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ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

Upper Fox River/Chain O' Lakes Watershed TMDL Stage 1 Report

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Executive Summary

As required by Section 303(d) of the Clean Water Act (CWA), the Illinois Environmental Protection Agency (Illinois EPA) is required to identify and list all state waters that fail to meet water quality standards and designated uses. This list is referred to as the 303(d) list and is revisited every two years to either remove those waters that have attained their designated uses, or to include additional waters not previously deemed impaired. Waterbodies included on the 303(d) list require Total Maximum Daily Load (TMDL) development.

A TMDL is an estimation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. It assesses contributing point and nonpoint sources to identify pollutant reductions necessary for designated use attainment. A TMDL identifies the sources of impairment and provides reduction estimates to meet water quality standards. Pollutant reductions are then allocated to contributing sources, thus triggering the need for pollutant control and increased management responsibilities amongst sources in the watershed.

For the Upper Fox River/Chain O' Lakes watershed, 31 impaired waterbodies were identified for TMDL development. The Upper Fox River/Chain O' Lakes watershed is located in Lake, McHenry, Kane and Cook Counties in far northeastern Illinois, and extends north into Wisconsin. The waterbody classification applicable to the Upper Fox River/Chain O' Lakes watershed is the General Use classification which includes designated uses such as aquatic life, aesthetic quality, and primary contact recreation uses. The identified impairments include dissolved oxygen (DO), fecal coliform, pH, total phosphorus and ammonia. The water quality standard criteria identified for these impairments provide an explicit assessment as to whether or not these waterbodies are in compliance.

Available data used for assessing these waterbodies originated from numerous water quality stations within the Upper Fox River/Chain O' Lakes watershed. Data were obtained from both legacy and modernized US EPA Storage and Retrieval (STORET) databases, Lake County data, Fox River Study Group data, and Illinois EPA database data. Data relevant to impairments were compiled for each impaired waterbody and summary statistics were calculated to further characterize each pollutant.

Various models were recommended for TMDL development, the level of which was primarily based on the complexity of the system and the availability of data. After a careful data review, it is likely that the dissolved oxygen, pH and ammonia impairments are related to excessive phosphorus concentrations, and therefore phosphorus TMDLs were recommended. For the majority of the phosphorus impaired waterbodies, the Lake Loading Response Model (LLRM) is recommended for loading analysis. A more complex simulation of phosphorus loading is suggested for the "Chain O' Lakes" portion of this watershed. A load duration curve is recommended for fecal coliform TMDLs.

1.0 Introduction

This Stage 1 Total Maximum Daily Load (TMDL) report is presented as partial fulfillment by the Illinois Environmental Protection Agency (Illinois EPA) and the United States Environmental Protection Agency (US EPA) in the development of TMDLs, as part of that state's Clean Water Act (CWA) Section 303(d) compliance. The purpose of the project is to develop TMDLs for 31 impaired waterbodies in the Upper Fox River/Chain O' Lakes watershed in Illinois.

Section 303(d) of the CWA and US EPA's Water Quality Planning Regulations (40 CFR Part 130) require states to develop TMDLs for impaired waterbodies that are not supporting designated uses or meeting water quality standards. A TMDL is a calculation of the maximum amount of pollutants that a waterbody can receive and still meet the water quality standards necessary to protect the designated beneficial use (or uses) for that waterbody. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between potential pollutant sources and water quality conditions, so that states and local communities can establish water quality based controls to reduce pollutants from both potential point and nonpoint sources and restore and maintain the quality of their water resources.

Water is an essential resource for the inhabitants of the Earth and protecting this resource is the goal for many across the globe. United States policies and regulations, such as the CWA, were created and are implemented to help maintain the quality of our water resources in the United States. The US EPA, via the CWA, charged each state with developing water quality standards (WQS). These WQS are laws or regulations that states authorize to protect and/or enhance water quality, to ensure that a waterbody's designated use (or uses) is (are) not compromised by poor water quality and to protect public health and welfare. In general, WQS consist of three elements:

- The designated beneficial use (e.g., recreation, protection of aquatic life, aesthetic quality, and public and food processing water supply) of a waterbody or segment of a waterbody,
- The water quality criteria necessary to support the designated beneficial use of a waterbody or segment of a waterbody, and
- An anti-degradation policy, so that water quality improvements are conserved, maintained and protected.

The Illinois Pollution Control Board (IPCB) established its WQS in Title 35: Environmental Protection, Subtitle C: Water Pollution, Chapter 1: Pollution Control Board, Part 302: Water Quality Standards. Every two years Illinois EPA submits the Illinois Integrated Water Quality Report and Section 303(d) List. This report documents surface and groundwater conditions throughout the state. The 303(d) List portion of this report identifies impaired water bodies, grouped by watershed, and identifies suspected sources of impairment. These waters are prioritized for TMDL development into high, medium, and low categories based on designated use and pollution severity and are then targeted for TMDL development. Non-pollutant causes of impairment, such as habitat degradation and aquatic algae are not addressed under the TMDL, but can address by programs such under the 319 program and other nonpoint source grant programs. Some nonpollutants may be addressed by reducing pollutants which a TMDL is developed. For example, some implementation activities to reduce phosphorus can reduce TSS, excessive algae and improve habitat.

A TMDL is a calculation of the maximum load a waterbody can be receive without exceeding water quality standards or result in non attainment of a designated use. A watershed's TMDL report consists of data analysis to quantitatively assess water quality, documentation of waterbodies or segments of waterbodies that are impaired, and identification of potential contributing sources to impairment. Based on these data, the amount and type of load reduction that is needed to bring water quality into compliance is calculated. The TMDL report provides the scientific basis for states and local communities to establish water quality-based controls to reduce pollutant loads from both potential point (i.e., wasteload allocations) and non-point sources (i.e., load allocations).

Illinois EPA uses a three-stage approach to develop TMDLs for a watershed:

- **Stage 1** – Watershed characterization, historical dataset evaluation, data analysis, methodology selection, data gap identification;
- **Stage 2** – Data collection to fill in data gaps, if necessary; and
- **Stage 3** – Model calibration, TMDL scenarios, and implementation plans.

The purpose of Stage 1 is to characterize the watershed background; verify impairments in the listed waterbody by comparing observed data with water quality standards or appropriate targets; evaluate spatial and temporal water quality variation; provide a preliminary assessment of sources contributing to impairments; and describe potential TMDL development approaches. If available water quality data collected for the watershed are deemed sufficient by Illinois EPA, Stage 2 may be omitted and Stage 3 will be completed. If sufficient water quality data or supporting information are lacking for an impaired waterbody, then Stage 2 is required and field sampling will be conducted in order to obtain necessary data to complete Stage 3.

This report documents Stage 1 in the Illinois EPA approach for TMDL development. The report is organized into six main sections. Section 1.0 discusses the definition of TMDLs and targeted impaired waterbodies in the Upper Fox River/Chain O' Lakes watershed, for which TMDLs will be developed. Section 2.0 describes the characteristics of the watershed, and Section 3.0 briefly discusses the process of public participation and involvement. Section 4.0 describes the applicable water quality standards and water quality assessment. Section 5.0 presents the assessment and analysis of available water quality data. Section 6.0 provides a description of each impaired segment's watershed and potential sources. Section 7.0 discusses the methodology selection for the TMDL development, the data gaps, and provides recommendations for additional data collection, if necessary.

1.1 Definition of a Total Maximum Daily Load (TMDL)

According to the 40 CFR Part 130.2, the TMDL (the maximum load a waterbody can be receive without exceeding water quality standards or result in non attainment of a designated use) for a waterbody is equal to the sum of the individual loads from point sources (i.e., wasteload allocations or WLAs), and load allocations (LAs) from nonpoint sources (including natural background conditions). Section 303(d) of the CWA also states that the TMDL must be established at a level necessary to implement the applicable water quality standards with seasonal variations and a margin of safety (MOS) which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. In equation form, a TMDL may be expressed as follows:

$$\mathbf{TMDL = WLA + LA + MOS}$$

Where:

WLA =	Waste Load Allocation (i.e., loadings from point sources);
LA =	Load Allocation (i.e., loadings from nonpoint sources including natural background); and
MOS =	Margin of Safety.

TMDLs can be expressed in terms of either mass per time, toxicity or other appropriate measures [40 CFR, Part 130.2 (i)]. US EPA recommends that all TMDLS and associated LA and WLAs be expressed in terms of daily increments but may include alternative non-daily expression of pollutant loads to facilitate implementation of the applicable water quality standard. Numerous methods have been developed that help account for the variability of waterbodies and allow for the derivation of a daily load from a non-daily load. Such methods can account for factors such as seasonality, flow, critical conditions, etc. and translate a non-daily load (e.g. annual, monthly, seasonal) to a daily load. TMDLs also shall take into account the seasonal variability of pollutant loading and hydrology to ensure water quality standards are met in all seasons and during all hydrologic conditions. Though not required by CWA, Illinois EPA requires that an implementation plan be developed for each watershed, which may be used as a guideline for local stakeholders to restore water quality. This implementation plan will include recommendations for implementing best management practices (BMPs), cost estimates, institutional needs to implement BMPs and controls throughout the watershed, and time frame for completion of implementation activities.

The MOS accounts for the lack of knowledge or uncertainty concerning the true relationship between loading and attainment of water quality standards. This uncertainty is often a product of data gaps, either temporally or spatially, in the measurement of water quality. The MOS should be proportional to the anticipated level of uncertainty; the higher the uncertainty, the greater the MOS. The MOS is generally based on a qualitative assessment of the relative amount of uncertainty as a matter of best professional judgment (BPJ). The MOS can be either explicit or implicit. If an explicit MOS is used, a portion of the total allowable loading is allocated to the MOS. If the MOS is implicit, a specific value is not assigned to the MOS, but is already factored in during the TMDL development process. Use of an implicit MOS is appropriate when assumptions used to develop the TMDL are believed to be so conservative that they sufficiently account for the MOS.

1.2 Targeted Waterbodies for TMDL Development

In May 2008, Illinois EPA prepared a draft Illinois Integrated Water Quality Report and Section 303(d) List-2008 (commonly referred to as the 303(d) List) to fulfill the requirement of Section 305(b), 303(d) and 314 of the CWA (Illinois EPA, 2008). Under US EPA's review and approval, the report presents a detailed water quality assessment process and results for streams and lakes in the State of Illinois. The water quality assessments are based on biological, physicochemical, physical habitat, and toxicity data. Each waterbody has one or more of designated uses which may include aquatic life, aesthetic quality, indigenous aquatic life (for specific Chicago-area waterbodies), primary contact (swimming), secondary contact (recreation), public and food processing water supply, and fish consumption. The degree of support (attainment) of a designated use in a waterbody (or segment) is assessed as Fully Supporting (good), Not Supporting (fair), or Not Supporting (poor). Waters in which at least one applicable use is not fully supported is designated as "impaired." Potential causes and sources of impairment are also identified for these waters. The 303(d) List is prioritized on a watershed basis based on the requirements of 40 CFR Part 130.7(b)(4). Watershed boundaries are based on United States Geological Survey (USGS) ten-digit hydrologic units, to provide the state with the ability to address watershed issues at a manageable level and document improvements to a watershed's health (Illinois EPA, 2008). TMDL development is also conducted on a watershed basis so that the impaired waters upstream of an individual segment may be addressed at the same time.

Table 1-1 presents the 2008 Integrated Report (303(d)) List and Stream Assessment Report impaired segments for the Upper Fox River/Chain O' Lakes watershed. The table includes impaired designated uses and potential causes. The segments in bold font are scheduled for TMDL development and are the focus of this report. TMDLs will not be developed for the lakes with surface area of less than 20 acres since the Illinois phosphorus standards apply only to those lakes where surface acreage is 20 or more acres. Nor will TMDLs be developed for segments impaired by water quality variables that do not have numerical WQS.

One river segment and 30 lakes are identified as impaired and selected for TMDL development in the Upper Fox River/Chain O' Lakes watershed (Illinois EPA, 2008). Table 1-1 summarizes these waterbodies, designated uses, and impairments identified by the Illinois EPA. The designated uses for these waterbodies are primarily aquatic life with some aesthetic quality and primary contact recreation uses. Water quality criteria applicable to these waters are the General Use Water Quality Standards. The identified causes for impairment that have numerical WQS include dissolved oxygen (DO), fecal coliform, pH, ammonia and total phosphorus. Although there is a numerical standard for DO, DO is considered a non-pollutant by Illinois EPA. The Illinois EPA will ascertain potential causes for low dissolved oxygen using the TMDL process and will develop a

TMDL only if the cause is attributable to a pollutant. For example, if a 50-acre lake suffers from low DO due to excessive algal densities which is related to elevated phosphorus concentrations, the Illinois EPA will develop a phosphorus TMDL for this waterbody. A TMDL will not be developed for pollutants listed as causes of impairment without numeric WQS, such as total suspended solids, sedimentation/siltation, and cause unknown. For these causes, the TMDL implementation plan can potentially address the impairment by reducing TMDL parameters that are associated with this impairment. Waterbodies and water quality variables targeted for TMDL development are listed in Table 1-2.

