Waushara County Lakes Study

White River Flowage

Spring 2015

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WAUSHARA COUNTY LAKES STUDY BACKGROUND

Lakes and rivers contribute to the way of life in Waushara County. Local residents and visitors alike enjoy fishing, swimming, boating, wildlife viewing, and the peaceful nature of the lakes. Healthy lakes add value to our communities. They provide places to relax and recreate, and they can stimulate tourism. Like other infrastructure in our communities, lakes require attention and good management practices to remain healthy in our developing watersheds.

Thirty-three lakes in Waushara County were selected for this study. The study focused on learning about the lakes' water quality, aquatic plant communities, shoreland habitats, watersheds and histories in order to help people make informed lake management decisions. This report summarizes data collected for White River Flowage between fall 2010 and fall 2013.

ABOUT WHITE RIVER FLOWAGE

To understand a lake and its potential for water quality, fish and wildlife, and recreational opportunities, we need to understand its physical characteristics and setting within the surrounding landscape. The White River Flowage is located in the township of Dakota, south of the city of Wautoma, and east of Highway 22, with two public boat launches located on its eastern side. White River Flowage is a 133-acre impoundment lake on the White River with surface runoff and groundwater contributing most of its water. Its maximum depth is 20 feet; the bed of the flowage has a gradual slope averaging 6 feet deep (Figure 1). Sand channel bottoms and significant deposits of muck are found throughout the flowage.

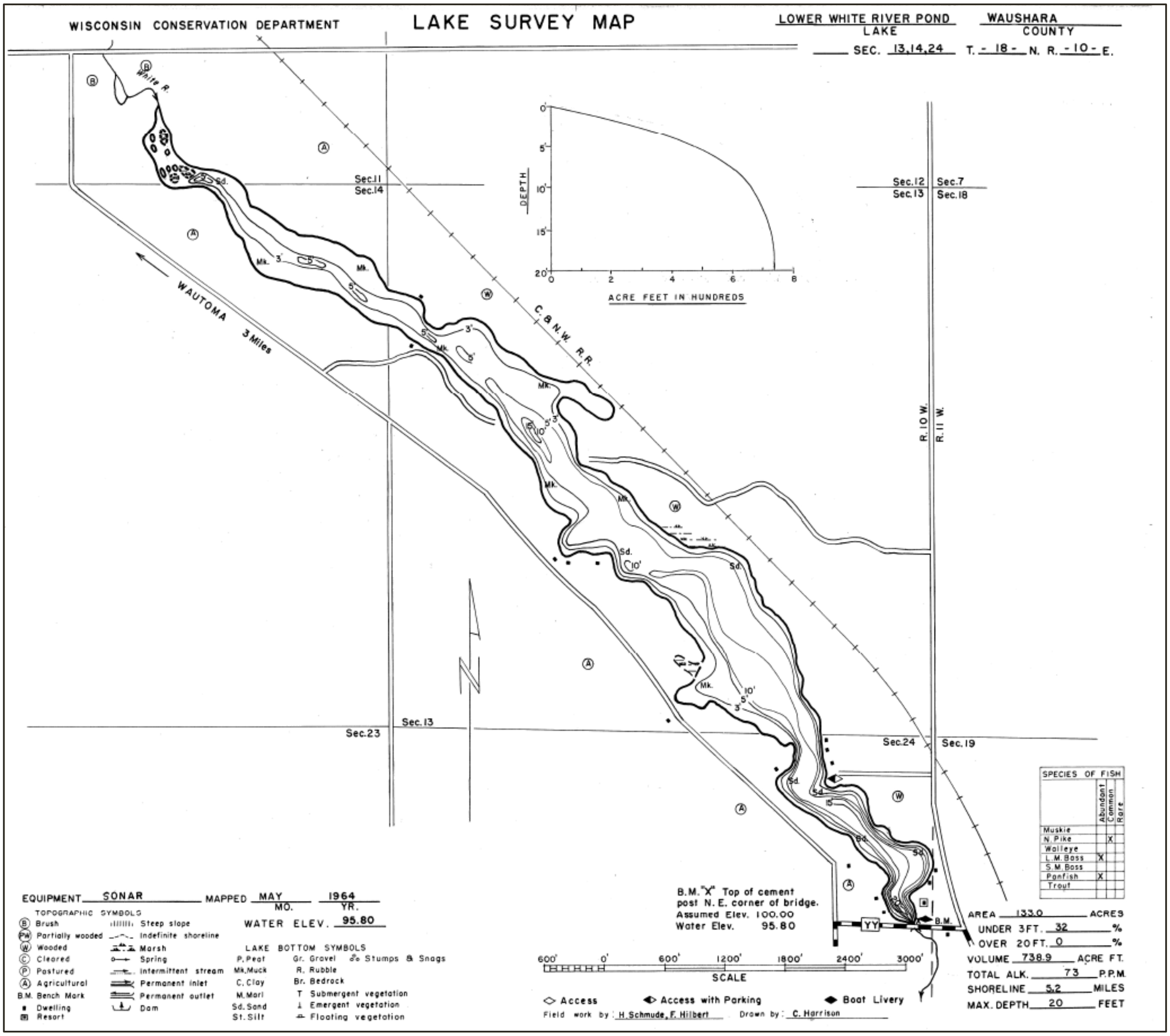


FIGURE 1. CONTOUR MAP OF THE WHITE RIVER FLOWAGE LAKEBED.

WHERE IS THE WATER COMING FROM? - WATERSHEDS AND LAND USE

The water quality in White River Flowage is a reflection of the land that drains to it. The water quality, the amount of algae, aquatic plants, the fishery and other animals in the lake are all affected by natural and man-made characteristics. Natural characteristics that affect a lake include the amount of land that drains to the lake, the hilliness of the landscape, types of soil, extent of wetlands, and the type of lake. Within the lake's watershed, alterations to the landscape, the types of land use, and the land management practices are examples of how people may affect the lake.

It is important to understand where White River Flowage's water originates in order to understand the lake's health. During snowmelt or a rainstorm, water moves across the surface of the landscape (runoff) towards lower elevations such as lakes, streams, and wetlands. The land area that contributes runoff to White River Flowage is called a surface watershed. Groundwater also feeds White River Flowage; its land area may be slightly different than the surface watershed. The surface watershed is shown in Figure 2.

The capacity of the landscape to shed or hold water and contribute or filter particles determines the amount of erosion that may occur, the amount of groundwater feeding a lake, and ultimately, the lake's water quality and quantity. Essentially, landscapes with a greater capacity to hold water during rain events and snowmelt help to slow the delivery of the water to the lake. Less runoff is desirable because it allows more water to recharge the groundwater, which feeds the lake year-round - even during dry periods or when the lake is covered with ice.

Land use and land management practices within a lake's watershed can affect both its water quantity and quality. While forests and grasslands allow a fair amount of precipitation to soak into the ground, resulting in more groundwater and better water quality, other types of land uses may result in increased runoff and less groundwater recharge, and may be sources of pollutants that can impact the lake and its inhabitants. Areas of land with exposed soil can produce soil erosion. Soil entering the lake can make the water cloudy and cover fish spawning beds. Soil also contains nutrients that increase the growth of algae and aquatic plants. Development on the land often results in changes to natural drainage patterns, alterations to vegetation on the landscape, and may be a source of pollutants. Impervious (hard) surfaces such as roads, rooftops, and compacted soil prevent rainfall from soaking into the ground, which may result in more runoff that carries pollutants to the lake. Wastewater, animal waste, and fertilizers used on lawns, gardens and crops can contribute nutrients that enhance the growth of algae and aquatic plants in our lakes.

A variety of land management practices can be put in place to help reduce impacts to our lakes. Some practices are designed to reduce runoff. These include protecting/restoring wetlands, installing rain gardens, swales, rain barrels, and routing drainage from pavement and roofs away from the lake. Some practices are used to help reduce nutrients from moving across the landscape towards the lake. Examples include manure management practices, eliminating/reducing the use of fertilizers, increasing the distance between the lake and a septic drainfield, protecting/restoring native vegetation in the shoreland, and using erosion control practices. Waushara County staff and other professionals can work with landowners to determine which practices are best suited to a particular property.

WHITE RIVER FLOWAGE SURFACE WATERSHED

The surface watershed for White River Flowage is approximately 33,501 acres (Figure 2). The dominant types of land use in the watershed are forests (36%) and agriculture (33%). The land closest to the lake often has the greatest impact on water quality and habitat; White River Flowage's shoreland is surrounded primarily by cultivated crops, wetlands and forests.

