Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids Upper Fox and Wolf Basins

Final U.S. EPA approved Report

02/27/2020

Including Forest, Langlade, Menominee, Shawano, Outagamie, Waupaca, Winnebago, Waushara, Calumet, Fond Du Lac, Green Lake, Marquette, Columbia, Adams, Dodge, and Portage Counties, Wisconsin

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303(d) List	List of Impaired Waters
AM	Wisconsin’s Watershed Adaptive Management Option
BMPs	Best Management Practices
CAFO	Concentrated Animal Feeding Operation
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
DATCP	Department of Agriculture, Trade, and Consumer Protection
DO	Dissolved Oxygen
FAL	Fish and Aquatic Life
FSA	Farm Service Agency
LA	Load Allocation
LAL	Limited Aquatic Life
LCD	Land Conservation Department
LFF	Limited Forage Fish
LWRM	Land and Water Resources Management
mL	Milliliters
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NCCW	Noncontact Cooling Water
NOD	Notice of Discharge
NPS Program	Nonpoint Source Pollution Abatement Program
NRCS	Natural Resources Conservation Service

PI	Phosphorus Index
POTW	Publicly Owned Treatment Works
RC	Reserve Capacity
WinSLAMM	Source Loading and Management Model
SWAT	Soil and Water Assessment Tool
TBEL	Technology-Based Effluent Limit
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TRM	Targeted Runoff Management
TSS	Total Suspended Solids
EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WDNR	Wisconsin Department of Natural Resources
WisCALM	Wisconsin Consolidated Assessment and Listing Methodology
WisDOT	Wisconsin Department of Transportation
WLA	Wasteload Allocation
WPDES	Wisconsin Pollutant Discharge Elimination System
WQBEL	Water Quality-Based Effluent Limit
WQT	Water Quality Trading
WVIC	Wisconsin Valley Improvement Company
WWSF	Warm Water Sport Fish
WWTF	Wastewater Treatment Facility

1 INTRODUCTION

1.1 Background

Section 303(d) of the Federal Clean Water Act (CWA) requires US states to identify waters within their boundaries that are not meeting state water quality standards. For these impaired waterbodies, Section 303(d) further requires EPA and states to develop a Total Maximum Daily Load (TMDL) for the pollutant(s) violating or causing violation of water quality standards. A TMDL defines the loading capacity which is the maximum amount of the pollutant that a waterbody can assimilate while continuing to meet water quality standards. A TMDL also allocates the maximum allowable pollutant load between point and nonpoint sources of the pollutant.

A TMDL provides a framework for EPA, states, and partner organizations to establish and implement pollution control and management plans, with the ultimate goal described in Section 101(a)(2) of the CWA: “water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable.”

This report presents TMDLs for total phosphorus (TP) and sediment (as Total Suspended Solids, TSS) for surface waters in the Upper Fox and Wolf Basins in Wisconsin. This TMDL is designed to both address impaired waters that are not meeting water quality standards and to protect waters from being listed as impaired by having the loading capacity meet water quality standards for both listed and unlisted waters.

1.2 Problem Statement

The Upper Fox and Wolf Basins (UFWB) are located in east-central Wisconsin (Figure 1). Surface waters in the UFWB are impaired by excessive phosphorus and sediment loading, which leads to nuisance algae growth, oxygen depletion, fish kills, reduced submerged aquatic vegetation, water clarity problems, and degraded habitat. These impairments adversely affect fish and aquatic life, drinking water supplies, recreation, and potentially navigation.

Although phosphorus is an essential nutrient for plant growth, excess phosphorus is a concern for most aquatic ecosystems. Under natural conditions where human activities do not dominate the landscape, phosphorus is generally in short supply and is a limiting factor for aquatic plant growth. As more phosphorus enters a waterbody, it acts to fertilize the aquatic system, allowing for more plant and algae growth. This condition of nutrient enrichment and high plant productivity is referred to as eutrophication. Eutrophication can alter the ecology of the waterbody and degrade the services it provides, including swimming, fishing, and other recreational uses, and supplies of clean drinking water.

A bloom of aquatic plants may also include cyanobacteria, also referred to as blue-green algae, which are harmful to fish and pose health risks to humans. Concerns associated with blue-green algae include discolored water, reduced light penetration, taste and odor problems, dissolved oxygen depletions during die-off, and toxin production. Algal blooms, and particularly surface scums that form, are unsightly and can have unpleasant odors. This makes recreational use of the waterbody unpleasant and poses a problem for people who live close to the affected waterbody. Further, when the large masses of aquatic plants die, their decomposition depletes levels of dissolved oxygen in the water, suffocating fish and other aquatic life. Depending on the severity of the low dissolved oxygen event, large fish kills can occur. Nearly all of these effects have economic impacts on local communities as well as state and federal governments.

The UFWB is also subject to excess sediment loading to surface waters. Excess sediment in streams, rivers, and lakes scatters and absorbs sunlight, reducing the amount of light available to submerged aquatic vegetation for growth and potentially increasing water temperature. The loss of submerged aquatic plants is problematic because within an aquatic ecosystem they act to release dissolved oxygen, provide food and habitat for fish and other aquatic life, stabilize bottom sediments, protect shorelines from erosion, and utilize nutrients that would otherwise be available for nuisance algae growth.

Reduced water clarity also interferes with the ability of fish and waterfowl to see and catch food. Suspended sediments can also clog fish and invertebrate gills and cause respiratory stress. Prolonged periods of very high sediment concentrations can be fatal to aquatic organisms (Newcombe and Jensen, 1996). When sediments settle to the bottom of river and lakes, they can smother the eggs of fish and aquatic insects, suffocate newly hatched insect larvae, and reduce dissolved oxygen concentrations in stream bottom substrates. Settling sediments can also fill in spaces between rocks, reducing the amount of sheltered habitat available to aquatic organisms.

Sediment is also a concern because of its ability to transport phosphorus to a waterbody. Total phosphorus consists of both dissolved phosphorus, which is mostly orthophosphate, and particulate phosphorus, including both inorganic and organic forms (Sharpley et al. 1994). Within the surface soil layer, inorganic phosphorus is typically bound tightly to soil particles. When these soil particles erode, the attached phosphorus is also carried into nearby waterbodies.

Over the last 20 years, the Wisconsin Department of Natural Resources (WDNR) has placed numerous waters in the UFWB on the state’s 303(d) Impaired Waters List and has ranked the waters as high priority for the development of TMDLs to address the impairments caused by excess phosphorus and sediment loading. The complete 2018 list of impaired waters and impairments addressed in this TMDL report is displayed in Table 1 and mapped in Figure 1. This list includes 43 stream and river assessment units impaired for excess phosphorus, 19 stream and river assessment units impaired for excess sediment, and 19 lakes and reservoirs impaired for excess phosphorus. Table 1 includes two numeric identifiers used by WDNR for surface water inventory and assessment: the waterbody identification code (WBIC) and the assessment unit identification code (WATERS ID). The impairment indicators listed in Table 1 are defined below:

- Water Use Restrictions. Sampled TP exceeds numeric criteria defined in water quality standards by at least 2 times for rivers and streams and 1.5 times for lakes and reservoirs;
- Eutrophication. Sampled chlorophyll-a values exceed threshold values used by WDNR for assessment of Fish and Aquatic Life Use attainment;
- Excess Algal Growth. Sampled chlorophyll-a values exceed threshold values used by WDNR for assessment of Recreation Use attainment;
- Degraded Biological Community: Fish or macroinvertebrate populations are in poor condition based on biological sample data;
- Degraded Habitat. Presence of physical degradation of aquatic habitat, such as excessive sedimentation or highly turbid water;
- Low Dissolved Oxygen (DO). Sampled dissolved oxygen is below numeric criteria defined in water quality standards;
- Elevated pH. Sampled pH is outside the range of numeric criteria defined in water quality standards;
- Elevated Water Temperature. Sampled temperature in the waterbody exceeds numeric criteria defined in water quality standards;
- Impairment Unknown: Sampled TP exceeds numeric criteria defined in water quality standards but no biological impairment is evident in biological sample data.

All of the impairments shown in Table 1 (with the exception of two impairments noted below) have TP and/or TSS identified as the pollutant causing impairment on the 2018 303(d) Impaired Waters List. TP and TSS are therefore the focus of the TMDLs presented in this report. The 2018 303(d) Impaired Waters List includes additional impairments for waters in the UFWB that are caused by other pollutants, including polycyclic aromatic hydrocarbon (PAHs), polychlorinated biphenyl (PCBs), mercury, E. coli, lead, and other metals. These impairments are not shown in Table 1 because they are not addressed by the TMDLs presented in this report and may instead be addressed under separate WDNR TMDL program efforts.

The impairments for Long Lake and Swan Lake are due to excess algal growth but have "Unknown" noted as the pollutant causing impairment on the 2018 303(d) Impaired Waters List (Table 1). This indicates that chlorophyll-a levels exceed the threshold used by WDNR for assessment of Recreation Use attainment but that TP sample results did not meet conditions for listing TP as the pollutant causing impairment.

Six lakes addressed in this report have both TP and TSS identified as the cause of impairment on the 2018 303(d) Impaired Waters List (Lake Butte des Morts, Lake Winnebago, Park Lake, Lake Poygan, Lake Puckaway, and Lake Winneconne; Table 1). This study does not address the lake TSS listings by explicitly defining numeric TSS concentration targets and associated allowable loads for the lakes. Instead, the lake TSS listings are addressed through the development of TP TMDLs for the impaired lakes and TSS TMDLs for tributary streams and rivers. A clear link exists between excess TP loading and elevated TSS concentrations in lakes due to high algae growth in the water column. Further, many of the same sources of phosphorus to lakes are also associated with high TSS loads, such as erosion of phosphorus-rich sediment from the land surface, stream channel erosion, and resuspension of lake bottom sediments due to wind and wave action. Reductions in lake TSS concentrations are expected to occur with the implementation of the TMDLs presented in this report. Monitoring and analysis of lake TSS following TMDL implementation will indicate whether these reductions are sufficiently addressing the lake TSS impairments or whether additional TSS reductions are needed. See Section 2.5.2 and Section 5.2.2 for more information on the lake TSS listings and approach to TMDL development.

1.3 Watershed Framework

The TMDLs presented in this report were developed using a watershed framework. Under a watershed framework, TMDLs are simultaneously completed for multiple water bodies in a watershed. For this effort, the entire UFWB was divided into 89 subbasins based on natural drainage areas, and individual TMDLs are developed for all 89 subbasins. Throughout this report, the 89 subbasins are referred to as "TMDL subbasins". The following factors were used to divide the UFWB into TMDL subbasins:

- The location of impaired waters on the Wisconsin 2018 303(d) Impaired Waters List;
- The location of facility outfalls individually permitted to discharge wastewater to surface waters through the Wisconsin Pollutant Discharge Elimination System (WPDES);
- Wisconsin water quality standards;
- Land use patterns; and
- Hydrologic/streamflow regimes.

The 89 TMDL subbasins are listed in Table 2 and mapped in Figure 2. The drainage boundaries of TMDL subbasins were geographically delineated as part of watershed modeling using topographic data acquired from the US Geological Survey (USGS; a 10-meter resolution digital elevation model). For the UFWB watershed model (described in Appendix C), a total of 218 subwatersheds were delineated. These model subwatersheds were aggregated to define drainage boundaries for the 89 TMDL subbasins.

Each of these subbasins, approximately the size of a 12-digit federal hydrologic unit code (HUC-12) watershed, has an allocated load for phosphorus based on the phosphorus criteria for the waterbodies in that subbasin and to address more stringent downstream water quality criteria. The delineation of these subbasins often directly corresponds with the spatial extent of impaired river and stream segments or the contributory drainage areas of impaired lakes; however, subbasins were also delineated for waterbodies not listed as impaired. Thus, allocations were assigned to subbasins with listed and unlisted waterbodies. The resulting system of subbasin allocations provide protection ensuring that allocated loads meet promulgated water quality criteria for all waterbodies within the subbasin as well as downstream waterbodies. If future monitoring determines that additional river or stream segments within a subbasin are impaired, these impaired segments can be added to Wisconsin's future 303(d) Impaired Waters Lists under Category 5B: impaired waters with an approved TMDL or restoration plan.

A crosswalk between the impairment listings addressed by this TMDL and the TMDL subbasins is provided in the "TMDL Subbasin" column of Table 1.

Table 1. Waterbodies and impairment listings on the WDNR 2018 303(d) list addressed in this TMDL report. Note: TP criterion vary by waterbody classification and are summarized in Table3.

Waterbody Name	WATERS ID	WBIC	County	Start Mile	End Mile	Source Category	Impairment Indicator(s)	Pollutant(s)	TP Criterion (µg/L)	Basin	TMDL Subbasin
Anderson Creek	10987	133300	Fond du Lac	0	7	NPS	Degraded Habitat	TSS	75	Upper Fox	33
						PS/NPS	Degraded Biological Community	TP			
Bear Creek	10414	292100	Outagamie, Waupaca	8	12	NPS	Degraded Habitat	TSS	75	Wolf	64
						PS/NPS	Degraded Biological Community	TP			
Bear Creek	9791	316000	Outagamie	1	2	PS/NPS	Water Quality Use Restrictions	TP	75	Wolf	52
Bear Creek	9792	316000	Outagamie	2	8	NPS	Water Quality Use Restrictions	TP	75	Wolf	52
Big Twin Lake	11025	146500	Green Lake	-	-	NPS	Excess Algal Growth	TP	30	Upper Fox	83
Black Creek	337866	317100	Outagamie, Shawano	16	28	PS/NPS	Degraded Biological Community	TP	75	Wolf	89
Black Otter Lake (Hortonville)	9789	315600	Outagamie	-	-	PS/NPS	Water Quality Use Restrictions	TP	40	Wolf	82
Byron Creek	1452243	137400	Fond du Lac	0	2	NPS	Degraded Habitat	TSS	75	Upper Fox	37
							Water Quality Use Restrictions	TP			
Byron Creek	10995	137400	Fond du Lac	2	7	NPS	Low DO, Elevated Water Temperature, Degraded Habitat	TSS	75	Upper Fox	37
							Impairment Unknown	TP			
Carpenter Creek	10784	248800	Waushara	0	6	NPS	Degraded Habitat	TSS	75	Wolf	45
Collins (Fish) Lake	10319	270200	Portage	-	-	NPS	Excess Algal Growth	TP	20	Wolf	65
Deneveu Creek	10982	138700	Fond du Lac	0	11	PS/NPS	Impairment Unknown	TP	75	Upper Fox	75
Deneveu Creek	10983	138700	Fond du Lac	11	12	NPS	Degraded Habitat	TSS	75	Upper Fox	38
East Branch Fond du Lac River	10991	135900	Fond du Lac	0	15	NPS	Impairment Unknown	TP	75	Upper Fox	43
East Trib. to Parsons Creek	903785	136200	Fond du Lac	0	2	NPS	Degraded Habitat	TSS	75	Upper Fox	40
Fond du Lac River	10989	133700	Fond du Lac	0	2	NPS	Water Quality Use Restrictions	TP	75	Upper Fox	88
Grand River	11097	159300	Green Lake, Marquette	0	21	PS/NPS	Impairment Unknown	TP	75	Upper Fox	14, 15
Grand River	10702	159300	Green Lake, Marquette, Fond du Lac	21	43	PS/NPS	Impairment Unknown	TP	75	Upper Fox	12
Green Lake (Big Green)	11023	146100	Green Lake	-	-	NPS	Low DO	TP	15	Upper Fox	20
Harrington Creek	11016	143700	Green Lake	0	3	NPS	Degraded Habitat	TSS	75	Upper Fox	26
Hill Creek	11024	146200	Green Lake	0	2	NPS	Degraded Habitat	TSS	75	Upper Fox	79

Waterbody Name	WATERS ID	WBIC	County	Start Mile	End Mile	Source Category	Impairment Indicator(s)	Pollutant(s)	TP Criterion (µg/L)	Basin	TMDL Subbasin
						PS/NPS	Degraded Biological Community	TP			
Kroenke Creek	11107	326700	Shawano	5	9	PS/NPS	Degraded Biological Community	TP	75	Wolf	55
Lake Butte des Morts	11004	139900	Winnebago	-	-	NPS	Low DO, Eutrophication, Excess Algal Growth	TP	40	Upper Fox	73
							Eutrophication	TSS			
Lake Emily	1525397	161600	Dodge	-	-	NPS	Excess Algal Growth	TP	40	Upper Fox	84
Lake Winnebago	358400	131100	Calumet, Winnebago, Fond du Lac	-	-	NPS	Low DO, Eutrophication, Water Quality Use Restrictions, Excess Algal Growth	TP	40	Upper Fox	75
							Turbidity	TSS			
Little Green Lake	18120	162500	Green Lake	-	-	NPS	Low DO, Eutrophication, Water Quality Use Restrictions, Degraded Habitat, Elevated pH	TP	40	Upper Fox	11
Long Lake	9816	321300	Shawano	-	-	NPS	Excess Algal Growth	Unknown	30	Wolf	57
Mason Lake	10733	175700	Adams, Marquette	-	-	NPS	Excess Algal Growth, Elevated pH	TP	40	Upper Fox	3
Mosher Creek	18156	133500	Fond du Lac	0	3	NPS	Degraded Habitat	TSS	75	Upper Fox	34
							Degraded Biological Community	TP			
Mud Creek	10259	131600	Calumet	0	3	NPS	Degraded Biological Community	TP	75	Upper Fox	46
North Tributary to Silver Creek	936838	147400	Fond du Lac	0	4	NPS	Impairment Unknown	TP	75	Upper Fox	87
Old Taylor Lake	10274	195000	Waupaca	-	-	NPS	Water Quality Use Restrictions	TP	20	Wolf	85
Park Lake	18131	180300	Columbia	-	-	NPS	Excess Algal Growth	TP	40	Upper Fox	5
							Eutrophication	TSS			
Parsons Creek	18157	136000	Fond du Lac	0	3	PS/NPS	Degraded Habitat	TP	75	Upper Fox	42
							Degraded Habitat	TSS			
Pigeon River	9711	293100	Waupaca	0	11	PS/NPS	Impairment Unknown	TP	75	Wolf	60
Post Lake, Upper	10650	399200	Langlade, Oneida	-	-	NPS	Excess Algal Growth	TP	40	Wolf	77
Poygan Lake	18137	242800	Waushara, Winnebago	-	-	NPS	Water Quality Use Restrictions, Excess Algal Growth	TP	40	Wolf	72
							Degraded Habitat, Turbidity	TSS			
Puckaway Lake	11081	158700	Green Lake, Marquette	-	-	NPS	Eutrophication, Water Quality Use Restrictions, Excess Algal Growth	TP	40	Upper Fox	16

Waterbody Name	WATERS ID	WBIC	County	Start Mile	End Mile	Source Category	Impairment Indicator(s)	Pollutant(s)	TP Criterion (µg/L)	Basin	TMDL Subbasin
							Degraded Habitat	TSS			
Pumpkinseed Creek	10766	243300	Waushara, Winnebago	0	3	NPS	Degraded Biological Community	TP	75	Wolf	72
Pumpkinseed Creek	10767	243300	Waushara, Winnebago	3	6	NPS	Degraded Biological Community	TP	75	Wolf	72
Rat River	10752	251800	Outagamie, Winnebago	13	25	NPS	Low DO	TP	75	Wolf	50
Rat River	18133	251800	Winnebago	0	13	NPS	Low DO	TP	75	Wolf	50
Roy Creek	11030	148200	Green Lake	0	7	NPS	Degraded Habitat	TSS	75	Upper Fox	17
						NPS	Impairment Unknown	TP			
Schoenick Creek	5513424	321000	Shawano	4	8	PS/NPS	Degraded Biological Community	TP	75	Wolf	57
Schoenick Creek	5513393	321000	Shawano	4	4	PS/NPS	Impairment Unknown	TP	75	Wolf	67
School Section Lake[1]	10346	283600	Waupaca	-	-	NPS	Excess Algal Growth	TP	30	Wolf	62
Sevenmile Creek	10994	136800	Fond du Lac	0	11	NPS	Water Quality Use Restrictions;	TP	75	Upper Fox	36
							Degraded Habitat	TSS			
Shawano Lake	9825	322800	Shawano	-	-	PS/NPS	Excess Algal Growth	TP	40	Wolf	56
Shioc River	9800	316800	Outagamie, Shawano	0	28	NPS	Water Quality Use Restrictions	TP	75	Wolf	53
Silver Creek	11028	146800	Green Lake, Fond du Lac	1	12	PS/NPS	Elevated Water Temperature, Degraded Habitat	TSS	75	Upper Fox	19, 87
							Impairment Unknown	TP			
Silver Creek	359092	146800	Fond du Lac	12	14	PS/NPS	Elevated Water Temperature, Degraded Habitat	TSS	75	Upper Fox	87
Spring Brook	11005	140300	Winnebago	0	2	NPS	Water Quality Use Restrictions	TP	75	Upper Fox	31
Spring Lake	10311	267200	Portage	-	-	PS/NPS	Impairment Unknown	TP	15	Wolf	86
Swan Lake	10744	179800	Columbia	-	-	NPS	Excess Algal Growth	Unknown	30	Upper Fox	6
Tributary (E.BR) to Deneveu Creek	1517827	139100	Fond du Lac	0	9	PS/NPS	Elevated Water Temperature, Degraded Habitat	TP	75	Upper Fox	39
Un Creek (T22n-R16e-S22)	9793	316100	Outagamie	0	5	PS/NPS	Water Quality Use Restrictions	TP	75	Wolf	52
Unnamed	1524881	323500	Shawano	0	3	PS/NPS	Degraded Biological Community	TP	75	Wolf	56

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[1] School Section Lake was present on the Wisconsin 303(d) Impaired Waters List at the start of this TMDL study but has been proposed for delisting on the 2018 303(d) Impaired Waters List.

Waterbody Name	WATERS ID	WBIC	County	Start Mile	End Mile	Source Category	Impairment Indicator(s)	Pollutant(s)	TP Criterion (µg/L)	Basin	TMDL Subbasin
Unnamed	1524901	325000	Shawano	0	3	PS/NPS	Degraded Biological Community	TP	75	Wolf	56
Unnamed	3994614	138800	Fond du Lac	0	4	PS/NPS	Impairment Unknown	TP	75	Upper Fox	75
Unnamed E Trib. to Schoenick Cr	5513459	321200	Shawano	0	2	PS/NPS	Degraded Biological Community	TP	75	Wolf	67
Unnamed Trib To Mason Lake	481686	176300	Adams	3	6	NPS	Degraded Habitat	TSS	75	Upper Fox	2
Unnamed Trib to Silver Creek	5476567	147700	Fond du Lac	0	8	NPS	Impairment Unknown	TP	75	Upper Fox	87
Unnamed Trib to Silver Creek	5476590	146900	Green Lake	0	3	NPS	Degraded Biological Community	TP	75	Upper Fox	19
Unnamed Trib to W Br Shioc R	5513990	319100	Shawano	0	1	PS/NPS	Degraded Biological Community	TP	75	Wolf	53
Van Dyne Creek	18155	132600	Winnebago, Fond du Lac	1	9	NPS	Degraded Habitat	TSS	75	Upper Fox	32
Waukau Creek	18163	140700	Winnebago	5	10	NPS	Impairment Unknown	TP	75	Upper Fox	27
West Branch Fond du Lac River	10990	134000	Fond du Lac	0	26	PS/NPS	Water Quality Use Restrictions	TP	75	Upper Fox	44
White Clay Lake	11102	326400	Shawano	-	-	PS/NPS	Excess Algal Growth	TP	30	Wolf	54
Winneconne Lake	10749	241600	Winnebago	-	-	NPS	Excess Algal Growth	TP	40	Wolf	72
							Degraded Habitat	TSS			
Wolf River-Main Stem	11237	241300	Winnebago	0	9	NPS	Degraded Habitat	TSS	100	Wolf	72, 73
							Low DO	TP			
Wuerches Creek	359163	148300	Green Lake	0	4	NPS	Degraded Habitat	TSS	75	Upper Fox	18
							Low DO, Elevated Water Temperature	TP			

DO = Dissolved Oxygen TP = Total Phosphorus

TSS = Total Suspended Solids µg/L = Micrograms per liter

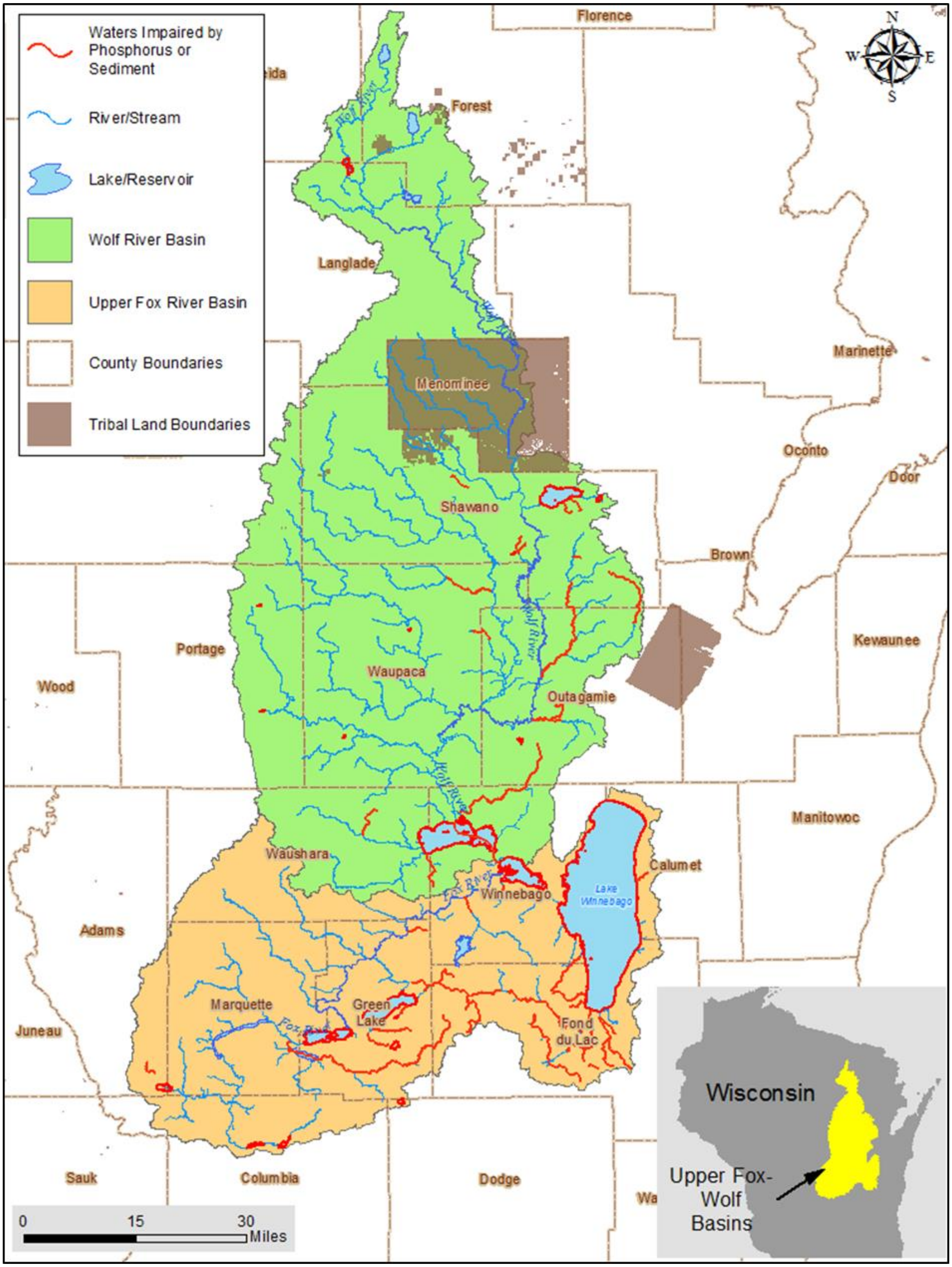


Figure 1. Location of waters impaired by phosphorus and sediment in the Upper Fox-Wolf Basins.

Table 2. Subbasins defined for TMDL development. The WDNR waterbody identification code (WBIC) and assessment unit identification code (WATERS ID) for the waterbodies and assessment units at each subbasin outlet are provided for reference. Subbasin IDs marked with an asterisk (*) contain tribal lands. For subbasins with tribal lands, the TMDLs in this report provide pollutant load allocations for sources on non-tribal lands only.

TMDL Subbasin	Subbasin Name	Outlet Location	WBIC at Outlet	WATERS ID at Outlet	Basin	TP Criterion (µg/L)
1	Upper Neenah Creek	Neenah Creek above Widow Green Creek	173800	10729	Upper Fox	75
2	Tributary to Mason Lake	Unnamed tributary to Mason Lake approximately 2 miles upstream of Mason Lake	176300	481686	Upper Fox	75
3	Mason Lake	Mason Lake outlet	175700	10733	Upper Fox	40
4	Neenah Creek	Neenah Creek above Fox River	173800	10729	Upper Fox	75
5	Park Lake	Park Lake outlet	180300	18131	Upper Fox	40
6	Swan Lake	Swan Lake outlet	179800	10744	Upper Fox	30
7	Buffalo Lake Inflow	Fox River above Buffalo Lake	117900	359274	Upper Fox	75
8	Westfield Creek	Westfield Creek above Tagatz Creek	166000	10717	Upper Fox	75
9	Buffalo Lake	Buffalo Lake outlet	168000	11083	Upper Fox	40
10	Montello River	Montello River above Fox River	164100	18122	Upper Fox	75
11	Little Green Lake	Little Green Lake outlet	162500	18120	Upper Fox	40
12	Upper Grand River	Grand River at Manchester, WI (at Madison St. bridge)	159300	10702	Upper Fox	75
13	Tributary to Grand River	Unnamed tributary to Grand River above Grand River	161300	5692097	Upper Fox	75
14	Middle Grand River	Grand River above Spring Creek	159300	11097	Upper Fox	75
15	Lower Grand River	Grand River above Fox River	159300	11097	Upper Fox	75
16	Lake Puckaway	Lake Puckaway outlet	158700	11081	Upper Fox	40
17	Roy Creek	Roy Creek above Green Lake	148200	11030	Upper Fox	75
18	Wuerches Creek	Wuerches Creek above Green Lake	148300	359163	Upper Fox	75
19	Silver Creek - Below South Koro Road	Silver Creek above Green Lake	146800	11028	Upper Fox	75
20	Green Lake	Green Lake outlet	146100	11023	Upper Fox	15
21	Mecan River	Mecan River above Fox River	155000	11061	Upper Fox	75
22	Upper White River	White River above Neshkoro Millpond	148500	11038	Upper Fox	75
23	Lower White River	White River above Sucker Creek	148500	11037	Upper Fox	75
24	Fox River - Downstream Lake Puckaway	Fox River above White River	117900	5774139	Upper Fox	100
25	Puchyan River	Puchyan River above Fox River	145200	11018	Upper Fox	75
26	Harrington Creek	Harrington Creek above Fox River	143700	11016	Upper Fox	75
27	Waukau Creek	Waukau Creek above Fox River	140700	18163	Upper Fox	75
28	Fox River - White River to Omro	Fox River above Omro, WI	117900	1857382	Upper Fox	100
29	Fox River - Omro to Lake Butte des Morts	Fox River above Lake Butte des Morts	117900	1857382	Upper Fox	100
30	Sawyer Creek	Sawyer Creek above Fox River	139800	11003	Upper Fox	75

TMDL Subbasin	Subbasin Name	Outlet Location	WBIC at Outlet	WATERS ID at Outlet	Basin	TP Criterion (µg/L)
31	Spring Brook	Spring Brook above Springbrook Rd	140300	11005	Upper Fox	75
32	Van Dyne Creek	Van Dyne Creek approx 2 miles upstream of Lake Winnebago	132600	18155	Upper Fox	75
33	Anderson Creek	Anderson Creek above Lake Winnebago	133300	10987	Upper Fox	75
34	Mosher Creek	Mosher Creek above Lake Winnebago	133500	10988; 18156	Upper Fox	75
35	Tributary to West Branch Fond du Lac River	Unnamed tributary to West Branch Fond du Lac River above West Branch Fond du Lac River	134800	5691049	Upper Fox	75
36	Sevenmile Creek	Sevenmile Creek above East Branch Fond du Lac River	136800	10994	Upper Fox	75
37	Campground Creek	Campground Creek above East Branch Fond du Lac River	137400	1452243	Upper Fox	75
38	De Neveu Creek	De Neveu Creek below Cearns Ln	138700	10982	Upper Fox	75
39	Tributary to De Neveu Creek	Unnamed tributary to De Neveu Creek above De Neveu Creek	139100	1517827	Upper Fox	75
40	Tributary to Parsons Creek	Unnamed tributary to Parsons Creek above Parsons Creek	136200	903785	Upper Fox	75
41	Upper Parsons Creek	Parsons Creek above unnamed tributary	136000	10993	Upper Fox	75
42	Parsons Creek	Parsons Creek above East Branch Fond du Lac River	136000	18157	Upper Fox	75
43	East Branch Fond du Lac River	East Branch Fond du Lac River above Fond du Lac River	135900	10991	Upper Fox	75
44	West Branch Fond du Lac River	West Branch Fond du Lac River above confluence with East Branch Fond du Lac River	134000	10990	Upper Fox	75
45	Carpenter Creek	Carpenter Creek above Pine River	248800	10784	Wolf	75
46	Mud Creek	Mud Creek above Lake Winnebago	131600	10259	Upper Fox	75
47	Pine River	Pine River above Lake Poygan	247800	10779	Wolf	75
48	Willow Creek	Willow Creek above Lake Poygan	243700	10768	Wolf	75
49	Tributary to Rat River	Unnamed tributary to Rat River above Rat River	252200	10753	Wolf	75
50	Rat River	Rat River above Wolf River	251800	18133	Wolf	75
51	Arrowhead River	Arrowhead River above Lake Winneconne	241700	10750	Wolf	75
52	Bear Creek (Wolf)	Bear Creek above Wolf River	316000	9790; 9791	Wolf	75
53	Shioc River	Shioc River above Wolf River	316800	9800	Wolf	75
54	White Clay Lake	White Clay Lake outlet	326400	11102	Wolf	30
55*	Upper Wolf River	Wolf River above confluence with Shawano Lake Outlet	241300	315370	Wolf	100
56*	Shawano Lake	Shawano Lake outlet	322800	9825	Wolf	40
57	Long Lake	Long Lake outlet	321300	9816	Wolf	30

TMDL Subbasin	Subbasin Name	Outlet Location	WBIC at Outlet	WATERS ID at Outlet	Basin	TP Criterion (µg/L)
58*	Upper Embarrass River	Embarrass River above North Branch Embarrass River	291900	1856388	Wolf	75
59*	Middle Embarrass River	Embarrass River above Pigeon River	291900	10411	Wolf	75
60	Pigeon River	Pigeon River above Embarrass River	293100	9711	Wolf	75
61	Lower Little Wolf River	Little Wolf River above Wolf River	272400	10360	Wolf	100
62	School Section Lake	School Section Lake outlet	283600	10346	Wolf	30
63	Tree Lake	Tree Lake outlet	289400	10324	Wolf	30
64	Bear Creek (Embarrass)	Bear Creek above unnamed tributary	292100	10414	Wolf	75
65	Collins Lake	Collins Lake outlet	270200	10319	Wolf	20
66	Waupaca River	Waupaca River above Wolf River	257400	10283	Wolf	75
67	Wolf River – Shawano to Shioc River	Wolf River above Shioc River	241300	314921	Wolf	100
68	Wolf River - Shioc River to Bear Creek	Wolf River above Bear Creek	241300	314890	Wolf	100
69	Wolf River - Bear Creek to Embarrass River	Wolf River above Embarrass River	241300	314890	Wolf	100
70	Lower Embarrass River	Embarrass River above Wolf River	291900	10411	Wolf	100
71	Wolf River - Embarrass River to Lake Poygan	Wolf River above Lake Poygan	241300	314842	Wolf	100
72	Lake Poygan and Lake Winneconne	Lake Winneconne outlet	241600	10749	Wolf	40
73	Lake Butte des Morts	Lake Butte des Morts outlet	139900	11004	Upper Fox	40
74	Fox River - Lake Butte des Morts to Lake Winnebago	Fox River above Lake Winnebago	117900	352759	Upper Fox	100
75	Lake Winnebago	Lake Winnebago outlet	131100	358400	Upper Fox	40
76	Crane Lake	Crane Lake outlet	388500	10605	Wolf	40
77	Upper Post Lake	Upper Post Lake outlet	399200	10650	Wolf	40
78	Pine Lake	Pine Lake outlet	406900	127787	Wolf	40
79	Hill Creek	Hill Creek above Green Lake	146200	11024	Upper Fox	75
80*	Wolf River - Upper Post Lake to Hunting River	Wolf River below Hunting River	241300	315427	Wolf	75
81*	Upper Little Wolf River	Little Wolf River below South Branch Little Wolf River	272400	10360	Wolf	75
82	Black Otter Lake	Black Otter Lake outlet	315600	9789	Wolf	40
83	Big Twin Lake	Big Twin Lake outlet	146500	11025	Upper Fox	30
84	Lake Emily	Lake Emily outlet	161600	1525397	Upper Fox	40
85	Old Taylor Lake	Old Taylor Lake outlet	195000	10274	Wolf	20
86	Spring Lake	Spring Lake outlet	267200	10311	Wolf	15
87	Silver Creek - Above South Koro Road	Silver Creek above South Koro Road	146800	11028	Upper Fox	75
88	Fond du Lac River	Fond du Lac River above Lake Winnebago	133700	10989	Upper Fox	75
89	Black Creek	Black Creek above Shioc River	317100	337848	Wolf	75

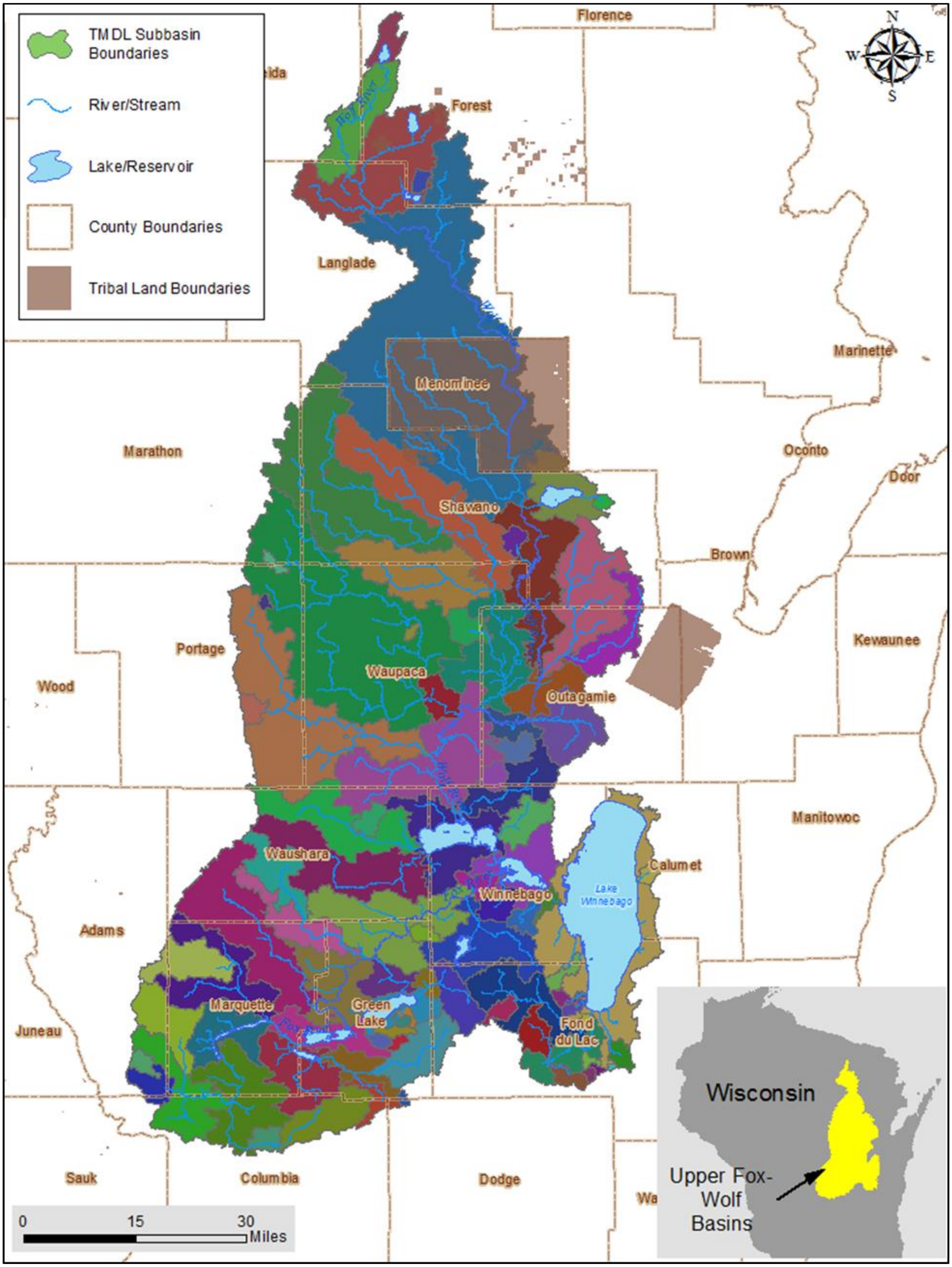


Figure 2. Map of TMDL subbasins.

