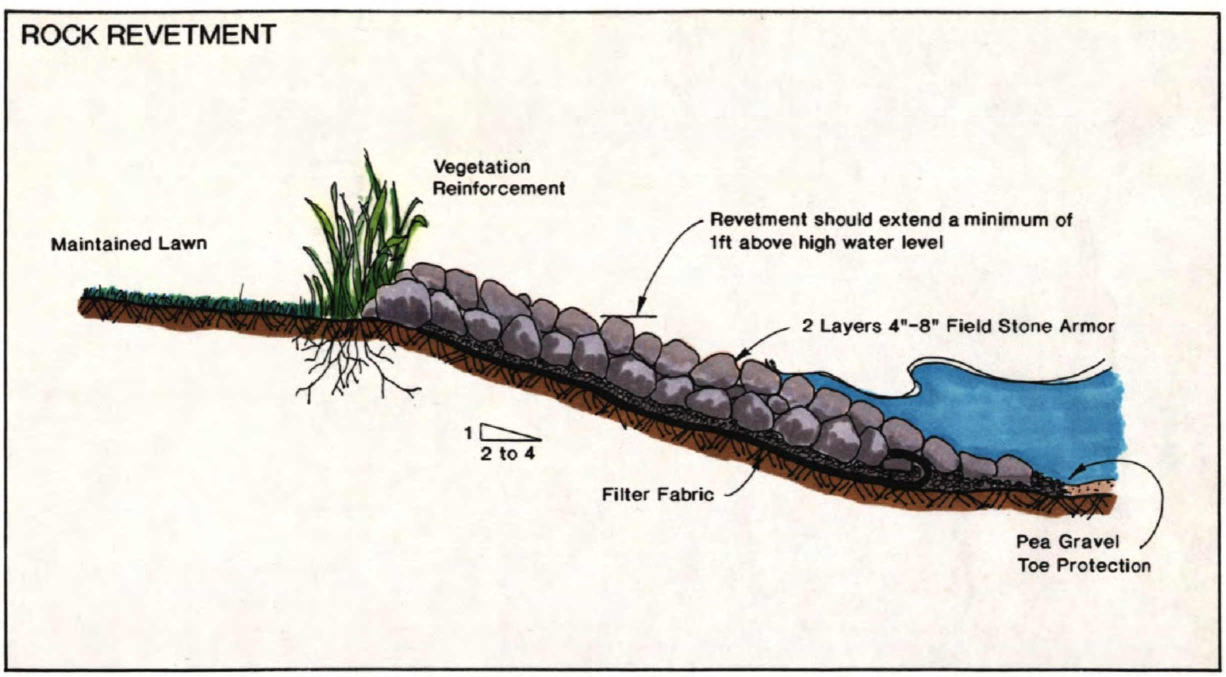
Desirable plant species that may be expected and encouraged to form an effective buffer strip, or which could be planted, include arrowhead (*Sagittaria latifolia*), water plantain (*Alisma plantago-aquatica*), bur-reed (*Sparganium eurycarpum*), and blue flag (*Iris versicolor*) in the wetter areas; and jewelweed (*Impatiens biflora*), elderberry (*Sambucus canadensis*), giant goldenrod (*Solidago gigantea*), marsh aster (*Aster simplex*), red-stem

[15]*See SEWRPC publication, "Managing the Water's Edge: Making Natural Connections," May 2010; this publication can be accessed through the Internet at:*
http://www.sewrpc.org/SEWRPCFiles/Environment/RecentPublications/ManagingtheWatersEdge-brochure.pdf.

Figure 2

RECOMMENDED ALTERNATIVES FOR SHORELINE EROSION CONTROL





NOTE: Design specifications shown herein are for typical structures. The detailed design of shoreline protection structures must be based upon analysis of local conditions.

Source: SEWRPC.

aster (*Aster puniceus*), and white cedar (*Thuja occidentalis*) in the drier areas. In addition, trees and shrubs, such as silver maple (*Acer saccharinum*), American elm (*Ulmus americana*), black willow (*Salix nigra*), and red-osier dogwood (*Cornus stolonifera*) could become established. These plants will develop a more extensive root system than lawn grass and the above-ground portion of the plants will protect the soil against the erosive forces of rainfall and wave action. Vegetative buffer strips would also serve to trap nutrients and sediments washing into the Lake via direct overland flow. This alternative would involve only minimal cost (less than $5.00 per linear foot of shoreline); the cost of riprap for application to moderate energy shorelines ranges from $15 to $20 per linear foot of shoreline.