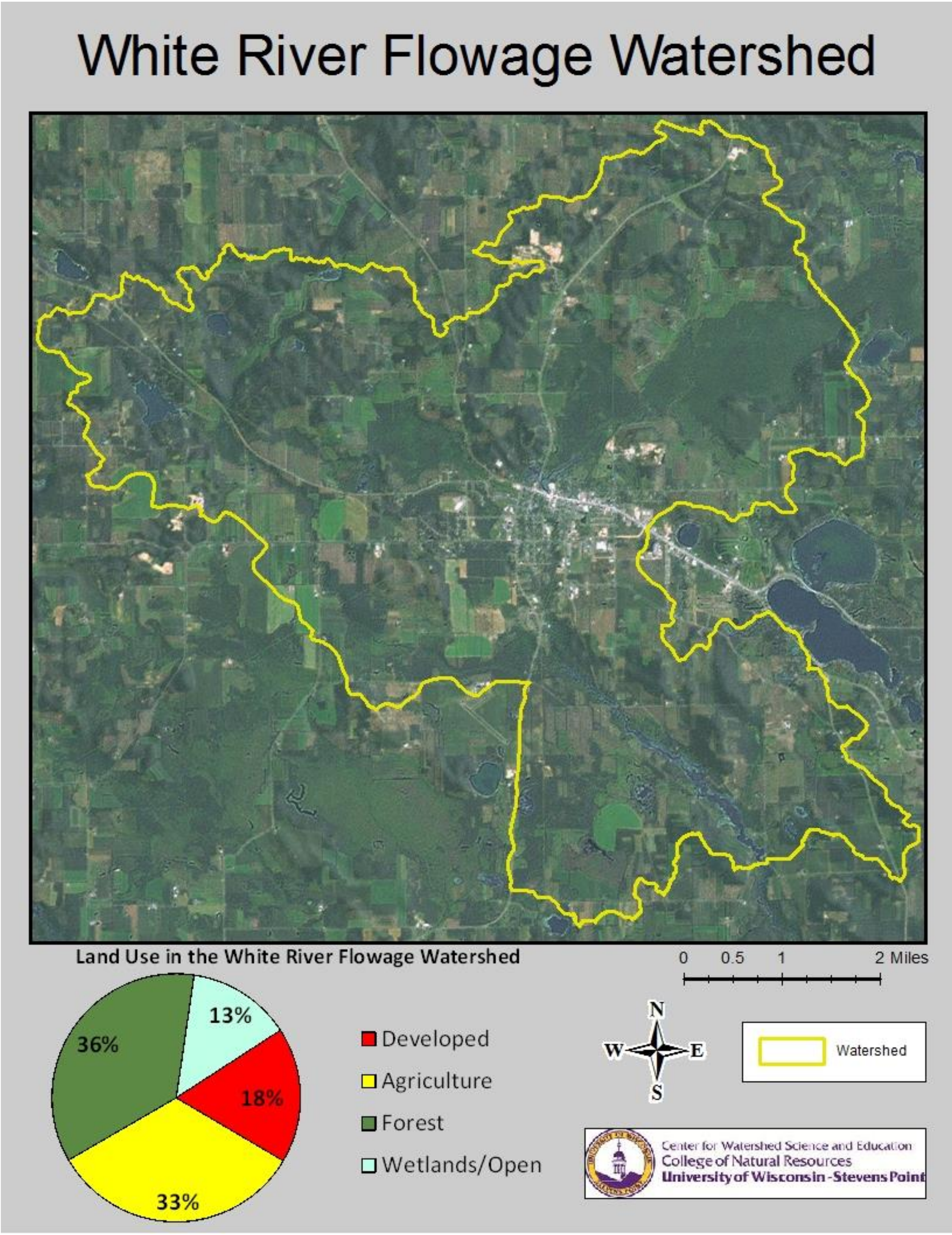


FIGURE 2. LAND USE IN THE WHITE RIVER FLOWAGE SURFACE WATERSHED.

The more the lake's water interacts with groundwater, the more influence the geology has on the lake. The length of time water remains below ground affects the temperature and chemistry of the groundwater. Groundwater temperature is near constant year round; during the summer, groundwater feeding White River Flowage will help keep the lake water cooler.

Groundwater flows below ground from higher to lower elevations, discharging into wetlands, streams, and lakes. The groundwater feeding the lakes in Waushara County originates nearby. The black arrows in Figure 3 indicate the general direction of groundwater flow. Much of the groundwater enters White River Flowage from the north and the east.

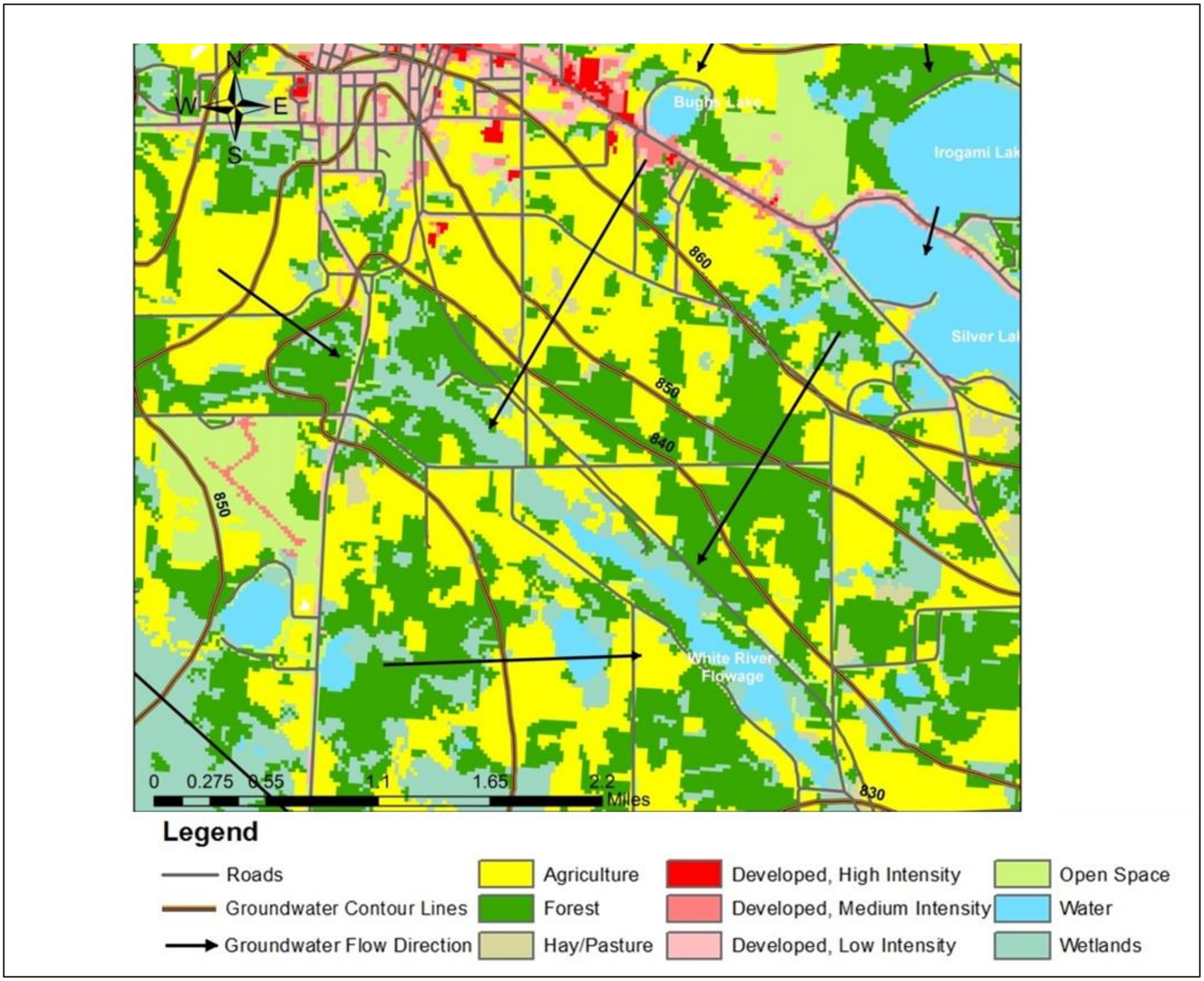
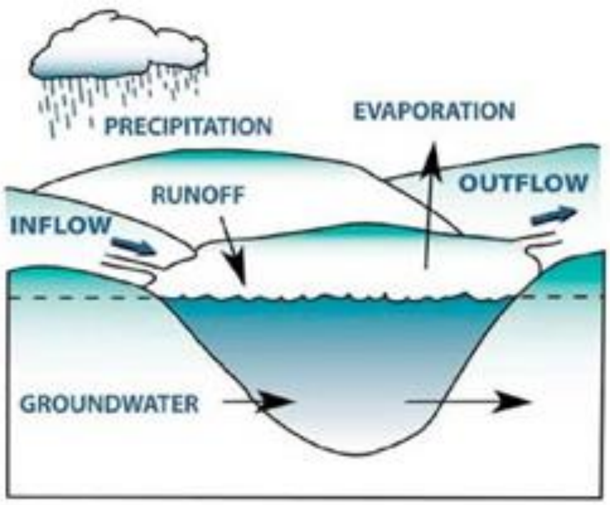


FIGURE 3. GROUNDWATER FLOW DIRECTION NEAR WHITE RIVER FLOWAGE.