Table 1-1: Illinois 2008 Integrated Report 303(d) and Assessment Report Information for Upper Fox River/Chain-O'-Lakes Watershed

Water ID	Segment Name	Size (acres)	Priority	Designated Use	Potential Causes
IL_DT-35	**Fox River**	**4.90 (miles)**	**Medium**	**Primary Contact Recreation**	**Fecal Coliform**
				Fish Consumption	Polychlorinated biphenyls
				Aquatic Life	Sedimentation/Siltation Total Suspended Solids
IL_RGK	**Grays**	**80.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus**
IL_RGZT	**Spring**	**42.92**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_RTC	**Sun**	**24.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus**
IL_RTD	**Catherine**	**164.68**	**Medium**	**Aesthetic Quality**	**Total Phosphorus**
			Medium	Fish Consumption	Polychlorinated biphenyls
IL_RTF	**Fox**	**1881.12**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
			Medium	Fish Consumption	Mercury, Polychlorinated biphenyls
IL_RTH	**Round**	**228.60**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_RTI	**Channel**	**337.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus**
				Fish Consumption	Mercury, Polychlorinated biphenyls
IL_RTJ	**Long**	**393.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_RTM	East Loon	170.00	Medium	Aesthetic Quality	Cause Unknown
IL_RTQ	**Grass**	**1623.42**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
				Aquatic Life	**Total Phosphorus** Sedimentation/Siltation, Total Suspended Solids
				Fish Consumption	Polychlorinated biphenyls
IL_RTR	**Marie**	**516.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
				Fish Consumption	Mercury, Polychlorinated biphenyls
IL_RTT	**Antioch**	**88.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_RTU	**Pistakee**	**1700.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
				Aquatic Life	**Total Ammonia** **Total Phosphorus** Sedimentation/Siltation, Total Suspended Solids
				Fish Consumption	Mercury, Polychlorinated biphenyls
IL_RTUA	**Nippersink**	**718.16**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
				Aquatic Life	**Total Phosphorus** Total Suspended Solids
IL_RTV	**Redhead**	**50.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_RTZG	**Duck**	**110.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_RTZH	**Wooster**	**98.50**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_RTZJ	Lily	89.00	Medium	Aesthetic Quality	Cause Unknown
IL_RTZL	Sullivan Lake	58.00	Medium	Aesthetic Quality	Cause Unknown
IL_STC	Little Silver	41.00	Medium	Aesthetic Quality	Cause Unknown

Table 1-1: Illinois 2008 Integrated Report 303(d) and Assessment Report Information for Upper Fox River/Chain-O'-Lakes Watershed

Water ID	Segment Name	Size (acres)	Priority	Designated Use	Potential Causes
IL_STG	Leisure	12.00	Medium	Aesthetic Quality	Total Phosphorus Total Suspended Solids
IL_STQ	**Davis Lake**	**36.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus**
IL_STR	**North Churchill**	**62.40**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
				Aquatic Life	**Total Phosphorus** Total Suspended Solids
IL_STS	**South Churchill**	**24.81**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
				Aquatic Life	**Total Phosphorus** Total Suspended Solids
IL_STU	Christa	8.90	Medium	Aesthetic Quality	Total Phosphorus Total Suspended Solids
IL_STW	Hook Lake	82.00	Medium	Aesthetic Quality	Cause Unknown, Total Suspended Solids
IL_STX	Countryside Glen	7.90	Medium	Aesthetic Quality	Total Phosphorus Total Suspended Solids
IL_UTA	Lake Matthews	9.00	Medium	Aesthetic Quality	Total Phosphorus Total Suspended Solids
IL_UTK	Lake Holloway	13.00	Medium	Aesthetic Quality	Total Phosphorus Total Suspended Solids
IL_UTL	Cranberry Lake	16.00	Medium	Aesthetic Quality	Cause Unknown
IL_UTM	**Hidden**	**19.00**	**Medium**	**Aquatic Life**	**Dissolved Oxygen, pH** Total Phosphorus Total Suspended Solids
				Aesthetic Quality	Total Phosphorus Total Suspended Solids
IL_UTV	Cross	88.91	Medium	Aesthetic Quality	Cause Unknown
IL_UTW	**Lake Tranquility**	**26.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_UTX	**Mcgreal Lake**	**24.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus**
IL_UTZ	Lake-Of-The-Hollow	75.00	Medium	Aesthetic Quality	Cause Unknown
IL_VTD	**Deep Lake**	**225.50**	**Medium**	**Primary Contact Recreation**	**Fecal Coliform**
				Aesthetic Quality	Cause Unknown
IL_VTH	**Dunns**	**68.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_VTJ	**Bluff**	**86.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_VTK	**Fish-Duncan**	**96.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_VTT	**Fischer Lake**	**23.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_VTW	**Petite**	**165.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus**
IL_VTZA	**Turner**	**43.00**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids
IL_VTZX	Owens	5.00	Medium	Aesthetic Quality	Total Phosphorus Total Suspended Solids
IL_WTA	**Summerhill Estate**	**49.90**	**Medium**	**Aesthetic Quality**	**Total Phosphorus** Total Suspended Solids

Those parameters in bold have numeric standards and will have TMDL allocations.

Table 1-2: Waterbodies targeted for TMDL development in the Upper Fox/Chain O' Lakes Watershed

Segment ID	Waterbody Name	Waterbody size (acres)	Impairment
IL_RTT	Antioch Lake	88.0	Total Phosphorus
IL_VTJ	Bluff Lake	86.0	Total Phosphorus
IL_RTD	Catherine Lake	164.7	Total Phosphorus
IL_RTI	Channel Lake	337.0	Total Phosphorus
IL_STQ	Davis Lake	36.0	Total Phosphorus
IL_VTD	Deep Lake	225.5	Fecal Coliform
IL_VTH	Dunns Lake	68.0	Total Phosphorus
IL_RTZG	Duck Lake	110.0	Total Phosphorus
IL_VTK	Fish-Duncan Lake	96.0	Total Phosphorus
IL_VTT	Fischer Lake	23.0	Total Phosphorus
IL_RTF	Fox Lake	1881.1	Total Phosphorus
IL_DT-35	Fox River	4.9 (miles)	Fecal Coliform
IL_RTQ	Grass Lake	1623.4	Total Phosphorus
IL_RGK	Grays Lake	80.0	Total Phosphorus
IL_UTM	Hidden Lake	19.0	pH, Dissolved Oxygen
IL_RTJ	Long Lake	393.0	Total Phosphorus
IL_RTR	Marie Lake	516.0	Total Phosphorus
IL_UTX	McGreal Lake	24.0	Total Phosphorus
IL_RTUA	Nippersink Lake	718.2	Total Phosphorus
IL_STR	North Churchill Lake	62.4	Total Phosphorus
IL_VTW	Petite Lake	165.0	Total Phosphorus
IL_RTU	Pistakee Lake	1700.0	Total Phosphorus Total Ammonia
IL_RTV	Redhead Lake	50	Total Phosphorus
IL_RTH	Round Lake	228.6	Total Phosphorus
IL_STS	South Churchill Lake	24.8	Total Phosphorus
IL_RGZT	Spring Lake	42.9	Total Phosphorus
IL_WTA	Summerhill Lake	49.9	Total Phosphorus
IL_RTC	Sun Lake	24.0	Total Phosphorus
IL_UTW	Lake Tranquility	26.0	Total Phosphorus
IL_VTZA	Turner Lake	43.0	Total Phosphorus
IL_RTZH	Wooster Lake	98.5	Total Phosphorus

2.0 Watershed Characterization

As part of the Stage 1 report, relevant geographic and hydrologic characteristics and general information are obtained for the watershed of interest. This section describes the general characteristics of the Upper Fox River/Chain O' Lakes watershed including location (Section 2.1), topography (Section 2.2), land use (Section 2.3), soil information (Section 2.4), population (Section 2.5), climate and precipitation (Section 2.6) and hydrology (Section 2.7).

2.1 Watershed Location

A watershed is a geographic area that shares a hydrologic connection - all the water within that area drains to a common waterway. Water movement can be influenced by topography, soil composition and water recharge (i.e. precipitation, snow melt, groundwater) ("What is a Watershed", 2007). Watersheds are important because pollution at the water's source may impact water quality in all downgradient areas including its convergence with a common waterway. Understanding the watershed is an essential step in the TMDL process – an essential tool in maintaining water quality standards within Illinois.

The Fox River watershed spans across two states, Wisconsin and Illinois with the headwaters located in Wisconsin. The river flows south into Illinois along the western portion of the Chicago Metropolitan suburban area. The watershed as a whole drains approximately 2,658 square miles (sq mi) with 1,720 sq mi located within Illinois (IDNR 1995) (Figure 2-1). The Fox River flows 115.1 miles from Wisconsin, through several Illinois Counties (Grundy, Kane, Kendall, Lake, La Salle, McHenry and Will) before discharging into the Illinois River at Ottawa.

The Illinois EPA 2008 Integrated Report (303(d)) List and Stream Assessment Report (Illinois EPA, 2008) divides the Fox River watershed into two portions: Upper Fox River watershed (USGS HUC:07120006) and the Lower Fox River watershed (USGS HUC:07120007) (Figure 2-1). The Illinois portion of the Upper Fox River is further divided into five smaller sub-watersheds (10-digit hydrologic unit codes). Three of these sub-watersheds (Nippersink Creek, North Branch Nippersink Creek and Squaw Creek) drain through a hydrologically connected system of lakes, commonly known as the Chain O' Lakes, to the Fox River. This Upper Fox River/Chain O' Lakes watershed drains 362 square miles in Lake and McHenry Counties, representing 50% of the Illinios portion of the Upper Fox River watershed. The Upper Fox River/Chain O' Lakes watershed includes the populous cities such as Round Lake Beach and Woodstock. Figure 2-2 illustrates the Upper Fox River/Chain O' Lakes watershed, the unique collection of lakes and identifies those waterbodies that are listed for TMDL development.

2.2 Topography

Topography influences soil types, precipitation, and subsequently watershed hydrology and pollutant loading. For the Upper Fox River/Chain O' Lakes watershed, a USGS 30-meter resolution Digital Elevation Model (DEM) was obtained from the Illinois Natural Resources Geospatial Data Clearinghouse and used in conjunction with 2-foot Lidar data to characterize the topography. The DEM was then cropped to the extents of the Upper Fox River/Chain O' Lakes watershed, as provided by the Illinois EPA, and analyzed. Figure 2-3 displays elevations in color ramp throughout the watershed.

In general, the higher elevations are located in the east/southeast with a gradation to a lower elevation in the west/northwest toward the Upper Fox River and Chain O' Lakes, resulting in an overall surface water flow from southeast to northwest to the Chain O' Lakes. The percent change of elevation across the Upper Fox River Watershed is approximately 25% and ranges from 915 feet to 730 feet.