Recreational Use Management

Current public recreational boating access standards, as set forth in Sections NR 1.91(4) and NR 1.91(5) of the *Wisconsin Administrative Code*, establish minimum and maximum standards, respectively, for public recreational boating access development to qualify waters for resource enhancement services, such as fish stocking, provided by the WDNR. As noted in Chapter II of this report, Saratoga Lake may lack adequate public access as defined in Chapter NR 1 of the *Wisconsin Administrative Code*, despite the fact that the Lake is entirely encompassed by the public park and that land-based recreational activities remain a popular pastime around the Lake. Carry-in access is possible, which would be consistent with the Chapter NR 1 standards for lakes of less than 50 acres in boatable surface area.

Public Informational and Educational Programming

As part of the overall citizen informational and educational programming to be conducted in the community, residents and visitors in the vicinity of the Lake should be made aware of the value of the ecologically significant areas in the overall structure and functioning of the ecosystems of the Lake. Specifically, informational programming related to the protection of ecologically valuable areas in and around the Lake is recommended and should focus on the need to minimize the spread of nuisance aquatic invasive species, such as purple loosestrife and Eurasian water milfoil.

With respect to aquatic plants, distribution of posters and pamphlets available from the UWEX and the WDNR that provide information and illustrations of aquatic plants, their importance in providing habitat and food resources in aquatic environments, and the need to control the spread of undesirable and nuisance plant species, is recommended. Inclusion of specific public informational and educational programming within the activities of the City of Waukesha is recommended. These programs should focus on the value and impacts of these plants on water quality, fish, and wildlife, and on alternative methods for controlling existing nuisance plants, including the positive and negative aspects of each method. These programs can be incorporated into the comprehensive informational and educational programs that also would include information on related topics, such as water quality, recreational use, and fisheries.

Educational and informational brochures and pamphlets are available from the UWEX Waukesha County Office, the WDNR, and many Federal agencies. These brochures could be provided to homeowners through local media, direct distribution, or targeted library/civic center displays. Many of the ideas contained in these publications can be integrated into ongoing, larger-scale activities, such as anti-littering campaigns, recycling drives, and similar community-oriented pro-environment activities. Other informational programming offered by the WDNR, Waukesha County, and the UWEX Lakes Program, such as the Project WET (Water Education Training) curriculum, can contribute to an informed public, actively involved in the protection of ecologically valuable areas within the area tributary to the Lake. Citizen monitoring and awareness of the positive value of native aquatic plant communities are important opportunities for public informational programming and participation.

Finally, the location of the Lake within the public open space system of the City of Waukesha, and the close proximity to both schools and Carroll University should be viewed as an opportunity for engaging the educational community in hands-on involvement in aquatic sciences.

Continuing Education
As part of their commitment to the effective managing of Saratoga Lake, those City personnel charged with primary responsibility for the maintenance of Saratoga Lake should be encouraged to avail themselves of opportunities to learn about current developments and issues involving lake management. There are numerous publications, writings, newsletters, seminars, and conventions available through governmental, educational, and other organizations and agencies dealing with the subject of lake management. UWEX, Wisconsin Lakes, the North American Lake Management Society (NALMS), and WDNR all produce written materials and conduct meetings and seminars dealing with lake management issues. Publications, such as *Lake Tides*, published by the Wisconsin Lakes Partnership and available from UWEX, are also readily available and cover a wide range of lake-related topics. The statewide Lakes Convention, held annually in Green Bay, Wisconsin, provides valuable opportunities to learn about important and timely developments in lake management and learn about lake issues from experts in their fields. Participation in activities that will further understanding of lake management issues is deemed an important part of the lake management experience.

SUMMARY

This plan, requested by the City of Waukesha, documents the findings and recommendations of a study of the aquatic plant communities of Saratoga Lake. The plan examines existing and anticipated conditions, potential management and protection problems, and recreational use issues on the Lake. The plan sets forth recommended actions and management measures for the resolution of those problems. The recommended plan is summarized in Table 11 and shown on Map 13.

Saratoga Lake was found to be a eutrophic lake of poor water quality. Appropriate land management practices designed to reduce nonpoint source pollutant discharges in stormwater runoff into the Lake are recommended.