Lake water quality is a result of many factors including the underlying geology, the climate, and land management practices. Assessing lake water quality allows us to evaluate current lake health and changes from the past. We can then identify what is needed to achieve a more desirable state or preserve an existing state for aesthetics, recreation, wildlife and the fishery. During this study, water quality in White River Flowage was assessed by measuring different characteristics including temperature, dissolved oxygen, water clarity, water chemistry, and algae.



The source of a lake's water supply is important in determining its water quality and choosing management practices to preserve or influence that quality. The White River Flowage is an impoundment, a manmade lake created with a dam, on the White River. An impoundment has an inlet and outlet, and its principal water sources are the inlet stream, and to lesser extents, direct runoff, groundwater and precipitation (Figure 4). Impoundments generally receive and retain more sediment and nutrients that can affect water chemistry than do other lake types. Over time, the sediments and nutrients will build up in an impoundment, providing ideal growing conditions for aquatic plants and algae.

FIGURE 4. CARTOON SHOWING INFLOW AND OUTFLOW OF WATER IN AN IMPOUNDMENT LAKE.

The geologic composition that lies beneath a lake has the ability to influence the temperature, pH, minerals, and other properties in a lake. As groundwater moves, some substances are filtered out, but some materials in the soil dissolve into the groundwater (Shaw et al., 2000). Minerals such as calcium and magnesium in the soil around White River Flowage are dissolved in the water. The average hardness for White River Flowage during the 2010-2012 sampling period was 173 mg/L, which is considered hard (Table 1). Hard water provides calcium necessary for building bones and shells for animals in the lake. The average alkalinity was 167 mg/L; higher alkalinity in inland lakes can support higher species productivity (Wetzel, 2001). Hardness and alkalinity also play a role in the type of aquatic plants that are found in a lake.

TABLE 1. MINERALS AND PHYSICAL MEASUREMENTS IN WHITE RIVER FLOWAGE, 2010-2012.

White River Flowage	Alkalinity (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L as $CaCO_3$)	Color (SU)	Turbidity (NTU)
Average Value	167	32.3	16.2	173	36	2.9

Chloride concentrations, and to lesser degrees sodium and potassium concentrations, are commonly used as indicators of how a lake is being impacted by human activity. The presence of these compounds where they do not naturally occur indicates sources of water contaminants.

The White River Flowage had slightly elevated chloride, potassium and sodium concentrations over the monitoring period (Table 2). These concentrations are not harmful to aquatic organisms, but indicated that pollutants are entering the lake. Sources of chloride and sodium include animal waste, septic systems, fertilizer, and road-salting chemicals. Sources of potassium include animal waste, septic systems, and some fertilizers. Atrazine, an herbicide commonly used on corn, was below the detection limit in the samples that were analyzed from White River Flowage (<0.01 ug/L).

TABLE 2. AVERAGE WATER CHEMISTRY IN WHITE RIVER FLOWAGE, 2010-2012.

White River Flowage	Average Value			Reference Value		
(Lower Pond)	Low	Medium	High	Low	Medium	High
Potassium (mg/L)		1.1		<.75	0.75-1.5	>1.5
Chloride (mg/L)		5.3		<3	3.0-10.0	>10
Sodium (mg/L)		3.7		<2	2.0-4.0	>4

Dissolved oxygen is an important measure in aquatic ecosystems because a majority of organisms in the water depend on oxygen to survive. Oxygen is dissolved into the water from contact with the air, which is increased by wind and wave action. Algae and aquatic plants also produce oxygen when sunlight enters the water, but the decomposition of dead plants and algae reduces oxygen in the lake. Some forms of iron and other metals carried by groundwater can also consume oxygen when the groundwater discharges to the lake.

In a lake, the water temperature changes throughout the year and may vary with depth. During winter and summer when some lakes stratify (layer), the amount of dissolved oxygen is often lower towards the bottom of the lake. Dissolved oxygen concentrations below 5 mg/L can stress some species of cold water fish and over time can reduce the amount of available habitat for cold water species of fish and other aquatic organisms.

Water temperature and dissolved oxygen were measured in the White River Flowage from the surface to the bottom at the time of sample collection. During the 2010-2012 study, temperatures were nearly uniform from the surface to the bottom of the lake, with weak stratification occurring during parts of the summer (Figure 5). Dissolved oxygen concentrations were uniform from surface to the bottom during the fall, but stratified during the rest of the year (Figure 6).

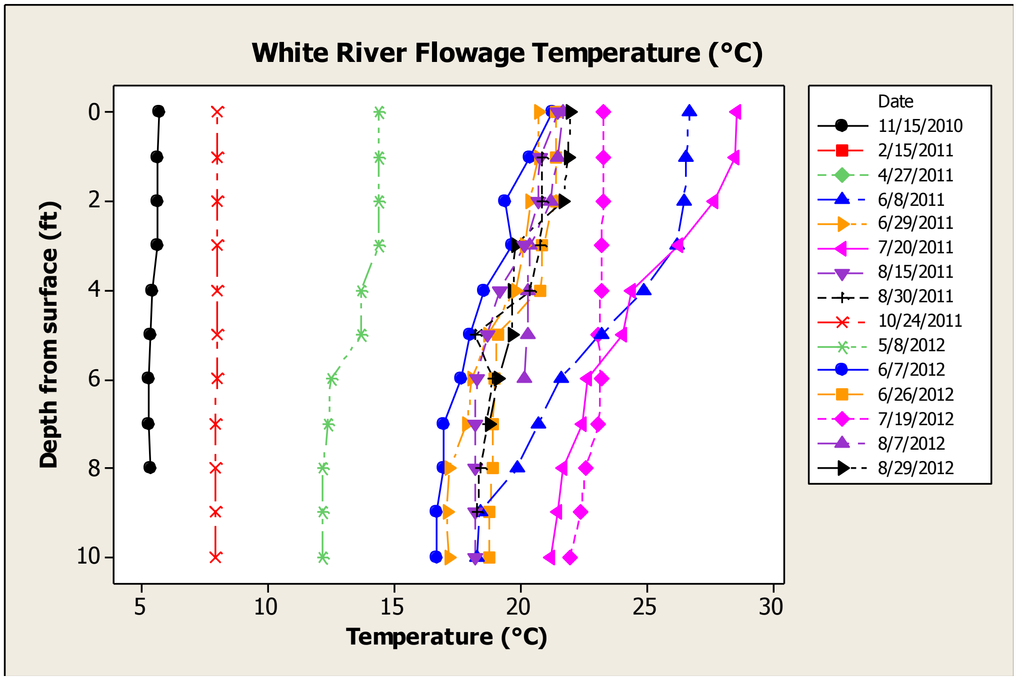


FIGURE 5. TEMPERATURE PROFILES IN WHITE RIVER FLOWAGE, 2010-2012.