Figure 2-1: Fox River Watershed

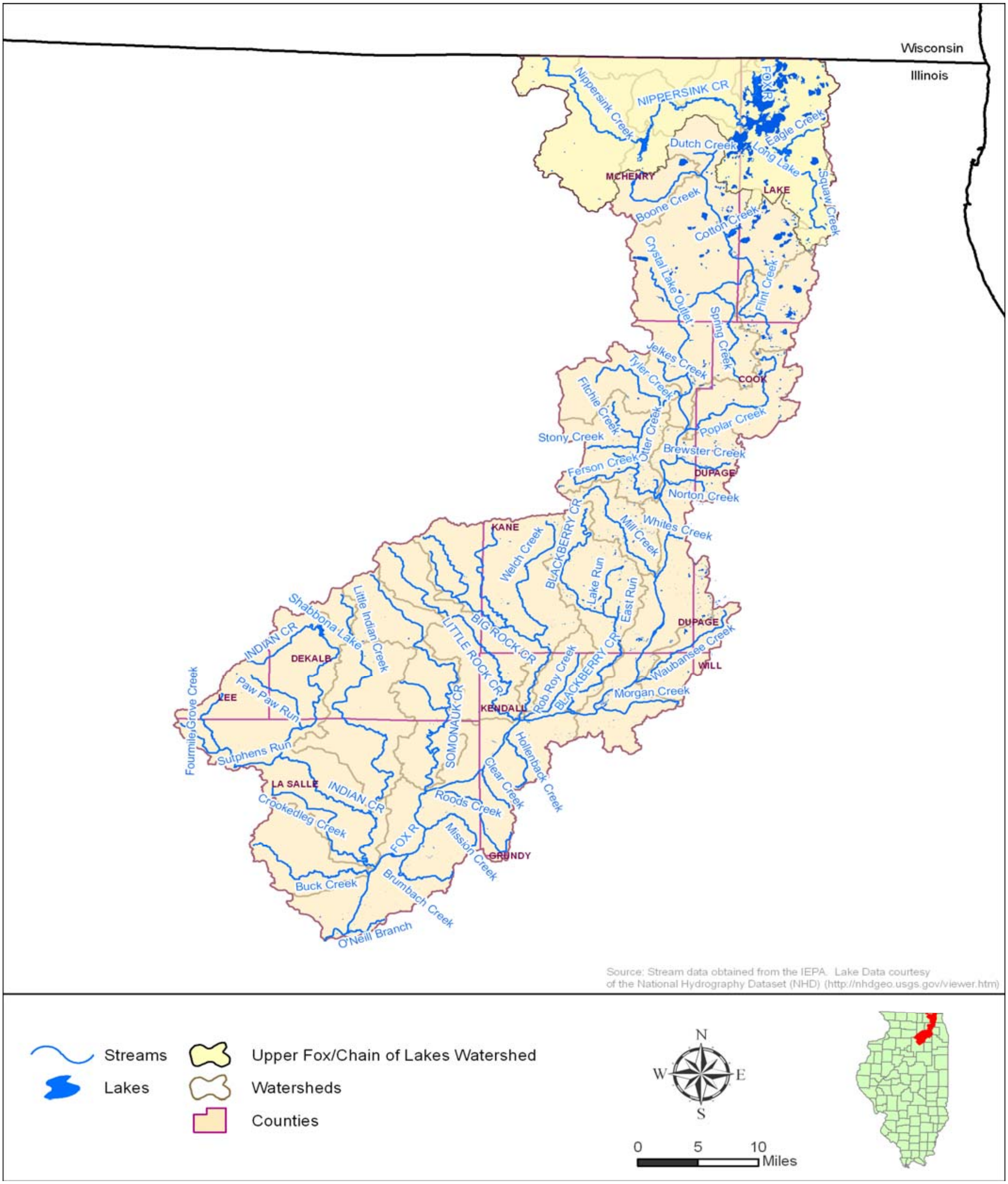


Figure 2-2: Upper Fox River/Chain O' Lakes Watershed Map

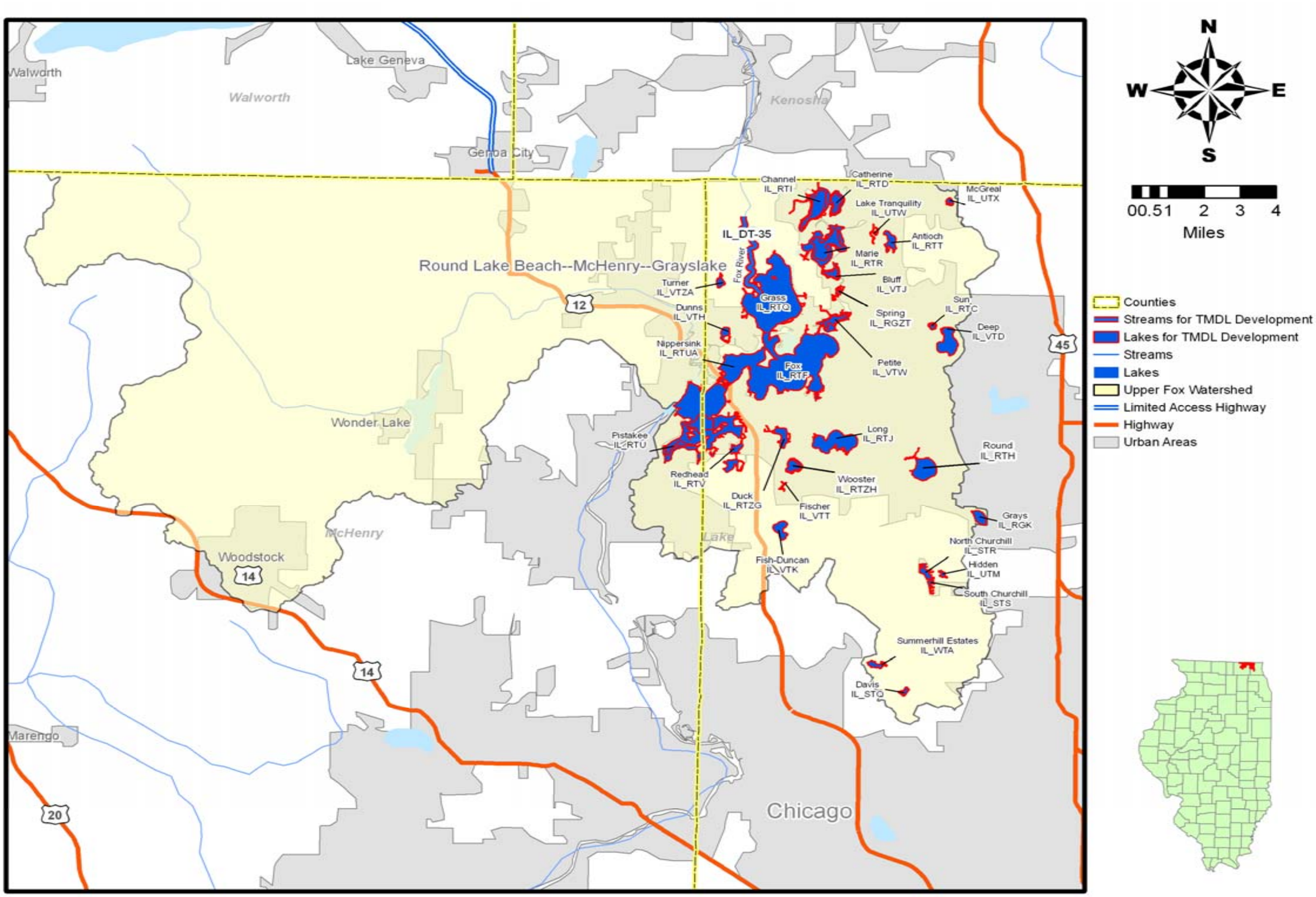
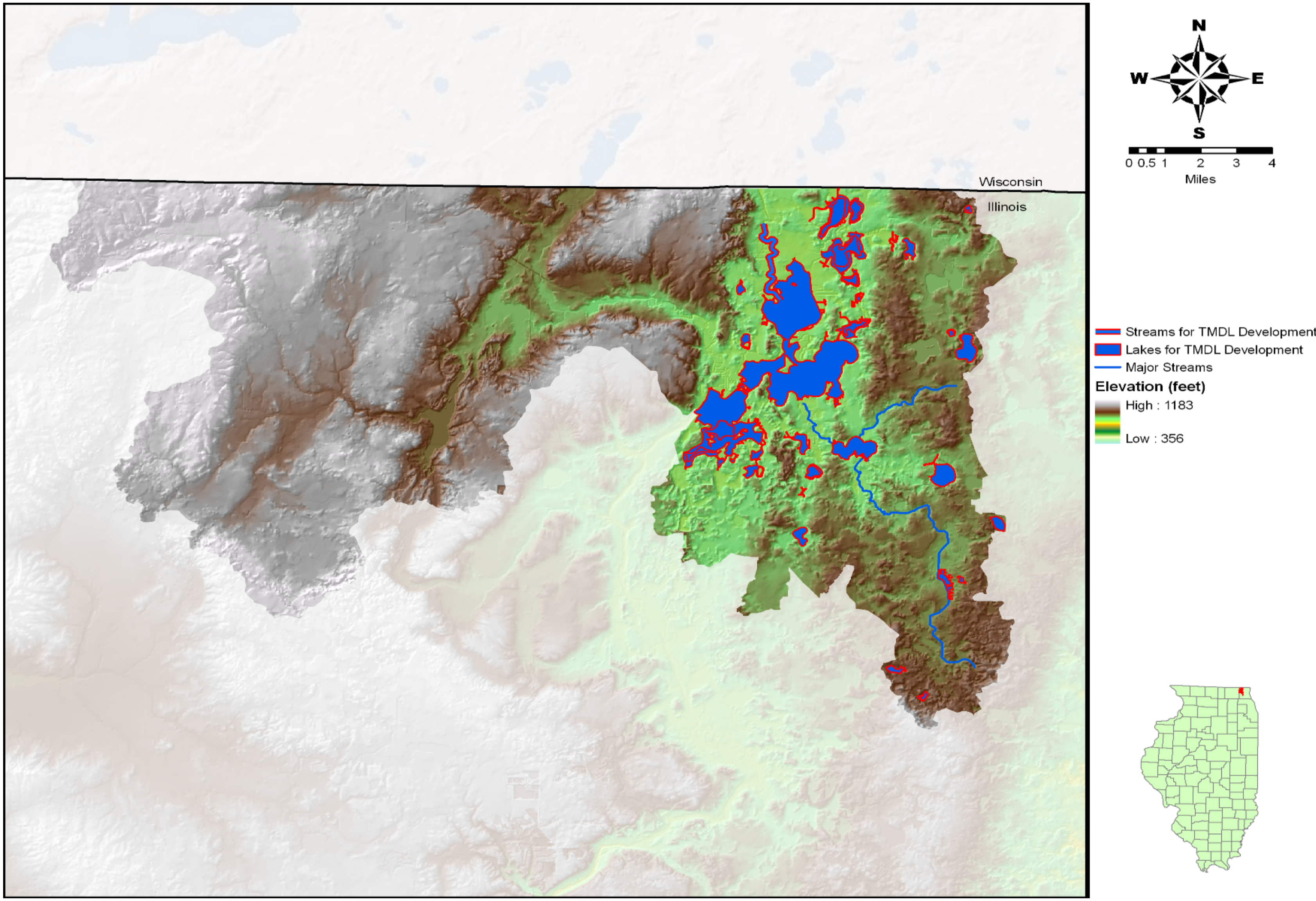


Figure 2-3: Upper Fox River/Chain O' Lakes Watershed Digital Elevation Model (DEM)



The Fox River elevation is 732 feet as it leaves Wisconsin and enters Illinois. It flows southward through the Chain O' Lakes and exits the watershed to the west at about 732 feet. The stream gradient of the Fox River mainstem in this watershed is minimal and is further minimized by the artificially maintained water level by the dam at McHenry (also known as the Stratton Dam), which was constructed in 1907. Although the dam impounds water, the Chain O' Lakes was naturally formed by glaciers.

2.3 Land Use

Land use is as dynamic as the water moving throughout a watershed. It is constantly changing and has a large impact on water quality. Land use data for the portion of Upper Fox River/Chain O' Lakes watershed within Lake County were obtained from Lake County Stormwater Management Commission (SMC). The data set is an update of the 2000 land use inventory data set for the County. The Lake County 2000 land use code definitions have been retained for the most part, but have been modified to identify land uses of special interest to the County and municipalities in 2005.

Land use data for the rest of the watershed were extracted from the 2001 land use inventory provided by the Chicago Metropolitan Agency for Planning (C-MAP). Land use is aggregated to 48 categories, and was created using black and white orthorectified aerial photography that was captured in April 2001. In addition to orthorectified aerial photography for the region, numerous GIS reference layers and several internet resources were used to support the Land Use Inventory. Land use interpretation methods and the consequent classification were conducted using a systematic approach working in thematic waves. The minimum land use classification area size was 1 acre or 2.5 acres (within the City of Chicago 0.5 acre or 1 acre), depending upon the type of land use being classified. Land use categories define homogeneous areas and represent features as they appear on the earth's surface. They are not generalized to any other geography. 2005 land use extents of Lake County were used to remove the exact portion of 2001 land use. The two layers were then merged. Land use codes from each data set were used to define the appropriate description and then combined into the appropriate classes, such as urban, agriculture, forest, water, wetland, barren or exposed lands.

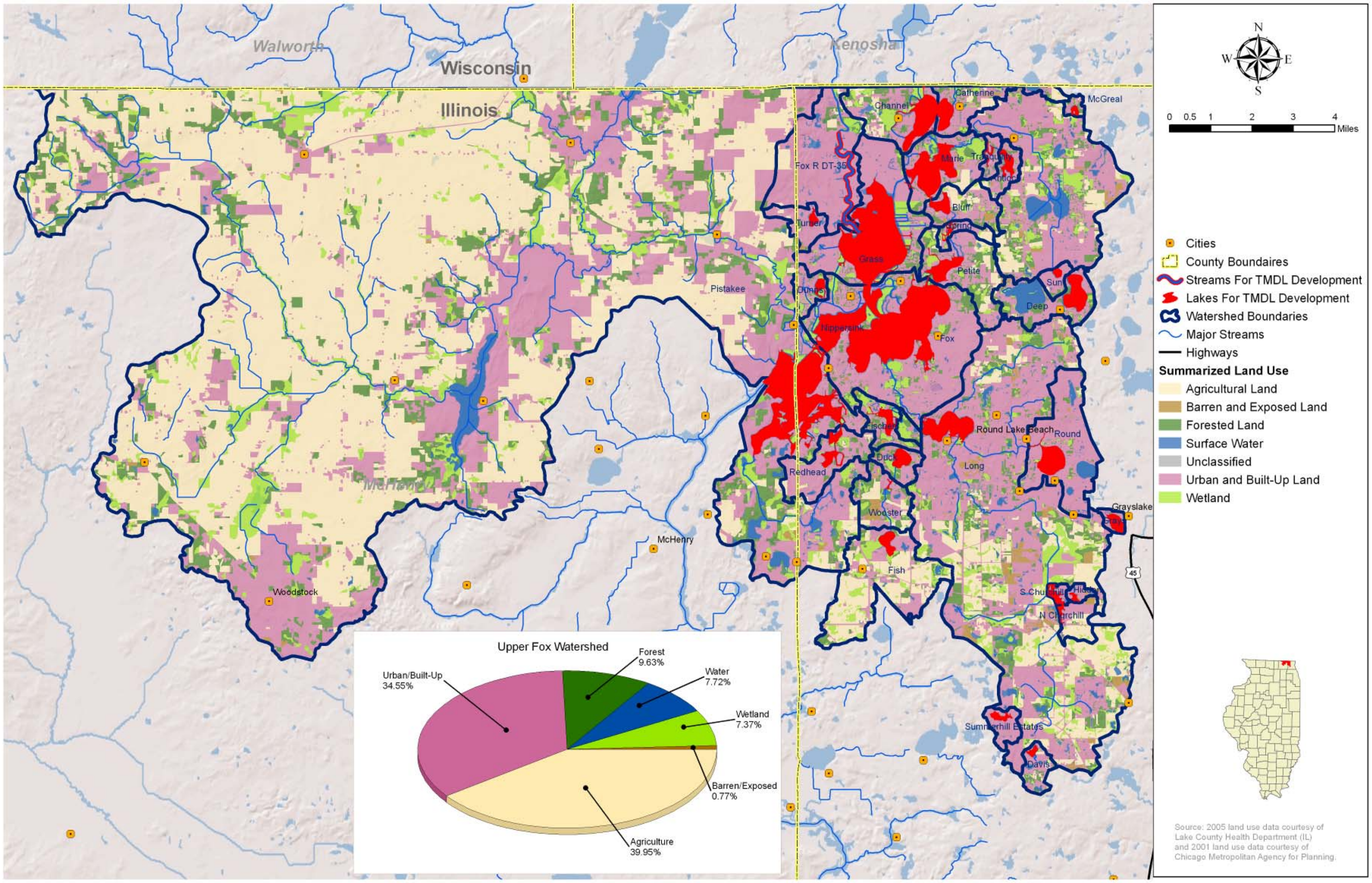
Much of the Upper Fox River/Chain O' Lakes watershed was forested prior to 1840. These forests were clear cut and converted to row crop agriculture. The progression of land use changes from agriculture to residential and urban use has increased with time. Although agricultural areas still dominate the watershed (40%), urban use is a close second, occupying 35% of the total area (Figure 2-4). Much of the urban land is located near the Chain O' Lakes. Forested land accounts for 10%. Surface water and wetlands comprise 8 and 7% of the watershed, respectively.

It is noted that Chicago Metropolitan Agency for Planning (C-MAP) is finalizing the consolidated land use data for the six northeast Illinois Counties. This data will be used for Stage 3 work once available.

2.4 Soils

Soils data and Geographic Information Systems (GIS) files from the Natural Resources Conservation Service (NRCS) were used to characterize soils in the Upper Fox River/Chain O' Lakes watershed. General soils data and map unit delineations for the country are provided as part of the Soil Survey Geographic (SSURGO) database. Field mapping methods using national standards are used to construct the soil maps in the SSURGO database. Mapping scales generally range from 1:12,000 to 1:63,360; SSURGO is the most detailed level of soil mapping prepared by the NRCS. A map unit is composed of several soil series having similar properties. Identification fields in the GIS coverage can be linked to a database that provides information on chemical and physical soil characteristics. The SSURGO database contains many soil characteristics associated with each map unit.

Figure 2-4: Upper Fox River/Chain O' Lakes Watershed Land Use Map



SSURGO data were analyzed based on drainage class (Figure 2-5), hydrologic group (Figure 2-6) and K-factor (Figure 2-7), a coefficient of the Universal Soil Loss Equation (USLE). The drainage class, as stated in the SSURGO database is, “The natural drainage condition of the soil [which] refers to the frequency and duration of wet periods” (Soil Survey Staff, “Table Column Descriptions”). Poorly drained soils can be found in areas where there is frequent flooding such as land adjacent to lakes and streams. Excessively drained areas are also present around the lakes and may be natural in nature or due to anthropogenic sources such as construction of residential and paved areas. The eastern border of the watershed is for the most part, moderately well drained, while portions to the west are well drained.

Soils that remain saturated or inundated for a sufficient length of time become hydric through a series of chemical, physical, and biological processes. Once a soil takes on hydric characteristics, it retains those characteristics even after the soil is drained. Therefore, hydric soils are the best indicator of what is or once was a wetland (SMC 2007). Wetlands help control flooding by retaining water when it rains and then releasing it slowly back into lakes and streams. The longer a soil is inundated the more likely it is that it will become hydric.

The hydrologic soil group classification identifies soil groups with similar infiltration and runoff characteristics during periods of prolonged wetting. Typically, clay soils that are poorly drained have lower infiltration rates, while well-drained sandy soils have the greatest infiltration rates. The United States Department of Agriculture (USDA) has defined four hydrologic groups (A, B, C, or D) for soils. Type A soil has high infiltration while D soil has very low infiltration rate. Figures 2-6 show the distribution of hydrologic soil groups. Generally, areas to the east have a moderately slow infiltration rate (hydrologic group C). Areas near the lakes contain both slow (hydrologic group D) to moderately high infiltration rates (hydrologic group B). High infiltration rates near the lakes may be anthropogenic in nature. The central and much of the western portion of the watershed is mostly hydrologic group B with a moderately high infiltration rate and corresponds to the well drained class.

A commonly used soil attribute of interest is the K-factor, a dimensionless coefficient used as a measure of a soil’s natural susceptibility to erosion. Factor values range from 0 for water surfaces to 1.00 (although in practice, maximum K-factor values do not generally exceed 0.67). Large K-factor values reflect greater potential soil erodibility.

The compilation of K-factors from the SSURGO data was performed in several steps. Soils are classified in the SSURGO database by map unit symbol. Each map unit symbol is made up of components consisting of several horizons (or layers). The K-factor was determined by selecting the dominant components in the most surficial horizon per each map unit. The distribution of K-factor values in the Upper Fox River/Chain O’ Lakes watershed is shown in Figure 2-7. Areas with the highest K-factor can be found on the western side of the watershed, while the eastern side of the watershed contains moderate to low erosion potential.