1.4 Report Organization

This report defines the TMDLs and load allocations and provides potential management actions that will help restore water quality in the UFWB. The main body of the report identifies the waterbodies and pollutants addressed by the TMDL; presents applicable water quality standards; assesses pollutant sources; summarizes results of loading capacity and source allocation analysis; and discusses considerations for TMDL implementation. The main body of the report is supplemented with appendices with technical details on the analyses completed to develop the TMDLs and detailed maps and tables. The contents of these appendices are summarized below:

- Appendix A (TMDL Subbasin Land Use and Maps) contains tables and maps describing the characteristics of TMDL subbasins.
- Appendix B (Impairments Requiring Additional Evaluation) is a summary of 303(d)-listed water quality impairments in the UFWB that are related to excess phosphorus and sediment loading but will require further evaluation to determine if the allocations presented in this report will be sufficient to achieve water quality criteria. These impairments include excess algal growth, eutrophication, degraded habitat, or turbidity in some lakes and reservoirs in the basin;
- Appendix C (SWAT Model Setup, Calibration, and Validation for the Upper Fox-Wolf Basins TMDL) provides technical details on the setup, calibration, and application of the Soil and Water Assessment Tool (SWAT) watershed model of the UFWB that was used as part of TMDL development;
- Appendix D (WiLMS Lake Model Setup and Results for the Upper Fox-Wolf Basins TMDL) provides technical details on the setup, calibration, and application of the Wisconsin Lake Modeling Suite (WiLMS) model used to estimate the phosphorus loading capacity of several lakes in the UFWB;
- Appendix E (Water-Quality Response to Changes in Phosphorus Loading of the Winnebago Pool Lakes, Wisconsin, with Special Emphasis on the Effects of Internal Loading in a Chain of Shallow Lakes) is a copy of a study completed by the US Geological Survey (USGS) to model the response of the Winnebago Pool to alternative TP loading magnitudes;
- Appendix F (Report of Lake Winnebago Paleoecological Study) provides results of a paleoecological study of Lake Winnebago bottom sediments;
- Appendix G (Baseline Load Tables) contains detailed tables of baseline phosphorus and sediment loads for TMDL subbasins;
- Appendix H (Total Phosphorus Allocation Tables) contains detailed tables of phosphorus TMDL source allocations for TMDL subbasins;
- Appendix I (Sediment Allocation Tables) contains detailed tables of sediment TMDL source allocations for TMDL subbasins;
- Appendix J (Agricultural Phosphorus and Sediment Targets) reports target TP and TSS yields for TMDL implementation that align with outputs from field-scale agricultural models.
- Appendix K (Trading and Adaptive Management Information) provides direction for implementing the TMDL with water quality trading and adaptive management.
- Appendix L (Response to Comments) contains responses to comments received on the draft TMDL.
- Appendix M Public Informational Hearing Comments
- Appendix N Response to Public Informational Hearing Comments
- Appendix O Copy of Agricultural Surveys

2 APPLICABLE WATER QUALITY STANDARDS AND NUMERIC TARGETS

The purpose of a TMDL is to define the maximum amount of a pollutant that a waterbody can assimilate while still attaining water quality standards. This section summarizes Wisconsin water quality standards that are relevant to the TMDLs presented in this report.

2.1 Narrative Water Quality Criteria

All waters of the State of Wisconsin are subject to the following narrative water quality criterion established in Section NR 102.04(1) of the Wisconsin Administrative Code:

"To preserve and enhance the quality of waters, standards are established to govern water management decisions. Practices attributable to municipal, industrial, commercial, domestic, agricultural, land development or other activities shall be controlled so that all waters including the mixing zone and the effluent channel meet the following conditions at all times and under all flow conditions: (a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water, shall not be present in such amounts as to interfere with public rights in waters of the state, (b) Floating or submerged debris, oil, scum or other material shall not be present in such amounts as to interfere with public rights in waters of the states, (c) Materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state."

Due to excessive phosphorus and sediment loading, the segments listed in Table 1 were not meeting Wisconsin's narrative water quality criterion for the 2018 assessment and reporting cycle. Excess phosphorus loading causes algal blooms, which may be characterized as floating scum, producing a green color, a strong odor, and an unsightly condition. Sometimes these algal blooms contain toxins which limit recreational uses of the water bodies. Excessive sediments are considered objectionable deposits. Because of the low dissolved oxygen and degraded habitat impairments caused by excess phosphorus and sediment, many designated fish and aquatic life uses are not supported in the waters of the UFWB.

2.2 Numeric Water Quality Criteria

In addition to narrative criteria, numeric water quality criteria for phosphorus must be met in the UFWB. Numeric criteria for phosphorus are defined in Section NR 102.06 of the Wisconsin Administrative Code (Table 3). The numeric criteria were established in 2010 and are based on relationships between phosphorus and designated use attainment in surface waters, as documented in *Wisconsin Phosphorus Water Quality Standards Criteria: Technical Support Document*.

To be consistent with the criteria development methods, attainment of phosphorus criteria is assessed in streams as median TP during the growing season (May through October) and in lakes as mean TP during the summer (June 1 through September 15). See https://dnr.wi.gov/topic/surfacewater/assessments.html for additional details on assessment.

Applicable numeric criteria for phosphorus are listed in Table 1 for each of the impaired waterbody segments in the UFWB. Table 2 lists the numeric criteria for phosphorus that applies to the waterbody segment at the outlet of each TMDL subbasin.

Table 3. Wisconsin numeric total phosphorus (TP) criteria defined in Section NR 102.06 of the Wisconsin Administrative Code. Note that reservoirs (impounded rivers and streams) with hydraulic residence time less than 14 days are assigned applicable river or stream criteria.

Water Type	TP Criteria
Large Rivers	100 µg/L
Other Rivers and Streams	75 µg/L
Non-Stratified Reservoirs (hydraulic residence time ≥ 14 days)	30 µg/L
Stratified Reservoirs (hydraulic residence time ≥ 14 days)	40 µg/L
Stratified, Two-Story Fishery Lakes	15 µg/L
Stratified Seepage Lakes	20 µg/L
Stratified Drainage Lakes	30 µg/L
Non-Stratified Lakes	40 µg/L

Revisions to other administrative codes supporting phosphorus criteria implementation went into effect concurrently with changes to NR 102. Chapter NR 217 was revised to include procedures for translating numeric phosphorus criteria into water quality-based effluent limits (WQBELs) and incorporating those limits into Wisconsin Pollutant Discharge Elimination System (WPDES) permits. Chapter NR 151 revisions that also went into effect concurrently with the changes to NR 102 included new phosphorus index (P-Index) performance standards addressing phosphorus from agricultural lands.

2.3 Designated Uses

Designated uses are the attainable condition specified in water quality standards for surface waters in Wisconsin. Designated uses are defined in Chapter NR 102 of Wisconsin Administrative Code. All waters of the state have the following designated uses: Fish and Aquatic Life; Recreation; Wildlife; and Public Health and Welfare. Wisconsin water quality standards establish criteria for water quality that correspond to attainment of these designated uses. All five designated uses are subject to the narrative criteria described in Section 2.1 of this report.

The Fish and Aquatic Life use also includes the numeric criteria for phosphorus described in Section 2.2 of this report. Section NR 102.04(3) of the Wisconsin Administrative Code defines the Fish and Aquatic Life use and identifies five fish and aquatic life subcategories for surface water classification (cold water communities; warm water sport fish communities; warm water forage fish communities; limited forage fish communities; limited aquatic life). All fish and aquatic life subcategories are subject to attainment of numeric phosphorus criteria except for waters with limited aquatic life designation.

Lake Winnebago (covered in this TMDL study) is one of three Wisconsin surface waters used as drinking water sources (the other two, Lake Michigan and Lake Superior, are outside of the TMDL study area). Approximately 250,000 people get their drinking water from Lake Winnebago. There is no standard procedure for assessing whether the use of a waterbody as a drinking water source is impaired by excess algal growth. The World Health Organization has an outdated human health standard based on microcystins (a cyanotoxin) and EPA is developing but has not yet promulgated an updated standard.

The Safe Drinking Water Act (SDWA) requires that EPA publish a list of unregulated contaminants that are known or expected to occur in public water systems in the U.S. that occur at a frequency and at levels of public health concern and where there is a meaningful opportunity for health risk reduction. Cyanotoxins are listed as unregulated contaminants and must be monitored by public water systems. This monitoring provides a basis for future regulatory determinations and, as warranted, actions to protect public health. The Drinking Water Protection Act (PDF), required EPA to develop and report to Congress a strategic plan outlining the risks to human health from drinking water provided by public water systems contaminated with algal toxins and to recommend feasible treatment options, including procedures and source water protection practices, to mitigate any adverse public health effects of algal toxins. EPA developed, and submitted to Congress, the Algal Toxin Risk Assessment and Management Strategic Plan outlining how the Agency will continue to assess and manage algal toxins in drinking water.

Drinking water programs at both the national and state levels use a multi-barrier protection approach in which source water is meeting or is as close to meeting its designated use as possible prior to treatment. Current treatment technologies employed by communities drawing water out of Lake Winnebago have not shown a breakthrough of toxins; however, it is still a concern. The 1993 Milwaukee Cryptosporidiosis outbreak demonstrates that problems in treatment can occur and the August 2014 algal bloom on Lake Erie resulted in 400,000 people having to drink bottled water due to microcystins. The allocations developed in this TMDL minimize the risk of a severe algal bloom and are consistent with the multi-barrier protection approach discussed above.

2.4 Evaluation of Potential Site-Specific Criteria

Wisconsin administrative code states that a "…site-specific criterion may be adopted in place of the generally applicable criteria where site-specific data and analysis using scientifically defensible methods and sound scientific rationale demonstrate a different criterion is protective of the designated use of the specific surface water segment or waterbody" (s. NR 102.06(7), Wis. Adm. Code). In the process of developing this TMDL, three sources were consulted to determine whether a site-specific TP criterion was appropriate for Lake Winnebago. Two of the sources, a paleoecological study and lake phosphorus model, estimated reference TP concentrations in Lake Winnebago (i.e., TP levels prior to extensive anthropogenic development of the watershed). The third source investigated the relationship between TP and chlorophyll-a in the lake.

2.4.1 Paleoecological Study

During 2016 and 2017, a paleoecological study, which looks at the interactions between organisms and their environments across geologic timescales, was conducted of Lake Winnebago bottom sediment. The purpose of the study was to estimate a reference TP concentration to evaluate historical phosphorus concentrations in the lake. In this study, two bottom sediment cores were collected from Lake Winnebago. The preserved diatoms (microscopic algae) in the top and bottom layers of each core were analyzed and used to estimate water column summer TP concentrations at the time the sediment layers were deposited from a statistical model relating diatom community composition and water column TP. The bottom layer of the cores was also dated using radiochemical dating and estimated sedimentation rates.

Results showed that the diatom community in the top (i.e., recently deposited) layer corresponded to estimated summer TP concentrations of 108 µg/L in the north basin of Lake Winnebago and 94 µg/L in the south basin. These estimates are in line with TP sample data collected from Lake Winnebago during 2009 through 2011 that show a summer TP concentration of 97 µg/L (see section 3.4). In the bottom core layers, the diatom community corresponded to estimated summer TP concentrations of 40 µg/L in the north basin and 47 µg/L in the south basin. The 90% confidence intervals for these estimates overlap the general 40 µg/L TP criterion for Lake Winnebago and are 32-50 µg/L for the north basin and 37-59 µg/L for the south basin. Dating procedures showed that bottom layer sediment was deposited at least 150 years ago and possibly as early as the 1300's. The full methods and results of the Lake Winnebago paleoecological study are documented in Appendix F.

2.4.2 Lake Phosphorus Model

The second source of estimated reference TP concentrations in Lake Winnebago was a companion study completed by USGS to model the response of lake TP concentrations to alternative TP loading magnitudes (Appendix E). As part of the USGS study, summer mean TP concentrations were modeled under a phosphorus loading scenario with tributary TP concentrations set to 20 µg/L and anthropogenic TP sources (point source and nearshore septic system discharges) set to zero. This loading scenario represented conditions in the lake prior to extensive development of the watershed, with tributary TP concentrations equal to estimated pre-settlement values. The lake models showed reference TP concentrations of 32 to 33 µg/L in Lake Winnebago.

2.4.3 Total Phosphorus-Chlorophyll Relationship

The analysis of reference TP in Lake Winnebago was intended to serve as a first step toward identifying a potential site-specific criterion for the lake. Since Wisconsin administrative code specifically states that a site-specific criterion must clearly be protective of designated uses, any potential site-specific criterion must be further evaluated to establish that it will result in attainment of designated uses. Toward this end, additional analysis was completed to identify the range of TP concentrations in Lake Winnebago that correspond to attainment of the chlorophyll-a (CHL) target for Lake Winnebago used by WDNR for assessing recreational use attainment.

The CHL target used by WDNR to assess recreational use attainment in shallow lakes is 20 µg/L, to be exceeded no more than 30% of days between July 15 and September 15 (Wisconsin DNR, 2015). This target can be converted to a geometric mean for a given monitoring station by calculating the 0.3 quantile of a normal distribution with a mean of log(20) and standard deviation calculated from CHL sample data collected from the station. For Lake Winnebago, the geometric mean CHL target calculated from this approach is 14 µg/L.

To project how CHL responds to changes in water column TP, and evaluate the TP concentration that corresponds to the 14 µg/L CHL target, a statistical regression curve between TP and CHL was initially fit to sampled summer TP and CHL means from Lake Winnebago (solid blue lines in Figure 3). A statistically significant relationship between TP and CHL was found for all three long-term monitoring stations in Lake Winnebago. However, confidence intervals around these relationships (dashed blue lines in Figure 3) were too wide for drawing meaningful conclusions in the vicinity of the CHL target because of the high standard error in the relationship and the extrapolation required to intersect the CHL target.

An alternative method was applied to derive a Lake Winnebago-specific relationship between TP and CHL from a general relationship based on data from multiple lakes. First, a statistical regression curve between TP and CHL was fit using samples from all Wisconsin lakes with at least four years of data in the WDNR Surface Water Integrated Monitoring System (SWIMS) (solid black lines in Figure 3). Next, the deviation of Lake Winnebago from the all-lake relationship was quantified using the mean of residual (observed minus predicted) CHL concentrations for Lake Winnebago. The Lake Winnebago-specific relationship between TP and CHL was then estimated by shifting the all-lake regression curve up/down by the mean of CHL residuals (solid red lines in Figure 3). The confidence interval for the Lake Winnebago-specific relationship (dashed red lines in Figure 3) was calculated as the standard deviation of CHL residuals. These steps were completed individually for the three long-term monitoring stations in Lake Winnebago to generate a lake-specific regression curve for each station.

The constrained regression curves for Lake Winnebago indicate that the lake should meet its CHL target with water column TP concentrations of 47, 41, and 35 µg/L at the south, middle, and north stations, respectively. The 90% confidence intervals for all three of the regressions overlap the general 40 µg/L TP criterion for Lake Winnebago and are 31-45 µg/L at the south station, 36-47 µg/L at the middle station, and 39-59 µg/L at the north station.

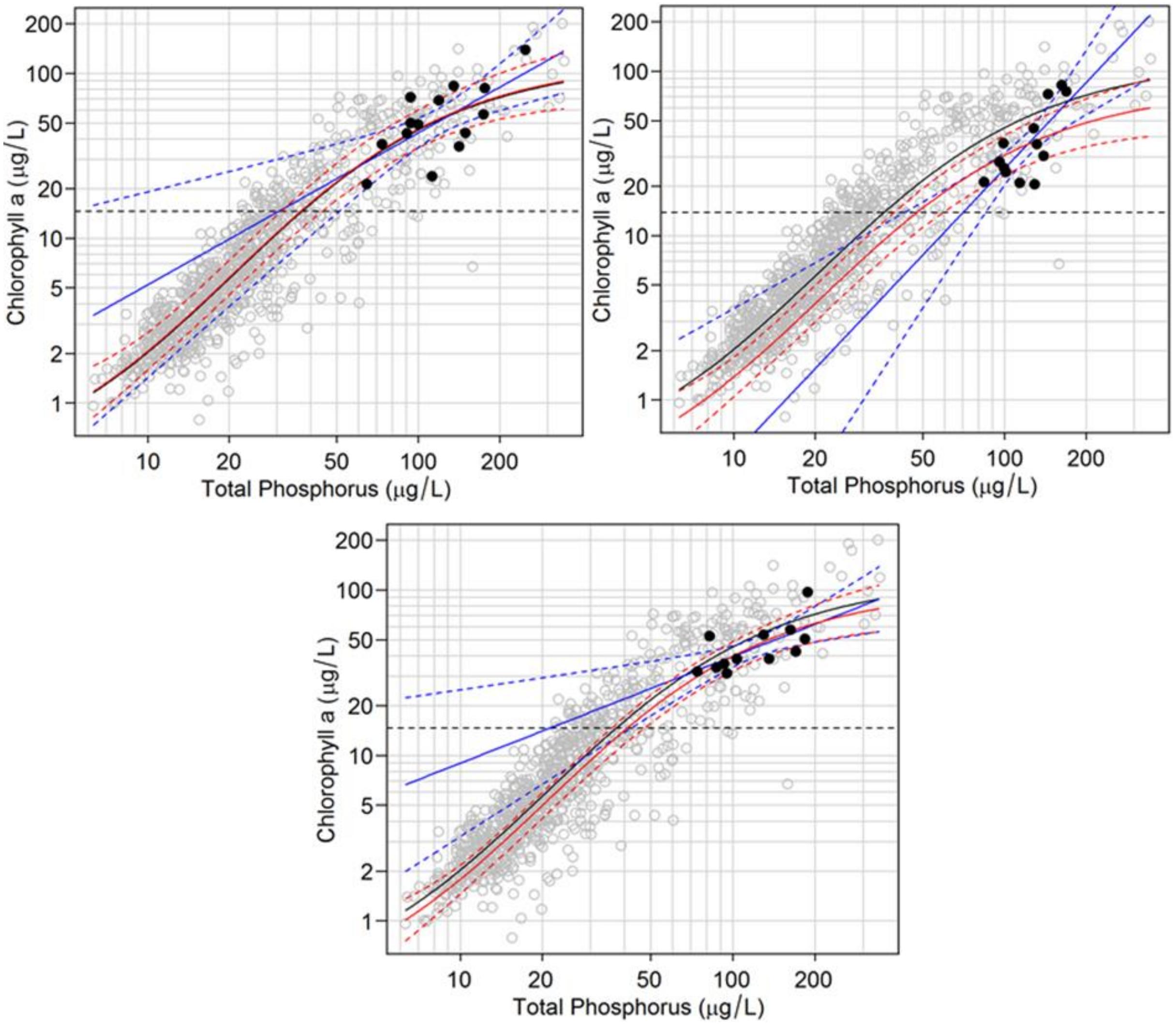


Figure 3. Regression curves for total phosphorus (TP) and chlorophyll-a (CHL) for the Lake Winnebago south (station ID 713244; top-left), middle (station ID 713243; top-right), and north (station ID 713245; bottom) monitoring stations. Gray circles are summer mean TP and CHL for all Wisconsin lakes with sufficient data; black circles are summer mean TP and CHL values for the station. The dashed black line is the CHL target of 14 µg/L for Lake Winnebago. The solid blue line is the linear regression curve for the station; the solid black line is the all-lake regression curve; the solid red line is the constrained regression curve for the station; dashed blue and red lines are 90% confidence intervals.

2.4.4 Evaluation of Site-Specific Criteria Analysis Results

Together, the analyses of reference TP and the TP:CHL relationship do not support the use of a site-specific TP criterion for Lake Winnebago for TMDL development. The reference TP analysis indicates that prior to extensive anthropogenic development of the watershed, TP concentrations in Lake Winnebago ranged from 32 to 47 µg/L (see Sections 2.4.1 and 2.4.2). The general TP criterion applicable to Lake Winnebago, 40 µg/L, falls within this range. Further, Wisconsin administrative code requires demonstration of designated use attainment for any potential site-specific criterion. The analysis of the TP:CHL relationship in Lake Winnebago provided estimates of TP concentrations projected to correspond to attainment of the recreation use. The range of these estimates (35 to 47 µg/L; see Section 2.4.3) also contains the 40 µg/L general TP criterion for Lake Winnebago. Because the 40 µg/L general TP criterion for Lake Winnebago is within the estimated range of reference TP and the range corresponding to recreation use attainment, these results do not indicate that a site-specific TP criterion is appropriate for Lake Winnebago. A site-specific criterion is therefore not appropriate and was not pursued as part of TMDL development for Lake Winnebago.

2.5 Numeric Water Quality Targets

2.5.1 Total Phosphorus

In a TMDL, the water quality target is a numeric endpoint that represents the level of acceptable water quality to be achieved by implementing the TMDL. For phosphorus, the numeric targets for the TMDLs presented in this report are equal to numeric water quality criteria defined in Wisconsin Administrative Code s. NR 102.06 and listed in Table 1 for impaired waterbody segments and in Table 2 lists for the waterbody segment at the outlet of each TMDL subbasin. To be consistent with the criteria development methods, attainment of criteria is assessed in streams as the median TP during the growing season (May through October) and in lakes as the mean TP during the summer (June 1 through September 15).

2.5.2 Total Suspended Solids

Numeric water quality criteria do not exist for total suspended solids in Wisconsin, but numeric water quality targets for this TMDL may be developed that are protective of narrative criteria specified in Wisconsin Administrative Code NR 102.04(1), to control activities that may result in harm to humans and fish and other aquatic life. A TSS target concentration for streams and rivers of 12 milligrams per liter (mg/l) was derived by WDNR for use in this TMDL to address the effects of excess sediment loading, based on the approach and data used to develop the State phosphorus criteria. The numeric sediment target is intended to meet the narrative criteria ("no objectionable deposits…") in Section NR 102.04 of Wisconsin Administrative Code. A similar numeric TSS target of 12 mg/L was also used for the Milwaukee River Basin TMDL (CDM Smith, 2018).

There is a strong correlation of excess TSS and degraded biota and habitat in streams and rivers, supported by numerous studies and sampling results. Turbid waters created by excess TSS concentrations reduce light penetration, which can adversely affect aquatic organisms. Also, TSS can interfere with fish feeding patterns because of the turbidity. Turbidity is a cloudiness or haziness caused by the suspended sediment particles and can interfere with light penetration and sight through reduced water clarity.

Prolonged periods of very high TSS concentrations can be fatal to aquatic organisms (Newcombe and Jensen, 1996). As TSS settles to the bottom of a stream, critical habitats such as spawning sites and macroinvertebrate habitats can be covered in sediment/siltation. Excess sediment in a stream bottom can reduce dissolved oxygen concentrations in stream bottom substrates, and it can reduce the quality and quantity of habitats for aquatic organisms.

Sediment is also a concern because of its ability to transport phosphorus to a waterbody. Total phosphorus consists of both dissolved phosphorus, which is mostly orthophosphate, and particulate phosphorus, including both inorganic and organic forms (Sharpley et al. 1994). Within the surface soil layer, inorganic phosphorus is typically bound tightly to soil particles. When these soil particles erode, the attached phosphorus is also carried into nearby waterbodies.

WDNR investigated the correlation between TSS and stream health in Wisconsin waters with support by USGS to determine a numeric TSS target. Although EPA has not published guidance on setting water quality criteria for TSS in flowing streams and rivers, EPA's Science Advisory Board guidance for nutrient criteria provides a framework that is equally applicable to TSS. That guidance emphasizes the use of multiple lines of evidence, relating concentrations to biotic impacts, using strong and supportable correlations between causal and response parameters.

U.S. Geological Survey Professional Paper 1754, *Nutrient Concentrations and Their Relations to the Biotic Integrity of Nonwadeable Rivers in Wisconsin* (2008), provides data and statistical results that allow for identification of a TSS target, as supplemented by unpublished analysis by the paper's primary author, Dr. Dale Robertson of USGS. On Tables 11 and 15 of the USGS report, strong correlations based on the Spearman rank correlation coefficients were identified between suspended sediment concentration (SSC) and a number of biotic indices, including macroinvertebrate species, percent of individuals from the order Ephemeroptera, Mean Pollution Tolerance Value, Hilsenhoff Biotic Index, percent intolerant fish species, percent lithophilic spawners, percent suckers, and fish index of biotic integrity. Subsequent breakpoint analysis by Dr. Robertson identified SSC concentrations which best represented thresholds between reference and degraded conditions for multiple chemical and biological parameters. SSC breakpoints ranged from 3.5 to 22.25 mg/L and averaged 13.8 mg/L.

The TSS target based on Wisconsin non-wadeable streams and river data is preferred over earlier and broader analyses for a variety of reasons, including:

- All data was collected using a defined protocol and during the same year, while other studies are based on available data collected using a variety of protocols over a number of years.
- All of the 42 non-wadeable rivers and streams are of similar size, stream order, etc., while other studies used a wide range of streams and rivers.
- Correlation to biotic impacts is considered as a stronger and more appropriate basis than a calculated pre-settlement reference condition.

Based on weighting strategies similar to what was used in the development of the phosphorus criteria, WDNR arrived at a TSS target value of 12 mg/L, expressed as the median of monthly samples collected during the growing season between May and October. The expression of the TSS target matches how the samples were collected and are intended to be used.

Breakpoint values served as the basis of selecting the numeric TSS target of 12 mg/L for TMDL development. The target is expressed as TSS (rather than SSC) to facilitate assessment of TMDL attainment because WDNR water quality monitoring programs regularly collect TSS samples and not SSC. TSS and SSC are both parameters that describe the concentration of solid-phase material suspended in the water column of a waterbody. The parameters differ in the specific laboratory procedures used for measurement. In general, SSC is analyzed by measuring the dry weight of all sediment in an entire water sample while TSS measures the dry weight of sediment within a subsample of the water sample. Comparisons of paired TSS and SSC measurements have indicated that TSS methods tend to underestimate sediment concentrations relative to SSC, particularly as larger particle sizes become more predominant in a sample. However, the exact relationship between TSS and SSC can vary significantly from one monitoring location to another.

The TSS target value of 12 mg/L is expressed as the median of monthly samples collected during the growing season between May and October. High TSS concentrations during the growing season are especially problematic because excess sediment reduces the amount of light available to submerged aquatic vegetation for growth and potentially increases water temperatures. Further, the spawning of many fish and aquatic insect species can be disrupted with high growing season sediment concentrations because settling particles can smother fish eggs and insect larvae.

The numeric TSS target selected for this TMDL study is applicable to stream and river reaches only. Although some UFWB lakes are present on the Wisconsin 2018 303(d) Impaired Waters List with “Sediment/Total Suspended Solids” as the cause of impairment, this TMDL study does not address the lake TSS impairment listings by defining a numeric target for TSS in lakes. At the time of this TMDL study there were insufficient data and methods available to determine a numeric target for TSS in lakes and to develop a water quality model to link sediment loading to in-lake TSS concentrations.

Elevated TSS concentrations in lakes can be driven by several factors in addition to external sediment loading, including high algal growth due to excess phosphorus loading and resuspension of bottom sediment from wind and wave action. Reductions in lake TSS concentrations are expected to occur with the implementation of the TMDLs presented in this report since tributary sediment and phosphorus loading will decrease. Monitoring and analysis of lake TSS following TMDL implementation will indicate whether these reductions are sufficient to address the lake TSS impairments or whether additional TSS reductions are needed.

2.5.3 Benefits of Achieving Numeric Targets

In addition to reduced TP and TSS concentrations in UFWB surface waters, the expected water quality benefits from achieving the numeric targets defined for this TMDL study include:

- Reduced density, frequency, and duration of nuisance algal blooms resulting in lowered health risks to humans and animals – especially pets;
- Increased dissolved oxygen concentrations that will support a more diverse and robust community of fish and other aquatic life;
- Increased water clarity/transparency due to the stabilizing effect of increased submerged aquatic vegetation;
- Improved biotic integrity index scores for fish and macroinvertebrate communities;
- Improved qualitative and quantitative aquatic habitat ratings;
- Reduced water temperatures;
- Improved pH levels;
- Increased numbers and safety of swimmers, boaters, wind-surfers, and other water craft users.

2.6 Replacement of Existing TMDLs for Parson’s Creek

In September 2007, the “Sediment & Nutrient TMDL for Parsons Creek & its East Tributary” (Parsons Creek TMDL) was approved by EPA. The Parsons Creek TMDL was developed to address excessive inputs of sediment and nutrients which resulted in degraded habitat, sedimentation, and aquatic toxicity due to high ammonia levels.

Parsons Creek (WBIC 136000) is a cold-water stream in Fond du Lac County, Wisconsin. The Parsons Creek TMDL covers Parsons Creek and the East Tributary to Parsons Creek (WBIC 136200). The Parsons Creek TMDL was divided into three subwatersheds; however, the allocations included in the TMDL were calculated using a point of standards application only at the pour point (bottom) of Parsons Creek. The areas covered by the Parsons Creek TMDL correspond with subbasins 40, 41, and 42 in the UFWB TMDL, which provides allocations for all three subbasins. As outlined below, the UFWB TMDL addresses impairments caused by the pollutants TSS /sediment and phosphorus; the UFWB TMDL does not address ammonia.

Once the UFWB TMDL is approved by EPA, the WNDR will remove the Parsons Creek TMDL for TSS / sediment and phosphorus and replace it with the UFWB TMDL. The Parsons Creek TMDL for ammonia will remain in effect. The report for the Parsons Creek TMDL will be updated to reflect the changes. The information presented in the Parsons Creek TMDL along with the allocations from the UFWB TMDL could be used to support the development of a 9 Element Plan.

2.6.1 Parsons Creek Sediment (TSS) TMDL

Both the UFWB TMDL and Parsons Creek TMDL used SWAT modeling to evaluate TSS/sediment loads. The Parsons Creek TMDL for TSS/sediment is divided into two components: a 'normal flow' target and a 'high flow' target, expressed in both concentrations and loads. The Parsons Creek TMDL used a median target concentration of 59 mg/L for the top 5% of flows that are at 8 cubic feet per second (cfs) or above. In addition to the median 'high flow' target concentration, a maximum 'high flow' concentration was set at 230 mg/L TSS following methodology outlined by USEPA (2007). Allocations were developed using load duration curves. Target concentrations were specified for different flow conditions and are listed below:

Sediment (TSS) TMDL Development
Sediment 'Normal Flow' Median Target Concentration: 8 mg/L TSS
Sediment 'Normal Flow' Maximum Target Concentration: 28 mg/L TSS
Sediment 'High Flow' Median Target Concentration: 59 mg/L TSS
Sediment 'High Flow' Maximum Target Concentration: 230 mg/L TSS

The flow duration curve approach roughly translates to a maximum daily load of 302 lbs./day using the normal flow target under average flow conditions, to 845 lbs./day under high flow conditions. Based on the best professional judgment of WDNR staff at the time, this translated to a 50% reduction in sediment to meet the narrative water quality criteria and improve Parsons Creek's habitat and the corresponding trout fishery.

Allocations for the UFWB TMDL are contained in Appendix I and an explanation of TSS/sediment targets used in the UFWB TMDL can be found in Section 2.5.2. The UFWB TMDL maximum daily load for Parsons Creek is 409 lbs./day; this represents a summation of subbasins 40, 41, and 42 minus the MOS. The difference in the maximum daily load between the two TMDLs can be attributed to a couple factors:

- The Parsons Creek TMDL used a variable concentration target at different flows producing different maximum daily loads at different flow conditions. The UFWB used one concentration target.
- The Parsons Creek TMDL used USGS flow data from 1997 – 2001. The UFWB TMDL used a longer flow record which included higher flows producing higher maximum daily loads.

The UFWB TMDL clearly defines the baseline condition from which a percent reduction was calculated. Subbasins 40, 41, and 42 will require 47%, 74%, and 17% reductions respectively from the baseline condition. Appendix J includes baseline, percent reductions, and the load allocation expressed as an edge of field target for each of the subbasins.

The UFWB TMDL is designed to meet water quality standards, has more current land use data reflecting updated management conditions, utilizes a longer flow record, and expresses the load allocation, baseline, and corresponding percent reductions at a field scale providing better support for nonpoint implementation. For these reasons, the WNDR will replace the Parsons Creek TMDL for TSS/sediment with the UFWB TMDL. The Parsons Creek TMDL report will be updated after the UFWB TMDL is approved by EPA, to reflect that the UFWB TMDL has replaced the Parsons Creek TMDL for TSS.

2.6.2 Parsons Creek Total Phosphorus TMDL

At the time of development of the Parsons Creek TMDL, the WDNR did not have promulgated numeric water quality criteria for total phosphorus. The Parsons Creek TMDL relied on target concentrations of 0.06 mg/L and 0.19 mg/L as a median and maximum target concentration under different flow conditions. It was estimated that a 50% reduction in loads would be needed to meet the water quality targets for phosphorus.

In 2010, Wisconsin adopted numeric water quality criteria for total phosphorus. As required by EPA, the UFWB TMDL was developed to meet the numeric water quality criteria. Allocations for the UFWB TMDL are contained in Appendix H and an explanation of the water quality criteria is contained in Section 2.2. The UFWB TMDL requires between a 52 and 78% reduction to meet water quality criteria in Parsons Creek. In order to meet water quality standards in downstream waters, additional reductions are required that bring the total reduction to 83%.

Because TMDLs must meet numeric water quality criteria, when available, the Parsons Creek TMDL for total phosphorus will be replaced with the UFWB TMDL. The Parsons Creek TMDL report will be updated after the UFWB TMDL is approved by EPA, to reflect that the UFWB TMDL has replaced the Parsons Creek TMDL for phosphorus.

2.6.3 Parsons Creek Ammonia TMDL

Since the UFWB TMDL does not address ammonia impairments, the Parsons Creek TMDL for ammonia will remain in effect. The Parsons Creek TMDL report will be updated after the UFWB TMDL is approved by EPA, to reflect that the UFWB TMDL has replaced the Parsons Creek TMDL for TSS and P, but not for ammonia.

3 WATERSHED CHARACTERIZATION

3.1 Watershed Setting

The 5,900 square mile UFWB is located in east-central Wisconsin and encompasses portions of eighteen counties (Adams, Calumet, Columbia, Dodge, Fond du Lac, Forest, Green Lake, Langlade, Marathon, Marquette, Menominee, Oneida, Outagamie, Portage, Shawano, Waupaca, Waushara, and Winnebago) and lands held by five tribes (Menominee Reservation, Sokaogon Chippewa Community, Stockbridge Munsee Community, Forest County Potawatomi Community, and Ho-Chunk Nation).

The UFWB is comprised of the Upper Fox River Basin and the Wolf River Basin (Figure 1). For this study, the Wolf River Basin is defined as the watershed extending from the headwaters of the Wolf River in Forest County south to the Wolf River confluence with Lake Butte des Morts in Winnebago County. The Upper Fox River Basin is defined as the watershed extending from the headwaters of the Upper Fox River in Columbia and Adams Counties northeast to the outlet of Lake Winnebago. The Upper Fox River Basin includes the Fond du Lac River watershed and the direct drainage area of Lake Winnebago.

Existing land use and land cover in the UFWB varies considerably throughout the basin. Forest and wetland cover predominate in the north in Forest, Oneida, Langlade, and Menominee Counties. The remainder of the basin is heavily farmed and primarily under row crop (corn and soybean) and forage (alfalfa) production as part of dairy farm operations. Major urban areas include the cities of Fond du Lac and Oshkosh on the shores of Lake Winnebago. A number of other smaller cities, towns, and villages are found throughout the basin.

Tables describing land use within each TMDL subbasin are provided in Appendix A.

Table 4. Summary of land use in the UFWB, including tribal lands. Based on the land cover dataset derived for watershed modeling described in Appendix C.