The shoreland protection and aquatic plant management elements of this plan recommend actions be taken that would reduce human impacts on ecologically valuable areas in and adjacent to the Lake, encourage a biologically diverse community of native aquatic plants, and limit the spread of nonnative invasive plant species.

The plan recommends the use of chemical herbicides, mainly in areas where nuisance levels of nonnative invasive species are present; use of mechanical harvesting of nuisance plants in those areas where depth of water and bottom substrate are sufficient to support such activity; manual harvesting aquatic plants around piers and docks, with subsequent removal of cut material from the Lake; and monitoring of invasive species populations. The plan further recommends periodic in-lake aquatic plant surveys every three to five years to monitor changes in the aquatic plant community and assess effectiveness of aquatic plant management techniques.

The plan also recommends regular participation in the expanded UWEX CLMN volunteer water quality monitoring program with consideration of participation in the Expanded Level II CLMN program.

Finally, the recommended plan includes continuation of an ongoing program of public information and education, focusing on providing riparian residents and lake users with an improved understanding of the lake ecosystem. Additional options regarding household chemical use, lawn and garden care, onsite sewage disposal system operation and maintenance, shoreland protection and maintenance, and recreational use of the Lake should be made available to riparian property owners, thereby providing riparian residents with alternatives to traditional activities. Additionally, City of Waukesha officials and electors are encouraged to maintain and broaden their awareness of current developments in the area of lake management through participation in meetings, seminars, conventions, and other lake management-related events and educational opportunities.

Adherence to the recommendations contained in this plan should provide the basis for a set of protection actions that are: aligned with the goals and objectives set forth in Chapter I of this report; reflective of the ongoing commitment by the City of Waukesha to sound planning with respect to the Lake; and sensitive to current needs, as well as those in the immediate future.

Table 11

RECOMMENDED LAKE USE PLAN ELEMENTS FOR SARATOGA LAKE

Plan Element	Subelement	Management Measures	Management Responsibility
Aquatic Plant Management Measures	Proactive Measures	Conduct periodic in-lake reconnaissance surveys of aquatic plant communities and update aquatic plant management plan every three to five years	CW
		Monitor shorelines and open water areas for new growths of nonnative invasive species and immediately report any new growths to the WDNR	CW
		Additional periodic monitoring of the aquatic plant community for the early detection and control of future-designated nonnative species that may occur	WDNR and CW
	Management Measures	Manually harvest around piers and docks as necessary[a]	CW
		Where they occur, remove isolated stands of purple loosestrife through bagging, cutting, and herbicide application to the cut stems	WDNR and CW
		Mechanically harvest nuisance plants in those areas where species locations, depths of water, and types of bottom substrate are supportive in order to maintain boating access, promote public safety, enhance angling opportunities, and encourage native plant growth and biodiversity (as is currently completed annually).	WDNR and CW
		Consider completion of a second annual mechanical harvest in preparation for water ski show.	
		Consider the use of limited aquatic herbicide applications to control nuisance growths of nonnative aquatic plants where deemed necessary and effective; specifically target Eurasian water milfoil, curly-leaf pondweed, and purple loosestrife as required[b]	
		Encourage growth of native plants in Saratoga Lake through use of vegetated buffer strips and control of Eurasian water milfoil and other invasive species	
Ancillary Management Measures	Water Quality Management	Participate in UWEX CLMN program; consider participation in WDNR Expanded Self-Help Program and periodic participation in USGS TSI or similar programs	UWEX, WDNR, USGS/UWSP, CW
	Shoreline Protection	Revegetate unprotected and unstable shoreline in environmentally valuable areas; maintain enhance vegetated buffer strips on the lakeshore	WDNR and CW
		Maintain shoreline protection structures; maintain riprap along the lake shore	CW and WDNR
	Recreational Use	Consider restoration of lake depths by dredging unconsolidated sediments; restore stream channel within the impoundment	CW and WDNR
		Periodic review of public recreational access opportunities; provide signage at access areas regarding invasive species	WDNR and CW

NOTE: The following abbreviations have been used:

CLMN = Citizen Lake Monitoring Network
CW = City of Waukesha
TSI = Trophic State Index calculated from the phosphorus and chlorophyll-*a* concentrations and Secchi-disk transparency value
USGS = U.S. Geological Survey
UWEX = University of Wisconsin-Extension
UWSP = University of Wisconsin-Stevens Point Water and Environmental Analysis Laboratory
WDNR = Wisconsin Department of Natural Resources

[a]*Manual harvesting beyond a 30-linear-foot width of shoreline is subject to WDNR individual permitting pursuant to Chapter NR 109 of* the Wisconsin Administrative Code.