Figure 2-5: Upper Fox/Chain O' Lakes SSURGO Drainage Class

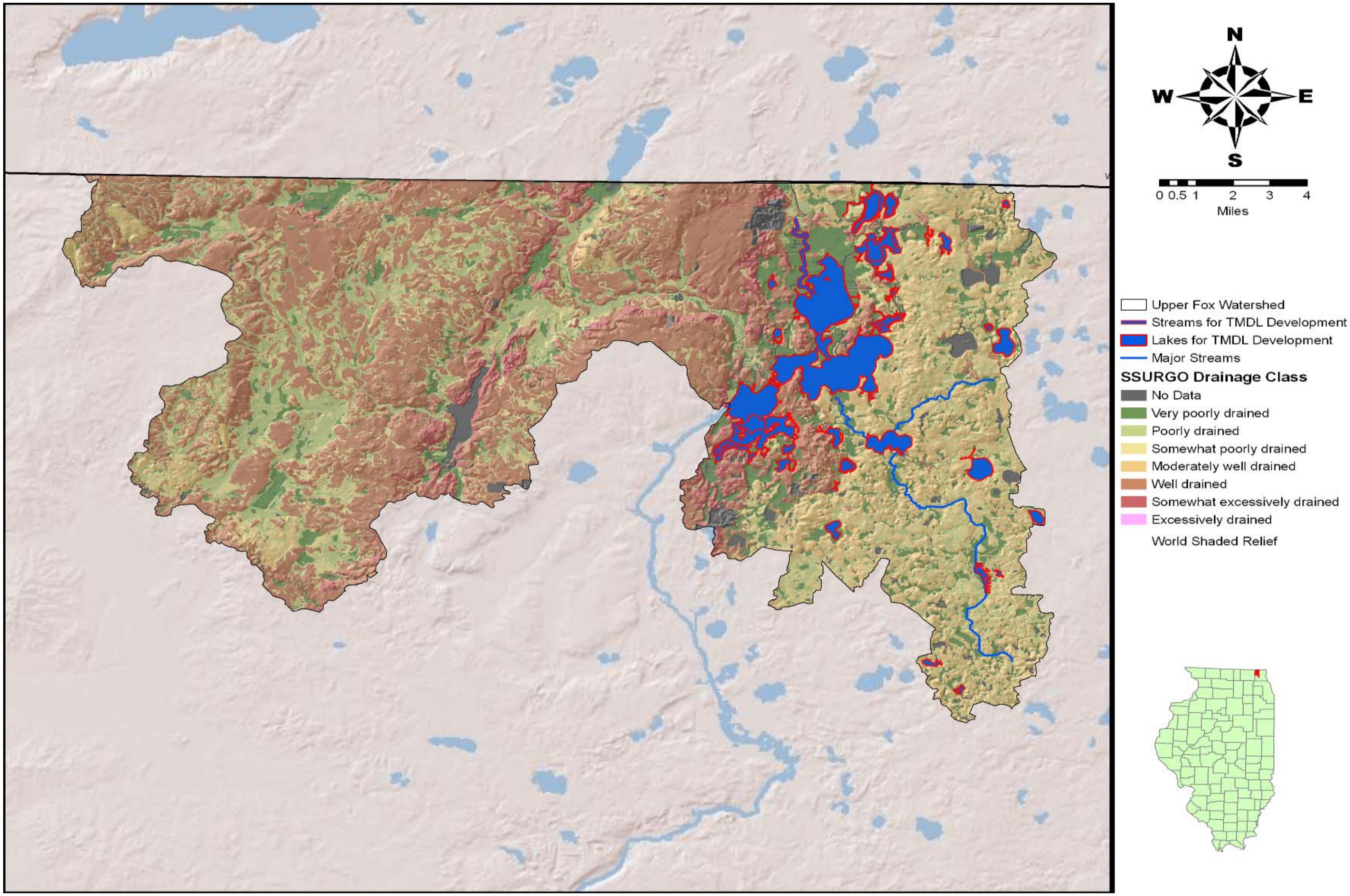


Figure 2-6: Upper Fox/Chain O' Lakes SSURGO Hydrologic Group

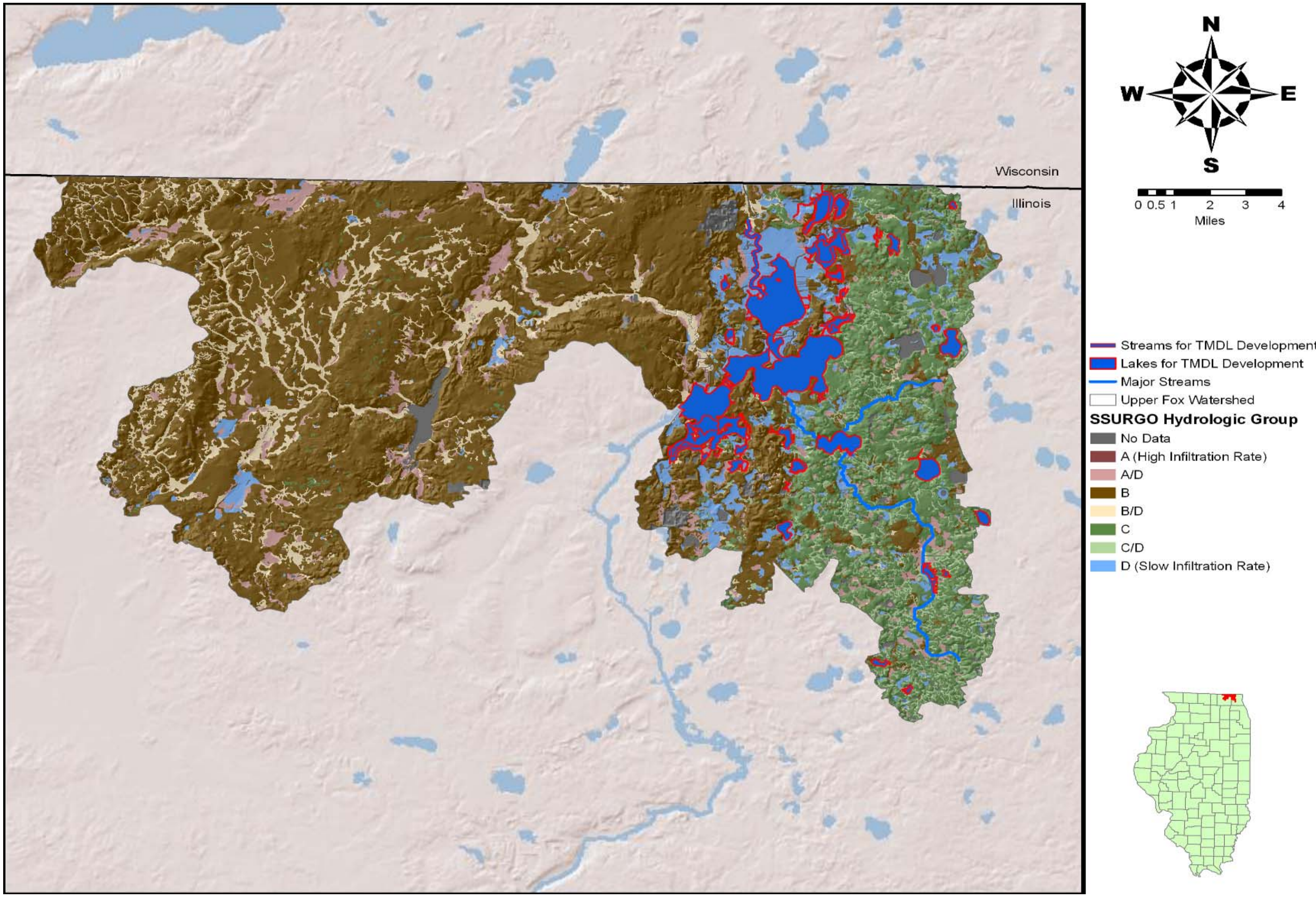
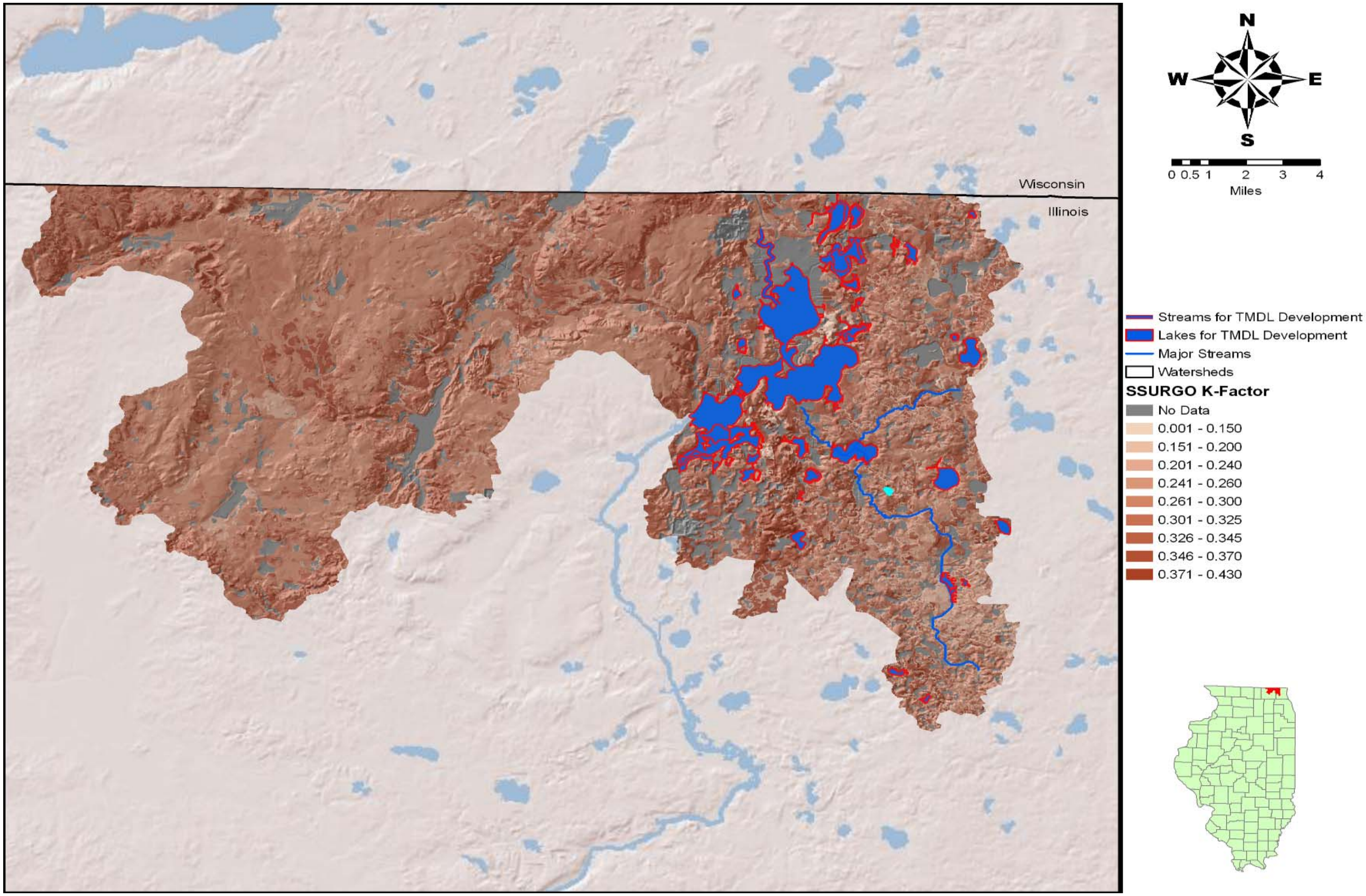


Figure 2-7: Upper Fox/Chain O' Lakes SSURGO K-Factor



2.5 Population

Circumstances in the Upper Fox River/Chain O' Lakes watershed today are not only the product of the geologic and natural processes that have occurred in the watershed, but also a reflection of human impacts and population growth. Development has changed the watershed's natural drainage system as channelization and dredging have replaced slow moving, shallow streams and wetlands. This alteration has affected the way water runs off of the landscape both in increased volume and velocity, resulting in the potential increase in pollutant transport.

The area surrounding the Chain O' Lakes is primarily residential and recreational areas. Land was first developed around the Chain O' Lakes for agriculture in the 1840's. Since that time much of the shorelines of the Chain O' Lakes have been developed for housing, restaurants, marinas and recreation (Kothandaraman et al., 1977). The Fox River watershed as a whole accounts for nearly 11% of the state of Illinois' population at roughly 1,000,000 individuals (McConkey et al., 2004). Census 2000 data in format of TIGER/Line Shape file were downloaded to analyze the population in the targeted TMDL watershed of this report. Census data were also available for groups of census blocks, but the original census block data were used since it is a finer resolution and, therefore, more precise.

The Upper Fox River/Chain O' Lakes watershed accounts for about 198,000 persons with an average of 1,400 persons per square mile. In comparison, the entire Fox River watershed has about 600 persons per square mile. Census blocks with the highest populations can be found in the central western and northwestern portion part of this watershed near the cities of Round Lake Beach and Woodstock, respectively.

The Illinois Department of Commerce and Economic Opportunity provide population projections by municipality on their website ("Population Projections", 2005). Figure 2-8 depicts the percent population change in the watershed from 2000 to 2030. Table 2-1 provides the most recent census population data and projected population numbers by town. In general, the south-central portion of the watershed is projected the most growth at an increase by 7000%. The town of Volo with a population of 180 persons in 2000, is projected to grow to 13,686 persons by 2030 – a significant increase at 7500%. The eastern portion of the watershed will also see growth but not as much as great as the southwest. Antioch and Lake Villa are proposed to grow by 94-248%, while Round Lake Park is said to increase by 249-377%. This magnitude of growth will result in landuse changes and have the potential to impact water quality if these areas are not responsibly developed, utilizing the most effective and innovative technologies to protect the water resources within the Upper Fox River/Chain O' Lakes watershed.