Land Use Category	Total UFWB		Wolf Basin		Upper Fox Basin	
	Acres	% Area	Acres	% Area	Acres	% Area
Forest	1,066,191	29%	836,231	36%	229,961	17%
Cropland	863,399	23%	443,148	19%	420,251	30%
Pasture/Grassland	676,448	18%	392,498	17%	283,950	21%
Wetland	712,066	19%	519,589	22%	192,477	14%
Open Water	239,602	6%	61,617	3%	177,985	13%
Urban (Non-Regulated)	154,990	4%	101,081	4%	53,908	4%
Urban (Regulated MS4)	27,222	1%	1,131	<1%	26,092	2%
TOTAL	3,739,919	-	2,355,295	-	1,384,624	-

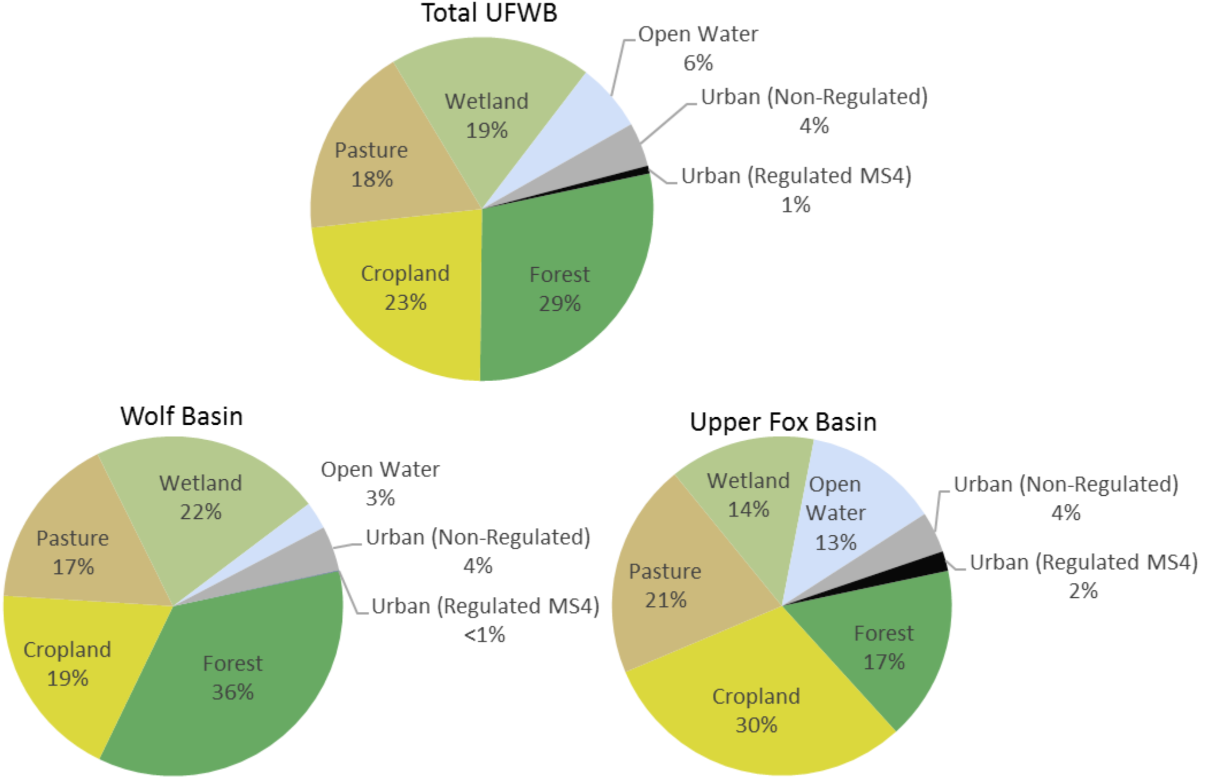


Figure 4. Summary of land use in the Upper Fox and Wolf Basins. Based on the land cover dataset derived for watershed modeling described in Appendix C.

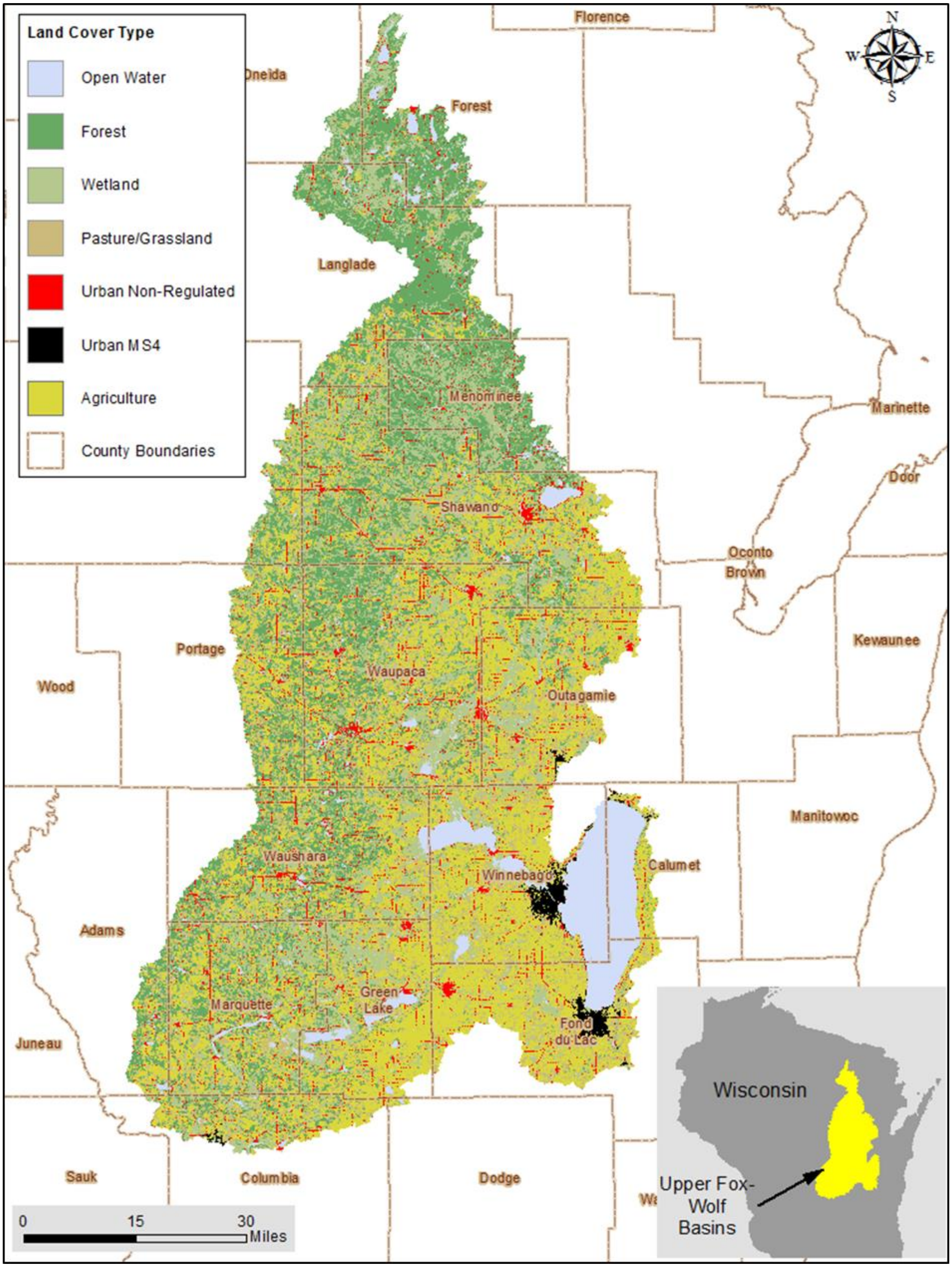


Figure 5. Land use in the Upper Fox and Wolf River Basins. Source data is the land cover dataset derived for watershed modeling described in Appendix C.

3.2 Hydrology and Water Resources

The UFWB contains a diverse network of rivers, streams, lakes, and reservoirs. The following sections describe the different categories of waterbodies addressed in this report.

3.2.1 Winnebago Pool Lakes

A major hydrologic feature of the UFWB is the Winnebago Pool (Figure 6). Located at the downstream end of the basin, the Winnebago Pool is a chain of four shallow lakes that cover approximately 259 square miles. From upstream to downstream the four lakes in the Winnebago Pool are:

- Lake Poygan (surface area = 22 square miles; mean depth = 5.9 feet);
- Lake Winneconne (surface area = 7 square miles; mean depth = 5.2 feet);
- Lake Butte des Morts (surface area = 13.5 square miles; mean depth = 5.2 feet);
- Lake Winnebago (surface area = 205 square miles; mean depth = 14.8 feet);

The major tributaries to the Winnebago Pool are the Wolf River draining into Lake Poygan, the Fox River draining into Lake Butte des Morts, and the Fond du Lac River draining into Lake Winnebago.

Water levels in the Winnebago Pool are regulated by a dam system that provides flood protection for residents and shoreland development. Dam outflows have been managed by the US Army Corps of Engineers since the late 1800's. The Winnebago Pool lakes serve as a principal water supply for approximately 250,000 people in Oshkosh, Neenah, Menasha and Appleton as well as numerous small communities in the watershed. They are also a key recreational resource for boaters and anglers from Wisconsin and other states.

3.2.2 Fox River and Wolf River Mainstem

The Fox River originates near the boundary of Columbia and Green Lake Counties, draining west to the city of Portage before turning north and east to empty into Lake Butte des Morts. The total length of the Fox River mainstem above Lake Butte des Morts is approximately 140 miles. The Fox River reemerges downstream of Lake Butte des Morts, flowing approximately 3 miles through the city of Oshkosh to Lake Winnebago. Mean annual streamflow measured at the USGS gaging station at the city of Berlin was approximately 1,450 cubic feet per second from 1980 through 2017. Streamflow typically peaks in the spring (late March to early June) and reaches lows during the late summer and late winter.

A number of lock and dam structures were constructed in the late 1800's to improve navigation for shipping boats and barges that altered the hydrologic regime of the Fox River. These included locks and dams at Governor's Bend, Montello, Grand River, Princeton, White River, Berlin and Eureka. WDNR has led projects to remove some of these dams but others remain. Dam construction flooded riparian and floodplain areas and created flowages and reservoirs such as Buffalo Lake and Lake Puckaway.

The Wolf River originates below Pine Lake in western Forest County and flows south across approximately 200 miles before emptying into Lake Poygan. Mean annual streamflow measured at the USGS gaging station at the city of New London was approximately 2,450 cubic feet per second from 1980 through 2017. Like the Fox River, streamflow reaches highs in the spring (late March to early June) and lows during the late summer and late winter.

Water quality in upper segments of the mainstem Wolf River is excellent and it is classified as an Outstanding Resource Water upstream of the Langlade-Menominee County line in Chapter NR 102 of Wisconsin Administrative Code and as a National Scenic River from the Langlade-Menominee County line south to Kenesha Falls.

Numerous man-made impoundments occur along the Wolf River. Unlike the Fox River dams which were constructed for navigation, many of the impoundments on the Wolf River were built to help transport fresh cut logs from the extensive logging industry that existed in the basin and for energy generation. These include the Balsam Row and Shawano Paper Mill Dams near the city of Shawano.

3.2.3 Tributary Rivers and Streams

Many tributary rivers and streams drain to the Fox River, Wolf River, and Winnebago Pool lakes. These tributaries offer a diverse range of fish habitat, including cold water trout streams, warm water sport fish streams, and warm water forage fish streams. Major tributaries to the Wolf River from upstream to downstream include the Red River, Shioc River, Embarrass River, Little Wolf River, and Waupaca River. Major tributaries to the Fox River from upstream to downstream include Neenah Creek, Montello River, Grand River, Mecan River, White River, and the Puchyan River. The Fond du Lac River drains approximately 2,000 square miles in the southeast corner of the Upper Fox Basin and discharges directly to Lake Winnebago.

3.2.4 Additional Lakes and Reservoirs

In addition to the Winnebago Pool, the UFWB contain numerous other lakes and reservoirs distributed throughout the basin. Eighteen of these additional lakes are addressed by this TMDL (Table 5) and they span a wide range of surface areas, mean depths, and hydrologic settings. The smallest lakes are less than 100 acres (Big Twin Lake, Black Otter Lake, Collins Lake, Long Lake, Old Taylor Lake, School Section Lake, Spring Lake, and Tree Lake) while others cover over 1,000 acres (Pine Lake, Buffalo Lake, Puckaway Lake, Shawano Lake, and Green Lake). Mean depths range from 3 to 5 feet in Puckaway Lake, Black Otter Lake, Old Taylor Lake, Lake Emily, and Buffalo Lake to 104 feet in Green Lake, the only two-story fishery lake (supporting both warm-water and cold-water species) in the group and the deepest natural inland lake in the state. Twelve lakes are drainage lakes, with surface water inflow and outflow from a river or stream. The remaining are seepage and spring lakes, which primarily receive inflow from precipitation, overland sheet flow from the watershed, and groundwater, rather than from a well-defined stream or river inflow.

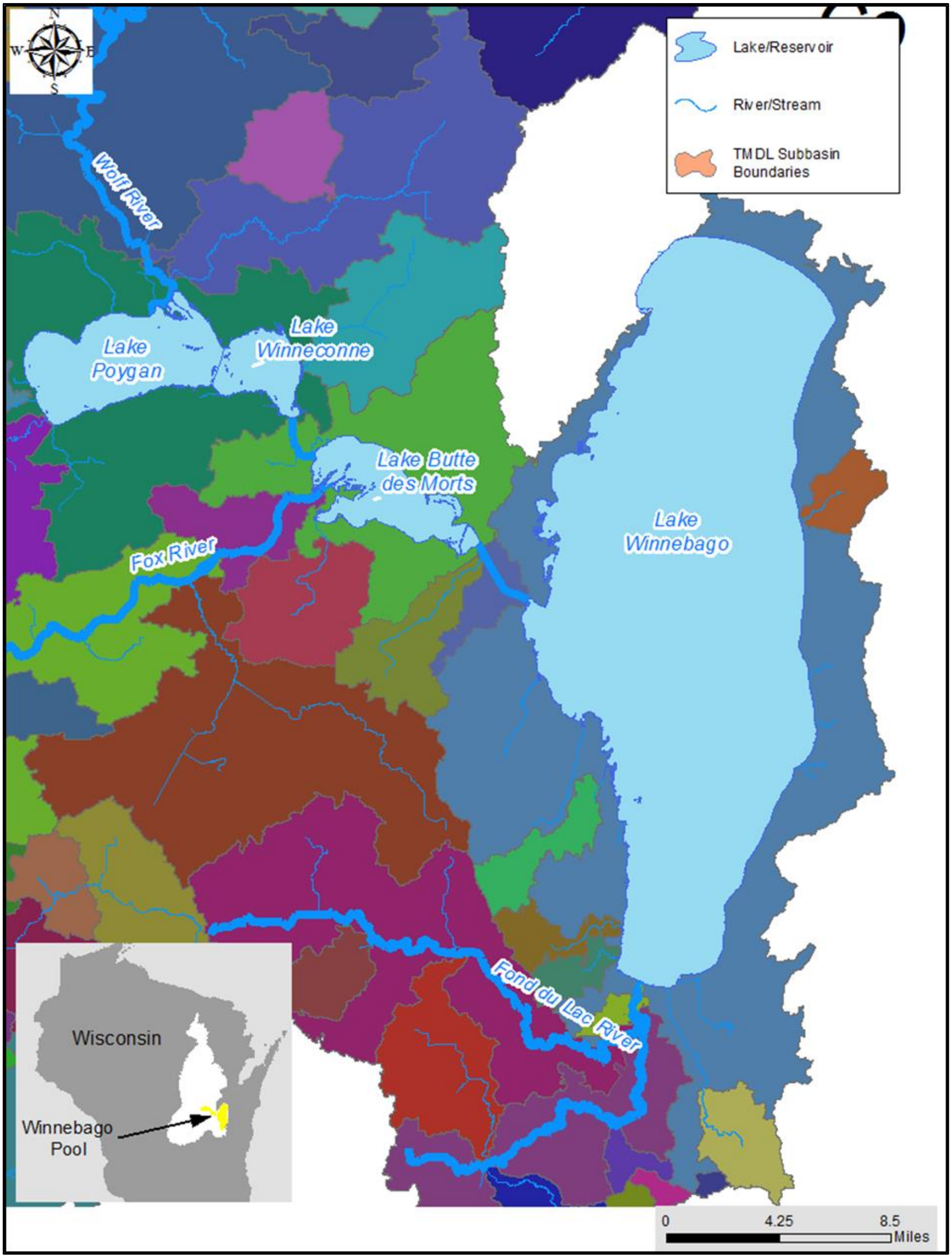


Figure 6. The Winnebago Pool: Lake Poygan, Lake Winneconne, Lake Butte des Morts, and Lake Winnebago.

Table 5. Lakes in the Upper-Fox Wolf Basins that are addressed in this TMDL report.

Lake Name	WATERS ID	WBIC	TMDL Subbasin	County	Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Hydrologic Lake Type
Big Twin Lake	11025	146500	83	Green Lake	78	16	46	Drainage
Black Otter Lake	9789	315600	82	Outagamie	75	5	9	Drainage
Buffalo Lake	11083	168000	9	Marquette	2,210	5	8	Drainage
Collins Lake	10319	270200	65	PORTAGE	42	25	56	Seepage
Green Lake	11023	146100	20	Green Lake	7,346	104	236	Drainage
Lake Butte des Morts	11004	139900	73	Winnebago	8,569	5	9	Drainage
Lake Emily	1525397	161600	84	Dodge	270	5	10	Spring
Lake Poygan	18137	242800	72	Waushara, Winnebago	14,024	6	11	Drainage
Lake Winnebago	358400	131100	75	Calumet, Fond du Lac, Winnebago	131,942	15	21	Drainage
Lake Winneconne	10749	241600	72	Winnebago	4,553	5	9	Drainage
Little Green Lake	18120	162500	11	Green Lake	466	10	28	Seepage
Long Lake	9816	321300	57	Shawano	86	19	35	Spring
Mason Lake	10733	175700	3	Adams, Marquette	856	7	9	Drainage
Old Taylor Lake	10274	195000	85	Waupaca	55	5	17	Seepage
Park Lake	18131	180300	5	Columbia	312	7	27	Drainage
Puckaway Lake	11081	158700	16	Marquette, Green Lake	5,039	3	5	Drainage
School Section Lake	10346	283600	62	Waupaca	37	19	38	Spring
Shawano Lake	9825	322800	56	Shawano	6,063	9	39.5	Drainage
Spring Lake	10311	267200	86	Portage	37	8	42	Spring
Swan Lake	10744	179800	6	Columbia	406	32	82	Drainage
Upper Post Lake	10650	399200	77	Langlade, Oneida	757	6	14	Drainage
White Clay Lake	11102	326400	54	Shawano	234	14	46	Spring

3.3 Ecological Landscapes

The UFWB spans portions of seven distinct ecological landscapes (WDNR, 2016): North Central Forest, Forest Transition, Northeast Sands, Northern Lake Michigan Coastal, Central Lake Michigan Coastal, Central Lake Michigan Coastal North Central Forest, Central Sand Hills , and Southeast Glacial Plains (Figure 7). General characteristics of the climate, topography, soils, and land cover of each ecological landscape are described in the following subsections.

3.3.1 North Central Forest

Covering the northern portion of the Wolf River Basin, the North Central Forest region is dominated by mesic northern hardwood forest. Forested and non-forested wetland communities are common and widespread. These include northern wet-mesic forest, northern wet forest, and non-forested acid peatlands (bogs, fens, and muskegs). Other relatively common wetland communities are alder thicket, sedge meadow, and marsh.

Landforms are characterized by end and ground moraines with some pitted outwash and bedrock-controlled areas. Kettle depressions are widespread and steep. Soils consist of sandy loams, sands, and silts. Organic soils (peats and mucks) are common in poorly drained lowlands. The region is predominantly underlain by igneous and metamorphic rock, generally covered by 5 to 100 feet of glacial drift deposits.

Climate is cooler than other ecological landscapes, with the mean growing season length at 115 days and a mean annual temperature of 40.3 degrees Fahrenheit. Summer temperatures can be cold or freezing at night in low-lying areas, limiting the occurrence of some biota. Mean annual precipitation is 32.3 inches, and mean annual snowfall is 63 inches. The cool temperatures and short growing season are not conducive to supporting agricultural row crops, such as corn.

3.3.2 Forest Transition

The Forest Transition region covers much of the headwater portions of the western tributaries of the Wolf River, including the Red River, Embarrass River, Little Wolf River, and Waupaca River headwaters. Land cover is a mixture of mesic forest and agriculture. The Forest Transition region was entirely glaciated and is covered by deposits of the Wisconsin glaciation. Glacial till is the major type of material deposited throughout, and the prevalent landforms are till plains or moraines. Throughout the area, postglacial erosion, stream cutting, and deposition formed floodplains, terraces, and swamps along major rivers.

Most soils are moderately well-drained sandy loams derived from glacial till, but there is considerable diversity in the range of soil attributes. The area includes sandy soils formed in outwash as well as organic soils and loam and silt loam soils on moraines. Density of the glacial till is generally high enough to impede internal drainage, so there are many lakes and wetlands in parts of the Forest Transition (e.g., in those that were more recently glaciated). Soils throughout the ecological landscape have silt loam surface deposits formed in aeolian loess, which is about 6 to 24 inches thick in much of the area.

The Forest Transition region straddles a major ecoclimatic zone (the “Tension Zone”) that runs southeast-northwest across the state. The mean growing season is 133 days, mean annual temperature is 41.9°F, mean annual precipitation is 32.6 inches, and mean annual snowfall is 50.2 inches. The growing season is long enough that agriculture is viable, although climatic conditions are not as favorable for many crops as they are in southern Wisconsin.

3.3.3 Northeast Sands

The Northeast Sands region encompasses a small segment of the mainstem Wolf River and surrounding area in the north-central part of the basin, from approximately the Evergreen River confluence to the Red River confluence. Forest cover predominates, with aspen, dry forests dominated by scrub-oak and jack pine, hemlock-hardwoods, and northern hardwoods among the important forest types in the Northeast Sands. Common lowland communities include wet-mesic forests dominated by northern white-cedar, black spruce-tamarack swamps, or alder dominated shrub swamps.

The Green Bay Lobe covered this ecological landscape during the last part of the Wisconsin glaciation. As the Green Bay Lobe melted and retreated eastward, outwash was deposited over lower-lying surface features, so the ecological landscape now appears as a nearly level-to-rolling sandy outwash plain, pitted in places, with sandy heads-of-outwash and loamy moraines protruding through the outwash sediments. Heads-of-outwash, uncommon in most of Wisconsin, are a distinctive glacial feature here. A series of north-south trending morainal and head-of-outwash hills runs the length of the west side of the Northeast Sands. They are oriented in roughly parallel positions, marking the outer extent of Green Bay Lobe deposits in northeastern Wisconsin.

Most upland soils formed in acid outwash sand on outwash plains or outwash heads. The dominant soil is excessively drained and sandy with a loamy sand surface, rapid permeability, and very low available water capacity. More than half the land surface is made up of outwash sand and gravel. Glacial till deposits here have pH values that are neutral to calcareous, unlike the acid tills of most of northern Wisconsin.

3.3.4 Northern Lake Michigan Coastal

The Northern Lake Michigan Coastal region covers a portion of the mainstem Wolf River (south of the Red River confluence), the middle section of the Embarrass River, and the headwaters of the Shioc River. Historically, the uplands were almost entirely covered by forest. Today most of this land is now in agricultural crops, with smaller amounts of forest, grassland, non-forested wetlands, shrubland, and urbanized areas. Generally, the land is covered by a layer of soils of glacial origin and ground moraine is the dominant landform. The ground moraine is composed mostly of moderately well-drained, rocky sandy loams, interspersed with lacustrine sands and clays.

The mean growing season is 140 days, mean annual temperature is 42.8°F, mean annual precipitation is 32.1 inches, and mean annual snowfall is 46 inches. Rainfall and growing degree days are adequate to support agricultural row crops, small grains, hay, and pastures.

3.3.5 Central Lake Michigan Coastal

The Central Lake Michigan Coastal region covers a portion of the mainstem Wolf River (from south of the city of Shawano to the Embarrass River confluence), and the lower portions of the Embarrass River, Little Wolf River, and Shioc River watersheds. Agriculture is the dominant land use here, though some large forest and wetlands occur in the Wolf River Bottoms State Natural Area and Navarino State Wildlife Area.

Landforms are mostly glacial in origin, especially till plains and moraines, reworked and overlain by Glacial Lake Oshkosh. Beach ridges, terraces, and dunes formed near the shorelines of this glacial lake when sandy sediments were present. At other locations, boulder fields were formed when silts and clays were removed by wave action. Most upland soils are reddish-brown calcareous loamy till or lacustrine deposits on moraines and till plains. Dominant soils are loamy or clayey with a silt loam surface with moderately slow permeability and high available water capacity.

Mean growing season is 160 days (second longest in the state), mean annual temperature is 45.1°F, mean annual precipitation is 31.1 (second lowest in the state), and mean annual snowfall is 43.4 inches. Rainfall and growing degree days are conducive to supporting row crops, small grains, and pastures.

3.3.6 Central Sand Hills

The Central Sand Hills region encompasses the headwaters and middle sections of the Upper Fox River Basin to approximately the city of Berlin. Land cover is a patchy mixture of forest, wetland, agriculture, and urban areas. Larger patches of natural cover appear in the western headwaters of the Fox River.

The landforms in this ecological landscape include a series of glacial moraines: the Johnstown Moraine is the terminal moraine of the Green Bay Lobe; the Arnott Moraine is older and has more subdued topography. Pitted outwash is extensive in some areas. Glacial tunnel channels occur here, e.g., in Waushara County. Soils are primarily sands. Organic soils underlie wetlands such as tamarack swamps and sedge meadows. Muck farming (on drained peatlands) still occurs in some areas.

The Central Sand Hills has a mean growing season of 144 days, mean annual temperature of 44.8°F, mean annual precipitation of 33 inches, and mean annual snowfall of 44 inches. Although the climate is suitable for agricultural row crops, small grains, and pastures, the sandy soils somewhat limit agricultural potential.

3.3.7 Southeast Glacial Plains

The Southeast Glacial Plains covers the lower portions of the Wolf River Basin, the Upper Fox River Basin, the direct drainage area of the Winnebago Pool lakes, and the Fond du Lac River watershed. Land cover is heavily agricultural cropland. Remaining forests occupy only a small portion of the land area. Wetlands are more extensive and include large marshes and sedge meadows and extensive forested lowlands within the lower Wolf River floodplain. This region also includes the urban centers of Fond du Lac and Oshkosh.

The dominant landforms are glacial till plains and moraines composed mostly of materials deposited during the Wisconsin glaciation. Other glacial landforms, including drumlins, outwash plains, eskers, kames, and kettles, are also well represented. Soils are derived from lime-rich tills overlain in most areas by a silt-loam loess cap.

The climate is typical of southern Wisconsin; mean growing season is 155 days, mean annual temperature is 45.9°F, mean annual precipitation is 33.6 inches, and mean annual snowfall is 39.4 inches. The climate is suitable for agricultural row crops, small grains, and pastures, which are prevalent in this ecological landscape.

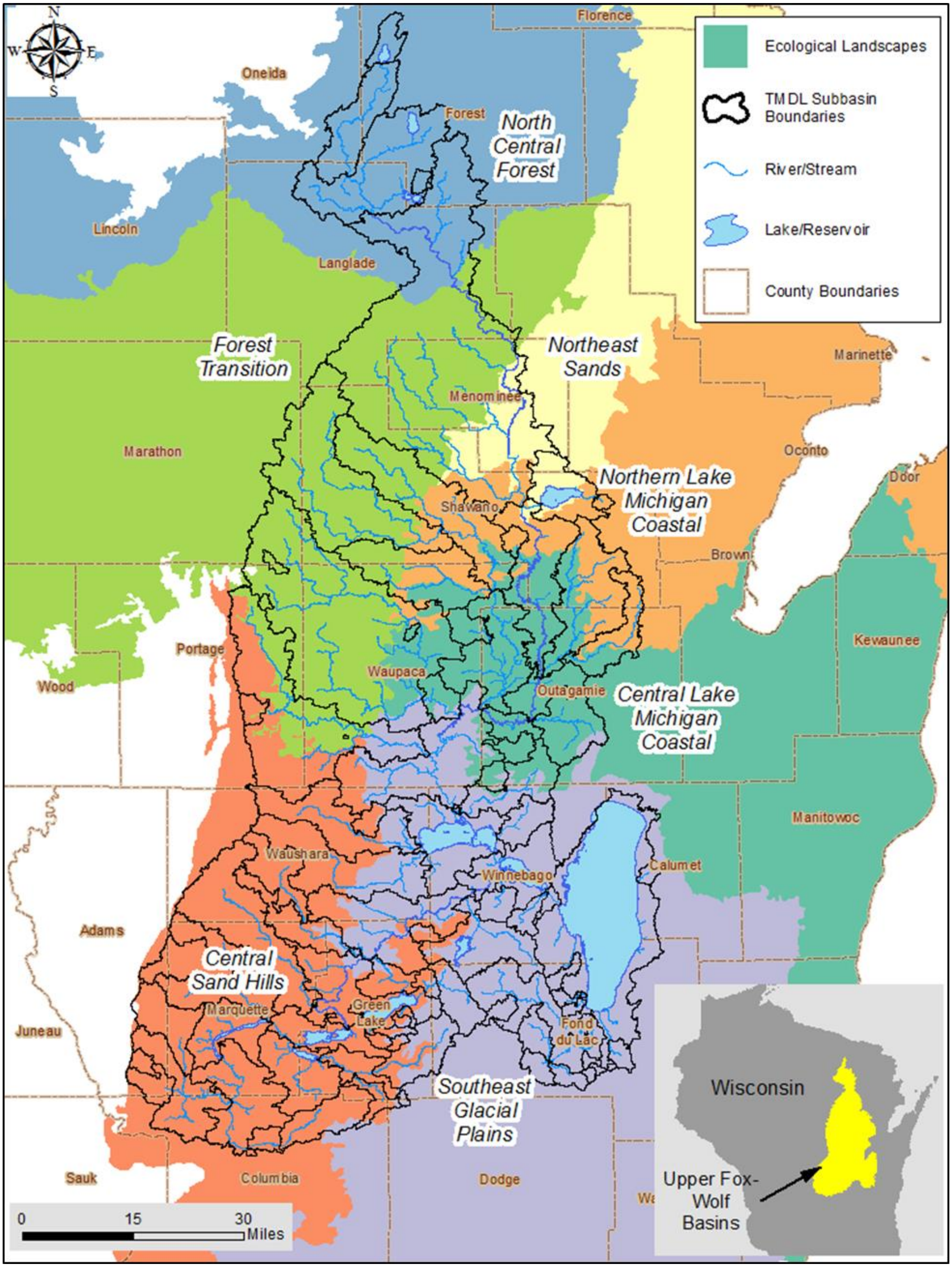


Figure 7. Ecological landscapes within the Upper Fox-Wolf Basins.

3.4 Water Quality

Phosphorus and sediment concentrations in UFWB waterbodies are sampled by WDNR and partner groups as part of the WDNR water quality monitoring program. The following subsections summarize these water quality monitoring data. The data summary is intended to provide a general overview of the range of observed water quality throughout the UFWB and geographic patterns.

3.4.1 Total Phosphorus

TP sample data have been collected at hundreds of monitoring sites in the UFWB over the past decades. For this summary, TP sample data from streams and rivers in the WDNR Surface Water Integrated Monitoring System (SWIMS) database were reviewed and 32 monitoring sites with at least 10 samples collected from more than one year during 2000 through 2014 were selected for reporting. Growing season (May through October) median TP concentrations for these 32 stream and river monitoring sites are listed in Table 6 and mapped in Figure 8 and Figure 9.

Stream and river sample data show that TP concentrations are generally lower in the Wolf Basin compared to the Fox Basin. Only one site in the Wolf Basin has a median TP concentration above its water quality criterion (Bear Creek at STH 76; median TP = 166 micrograms per liter [µg/L]). However, TP conditions in the Wolf River and its tributaries appear to become degraded downstream of their forested headwaters. For example, median TP in the Wolf River is 29 µg/L at the Langlade site and increases downstream to 74 µg/L at the New London site. Similarly, median TP in the Embarrass River is 40 µg/L at the Village of Embarrass site and increases to 83 µg/L at the New London site.

Sixteen of the 22 stream and river monitoring sites in the Upper Fox Basin have median TP above water quality criteria, with median concentrations as high as 306 µg/L at the West Branch Fond du Lac River site. In the Fox River, phosphorus levels appear to be elevated throughout most of its length, with median TP at the four Fox River sites ranging from 86 to 109 µg/L.

TP sample data for the Winnebago Pool lakes and other lakes and reservoirs addressed in this report are summarized in Table 7 and mapped in Figure 8 and Figure 9. The monitoring data summarized in this section for the Winnebago Pool Lakes were collected as part of a study documented in Appendix E. Monitoring data for the remaining lakes were compiled from the WDNR SWIMS database. Summer (June through September) mean TP concentrations in the Winnebago Pool lakes during 2009 through 2011 were 97 µg/L in Lake Winnebago, 104 µg/L in Lake Butte des Morts, 88 µg/L in Lake Winneconne, and 94 µg/L in Lake Poygan. All of these concentrations are above their water quality criterion of 40 µg/L. Summer mean TP concentrations in other lakes range from 17 µg/L in Green Lake to 135 µg/L in Buffalo Lake.

Table 6. Median growing season total phosphorus (TP) concentrations for stream and river monitoring sites in the Upper Fox-Wolf Basins. Sites are labeled in Figure 8 and Figure 9 using their Map ID. Concentrations marked with an asterisk (*) are above TP criteria.

Map ID	SWIMS Station ID	Station Name	TMDL Subbasin	Basin	Period of Record	No. Samples	TP (µg/L)	TP Criterion (µg/L)
1	453259	Bear Creek at St Hwy 76	52	Wolf	2009-2013	12	166*	75
2	10007739	De Neveu Creek at 4th St (Cth T)	75	Upper Fox	2007-2013	12	164*	75
3	10029782	East Branch Fond du Lac River Morris Court 200 yds east	43	Upper Fox	2012-2013	11	203*	75
4	593162	Embarrass River - Near Embarrass WI USGS Site ID 04078500	59	Wolf	2003-2012	45	40	75
5	10033493	Embarrass River at New London Hwy 54	70	Wolf	2011-2012	35	83	100
6	593164	Embarrass River Middle Branch at Weasel Dam Road	58	Wolf	2005-2007	10	64	75
7	10022877	Fond du Lac River at W. Arndt St. USGS Site ID 04083545	88	Upper Fox	2008-2011	62	249*	75
8	713056	Fox River - A Main St Bridge Oshkosh	74	Upper Fox	2005-2014	60	95	100
9	10033616	Fox River - Center near Wicks Landing	24	Upper Fox	2011-2014	39	101*	100
10	10033617	Fox River - near Grand River	16	Upper Fox	2011-2014	38	86*	75
11	243020	Fox River at Berlin WI USGS Site ID 04073500	28	Upper Fox	2005-2014	80	109*	100
12	10033618	Grand River - Near Fox River	15	Upper Fox	2011-2014	36	108*	75
13	243015	Grand River at Cth H Near Kingston WI	14	Upper Fox	2006-2008	10	136*	75
14	243034	Green Lake Inlet (Silver Creek) at Cth A, Green Lake WI	20	Upper Fox	2002-2011	274	133*	75
15	10034898	Green Lake Inlet Silver Creek (USGS Site 2)	20	Upper Fox	2006-2012	29	114*	75
16	10034899	Green Lake Inlet Silver Creek (USGS Site1)	20	Upper Fox	2006-2012	28	134*	75
17	693217	Little Wolf River at Royalton WI USGS Site ID 04080000	61	Wolf	2003-2012	46	43	100
18	10022879	Montello River At 11th St. Bridge USGS Site ID 04072845	10	Upper Fox	2008-2011	66	66	75
19	593131	Pickerel Creek at James St Cecil	56	Wolf	2008-2014	12	51	75
20	243048	Puchyan River at Green Lake WI	25	Upper Fox	2003-2012	53	41	75
21	10022878	Puchyan River at N. Lawson St. Bridge USGS Site ID 04073473	25	Upper Fox	2008-2011	62	51	75
22	10021317	Roy Creek 200 Feet Above Cth O	17	Upper Fox	2011-2014	64	106*	75
23	10017340	Silver Creek at Spaulding Road	20	Upper Fox	2006-2014	115	136*	75
24	10014656	Spring Brook at Hwy 21	31	Upper Fox	2006-2013	13	244*	75
25	10012583	Unnamed Creek (Wuerches Creek) North Side of Cth B Near St Hwy 73	18	Upper Fox	2006-2011	15	114*	75
26	713285	Waukau Creek at Cth E USGS Site ID 04073970	27	Upper Fox	2006-2011	68	121*	75
27	693161	Waupaca River at Harrington Rd USGS Site ID 04081000	66	Wolf	2007-2012	40	44	75
28	10031557	West Branch of Fond du Lac at Estabrook Park	44	Upper Fox	2012-2013	10	306*	75
29	243047	White Creek at Mouth of Green Lake	20	Upper Fox	2003-2012	141	38	75
30	343033	Wolf River - Downstream of St Hwy 64 At Langlade WI	55	Wolf	2005-2014	60	29	100
31	693035	Wolf River at New London	71	Wolf	2005-2014	60	74	100
32	693218	Wolf River at New London WI USGS Site ID 04079000	71	Wolf	2003-2012	45	74	100

Table 7. Mean summer total phosphorus (TP) concentrations for lakes and reservoirs in the Upper Fox-Wolf Basins that are addressed in this TMDL report. Lakes are labeled in Figure 8 and Figure 9 using their Map ID. Concentrations marked with an asterisk (*) are above TP criteria.