[b]*Use of aquatic herbicides requires a WDNR permit pursuant to Chapter NR 107 of the* Wisconsin Administrative Code.

Source: SEWRPC.

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APPENDICES

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Appendix A

ILLUSTRATIONS OF COMMON AQUATIC PLANTS FOUND IN SARATOGA LAKE

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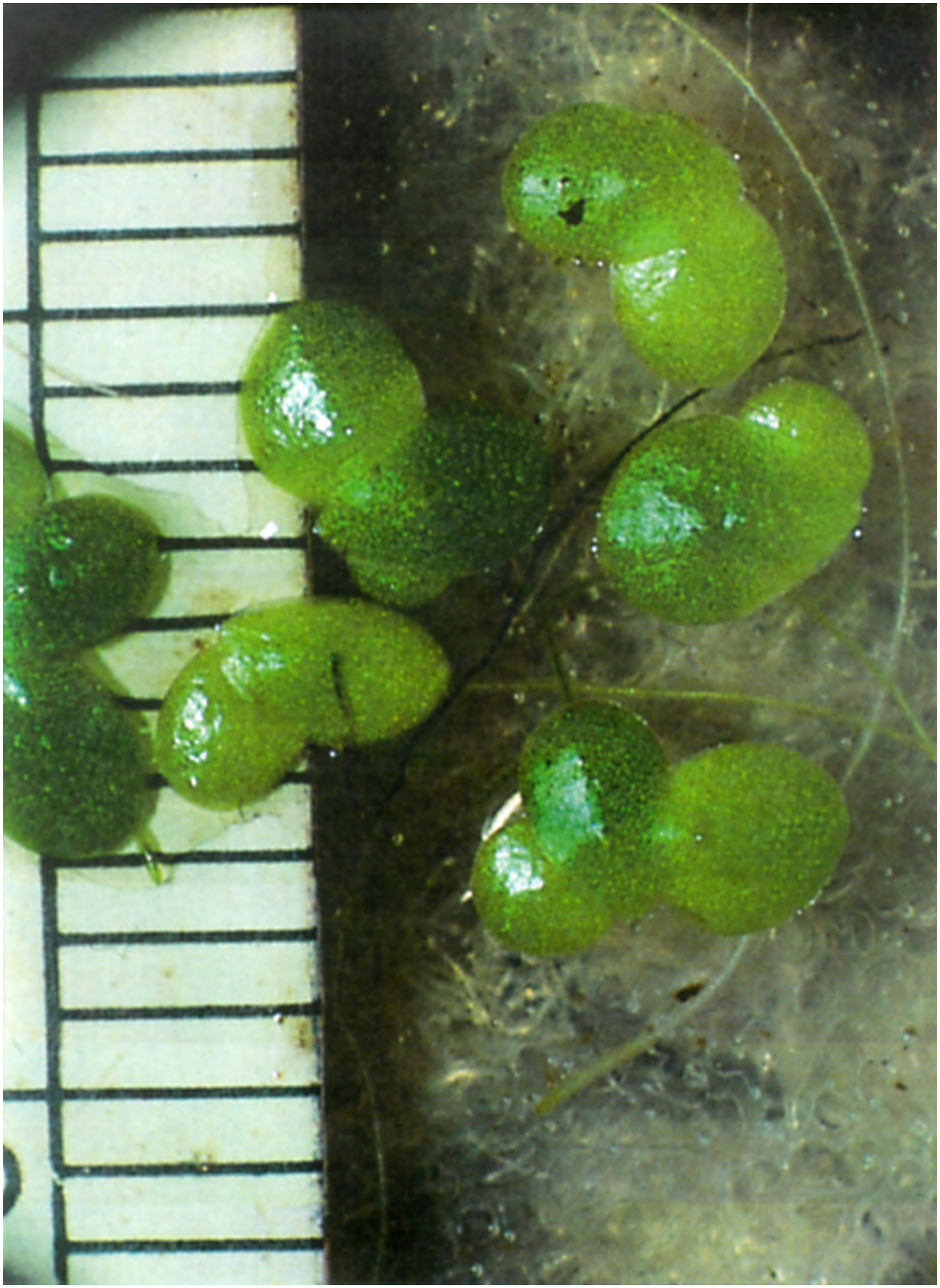
Coontail (*ceratophyllum demersum*)