Figure 2-8: Upper Fox River/Chain O' Lakes Population Projection

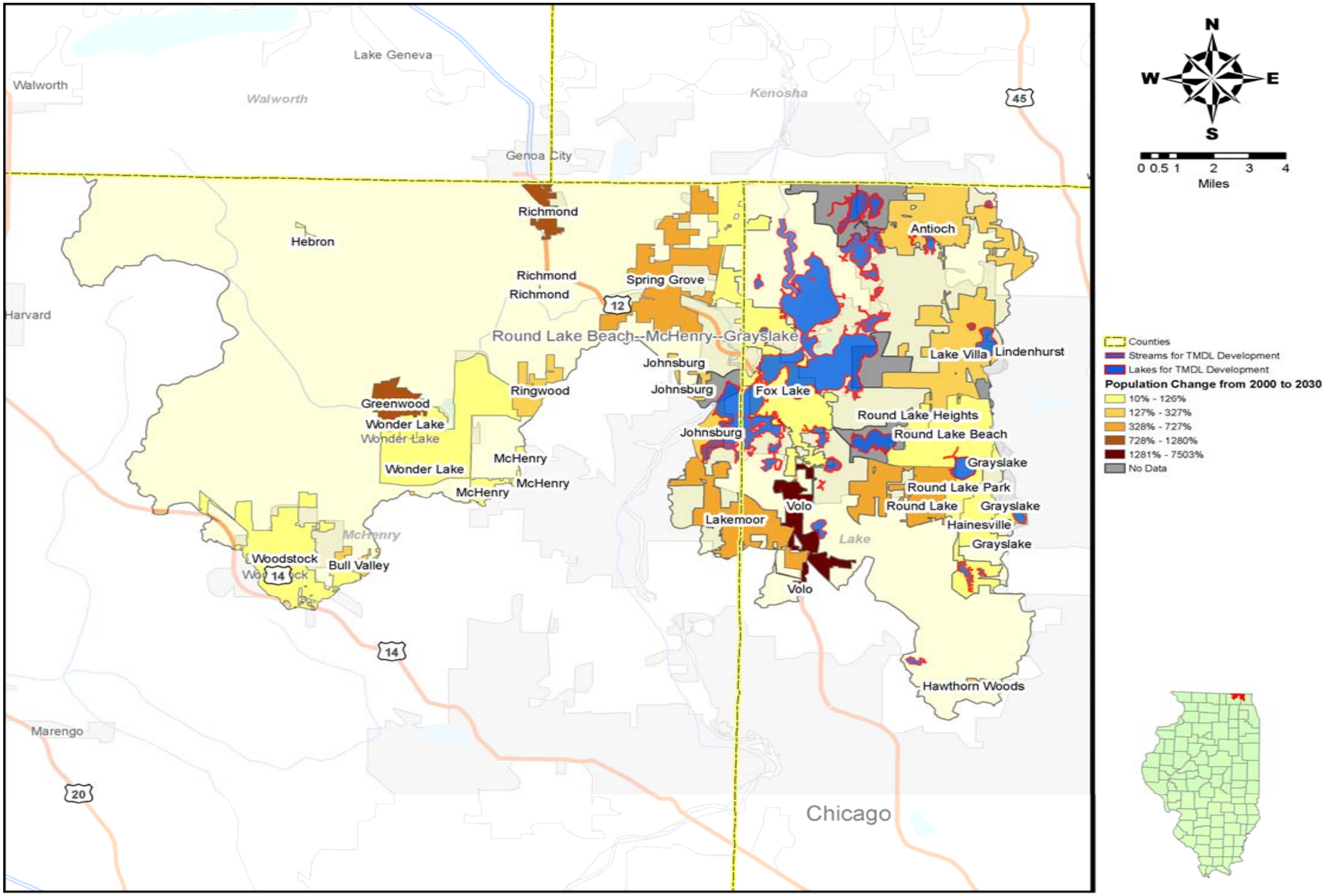


Table 2-1: Upper Fox River/Chain O' Lakes Watershed Population and Projections

Town/Village	2000 Population	2000 Population/Mi^2	Projected 2030 Population	Projected 2030 Population/Mi^2	Area (Mi^2)
Antioch	8788	1209	30594	4208	7.3
Bull Valley	726	127	2435	424	5.7
Fox Lake	9178	1013	12589	1390	9.1
Grayslake	18506	1969	24094	2563	9.4
Greenwood	244	154	3289	2082	1.6
Hainesville	2129	1145	4118	2214	1.9
Hawthorn Woods	6002	1057	15951	2808	5.7
Hebron	1038	1504	2074	3006	0.7
Johnsburg	5391	828	23024	3537	6.5
Lakemoor	2788	614	23055	5078	4.5
Lake Villa	5864	913	16546	2577	6.4
Lindenhurst	12539	3051	19843	4828	4.1
McHenry	21501	1790	48502	4038	12.0
Mundelein	30935	3430	34126	3783	9.0
Richmond	1091	796	15059	10992	1.4
Ringwood	471	196	1890	787	2.4
Round Lake	5842	1583	27338	7409	3.7
Round Lake Beach	25859	5041	29900	5828	5.1
Round Lake Heights	1347	2245	2552	4254	0.6
Round Lake Park	6038	1973	9954	3253	3.1
Spring Grove	3880	598	18523	2854	6.5
Volo	180	68	13686	5145	2.7
Wonder Lake	7463	1077	2715	392	6.9
Woodstock	20151	1923	30522	2912	10.5

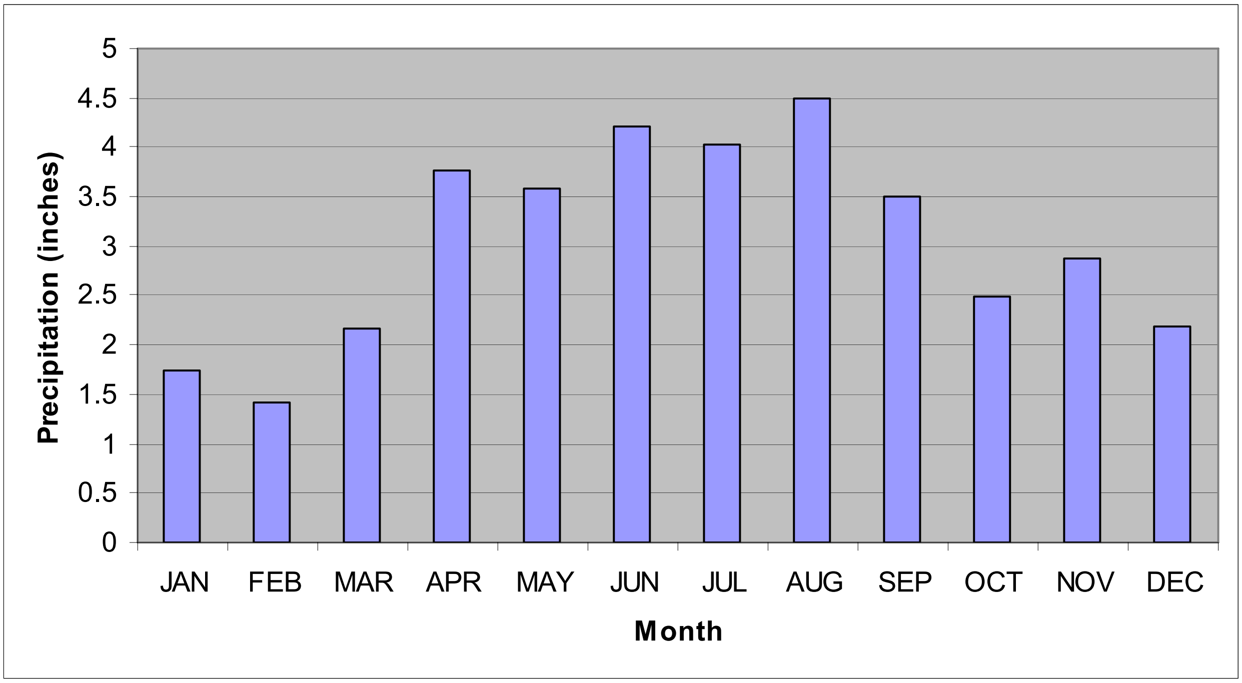
2.6 Climate and Precipitation

Northeast Illinois has a continental climate, with highly variable weather. The temperatures of continental climates are not buffered by the influence of a large waterbody (like an ocean, inland sea or Great Lake). Areas with continental climates often experience wide temperature fluctuations throughout the year. Summer maximum temperatures are generally in the 80s or low 90s while daily high temperatures in the winter are generally in the 20's or 30's ^{o}F (McConkey, 2004). Temperature and precipitation data were obtained from the Illinois State Climatologist Office website. There are several climate monitoring stations within the Upper Fox/Chain O' Lakes watershed. One of them is in the city of Antioch, which is located north portion of the watershed.

Climate data were analyzed for the city of Antioch between the years of 1971 to 2007 although data were not available for all years. Based on the available data, the mean high summer temperature is 78.9° F and the mean low temperature in winter is 4.9° F. Mean annual high temperatures are about 52° F, while mean annual low temperatures are about 43.9° F.

The mean monthly precipitation in Antioch from 1971-2007 can be found in Figure 2-9. Antioch receives most of its precipitation in the spring and summer months, with the greatest precipitation occurring in August at around 4.5 inches. The least precipitation is received in February at around 1.42 inches on average. Annual total precipitation averages about 36.5 inches.

Figure 2-9: Mean Monthly Precipitation in Antioch, IL (1971-2000)



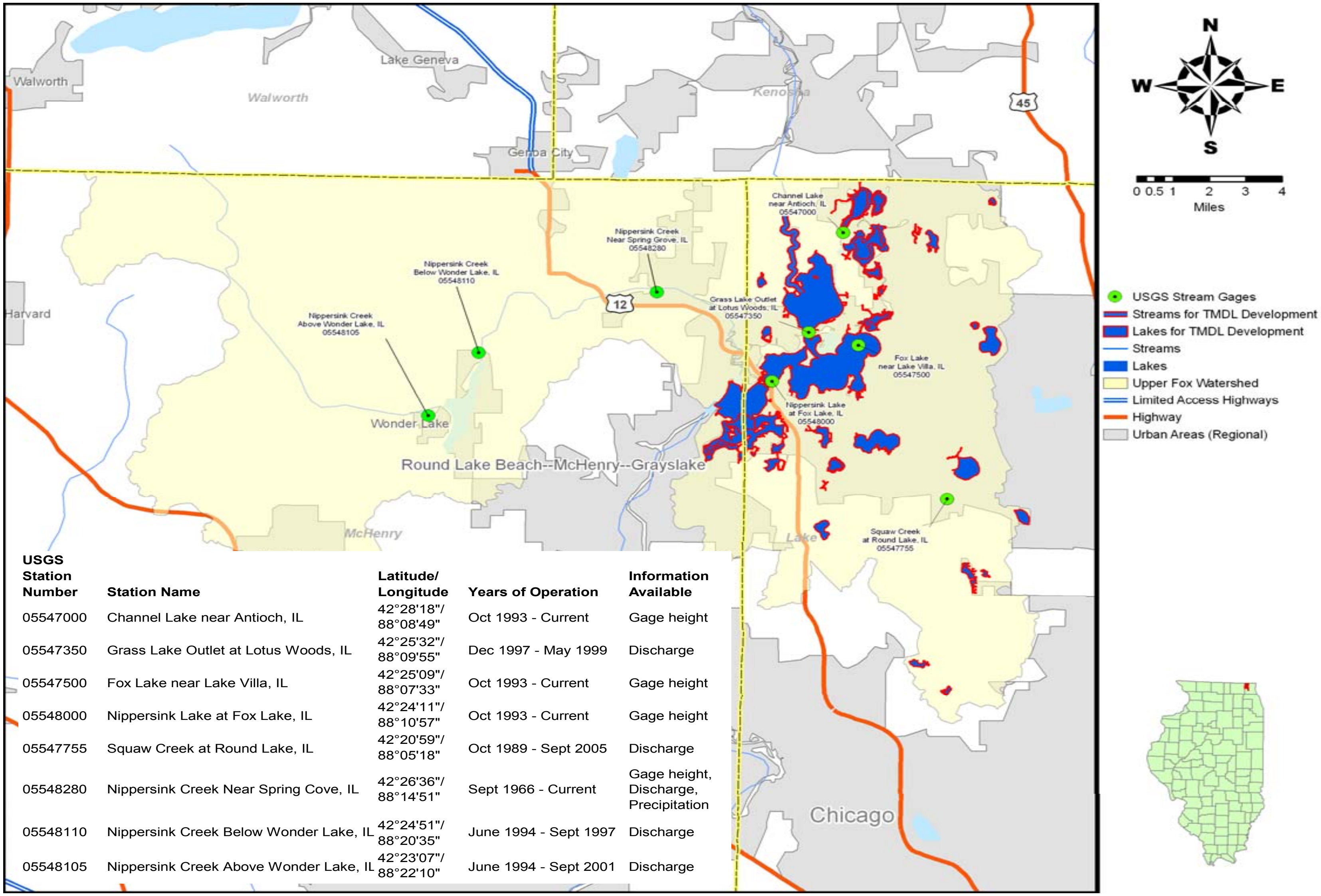
2.7 Hydrology

Understanding how water moves and flows is an important component of understanding a watershed. All parameters discussed in the previous sections (i.e. topography, soils, and precipitation) impact hydrology. Hydrological data are available from the United States Geological Survey website (USGS Water Data for the Nation http://waterdata.usgs.gov/nwis). The USGS maintains stream gages throughout the US which monitor conditions such as gage height, stream flow and precipitation at select locations.

There are eight USGS gages within the Upper Fox/Chain O' Lakes, five of which have stream flow (or discharge) information (Figure 2-10). Data for three of these gages (Nippersink Creek, Squaw Creek and Grass Lake) are summarized in Figures 2-11 through 2-16. Data for the other two gages are not summarized since they are upstream of the Nippersink Creek gage described herein. The Grass Lake Outlet at Lotus Woods, IL (05547350) gage is located between the confluence of Grass Lake and Fox Lake (both part of the Chain O' Lakes) in the northwestern portion of the watershed and contains data from December 1997 through May 1999. The Squaw Creek at Round Lake, IL (05547755) gage is located in the south central portion of the watershed along Squaw Creek and contains data from October 1989 through September 2005. The Nippersink Creek near Spring Cove (05548280) is located in McHenry County north of Route 12. This is the only Real Time gage (provides a continuous record of information) in the Upper Fox River/Chain O' Lakes watershed. Data used for the Nippersink Creek gage is from September 1966 through September 2008.

Flow data for the period of record were used to establish flow duration curves for the Grass Lake, Squaw Creek and Nippersink Creek near Spring Cove gages. These duration curves show the percentage of time flows are met or exceeded based on the period of record. They can be used to determine the percentage of time a given flow is expected to be equaled or exceed. Alternatively the duration curve could be used to determine the flow that is equaled or exceed for some percentage of time. Flow duration curves were developed by ranking flows from highest to lowest and calculating the probability of occurrence (presented as a percentage or duration interval), where zero corresponds to the highest flow. Flow duration curves and mean monthly stream flow for these gages are provided in Figures 2-11 through 2-16.

Figure 2-10: Upper Fox River/Chain O' Lakes Watershed USGS Gage Stations



USGS Station Number	Station Name	Latitude/ Longitude	Years of Operation	Information Available
05547000	Channel Lake near Antioch, IL	42°28'18"/ 88°08'49"	Oct 1993 - Current	Gage height
05547350	Grass Lake Outlet at Lotus Woods, IL	42°25'32"/ 88°09'55"	Dec 1997 - May 1999	Discharge
05547500	Fox Lake near Lake Villa, IL	42°25'09"/ 88°07'33"	Oct 1993 - Current	Gage height
05548000	Nippersink Lake at Fox Lake, IL	42°24'11"/ 88°10'57"	Oct 1993 - Current	Gage height
05547755	Squaw Creek at Round Lake, IL	42°20'59"/ 88°05'18"	Oct 1989 - Sept 2005	Discharge
05548280	Nippersink Creek Near Spring Cove, IL	42°26'36"/ 88°14'51"	Sept 1966 - Current	Gage height, Discharge, Precipitation
05548110	Nippersink Creek Below Wonder Lake, IL	42°24'51"/ 88°20'35"	June 1994 - Sept 1997	Discharge
05548105	Nippersink Creek Above Wonder Lake, IL	42°23'07"/ 88°22'10"	June 1994 - Sept 2001	Discharge

Figure 2-11: Mean Daily Flow Duration Curve for Grass Lake Outlet at Lotus Woods, IL (USGS 05547350) 1997-1999.