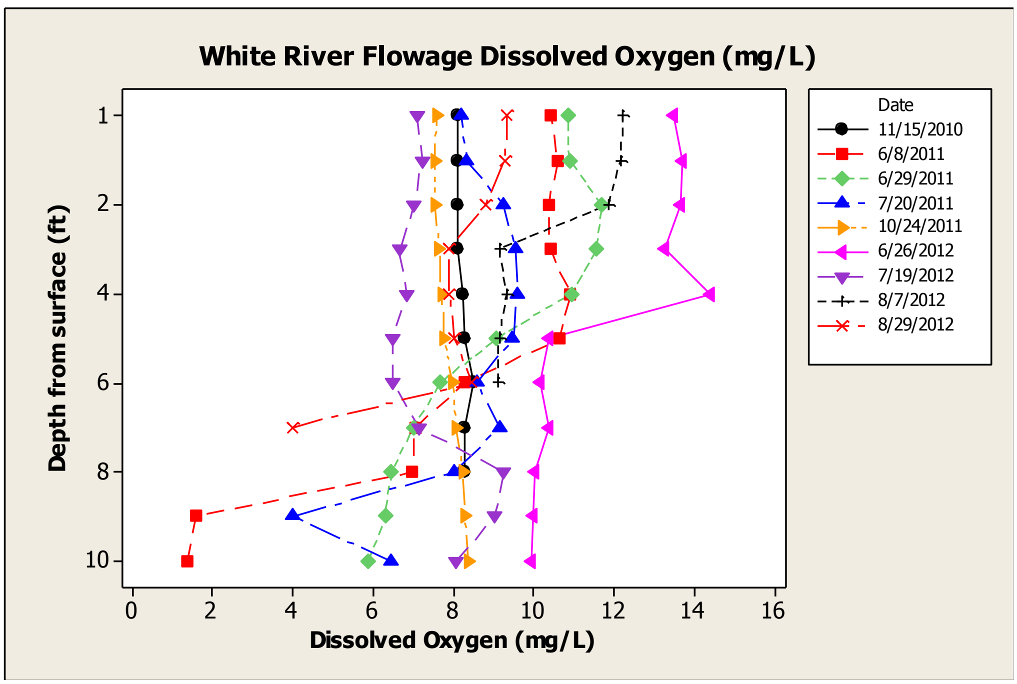


FIGURE 6. DISSOLVED OXYGEN CONCENTRATIONS IN WHITE RIVER FLOWAGE, 2010-2012.

Water clarity is a measure of the depth that light can penetrate into the water. It is an aesthetic measure and is also related to the depth that rooted aquatic plants can grow. Water clarity is affected by water color, turbidity (suspended sediment), and algae, so it is normal for water clarity to change throughout the year and from year to year.

In White River Flowage, color was relatively low (Table 1), so the variability in transparency throughout the year was primarily due to fluctuating algae concentrations and suspended sediment following storms.

The water clarity measured in White River Flowage was considered fair. Water clarity ranged from 3.5 feet to 11 feet (Figure 7). When compared with past data, the average water clarity measured during the study was poorer than past averages in all months sampled.

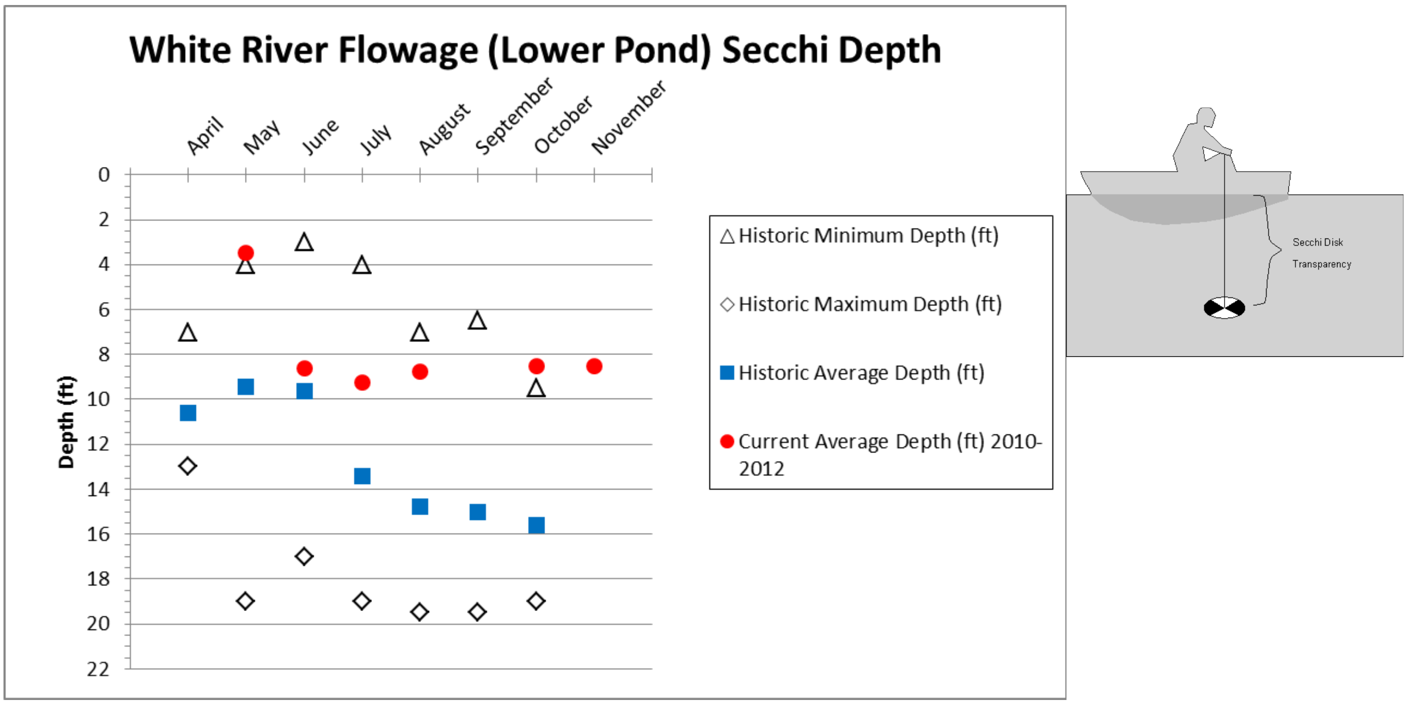


FIGURE 7. WATER CLARITY IN WHITE RIVER FLOWAGE, 2010-2012 AND HISTORIC.

Nutrients (phosphorus and nitrogen) are used by algae and aquatic plants for growth. Phosphorus is present naturally throughout the watershed in soil, plants, animals and wetlands. Common sources from human activities include soil erosion, animal waste, fertilizers and septic systems.

It is most common for phosphorus to move from the land to the water through surface runoff, but it can also travel to the lake in groundwater. Once in a lake, a portion of the phosphorus becomes part of the aquatic system in the form of plant and animal tissue, and sediment. The phosphorus continues to cycle within the lake for many years.

During the study, total phosphorus concentrations in White River Flowage ranged from a high of 38 ug/L in May 2012 to a low of 10 ug/L in August 2012 (Table 3). The summer median total phosphorus concentrations were 24 and 13 ug/L in 2011 and 2012, respectively. This is below Wisconsin’s phosphorus standard of 40 ug/L for shallow impoundments.

Chlorophyll-a is a measurement of algae in the water. Chlorophyll-*a* concentrations in the White River Flowage varied slightly throughout the monitoring period ranging from a high of 6 ug/L in June 2011 to a low of 0.5 ug/L in August 2011 and again in July 2012. The average over the monitoring period was 2.2 ug/L. Inorganic nitrogen was elevated in all samples collected from the White River Flowage. In spring, concentrations of 0.3 mg/L inorganic nitrogen are sufficient to fuel algal blooms throughout the summer. Sources of inorganic nitrogen include animal waste, septic systems, and fertilizers.

TABLE 3. SEASONAL SUMMARY OF NUTRIENT CONCENTRATIONS IN WHITE RIVER FLOWAGE, 2010-2012.

White River Flowage (Lower Pond)	**Inorganic Nitrogen** (mg/L)			**Organic Nitrogen** (mg/L)			**Total Nitrogen** (mg/L)			**Soluble Reactive Phosphorus** (ug/L)			**Total Phosphorus** (ug/L)		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Fall	2.05	2.09	2.13	0.31	0.31	0.31	2.36	2.36	2.36	7	7	7	16	16	16
Spring	1.25	1.54	1.84	0.39	0.52	0.64	1.89	2.06	2.23	4	8	12	17	28	38
Summer													10	18	30
Winter	2.25	2.25	2.25							8	8	8	17	17	17

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to White River Flowage. Land use in the surface watershed was evaluated and used to populate the Wisconsin Lakes Modeling Suite (WILMS) model. In general, each type of land use contributes different amounts of phosphorus in runoff and through groundwater. The types of land management practices that are used and their distances from the lake also affect the contributions to the lake from a parcel of land. Based on modeling results, agriculture had the greatest percentages of phosphorus contributions from the watershed to White River Flowage (Figure 8). The phosphorus contributions by land use category, called phosphorus export coefficients, are shown in Table 4. The phosphorus export coefficients have been obtained from studies throughout Wisconsin (Panuska and Lillie, 1995).