Curly-Leaf Pondweed (*potamogeton crispus*)
Exotic Species (nonnative)

Eurasian Water Milfoil (*myriophyllum spicatum*)
Exotic Species (nonnative)

Flat-Stem Pondweed (*potamogeton zosteriformis*)

Leafy Pondweed (*potamofeton foliosus*)



Lesser Duckweed (*lemna minor*)

NOTE: Plant species in photograph are not shown proportionate to actual size

Source: Steve D. Eggers and Donald M. Reed, Wetland Plants and Plant Communities of Minnesota & Wisconsin*,*
2nd Edition, 1997

Native Water Milfoil (*myriophyllum* sp.)

Sago Pondweed (*potamogeton pectinatus*)

Water Stargrass (*zosterella dubia*)

Waterweed (*elodea canadensis*)

Eel-Grass / Wild Celery (*valisneria americana*)

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Appendix B

LOCATION OF COMMON AQUATIC PLANTS FOUND IN SARATOGA LAKE

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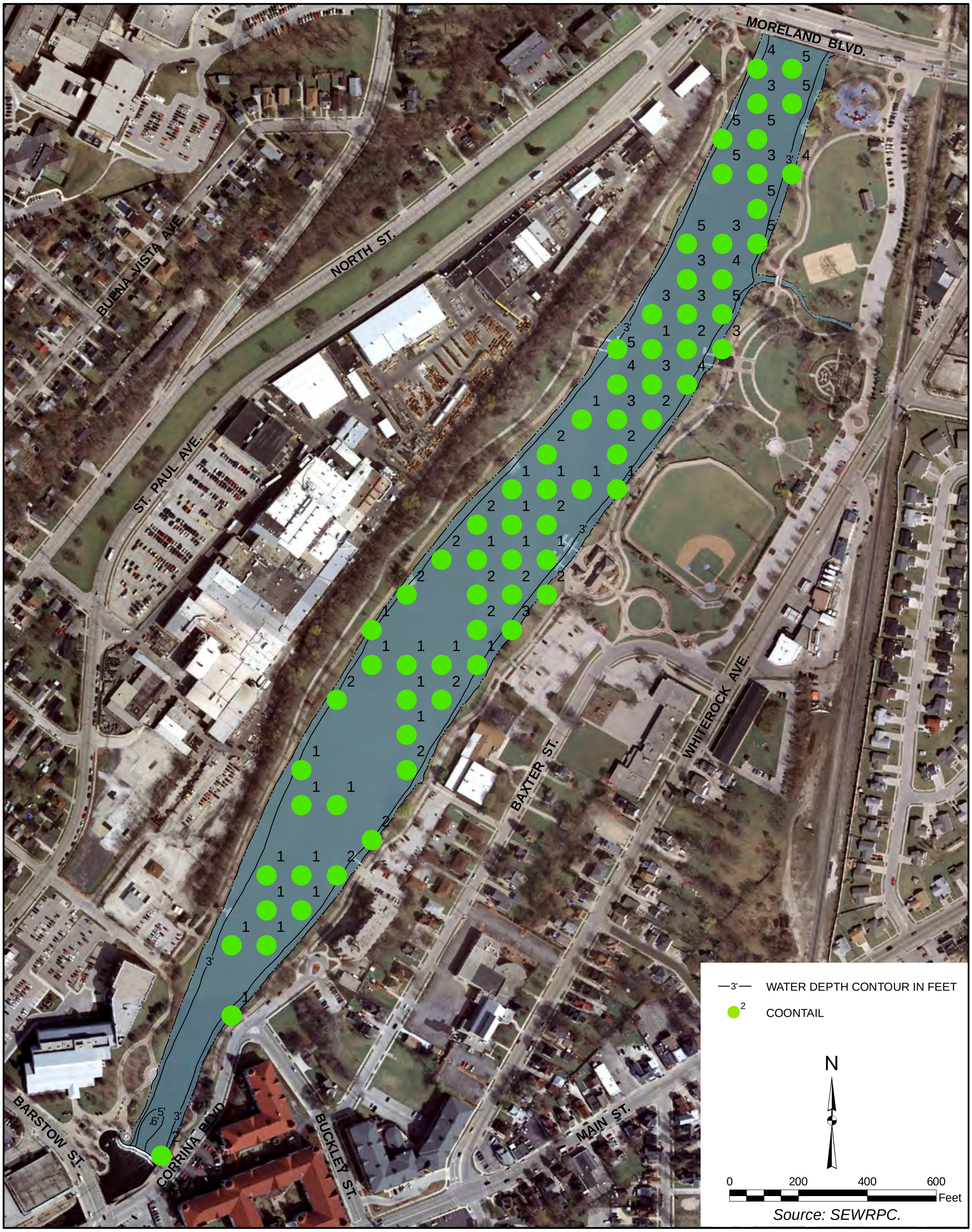
Map B-1