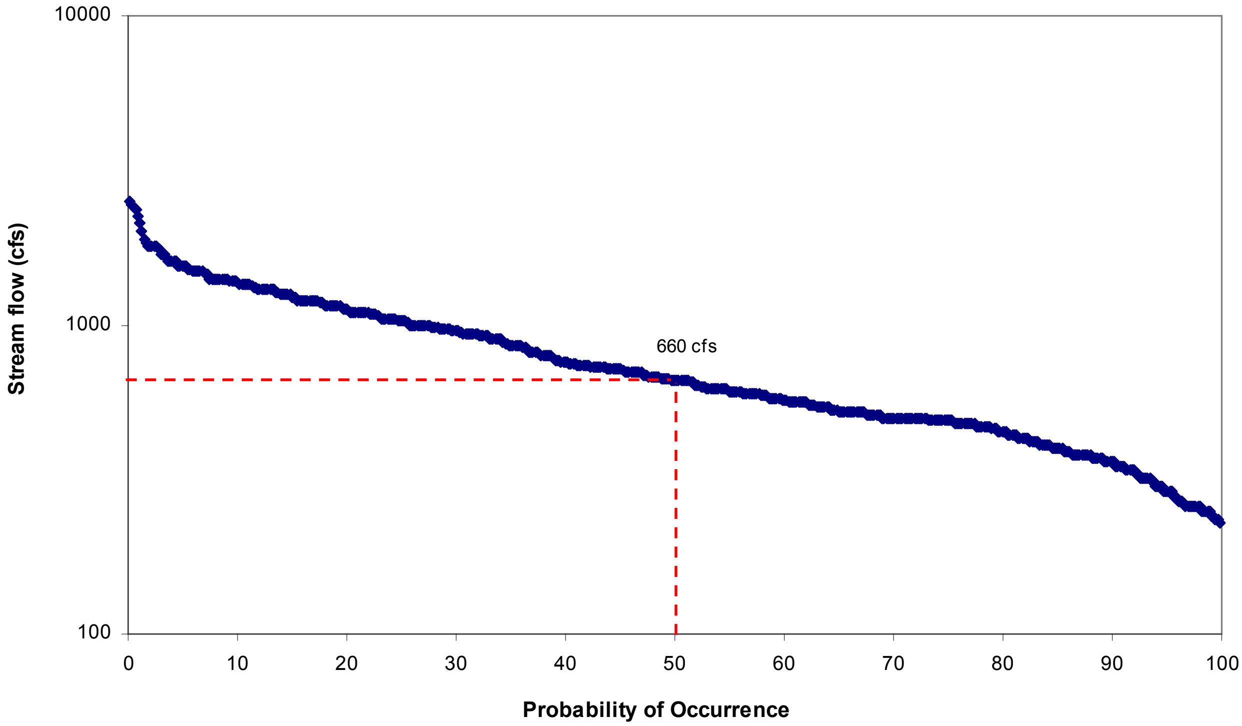


Figure 2-12: Mean Monthly Flow for Grass Lake Outlet at Lotus Woods, IL (USGS 05547350) 1997-1999.

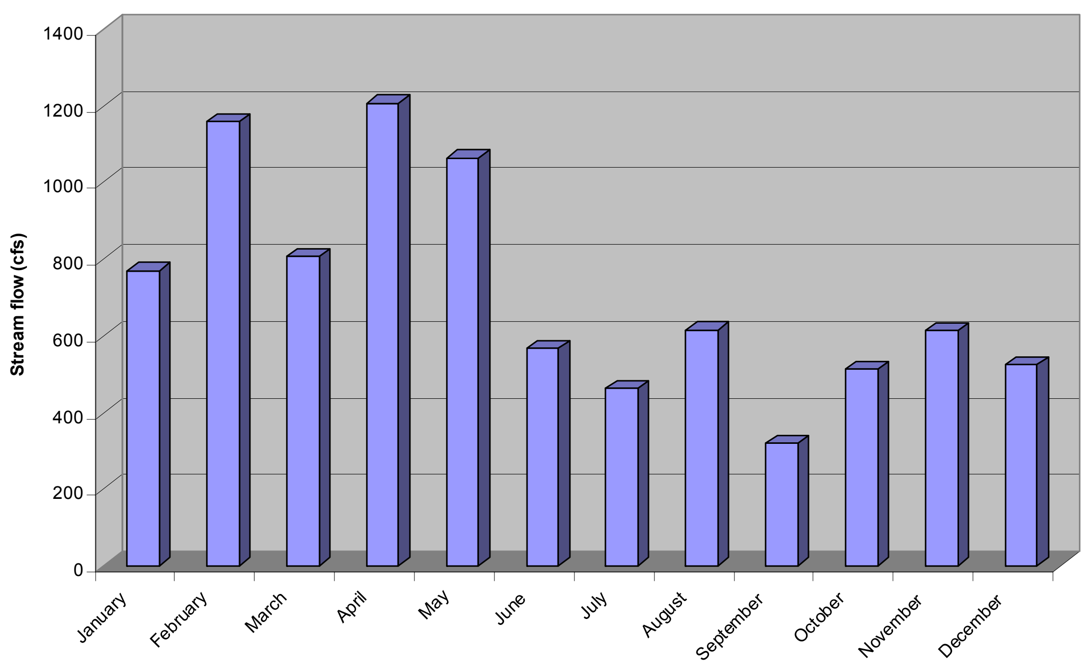


Figure 2-13: Mean Daily Flow Duration Curve for Squaw Creek at Round Lake, IL (USGS 05547755) 1989-2005.

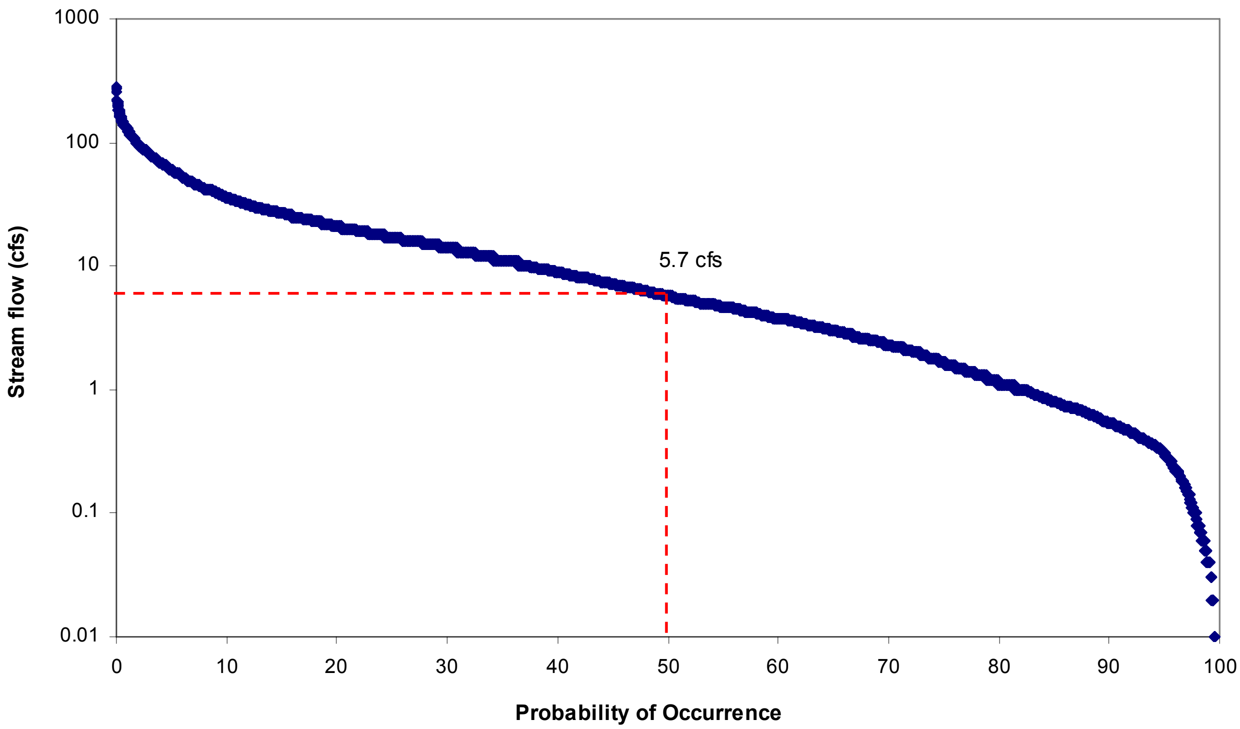


Figure 2-14: Mean Monthly Stream Flow for Squaw Creek at Round Lake, IL (USGS 05547755) 1989-2005

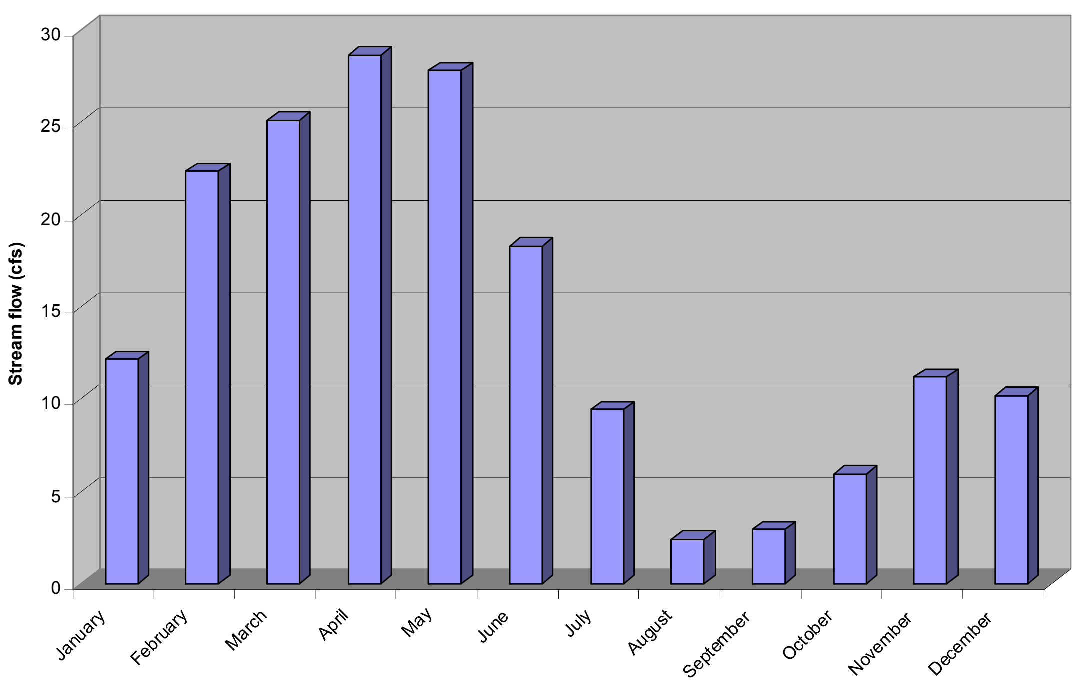


Figure 2-15: Mean Daily Flow Duration Curve for Nippersink Creek near Spring Cove, IL (USGS 05548280) 1966-2008

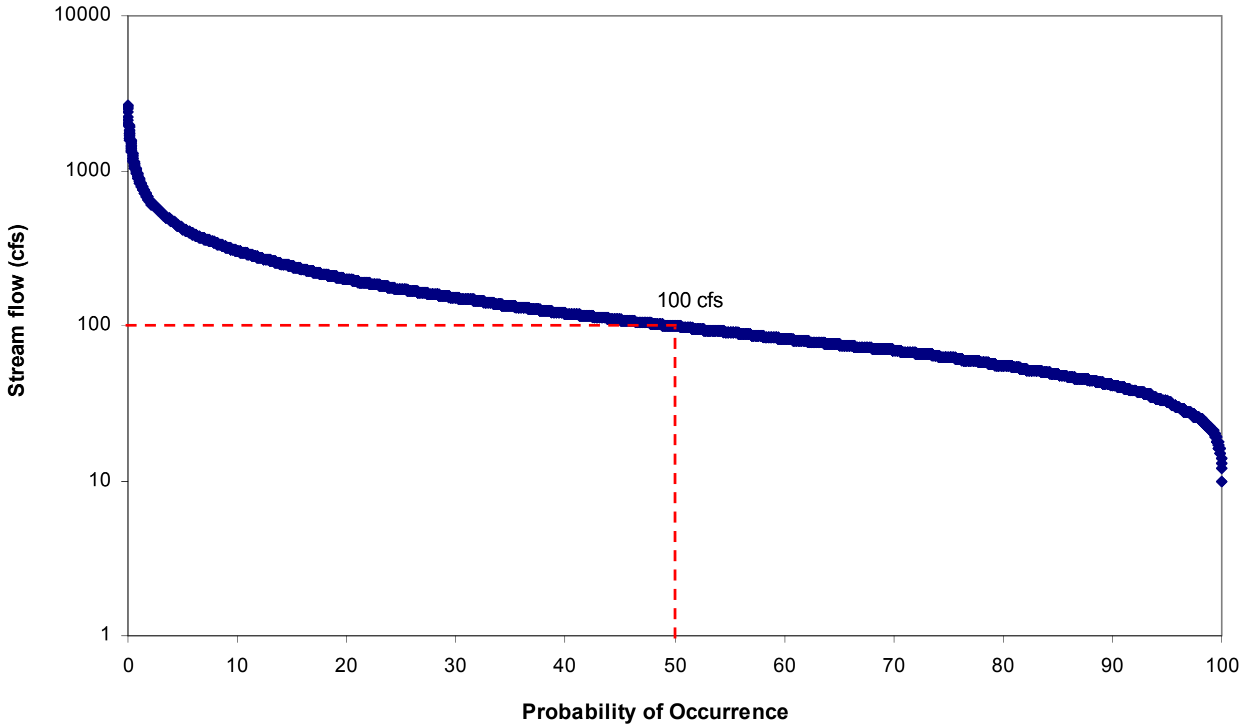
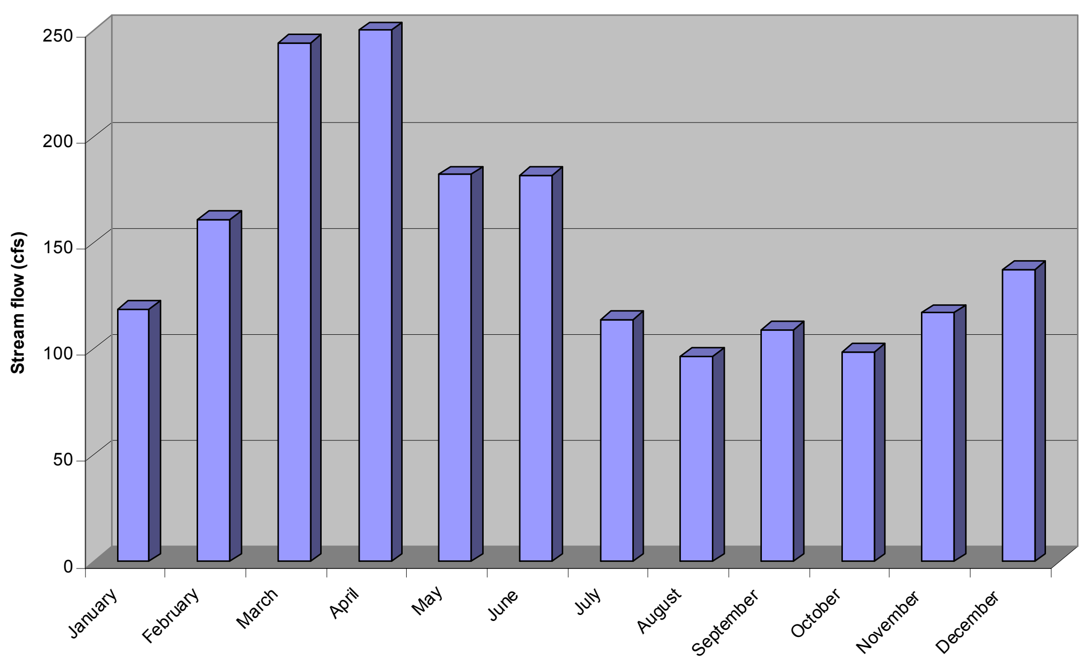


Figure 2-16: Mean Monthly Stream Flow for Nippersink Creek near Spring Cove, IL (USGS 05548280) 1966-2008



The Grass Lake gage has been discontinued but provides mean daily stream flow for 919 square miles (sq mi) from December 1997 through May 1999 (McConkey et al., 2004). The minimum and maximum mean daily stream flow recorded at the Grass Lake gage was 230 and 2500 cubic feet per second (cfs), respectively. The median daily stream flow, obtained from the flow duration curve (50% probability of occurrence), is 660 cfs (Figure 2-11). However the period of record at this gage is short. The mean daily mean flow is 786 cfs. Mean monthly stream flow for the period of record (1997-1999) at the Grass Lake gage is provided in Figure 2-11. The greatest monthly mean stream flow for the period of record occurs in April while the lowest mean monthly flow occurs in September (Figure 2-12). The highest stream flow for this gage generally occurs during the late winter and spring months, likely in response to winter snow melt and spring precipitation.