Map ID	SWIMS Station ID(s)	Lake Name	TMDL Subbasin	Basin	Period of Record	TP (µg/L)	TP Criterion (µg/L)
33	243018	Big Twin Lake	83	Upper Fox	2004-2009	43*	30
34	453121	Black Otter Lake	82	Wolf	2002-2013	100*	40
35	393133; 393134; 393135	Buffalo Lake	9	Upper Fox	2000-2001	135*	40
36	503139	Collins Lake	65	Wolf	2009-2013	27*	20
37	243021; 243049	Green Lake	20	Upper Fox	2009-2013	17*	15
38	N/A	Lake Butte des Morts	73	Upper Fox	2009-2011	104*	40
39	143274	Lake Emily	84	Upper Fox	2005-2013	64*	40
40	N/A	Lake Poygan	72	Wolf	2009-2011	94*	40
41	243039; 243041; 243056	Lake Puckaway	16	Upper Fox	2009-2013	142*	40
42	N/A	Lake Winnebago	75	Upper Fox	2009-2011	97*	40
43	N/A	Lake Winneconne	72	Wolf	2009-2011	88*	40
44	243022; 243037	Little Green Lake	11	Upper Fox	2011-2013	96*	40
45	593003	Long Lake	57	Wolf	2008-2013	35*	30
46	13029	Mason Lake	3	Upper Fox	2008-2013	125*	40
47	693166	Old Taylor Lake	85	Wolf	2003-2005	49*	20
48	113078	Park Lake	5	Upper Fox	2009-2013	106*	40
49	693025	School Section Lake	62	Wolf	2009-2013	35*	30
50	593072	Shawano Lake	56	Wolf	2007-2013	44*	40
51	503141	Spring Lake	86	Wolf	2012-2013	30*	15
52	113076	Swan Lake	6	Upper Fox	2006-2013	30	30
53	343136	Upper Post Lake	77	Wolf	2010-2013	46*	40
54	593121	White Clay Lake	54	Wolf	2010-2013	39*	30

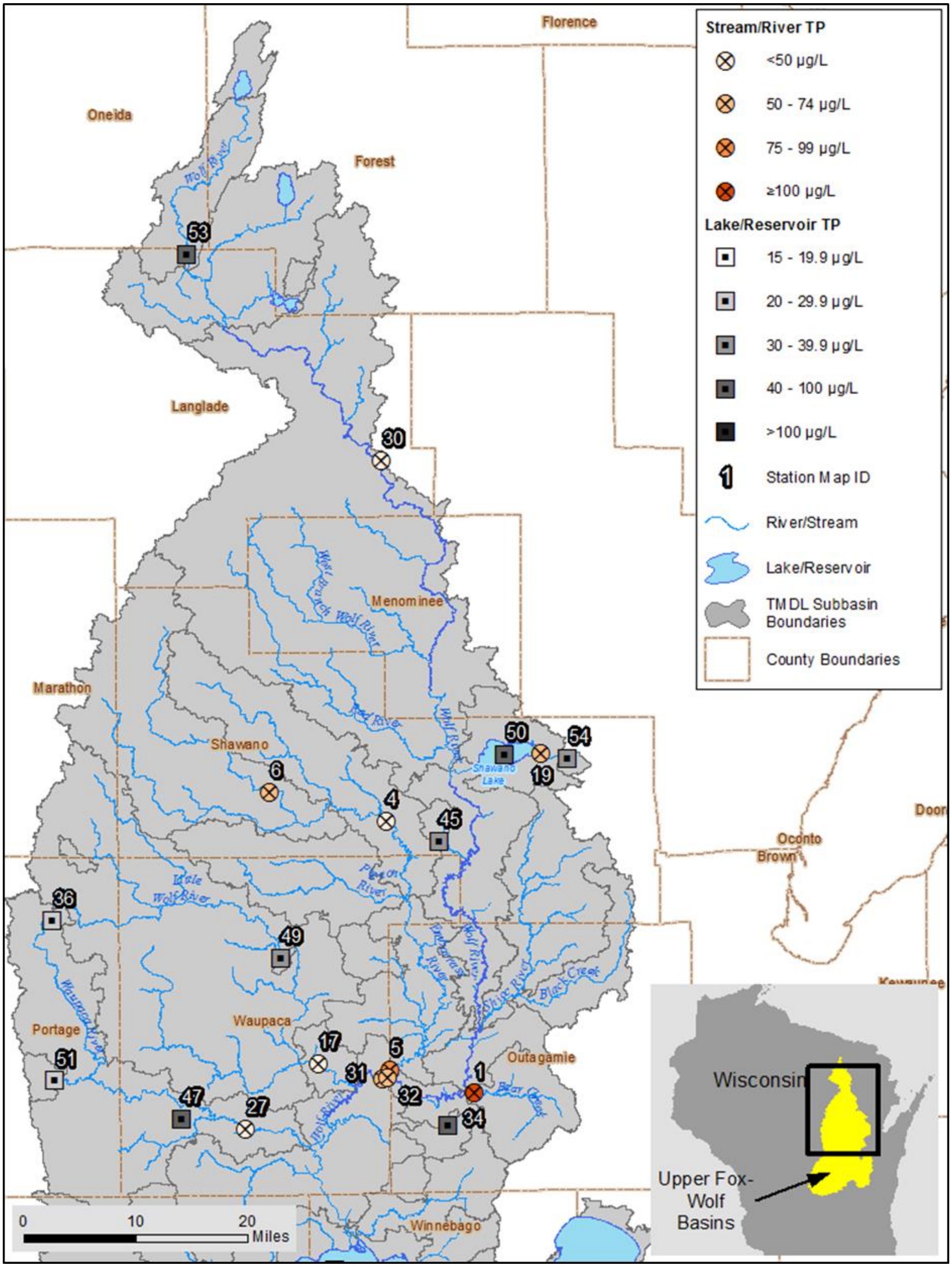


Figure 8. Total phosphorus (TP) concentrations at monitoring sites in the Wolf Basin. TP values are May through October medians for stream and river sites and June through September means for lake and reservoir sites.

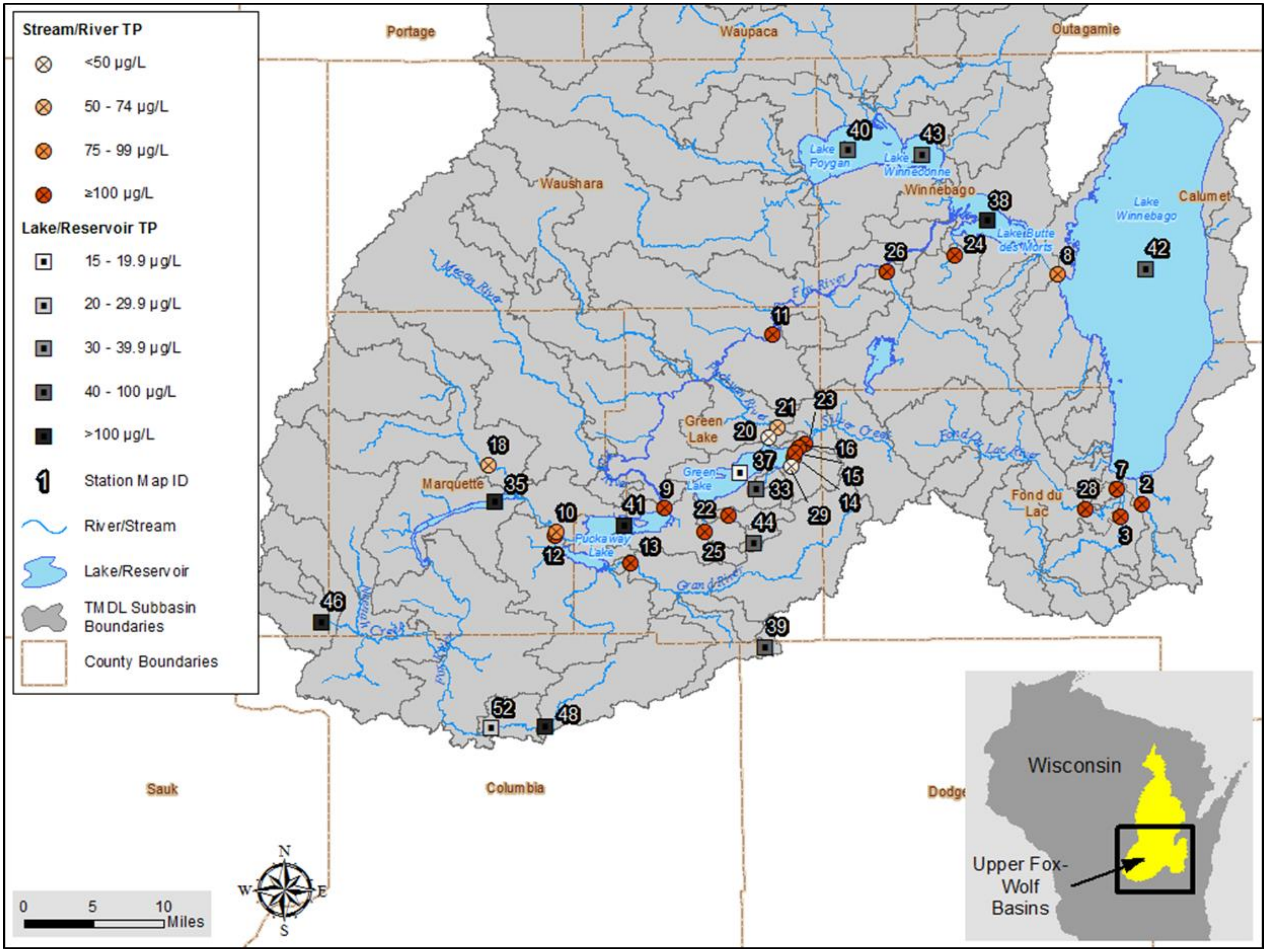


Figure 9. Total phosphorus (TP) concentrations at monitoring sites in the Upper Fox Basin. TP values are May through October medians for stream and river sites and June through September means for lake and reservoir sites.

3.4.2 Total Suspended Solids

Total suspended solids (TSS) sample data have been collected at fewer monitoring sites in the UFWB relative to TP. Thirty-four stream and river sites in the WDNR SWIMS database were identified with TSS sample data collected during 1997 through 2014. Growing season (May through October) median TSS concentrations for these stream and river monitoring sites are listed in Table 8 and mapped in Figure 10 and Figure 11.

Like phosphorus, elevated TSS concentrations in the Wolf Basin appear to occur more frequently in stream and rivers in the lower portion of the basin where agriculture and development are more prominent. Monitoring sites in the upper and middle sections of the Wolf Basin (above the Shioc River confluence) have median TSS concentrations which are all below the 12 mg/L target, ranging from 3.6 to 8 mg/L. In the lower portion of the basin, median TSS ranges from 6 to 24 mg/L and six of the 10 sites are above the 12 mg/L target, including sites on the Wolf River, Little Wolf River, and Embarrass River.

Median TSS concentrations in the Upper Fox Basin are as low as 3.2 mg/L at the Puchyan River site and up to 31.9 mg/L at the Fox River at Berlin. Eight of the 15 sites in the Fox Basin have median TSS above the 12 mg/L target. These include sites along the Fox River mainstem, one Fox River tributary (Belle Fountain Creek), and sites on streams and rivers in the southeast section of the basin in the Lake Winnebago direct drainage area (Parsons Creek, De Neveu Creek, and East Branch Fond du Lac River).

Table 8. Median growing season total suspended solids (TSS) concentrations for stream and river monitoring sites in the Upper Fox-Wolf Basins. Sites are labeled in Figure 10 and Figure 11 using their Map ID. Concentrations marked with an asterisk (*) are above the 12.0 mg/L TSS target.

Map ID	SWIMS Station ID	Station Name	TMDL Subbasin	Basin	Years Sampled	No. Samples	TSS (mg/L)
1	713265	Arrowhead River - S of Oakridge (Lakeview) Road	51	Wolf	2006-2007	7	5.8
2	453259	Bear Creek at Sth 76	52	Wolf	2009-2013	12	5.9
3	243028	Belle Fountain Creek at Cth B	15	Upper Fox	2008-2009	7	15.5*
4	10007739	De Neveu Creek at 4th St (Cth T)	75	Upper Fox	2007-2008	6	22.5*
5	10014745	East Branch Fond du Lac River Immediately Below 12 St.	43	Upper Fox	2006-2013	8	19.0*
6	593162	Embarrass River - Near Embarrass WI USGS Site ID 04078500	59	Wolf	2010-2012	35	4.7
7	593168	Embarrass River at Cth M	59	Wolf	2005-2006	9	8.0
8	10033493	Embarrass River at New London Hwy 54	70	Wolf	2011-2012	34	24.2*
9	593164	Embarrass River Middle Branch at Weasel Dam Road	58	Wolf	2005-2007	10	7.0
10	10022877	Fond du Lac River At W. Arndt St. USGS Site ID 04083545	88	Upper Fox	2008-2011	62	8.7
11	713056	Fox River - A Main St Bridge Oshkosh	74	Upper Fox	2005-2014	60	19.2*
12	243020	Fox River at Berlin WI USGS Site ID 04073500	28	Upper Fox	2007-2014	77	31.9*
13	693217	Little Wolf River - Hwy 54 (at Royalton WI USGS Site ID 04080000)	61	Wolf	2010-2012	37	7.8
14	10022879	Montello River At 11th St. Bridge USGS Site ID 04072845	10	Upper Fox	2008-2011	63	7.3
15	393013	Neenah Creek - Hwy 23	4	Upper Fox	2008-2009	7	5.2
16	203104	Parsons Creek - 100 Feet Above Cth B	42	Upper Fox	1997-2001	69	21.6*
17	203103	Parsons Creek - Middle Site Near Fond du Lac WI	42	Upper Fox	1997-2005	69	20.8*
18	203102	Parsons Creek Upstream Hickory Rd	42	Upper Fox	2005-2013	7	12.3*
19	693135	Pigeon River at Klemp Road	60	Wolf	2005-2006	9	3.7
20	10022878	Puchyan River At N. Lawson St. Bridge USGS Site ID 04073473	25	Upper Fox	2008-2011	33	3.2
21	10016643	S. Branch Little Wolf R. - 20 Feet Upstream From Bridge Sunnyview Rd.	81	Wolf	2009-2010	6	15.4*
22	10042142	Schoenick Creek 100m ds Long Lake Confluence	67	Wolf	2014-2014	6	6.2
23	10042141	Schoenick Creek 175m US Long Lake Confluence	57	Wolf	2014-2014	6	7.9
24	453030	Shioc River at Sth 187 Bridge	53	Wolf	2009-2010	6	8.7
25	10014656	Spring Brook At Hwy 21	31	Upper Fox	2006-2013	13	5.7
26	713285	Waukau Creek at Cth E USGS Site ID 04073970	27	Upper Fox	2006-2011	68	8.1
27	693161	Waupaca River at Harrington Rd (USGS Site ID 04081000)	66	Wolf	2007-2012	40	10.6
28	10019838	Wolf River -- Canoe Launch	67	Wolf	2009-2010	6	3.6
29	593143	Wolf River - Cth A	55	Wolf	2010-2011	6	6.6
30	343033	Wolf River - Downstream Of Sth 64 At Langlade WI	55	Wolf	2005-2014	51	4.2

Map ID	SWIMS Station ID	Station Name	TMDL Subbasin	Basin	Years Sampled	No. Samples	TSS (mg/L)
31	10019616	Wolf River -- Gills Landing Access	71	Wolf	2010-2011	6	12.7*
32	10019350	Wolf River -- Shaw Landing Access	71	Wolf	2010-2011	6	17.8*
33	693035	Wolf River at New London	71	Wolf	2005-2014	60	15.4*
34	693218	Wolf River at New London WI USGS Site ID 04079000	71	Wolf	2010-2012	39	13.9*

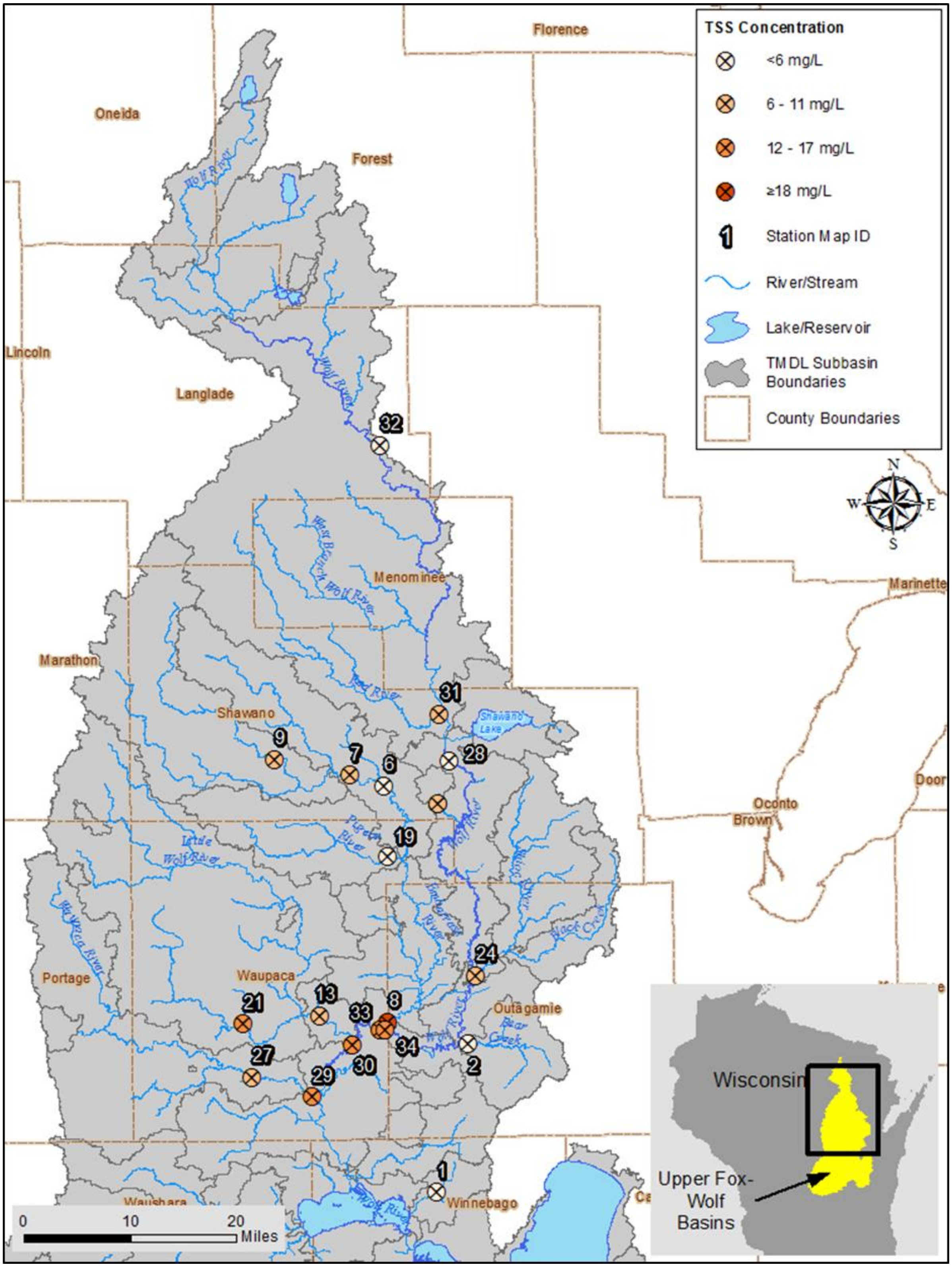


Figure 10. Total suspended solids (TSS) concentrations at monitoring sites in the Wolf Basin. TSS values are May through October medians.

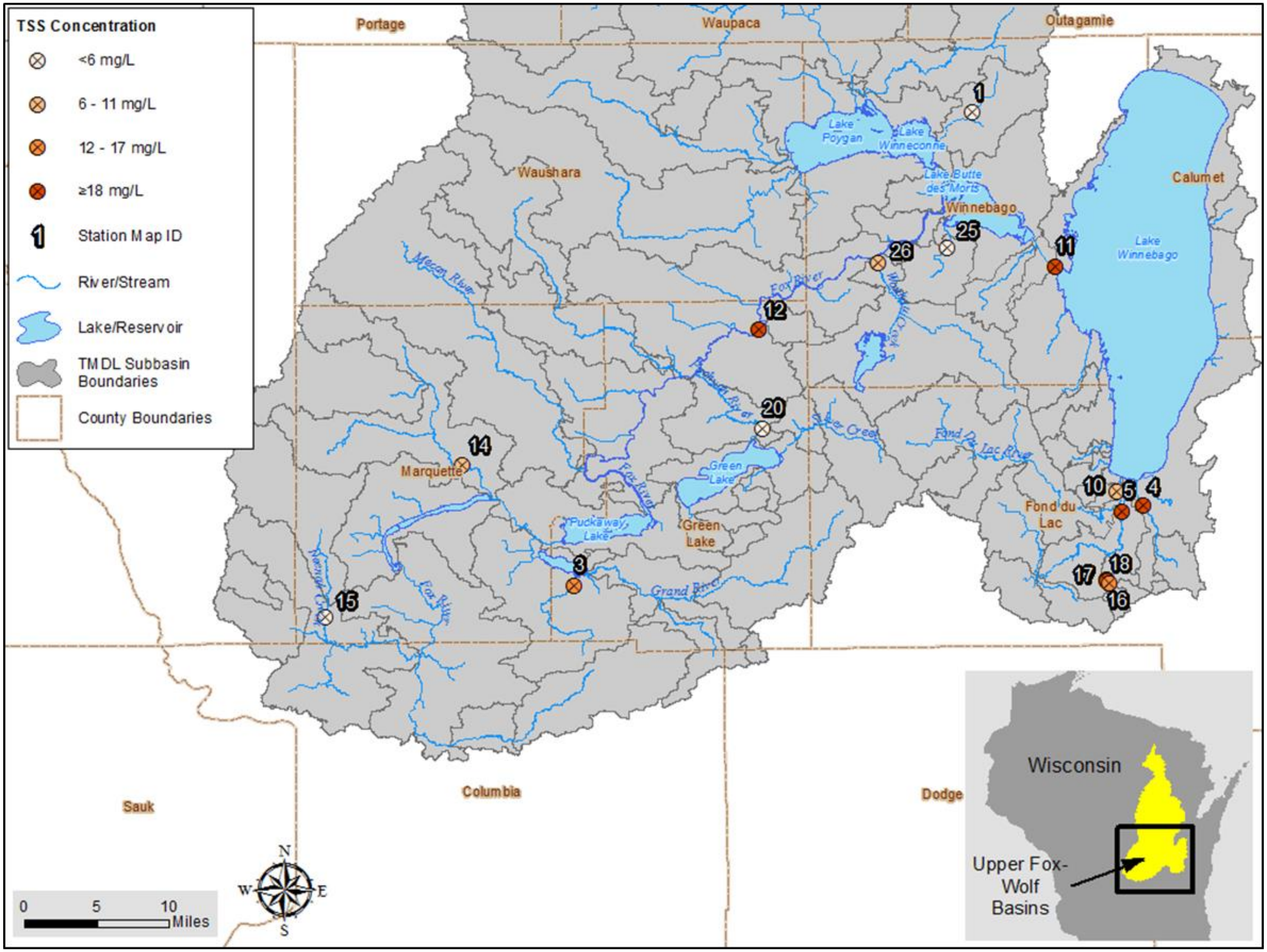


Figure 11. Total suspended solids (TSS) concentrations at monitoring sites in the Upper Fox Basin. TSS values are May through October medians.

4 SOURCE ASSESSMENT

4.1 Review of Phosphorus and Sediment Sources

There are two general types of water pollution: point source and nonpoint source. The Clean Water Act defines a point source of pollution as any discrete conveyance that discharges polluted material, such as a pipe or ditch that discharges treated effluent from a municipal wastewater treatment facility (WWTF) into a surface water. Nonpoint sources of pollution include any sources that do not meet the definition of a point source, such as runoff from agricultural lands. This section provides a general description of point and nonpoint sources of phosphorus and sediment to surface waters in the UFWB. Section 4.2 of this report provides further discussion of how loads from each source were quantified for TMDL development. Additional information on sources of pollution to surface waters and loading mechanisms can be found in Carpenter et al. (1998), Sims et al. (1998), and Steele et al. (2010).

4.1.1 Point Sources

Point sources of phosphorus and sediment discharge from a discrete conveyance and are regulated by WDNR under the Wisconsin Pollutant Discharge Elimination System (WPDES) program. The UFWB also includes point sources on tribal lands that are regulated under the EPA National Pollutant Discharge Elimination System (NPDES) program. Several subtypes of point sources are present in the UFWB and are described in the following paragraphs.

Publicly Owned Treatment Works

The term Publicly Owned Treatment Works (POTWs) refers to a sewage treatment plant that is owned and operated by a government entity, typically a city, town, or other local government. POTWs receive domestic and industrial wastewater via sewer systems; treat the wastewater to reduce or remove solid and chemical contaminants; and typically discharge treated effluent to surface waters. Raw sewage contains very high levels of suspended solids and phosphorus. Although these levels are reduced during treatment, suspended solids and phosphorus are present in the treated effluent discharged to surface waters.

Industrial Facilities

As part of their manufacturing process, many industrial facilities generate wastewater that contains sediment/suspended solids and/or phosphorus. This wastewater may be discharged to a POTW or be treated by the industry and discharged directly into a nearby surface water. Examples include water used to wash manufacturing equipment or fruits and vegetables as part of food processing.

Regulated Stormwater

As described here, stormwater refers to runoff that is generated from surfaces that have been affected by human development (e.g., parking lots, roads, lawns, exposed soils). These surfaces typically accumulate solid particles (dust, small rocks, plant matter, etc.) that are carried into waterbodies with stormwater. Some of these solid particles, such as soil or plant matter, also contain phosphorus. Other sources of elevated phosphorus in stormwater can include lawn fertilizers and pet waste.

Even though stormwater is driven by precipitation and fits the description of nonpoint source pollution, certain stormwater discharges to surface water are regulated under the WPDES program and are therefore considered point sources for TMDL development. Stormwater drainage systems (ditches, curbs, gutters, storm sewers, etc.) that are publicly-owned and do not connect with a wastewater collection system are termed Municipal Separate Storm Sewer Systems (MS4s). Most MS4s that are located in a federally designated Urbanized Area and serve populations of 10,000 or more are required to have a WPDES permit to discharge stormwater into surface waters. WPDES permits are also required for stormwater discharge from some construction sites and industrial sites. A Transportation Separate Storm Sewer System (TS4) permit has also been developed and was signed on June 30, 2018, covering Wisconsin Department of Transportation administered facilities within permitted MS4s.

Regulated Concentrated Animal Feeding Operations

A Concentrated Animal Feeding Operation (CAFO) is an agricultural operation that raises 1,000 or more animal units in confined areas. Wastewater that is generated by CAFOs is high in suspended solids and phosphorus from animal sewage and other animal production operations. Because of the potential water quality impacts from CAFOs, animal feeding operations with 1,000 animal units or more are required to have a WPDES CAFO permit. These permits are designed to ensure that operations use proper planning, construction, and manure management to protect water quality from adverse impacts.

WPDES permits for CAFO facilities cover the production area, ancillary storage areas, storage areas and land application areas. Any runoff from CAFO land application activities is considered a nonpoint source and is covered in the TMDL through the load allocation. CAFOs must comply with all WPDES permit conditions which include the livestock performance standards and prohibitions in ch. NR 151, Wis. Admin. Code. Specific WPDES permit conditions for the production area specify that CAFOs may not discharge manure or process wastewater pollutants to navigable waters from the production area, including approved manure stacking sites, unless all of the following apply:

- Precipitation causes an overflow of manure or process wastewater from a containment or storage structure.
- The containment or storage structure is properly designed, constructed and maintained to contain all manure and process wastewater from the operation, including the runoff and the direct precipitation from a 25-year, 24-hour rainfall event for this location.
- The production area is operated in accordance with the inspection, maintenance and record keeping requirements in s. NR 243.19, Wis. Admin. Code.
- The discharge complies with surface water quality standards.

For ancillary service and storage area, CAFOs may discharge contaminated stormwater to waters of the state provided the discharges comply with groundwater and surface water quality standards. The permittee shall take preventive maintenance actions and conduct periodic visual inspections to minimize the discharge of pollutants from these areas to surface waters. For CAFO outdoor vegetated areas, the permittee shall also implement the following practices:

- Manage stocking densities, implement management systems and manage feed sources to ensure that sufficient vegetative cover is maintained over the entire area at all times.
- Prohibit direct access of livestock or poultry to surface waters or wetlands located in or adjacent to the area unless approved by the Department.

4.1.2 Nonpoint Sources

Nonpoint sources of pollution include any sources that do not meet the definition of a point source. Nonpoint source pollution is typically driven by watershed runoff, or the movement of water over the land surface and through the ground into waterbodies, though other types of nonpoint source pollution exist. The following paragraphs describe nonpoint sources of phosphorus and sediment in the UFWB.

Agricultural Runoff

High levels of sediment and phosphorus in agricultural runoff can occur as a result of a number of factors. Chemical fertilizer and/or animal manure contains phosphorus, a critical plant nutrient, and are often applied to cropland to support crop growth. The phosphorus in chemical fertilizer and manure often becomes bound to soil particles. Because agricultural lands typically have lower vegetative cover than natural areas, they are prone to erosion during runoff events. Erosion from cropland not only carries sediment into nearby surface waters but also carries phosphorus from fertilizer and manure that is attached to soil particles. Alternatively, on cropland with phosphorus saturated soils or recent fertilizer/manure applications, phosphorus can become dissolved in surface or subsurface runoff and wash into nearby waterbodies. The transport of dissolved phosphorus in subsurface agricultural runoff can be accelerated on fields with tile drainage systems, which act as a conduit between subsurface water and adjacent drainage channels.

Phosphorus and sediment loading also occurs from areas where livestock are raised. As noted in Section 4.1.1, concentrated animal feeding operations (CAFOs) with over 1,000 animal units are regulated under the WPDES program. Smaller, nonpermitted animal feeding operations can also contribute phosphorus and sediment to adjacent waters as a result of leakage of animal sewage from covered facilities and from sediment erosion or wash-off of manure from outdoor feedlots, barnyards, and grazing areas.

Non-Regulated Urban Runoff

Developed areas are significant sources of phosphorus and sediment. Loading magnitudes typically increase with greater intensity of development. For example, runoff from areas with a high proportion of impervious surfaces tends to have high sediment and phosphorus concentrations because any dust, plant debris, pet/wildlife waste, or other material deposited on the surface is carried into nearby waters without being filtered through soil. Roads, driveways, rooftops, parking lots, and other paved areas in cities, suburban, and rural areas therefore all act as phosphorus and sediment sources. Other unpaved areas with disturbed soils (gravel or dirt roads, trails, paths, construction sites, etc.) also contribute high levels of sediment and attached phosphorus to surface waters. Vegetated spaces such as lawns, golf courses, and parks typically have lower phosphorus and sediment loading than impervious areas since soil particles are held in place by plant roots and precipitation can infiltrate the soil. However, loading from these areas is generally still higher than undisturbed natural lands because of lower canopy densities and a minimal plant litter layer. Phosphorus loads can be particularly high from vegetated developed lands when plant fertilizers are applied.

Septic systems are an additional source of phosphorus in developed areas that lack a centralized system for sanitary sewage disposal. Septic systems are underground systems that function by receiving domestic sewage in a holding tank that allows solids to settle out of suspension and for an initial breakdown of organic material. Liquid sewage exits the tank into a drain field. The drain field is typically two to five feet below the soil surface in the unsaturated zone and is comprised of multiple rows of perforated pipes. As the liquid sewage percolates through the soil, phosphorus is reduced as it binds to soil particles before reaching groundwater.

A fully functioning septic system should result in the retention of 90% or more of the phosphorus discharged in liquid sewage. However, excess phosphorus loading to waterbodies from septic systems can occur when sewage pools on the land surface and is transported in runoff during precipitation events; when sewage is not adequately treated by soil before reaching groundwater; and when liquid sewage "short-circuits" groundwater and is instead routed to a nearby waterbody with minimal soil contact time. These issues can be significant with aging or improperly sited septic systems or with extreme rainfall events.

As discussed in Section 4.1.1, the WPDES program regulates stormwater discharges from some MS4s, construction sites, and industrial sites. The UFWB contains many additional acres of urban, suburban, and developed rural areas that are not covered by WPDES stormwater permits. Runoff and pollutant loading from these areas is referred to as “non-regulated urban” or “non-permitted urban” throughout this report and is accounted for in the load allocation as nonpoint source.

Background Sources

Phosphorus is a naturally occurring compound that is present in rocks, plant material, soils, and wildlife waste. Phosphorus loading is therefore expected from undisturbed forests, wetlands, and other natural areas. However, these areas contribute significantly lower loads per unit acre than agricultural and developed areas since runoff volumes and phosphorus concentrations are reduced with a more extensive plant canopy, leaf litter layer, and soil infiltration and percolation. These same factors also reduce soil erosion and sediment loading from undeveloped vegetated lands.

An additional background source of phosphorus and sediment loading to large, open waterbodies is atmospheric deposition. Dust and plant material in the atmosphere can be deposited to a lake or reservoir surface from the wind during dry periods or carried by precipitation. In developed watersheds, this typically represents a small fraction of phosphorus and sediment loading.

Stream Channels and Lakeshores

Under natural conditions, stream channels exist in dynamic equilibrium, with balanced erosion and deposition. Channel morphology (width, depth, slope, etc.) is in a stable state that is only altered with an extreme flow event or major disturbance to the landscape. In watersheds with urban or agricultural development, the equilibrium between channel erosion and deposition has been disrupted due to altered streamflow and sediment loading patterns or artificial channel modifications. Because of these changes, the stream channel adjusts through transitional phases that can persist for years to centuries before again reaching a stable form. Channel downcutting and widening are two channel evolution phases that result in bed and bank erosion and contribute sediment and attached phosphorus to downstream waters. Conversely, when excess sediment enters a stream from the watershed or upstream reaches, the aggradation phase occurs, with sediment settling out of the water and the channel becoming increasingly shallow.

Lakeshores typically exist in a similar state of equilibrium as stream channels under natural conditions, with significant erosion only occurring with extreme water level changes or major disturbances to the landscape. Accelerated lakeshore erosion can occur when human activity removes trees and other deep-rooted vegetation from the nearshore area, when water levels are artificially manipulated, and/or with high wave action from boaters.

Lake and Reservoir Internal Sources

An additional category of nonpoint source loading in lakes and reservoirs is the release of phosphorus from sources that are internal to the lake. When phosphorus enters a lake from external sources (e.g., runoff or point source discharges), it cycles between inorganic and organic forms in the water column and bottom sediment. The net release of phosphorus from bottom sediments into the water column can be significant in lakes where several years of high external phosphorus loading have left a legacy of stored phosphorus. Release of phosphorus from bottom sediments can occur through a variety of processes, including aerobic and anaerobic decomposition of organic sediments, release of iron-bound phosphorus under anoxic conditions, simple diffusion due to sediment-water column concentration differences, or resuspension of phosphorus-laden sediment through wind and other disturbances.

It is important to note that bottom sediments should not be considered an independent source of phosphorus to a lake. A fundamental coupling exists between loading of phosphorus from external sources and loading from bottom sediment. The magnitude of phosphorus loading from bottom sediment is largely determined by the amount held in storage in the lake due to historical external phosphorus loading.

4.2 Analysis of Baseline Phosphorus and Sediment Loading

An assessment of the magnitude of phosphorus and sediment loading by source provides an understanding of the relative contribution of each source to total loading, establishes a starting point for the allocation of allowable pollutant loads, and provides a foundation for TMDL implementation. This section describes the analysis of phosphorus and sediment loads completed for each of the sources described in Section 4.1.

This report uses the term "baseline load" to refer to phosphorus or sediment loads that were used as the basis for determining TMDL allocations and reductions needed to meet allowable loads. It is important to note that for wastewater dischargers, baseline loads differ from "existing conditions" or "present-day" loading magnitudes. This is due to the distinction between loading assumptions used for TMDL development versus assumptions that would be used to estimate existing loading magnitudes.

The magnitude of baseline phosphorus and sediment loads from sources in the UFWB was assessed using multiple tools and methods. One key tool used for estimating nonpoint source loading and loading from regulated stormwater was a watershed model of the UFWB developed with the Soil and Water Assessment Tool (SWAT). SWAT uses information on watershed characteristics, weather records, and mathematical equations describing runoff generation and water quality processes to estimate daily watershed runoff volumes and pollutant loads (Neitsch et al. 2011).

The UFWB SWAT model was configured to simulate geographic differences in runoff and pollutant loading due to variation in land use, soil attributes, weather, topography, and agricultural practices. SWAT represents a basin as a collection of subwatersheds and Hydrologic Response Units (HRUs). Each HRU is a land area with a unique combination of land use, soil, and slope. The UFWB SWAT model simulated HRUs with eight major land use types: forest, wetland, pasture/grassland, cash grain agriculture (corn and soybean), dairy farm agriculture (corn and forage crops), potato and vegetable farm agriculture, non-regulated urban, and MS4 regulated urban. The UFWB SWAT model was calibrated to measurements of streamflow, phosphorus, and sediment collected in multiple streams and rivers in the UFWB. Appendix C of this report provides a full description of SWAT model inputs, configuration, and calibration results.

As part of the baseline loading analysis, SWAT estimates of runoff volumes, phosphorus loads, and sediment loads for each HRU in the model were adjusted to account for any retention estimated to occur in stream or river channels. The SWAT estimates of runoff and pollutant loading from HRUs represent loads delivered from the HRU to the mainstem stream or river reach in the subwatershed that the HRU is located. Depending on channel routing settings, a portion of the pollutant load delivered from HRUs can be temporarily retained in the reach and later transported downstream or permanently retained in the reach. This can result in a difference between estimates of the total pollutant load generated in a subwatershed when calculated by summing SWAT's HRU outputs versus loads reported for reaches. For example, if significant retention occurs in modeled reaches then the total load calculated from HRU outputs will be much greater than the load reported in SWAT's reach output file.

Any discrepancy between HRU loads and reach loads due to routing must be considered when using HRU outputs for estimating baseline loads since SWAT models are typically calibrated by matching reach outputs (and not HRU outputs) to water quality data collected from stream channels. The routing parameters selected for the UFWB SWAT model resulted in minimal retention of phosphorus and sediment loads in modeled reaches. However, to ensure that baseline nonpoint source loads were not over- or underestimated because of routing, an adjustment was applied to HRU outputs to account for any channel routing simulated in the model. This adjustment was applied by:

1. Calculating total monthly HRU loads in each subwatershed by summing loads from all HRUs in the subwatershed;
2. Calculating the proportional contribution of each HRU as the individual HRU load divided by total HRU load from step 1;
3. Calculating the routed load from each HRU by multiplying the monthly reach load by the proportional contribution from step 2. For reaches with point sources, the point source load was first subtracted from the monthly reach load before calculating the routed HRU load.

The following sections note specific cases where SWAT outputs were adjusted to account for channel routing.

Also, as part of baseline loading analysis, nonpoint source loads originating from tribal lands were estimated using SWAT model results, tribal area boundaries, and land cover data. Nonpoint source loads were divided into "Tribal" and "State of Wisconsin" loads by area-weighting total TMDL subbasin loads according to the proportion of total subbasin land use area within tribal lands. For example, if 60% of a subbasin's forest area was located in tribal lands, then 60% of the subbasin forest load was assigned as the "Tribal" load and the remaining 40% was assigned as the "State of Wisconsin" load. Nonpoint source loads from tribal lands are not assigned load allocations under this TMDL but are quantified in the baseline source assessment for completeness.