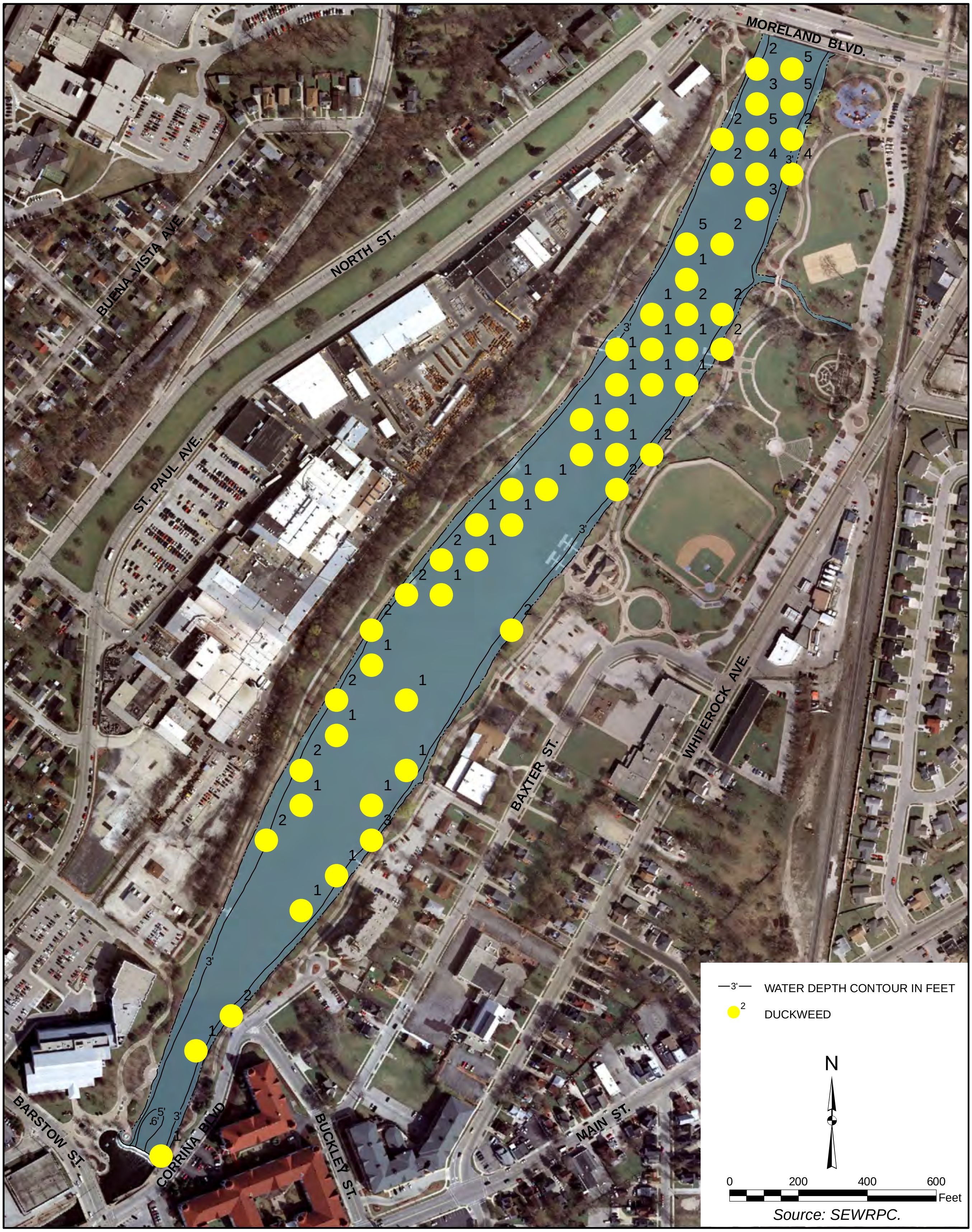
COONTAIL IN SARATOGA LAKE: 2012



DATE OF PHOTOGRAPHY: APRIL 2010

Map B-2

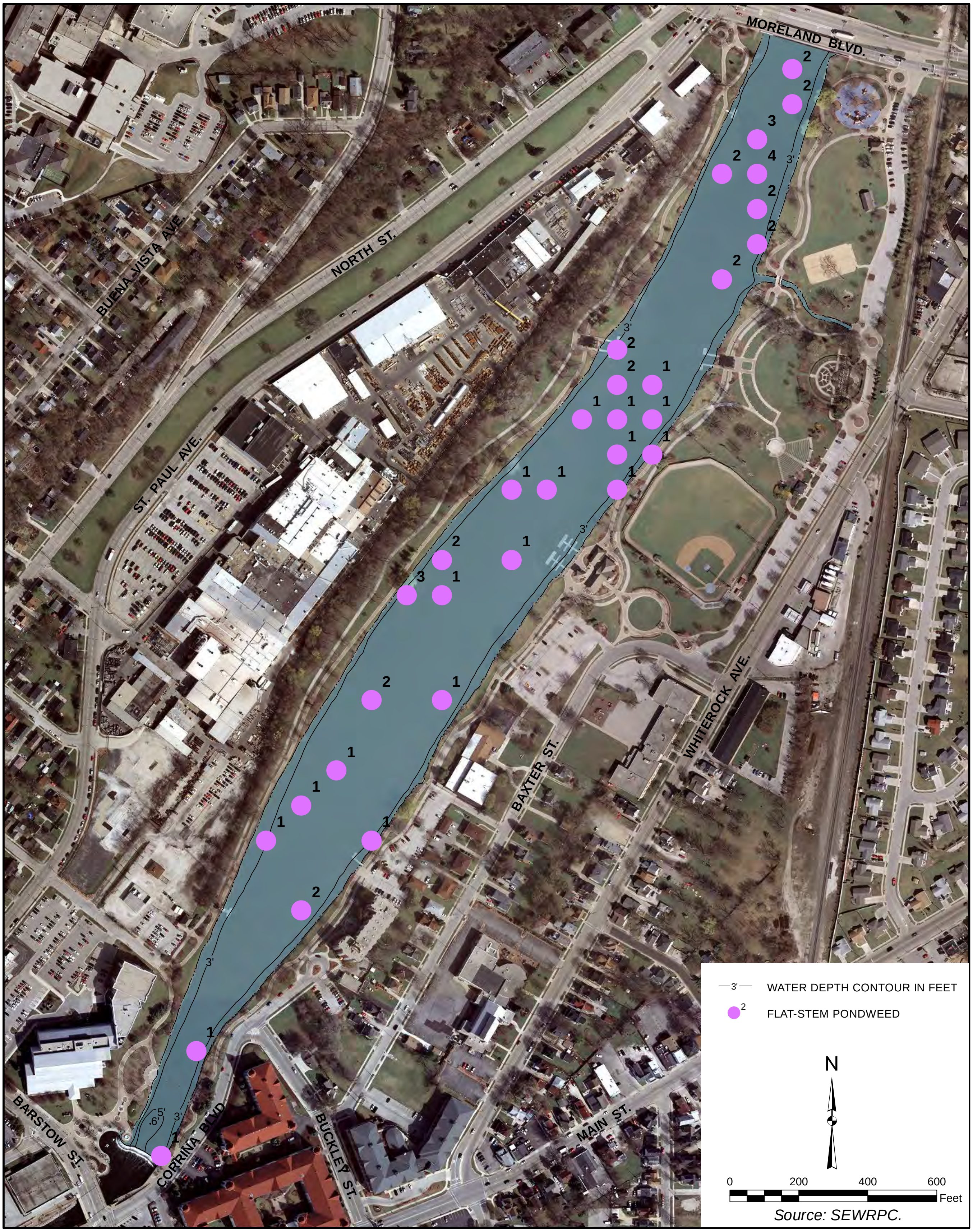