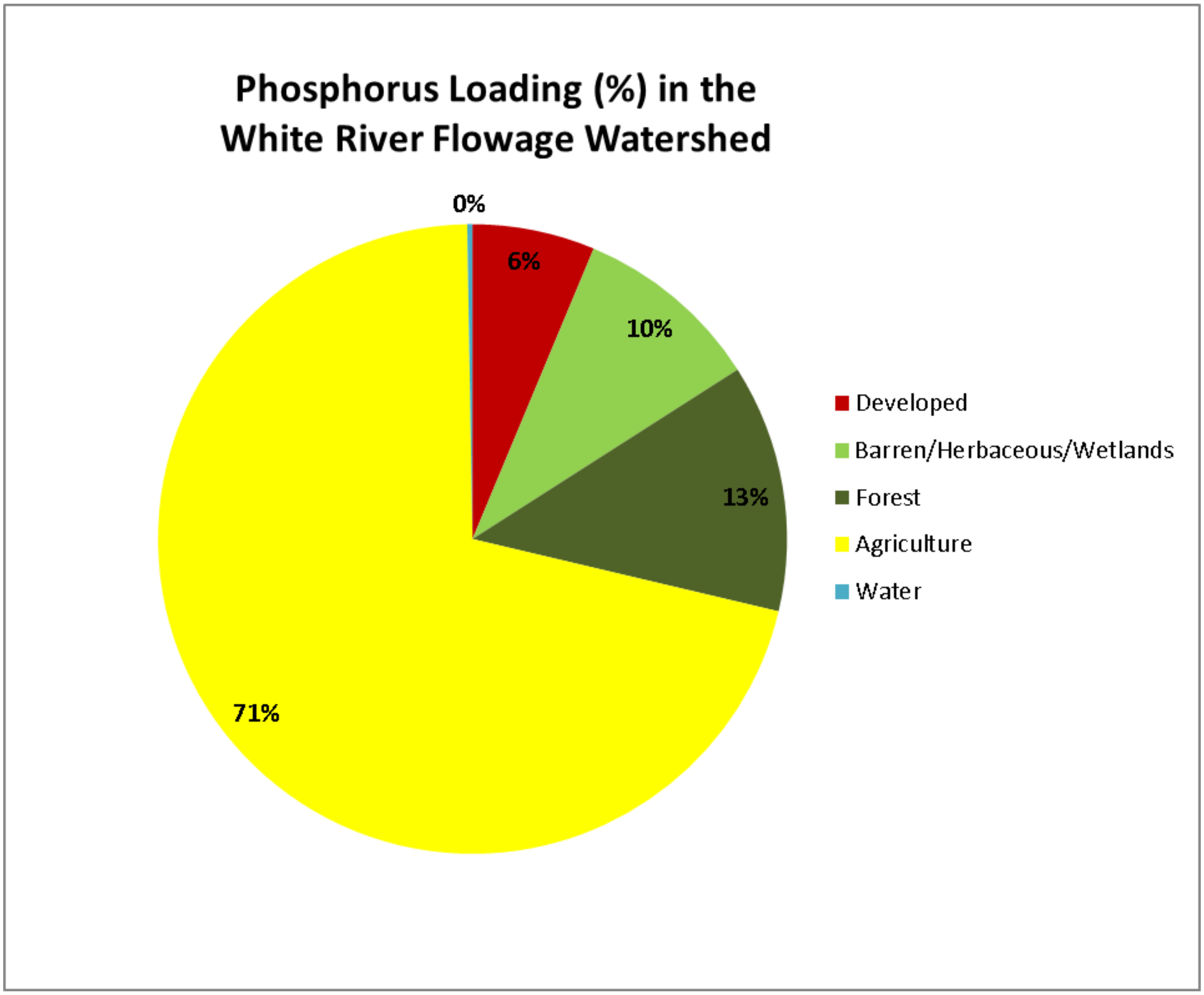


FIGURE 8. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE WHITE RIVER FLOWAGE WATERSHED.

TABLE 4. MODELING DATA USED TO ESTIMATE PHOSPHORUS INPUTS FROM LAND USES IN THE WHITE RIVER FLOWAGE WATERSHED (LOW AND MOST LIKELY COEFFICIENTS USED TO CALCULATE RANGE IN POUNDS).

White River Flowage Land Use	**Phosphorus Export Coefficient** (lbs/acre-yr)	**Land Use Area Within the Watershed**		**Phosphorus Load**	
		Acres	Percent	Pounds	Percent
Water	0.1	332	**1**	11-33	**0**
Developed	0.04	5853	**17**	261-522	**6**
Barren/Herbaceous/Wetland	0.09	4486	**13**	400-1202	**10**
Forest	0.04	11829	**35**	528-950	**13**
Cultivated Agriculture	0.45	11000	**33**	2944-7851	**71**

*Values are not exact due to rounding and conversion

(Based on contributions from Golden Sands Resource Conservation & Development Council, Inc., 2013.)

Aquatic plants play important roles in a lake's ecosystem. They provide habitat for the fishery and other aquatic organisms, stabilize the sediment, reduce erosion, buffer temperature changes and waves, and infuse oxygen into the water. Aquatic plants near shore provide food, shelter and nesting material for shoreland mammals, shorebirds and waterfowl. It is not unusual for otters, beavers, muskrats and deer to be seen along a shoreline in their search for food or nesting material. The aquatic plants that attract the animals to these areas contribute to the beauty of the shoreland and lake. The rapid and dominant growth of aquatic invasive plants, such as Eurasian watermilfoil (EWM), can reduce the recreational value of a lake. Aquatic invasive plants may also outcompete and cause a decline in native vegetation, which degrades habitat diversity and can alter the aquatic ecosystem.

An aquatic plant survey was conducted on the White River Flowage (Lower Pond) in August 2013 by staff from Golden Sands Resource Conservation & Development Council, Inc. Twenty-one species of aquatic plants were found, with an additional three species observed visually (Table 5). This is above average for lakes in the Waushara County Lakes Study. The greatest diversity of plants was found in the shallows of the Flowage, particularly at the lower end (Figure 9). Eighty-nine percent (179 of 201) of the sites visited had vegetative growth. The greatest depth at which aquatic plant growth was found was 16 feet.

The dominant plant species found in the White River Flowage was common waterweed (*Elodea canadensis*), followed by coontail (*Ceratophyllum demersum*) and water stargrass (*Heteranthera dubia*). Common waterweed is a food source for muskrats and waterfowl, and it also provides shelter and grazing opportunities for fish. Coontail also offers an important food source to a wide range of waterfowl species. A number of invertebrate and fish species use the bushy stems and stiff whorls of the leaves of the coontail as habitat, especially in the winter when other aquatic plants have died back. Much like the other two plants, water stargrass serves as an important food source for waterfowl and provides good cover and food opportunities (Borman et al., 2001).

The Floristic Quality Index (FQI) evaluates the closeness of a plant community to undisturbed conditions. Each plant is assigned a coefficient of conservatism value (C-value) that reflects its sensitivity to disturbance, and these numbers are used to calculate the FQI. C-values range from 0 to 10. The lower the number, the more tolerant the plant is of disturbance. A C-value of 0 was assigned to exotic species. Having more plants with low C-values than high C-values is an indicator of disturbance, as the lower C-value plants better tolerate stresses caused by disturbance. The FQI for the White River Flowage was 26.2, which was average for lakes in the Waushara County Lakes Study.

In the White River Flowage, C-values ranged from 0 to 8 (Table 5). The average C-value for the White River Flowage was above the statewide average for flowages. Five of the twenty-four species found in the White River Flowage (Lower Pond) had a C-value of 8, indicating good health in the aquatic plant community. The species with the highest frequency of occurrence within vegetated areas was common waterweed, with a C-value of 3. Two invasive aquatic plant species were present, EWM and curly-leaf pondweed (CLP); both species have a C-value of 0.