4.2.1 POTW and Industrial Wastewater

Baseline phosphorus and sediment loads for municipal, industrial, and tribal wastewater facilities that discharge under individual WPDES or NPDES permits were calculated from facility design flows, phosphorus and TSS discharge limits, and effluent monitoring data. Separate methods were used for each pollutant and for Publicly Owned Treatment Works (POTWs), industrial facilities, and tribal facilities. Tribal facilities are not assigned wasteload allocations under this TMDL but are included in the baseline source assessment for completeness. The effluent flow rates, TP concentrations, and TSS concentrations used to estimate baseline loads from individual facilities are listed in Table 9. Baseline loads by TMDL subbasin and facility are provided in Appendix G.

Discharges can be intermittent or seasonal and specific permit conditions are on a case-by-case determination. Typical operation of some seasonal or intermittent discharges is to take advantage of higher or seasonal flows; however, some discharges, such as from food processors, is based on production times corresponding with harvests. The TMDL was developed to account for these variations and evaluated timing of discharges when assigning allocations.

During TMDL development, noncontact cooling water (NCCW) discharges were evaluated for the purposes of determining whether WLAs for phosphorus were needed to meet TMDL goals. Elevated phosphorus concentrations may be present in NCCW discharges where city water is the main source, due to the use of additives to control lead in municipal water supplies. Phosphorus WQBELs that are imposed because of this TMDL, or according to s. NR 217.13, Wis. Adm. Code, do not intend to suggest that additives in finished drinking water are not needed or should not be used. In the case of lead, additives are often needed to ensure healthy and safe drinking water. However, alternatives may need to be explored to reduce phosphorus inputs into receiving waters.

For facilities with individual permits that add phosphorus to their discharge or that use water from a public water supply that adds phosphorus, design flows and discharge concentrations were used to determine individual WLAs. For pass through systems (i.e., facilities with surface water intake structures) where phosphorus is not added, and the water is withdrawn from and discharged to the same or downstream waterbody, the baseline condition for the allocation process utilized actual discharge flows with TP concentrations set to zero to reflect that no net addition of phosphorus is occurring. This would result in an allocation of zero but allow the facility to discharge the pass-through phosphorus load.

Baseline Phosphorus Loading for POTWs

POTW baseline phosphorus loading was calculated by multiplying the facility's annual average effluent design flow by the technology-based effluent concentration limit (TBEL) for phosphorus, 1 milligram per liter, defined in Chapter NR 217 of the Wisconsin Administrative Code. If the facility's average annual flow estimated from monitoring data from 2012 through 2016 was greater than its design flow, then the maximum annual average flow from 2012 through 2016 was used in place of design flow. If the facility's permitted discharge concentration limit for phosphorus was less than 1.0 mg/L, then the lower permitted effluent limit was used.

Baseline Phosphorus Loading for Industrial Dischargers

For industrial dischargers, baseline phosphorus loading was calculated by multiplying the facility's maximum annual average effluent flow estimated from monitoring data for 2012 through 2016 by its permitted discharge concentration limit for phosphorus. If the facility did not have a phosphorus concentration specified in its permit, then the average of effluent phosphorus concentrations measured at the facility from 2010 through 2017 was used in place of the concentration limit to determine the baseline load.

Baseline Phosphorus Loading for Tribal Facilities

For tribal facilities, baseline phosphorus loading was calculated by multiplying the facility's annual average effluent design flow by its permitted discharge concentration limit for phosphorus. If the facility did not have a phosphorus concentration specified in its permit, then the average of effluent phosphorus concentrations measured at the facility from 2012 through 2016 was used in place of the concentration limit to determine the baseline load. One facility (Menominee Tribal Enterprises) did not have a design flow available. The discharge flow volume used for this facility was set to the maximum average annual effluent flow estimated from monitoring data for 2012 through 2016. Tribal facilities are not assigned wasteload allocations under this TMDL but are included in the baseline source assessment for completeness.

Baseline Sediment Loading for POTWs

POTW baseline sediment loading was calculated by multiplying the facility's annual effluent design flow by the facility's permitted monthly average discharge concentration limit for TSS. If the facility's average annual flow estimated from monitoring data reported for 2012 through 2016 was greater than its design flow, then the maximum annual flow from 2012 through 2016 was used in place of design flow. If the facility's TSS limit varied throughout the year, then baseline loading was calculated from the time-weighted average of the different TSS limits. If the facility had a monthly average mass limit for TSS specified in its permit, then the baseline sediment load was set to the mass limit.

Baseline Sediment Loading for Industrial Dischargers

For industrial dischargers, baseline sediment loading was calculated by multiplying the facility's maximum annual effluent flow estimated from monitoring data for 2012 through 2016 by its permitted discharge concentration limit for TSS. If the facility did not have a TSS limit specified in its permit, then the average of effluent TSS concentrations measured at the facility from 2012 through 2017 was used in place of the concentration limit to determine the baseline load. If no TSS measurements were available, estimates based on data from other similar facilities were made to determine a suitable baseline TSS concentration. In these cases, the baseline TSS concentration was assumed to be 10 mg/L for non-contact cooling water discharges and 10 mg/L for fish farm discharges.

Baseline Sediment Loading for Tribal Facilities

For tribal facilities, baseline sediment loading was calculated by multiplying the facility’s annual average effluent design flow by its permitted discharge concentration limit for TSS. One facility (Menominee Tribal Enterprises) did not have a design flow available. The discharge flow volume used for this facility was set to the maximum annual average effluent flow estimated from monitoring data for 2012 through 2016. Tribal facilities are not assigned wasteload allocations under this TMDL but are included in the baseline source assessment for completeness.

Table 9. Data used to estimate baseline loading for individual WPDES and NPDES facility permits.

Facility Name	Facility Type	Permit Number	Outfall Number	TMDL Subbasin	Baseline Flow (MGD)	Baseline TP (mg/L)	Baseline TSS (mg/L)
Agropur Inc Weyauwega Plant	Industrial	1449	1	66	0.33	0.47	3.81
Amherst Wastewater Treatment Facility	POTW	23213	1	66	0.18	1	30
Artesian Trout Farm	Industrial	PENDING	-	8	0.5	0.068	10
Bear Creek Wastewater Treatment Facility	POTW	28061	1	64	0.1	1	20
Berlin Wastewater Treatment Facility	POTW	21229	1	28	1.5	1	30
Birnamwood Wastewater Treatment Facility	POTW	22691	2	58	0.11	1	20
Black Creek Wastewater Treatment Facility	POTW	21041	1	89	0.34	1	20
Bonduelle USA – Fairwater	Industrial	2666	10	12	0.02	0.098	1.2
Bowler Wastewater Treatment Facility	POTW	21237	1	59	0.03	1	30
Butte des Morts Consolidated SD 1	POTW	32492	1	73	0.08	1	60
Caroline SD 1 Wastewater Treatment Facility	POTW	22829	3	58	0.02	1	60
Clintonville Wastewater Treatment Facility	POTW	21466	1	60	0.64	1	30
Dale Sanitary District No 1 WWTF	POTW	30830	1	49	0.06	1	60
Darling International Inc	Industrial	38083	1	26	0.39	0.016	6.6
Eden Wastewater Treatment Facility	POTW	30716	1	39	0.18	1	20
Embarrass Cloverleaf Lakes SD Lagoon System	POTW	23949	1	59	0.17	1	30
Fairwater Wastewater Treatment Facility	POTW	21440	4	12	0.05	1	20
Fond du Lac Water Pollution Control Plant	POTW	23990	3	75	11.1	1	30
Fremont Orihula Wolf River Joint S C	POTW	26158	1	71	0.2	1	30
Friesland Wastewater Treatment Facility	POTW	31780	1	13	0.03	1	60
Great Lakes Kraut	Industrial	50407	2	70	0.02	0.17	1.2
Green Lake Sanitary District	POTW	36846	1	24	0.1	1	60
Green Lake Wastewater Treatment Facility	POTW	21776	1	25	0.5	1	30
Gresham Wastewater Treatment Facility	POTW	22781	1	55	0.11	1	30
Hortonville Wastewater Treatment Facility	POTW	22896	1	69	0.5	1	30
Iola Wastewater Treatment Facility	POTW	21717	3	81	0.18	1	30
Keshena Wastewater Treatment Facility	Tribal POTW	71315	1	55	0.34	1	30
Kingston Wastewater Treatment Facility	POTW	36421	1	14	0.02	1	60
Larsen Winchester SD WWTF	POTW	31925	1	51	0.05	1	60
Leach Farms – Auroraville	Industrial	52809	5	48	0.02	0.197	20
Little Rapids Corp Shawano Specialty Papers	Industrial	1341	2	67	2	1	61

Facility Name	Facility Type	Permit Number	Outfall Number	TMDL Subbasin	Baseline Flow (MGD)	Baseline TP (mg/L)	Baseline TSS (mg/L)
Manawa Wastewater Treatment Facility	POTW	20869	1	81	0.2	1	30
Shawano County Utilities	POTW	29718	1	57	0.04	1	20
Marion Wastewater Treatment Facility	POTW	20770	3	60	0.4	1	14.5
Markesan Wastewater Treatment Facility	POTW	24619	1	12	0.36	1	30
Menominee Tribal Enterprises	Tribal Industrial	46868	1	55	0.02	0.19	40
Menominee Tribal Enterprises	Tribal Industrial	46868	3	55	0.01	0	24.5
Montello Wastewater Treatment Facility	POTW	24813	1	16	0.3	1	30
Neshkoro Wastewater Treatment Facility	POTW	60666	2	23	0.05	1	30
New London Wastewater Treatment Facility	POTW	24929	1	71	2	1	30
Nichols Wastewater Treatment Facility	POTW	20508	1	53	0.03	1	25
North Lake Poygan SD WWTF	POTW	36251	1	72	0.05	1	60
Oakfield Wastewater Treatment Facility	POTW	24988	1	37	0.31	1	24.5
Omro Wastewater Treatment Facility	POTW	25011	1	29	0.67	1	30
Oshkosh Wastewater Treatment Plant	POTW	25038	1	74	20	1	30
Oxford Wastewater Treatment Facility	POTW	32077	1	1	0.06	1	30
Packwaukee Sanitary District No 1	POTW	60933	2	9	0.06	1	20
Power Packaging Inc	Industrial	69965	1	35	0.09	0.048	10
Poy Sippi SD Wastewater Treatment Facility	POTW	31691	1	47	0.05	1	60
Poygan Poy Sippi SD 1 WWTF	POTW	35513	1	72	0.08	1	30
Princeton Wastewater Treatment Facility	POTW	22055	1	24	0.26	1	30
Redgranite Wastewater Treatment Facility	POTW	20729	1	48	0.32	1	30
Ripon Wastewater Treatment Facility	POTW	21032	1	87	1.8	1	10
Rosendale Wastewater Treatment Facility	POTW	28428	1	35	0.22	1	20
Saputo Cheese USA Fond du Lac (Scott St)	Industrial	56120	1	75	0.04	0.198	10
Hillshire Brands (Sara Lee Foods - New London)	Industrial	23094	1	71	0.79	1	20
Seymour Wastewater Treatment Facility	POTW	21768	1	89	0.58	1	20
Shiocton Wastewater Treatment Facility	POTW	28100	1	68	0.15	1	30
Silver Lake Sanitary District	POTW	61301	1	22	1.03	1	30
Silver Moon Springs	Industrial	64548	1	55	4.04	0.049	10
Sokaogon Chippewa Community Wastewater Treatment System	Tribal POTW	71501	1	80	0.09	3.99	20
Stephensville Sanitary District No 1	POTW	32531	1	52	0.02	1	20

Facility Name	Facility Type	Permit Number	Outfall Number	TMDL Subbasin	Baseline Flow (MGD)	Baseline TP (mg/L)	Baseline TSS (mg/L)
Stockbridge Wastewater Treatment Facility	POTW	21393	1	46	0.11	1	20
Stockbridge-Munsee Community Wastewater Ponds	Tribal POTW	36188	10	55	0.04	1.79	60
Tigerton Wastewater Treatment Facility	POTW	22349	1	58	0.11	1	30
Waupaca Foundry Plant 1	Industrial	26379	1	66	0.6	0.02	3.3
Waupaca Wastewater Treatment Facility	POTW	30490	1	66	1.5	1	30
Westfield Wastewater Treatment Facility	POTW	22250	1	8	0.25	1	30
Weyauwega Star Dairy	Industrial	39527	1	66	0.01	0.7	10
Weyauwega Wastewater Treatment Facility	POTW	20923	1	66	0.85	1	30
WI DNR Wild Rose Fish Hatchery	Industrial	22756	1	47	2.13	0.027	10
WI DNR Wild Rose Fish Hatchery	Industrial	22756	18	47	2.54	0.035	10
Wild Rose Wastewater Treatment Facility	POTW	60071	2	47	0.12	1	60
Winneconne Wastewater Treatment Facility	POTW	21938	1	73	0.78	1	30
Wisconsin Veneer And Plywood Inc	Industrial	47929	1	55	0.14	0.054	11.71
Wittenberg Wastewater Treatment Facility	POTW	28444	2	58	0.33	1	30
Wolf River Ranch Wastewater Treatment Facility	Tribal POTW	71307	1	55	0.07	1	20
Wolf Treatment Plant	POTW	28452	1	67	2.63	1	30

4.2.2 Regulated Municipal Separate Storm Sewer Systems (MS4s)

Twenty-nine municipalities with WPDES MS4 stormwater permits intersect the UFWB. Of these, twenty-eight have all or a portion of their regulated area within the UFWB (the exception is the Town of Clayton). The regulated area of cities and villages with MS4 permits is defined as their entire incorporated area. The regulated area of towns and counties with MS4 permits is defined as the area served by their MS4 system within the US Census urbanized area boundary. The Town of Clayton intersects the UFWB but its regulated area is entirely outside of the UFWB. The Town of Clayton therefore is not included in this TMDL. Figure 12 shows the location of the regulated area of permitted MS4s in the UFWB.

The UFWB SWAT model was used to calculate phosphorus and sediment loading from urban sources regulated by a WPDES MS4 permit. As part of SWAT model setup, maps of municipal boundaries for cities, villages, and towns with MS4 permits and US Census urbanized areas were overlain with land cover data to define SWAT HRUs with regulated MS4 urban land cover. These HRUs represented areas where runoff and pollutant loading from urban and developed land cover was regulated by a MS4 permit. Table 10 lists the regulated urban area of permitted MS4s within TMDL subbasins.

The UFWB SWAT model was configured to simulate runoff and pollutant loading from four different regulated MS4 urban land use types: developed open space, developed low-density, developed medium-density, and developed high-density. SWAT allows users to input unique percentages of the total impervious area and the directly connected impervious area (i.e., impervious area that is drained directly to surface waters) within each urban land use type. These percentages are used in equations that calculate runoff volumes and pollutant loads from urban HRUs. In the UFWB SWAT model, the lowest percentages were applied to developed open space and the highest percentages were assigned to developed high-density.

Baseline loading for MS4 permitted sources was determined from SWAT predictions of monthly phosphorus and sediment loading from HRUs with regulated MS4 urban land cover in the model. Baseline loads were calculated using SWAT simulation results for the period January 2009 through December 2013. SWAT outputs for regulated MS4 urban HRUs were adjusted to account for any channel routing simulated in the model (see Section 4.2).

SWAT loads for regulated MS4 urban HRUs were reduced by 20% for TSS and by 15% for TP to define baseline conditions. These reductions were applied to be consistent with performance standards for existing development defined in WPDES MS4 permits and required under chapters NR 216 and NR 151 of Wisconsin Administrative Code. The reduction relationship between TP and TSS is not 1:1 because of the portioning between phosphorus attached to sediment and the soluble phosphorus in the urban runoff.

SWAT results provided values of TP and sediment loads from regulated MS4 urban sources in each model subwatershed, however, results did not differentiate between loads generated from individual municipalities. An area-weighting approach was therefore used to estimate phosphorus and sediment loading for individual MS4 permittees by proportionally dividing regulated MS4 loads per model subwatershed among the MS4 permitted municipalities located in each subwatershed. The area-weighting approach distributed subwatershed loads for each urban cover type (open space, low-density, medium-density, and high-density) using the ratio of the area of the cover type in the municipality relative to the subwatershed total. For example, if a given municipality contained 75% of the total high-density regulated MS4 cover in a subwatershed, then the municipality was assigned 75% of the high-density regulated MS4 load estimated for the subwatershed.

Baseline loads for regulated MS4s by TMDL subbasin and municipality are listed in Appendix G. The values reported in Appendix G are derived from the UFWB SWAT model using the process described above and represent loads from regulated MS4s that are delivered to a TMDL subbasin outlet after being routed across the landscape and through stream channels. These values are significantly lower than loads that could be estimated from alternative urban water quality models that do not simulate the same degree of routing. For example, the Source Loading and Management Model (SLAMM), commonly used by Wisconsin municipalities for stormwater management planning, simulates direct export of pollutants from urban lands and effects of various treatment. This however does not impact implementation which is conducted using a percent reduction framework as outline in both MS4 TMDL Implementation Guidance ("TMDL Guidance for MS4 Permits: Planning, Implementation, and Modeling Guidance" effective October 20, 2014. The guidance and addendums can be found at https://dnr.wi.gov/topic/stormwater/standards/ms4_modeling.html) and in the MS4 permit.

A municipality is deemed in compliance with the TMDL wasteload allocations if the overall percent reductions listed in Table 5 of Appendices H and I, for total phosphorus and TSS respectively, are met. This approach allows the use of SLAMM and other urban runoff models to be used to help evaluate compliance with the TMDL without the added complications of matching wasteload allocations that are calculated using different models with different rainfall files and differing capacities to route pollutants.

Calumet County, Fond du Lac County, Winnebago County, and University of Wisconsin-Oshkosh are all covered by a WPDES MS4 permit but will not receive individual allocations in this TMDL. Instead, they are accounted for in the portions of each city, village, or town MS4 that they discharge to or within which they are located. Although these MS4s are not given specific allocations they will still be expected to achieve the applicable identified reductions within their portion of their jurisdictional area. Please refer to the MS4 TMDL Implementation Guidance for details; "TMDL Guidance for MS4 Permits: Planning, Implementation, and Modeling Guidance" effective October 20, 2014. The guidance and addendums can be found at https://dnr.wi.gov/topic/stormwater/standards/ms4_modeling.html.

Table 10. List of permitted MS4s within the Upper Fox-Wolf Basins.

Permittee	County	TMDL Subbasin	Area (acres)
Town of Algoma	Winnebago	30	97
		73	1,012
		74	6
		75	66
City of Appleton	Outagamie, Calumet, Winnebago	52	0.4
		75	174
Town of Black Wolf	Winnebago	75	207
Calumet County	Calumet	-	-
Village of Eden	Fond du Lac	39	165
Town of Empire	Fond du Lac	39	63
		75	61
City of Fond du Lac	Fond du Lac	43	2,505
		44	1,115
		75	3,069
		88	1,128
Town of Fond du Lac	Fond du Lac	34	13
		39	1.8
		43	79
		44	57
		75	411

Permittee	County	TMDL Subbasin	Area (acres)
		88	88
Fond du Lac County	Fond du Lac	-	-
Village of Fox Crossing	Winnebago	75	4.2
Town of Friendship	Adams	33	101
		34	130
		75	144
Town of Grand Chute	Outagamie	52	25
Town of Greenville	Outagamie	50	100
		52	967
Town & Village of Harrison	Calumet	75	431
City of Menasha	Winnebago	75	91
City of Neenah	Winnebago	75	71
Town of Neenah	Winnebago	75	185
Town of Nekimi	Winnebago	75	176
Village of North Fond du Lac	Fond du Lac	33	43
		34	745
		75	183
Town of Omro	Winnebago	73	42
City of Oshkosh	Winnebago	30	1,800
		73	984
		74	3,406
		75	4,917
Town of Oshkosh	Winnebago	73	243
		75	316
City of Portage	Columbia	4	43
		7	930
Village of Sherwood	Calumet	75	358
Town of Taycheedah	Fond du Lac County	75	262
University of Wisconsin Oshkosh	Winnebago	-	-
Town of Vinland	Winnebago	75	11
Winnebago County	Winnebago	-	-

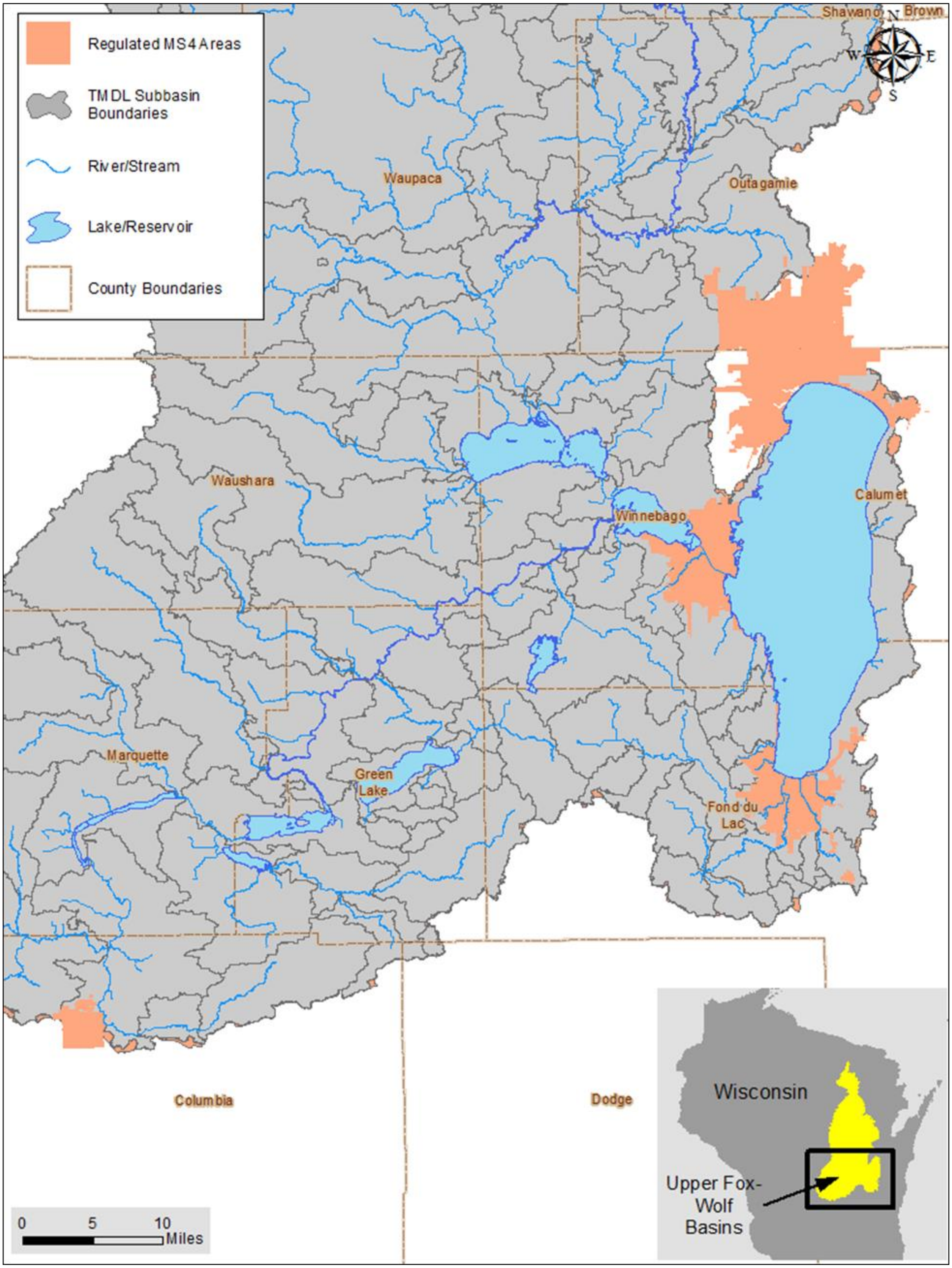


Figure 12. Regulated area of permitted MS4s in the Upper Fox-Wolf Basins.

4.2.3 Stormwater and Wastewater General Permits

WDNR authorizes certain stormwater and wastewater discharges under a set of general WPDES permits. Unlike individual WPDES permits, the general permits are not written to reflect site-specific conditions of a single discharger but rather are issued to cover multiple dischargers with similar operations and types of discharges. These general permits vary in requirements for chemical monitoring, inspection frequency, and plan development. Examples of discharges that can be covered by WPDES general permits include:

- Stormwater discharge from construction sites;
- Stormwater discharge from industrial sites;
- Discharge of non-contact cooling water from industrial facilities;
- Discharge of construction site pit and trench dewatering wastewater to surface waters or seepage systems;
- Discharge from facilities that wash equipment, vehicles and other objects outside.

Note that individual WPDES permits can be issued for the above examples if they are determined to be a significant source of pollution. A complete list of wastewater general permit categories can be found on the WDNR wastewater website (https://dnr.wi.gov/topic/wastewater/generalpermits.html).

Baseline phosphorus loads for stormwater general permittees located within an MS4 boundary were included in the MS4 baseline load described in Section 4.2.2. Baseline phosphorus loads for all other stormwater and wastewater general permittees were set to 10% of the baseline non-regulated urban loads in the subbasin estimated from the UFWB SWAT model (see Section 4.2.6). The assumption of 10% of baseline non-regulated urban loads was based on the number and typical types of facilities present within the watersheds and best professional judgment of the TMDL development team. General permit loads are reported by TMDL subbasin in Appendix G.

4.2.4 Regulated Concentrated Animal Feeding Operations

There are 32 CAFOs in the UFWB that are covered under the WPDES general permit for CAFOs (Table 11; Figure 13). Any runoff from CAFO land application activities is considered a nonpoint source and is included implicitly as nonpoint source agricultural loads derived from the UFWB SWAT model (discussed in Section 4.2 and Appendix C.

Table 11. List of permitted CAFOs in the Upper Fox-Wolf Basins.

Name	County
Abel Dairy Farms LLC	Fond du Lac
Crailoo Dairy Farm LLC	Fond du Lac
Lake Breeze Dairy LLC	Fond du Lac
Murph-ko Farms Inc	Fond du Lac
Redtail Ridge Dairy	Fond du Lac
Rickert Bros. LLC	Fond du Lac
Rosendale Dairy LLC	Fond du Lac
Ruedinger Farms Inc	Fond du Lac
Vir-Clar Farms LLC	Fond du Lac
Pride View Dairy LLC	Green Lake
MAM Farms	Green Lake
Trillium Hill Farm Inc	Green Lake
Slowey Farms Inc	Marquette
Omro Dairy LLC	Winnebago
Thistle Dairy LLC	Winnebago
Ostrowski Farm	Marathon
Schairer Farms	Marathon
Birlings Bovines LLC	Outagamie
Rohan Dairy Farms LLC	Outagamie
Sugar Creek Farm LLC	Outagamie
Gordondale Farms	Portage
Betley Farms LLC	Shawano
Krueger Dairy LLC	Shawano
Matsche Farms Inc	Shawano
Schimdt's Ponderosa LLC	Shawano
Strassburg Creek Dairy LLC	Shawano
Tauchen Harmony Valley Inc	Shawano
Egan Bros. Partnership	Waupaca
Friendship Valley Dairy LLC	Waupaca
Quantum Dairy LLC	Waupaca
Krentz Family Dairy Inc	Waushara
Pine Breeze Dairy LLC	Waushara
Cross Farms LLC	Winnebago

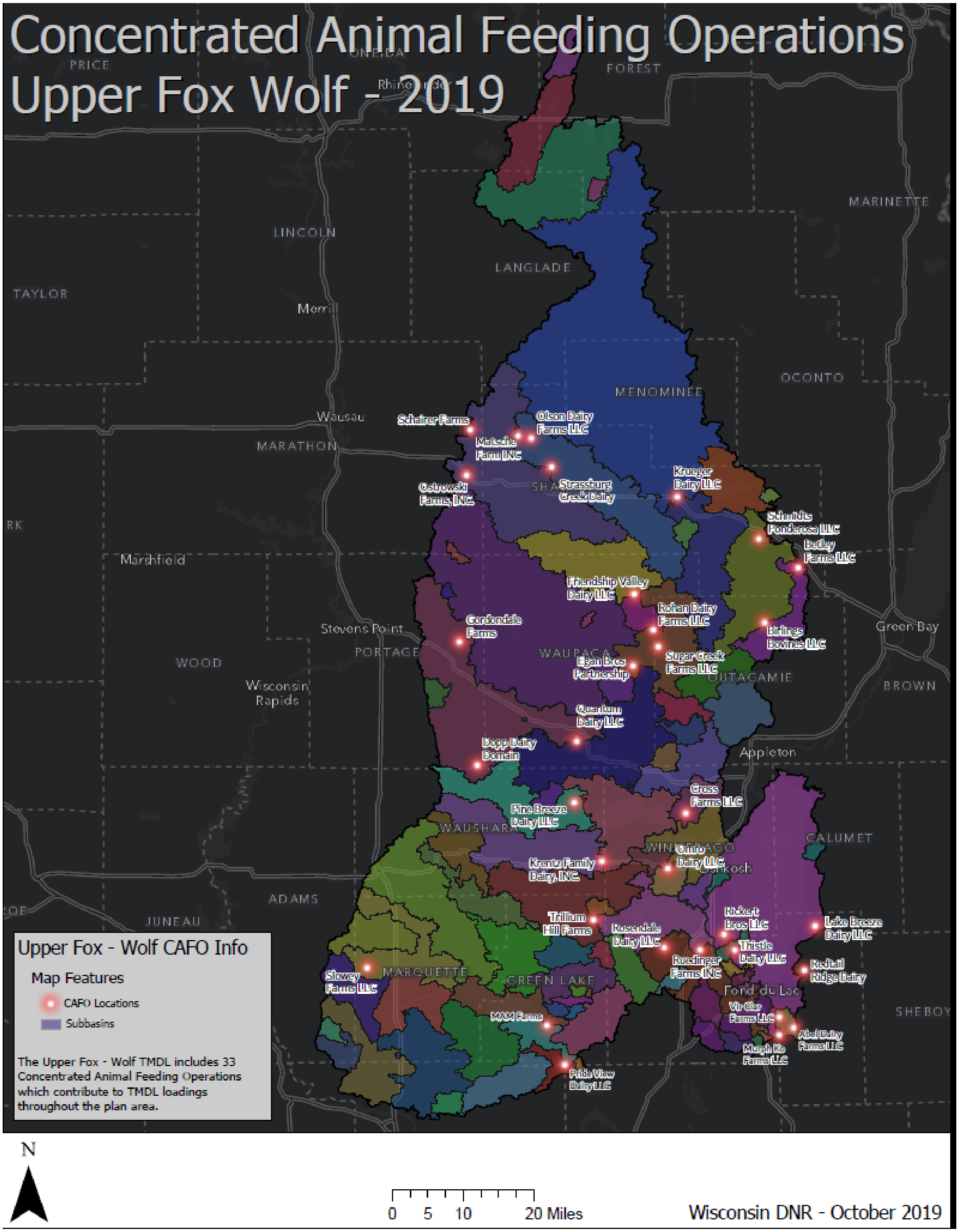


Figure 13. Concentrated Animal Feeding Operations (CAFOs) in the UFWB that are covered under the WPDES general permit for CAFOs. Points on the map are an approximation of the operation's main location; points located outside of the UFWB have other production areas within the UFWB.

4.2.5 Agricultural Runoff

Baseline phosphorus and sediment loads from agricultural lands were calculated using SWAT simulation results for the period January 2009 through December 2013. SWAT outputs for agricultural HRUs were adjusted to account for any channel routing simulated in the model (see Section 4.2).

The UFWB SWAT model was configured to simulate runoff and pollutant loading from four different agricultural land use types: pasture/grassland, cash grain agriculture (corn and soybean), dairy farm agriculture (corn and forage crops), and potato/vegetable farms. SWAT allows users to input specific management operations associated with each agricultural land use type. Agricultural operation settings include the type(s) of crops planted and rotation schedule, chemical fertilizer application rates and timing, manure application rates and timing, and tillage intensity and timing.

Agricultural operation settings were determined based on significant input from county land and water conservation departments (LWCDs) in the UFWB in 2014. LWCD staff were asked to provide information on typical farming practices in their county and responses were translated into 46 unique agricultural operation tables for input to SWAT. Due to limitations imposed by the scale of the watershed modeling effort, operations could not be developed for each and every unique farm in the UFWB. However, the 46 agricultural operation classes reflect typical farming behaviors in the UFWB while capturing variation in factors that have the greatest impact on runoff volumes, soil erosion, and phosphorus loading. Details on the SWAT configuration and the agricultural management classes used in the UFWB can found in Appendix C. Baseline agricultural nonpoint source loads by TMDL subbasin are reported in Appendix G.

4.2.6 Non-Regulated Urban Runoff

Baseline phosphorus and sediment loads from non-regulated urban lands (i.e., developed areas outside of regulated MS4s) were calculated using SWAT simulation results for the period January 2009 through December 2013. SWAT outputs for non-regulated urban HRUs were adjusted to account for any channel routing simulated in the model (see Section 4.2).

The UFWB SWAT model was configured to simulate runoff and pollutant loading from four different non-regulated urban land use types: developed open space, developed low-density, developed medium-density, and developed high-density. SWAT allows users to input unique percentages of the total impervious area and the directly connected impervious area (i.e., impervious area that is drained directly to surface waters) within each urban land use type. These percentages are used in equations that calculate runoff volumes and pollutant loads from urban HRUs. In the UFWB SWAT model, the lowest percentages were applied to developed open space and the highest percentages were assigned to developed high-density corresponding with the typical impervious levels for the different urban land use types.

Phosphorus loading to streams and rivers from septic systems was not explicitly simulated in the UFWB SWAT model. Septic loading to streams and rivers is instead assumed to be factored into SWAT estimates of non-permitted urban loading. For lakes and reservoirs addressed in this TMDL, septic loading from nearshores estimated outside of SWAT using the equation:

$$L = E * P * (1 - R)$$

where L is the annual phosphorus load from septic systems, E is the septic tank phosphorus export rate, P is the number of persons using septic systems per year, and R is the soil phosphorus retention coefficient. For each lake, the septic tank phosphorus export rate (E) was estimated from published values; the number of persons using septic systems per year (P) was estimated from the number of lakeshore residences without centralized sewer service and the number of persons in each residence; and the soil phosphorus retention coefficient (R) was estimated from published values and nearshore soil characteristics. A detailed description of the data sources and assumptions used for estimating baseline septic system loading to lakes and reservoirs is provided in Appendix E for the Winnebago Pool lakes and in Appendix D for the remaining lakes.

Baseline non-regulated urban loads by TMDL subbasin are reported in Appendix G. The values reported in Appendix G represent the sum of non-regulated urban loads derived from SWAT plus septic system loads estimated for lakes and reservoirs.

4.2.7 Background Sources

Baseline phosphorus and sediment loads from forests and wetlands were calculated using SWAT simulation results for the period January 2009 through December 2013. SWAT outputs for forest and wetland HRUs were adjusted to account for any channel routing simulated in the model (see Section 4.2).

The UFWB SWAT model was configured to simulate runoff and pollutant loading from three different natural/background land use types: upland forest, forested wetlands, and herbaceous wetlands. The calibrated SWAT parameters for these HRUs reflect the presence of undisturbed vegetative cover, an established plant litter layer, and other factors that result in low phosphorus and sediment loading relative to other land use types.

An additional background source of phosphorus quantified for the four Winnebago Pool lakes is direct groundwater discharge through the lake bed and shoreline. Although the UFWB SWAT model simulates groundwater discharge, its algorithms are better suited to describe groundwater dynamics along linear stream and river channels. Because of the large size of the Winnebago Pool lakes, a groundwater term was added for the baseline loading analysis. Groundwater phosphorus loading to Lake Poygan, Winneconne, Butte des Morts, and Winnebago was estimated in the USGS companion study on the Winnebago Pool lakes (Appendix E). To estimate groundwater loading, the study used results of a regional groundwater-flow model for the Lake Michigan Basin and an assumed groundwater TP concentration based on concentrations measured around the perimeter of nearby Nagawicka Lake. Estimated groundwater TP loads were equal to 351 pounds per year for Lake Poygan and Winneconne, 351 pounds per year for Lake Butte des Morts, and 1,387 pounds per year for Lake Winnebago.

The USGS report for the Nagawicka Lake study noted that the average measured TP concentration (0.053 mg/L) was above the natural background concentration of 0.03 mg/L assumed for the area and may be affected by human activity (Herbert et al., 2006). However, a detailed assessment of the anthropogenic sources of phosphorus to groundwater was not completed as part of the Nagawicka Lake study. For this TMDL, groundwater loads to the Winnebago Pool lakes are included in the background source category in the baseline loading summary and TMDL allocations. This represents a conservative assumption for TMDL development and is further discussed in Section 6.6.

Atmospheric input of phosphorus to the Winnebago Pool lakes is also considered a background source. Atmospheric input was determined as part of the companion study of the Winnebago Pool lakes completed by USGS (Appendix E). In the USGS study, phosphorus loading from direct precipitation onto each lake surface was estimated from the volume of precipitation and an assumed concentration of phosphorus in precipitation (0.036 mg/L). Estimated atmospheric TP loads were equal to 5,104 pounds per year for Lake Poygan and Winneconne, 2,346 pounds per year for Lake Butte des Morts, and 36,330 pounds per year for Lake Winnebago.

Baseline background loads by TMDL subbasin are reported in Appendix G. The values reported in Appendix G represent the sum of baseline loads derived from SWAT plus atmospheric deposition and groundwater loads for the Winnebago Pool lakes.

4.2.8 Stream Channels and Lakeshores

The presence and magnitude of phosphorus and sediment loading from stream channel erosion is dependent on the amount of sediment entering a stream reach and local reach characteristics such as width, depth, slope, substrate, and vegetative cover that determine whether channel aggradation or degradation occurs. Similarly, rates of lakeshore erosion are highly dependent on nearshore vegetation and soil characteristics. Due to the limitations imposed by the scale of the watershed modeling effort, such reach and lakeshore characteristics could not be evaluated for every waterbody in the UFWB. Stream channel and lakeshore erosion were therefore not explicitly simulated in the UFWB SWAT model. Any sediment and phosphorus loading from stream channel and lakeshore erosion is instead factored into calibrated estimates of nonpoint source loading from agricultural and urban areas. Loading from stream channels and lakeshores is therefore accounted for in baseline loading estimates for nonpoint source agriculture, non-regulated urban, and regulated MS4 urban sources.