The Squaw Creek gage (1989-2005) captures stream flow from a much smaller area (17.2 sq mi; McConkey et al., 2004). Minimum and maximum mean daily stream flow for the Squaw Creek gage was 0 and 284 cfs, respectively. The median daily flow is 5.7 cfs (Figure 2-13), with a mean daily flow of 14.6 cfs. Like the Grass Lake gage data, stream flows are highest in the late winter and spring months, with lower flows in the fall. Mean monthly flow is greatest in April and lowest in August (Figure 2-14).

The Nippersink Creek near Spring Cove gage (1966-2008) provides stream 192 square mile catchment. Minimum and maximum mean daily flow for this gage was 10 and 2660 cfs respectively. The median flow is 100 cfs (Figure 2-15), with a mean daily flow of 151 cfs. Stream flow for this gage is highest on average in March and April, with lower flows during the summer and early fall.

The water in the Chain O' Lakes moves in a southwesterly direction toward the Fox River at times of high inflow rates (in the late winter and spring months). When flow rates diminish in the fall, water does not pass as quickly through the Chain O' Lakes and thus flow to the Fox River is much lower. To illustrate this, one can compare hydraulic residence times (HRTs) or detention times of water in these lakes. In April, the HRT is about five days compared to 21 days in September. Water spends a shorter amount of time in the lakes in the spring, when there is greater flow to flush the water through the lake system downstream to the Fox River. The reverse is true during the fall; the HRT in the fall is higher because there is lower flow and water is retained in the lake basin longer (Kothandaraman et al., 1977). The artificial manipulation of water level at the dam also greatly affects HRTs. USGS recorded water levels in Fox River, Fox Lake, and Nippersink Lake. In addition, Lake County SMC collected precipitations data at multiple locations within the watershed. These data will be used in Stage 3 for model development.

3.0 Public Participation and Involvement

The Illinois EPA is committed to keeping the watershed stakeholders and general public informed and involved throughout the TMDL process. Success for any TMDL implementation plan relies on a knowledgeable public able to aid in the follow-through needed for their watershed to meet the recommended TMDL. It is important to engage the local citizens as early in the process as possible by providing opportunities to learn and process information. This is to ensure that concerns and issues are identified at an early stage, so that they can be addressed and facilitate maximum cooperation in the implementation of the recommended courses of actions identified in the TMDL process. All stakeholders should have access to enough information to allay concerns, gain confidence in the TMDL process and understand the purpose and the regulatory authority that will implement any recommendations.

Illinois EPA, along with ENSR/AECOM, will hold up to two public meetings within the Upper Fox River/Chain O' Lakes watershed throughout the course of TMDL development.

General information regarding the process of TMDL development in Illinois can be found at http://www.epa.state.il.us/water/tmdl. This link also contains paths to notice of public meetings and other TMDL-related watershed information for the entire state of Illinois.

Background information about watersheds, watershed management, best management practices and the Clean Water Act (CWA) can be found on the EPA's water website at http://www.epa.gov/watertrain/.

For other reports and studies concerning the Fox River Watershed please visit the Illinois Rivers Decision Support System: Fox River Watershed Investigation website (http://ilrdss.sws.uiuc.edu/fox/). The website contains reports, data and additional links to other sources specifically related to this watershed. Lake County reports can be found at: http://www.lakecountyil.gov/Health/want/LakeReports.htm. This website contains detailed lake reports for lakes sampled by Lake County's Lake Management Unit.

4.0 Applicable Water Quality Standards and TMDL Targets

Water pollution control programs are designed to protect the beneficial uses of the water resources within the state. Each state has the responsibility to set water quality standards that protect these beneficial uses, also called “designated uses.” Illinois waters are designated for various uses including aquatic life, wildlife, agricultural use, primary contact (e.g., swimming, water skiing), secondary contact (e.g., boating, fishing), industrial use, drinking water, food-processing water supply and aesthetic quality. Illinois’ WQS provide the basis for assessing whether the beneficial uses of the state’s waters are being attained.

4.1 Illinois Pollution Control Board

The Illinois Pollution Control Board (IPCB) is responsible for setting WQS to protect designated uses. The federal CWA requires the states to review and update their WQS every three years. Illinois EPA, in conjunction with US EPA, identifies and prioritizes those standards to be developed or revised during thie three-year period. The IPCB has established four primary sets (or categories) of narrative and numeric water quality standards for surface waters: general use, public and food processing, secondary contact and indigenous aquatic life, and Lake Michigan basin standards. Each set of standards is intended to help protect various designated uses established for each category.

Illinois EPA is also responsible for developing scientifically based water quality criteria and proposing them to the IPCB for adoption into state rules and regulations. The Illinois WQS are established in the Illinois Administrative Rules Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards.

Water resource management activities involving interstate waters are also coordinated with various interstate committees and commissions. The Illinois EPA participates in water resource management activities of the Association of State and Interstate Water Pollution Control Administrators, International Joint Commission of the Great Lakes Water Quality Board, Ohio River Valley Water Sanitation Commission, Upper Mississippi River Conservation Committee, Upper Mississippi River Basin Association, Council of Great Lakes Governors, and other interstate committees, and commissions

4.2 Designated Uses

The waters of Illinois are classified by designated uses assessed in 2008 (Table 4-1). Designated uses applicable to the Upper Fox/Chain O’ Lakes watershed include: aesthetic quality, aquatic life, and primary contact recreation. The corresponding water quality standard classification for these designated uses is the General Use classification.

The General Use classification is defined by IPCB as: The General Use standards will protect the state's water for aquatic life, wildlife, agricultural use, secondary contact use and most industrial uses and ensure the aesthetic quality of the state's aquatic environment. Primary contact uses are protected for all General Use waters whose physical configuration permits such use.

Table 4-1: Upper Fox River Designated Uses and Assessment Levels

Waterbody Name	Designated Use	Assessed?	Assessment Level?
Antioch, Bluff, Davis, Dunns, Duck, Fish-Duncan, Fischer, Grays, Long, McGreal, Petite, Redhead, Spring, Summerhill, Sun, Tranquility, Turner	Aquatic Life	Yes	Fully Supporting
	Fish Consumption	No	Not Assessed
	Primary Contact	No	Not Assessed
	Secondary Contact	No	Not Assessed
	Aesthetic Quality	Yes	Not Supporting
Catherine, Channel, Fox,	Aquatic Life	Yes	Fully Supporting
	Fish Consumption	Yes	Not Supporting
	Primary Contact	No	Not Assessed
	Secondary Contact	No	Not Assessed
	Aesthetic Quality	Yes	Not Supporting
Fox River	Aquatic Life	Yes	Not Supporting
	Fish Consumption	No	Not Supporting
	Primary Contact	No	Not Supporting
	Secondary Contact	No	Not Assessed
	Aesthetic Quality	No	Not Assessed
Deep	Aquatic Life	Yes	Fully Supporting
	Fish Consumption	No	Not Assessed
	Primary Contact	Yes	Not Supporting
	Secondary Contact	No	Not Assessed
	Aesthetic Quality	Yes	Not Supporting
Grass, Pistakee	Aquatic Life	Yes	Not Supporting
	Fish Consumption	Yes	Not Supporting
	Primary Contact	No	Not Assessed
	Secondary Contact	No	Not Assessed
	Aesthetic Quality	Yes	Not Supporting
Hidden, Nippersink, North Churchill, South Churchill,	Aquatic Life	Yes	Not Supporting
	Fish Consumption	No	Not Assessed
	Primary Contact	No	Not Assessed
	Secondary Contact	No	Not Assessed
	Aesthetic Quality	Yes	Not Supporting
Marie Lake	Aquatic Life	Yes	Fully Supporting
	Fish Consumption	Yes	Not Supporting
	Primary Contact	No	Not Assessed
	Secondary Contact	No	Not Assessed
	Aesthetic Quality	Yes	Not Supporting
Round Lake, Wooster Lake	Aquatic Life	Yes	Fully Supporting
	Fish Consumption	No	Not Assessed
	Primary Contact	Yes	Fully Supporting
	Secondary Contact	Yes	Fully Supporting
	Aesthetic Quality	Yes	Not Supporting

4.3 Assessing Designated Use Attainment

Designated use attainment is based on waterbody type and applies to aquatic life, fish consumption, primary and secondary contact, and aesthetic quality. The following sections regarding use attainment in Illinois were directly selected and excerpted from Illinois EPA's 305(b) report:

Aquatic life use assessments in streams are typically based on the interpretation of biological information, physicochemical water data and physical-habitat information from the Intensive Basin Survey, Ambient Water Quality Monitoring Network or Facility-Related Stream Survey programs. The primary biological measures used are the fish Index of Biotic Integrity, the new macroinvertebrate Index of Biotic Integrity and the Macroinvertebrate Biotic Index. Physical-habitat information used in assessments includes quantitative or qualitative measures of stream-bottom composition and qualitative descriptors of channel and riparian conditions. Physicochemical water data used include measures of "conventional" parameters (e.g., dissolved oxygen, pH, temperature), priority pollutants, non-priority pollutants, and other pollutants (USEPA 2002 and www.epa.gov/waterscience/criteria/wqcriteria.html). In a minority of streams for which biological information is unavailable, *aquatic life* use assessments are based primarily on physicochemical water data. Physicochemical data (from water and sediment) and habitat information play primary roles in identifying potential causes and sources of *aquatic life* use impairment.

Assessments of *aquatic life* use are based primarily on physical and chemical water quality data collected via the Ambient Lake Monitoring Program, the Illinois Clean Lakes Program, or by non-Illinois EPA persons under an approved quality assurance project plan. The physical and chemical data used for *aquatic life* use assessments include: Secchi-disk transparency, chlorophyll *a*, total phosphorus (epilimnetic samples only), nonvolatile suspended solids (epilimnetic samples only), and percent surface area macrophyte coverage. Data are collected a minimum of five times per year (April through October) from one or more established lake sites. Data are considered usable for assessments if meeting the following minimum requirements (Figure C-2): 1) at least four out of seven months (April through October) of data are available; 2) at least two of these months occur during the peak growing season of June through August (this requirement does not apply to NVSS); and 3) usable data are available from at least half of all lake sites within any given lake each month. A whole-lake TSI value is calculated for the median Secchi-disk transparency, median total phosphorus (epilemnetic sample depths only), and median chlorophyll *a* values. A minimum of two parameter-specific TSI values are required to calculate parameter-specific use support determinations. An assessment is then made based on the parameter-specific use support determinations. The 0.05 mg/L Illinois General Use Water Quality Standard for total phosphorus in lakes (35 Ill. Adm. Code 302.205) has been incorporated into the weighting criteria used to assign point values for the ALI.

Fish consumption use is associated with all water bodies in the state. The assessment of *fish consumption* use is based on water body-specific fish-tissue data and also on fish-consumption advisories issued by the Illinois Fish Contaminant Monitoring Program (FCMP). A list of water bodies having advisories can be found in the Illinois Department of Natural Resources' (IDNR) publication ***2007 Illinois Fishing Information*** (http://dnr.state.il.us/fish/digest/). Fish-consumption advisories are incorporated into the process for assessing *fish consumption* use as explained below.

The FCMP uses the U.S. Food & Drug Administration's (FDA) Action Levels as criteria for determining the need for advisories, except for polychlorinated biphenyls (PCBs), mercury, and chlordane. For these contaminants the FDA criteria have been replaced by a risk-based process developed in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson et al. 1993, herein after referred to as the Protocol). The Protocol requires the determination of a Health Protection Value (HPV) for a contaminant, which is then used with five meal consumption frequencies (eight ounces of uncooked filet): 1) Unlimited (140 meals/year); 2) One meal/week (52 meals/year); 3) One meal/month (12 meals/year); 4) One meal/two months (six meals/year); and 5) Do not eat (0 meals/year). The level of contaminant in fish is then calculated that will not result in exceeding the HPV at each meal consumption frequency. The Protocol also assumes a 50% reduction of contaminant levels for organic chemicals (not used for mercury) when recommended cleaning and cooking methods are used. The HPVs, target populations, critical health effects to be protected by the HPVs, and the criteria for PCBs, mercury and chlordane for the various meal frequencies, are listed in Table C-13 (*of the 305(b)*) as well as the FDA action levels for other contaminants.

According to Illinois water quality standards, "primary contact" means "*...any recreational or other water use in which there is prolonged and intimate contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard, such as swimming and water skiing*" (35 Ill. Adm. Code 301.355). The assessment of *primary contact* use is based on fecal coliform bacteria data. The General Use Water Quality Standard for fecal coliform bacteria specifies that during the months of May through October, based on a minimum of five samples taken over not more than a 30-day period, fecal coliform bacteria counts shall not exceed a geometric mean of 200/100 ml, nor shall more than 10 percent of the samples during any 30-day period exceed 400/100 ml (35 Ill. Adm. Code 302.209). This standard protects *primary contact* use of Illinois waters by humans. Due to limited state resources, fecal coliform bacteria is not normally sampled at a frequency necessary to apply the General Use standard, i.e., at least five times per month during May through October, and very little data available from others are collected at the required frequency. Therefore, assessment guidelines are based on application of the standard when sufficient data is available to determine standard exceedances; but, in most cases, attainment of *primary contact* use is based on a broader methodology intended to assess the likelihood that the General Use standard is being attained.