DUCKWEED IN SARATOGA LAKE: 2012



DATE OF PHOTOGRAPHY: APRIL 2010

Map B-3

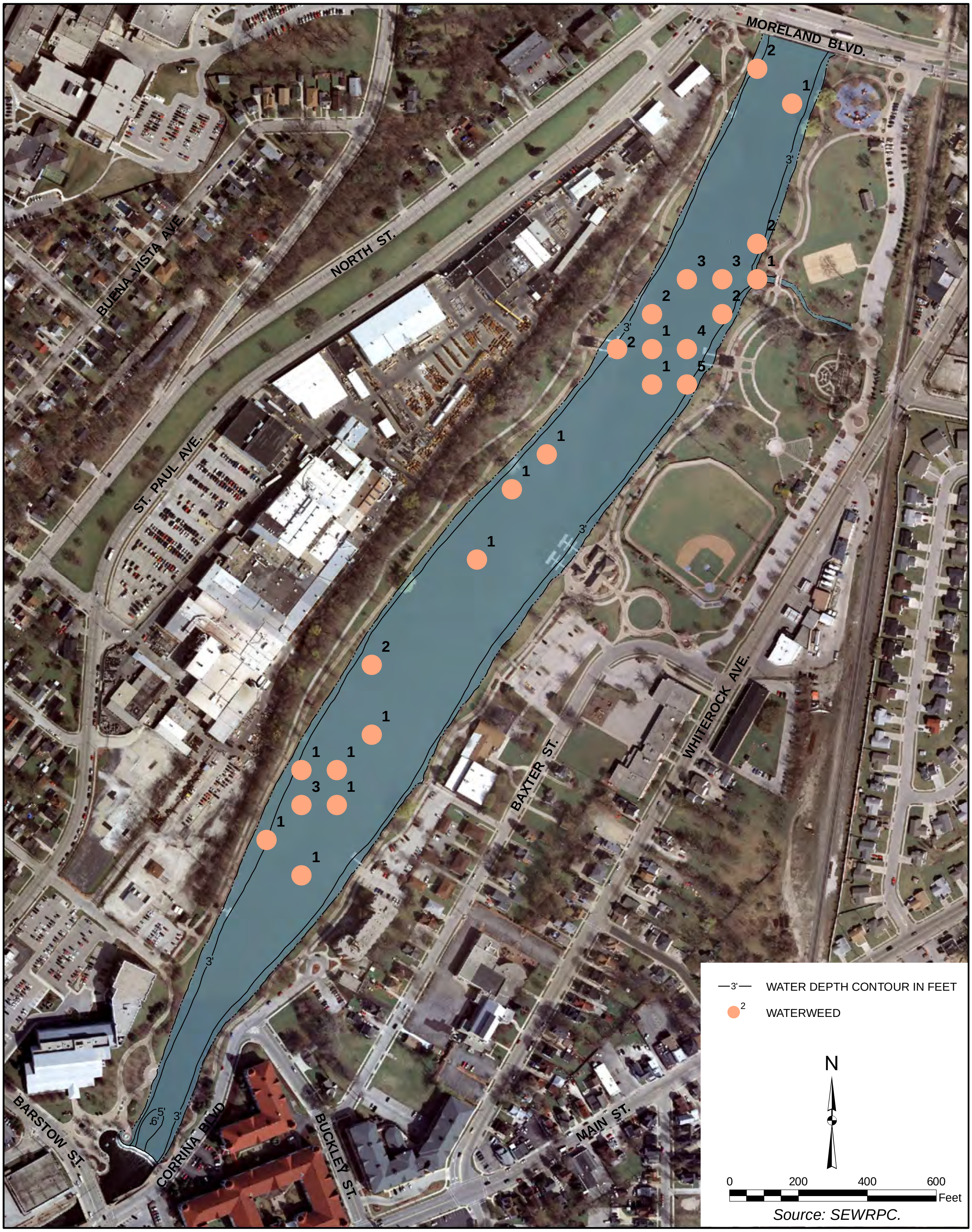
FLAT-STEM PONDWEED IN SARATOGA LAKE: 2012



DATE OF PHOTOGRAPHY: APRIL 2010

Map B-4

WATERWEED IN SARATOGA LAKE: 2012



DATE OF PHOTOGRAPHY: APRIL 2010