4.2.9 Lake and Reservoir Internal Sources

When phosphorus enters a lake from tributaries or other sources it cycles between the water column and bottom sediment before being exported in lake outflow or retained in long-term sediment storage. Internal phosphorus loading refers to the net release of phosphorus from bottom sediment into the water column during a given time period (i.e., phosphorus release minus sedimentation). While the rate of phosphorus sedimentation has been shown to be highly dependent on hydraulic residence time (Vollenweider, 1976), the mechanisms driving phosphorus release are varied (Pettersson, 1998) and include simple diffusion due to sediment-water column concentration differences, resuspension of phosphorus-laden sediment through wind, waves, and fish feeding, or biochemical reactions. The magnitude of internal loading therefore can vary significantly from one lake to another and over time based on hydraulic characteristic, the amount of phosphorus stored in sediments, water temperatures, weather, and water column and sediment chemistry.

Internal phosphorus loading in the four Winnebago Pool lakes (Poygan, Winneconne, Butte des Morts, and Winnebago) was evaluated by USGS as part of a companion study documented in Appendix E. Internal phosphorus loading cannot be easily measured directly within a lake. Instead, the USGS study used multiple methods for inferring internal loading, including a phosphorus mass balance, the BATHTUB lake response model, and an additional lake response model introduced in Jensen et al. (2006).

In the phosphorus mass balance method, internal loading for Lake Winnebago was calculated as the difference between the phosphorus load exported from the lake in outflow and the phosphorus load entering the lake from external sources during the period from May through September. The BATHTUB model provides a prediction of a lake’s phosphorus concentration as a function of the phosphorus load received by the lake. The growing season internal load in each pool lake was estimated with the BATHTUB model as the additional load (beyond loading from external sources) needed to match the BATHTUB-predicted phosphorus concentrations to concentrations measured in each lake. In the Jensen model, internal loading is simulated directly using empirical equations that quantify phosphorus sedimentation and release as a function of sediment phosphorus concentrations and water temperatures. In the Jensen model, phosphorus release and sedimentation rates were estimated by minimizing the difference in predicted and measured phosphorus concentrations in the lakes.

The USGS study found that net internal loading was near zero or slightly negative (i.e., net phosphorus deposition to sediment) in the Winnebago Pool lakes over an annual time scale. On a seasonal basis, however, internal loading of phosphorus is significant in Lake Winnebago during the growing season and contributes to high summer water column phosphorus concentrations. For example, the estimated internal load during the growing season accounted for 56% of the total growing season phosphorus load to Lake Winnebago during 2009 through 2011 compared to 15% for Lake Poygan, 14% for Lake Butte des Morts, and 3% for Lake Winneconne. The average net TP release from Lake Winnebago sediments was estimated to be 3.0 milligrams per square meter per day (mg/m^2/d) using the mass balance approach, 2.8 mg/m^2/d from the BATHTUB model, and 3.5 mg/m^2/d from the Jensen model.

The high rate of internal phosphorus loading in Lake Winnebago during the growing season is likely due to physical resuspension of phosphorus-rich bottom sediment into the water column from wind and wave energy, including boat wakes, and physical disturbance by aquatic species rather than by chemical diffusion of phosphorus into the water column (Appendix E).

Because internal loads are not an independent source of phosphorus to a lake or reservoir, they are not included in baseline loading summaries for subbasins with lakes and reservoirs and are not assigned allocations under the TMDL. Internal loads reflect the cycling of phosphorus contributed from external sources and therefore are inherently linked to external phosphorus loading. Further, the focus of the baseline load summary and TMDL allocations is on *annual* phosphorus loads and internal loading is typically near zero or negative on an annual basis.

Although internal phosphorus loads are not explicitly quantified in baseline loading summaries or TMDL allocations for the reasons described above, they are factored into the analysis of the TP loading capacity of lakes and reservoirs (i.e., the TP load from external sources needed to achieve TP concentration targets). Any net release of phosphorus from lake sediments during the summer months will increase summer TP concentrations in the water column and the lake models used to relate external TP loads to water column TP concentrations do account for the effects of internal phosphorus loading on summer TP concentrations. The lake models also account for the coupling of internal and external phosphorus loading magnitudes, with internal loads decreasing as external loads are reduced. The lake models and their application are introduced in more detail in Section 5.1.2.

4.3 Summary of Baseline Phosphorus and Sediment Loading

This section provides a general summary of baseline TP and TSS loads in the UFWB estimated from the methods described in the preceding section. Detailed tables of baseline loads summarized by TMDL subbasin are provided in Appendix G.

Table 12 and Table 13 list baseline loads for five regions of the UFWB by source category. The five regions include the Wolf Basin, the Fox River watershed above Lake Winnebago, the Fond du Lac River watershed, the direct drainage watershed of Lake Winnebago, the Upper Fox Basin. A map of the five regions is provided in Figure 14. Table 12 and Table 13 also provide total baseline loads by source category for the entire UFWB.

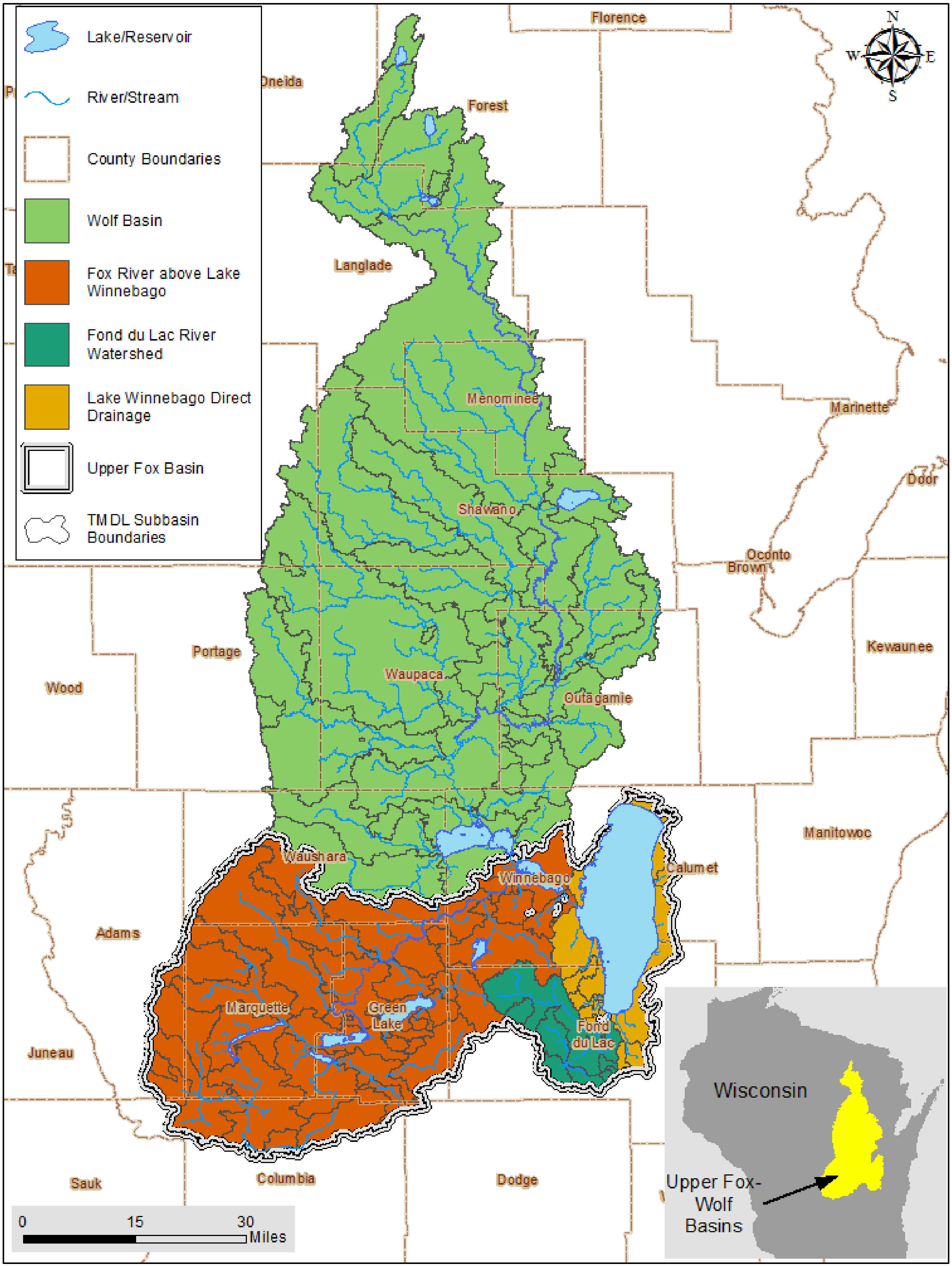


Figure 14. Regional watersheds used to summarize baseline phosphorus and sediment loading.

Table 12. Summary of baseline total phosphorus loads (in pounds per year) by source for the five regions mapped in Figure 14.

General Source Category	Source	Wolf Basin		Fox River above Lake Winnebago		Fond du Lac River above Lake Winnebago		Lake Winnebago Direct Drainage		Upper Fox Basin		Total UFWB	
		lbs/yr	%	lbs/yr	%	lbs/yr	%	lbs/yr	%	lbs/yr	%	lbs/yr	%
Background	Forest & Wetland	69,410	15%	20,875	8%	588	1%	417	<1%	21,880	5%	91,290	10%
	Groundwater[1]	351	<1%	351	<1%	0	<1%	1,387	2%	1,738	<1%	2,089	<1%
	Atmospheric[1]	5,104	1%	2,346	<1%	0	<1%	36,330	41%	38,676	9%	43,780	5%
Nonpoint Agriculture	Cropland	202,769	44%	101,423	37%	43,912	80%	10,282	12%	155,616	38%	358,385	41%
	Pasture/Grassland	105,581	23%	49,981	18%	7,665	14%	3,253	4%	60,899	15%	166,481	19%
Non-Regulated Urban	Non-Regulated Urban	28,847	6%	7,977	3%	392	<1%	425	<1%	8,793	2%	37,641	4%
	Nearshore Septic[2]	420	<1%	966	<1%	0	<1%	348	<1%	1,314	<1%	1,734	<1%
Point Source	Regulated MS4 Urban	136	<1%	730	<1%	393	<1%	920	1%	2,043	<1%	2,179	<1%
	General Permits	2,927	<1%	894	<1%	39	<1%	77	<1%	1,011	<1%	3,937	<1%
	Individual Permits	49,627	11%	85,073	31%	1,601	3%	34,747	39%	121,420	29%	171,047	19%
TOTAL		465,172	-	270,615	-	54,590	-	88,187	-	413,391	-	878,563	-

[1] Calculated for Winnebago Pool lakes only

[2] Calculated for lakes listed in Table 5 only

Table 13. Summary of baseline sediment loads (in tons per year) by source for the five regions mapped in Figure 14.

General Source Category	Source	Wolf Basin		Fox River above Lake Winnebago		Fond du Lac River above Lake Winnebago		Lake Winnebago Direct Drainage		Upper Fox Basin		Total UFWB	
		tons/yr	%	tons/yr	%	tons/yr	%	tons/yr	%	tons/yr	%	tons/yr	%
Background	Forest & Wetland	1,469	3%	368	2%	14	<1%	10	<1%	391	2%	1,861	3%
Nonpoint Agriculture	Cropland	29,737	71%	12,394	66%	3,683	83%	939	47%	17,016	67%	46,753	69%
	Pasture/Grassland	9,045	21%	4,609	24%	647	15%	485	24%	5,742	23%	14,787	22%
Non-Regulated Urban	Non-Regulated Urban	843	2%	230	1%	34	<1%	18	<1%	282	1%	1,125	2%
Point Source	Regulated MS4 Urban	8	<1%	27	<1%	30	<1%	23	1%	80	<1%	88	<1%
	General Permits	84	<1%	23	<1%	3	<1%	2	<1%	28	<1%	112	<1%
	Individual Permits	918	2%	1,239	7%	19	<1%	517	26%	1,776	7%	2,693	4%
TOTAL		42,104	-	18,890	-	4,430	-	1,994	-	25,314	-	67,419	-

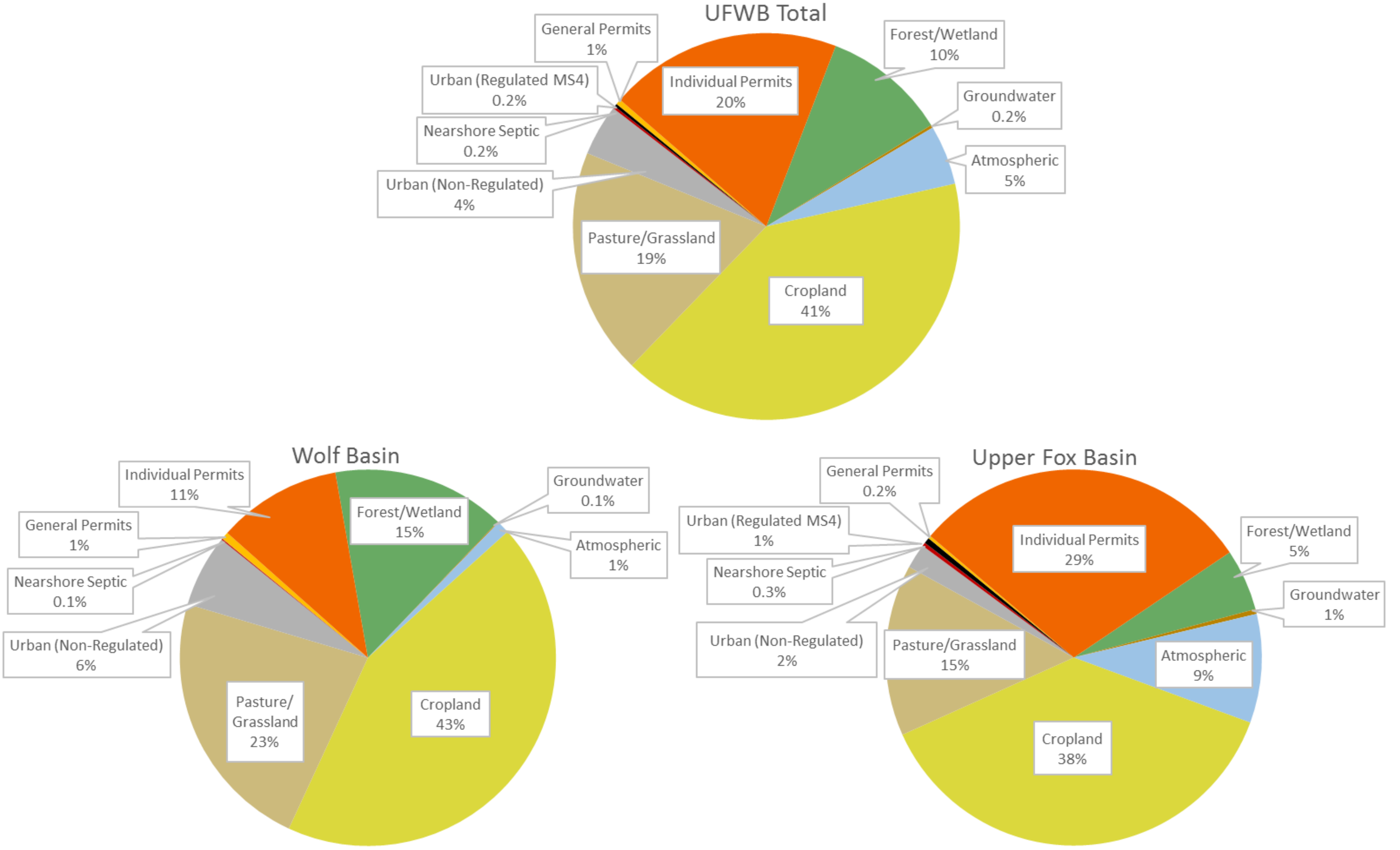


Figure 15. Pie charts displaying total phosphorus loading by source in the Wolf Basin, Upper Fox Basin, and the entire Upper Fox-Wolf Basins (UFWB). Atmospheric and groundwater loads were calculated for Winnebago Pool lake only. Nearshore septic loads were calculated for lakes listed in Table 5 only.

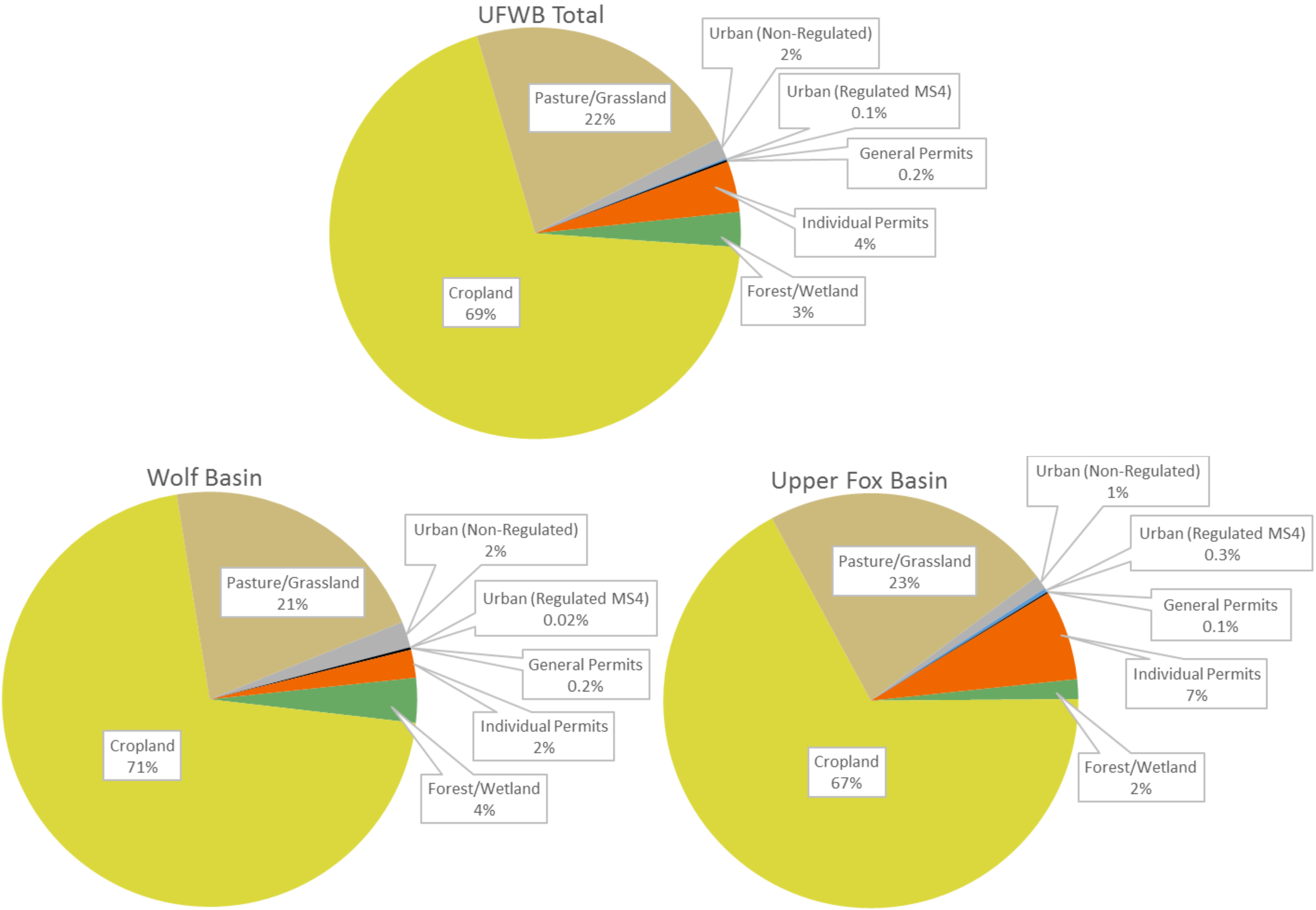


Figure 16. Pie charts displaying total suspended solids loading by source in the Wolf Basin, Upper Fox Basin, and the entire Upper Fox-Wolf Basins (UFWB).

5 DETERMINATION OF LOAD CAPACITY

The pollutant loading capacity of a waterbody is defined as the amount of a pollutant that the waterbody can assimilate and still meet water quality standards. By definition, a TMDL is a daily loading capacity; however, loading capacities can also be calculated for time periods other than daily if the effects of a pollutant manifest themselves over longer periods. This section describes how phosphorus and sediment loading capacities were calculated for TMDL subbasins.

5.1 Phosphorus Loading Capacity

Separate methods were applied to calculate the phosphorus loading capacity of subbasins with a river or stream reach at their outlet versus subbasins with a lake or reservoir at their outlet. Each method is summarized in the following subsections.

5.1.1 Stream and River Reaches

Numeric water quality targets for TP concentrations in streams and rivers are equal to Wisconsin's total phosphorus criteria and are expressed as growing season (May through October) median (GSM) concentrations (see Section 2). To determine annual TP loads that meet these targets, a method is required to translate loading magnitudes to instream TP concentrations. A typical approach for streams and rivers is to calculate a flow-weighted mean (FWM) concentration as the TP load divided by flow volume in the reach over a given time-period. For this study, the annual FWM TP concentration in each TMDL subbasin was calculated by dividing the baseline mean annual TP load for the subbasin by the subbasin's baseline mean annual flow volume.

Since phosphorus targets are expressed as GSM concentrations, an additional step is needed to relate the target to an annual FWM concentration. A stream's annual FWM concentration is generally higher than its GSM concentration in streams where TP concentration increases with discharge and where there is little seasonal variation. In contrast, the GSM concentration may be higher than the annual FWM concentration in streams where TP exhibits a strong seasonal pattern that peaks in summer and is independent of discharge.

The annual FWM TP concentration of a TMDL subbasin can be translated to a GSM concentration using a conversion ratio. We assume that the ratio between FWM and GSM concentrations for a given subbasin will remain constant as TP loadings change because the underlying hydrologic drivers of the ratio will remain steady. The FWM / GSM ratio for a subbasin is used to estimate the TP loading that will meet its concentration target – the ratios do not change the targets themselves.

To determine appropriate FWM / GSM ratios for TMDL development, FWM and GSM concentrations were estimated for six stream and river monitoring sites in the UFWB with daily TP and flow data. For each station, the annual FWM was calculated from measured daily flow and daily phosphorus loads reported by USGS. GSMs were estimated from monitoring data adjusted to control for the influence of antecedent precipitation on TP concentration (WDNR PhosMER model). PhosMER was chosen to estimate GSMs because WDNR intends to use it to assess future TP monitoring data where flow may not be monitored.

FWM / GSM ratios at UFWB monitoring stations ranged from 0.72 (Fox River at Berlin) to 1.09 (Waukau Creek) with a median of 0.94 (Table 14). The Fox River ratio is well below 1.0 and indicates that TP shows a strong growing season peak that is independent of streamflow. The remaining ratios cluster around 1.0 and indicate that TP concentrations are more stable throughout the year.

For loading capacity analysis, measured ratios for the six monitoring sites were applied to the TMDL subbasin in which the site was located. The ratio for the Fond du Lac River site was also applied to two upstream subbasins containing the East Branch and West Branch Fond du Lac River. The ratio for the Fox

River site was also applied to two subbasins containing the mainstem Fox River between the Lake Puckaway outlet and Lake Butte des Morts. The ratio for the Wolf River site was applied to three additional upstream subbasins containing the mainstem Wolf River, below the Red River confluence. The ratio for the Green Lake inlet site was also applied to the upstream Silver Creek subbasin. Ratios for all remaining ungauged TMDL subbasins were set to the basin wide median (0.94).

After determining appropriate FWM / GSM ratios, the phosphorus loading capacity was initially calculated for headwater TMDL subbasins as:

$$Loading\ Capacity = Q_{mean} * TP_{crit} * FWM\ /\ GSM$$

where *Qmean* is the mean annual flow in the subbasin, *TPcrit* is the total phosphorus criterion for the subbasin (75 µg/L for headwater subbasins), and *FWM/GSM* is the conversion factor described in the preceding paragraphs. The phosphorus loading capacity for non-headwater subbasins was then calculated using the above equation minus the loading capacity of all upstream subbasins. Phosphorus loading capacities for each TMDL subbasin are reported in Appendix H.

Table 14. Annual flow-weighted mean (FWM) and growing season median (GSM) total phosphorus (TP) concentrations and ratios measured at monitoring sites in the Upper Fox-Wolf Basins.

USGS Station ID	Station Name	FWM TP (µg/L)	GSM TP (µg/L)	FWM / GSM Ratio	Applicable TMDL Subbasins
04083545	Fond du Lac River at W. Arndt St.	229	249	0.92	43, 44, 88
04073500	Fox River at Berlin, WI	79	109	0.72	24, 28, 29
04073468	Green Lake Inlet at Ct Highway A Near Green Lake, WI	115	133	0.87	19, 87
04072845	Montello River Near Montello, WI	70	66	1.06	10
04073970	Waukau Creek Near Omro, WI	132	121	1.09	27
04079000	Wolf River at New London, WI	71	74	0.96	67, 68, 69, 71
Median				0.94	All remaining subbasins

5.1.2 Lakes and Reservoirs

The phosphorus loading capacity of each lake and reservoir addressed in this TMDL study was calculated based on results from lake response models. A response model estimates a lake's water column phosphorus concentration given its morphological attributes, inflow volume, and phosphorus loading. The phosphorus loading capacity of the Winnebago Pool lakes was determined using results from two response models: the BATHTUB model (Walker, 1999) and a custom model based on a paper by Jensen et al. (2006). Loading capacities for the remaining 18 lakes were determined using a custom version of the Wisconsin Lake Modeling Suite (WiLMS) (Wisconsin DNR, 2003).

All three lake response models used for the loading capacity analysis are empirical models that use inflows of water and phosphorus and lake morphology as inputs to predict in-lake TP concentration. The models differ from each other in their inputs needed for phosphorus prediction, their simulation time step, and spatial representation of a lake as a single pool versus multiple connected segments:

- The WiLMS model represents a lake as a single zero-dimensional, completely-mixed body of water with no horizontal or vertical variability in water quality. For this study, water and phosphorus inputs were entered as annual amounts and predicted lake TP concentrations were summer averages for the years being modeled.

- The BATHTUB model is similar to WiLMS but includes a hydrologic transport algorithm and is capable of simulating phosphorus concentrations in a lake or chain of lakes, like the Winnebago Pool lakes, as multiple connected segments. Each segment is represented as a zero-dimensional, completely-mixed body of water with no horizontal or vertical variability in water quality. For this study, water volumes and phosphorus concentrations were entered as growing season values and predicted lake TP concentrations were summer averages for the years being modeled.
- The Jensen model represents a lake as a zero-dimensional, completely-mixed body of water with no horizontal or vertical variability in water quality. Daily water and phosphorus inflows, and daily water temperatures, are used to predict daily TP concentrations. The Jensen model also requires input values of parameters that affect simulated deposition of phosphorus in bottom sediment and release of stored phosphorus from sediment. These values are determined by minimizing the difference in predicted and observed phosphorus concentrations in the lake. Summer average phosphorus concentrations from the Jensen model can be calculated by averaging daily predictions for June 1 through September 15.

Additional information on the lake response model setup and results is available in Appendix E for the Winnebago Pool Lakes and in Appendix D for the remaining lakes modeled with WiLMS.

The same general approach for evaluating phosphorus loading capacity was used for each lake response model. After setting up and calibrating the model, an “existing conditions” scenario was setup with estimates of 2009 through 2013 phosphorus loads input and an initial TP concentration was predicted. The modeled phosphorus load was then incrementally reduced until the predicted growing season TP concentration met the applicable target for the lake. The lake’s phosphorus loading capacity was identified as the phosphorus load that resulted in a predicted summer mean TP concentration equal to or just below the lake’s applicable target. Additional details and results of the loading capacity analysis are described in the following sections.

5.1.3 Winnebago Pool Lakes

Lake Model Results

The BATHTUB and Jensen models were both applied as part of the loading capacity analysis for the Winnebago Pool lakes. When evaluating phosphorus reductions needed to reach the numeric TP target, reductions in external and internal phosphorus sources were considered. As discussed in Section 4.2.9, internal phosphorus loading during the growing season is significant in Lake Winnebago and contributes to elevated summer TP concentrations.

The reasons for using two separate lake response models (BATHTUB and Jensen) were: (1) the results of one model can be validated from the results of the other model; and (2) each model has distinct advantages for loading capacity analysis. The BATHTUB model allows users to manually adjust both external and internal phosphorus loading to evaluate alternative lake management scenarios and assumptions on load reduction magnitudes. With the Jensen model, users can adjust external phosphorus loading and evaluate the subsequent effects on internal loading and water column phosphorus concentrations over time.

When applying the BATHTUB model for loading capacity analysis, incremental reductions in growing season phosphorus loading must be specified for both external *and* internal phosphorus sources (in contrast, only external load magnitudes must be specified in the Jensen model). To investigate alternative assumptions on internal load reductions, separate BATHTUB scenarios were run with different relationships between external and internal load reductions:

- BATHTUB Scenario A. In this scenario, the change in internal load was assumed to be proportional to the change in external load. For example, in this scenario a 50% reduction in all external loads considered controllable (all inputs except those from groundwater and the atmosphere) would be accompanied by a 50% reduction in internal loads.
- BATHTUB Scenario B. This scenario reflected a 25% higher internal load reduction relative to Scenario A for each incremental reduction in external loads. In this scenario, a 50% external load reduction would be accompanied by a 62.5% internal load reduction. Scenario B reflects a targeted management effort to support growing season internal load reductions through activities that could promote macrophyte growth to reduce wind-driven sediment suspension and other lake management activities.

Key results of the BATHTUB and Jensen lake models are:

- Both models showed that of the four lakes in the Winnebago Pool system, Lake Winnebago was the limiting factor for determining the phosphorus reductions needed to meet TP targets. Lake Winnebago required the largest reduction to phosphorus loads input to the system in order to reach the 40 µg/L TP target;
- BATHTUB Scenario A showed that a 73% reduction from the initial (existing conditions) external phosphorus load to the Winnebago Pool system during the growing season was needed to achieve the 40 µg/L TP target in Lake Winnebago. This scenario assumed a proportional 73% reduction in the growing season internal phosphorus load.
- BATHTUB Scenario B showed that a 67% reduction from the initial (existing conditions) external phosphorus load to the Winnebago Pool system during the growing season was needed to achieve the 40 µg/L TP target in Lake Winnebago. This scenario assumed a 75% reduction in the growing season internal phosphorus load, calculated as an additional 25% decrease from the external load reduction.
- The Jensen model showed that TP concentrations in Lake Winnebago showed the greatest improvement to water quality within the first 20 to 30 years of external load reductions. The change in TP concentrations then slowed until eventually stabilizing around the 40 µg/L target. This indicates that the bottom sediment of Lake Winnebago may continue to release excess phosphorus accumulated from external sources for several decades after reductions until a new equilibrium is achieved.
- The Jensen model showed that a 75% reduction from the initial (existing conditions) phosphorus load to the Winnebago Pool system during the growing season was needed to achieve the 40 µg/L TP target in Lake Winnebago. Once the 75% reduction in phosphorus loads is implemented, modeling indicates that it will take 65 to 70 years for the lakes to reach the 40 µg/L TP target. The Jensen model showed a 69% reduction was needed to achieve the 40 µg/L TP target in Lake Winnebago taking an estimated 100 to 105 years to reach the water quality criteria. Since the Jensen model includes algorithms to simulate internal phosphorus loading dynamics, a specific assumption on the internal phosphorus load reduction was not required as a model input.

The BATHTUB and Jensen lake models provide alternative phosphorus loading capacity values for the Winnebago Pool lakes. For this study, the loading capacity associated with BATHTUB Scenario B was selected for defining the TMDL and calculating allocations (67% reduction from the “existing conditions” external phosphorus load to the Winnebago Pool system). Both of the BATHTUB scenarios assume that proportional reductions in internal TP loading will occur with reduced external TP loading. BATHTUB Scenario B further assumes that additional reductions in internal TP loading will occur through targeted efforts to mitigate TP release from lake sediments (Table 15). These assumptions are discussed in more detail in the following section.

Table 15. Summary of Lake Winnebago internal TP loads and reductions in BATHTUB Scenarios A and B. Both scenarios assume that proportional reductions in internal TP loading will occur with reduced external TP loading. BATHTUB Scenario B further assumes that additional reductions in internal TP loading will occur through targeted efforts to mitigate TP release from lake sediments.

	Scenario A	Scenario B
Initial Growing Season Internal TP Load (pounds)	502,707	502,707
Final Growing Season Internal TP Load (pounds)	135,731	125,677
Total Growing Season Internal TP Load Reduction (pounds)	366,976	377,030
Proportional Reduction (pounds)	*366,976*	*336,814*
Additional Reduction (pounds)	*0*	*40,216*

Discussion of Internal Load Reduction

The internal phosphorus loading rates in the Winnebago Pool lakes estimated through mass balance, the BATHTUB model, and the Jensen model reflect the current sediment phosphorus concentration and a combination of physical, chemical, and biological factors that lead to flux of phosphorus from the sediment to the water column. If external phosphorus loads to the system are reduced, sediment phosphorus concentration should also decrease by a similar proportion, although there may be a significant lag time before a new equilibrium is reached. If the factors that facilitate phosphorus flux remained the same, internal loading would also decrease in proportion to external loading. However, some of these factors could also change through both positive feedback processes and intentional management actions.

The most likely mechanism for reducing sediment phosphorus flux to the water column is the re-establishment of rooted aquatic plants in significant areas of the Winnebago Pool lakes. Currently, 20% of the surface area of the upper pool lakes is occupied by aquatic plants. Aquatic plants are absent in the remaining area because of low water clarity and wind-driven turbulence. The increase in water clarity that results from reductions in external phosphorus loads would allow aquatic plants to grow in an additional 40% (for a total of 60%) of the upper pool lakes if wind-driven turbulence does not prevent re-establishment (Figure 17). The effective wind fetch on the upper pool could be reduced through the construction of strategically-located breakwaters. Aquatic plant coverage in Lake Winnebago could increase from 12% to 20% of the surface area from the expected increase in water clarity, although wind-driven turbulence is likely to be more difficult to mitigate in Lake Winnebago because of its larger surface area and depth. The areas of potential aquatic plant coverage would further increase throughout the Winnebago pool if water levels could be reduced. Resuspension of sediment by bottom-feeding fish could also be reduced by removing large numbers of certain species, such as carp, but this approach may be difficult to implement because of the size of the system and the presence of desirable bottom-feeding fishes, especially lake sturgeon. The influence of all these factors on the Winnebago pool's water quality and overall ecosystem are discussed in more detail in a report by Tetra Tech (2018).

Regardless of how it is achieved, re-establishment of rooted aquatic plants in the Winnebago pool will almost certainly reduce the flux of phosphorus from the sediment to the water column. There are only a few studies that have measured the relative rates of phosphorus flux from sediments in areas of the same lake with and without plants. In Lake Taihu, China, TP resuspension was 16 times higher in areas with no plants as in areas with plants (Zhu et al. 2015). Lake Taihu is larger and shallower than the Winnebago pool lakes, so wind-driven sediment resuspension is probably stronger in Taihu. In Lake Hiidenvesi, Finland, TP resuspension was 2-3 times higher in areas with no plants as in areas with plants (Horppila and Nurminen 2001, 2003). Lake Hiidenvesi is much smaller than any of the Winnebago pool lakes. Based on these studies, it is reasonable to expect that the TP resuspension rate in plant beds in the Winnebago pool would be 3-16 times less than the rate outside of plant beds. This range brackets the ratio of the mass-balance-derived internal loading rate for Lake Winnebago (3.00 mg/m^2/d) with the laboratory-determined aerobic rate (0.43 mg/m^2/d), equal to approximately 7x (see Appendix E). Based on the consistency of these different lines of evidence, it is reasonable to interpret the laboratory-determined aerobic TP release rate as a good approximation of the release rate in plant beds, and that the additional release evident in the mass balance is caused by wind-driven resuspension.

Two scenarios were evaluated for how aquatic plant re-establishment might affect internal loading in the Winnebago pool lakes. The first scenario, termed “clarity”, reflects only the effects of increased water clarity on areas of potential aquatic plants. The second scenario, termed “clarity and level”, also assumes a three-foot reduction in the summer water level in the Winnebago pool, which would increase the area of potential aquatic plants. In both scenarios, internal TP loading was first estimated by reducing it from the baseline by the same percentage as the reduction in external loading. Then, further reductions were estimated by assuming that areas where plants are re-established will have 7x lower internal loading than areas without plants. The effects of reduced internal loading in each of the upper pool lakes on the external load to the next downstream lake were estimated with BATHTUB.

With the 67% reduction in “existing conditions” external loading to the system, mean summer TP in Lake Winnebago drops from 45 µg/L if the spatial extent of aquatic plants does not change to 42 µg/L for the clarity scenario, and 39 µg/L for the clarity and level scenario. These scenarios indicate that positive feedback processes and intentional management actions can add to the effects of external load reductions to meet the 40 µg/L TP criterion for Lake Winnebago and support the TMDL assumption of a 25% additional reduction in internal loading beyond the proportional response to external loading.

Decisions about where to promote aquatic plant re-establishment and whether to alter water levels will require further discussion and planning. Because these scenarios rely on re-establishment of aquatic plants over substantial areas, and potentially reduction in summer water levels, they will affect recreational use of the Winnebago pool lakes. Some lake users may consider these changes undesirable but may be asked to accept them as a fair contribution alongside the substantial external TP load reductions.