Invasive species are present in the White River Flowage. During the time of the survey, they were not overly dense, but were scattered throughout the Flowage. EWM can create dense beds that can damage boat motors, make areas non-navigable, stunt or alter the fishery, create problems with dissolved oxygen, and prevent activities like fishing and swimming. This plant can produce a viable seed; however, its primary mode of reproduction and spread is fragmentation. A one-inch fragment is enough to start a new plant, making EWM very successful at reproducing. CLP has a unique life cycle. It typically dies off in late June and can release phosphorus into the water. This phosphorus release can become problematic by influencing algae blooms. CLP starts growing under the ice in early spring before other plants, giving it a competitive advantage over native plant species.

The Simpson Diversity Index (SDI) quantifies biodiversity based on a formula that uses the number of species surveyed and the number of individuals per site. The SDI uses a decimal scale from 0 to 1. Values closer to one represent higher amounts of biodiversity. The SDI of the White River Flowage was 0.89, which was above average compared to other lakes in the Waushara County Lakes Study.

Aquatic plants play another critical role in the lake's ecosystem by using nutrients that would otherwise be available to algae. Any management activities should be planned to minimize the disturbance of native species in the water and on shore in order to maintain the balance between aquatic plants and algae. In addition, care should be taken to minimize raking the lakebed and pulling plants, since disturbing these valuable open spaces may allow invasive plants such as EWM to establish.

TABLE 5. LIST OF AQUATIC PLANTS IDENTIFIED IN THE 2013 SURVEY OF WHITE RIVER FLOWAGE (LOWER POND), 2013.

Scientific name	Common name	Sampled	Visuals	C-value
Bolboschoenus fluviatilis	River bulrush		x	6
Ceratophyllum demersum	Coontail	x	x	3
Chara spp.	Muskgrasses	x	x	7
Elodea canadensis	Common waterweed	x	x	3
Heteranthera dubia	Water stargrass	x	x	6
Lemna trisulca	Forked duckweed	x		6
Myriophyllum sibiricum	Northern watermilfoil	x	x	6
Myriophyllum spicatum	Eurasian watermilfoil	x	x	0
Najas guadalupensis	Southern naiad	x	x	8
Nymphaea odorata	White water lily	x	x	6
Polygonum amphibium	Amphibious smartweed	x	x	5
Potamogeton crispus	Curly-leaf pondweed	x	x	0
Potamogeton friesii	Fries' pondweed	x	x	8
Potamogeton natans	Floating-leaf pondweed	x	x	5
Potamogeton nodosus	Long-leaf pondweed	x		7
Potamogeton praelongus	White-stem pondweed	x	x	8
Potamogeton pusillus	Small pondweed	x		7
Potamogeton zosteriformis	Flat stem pondweed	x	x	6
Ranunculus aquatilis	White water crowfoot	x	x	8
Sparganium spp.	Bur-reeds		x	5
Stuckenia pectinata	Sago pondweed	x	x	3
Vallisneria americana	Water celery	x	x	6
Zizania spp.	Wild rice	x	x	8
	Freshwater sponges	x	x	-
	Filamentous algae	x		-

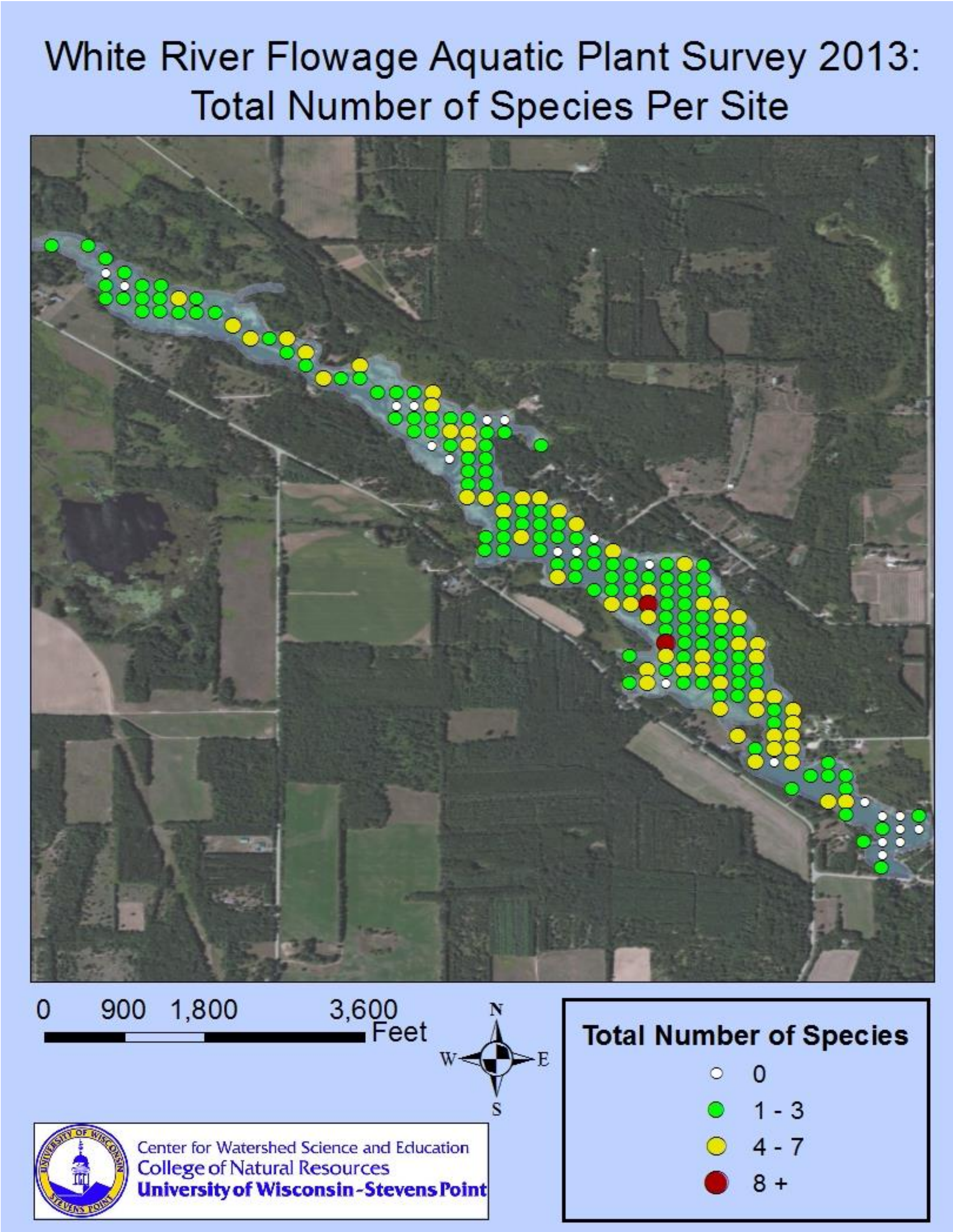


FIGURE 9. NUMBER OF AQUATIC PLANT SPECIES OBSERVED AT EACH SURVEY SITE IN THE WHITE RIVER FLOWAGE, AUGUST 2013.

Shoreland vegetation is critical to a healthy lake's ecosystem. It provides habitat for many aquatic and terrestrial animals including birds, frogs, turtles, and many small and large mammals. It also helps to improve the quality of the runoff that is flowing across the landscape towards the lake. Healthy shoreland vegetation includes a mix of tall grasses/flowers, shrubs and trees which extend at least 35 feet landward from the water's edge.

To better understand the health of the Waushara County lakes, shorelands were evaluated by professionals from the Center for Land Use Education and Waushara County as a part of the Waushara County Lakes Study. The survey inventoried the type and extent of shoreland vegetation. Areas with erosion, rip-rap, barren ground, sea walls, structures and docks were also inventoried.

A scoring system was developed for the collected data to provide a more holistic assessment. Areas that are healthy will need strategies to keep them healthy, and areas with potential problem areas and where management and conservation may be warranted may need a different set of strategies for improvement. The scoring system is based on the presence/absence and abundance of shoreline features, as well as their proximity to the water's edge. Values were tallied for each shoreline category and then summed to produce an overall score. Higher scores denote healthier shorelines with good land management practices. These are areas where protection and/or conservation should be targeted. On the other hand, lower scores signify ecologically unhealthy shorelines. These are areas where management and/or mitigation practices may be desirable for improving water quality.