Phosphorus Loading Capacity

Phosphorus loading capacities for the Winnebago Pool lakes are listed in Table 16. It is important to note the following when interpreting the values in Table 16:

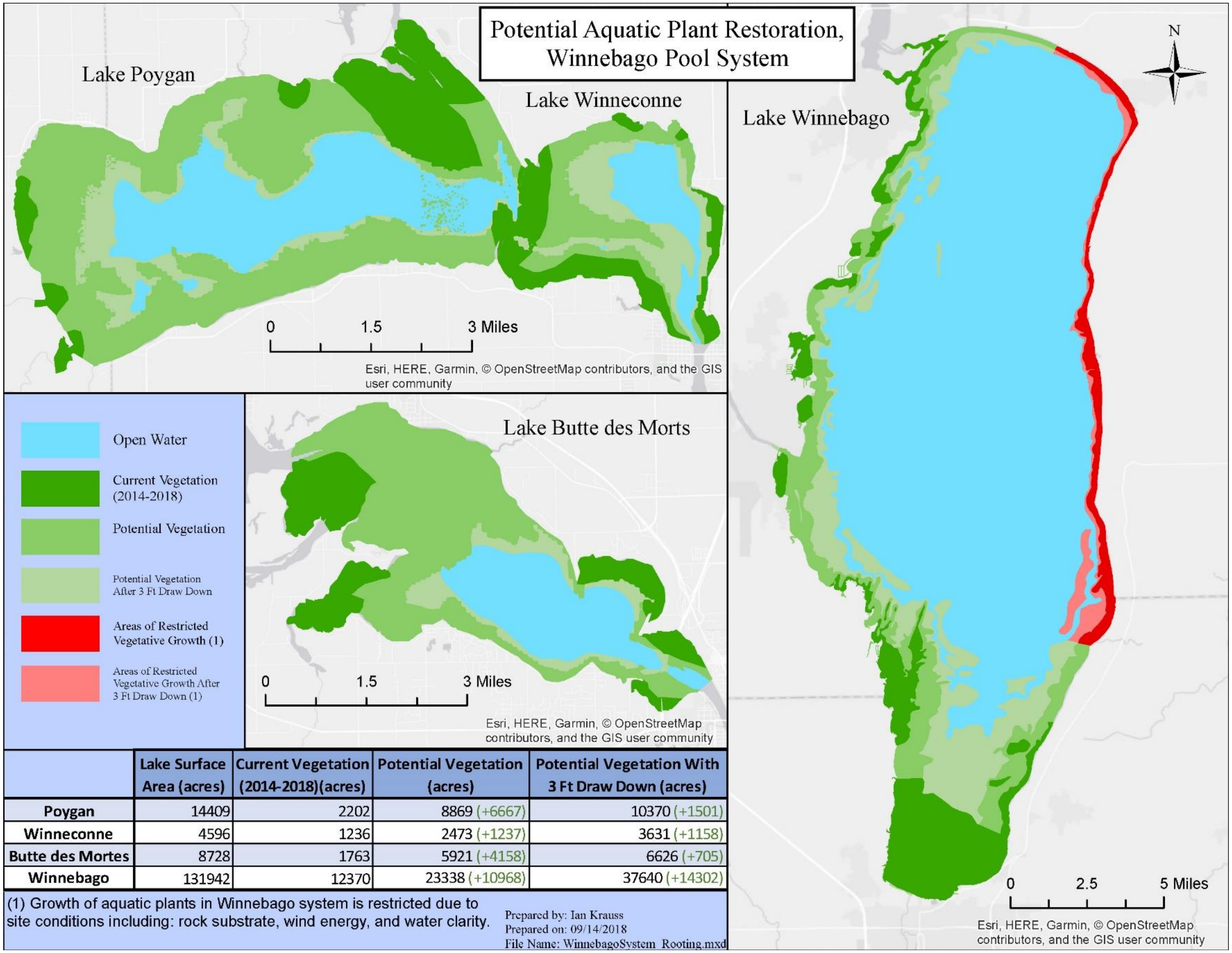
- Loading capacities are expressed as annual TP loads from external sources;
- The percentage reductions described in the preceding sections and the USGS study are based on reductions from an “existing conditions” loading magnitude applied for lake modeling. Different percentage reductions are needed from the “baseline” loading magnitude defined for this TMDL. The “baseline” load is higher than the “existing conditions” load because of assumptions applied to point source facility discharges (the baseline assumes point sources are discharging at their design flow and maximum permitted TP concentrations, for example). Further, the USGS study applies a uniform reduction to all incoming tributary loads without separating loads from non-controllable background sources (forests and wetlands). The USGS study also does not include a set-aside for Reserve Capacity;
- The loading capacity of the Upper Pool Lakes represents annual phosphorus loading from all external sources to Lake Poygan, Lake Winneconne, and Lake Butte des Morts. Separate loading capacities could not be derived for each individual lake because of the configuration of the

Winnebago Pool lakes and the fact that Lake Winnebago requires the largest reduction in external phosphorus loading;

- The loading capacity of Lake Winnebago represents annual phosphorus loading from all external sources to the entire Winnebago Pool system and accounts for routing effects of the Upper Pool lakes.
- The loading capacities reflect the implementation of a targeted management effort to support a growing season internal load reduction that is on a percentage basis larger than the change in external loading (see Table 15). Lake management strategies to reduce internal loading, such as activities that promote macrophyte growth to reduce wind-driven sediment suspension, are needed to achieve the numeric TP target in the Winnebago Pool lakes.

Table 16. Total phosphorus loading capacity of the Winnebago Pool lakes.

Lake Name	TMDL Subbasin	TP Water Quality Target (µg/L)	TP Loading Capacity (lbs/yr)
Upper Pool Lakes (Lake Poygan, Lake Winneconne, and Lake Butte des Morts)	72 & 73	40	218,450
Lake Winnebago	75	40	285,459



	Lake Surface Area (acres)	Current Vegetation (2014-2018)(acres)	Potential Vegetation (acres)	Potential Vegetation With 3 Ft Draw Down (acres)
Poygan	14409	2202	8869 (+6667)	10370 (+1501)
Winneconne	4596	1236	2473 (+1237)	3631 (+1158)
Butte des Mortes	8728	1763	5921 (+4158)	6626 (+705)
Winnebago	131942	12370	23338 (+10968)	37640 (+14302)

(1) Growth of aquatic plants in Winnebago system is restricted due to site conditions including: rock substrate, wind energy, and water clarity.

Prepared by: Ian Krauss
Prepared on: 09/14/2018
File Name: WinnebagoSystem_Rooting.mxd

Figure 17. Extent of current aquatic vegetation in the Winnebago Pool lakes and potential restoration areas under existing water levels and a three-foot drawdown scenario.

5.1.4 Additional Lakes and Reservoirs

For the remaining 18 lakes and reservoirs addressed in this study, the phosphorus loading capacity was determined using results from the WiLMS model by identifying the external annual TP load that provided a predicted summer mean TP concentration equal to the applicable target for each lake. Loading capacities are shown in Table 17.

Table 17. Total phosphorus loading capacity of the additional lakes and reservoirs addressed in this TMDL report.

Lake Name	TMDL Subbasin	TP Water Quality Target (µg/L)	TP Loading Capacity (lbs/yr)
Big Twin Lake	83	30	327
Black Otter Lake	82	40	1,749
Buffalo Lake	9	40	13,694
Collins Lake	65	20	359
Green Lake	20	15	9,319
Lake Emily	84	40	207
Little Green Lake	11	40	134
Long Lake	57	30	812
Mason Lake	3	40	1,312
Old Taylor Lake	85	20	8
Park Lake	5	40	3,316
Puckaway Lake	16	40	27,594
School Section Lake	62	30	297
Shawano Lake	56	40	5,619
Spring Lake	86	15	622
Swan Lake	6	30	11,402
Upper Post Lake	77	40	5,485
White Clay Lake	54	30	319

5.2 Sediment Loading Capacity

5.2.1 Stream and River Reaches

The sediment loading capacity of each TMDL subbasin was calculated using the same approach applied for TP in stream and river reaches. The sediment loading capacity for headwater TMDL subbasins was initially calculated as:

$$Loading\ Capacity = Q_{mean} * TSS_{crit} * FWM \ / \ GSM$$

where *Qmean* is the mean annual flow in the subbasin, *TSScrit* is the numeric concentration target for TSS (12 mg/L for all subbasins), and *FWM/GSM* is the conversion factor for translating annual FWM TSS concentrations to GSM concentrations (described below). The sediment loading capacity for non-headwater subbasins was then calculated using the above equation minus the loading capacity of all upstream subbasins.

Like phosphorus, the TSS target is expressed as a growing season (May through October) median (see Section 2) and a FWM / GSM ratio is needed for each subbasin to relate the target to annual TSS loading. Table 18 displays FWM TSS concentrations (calculated as average annual TSS load divided by average annual flow volume), GSM TSS concentrations (calculated from growing season samples), and FWM / GSM ratios for five sites in the UFWB with daily streamflow and TSS monitoring data. The FWM / GSM ratios for TSS cover a wide range, from 0.5 at the Fox River site to 3.7 at the Fond du Lac River site, with a median of 1.1. Higher FWM / GSM ratios, such as the Fond du Lac River and Waukau Creek values, would be expected to occur where TSS concentrations strongly correlate with streamflow magnitude and where there is little seasonal variation. Lower ratios, such as the Fox River and Wolf River values, occur where TSS shows a strong growing season peak and is independent of streamflow.

Site-specific FWM / GSM ratios for determining sediment loading capacities were only used for mainstem Fox River and Wolf River subbasins. The ratio for the Fox River site (0.5) was applied to three subbasins containing the mainstem Fox River between the Lake Puckaway outlet and Lake Butte des Morts (subbasins 24, 28, and 29). The ratio for the Wolf River site was applied to four subbasins containing the mainstem Wolf River, below the Red River confluence (subbasins 55, 67, 68, 69). All other TMDL subbasins were assigned a FWM / GSM ratio of 1.0 for the sediment loading capacity analysis. While it is acknowledged that ratios above 1.0 are observed for 3 of the 5 sites listed in Table 18, a ratio of 1.0 was selected as a conservative assumption for TMDL development since a lower ratio magnitude results in a lower calculated loading capacity. Sediment loading capacities for each TMDL subbasin are reported in Appendix I.

Table 18. Annual flow-weighted mean (FWM) and growing season median (GSM) total suspended solids (TSS) concentrations and ratios measured at monitoring sites in the Upper Fox-Wolf Basins.

USGS Station ID	Station Name	FWM TSS (mg/L)	GSM TSS (mg/L)	FWM / GSM Ratio
04083545	Fond du Lac River at W. Arndt St.	32.3	8.7	3.7
04073500	Fox River at Berlin, WI	17.5	31.9	0.5
04072845	Montello River Near Montello, WI	7.9	7.3	1.1
04073970	Waukau Creek Near Omro, WI	21.7	8.1	2.7
04079000	Wolf River at New London, WI	9.7	13.9	0.7
Median				1.1

5.2.2 Lakes and Reservoirs

Six lakes addressed in this report are present on the Wisconsin 2018 303(d) Impaired Waters List with both TSS and TP identified as the cause of impairment (Lake Butte des Morts, Lake Winnebago, Park Lake, Lake Poygan, Lake Puckaway, and Lake Winneconne; see Table 1). This study does not address the lake TSS impairment listings by defining numeric TSS targets for the lakes and analyzing associated TSS loading capacities. At the time of this TMDL study, there were insufficient data and methods available to determine a numeric target for TSS in lakes and to develop a water quality model to link sediment loading to in-lake TSS concentrations. Instead, the lake TSS listings are addressed through the development of TP TMDLs for the impaired lakes and TSS TMDLs for tributary streams and rivers.

A clear link exists between excess TP loading and elevated TSS concentrations in lakes due to high algae growth in the water column. Further, many of the same mechanisms that lead to high phosphorus loading to lakes are also associated with high TSS loads. These include erosion of phosphorus-rich sediment from the land surface, stream channel erosion, and resuspension of lake bottom sediments due to wind and wave action. Reductions in lake TSS concentrations are expected to occur with the implementation of the TMDLs presented in this report. Implementation actions to achieve the lake TP TMDLs and stream/river TSS TMDLs will reduce sediment loading in agricultural runoff, urban runoff, and point source discharges. Efforts to stabilize streambanks and lake bottom sediments are also planned. Together, these activities are expected to reduce TSS loading, algae growth, and bottom sediment resuspension in lakes with TSS impairments. Monitoring and analysis of lake TSS following TMDL implementation will indicate whether these reductions are sufficiently addressing the lake TSS impairments or whether additional TSS reductions are needed.

5.3 Critical Conditions

A TMDL must consider critical conditions for pollutant loading and their effects on water quality as part of the analysis of loading capacity. Wisconsin's phosphorus criteria are assessed during the growing season (May through October) in streams and the summer (June 1 through September 15) in lakes. These periods can be considered critical conditions for the water quality effects of phosphorus loading because they are times when the biological responses to excess phosphorus are strongest due to temperature, flow, and sunlight conditions that are conducive to excessive plant growth. Similarly, the water quality target for sediment is expressed as a growing season (May through October) TSS concentration. High TSS concentrations during the growing season are especially problematic because excess sediment reduces the amount of light available to submerged aquatic vegetation for growth and potentially increases water temperatures. Further, the spawning of many fish and aquatic insect species can be disrupted with high growing season sediment concentrations because settling particles can smother fish eggs and insect larvae.

Although critical conditions for assessment of phosphorus and sediment occur during the summer and growing season, critical conditions for phosphorus and sediment loading include the entire year. This is because phosphorus and sediment entering a waterbody during non-growing season months can be stored over time and released during the growing season. Loading capacities and TMDL allocations for phosphorus and sediment were therefore calculated on an annual basis, with methods described in the preceding sections to translate annual loads to growing season or summer concentration targets (i.e., FWM / GSM ratios for stream and river reaches; lake response models for lakes and reservoirs).

6 POLLUTANT LOAD ALLOCATIONS

6.1 TMDL Equation

The main objective of a TMDL is to allocate the pollutant loads that result in attainment of water quality standards among pollutant sources. Sources that contribute loads greater than allocated amounts can then be identified and control measures can be implemented to achieve water quality standards. Wasteload allocations (WLAs) are assigned to point source discharges regulated by WPDES permits. Nonpoint source loads, including natural background sources, are assigned load allocations (LAs). A TMDL must also include a margin of safety (MOS) to account for uncertainty in loading capacity. A reserve load capacity (RC) may be included in a TMDL to account for future discharges, changes in discharges, and other sources not defined through the TMDL study. A TMDL is therefore expressed as the sum of all individual WLAs for point source loads, LAs for nonpoint source loads, the MOS, and the RC:

$$TMDL = \sum WLA + \sum LA + MOS + RC$$

6.2 Allocation Approach

As described in Section 1.3, this TMDL was developed using a watershed framework. Under a watershed framework, TMDLs and the associated tasks are simultaneously completed for multiple impaired water bodies in a watershed. This section describes the methodology used to allocate the phosphorus and sediment loading capacity of TMDL subbasins (described in Section 5) among pollutant sources.

For this TMDL study, load and wasteload allocations are specified for the following source categories:

- Load allocations
    - Background sources. Includes nonpoint source loading from forests and wetlands, atmospheric deposition of phosphorus to the Winnebago Pool Lakes, and phosphorus loading from direct groundwater inflow to the Winnebago Pool Lakes.
    - Agricultural sources. Includes nonpoint source loading from cropland and pasture/grassland.
    - Non-regulated urban areas. Includes nonpoint source loading from non-regulated urban areas, including septic systems.
- Wasteload allocations
    - POTWs and industrial dischargers with individual WPDES permits.
    - Municipalities with WPDES MS4 stormwater permits.
    - CAFOs covered under the WPDES general CAFO permit.
    - General WPDES permits for discharges not included in the above groups (e.g., stormwater discharges from construction sites or industrial facilities located outside of a permitted MS4).

The load allocation approach involved several steps which were applied incrementally to the 89 TMDL subbasins, starting with upstream headwater subbasins and proceeding downstream. The process started by comparing the baseline load for the subbasin to the loading capacity of the receiving waters in the subbasin. For subbasins with stream and river reaches, this step used local, incremental baseline loads and loading capacities (i.e., only loads generated in the subbasin and not upstream loads). For phosphorus allocations, the analysis also considered whether the subbasin contained a lake or reservoir. If the subbasin contained a lake or reservoir, then TP loading capacities determined from lake response models were used to evaluate reductions for all sources contributing to each lake/reservoir, including sources in upstream subbasins.

The TSS allocation analysis applied a similar process as the TP lake/reservoir allocation to evaluate reductions from local and upstream sources contributing to the Fox River from the Lake Puckaway outlet to Lake Butte des Morts (Subbasins 24, 28, and 29) and the Wolf River below the Embarrass River (Subbasin 71). These TMDL Subbasins were assigned FWM:GSM ratios that reflected the strong growing season peak evident in TSS sample data and the ratios were much lower in magnitude than ratios for their tributaries (see Section 5.2.1). To meet the loading capacities for Subbasins 24, 28, 29, and 71, additional reductions from sources in upstream subbasins were needed beyond those required to meet local targets in the upstream subbasins.

In summary, the allocation steps depended on the pollutant analyzed (TP or TSS), whether the TMDL subbasin contained a stream/river reach or a lake/reservoir reach, and whether the subbasin's baseline load was greater than or less than the loading capacity. Each case is reviewed below.

Case 1: Stream/river reach with baseline load above loading capacity

a) The total allocated load for controllable sources in the subbasin was calculated as the loading capacity minus the background load (forest and wetland) and general permit load for the subbasin.
b) Reserve capacity was set to 5% of this allocated load from controllable sources.
c) The total allocated load for controllable sources in the subbasin calculated in step (a) was reduced by subtracting the reserve capacity load calculated in step (b).

Case 2: Stream/river reach with baseline load below loading capacity

a) Since the subbasin's baseline load is less than its loading capacity, no load reductions are required to meet water quality targets in the subbasin. The reserve capacity was set to 5% of the subbasin's baseline controllable load and added to the baseline subbasin load for analysis in downstream subbasins.

Case 3: Subbasin contains a lake/reservoir (phosphorus allocations only)

a) Calculate the cumulative incoming load from local and upstream sources, accounting for any reductions already applied to meet upstream targets and compare the incoming load to the loading capacity for the lake/reservoir.
b) Determine the load reduction needed to come from local and upstream sources as the incoming load minus the loading capacity.
c) Incrementally reduce controllable loads from local and upstream sources by an equal percentage until the required load reduction calculated in step (b) is achieved. During each incremental reduction, the group of upstream subbasins considered "available" for load reductions is defined. Subbasins that are not available for reductions are those that have already had reductions applied for another upstream lake/reservoir, subbasins with reductions that already exceed the percent reduction for the current increment, or subbasins in the watershed of an upstream lake/reservoir with a lower numeric concentration target than the current lake/reservoir.
d) Reserve capacity was set to 5% of the total allocated load for controllable sources in the subbasin determined from step (c).
e) The total allocated load for controllable sources in the subbasin was reduced by subtracting the reserve capacity load calculated in step (d).

Case 4: Subbasin contains Fox River between the Lake Puckaway outlet and Lake Butte des Morts or Wolf River below the Embarrass River (TSS allocations only)

a) Calculate the cumulative incoming load from local and upstream sources, accounting for any reductions already applied to meet upstream targets and compare the incoming load to the loading capacity for the subbasin.

b) Determine the load reduction needed to come from local and upstream sources as the incoming load minus the loading capacity.
c) Incrementally reduce controllable loads from local and upstream sources by an equal percentage until the required load reduction calculated in step (b) is achieved. During each incremental reduction, the group of upstream subbasins considered "available" for load reductions is defined. Subbasins that are not available for reductions are those that have already had reductions applied for another upstream mainstem Fox/Wolf River reach or subbasins with reductions that already exceed the percent reduction for the current increment.
d) Reserve capacity was set to 5% of the total allocated load for controllable sources in the subbasin determined from step (c).
e) The total allocated load for controllable sources in the subbasin was reduced by subtracting the reserve capacity load calculated in step (d).

Proportional Allocation Method

In all cases, calculation of the total allocated load for controllable sources was followed by calculating allocations for individual source categories (e.g., agriculture, non-regulated urban, MS4s, POTWs). The total allocated load for controllable sources was distributed among each source category based on the fraction of the baseline load represented by the source category. For example, if agricultural sources accounted for 50% of the baseline controllable source load, then they were given 50% of the total allocated controllable load. These fractions were calculated separately for each subbasin. This method assigns responsibility for attaining water quality targets in proportion to each source's current contribution to the excess load.

A final check was completed to determine if any of the permitted wastewater facilities received an allocation that requires an effluent concentration below their subbasin's target concentration. If the reduction was due to a downstream waterbody, the following applied:

- If the facility's baseline effluent concentration was greater than its subbasin target concentration, then the facility's allocated load was recalculated so that the final effluent concentration was equal to the subbasin target. Adjustments were made to other controllable source allocations to balance the modified facility allocation. All allocations were then rebalanced so that reserve capacity was 5% of the total allocated load from controllable sources and each source's allocation was proportional to its baseline contribution.
- If the facility's baseline effluent concentration was less than its subbasin target concentration, then the facility's allocated load was recalculated so that the final effluent concentration was equal to its baseline concentration. Adjustments were made to other controllable source allocations to balance the modified facility allocation. All allocations were then rebalanced so that reserve capacity was 5% of the total allocated load from controllable sources and each source's allocation was proportional to its baseline contribution.

Allocations were calculated separately for each source or source type in TMDL subbasins on an annual basis. Phosphorus allocations by subbasin and source type are presented in Appendix H**.** Sediment allocations by subbasin and source type are presented in Appendix I.

6.3 Load Allocations

6.3.1 Background Sources

Load allocations for background sources of phosphorus and sediment include nonpoint source loading from forests and wetlands, atmospheric deposition of phosphorus to the Winnebago Pool Lakes, and phosphorus loading from direct groundwater inflow to the Winnebago Pool Lakes. Background source allocations were set equal to baseline loads for background sources (i.e., no load reduction from baseline). Load allocations for background sources are listed in Appendix H for total phosphorus and in Appendix I for sediment.

6.3.2 Agricultural and Non-Regulated Urban Sources

Load allocations for nonpoint agricultural sources and non-regulated urban sources of phosphorus and sediment were calculated from baseline loads and reductions determined using the steps described in Section 6.2. Load allocations for agricultural nonpoint sources and non-regulated urban sources are listed in Appendix H for total phosphorus and in Appendix I for sediment.

6.4 Wasteload Allocations

6.4.1 Permitted Municipal and Industrial Wastewater Discharges

Wasteload allocations for municipal and industrial wastewater discharges covered by an individual WPDES permit were calculated from baseline loads and reductions determined using the steps described in Section 6.2. Wasteload allocations for municipal and industrial wastewater discharges covered by an individual WPDES permit are listed in Appendix H for total phosphorus and in Appendix I for sediment.

Section 40 CFR 122.45 (d), s. NR 212.76 (4), and s. NR 205.065 (7), Wis. Adm. Code, specifies that unless impracticable, permit effluent limits must be expressed as weekly and monthly averages for publicly owned treatment works and as daily maximums and monthly averages for all other continuous discharges. A continuous discharge is a discharge which occurs without interruption throughout the operating hours of the facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities (s. 40 CFR 122.2 and s. NR 205.03 (9g), Wis. Adm. Code).

The WDNR has demonstrated the impracticability of expressing WQBELs for TP as specified in 40 CFR 122.45 (d). The impracticability demonstration indicates that WQBELs for TP shall be expressed as a monthly average, if the TP WQBEL is equivalent to a concentration value greater than 0.3 mg/L, and as a six-month average and a monthly average limit of 3 times the six-month average, if the TP WQBEL is equivalent to a concentration value less than 0.3 mg/L. This will be implemented pursuant to the WPDES permit process.

For non-continuous discharges, methods for converting WLAs into permit limits should be determined on a case-by-case basis. For example, some discharges do not occur continuously and often vary from year to year, depending on weather conditions or production processes. In these cases, it may be appropriate to express limits by season or as a total annual amount. In many cases, using shorter term limits (daily, monthly) might have the effect of unduly limiting operational flexibility and, since TMDLs are required to be protective of critical conditions, a seasonal or annual limit would be consistent with the TMDL and protective of water quality. This will be implemented pursuant to the WPDES permit process.

Discharges covered by individual permits that have surface water intake structures are allowed to pass through the phosphorus that is present due to the water supply but are expected to remove any excess that is added or concentrated in their discharge to meet their wasteload allocation.

For phosphorus, the mass allocation contained in the TMDL will be expressed as a mass limit. In many cases, dischargers will also receive a concentration limit for phosphorus, based on the technology-based effluent concentration limit (TBEL) requirements in ch. NR 217, Wis. Adm. Code.

For sediment, the TSS allocation contained in the TMDL will be expressed as a mass limit. In many cases, dischargers will also receive a concentration limit for TSS, based on TBEL requirements in ch. NR 210, Wis. Adm. Code, or applicable effluent limit guidelines for industrial discharges. Since standard wastewater treatment processes such as grit removal and primary and secondary clarification, which are necessary to reduce wastewater TSS levels to 12 mg/L, will have removed settable material that would contribute to sedimentation, wastewater discharges at or below 12 mg/L will not contribute to sediment impairments. Contributions to turbidity, a condition that is related to concentration and not mass, would also be absent at 12 mg/L effluent concentrations. Therefore, wastewater dischargers will not be required to meet effluent limits lower than 12 mg/L (including equivalent mass limits) in order to comply with the water quality targets developed for this TMDL.

Appendix H and Appendix I present wasteload allocations broken out by the total wasteload allocation for the facility, the wasteload allocation assigned to the facility needed to meet local water quality in the subbasin the facility discharges into, and the wasteload allocation required to meet downstream water quality. Allocations have been broken out in this manner to help facilitate water quality trading, since the geographic extent in which trades can occur is based on the point of standards application as outlined in the "Guidance for Implementing Water Quality Trading in WPDES Permits", 08/21/2013. A copy of the guidance can be found at: http://dnr.wi.gov/topic/SurfaceWater/documents/WQT_guidance_Aug_21_2013signed.pdf or by searching for "water quality trading" at http://dnr.wi.gov/.

6.4.2 General Permits

WPDES general permits address stormwater discharges from industrial facilities and construction sites and wastewater discharges that are considered to not be significant contributors of pollution. Wasteload allocations for stormwater general permittees located within an MS4 boundary are included in the MS4 WLA. As described in Section 4.2.3, baseline TP and TSS loads for all other stormwater and wastewater general permittees were estimated by TMDL subbasin as 10% of the baseline non-regulated urban load in the subbasin. The wasteload allocations for these general permits were set aside with no reduction from baseline values.

Some NCCW discharges in this TMDL area covered by a general permit (WI-0044938). Similar conditions are assumed for these facilities as for those with individual permits. That is, for facilities that use water from a public water supply, it is assumed that phosphorus will be present in the NCCW if added by the water supply. Discharges covered by general permits that have surface water intake structures are assumed to have no net addition. Similar to individual permit holders, general permittees are allowed to pass through the phosphorus that is present due to the water supply, but are expected to remove any excess that is added or concentrated in their discharge.

NCCW facilities covered under the general permit and located in watersheds with approved TMDLs are required to submit quarterly monitoring results for P and TSS. These monitoring results will be used to track the total mass allocation used by NCCW facilities in each watershed. If through the increased monitoring and tracking it is determined that sufficient allocation has not been set aside for NCCW facilities, facilities may be switched to individual permits with discharge requirements placed in the permit sufficient to meet TMDL allocations and/or reserve capacity may be used to increase the WLA for general permits, where necessary.

6.4.3 Permitted Municipal Separate Storm Sewer Systems

As described in Section 4.2.2, there are 29 permitted MS4s within the UFWB that receive wasteload allocations under this TMDL project. Baseline MS4 loads were determined from the UFWB SWAT model (see Section 4.2.2). SWAT model results were adjusted for defining baseline conditions to reflect a 20% TSS reduction, consistent with requirements in ch. NR 216 and NR 151, Wis. Admin. Code, and a corresponding 15% reduction in TP. The corresponding 15% TP reduction is calculated in SLAMM by applying BMPs to obtain the 20% TSS reduction. The reduction relationship between TP and TSS is not 1:1

because of the portioning between phosphorus attached to sediment and the soluble phosphorus in the urban runoff.

There may be MS4s in the basin that have already implemented practices that achieve an annual average TSS reductions of greater than 20% or TP reduction of greater than 15%. While these individual modeled results have not been included in the TMDL analysis, these above-baseline reductions will be credited towards meeting water quality targets established in the WPDES permits regulating these municipalities.

Wasteload allocations for MS4 permittees were calculated using the steps described in Section 6.2, with baseline loads reduced according to the percentage reduction required for all controllable sources to achieve calculated loading capacities. Wasteload allocations for permitted MS4s are listed in Appendix H for total phosphorus and in Appendix I for sediment.

Calumet County, Fond du Lac County, Winnebago County, and University of Wisconsin-Oshkosh are all covered by a WPDES MS4 permit but will not receive individual allocations. Instead, they are accounted for in the portions of each city, village, or town MS4 that they discharge to or lie within; however, these regulated MS4s that are not given specific allocations will be required to achieve the applicable identified reductions within their portion of their jurisdictional area. The permitted area is determined by the US Census Bureau’s mapped Urbanized Area, adjacent developed areas, or areas that are connected or will connect to other municipal separate storm sewer systems regulated under subch. I of NR 216, Wis. Adm. Code.

Stormwater discharge from Wisconsin Department of Transportation (WisDOT) land areas were not covered by a WPDES permit when the TMDL analysis was conducted; however, a WPDES permit has been developed for WisDOT. This permit, referred to as the TS4 permit, along with the conditions of a memorandum of understanding with WDNR will be used to implement the TMDL requirements for WisDOT discharges. A section of the MS4 permit is dedicated to the implementation of the TMDL requiring WisDOT to comply with the TMDL allocation set forth in this TMDL.

The specific TS4 allocation is considered to be included in the allocation for each MS4 with WisDOT area. At the time the watershed modeling was conducted for this TMDL, sufficient detail did not exist to partition out the TS4 allocation and assign an explicit allocation. Please refer to the MS4 TMDL Implementation Guidance for details on how to partition the allocation; “TMDL Guidance for MS4 Permits: Planning, Implementation, and Modeling Guidance” effective October 20, 2014. The guidance and addendums can be found at: https://dnr.wi.gov/topic/stormwater/standards/ms4_modeling.html.

Percent reductions from baseline loading that apply to each MS4 are broken out by TMDL Subbasin in Appendix H and Appendix I. Percent reductions from baseline are expressed in three ways; as the percent reduction needed to protect local water quality (i.e., within the TMDL Subbasin the MS4 is located), as the percent reduction necessary to meet downstream water quality targets, and the total percent reduction. The total percent reduction represents what is needed to meet both local and downstream water quality targets. Guidance related to applying the percent reduction to implement the TMDL can be found in the MS4 TMDL Implementation Guidance: “TMDL Guidance for MS4 Permits: Planning, Implementation, and Modeling Guidance” effective October 20, 2014. The guidance and addendums can be found at: https://dnr.wi.gov/topic/stormwater/standards/ms4_modeling.html.

6.4.4 Concentrated Animal Feeding Operations

The production area, storage areas, and ancillary service areas for CAFOs have been assigned a WLA of zero based on WPDES permit conditions that do not allow discharges that cause or contribute to a violation of water quality standards. In addition, a CAFO may not discharge any pollutants from the production area to a 303(d)-listed surface water if the pollutants discharged are related to the cause of the impairment. For this TMDL study, these pollutants include TP and TSS; however, surface waters may be listed as impaired for additional pollutants such as bacteria.

CAFOs must comply with all WPDES permit conditions which include the livestock performance standards and prohibitions in ch. NR 151, Wis. Admin. Code. These WPDES permit conditions have been translated into a WLA of zero. Specific WPDES permit conditions for the production area specify that CAFOs may not discharge manure or process wastewater pollutants to navigable waters from the production area, including approved manure stacking sites, unless all of the following apply:

- Precipitation causes an overflow of manure or process wastewater from a containment or storage structure.
- The containment or storage structure is properly designed, constructed and maintained to contain all manure and process wastewater from the operation, including the runoff and the direct precipitation from a 25-year, 24-hour rainfall event for this location.
- The production area is operated in accordance with the inspection, maintenance and record keeping requirements in s. NR 243.19, Wis. Admin. Code.
- The discharge complies with surface water quality standards.

For ancillary service and storage area, CAFOs may discharge contaminated storm water to waters of the state provided the discharges comply with groundwater and surface water quality standards. The permittee shall take preventive maintenance actions and conduct periodic visual inspections to minimize the discharge of pollutants from these areas to surface waters. For CAFO outdoor vegetated areas, the permittee shall also implement the following practices:

- Manage stocking densities, implement management systems and manage feed sources to ensure that sufficient vegetative cover is maintained over the entire area at all times.
- Prohibit direct access of livestock or poultry to surface waters or wetlands located in or adjacent to the area unless approved by the Department.

Any runoff from CAFO land application activities is considered a nonpoint source and is covered in the TMDL through the load allocation.

Reserve capacity, if available, (see Section 6.7) and water quality trading can be used to off-set phosphorus or TSS loads associated with a continuous surface water discharge as part of an approved alternative manure treatment system.

6.5 Tribal Lands

Portions of the Wolf River Basin are located within the boundaries of lands under the authority of the Forest County Potawatomi, Ho-Chunk Nation, Menominee, Sokaogon Chippewa, and Stockbridge Munsee tribes. The TMDLs established for the UFWB are not applicable to lands and waterbodies located within the boundary of tribal lands. However, to meet the TMDLs for the UFWB, voluntary reductions are needed from sources within the tribal lands to ensure/demonstrate that Tribal sources are not causing or contributing to an exceedance of a downstream WQS. Therefore, load reduction goals for pollutant loads originating from within tribal lands are also identified in Appendix H and Appendix I. These load reduction goals were calculated for point and nonpoint sources within tribal lands using the same methods applied to develop load and wasteload allocations for areas outside of tribal lands.

6.6 Margin of Safety

The margin of safety (MOS) can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. An implicit margin of safety has been incorporated into the TMDLs presented in this report. The implicit MOS is based on the following aspects of the loading capacity and allocation analysis.

- Streams and Rivers
    - The FWM / GSM ratios used for sediment loading capacity analysis were set to 1.0 or less for all TMDL subbasins. Ratios below 1.0 were only observed at two monitoring sites in the UFWB (Fox River at Berlin and Wolf River at New London, see Table 18) and ratios for mainstem Fox River and Wolf River subbasins were set to those observed for loading capacity calculations. Ratios for the three remaining monitoring sites were all above 1.0. Since lower FWM / GSM ratios result in a lower calculated loading capacity for streams and rivers, the use of a ratio of 1.0 for all other TMDL subbasins (i.e., below measured values) represents a conservative assumption for TMDL development.
    - The phosphorus loading capacity of Lake Winnebago requires load reductions from most TMDL subbasins that are beyond what would be needed to meet local stream and river targets for phosphorus. The difference between these two levels of load reductions represents an implicit MOS for subbasins with phosphorus allocations determined by Lake Winnebago.
- Lakes and Reservoirs
    - The phosphorus loading capacity analysis for lakes and reservoirs used lake response models to estimate water column TP concentrations under a given magnitude of water inflow and external phosphorus loading (see Section 5.1.2). Within these models, the assumed volume of water entering a lake is relevant to the loading capacity analysis since the lake's calculated loading capacity decreases with less water inflow. In the lake response models developed for this study, values of water inflow volume were set to estimates of existing average flows from tributaries and point sources during the 2009-2013 baseline period. These water volumes are less than the baseline flows used for calculating stream and river loading capacities, which were derived from facility design flows (for POTWs) or maximum annual observed flows (for industrial dischargers). The use of average point source flows from 2009-2013 in the lake models (rather than design flows or maximum annual flows) was therefore a conservative assumption for phosphorus loading capacity calculation in lakes and reservoirs.
- Winnebago Pool Lakes
    - In the allocation analysis for the Winnebago Pool lakes, TP loads from direct groundwater discharge (discussed in Section 4.2.7) are assigned to the background source category, with no reductions applied to baseline loads. However, the TP sample data used to estimate baseline groundwater TP loading may have been elevated from human activity (see Section 4.2.7), and a reduction in TP loading from direct groundwater discharge to the Winnebago Pool may occur as land management activities are implemented to reduce TP in surface water. The assumption of no change in baseline groundwater TP loading for allocation analysis therefore represents a conservative assumption for TP TMDL development.
    - The USGS study of the Winnebago Pool lakes documented in Appendix E used two lake response models to evaluate the phosphorus loading capacity of Lake Poygan, Winneconne, Butte des Morts, and Winnebago. The models were based on water quality and streamflow monitoring data collected in the lakes and tributaries and from detailed water and phosphorus budgets developed from sample data. Although each model used a different time step (daily versus growing season), different representations of internal phosphorus loading, and different algorithms for estimating water column TP, they both provided similar loading capacity results (see Section 5.1.2). The close agreement between the results of the two models provides confidence in the estimated phosphorus loading capacities of the Winnebago Pool Lakes and reflects an implicit MOS for TP TMDL development.

- All waterbody types
  - Section 4.2.8 notes that TP and TSS loading from streambank erosion is not explicitly modeled in this study but is factored into baseline loading estimates for other nonpoint source categories (agriculture, urban, etc.). This approach represents an implicit margin of safety in nonpoint source allocations because WDNR plans to encourage practices in the UFWB specifically aimed at reducing streambank erosion while also attaining allocations for land-based sources.

6.7 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. A reserve capacity was included in the TMDL allocations to account for future discharges, changes in current discharger loading, and other sources not defined through TMDL development. To calculate the reserve capacity in each TMDL subbasin, the natural background load and general permitted baseline loads were subtracted from the total allowable load, and then the reserve capacity was set as 5% of the remaining controllable load. Reserve capacity allocations are listed in Appendix H for total phosphorus and in Appendix I for sediment.

This provides adequate reserve capacity for potential new or expanding dischargers in headwater sections of the basin. In addition, reserve capacity accumulates from contributing subbasins moving down through the basin making more available for dischargers located on larger downstream rivers. This approach affords dischargers greater flexibility in where they can locate or expand, minimizes impacts on existing dischargers, and is consistent with the observed practice of larger dischargers locating on larger bodies of water.

Reserve capacity is intended to provide wasteload allocation for new or expanding industrial, CAFOs, or municipal WPDES individual permit holders. Reserve capacity may be applied to general permittees if it is determined, through analysis of discharge monitoring data, that the amount set aside for GPs is not enough to cover the actual discharge amount from existing, new, or expanding discharges.

Reserve capacity is not required for new or expanding permitted MS4s. For new or expanding permitted MS4s, the mass associated with the load allocation for the nonpermitted, undeveloped, or agricultural land, that is now part of the permitted MS4, is transferred to the wasteload allocation with a percent reduction in pollutant load assigned to the new or expanding permitted MS4 area consistent with the reductions stipulated in the TMDL for the subbasin. Refer to “TMDL Guidance for MS4 Permits: Planning, Implementation, and Modeling Guidance” and corresponding addendums for process details. The MS4 guidance and addendums can be found at https://dnr.wi.gov/topic/stormwater/standards/ms4_modeling.html.

For CAFOs, the TMDL assigns the production area a wasteload allocation of zero; however, reserve capacity may be available to cover a new or expanding continuous or intermittent surface water discharge resulting from a manure treatment system. If reserve capacity is not available, the mass resulting from a treatment system discharge must be off-set through water quality trading. This off-set can be generated through reductions in pollutant loads associated with modifications in manure applications to fields resulting from the treatment system or changes in the CAFO’s operation. Fields receiving manure from the CAFO are covered by the nonpoint load allocation.

Baseline loads from municipal wastewater treatment plants were calculated using the design flow of the facility, which is based on a 20-year design life; therefore, the allocations for these point sources should account for future growth in many communities.