The summary of scores for shorelands around White River Flowage is displayed in Figure 10. The shorelands were color-coded to show their overall health based on natural and physical characteristics. Blue shorelands identify healthy shorelands with sufficient vegetation and few human disturbances. Red shorelands indicate locations where changes in management or mitigation may be warranted. Large stretches of White River Flowage's shorelands are in good shape, but some sections have challenges that could be addressed. No White River Flowage shorelands ranked as poor. A summary of shoreland disturbances within 15 feet of the water is displayed in Table 6. For a more complete understanding of the ranking, an interactive map showing results of the shoreland surveys can be found on the Waushara County's website at http://gis.co.waushara.wi.us/ShorelineViewer/.

TABLE 6. DISTURBANCES WITHIN 15 FEET OF SHORE AROUND WHITE RIVER FLOWAGE, 2011. SOME AREAS OF DISTURBANCE OVERLAP. CLOSE TO 2/3 OF THE SHORELINE IS UNDISTURBED.

Disturbance	**Length of Shoreline**	
	Feet	Percent
Artificial beach	0	0
Barren, bare dirt	0	0
Boat landing	459	1
Gully erosion	45	<1
Undercut banks erosion	0	0
Mowed lawn	4,988	16
Rip-rap	2,836	9
Seawall	908	3

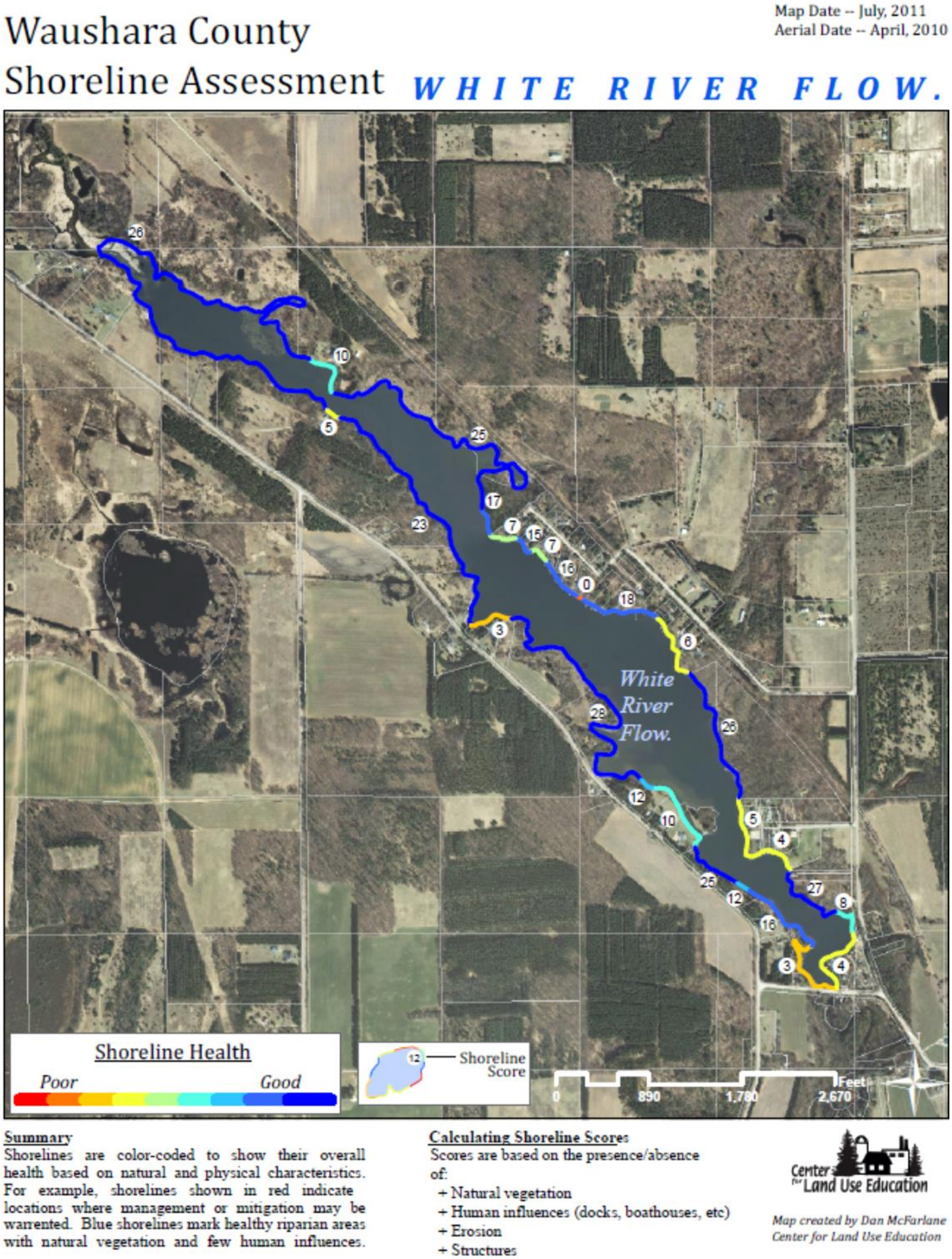


FIGURE 10. OVERALL SHORELAND HEALTH AROUND WHITE RIVER FLOWAGE, 2011.

CONCLUSIONS & RECOMMENDATIONS

The water quality in the White River Flowage showed both good measurements and measurements of concern. The dissolved oxygen concentrations were sufficient throughout the year to support a wide range of fish and other aquatic species. The White River Flowage contains calcium-rich (hard) water which provides calcium for the production of bones and shells and can help to reduce the impacts of phosphorus. Atrazine (an herbicide) was not measured in water samples collected from the White River Flowage.

The White River Flowage had slightly elevated chloride, potassium and sodium concentrations. These concentrations are not harmful to aquatic organisms, but indicate pollutants are entering the lake. Sources of chloride and sodium include animal waste, septic systems, fertilizer, and road-salting chemicals. Sources of potassium include animal waste, septic systems, and some fertilizers.

In general, each type of land use contributes different amounts of phosphorus, nitrogen and pollutants in runoff and through groundwater. The types of land management practices that are used and their distances from the lake affect the contributions to the lake from a parcel of land.

- Identifying and taking steps to maintain or improve water quality in White River Flowage depends upon understanding the sources of nutrients to the lake and identifying those that are manageable. Based on modeling results, agriculture had the greatest percentages of phosphorus contributions from the watershed to White River Flowage.
- During the study, the summer median total phosphorus concentrations were 24 and 13 ug/L in 2011 and 2012, respectively. This is below Wisconsin's phosphorus standard of 40 ug/L for shallow impoundments.
- Inorganic nitrogen was elevated in all samples collected from the White River Flowage. Concentrations of 0.3 mg/L inorganic nitrogen in spring are sufficient to fuel algal blooms throughout the summer. Sources of inorganic nitrogen include animal waste, septic systems, and fertilizers. The nitrate is likely moving to the flowage in groundwater.
    - Water users around and upgradient of the flowage should consider having the water from their private wells tested to determine if they exceed the health standards for drinking water.
    - In a flowage, nitrate can be readily used by aquatic plants and some types of algae, increasing their growth.
- Over-application of chemicals and nutrients should be avoided. Landowners in the watershed should be aware of their connections to the lake and should consider working to reduce their impacts through the implementation of water quality-based best management practices.
- Routine monitoring of water quality can help track changes in the White River Flowage. Consider designing and carrying out a monitoring plan.

  Shoreland health is critical to a healthy lake's ecosystem. The shoreland of the White River Flowage was assessed for the extent of vegetation and disturbances. Shoreland vegetation provides habitat for many aquatic and terrestrial animals, including birds, frogs, turtles, and many small and large mammals. Vegetation also helps to improve the quality of the runoff that is flowing across the landscape towards the lake. Healthy shoreland vegetation includes a mix of tall grasses/flowers, shrubs and trees extending at least 35 feet inland from the water's edge. Alone, each manmade disturbance may not pose a problem for a lake, but on developed lakes, the collective impact of these disturbances can be a problem for lake habitat and water quality.