If a municipality, CAFO, or industry wishes to commence a new discharge or expand an existing discharge of a pollutant covered by the TMDL and within the area covered by the TMDL, the permittee must submit a written notice of interest for reserve capacity along with a demonstration of need to WDNR. Interested dischargers will not be given a portion of the reserve capacity unless they can demonstrate a need for a new or increased wasteload allocation. Examples of point sources in need of WLA would include those that are a new discharge or those that are significantly expanding their current discharge and would be unable to meet current WLAs despite optimal operation and maintenance of their treatment facility.

A demonstration of need should include an evaluation of conservation measures, recycling measures, and other pollution minimization measures. New dischargers must evaluate current available treatment technologies and expanding dischargers should evaluate optimization of their existing treatment system and evaluation of alternative treatment technologies. In addition to evaluation of treatment options, an expanding discharger must demonstrate that the request for reserve capacity is due to increasing productions levels or industrial, commercial, or residential growth in the community.

If the department determines that a new or expanding discharger qualifies for reserve capacity, the reserve capacity, if available, will be distributed using the procedures outline below:

<u>New Discharger</u>: For a new discharger, calculate the water quality based effluent limit (WQBEL) per ch. NR 217 for phosphorus and chs. NR 102 or NR 106, Wis. Adm. Code, for other pollutants. If there is no water quality based effluent limit available for the pollutant, apply the TMDL reductions consistent with the applicable subbasin to the baseline condition used in the TMDL. Baseline conditions, consisting of concentration and flows, are set for different pollutants and classes of dischargers and are summarized in Section 4. If the discharger can meet the resulting limit with available technology, then the limit is translated into a mass and this mass becomes the amount of reserve capacity allocated to the discharger. If the discharger is unable to meet the limit with available technology, then more reserve capacity, up to a maximum cap, can be allocated to the discharger. The maximum cap is calculated based on the facility's flow and the highest concentration for a similar type facility and treatment system.

Determination of the wasteload allocation available to a new discharge will depend on the type and condition of the immediate receiving water. Limitations for new discharges to Outstanding Resource Waters shall be based on s. NR 207.03(3), Wis. Adm. Code. Limitations for new discharges to Exceptional Resource Waters which are not needed to prevent or correct either an existing surface or groundwater contamination situation, or a public health problem shall be based on s. NR 207.03(4)(b), Wis. Adm. Code. For all other new discharge situations, the following procedures apply to determine the appropriate mass allocation:

a) Determine the mass of reserve capacity that is available in the given subbasin.
b) Calculate the water quality based effluent limit (WQBEL) per s. NR 217.13(2)(a) and the associated mass limit per s. NR 217.14(3). Calculation should be based on current upstream water quality and for purposes of this calculation any other discharges within the given subbasin may be ignored.
c) Calculate the mass load associated with the baseline condition (see Section 4) for the class of the new discharger. Then apply the TMDL reductions, consistent with the applicable subbasin, to the baseline condition to determine the resultant mass.
d) Set the wasteload allocation equal to the most restrictive of the values determined by the above methods.

For a new discharge directly to a lake or reservoir, use the following procedure to determine the appropriate mass allocation:

a) Determine the amount of reserve capacity that is available for the lake or reservoir. This can include unassigned reserve capacity from contributing subbasins located upstream of the lake or reservoir.
b) Calculate the WQBEL per s. 217.13(3) and associated mass limit per s. NR 217.14(3).
c) Set the wasteload allocation equal to the more restrictive of the values determined by the above methods.

Expanding Discharger: For an expanding discharger, reserve capacity will be allocated to cover the increased mass attributed to the facility expansion, measured as the increase in flow over the flow assumed in the TMDL baseline (see Section 4), minus any reductions that can be realized through optimization or economically viable treatment technologies.

If a new or expanding discharger requires more mass than what was allocated through reserve capacity the difference between the mass discharged and their allocation can be made up through an off-set such as water quality trading. If there is not sufficient reserve capacity available, the discharge must be off-set or the TMDL can be re-evaluated to determine if more assimilative capacity has become available since the original analysis.

Reserve capacity should be taken equally from all subbasins upstream and in which the discharger is located. As additional demands are placed on available reserve capacity, it may become necessary to shift the location that previously assigned reserve capacity was taken, provided the total loading capacity for each subbasin is maintained. WDNR will maintain a system to track assigned reserve capacity and WDNR will notify EPA in writing of reserve capacity assignments. Once reserve capacity reaches levels that it is no longer usable, the TMDL will need to be re-evaluated to see if additional assimilative capacity has become available since the original TMDL analysis due to changes in flow or implementation of the reductions prescribed in the TMDL.

WDNR will use the information provided by the permittee to determine if reserve capacity is available and then issue, reissue, or modify a WPDES permit to implement a new WLA based on application of reserve capacity. The new WLA will be used as the basis for effluent limits in the WPDES permit. EPA will be notified if a new or expanded WLA is developed.

Pursuant to s. 40 CFR 122.41(g) and s. NR 205.07(1)(c), Wis. Adm. Code, a WPDES permit does not convey any property rights of any sort nor any exclusive privilege. Distribution of reserve capacity does not require re-opening of the TMDL; rather, the permit process can be used for reserve capacity assignments. All proposed reserve capacity assignments are subject to WDNR review and approval and must be consistent with applicable regulations. Reserve capacity decisions and related permit determinations are subject to public notice and participation procedures as well as opportunities for challenge at the time of permit modification, revocation and reissuance, or reissuance under chapter 283, Wis. Stats.

6.8 Seasonal Variation

TMDLs must take into account seasonal variation in environmental conditions. As discussed in Section 5.3, critical conditions for phosphorus impairments generally occur during summer months when temperature, flow, and sunlight conditions are conducive to excessive plant growth. However, phosphorus loading throughout the entire year can contribute to high phosphorus concentrations during this critical period since phosphorus stored in stream channels and lakes can be released during the summer months. Critical loadings for TSS impairments occur during wet weather events, which result in upland and stream bank erosion. Wet weather events are prevalent in spring and summer in the UFWB but loading throughout the entire year can contribute to high sediment concentrations during these events since deposited sediment stored in stream channels can be resuspended into the water column during high flows.

The method used to link TP and TSS concentration targets to loading capacities is based on observed FWM / GSM ratios, which describe the relationship between annual loads and growing season (i.e., critical condition) concentrations (see Sections 5.1 and 0). Variable allocations by season or month were therefore not developed under this TMDL study.

The methods applied for TMDL development assume that the seasonal pattern of reduced phosphorus and sediment loads will be similar to the existing pattern. For nonpoint sources, this means that actions implemented to reduce loads will need to be effective throughout the year. While this may not be true for any single practice, it is anticipated that a broad suite of practices will be used, and that the collective effects of these practices at the watershed scale will meet this assumption. Discharges from point sources have much less seasonal variation, and it is expected that any required reductions will be approximately uniformly distributed seasonally.

7 IMPLEMENTATION

7.1 Implementation Planning

Following approval of a TMDL, an implementation plan may be developed that specifically describes how the TMDL goals can be achieved over time. Wisconsin DNR has initiated an implementation planning process, which builds on past planning and implementation of practices to control or reduce nutrient and sediment pollutants in the UFWB. The implementation planning process will develop strategies to most effectively use existing federal, state, and county-based programs to achieve wasteload and load allocations outlined in the TMDL. The plan will build upon recommendations made in recent planning efforts, which are discussed in more detail below. Details of the implementation plan may include project goals, actions, costs, timelines, reporting requirements, and evaluation criteria.

Implementation of the load allocations are implemented through ch. NR 151, Wis. Adm. Code. Implementation of the load allocations that exceed the current performance standards in subchs. III and IV of ch. NR 151, Wis. Adm. Code, is voluntary unless adopted through ch. NR 151.005, Wis. Adm. Code.

The UFWB TMDL expresses wasteload allocations for TP as maximum annual loads (pounds per year) and maximum daily loads (pounds per day), which equal the maximum annual loads divided by the number of days in the year. As described in the “TMDL Implementation Guidance for Wastewater Permits” (available on-line at http://dnr.wi.gov/topic/tmdls/implementation.html), total phosphorus WQBELs for wastewater discharges covered by the UFWB TMDL should be derived in a similar manner as methods used for Lower Fox River TMDL discharges. That is, consistent with the impracticability demonstration, TP limits should be expressed as a monthly average when wasteload allocations equate to a TP effluent concentration greater than 0.3 mg/L, and as a six-month average and monthly average equal to 3 times the six-month average when WLAs equate to a TP effluent concentration equal to or less than 0.3 mg/L.

The UFWB TMDL establishes TP wasteload allocations to reduce the loading in the entire watershed including WLAs to meet water quality standards for tributaries. Therefore, WLA-based WQBELs are protective of immediate receiving waters and limit calculators will not need to include TP WQBELs derived according to s. NR 217.13, Wis. Adm. Code.

Since wasteload allocations are expressed as annual loads (lbs./yr.), permits with TMDL-derived monthly average permit limits should require the permittee to calculate and report rolling 12-month sums of total monthly loads for TP. Rolling 12-month sums can be compared directly to the annual wasteload allocation.

The above guidance for expressing TMDL wasteload allocations as permit limits is based on USEPA’s statistical method for deriving water quality-based effluent limits as presented in 5.4 and 5.5 of the Technical Support Document for Water Quality-based Toxics Control (EPA/505/2-90-001; https://www3.epa.gov/npdes/pubs/owm0264.pdf).

Required by the Clean Water Act, reasonable assurances provide a level of confidence that the wasteload allocations and load allocations in TMDLs will be implemented. This TMDL will be implemented through enforcement of existing regulations, financial incentives, and various local, state, and federal water pollution control programs. The following subsections describe some of the activities, programs, requirements, and institutional arrangements that will provide reasonable assurance that this TMDL will be implemented and that the water quality goals should be achieved.

7.2 Reasonable Assurance for Point Sources

WDNR regulates point sources through the WPDES permit program. Individual permits are issued to municipal and industrial wastewater discharges. General permits are issued to some classes of industries or activities that are similar in nature, such as non-contact cooling water and certain stormwater discharges. After the WLAs presented in this report have been state and federally approved, reissued permits must contain conditions consistent with the wasteload allocations.

Individual permits issued to municipal and industrial wastewater discharges will include discharge limits consistent with the approved wasteload allocations. For phosphorus, the mass allocation contained in the TMDL will be expressed as a mass limit. In many cases, discharges will also receive a concentration limit for P, based on the TBEL requirements in ch. NR 217, Wis. Adm. Code. For sediment, the TSS allocation contained in the TMDL will be expressed as a mass limit. In many cases, dischargers will also receive a concentration limit for TSS, based on TBEL requirements in ch. NR 210, Wis. Adm. Code, or applicable effluent limit guidelines for industrial discharges.

Dischargers with general WPDES permits will be evaluated to determine if additional requirements are necessary to ensure that discharges remain consistent with TMDL goals. This could include issuing individual WPDES permits to facilities that currently hold general permits.

WDNR regulates stormwater discharges from certain MS4s, industries, and construction sites under WPDES permits issued pursuant to Chapter NR 216, Wis. Adm. Code. WDNR also established developed urban area, construction site, and post-construction performance standards under NR 151, Wis. Adm. Code, which are implemented through stormwater MS4 and construction site permits. When the TMDL WLAs have been state and federally approved, WDNR will incorporate permit conditions into stormwater permits consistent with the TMDL WLAs. Existing programs that detect and eliminate illicit discharges will continue to be implemented by municipalities. WPDES permit conditions already require monitoring and elimination of discovered discharges.

WDNR and appropriate state agencies will monitor and enforce CAFO permit requirements so that CAFOs are operated and maintained to prevent discharges as required by their WPDES permit.

7.3 Reasonable Assurance for Nonpoint Sources

To attain the TMDL reduction goals, management measures must be implemented and maintained over time to control phosphorus and sediment loadings from nonpoint sources of pollution. Wisconsin’s Nonpoint Source Pollution Abatement Program (NPS Program), described in the state’s Nonpoint Source Program Management Plan (WDNR, 2015), outlines a variety of financial, technical, educational, and enforcement programs, which support implementation of management measures to address nonpoint source pollution. WDNR and the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) coordinate statewide implementation of the NPS Program. The NPS Program includes core activities and programs, which are a high priority and the focus of WDNR and DATCP’s efforts to address NPS pollution; these programs include those described in the following sections.

7.3.1 Statewide Agricultural Performance Standards & Manure Management Prohibitions

WDNR is a leader in the development of regulatory authority to prevent and control nonpoint source pollution. Chapter NR 151, Wis. Adm. Code, establishes runoff management performance standards and prohibitions for agricultural and non-agricultural facilities and practices. These standards are intended to be minimum standards of performance necessary to achieve water quality standards, as described in Chapter 281.16. Implementing the performance standards and prohibitions on a statewide basis is a high priority for the NPS Program and requires having adequate WDNR staff and financial resources to meet the NR 151 implementation and enforcement procedures (NR 151.09 and 151.095). In particular, the implementation and enforcement of agricultural performance standards and manure management prohibitions, listed below, throughout the TMDL area will be critical to achieve the necessary nonpoint source load reductions. Such effort will require having adequate amounts of cost share funding to cover the cost for meeting TMDL NPS reductions.

- **Tillage setback:** A setback of 5 feet from the top of a channel of a waterbody for the purpose of maintaining stream bank integrity and avoiding soil deposits into state waters. Tillage setbacks greater than 5 feet but no more than 20 feet may be required if necessary, to meet the standard. Harvesting of self-sustaining vegetation within the tillage setback is allowed.
- **Phosphorus Index (PI):** A limit on the amount of phosphorus that may run off croplands and pastures as measured by a phosphorus index with a maximum of 6, averaged over an eight-year accounting period, and a PI cap of 12 for any individual year. The PI is measured in pounds per acre per year.
- **Process wastewater handling**: a prohibition against significant discharge of process wastewater from milk houses, feedlots, and other similar sources.
- **Meeting TMDLs:** A standard that requires crop and livestock producers to reduce discharges if necessary, to meet a load allocation specified in an approved Total Maximum Daily Load (TMDL) by implementing targeted performance standards specified for the TMDL area using best management practices specified in ch. ATCP 50, Wis. Adm. Code. If a more stringent or additional performance standard is necessary to meet water quality standards, it must be promulgated by rule before compliance is required. Before promulgating targeted performance standards to implement a TMDL, the department must determine, using modeling or monitoring, that a specific waterbody or area will not attain water quality standards or groundwater standards after substantial implementation of the existing NR 151 performance standards and prohibitions.
- **Sheet, rill and wind erosion:** All cropped fields shall meet the tolerable (T) soil erosion rate established for that soil. This provision also applies to pastures.
- **Manure storage facilities:** All new, substantially altered, or abandoned manure storage facilities shall be constructed, maintained or abandoned in accordance with accepted standards, which includes a margin of safety. Failing and leaking existing facilities posing an imminent threat to public health or fish and aquatic life or violate groundwater standards shall be upgraded or replaced.
- **Clean water diversions:** Runoff from agricultural buildings and fields shall be diverted away from contacting feedlots, manure storage areas and barnyards located within water quality management areas (300 feet from a stream or 1,000 feet from a lake or areas susceptible to groundwater contamination).
- **Nutrient management:** Agricultural operations applying nutrients to agricultural fields shall do so according to a nutrient management plan (Each nutrient management plan must be designed to limit or reduce the discharge of nutrients to waters of the state for the purpose of complying with state water quality standards and groundwater standards. In addition, for croplands in watersheds that contain impaired surface waters, a plan must be designed to manage soil nutrient concentrations so as to maintain or reduce delivery of nutrients contributing to the impairment of impaired surface waters. ATCP 50.04 c additional requirements for all nutrient management plans. This standard does not apply to applications of industrial waste, municipal sludge or septage regulated under other WDNR programs provided the material is not commingled with manure prior to application.
- **Manure management prohibitions:**
  - no overflow of manure storage facilities
  - no unconfined manure piles in a water quality management area
  - no direct runoff from feedlots or stored manure into state waters
  - no unlimited livestock access to waters of the state in locations where high concentrations of animals prevent the maintenance of adequate or self-sustaining sod cover.

WDNR, DATCP, and the county Land Conservation Departments (LCDs) will work with landowners to implement agricultural and non-agricultural performance standards and manure management prohibitions to address sediment and nutrient loadings in the TMDL area.

Some landowners voluntarily install BMPs to help improve water quality and comply with the performance standards. Cost-sharing funds, provided via state or federal funds, may or may not be available for many of these BMPs. Wisconsin statutes, and the NR 151 implementation and enforcement procedures of NR 151.09 and 151.095, require that farmers must be offered at least 70% cost-sharing funds for BMP installation before they can be required to comply with the agricultural performance standards and prohibitions. If cost share money is offered, those in violation of the standards are obligated to comply with the rule. The amount of cost sharing funds available for use by LCD's, DATCP and WDNR will require implementing the performance standards and prohibitions throughout the TMDL area over time. DATCP's Farmland Preservation Program requires that any agricultural land enrolled in the program must be determined to be in compliance with the performance standards by no later than 2020 to continue receive tax credits associated with the program.

7.3.2 WDNR Cost-Sharing Grant Programs

The counties and other local units of government in the TMDL area may apply for grants from WDNR to control NPS pollution and, over time, meet the TMDL load allocation. The WDNR supports NPS pollution abatement by administering and providing cost-sharing grants to fund BMPs through various grant programs, including, but not limited to:

- The Targeted Runoff Management (TRM) Grant Program
- The Notice of Discharge (NOD) Grant Program
- The Urban Nonpoint Source & Storm Water Management Grant Program
- The Lake Planning Grant Program
- The Lake Protection Grant Program
- The River Planning & Protection Grant Program

Many of the counties and municipalities in the TMDL area have a track record of participating in these NPS related grant programs.

7.3.3 Targeted Runoff Management (TRM) Grant Program

TRM Grant Program Overview

Targeted Runoff Management (TRM) grants are provided by the WDNR to control nonpoint source pollution from both urban and agricultural sites. A combination of state General Purpose Revenue, state Bond Revenue, and federal Section 319 Grant funds is used to support TRM grants. The grants are available to local units of government (typically counties) and targeted at high-priority resource problems. TRM grants can fund the design and construction of agricultural and urban BMPs. Some examples of eligible BMPs include livestock waste management practices, some cropland protection, and streambank protection projects. These and other practices eligible for funding are listed in s. NR 154.04, Wis. Adm. Code.

Revisions to ch. NR 153, Wis. Adm. Code, (http://legis.wisconsin.gov/rsb/code/nr/nr153.pdf) which governs the program, took effect on January 1, 2011, and modified the grant criteria and procedures, increasing the state's ability to support performance standards implementation and TMDL implementation. Since the calendar year 2012 grant cycle, projects may be awarded in four categories:

	TMDL	Non-TMDL
Small Scale	• Implements a TMDL • Agricultural or urban focus	• Implements NR 151 performance standards • Agricultural or urban focus
Large Scale	• Implements a TMDL • Agricultural focus only	• Implements NR 151 performance standards • Agricultural focus only

Section 281.65(4c), Wis. Stats., defines additional priorities for Targeted Runoff Management Projects as follows:

- TRM projects must be targeted to an area based on any of the following:
  - Need for compliance with established performance standards.
  - Existence of impaired waters.
  - Existence of outstanding or exceptional resource waters.
  - Existence of threats to public health.
  - Existence of an animal feeding operation receiving a Notice of Discharge.
  - Other water quality concerns of national or statewide importance.
- Projects are consistent with priorities identified by WDNR on a watershed or other geographic basis.
- Projects are consistent with approved county land and water resource management plans.

The maximum cost-share rate available to TRM grant recipients is up to 70 percent of eligible costs (maximum of 90% in cases of economic hardship), with the total of state funding not to exceed established grant caps. TRM grants may not be used to fund projects to control pollution regulated under Wisconsin law as a point source. Grant application materials are available on the WDNR web site at: http://dnr.wi.gov/aid/targetedrunoff.html.

7.3.4 Notice of Discharge (NOD) Grants Program

NOD Program Overview

Notice of Discharge (NOD) Project Grants, also governed by ch. NR 153, Wis. Adm. Code, are provided by WDNR and DATCP to local units of government (typically counties). A combination of state General Purpose Revenue, state Bond Revenue, and federal Section 319 Grant funds are used to support NOD grants. The purpose of these grants is to provide cost sharing to farmers who are required to install agricultural best management practices to comply with Notice of Discharge requirements. Notices of Discharge are issued by the WDNR under ch. NR 243 Wis. Adm. Code (Animal Feeding Operations - http://legis.wisconsin.gov/rsb/code/nr/nr243.pdf), to small and medium animal feeding operations that pose environmental threats to state water resources. The project funds can be used to address an outstanding NOD or an NOD developed concurrently with the grant award.

Both state agencies work cooperatively to administer funds set aside to make NOD grant awards. Although the criteria for using agency funds vary between the two agencies, WDNR and DATCP have jointly developed a single grant application that can be used to apply for funding from either agency. The two agencies jointly review the project applications and coordinate funding to assure the most cost-effective use of the available state funds. Funding decisions must take into account the different statutory and other administrative requirements each agency operates under. Grant application materials are available on the WDNR web site at: http://dnr.wi.gov/Aid/NOD.html.

7.3.5 Lake Management Planning Grants

The WDNR provides grants to eligible parties to collect and analyze information needed to protect and restore lakes and their watersheds and develop lake management plans. Section 281.68, Wis. Stats., and ch. NR 190, Wis. Adm. Code, provide the framework and guidance for WDNR's Lake Management Planning Grant Program. Grant awards may fund up to 66% of the cost of a lake planning project. Grant awards cannot exceed $25,000 per grant for large-scale projects. Eligible planning projects include:

- Gathering and analysis of physical, chemical, and biological information on lakes.
- Describing present and potential land uses within lake watersheds and on shorelines.
- Reviewing jurisdictional boundaries and evaluating ordinances that relate to zoning, sanitation, or pollution control or surface use.
- Assessments of fish, aquatic life, wildlife, and their habitats. Gathering and analyzing information from lake property owners, community residents, and lake users.
- Developing, evaluating, publishing, and distributing alternative courses of action and recommendations in a lake management plan.

Grants can also be used to investigate pollution sources, including nonpoint sources, followed by incorporation into the lake management plan of strategies to address those sources. Investigation can involve many types of assessment, including determining whether or not the water quality of the lake is impaired. A plan approved by WDNR for a lake impaired by NPS pollution should incorporate the U.S. EPA's "Nine Key Elements" for watershed-based plans. Grant application materials are available on the WDNR web site at: http://dnr.wi.gov/Aid/SurfaceWater.html.

7.3.6 Lake and River Protection Grants

Lake Protection Grant Program Overview

The WDNR provides grants to eligible parties for lake protection grants. Sections 281.69 and 281.71, Wis. Stats., and ch. NR 191, Wis. Adm. Code, provide the framework and guidance for the Lake Protection Grant Program. Grant awards may fund up to 75 percent of project costs (maximum grant amount $200,000). Eligible projects include:

- Purchase of land or conservation easements that will significantly contribute to the protection or improvement of the natural ecosystem and water quality of a lake.
- Restoration of wetlands and shorelands (including Healthy Lakes best practices) that will protect a lake's water quality or its natural ecosystem (these grants are limited to $100,000). Special wetland incentive grants of up to $10,000 are eligible for 100 percent state funding if the project is identified in the sponsor's comprehensive land use plan.
- Development of local regulations or ordinances to protect lakes and the education activities necessary for them to be implemented (these grants are limited to $50,000)
- Lake management plan implementation projects recommended in a plan and approved by WDNR.

These projects may include watershed management BMPs, in-lake restoration activities, diagnostic feasibility studies, or any other projects that will protect or improve lakes. Sponsors must submit a copy of their lake management plan and the recommendation(s) it wants to fund for WDNR approval at least two months in advance of the February 1 deadline. Plans must have been officially adopted by the sponsor and made available for public comment prior to submittal. The WDNR will review the plan and advise the sponsor on the project's eligibility and development of a lake protection grant application for its implementation. Grant application materials are available on the WDNR web site at: http://dnr.wi.gov/Aid/SurfaceWater.html.

River Grant Program Overview

The WDNR provides grants to eligible parties for river protection grants. Chapter 195, Wis. Adm. Code, provides the framework and guidance for the River Protection Grant Program. This program provides assistance for planning and management to local organizations that are interested in helping to manage and protect rivers, particularly where resources and organizational capabilities may be limited.

River Planning Grants up to $10,000 are available for:

- Developing the capacity of river management organizations,
- Collecting information on riverine ecosystems,
- River system assessment and planning,
- Increasing local understanding of the causes of river problems

River Management Grants up to $50,000 are available for:

- Land/easement acquisition,
- Development of local regulations or ordinances that will protect or improve the water quality of a river or its natural ecosystem,
- Installation of practices to control nonpoint sources of pollution,
- River restoration projects including dam removal, restoration of in-stream or shoreland habitat,
- An activity that is approved by the WDNR and that is needed to implement a recommendation made as a result of a river plan to protect or improve the water quality of a river or its natural ecosystem
- Education, planning and design activities necessary for the implementation of a management project.

The state share of both grants is 75% of the total project costs, not to exceed the maximum grant amount. Grant application materials are available on the WDNR web site at: http://dnr.wi.gov/Aid/SurfaceWater.html.

7.3.7 DATCP Soil & Water Resource Management Program

DATCP oversees and supports county conservation programs that implement the state performance standards and prohibitions and conservation practices. DATCP's Soil and Water Resource Management (SWRM) Program requires counties to develop Land and Water Resource Management (LWRM) Plans to identify conservation needs. Each county Land and Water Conservation Department in the TMDL area developed an approved plan for addressing soil and water conservation concerns in its respective county. County LWRM plans advance land and water conservation and prevent NPS pollution by:

- Inventorying water quality and soil erosion conditions in the county.
- Identifying relevant state and local regulations, and any inconsistencies between them.
- Setting water quality goals in consultation with the WDNR.
- Identifying key water quality and soil erosion problems, and practices to address those problems.
- Identifying priority farm areas using a range of criteria (e.g., impaired waters, manure management, high nutrient applications).
- Identifying strategies to promote voluntary compliance with statewide performance standards and prohibitions, including information, cost-sharing, and technical assistance.
- Identifying enforcement procedures, including notice and appeal procedures.
- Including a multi-year work plan to achieve soil and water conservation objectives.

Counties must receive DATCP's approval of their plans to receive state cost-sharing grants for BMP installation. DATCP is also responsible for providing local assistance grant funding for county conservation staff implementing NPS control programs included in the LWRM plans. This includes local staff support for DATCP and WDNR programs.

The UFWB TMDL provides County Land and Water Conservation Departments with the data necessary to more effectively identify and prioritize pollutant sources so that strategies can be developed and applied to reduce pollutant loads in the TMDL area over time.

7.3.8 DATCP Producer Led Watershed Protection Grants Program

In an effort to improve the quality of Wisconsin's waterways, DATCP developed and launched the first Producer Led Watershed Protection Grants Program in 2016. The new grant program included in the 2015-17 Wisconsin state budget, was designed to give financial support to farmers willing to lead conservation efforts in their own watersheds.

In the first round of 2016 grants, $242,550 was awarded to 14 groups of innovative farmers throughout Wisconsin to work with resource conservation agencies and organizations to address soil and water issues tailored to their local conditions.

7.3.9 Federal Programs

Numerous federal programs are also being implemented in the TMDL area and are expected to be an important source of funds for future projects designed to control phosphorus and sediment loadings in the Upper Fox and Wolf River Basins. A few of the federal programs include:

- Environmental Quality Incentive Program (EQIP). EQIP is a federal cost-share program administered by the Natural Resources Conservation Service (NRCS) that provides farmers with technical and financial assistance. Farmers receive flat rate payments for installing and implementing runoff management practices. Projects include terraces, waterways, diversions, and contour strips to manage agricultural waste, promote stream buffers, and control erosion on agricultural lands.
- Conservation Reserve Program (CRP). CRP is a voluntary program available to agricultural producers to help them safeguard environmentally sensitive land. Producers enrolled in CRP plant long-term, resource conserving covers to improve the quality of water, control soil erosion, and enhance wildlife habitat. In return, the Farm Service Agency (FSA) provides participants with rental payments and cost-share assistance.
- Conservation Reserve Enhancement Program (CREP). CREP provides annual rental payments up to 15 years for taking cropland adjacent to surface water and sinkholes out of production. A strip of land adjacent to the stream must be planted and maintained in vegetative cover consisting of certain mixtures of tree, shrub, forbs, and/or grass species. Cost-sharing incentives and technical assistance are provided for planting and maintenance of the vegetative strips. Landowners also receive an upfront, lump sum payment for enrolling in the program, with the amount of payment dependent on whether they enroll in the program for 15 years or permanently.
- Regional Conservation Partnership Program (RCPP) promotes coordination between NRCS and its partners to deliver conservation assistance to producers and landowners. NRCS provides assistance to producers through partnership agreements and through program contracts or easement agreements RCPP combines the authorities of four former conservation programs – the Agricultural Water Enhancement Program, the Chesapeake Bay Watershed Program, the Cooperative Conservation Partnership Initiative and the Great Lakes Basin Program. Assistance is delivered in accordance with the rules of EQIP, CSP, ACEP and HFRP; and in certain areas the Watershed Operations and Flood Prevention Program.

7.3.10 Water Quality Trading & Adaptive Management

Water Quality Trading (WQT) and Adaptive Management (AM) may be used by eligible municipal and industrial wastewater dischargers to demonstrate compliance with TMDL WLAs. Both of these compliance options provide a unique watershed-based opportunity to reduce pollutant loading to streams, rivers, and lakes through point and nonpoint source collaboration. AM and WQT may also provide a new source of funding for local assistance and implementation of management measures to address nonpoint source pollution and improve water quality. The WDNR web site provides more details about water quality trading at: http://dnr.wi.gov/topic/SurfaceWater/WaterQualityTrading.html and adaptive management at: http://dnr.wi.gov/topic/SurfaceWater/AdaptiveManagement.html. Wasteload allocations have also been broken down into the amount needed for the subbasin to meet local water quality requirements and the amount needed to meet downstream water quality targets for lakes and reservoirs in the UFWB.

7.3.11 Phosphorus Multi-discharger Variance (MDV)

The statewide multi-discharger variance (MDV) for phosphorus (s. 283.16, Wis. Stat.) extends the timeline for wastewater dischargers that have to comply with low-level phosphorus limits. In exchange, point sources commit to step-wise reductions of phosphorus in their effluent as well as helping to address nonpoint sources of phosphorus from farm fields, cities or natural areas to implement projects designed to improve water quality.

Wisconsin's phosphorus MDV was approved by EPA on February 6, 2017. MDV implementation guidance (https://dnr.wi.gov/topic/surfacewater/phosphorus/variance/) is available to provide details about MDV eligibility and programmatic requirements. If a facility meets the eligibility requirements and requests and gets approval for the MDV, the WPDES permit will be modified or reissued with the following requirements:

1. *Reductions of effluent phosphorus:* Point sources are required to reduce their phosphorus load each permit term of MDV coverage.
2. *Implement a watershed project:* Point sources must implement one of the following watershed project options to help reduce nonpoint source of phosphorus pollution:
    a. Implement a watershed project directly;
    b. Work with a third party to implement a watershed project; or
    c. Make payments to a county (or counties) to be used for nonpoint source pollution control activities.

7.4 Follow-up Monitoring

A post-implementation monitoring effort will determine the effectiveness of the implementation activities associated with the TMDL. WDNR and/or its partners will monitor the waters of the UFWB based on the rate of management practices installed and tracked through the implementation of the TMDL, including sites where WDNR, DATCP, and NRCS grants are aimed at mitigating phosphorus and sediment loading. Monitoring will occur as staff and fiscal resources allow until it is deemed that stream quality has responded to the point where it is meeting its codified designated uses and applicable water quality standards.

In addition, waterbodies in the UFWB may be monitored on a rotational basis as part of WDNR’s statewide water quality monitoring strategy to assess current conditions and trends in overall stream quality. That monitoring consists of collecting data to support a myriad of metrics contained in WDNR’s baseline protocol for wadeable streams, such as the index of biological integrity (IBI), the Hilsenhoff Biotic Index (HBI), a habitat assessment tool, and several water quality parameters determined on a site by site basis.

WDNR will work in partnership with local citizen monitoring groups to support monitoring efforts which often provide a wealth of data to supplement WDNR data. All other quality-assured available data in the basin will be considered when looking at the effectiveness of the implementation activities associated with the TMDL.

7.4.1 Statewide Tracking Database

Tracking the implementation of nonpoint source pollution reduction practices on the landscape is an important but often challenging component of TMDL implementation tracking and assessment. These challenges become even greater in the context of point source permit programs that require NPS partnerships such as adaptive management, water quality trading and the multi-discharger variance. A database system for efficiently and effectively tracking implementation of nonpoint source pollution implementation practices is currently under development by the WDNR. The system will include a web-based portal, allowing externals to easily and efficiently submit information via a GIS-based application for submitting, visualizing and tracking spatial data.

8 PUBLIC PARTICIPATION

USEPA expects full and meaningful public participation in the TMDL development process, and TMDL regulations require that states must provide opportunities for public review consistent with its own continuing planning process (40 C.F.R. §130.7(c)(1)(ii)). EPA is required to publish a notice seeking public comment when it establishes a TMDL (40 C.F.R. §130.7(d)(2)).

Wisconsin DNR believes that public outreach and meaningful stakeholder engagement throughout the TMDL development, TMDL implementation planning, and TMDL implementation process results in better outcomes and overall TMDL success. With this in mind, the WDNR has provided many ways for stakeholders to learn about the UFWB TMDL and provide input in the TMDL development process, as described in the following subsections.

8.1 Technical Meetings

During the development of the UFWB, the TMDL study team held multiple meetings with stakeholders to describe the TMDL effort, analysis and modeling methods, and draft model results:

- In September 2014, the TMDL study team hosted a half-day meeting with technical stakeholders to introduce the TMDL project, describe the proposed watershed and lake modeling approaches, and present the data to be used for the project;
- In June 2016, the TMDL study team hosted a half-day meeting to present initial watershed modeling and lake inputs, methods, and results;
- In August 2017, the TMDL study team hosted a half-day meeting to present updated watershed modeling and lake results and allocation methods for TMDL development.

In each of these meetings, stakeholders were given the opportunity to ask questions and provide feedback on the meeting topics. Draft reports documenting SWAT watershed modeling and WiLMS lake modeling were also posted on the WDNR UFWB TMDL website for stakeholder review.

8.2 Draft Data Review

In September 2014, the TMDL study team posted the following information and data to the UFWB TMDL website for stakeholder review and comment:

- List of water quality impairments addressed by the TMDL, including waterbodies and pollutants;
- List of permitted MS4s requiring a wasteload allocation under the TMDL;
- Maps of the regulated area of each permitted MS4 requiring a wasteload allocation under the TMDL;
- List of point sources with individual WPDES and NPDES permits included in the SWAT watershed model;
- Estimated point source discharge flow volumes, phosphorus loads, and sediment loads for point sources with individual WPDES and NPDES permits used for the SWAT watershed model;
- Data used to estimate nearshore septic system phosphorus loading to lakes and reservoirs addressed in the TMDL;
- Draft subwatershed boundaries delineated for SWAT watershed modeling.

The TMDL study team invited stakeholder comments on the above information and data and incorporated feedback into subsequent analysis.

8.3 Draft TMDL Allocations and Draft TMDL Report Review

The WDNR held a public meeting on July 11, 2018 to provide the public with a detailed explanation of the TMDL analysis, allocations and any needed reductions, implementation and compliance options, and to provide opportunities for additional stakeholder input. The webinar was also recorded and made available on the WDNR website, http://dnr.wi.gov (search Upper Fox and Wolf TMDL). A copy of the presentation slides can be found on the WDNR website. Total attendance for the meeting was 129.

Stakeholder input from the public meeting as well as written comments received during the July 11 through August 5, 2018 comment period were incorporated into the final draft of the TMDL report. The WDNR received 37 comments. A summary of the comments and responses can be found in Appendix L.

8.4 Public Informational Meeting and Comment Period

Per s. NR 212.77 Wis. Admin. Code, on December 12, 2018 the WDNR is conducting a public informational meeting and hearing followed by a comment period. Written comments will be accepted through January 18, 2019. Verbal comments received during the public hearing, and written comments received prior to the close of the comment period will be considered prior to making a final approval and submittal of the TMDL Study to EPA. Written and verbal comments carry the same weight.

The notice was sent out as an official WDNR press release hitting all news outlets, distributed through the WDNR permit distribution list, and posted on the WDNR website and public hearings calendar. A copy of the official public notice is included below.

A copy of the comments that were received during the public informational comment period can be found in Appendix M. Appendix N provides the comments and responses grouped by category. The commenter is identified in parentheses.

STATE OF WISCONSIN DEPARTMENT OF NATURAL RESOURCES
PUBLIC NOTICE OF INFORMATIONAL HEARING FOR THE UPPER FOX AND WOLF BASIN TOTAL MAXIMUM DAILY LOAD STUDY

The Wisconsin Department of Natural Resources is conducting a public informational hearing on December 12, 2018 to receive comments on the "Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Upper Fox and Wolf Basins" (TMDL Study). The Upper Fox and Wolf River Basins (UFW) spans Wisconsin's east central corridor from the headwaters in Forest County and the city of Portage to Lake Winnebago, covering 5,900 square miles, approximately 10 percent of the state. The TMDL study addresses surface waters within the UFW including the series of pool lakes in Winnebago County before draining into Lake Winnebago. This TMDL Study quantifies the different sources of pollution, provide allocations, and prescribes reductions, as needed, to meet water quality standards.

The public informational hearing will be held on December 12th, 2018 from 2:00 to 4:00 pm at the JP Coughlin Building (625 E. County Road Y, Oshkosh WI 545901).

Contact: Keith Marquardt, KeithA.Marquardt@wisconsin.gov
Kevin Kirsch, Kevin.Kirsch@wisconsin.gov

A copy of the public hearing version of the TMDL Study and supporting material will be available for public review on the website (https://dnr.wi.gov/topic/tmdls/foxwolf/) beginning November 30, 2018.

The public hearing version of the TMDL Study incorporates input and comments received during the July and August listening sessions and comment period. The public informational hearing on December 12th will include a presentation outlining the modifications made.

Written comments will be accepted through January 18h, 2019. Verbal comments, received during the public hearing, and written comments received prior to the close of the comment period will be considered prior to making a final approval and submittal of the TMDL Study to EPA. Written and verbal comments carry the same weight. A summary with response to comments shall be included in the final TMDL Study report.

Written comments can be submitted via e-mail: KeithA.Marquardt@wisconsin.gov or regular mail: Wisconsin Department of Natural Resources Attn: Keith Marquardt
625 E County Road Y Ste 700 Oshkosh, WI 54901-9731

Reasonable accommodation, including the provision of informational material in an alternative format, will be provided for qualified individuals with disabilities upon request.

# # #

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