- Large stretches of White River Flowage's shorelands are in good shape, but some sections have challenges that should be addressed.
    - Structures such as seawalls, rip-rap (rocked shoreline), and artificial beach can result in habitat loss.
    - Erosion can contribute sediment to the lake, altering spawning habitat and carrying nutrients into the lake.
    - Unmanaged runoff from rooftops of structures located near shore can also contribute sediment to the lake.
    - Docks and artificial beaches can result in altered in-lake habitat. Denuded lakebeds provide opportunities for invasive species to become established, reducing the habitat important to fish and other lake inhabitants.
- Consider the development of strategies to ensure that healthy shorelands remain intact and efforts may be needed to improve shorelands that have disturbances. Depending upon the source of the disturbances, erosion may need to be controlled, vegetation might need to be restored, and/or excess runoff should be minimized.
- Dissemination of relevant information to property owners is the recommended first step towards maintaining healthy shorelands.
- The Waushara County Land Conservation Department and Natural Resources Conservation Service (NRCS) have professional staff available to assist landowners interested in learning how they can improve water quality through changes in land management practices.

Aquatic plants are the forested landscape within a lake. They provide food and habitat for a wide range of species including fish, waterfowl, turtles, and amphibians, as well as invertebrates and other aquatic animals. They improve water quality by releasing oxygen into the water and utilizing nutrients that would otherwise be used by algae. A healthy lake typically has a variety of aquatic plant species creating the diversity needed to make the aquatic plant community more resilient and help prevent the establishment of non-native aquatic species.

- The diversity of an aquatic plant community is defined by the type and number of species present throughout the lake. Twenty-one species of aquatic plants were found in the White River Flowage, with an additional three species observed visually. This is above average for the lakes in the Waushara County Lakes Study.
- The species diversity index of the White River Flowage was 0.89, also above average compared to other lakes in the Waushara County Lakes Study.
- Two species of aquatic invasive plants exist in the White River Flowage, Eurasian watermilfoil (EWM) and curly leaf pondweed (CLP).
    - EWM can create dense beds that can damage boat motors, make areas non-navigable, stunt or alter the fishery, create problems with dissolved oxygen, and prevent activities like fishing and swimming.
    - EWM can produce a viable seed; however, its primary mode of reproduction and spread is fragmentation. A one-inch fragment is enough to start a new plant, making EWM very successful at reproducing.
    - CLP has a unique life cycle, typically growing early in the season, dying off in late June and releasing phosphorus into the water from its tissue. This phosphorus release can become problematic by enhancing algal blooms throughout the balance of the summer.
    - Continue reducing the populations of invasive aquatic plants in the White River Flowage.

- The amount of disturbed lakebed from raking or pulling plants should be minimized, since these denuded spaces are “open real estate” for aquatic invasive plants to establish.
- Early detection of new aquatic invasive species (AIS) can help to prevent their establishment should they be introduced into the lake. Boats and trailers that have visited other lakes can be a primary vector for the transport of AIS.
- Programs are available to help volunteers learn to monitor for AIS and to educate lake users at the boat launch about how they can prevent the spread of AIS.

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GLOSSARY OF TERMS

Algae: One-celled (phytoplankton) or multicellular plants either suspended in water (plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll a (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Numerous species occur. Algae are an essential part of the lake ecosystem and provide the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short.

Atrazine: A commonly used herbicide. Transports to lakes and rivers by groundwater or runoff. Has been shown to have toxic effects on amphibians.

Blue-Green Algae: Algae that are often associated with problem blooms in lakes. Some produce chemicals toxic to other organisms, including humans. They often form floating scum as they die. Many can fix nitrogen (N2) from the air to provide their own nutrient.

Calcium (Ca++): The most abundant cation found in Wisconsin lakes. Its abundance is related to the presence of calcium-bearing minerals in the lake watershed. Reported as milligrams per liter (mg/1) as calcium carbonate (CaCO3), or milligrams per liter as calcium ion (Ca++).

Chloride (Cl-): The chloride ion (Cl-) in lake water is commonly considered an indicator of human activity. Agricultural chemicals, human and animal wastes, and road salt are the major sources of chloride in lake water.

Chlorophyll *a*: Green pigment present in all plant life and necessary for photosynthesis. The amount present in lake water depends on the amount of algae, and is therefore used as a common indicator of algae and water quality.

Clarity: See "Secchi disk."

Color: Color affects light penetration and therefore the depth at which plants can grow. A yellow-brown natural color is associated with lakes or rivers receiving wetland drainage. Measured in color units that relate to a standard. The average color value for Wisconsin lakes is 39 units, with the color of state lakes ranging from zero to 320 units.

Concentration units: Express the amount of a chemical dissolved in water. The most common ways chemical data is expressed is in milligrams per liter (mg/l) and micrograms per liter (ug/l). One milligram per liter is equal to one part per million (ppm). To convert micrograms per liter (ug/l) to milligrams per liter (mg/l), divide by 1000 (e.g. 30 ug/l = 0.03 mg/1). To convert milligrams per liter (mg/l) to micrograms per liter (ug/l), multiply by 1000 (e.g. 0.5 mg/l = 500 ug/l).

Cyanobacteria: See "Blue-Green Algae."

Dissolved oxygen: The amount of oxygen dissolved or carried in the water. Essential for a healthy aquatic ecosystem in Wisconsin lakes.

Drainage basin: The total land area that drains runoff towards a lake.

Drainage lakes: Lakes fed primarily by streams and with outlets into streams or rivers. They are more subject to surface runoff problems, but generally have shorter residence times than seepage lakes.

Emergent: A plant rooted in shallow water and having most of its vegetative growth above water.

Eutrophication: The process by which lakes and streams are enriched by nutrients, and the resulting increase in plant and algae. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Groundwater drainage lake: Often referred to as a spring-fed lake, it has large amounts of groundwater as its source and a surface outlet. Areas of high groundwater inflow may be visible as springs or sand boils. Groundwater drainage lakes often have intermediate retention times with water quality dependent on groundwater quality.

Hardness: The quantity of multivalent cations (cations with more than one +), primarily calcium (Ca++) and magnesium (Mg++) in the water expressed as milligrams per liter of CaCO3. Amount of hardness relates to the presence of soluble minerals, especially limestone or dolomite, in the lake watershed.

Intermittent: Coming and going at intervals, not continuous.

Macrophytes: See "Rooted aquatic plants."

Marl: White to gray accumulation on lake bottoms caused by precipitation of calcium carbonate (CaCO3) in hard water lakes. Marl may contain many snail and clam shells. While it gradually fills in lakes, marl also precipitates phosphorus, resulting in low algae populations and good water clarity. In the past, marl was recovered and used to lime agricultural fields.

Mesotrophic: A lake with an intermediate level of productivity. Commonly clear water lakes and ponds with beds of submerged aquatic plants and mediums levels of nutrients. See also "eutrophication".

Nitrate (NO3-): An inorganic form of nitrogen important for plant growth. Nitrate often contaminates groundwater when water originates from manure, fertilized fields, lawns or septic systems. In drinking water, high levels (over 10 mg/L) are dangerous to infants and expectant mothers. A concentration of nitrate-nitrogen (NO3-N) plus ammonium-nitrogen (NH4-N) of 0.3 mg/L in spring will support summer algae blooms if enough phosphorus is present.

Oligotrophic: Lakes with low productivity, the result of low nutrients. Often these lakes have very clear waters with lots of oxygen and little vegetative growth. See also "eutrophication".

Overturn: Fall cooling and spring warming of surface water increases density, and gradually makes lake temperatures and density uniform from top to bottom. This allows wind and wave action to mix the entire lake. Mixing allows bottom waters to contact the atmosphere, raising the water's oxygen content. Common in many lakes in Wisconsin.

Phosphorus: Key nutrient influencing plant growth in more than 80% of Wisconsin lakes. Soluble reactive phosphorus is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

Rooted aquatic plants (macrophytes): Refers to higher (multi-celled) plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects and provide food for many aquatic and terrestrial animals. Overabundance of such plants, especially problem species, is related to shallow water depth and high nutrient levels.

Secchi disk: An 8-inch diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration).

Sedimentation: Materials that are deposited after settling out of the water.

Stratification: The layering of water due to differences in density. As water warms during the summer, it remains near the surface while colder water remains near the bottom. Wind mixing determines the thickness of the warm surface water layer (epilimnion), which usually extends to a depth of about 20 feet. The narrow transition zone between the epilimnion and cold bottom water (hypolimnion) is called the metalimnion. Common in many deeper lakes in Wisconsin.

Watershed: See "Drainage basin."