To assess *primary contact* use, Illinois EPA uses all fecal coliform bacteria from water samples collected in May through October, over the most recent five-year period (i.e., 2002 through 2006 for this report). Based on these water samples, geometric means and individual measurements of fecal coliform bacteria are compared to the concentration thresholds in Tables C-16 and C-17 (*of the 305(b)*). To apply the guidelines, the geometric mean of fecal coliform bacteria concentration is calculated from the entire set of May through October water samples, across the five years. No more than 10% of all the samples may exceed 400/100 ml for a water body to be considered Fully Supporting.

According to Illinois water quality standards, "secondary contact" means *"...any recreational or other water use in which contact with the water is either incidental or accidental and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, commercial and recreational boating and any limited contact incident to shoreline activity"* (35 Ill. Adm. Code 301.380). Although secondary contact use is associated with all waters of the state, no specific assessment guidelines have been developed to assess secondary contact use because existing water quality standards have no water quality criterion that specifically address this use. However, consistent with the meanings of these two uses, in any water where primary contact use is assessed as Fully Supporting, secondary contact use is also assessed as Fully Supporting. In all other circumstances secondary contact use is not assessed.

Attainment of *public and food processing water supply* use is assessed only in waters in which the use is currently occurring, as evidenced by the presence of an active public-water-supply intake. The assessment of *public and food processing water supply* use is based on conditions in both untreated and treated water (Table C-21). By incorporating data through programs related to both the federal Clean Water Act and the federal Safe Drinking Water Act, Illinois EPA believes that these guidelines provide a comprehensive assessment of *public and food processing water supply* use.

Assessments of *public and food processing water supply* use recognize that characteristics and concentrations of substances in Illinois surface waters can vary and that a single assessment guideline may not protect sufficiently in all situations. Using multiple assessment guidelines helps improve the reliability of these assessments. When applying these assessment guidelines, Illinois EPA also considers the water-quality substance, the level of treatment available for that substance, and the monitoring frequency of that substance in the untreated water.

Assessments of *aesthetic quality* use are based primarily on physical and chemical water quality data collected by the Illinois EPA through the Ambient Lake Monitoring Program or the Illinois Clean Lakes Program, or by non-Illinois EPA persons under an approved quality assurance project plan. The physical and chemical data used for *aesthetic quality* use assessments include: Secchi-disk transparency, chlorophyll *a*, total phosphorus (epilimnetic samples only), nonvolatile suspended solids (epilimnetic samples only), and percent surface area macrophyte coverage. Data are collected a minimum of five times per year (April through October) from one or more established lake sites. Data are considered usable for assessments if meeting the following minimum requirements: 1) At least four out of seven months (April through October) of data are available, 2) At least two of these months occurs during the peak growing season of June through August (this requirement does not apply to NVSS) and 3) Usable data are available from at least half of all lakes sites within any given lake each month. As outlined in Figure C-3 (*of the 305(b)*), a whole-lake TSI value is calculated for the median Secchi-disk transparency, median total phosphorus (epilimnetic sample depths only), and median chlorophyll *a* values. A minimum of two parameter-specific TSI values are required to calculate a parameter-specific use support determination. An assessment is then made based on the parameter specific use support determinations. The 0.05 mg/L Illinois General Use Water Quality Standard for total phosphorus in lakes (35 Ill. Adm. Code 302.205) has been incorporated into the weighting criteria used to assign point values for the AQI. Table C-25 (*of the 305(b)*) lists the guidelines for identifying potential causes of *aesthetic quality* use impairment.

4.4 Applicable Illinois Water Quality Standards

To make 303(d) listing determinations for aquatic life uses, Illinois EPA first collects biological data and if these data suggest that impairment to aquatic life exists, then a comparison of available water quality data with WQS and criteria occurs. Table 4-2 summarizes the applicable General Use WQS for impaired water quality variables within the Upper Fox River/Chain O' Lakes Creek watershed.

Table 4-2: Applicable Water Quality Standards for the Upper Fox River/Chain O' Lakes Watershed

Parameter	Units	Regulatory Statute	General Use Water Quality Standard
Dissolved Oxygen (above thermocline in thermally stratified waters or entire water column in unstratified waters[4)]	mg/L	Title 35, Subtitle C, Chapter I, Part 302.206	March – July 5.0 instantaneous minimum 6.0 as daily mean averaged over 7 days August – February 3.5 instantaneous minimum 4.0 as daily mean averaged over 7 days 5.5 as daily mean averaged over 30 days
Fecal Coliform	cfu/100 ml	Title 35, Subtitle C, Chapter I, Part 302.209	May – October 200 geometric mean based on a minimum of 5 samples taken over any 30 day period 400 maximum not to be exceeded in more than 10% of samples taken during any 30 day period
pH	SU	Title 35, Subtitle C, Chapter I, Part 302.204	6.5 – 9.0 except for natural causes
Total Ammonia Nitrogen	mg/L	Title 35, Subtitle C, Chapter I, Part 302.212	≤ 15 at any time Not to exceed Acute Standard at any time[1] 30-day average not to exceed Chronic Standard[2] 4-day average not to exceed Sub-Chronic Standard[3]
Total Phosphorus	mg/L	Title 35, Subtitle C, Chapter I, Part 302.205	Not to exceed 0.05 in any reservoir or lake with a surface area of at least 20 acres or in any stream at the point where it enters any such lake or reservoir

[1] Acute Standard (AS): $AS = \frac{0.411}{1 + 10^{7.204-pH}} + \frac{58.4}{1 + 10^{pH-7.204}}$

[2] Chronic Standard (CS): Where T = water temperature in degrees Celsius

Early Life Stage Present (or March-October)

Water temperature ≤ 14.51 ºC

$$CS = \left\{ \frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}} \right\} (2.85)$$

Water temperature > 14.51 ºC

$$CS = \left\{ \frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}} \right\} \left(1.45 * 10^{0.028*(25-T)}\right)$$

Early Life Stage Absent

Water temperature ≤ 7 ºC

$$CS = \left\{ \frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}} \right\} \left(1.45 * 10^{0.504}\right)$$

Water temperature > 7 ºC

$$CS = \left\{ \frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}} \right\} \left(1.45 * 10^{0.028(25-T)}\right)$$

[3] Sub-Chronic Standard (SCS) = 2.5 times the Chronic Standard

[4] In order for DO to be listed as a cause, the aquatic life use must first be assessed as impaired.

Table 4-3: Guidelines for Assessing *Primary Contact* Use in Illinois Streams and Inland Lakes

Degree of Use Support	Guidelines
Fully Supporting (Good)	No exceedances of the fecal coliform bacteria standard in the last five years and the geometric mean of all fecal coliform bacteria observations ≤200/100 ml, and ≤10% of all observations exceed 400/100 ml.
Not Supporting (Fair)	One exceedance of the fecal coliform bacteria standard in the last five years (when sufficient data is available to assess the standard) or The geometric mean of all fecal coliform bacteria observations in the last five years ≤200/100 ml, and >10% of all observations in the last five years exceed 400/100 ml or The geometric mean of all fecal coliform bacteria observations in the last five years >200/100 ml, and ≤25% of all observations in the last five years exceed 400/100 ml.
Not Supporting (Poor)	More than one exceedance of the fecal coliform bacteria standard in the last five years (when sufficient data is available to assess the standard) or The geometric mean of all fecal coliform bacteria observations in the last five years >200/100 ml, and >25% of all observations in the last five years exceed 400/100 ml

Table 4-4: Guidelines for Identifying Potential Causes of Impairment of *Primary Contact* (Swimming) Use in Illinois Streams and Inland Lakes

Potential Cause	Basis for Identifying Cause - Numeric Standard[1]
Fecal Coliform	Geometric mean of at least five fecal coliform bacteria observations collected over not more than 30 days during May through October >200/100 ml or > 10% of all such fecal coliform bacteria observations exceed 400/100 ml or Geometric mean of all fecal coliform bacteria observations (minimum of five samples) collected during May through October >200/100 ml or > 10% of all fecal coliform bacteria observation exceed 400/100 ml.

1. The applicable fecal coliform standard (35 Ill. Adm. Code, 302, Subpart B, Section 302.209) requires a minimum of five samples in not more than a 30-day period. However, because this number of samples is seldom available in this time frame the criteria are also based on a minimum of five samples over the most recent five-year period.

4.5 TMDL Targets

In order for a water body to be listed as Full Support, it must meet all of its applicable designated uses. Because WQS are designed to protect those designated uses, a pollutant's numeric WQS is therefore used as the target or endpoint for establishing a TMDL. Table 4-3 summarizes the targets that will be used in the TMDL development for the Upper Fox River/Chain O' Lakes watershed.

Table 4-5: TMDL Targets for Impaired Waterbodies in the Upper Fox River/Chain O' Lakes Watershed

Segment ID	Waterbody Name	Impairment	TMDL Target	Units
IL_DT-35	Fox River	Fecal Coliform	≤ 200 single sample ≤ 200 geomean ≤ 400 <10% samples	cfu/100 ml
IL_RGK	Grays Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RGZT	Spring Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTC	Sun Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTD	Catherine Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTF	Fox Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTH	Round Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTI	Channel Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTJ	Long Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTQ	Grass Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTR	Marie Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTT	Antioch Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTU	Pistakee Lake	Total Ammonia Total Phosphorus	≤ 15 or AS[2] ≤ 0.05	mg/L mg/L
IL_RTUA	Nippersink Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTV	Redhead Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTZG	Duck Lake	Total Phosphorus	≤ 0.05	mg/L
IL_RTZH	Wooster Lake	Total Phosphorus	≤ 0.05	mg/L
IL_STQ	Davis Lake	Total Phosphorus	≤ 0.05	mg/L
IL_STR	North Churchill Lake	Total Phosphorus	≤ 0.05	mg/L
IL_STS	South Churchill Lake	Total Phosphorus	≤ 0.05	mg/L
IL_UTM	Hidden Lake	Dissolved Oxygen pH	* 6.5 – 9.0	mg/L SU
IL_UTW	Lake Tranquility	Total Phosphorus	≤ 0.05	mg/L
IL_UTX	McGreal Lake	Total Phosphorus	≤ 0.05	mg/L
IL_VTD	Deep Lake	Fecal Coliform	≤ 200 single sample ≤ 200 geomean ≤ 400 <10% samples	cfu/100 ml
IL_VTH	Dunns Lake	Total Phosphorus	≤ 0.05	mg/L
IL_VTJ	Bluff Lake	Total Phosphorus	≤ 0.05	mg/L
IL_VTK	Fish-Duncan Lake	Total Phosphorus	≤ 0.05	mg/L
IL_VTT	Fischer Lake	Total Phosphorus	≤ 0.05	mg/L
IL_VTW	Petite Lake	Total Phosphorus	≤ 0.05	mg/L
IL_VTZA	Turner Lake	Total Phosphorus	≤ 0.05	mg/L
IL_WTA	Summerhill Lake	Total Phosphorus	≤ 0.05	mg/L

[1] Apply general standard of 15 mg/L or Acute Standard calculated using average summer epilimnion pH (Table 4-1), which ever is lower

*Refer to Table 4-2 for the dissolved oxygen standard.

5.0 Water Quality Analysis

This section discusses the pollutants of concern for the Upper Fox River/Chain O' Lakes watershed. The available water quality data were analyzed, assessed, and compared with WQS to verify the impairments of the 31 segments. The water quality conditions in the watershed were evaluated by sampling location and time. Available potential point and non-point source data were also assessed and discussed in more detail throughout the remainder of the section.

Section 5.1 provides a summary of water quality data for each pollutant. Detailed information for each impaired segment and potential causes and sources of impairment are provided in Section 6.0 of this document.

5.1 Monitoring Programs

Illinois EPA maintains a comprehensive monitoring program designed to accommodate varying waterbody types and designated uses. Their ambient water quality monitoring program consists of 214 stream stations that are samples once every six weeks and are analyzed for at least 55 parameters. For pesticide analyses Illinois EPA founded a pesticide monitoring subnetwork that allows for further screening of toxic organic substances. A facility-related stream survey program was also developed that specifically caters to field studies (macroinvertebrate, water chemistry, stream flow, habitat data) to analyze impacts from municipal and industrial dischargers.

For inland lakes, Illinois EPA also conducts an ambient lake monitoring program that is responsible for the sampling of approximately 50 inland lakes. Another lake program is the Clean Lakes Program which is a two-part program consisting of Phase 1 diagnostic-feasibility studies and Phase 2 implementation projects. Lake sampling conducted through the Clean Lakes Program include water sampling twice per month from April through October and monthly from November through March for a one-year period.

Illinois EPA also operates in conjunction with other agencies to monitor its surface waters. Intensive basin surveys are conducted by both Illinois EPA and the Illinois Department of Natural Reosurces. The data from these surveys provide much of the data used for aquatic life assessments. The Fish Contaminant Monitoring Program (FCMP) focuses on determining the levels of contaminants in sport fish and also is responsible for issuing fish consumption advisories. The FCMP operates under a Memorandum of Agreement (MOA) that details the responsibilities of those cooperating agencies (Departments of Agriculture, Natural Resources, Nuclear Safety, Public Health, and EPA).

Illinois EPA also administered the Volunteer Lake Monitoring Program (VLMP) in 1981. This program consists of citizen volunteers that are trained on lake ecosystems as well as cost-effective methods of collecting data. VLMP monitoring is conducted twice per month from May through October and typically consists of three monitoring stations per site.

Ambient data are also collected through the Lakes Management Unit (LMU) of Lake County. This program has been monitoring Lake County lakes since the late 1960's. Since 2000, 32 different lakes have been studied per year and data have been collected for various parameters. Detailed reports are written for each lake study and can be found at: http://www.lakecountyil.gov/Health/want/LakeReports.htm.

5.2 Water Quality Data

The Upper Fox River/Chain O' Lakes watershed has 31 impaired segments targeted for TMDL development, 30 of which are lakes and one is a river segment. Available data used for assessing these waterbodies originated from over 80 water quality stations within the Upper Fox River/Chain O' Lakes watershed. Figure 5-

1 shows the water quality data stations within the watershed that contain data relevant to the impaired segments (individual watershed maps are provided in Appendix A).

Data used for analysis are a combination of both legacy and modernized US EPA Storage and Retrieval (STORET) databases, Lake County data, Fox River Study Group (FRSG) data, and Illinois EPA database data. The compiled database ranges from 1972 through 2008. The completed water quality database is included in Appendix B.

Data relevant to impairments were compiled for each impaired waterbody and summarized. The following parameters are grouped by impairment and discussed in relation to the relevant Illinois numeric WQS. For all assessments, compliance is determined at the surface of a stream or at the one-foot depth from the lake surface.

5.2.1 Dissolved Oxygen

Hidden Lake is the only segment targeted for TMDL development due to low DO concentrations. DO was measured five times in Hidden Lake during 2002 at up to five depths. DO concentrations were below the instantaneous minimum numerical WQS of 5.0 mg/L in June and July 2002. DO remained below 5.0 mg/L in August, but did not drop below the 3.5 mg/L WQS in August 2002 (Figure 5-2). Temperature and DO concentrations did not vary greatly with water depth and indicate no thermal or DO stratification. Percent DO saturation, defined as the percent DO present compared with the amount that could be available at a given temperature, was below 63% during the period of WQS non-compliance.

Low dissolved oxygen is likely related to eutrophication which is caused by point and non-point sources. Eutrophication is an environmental phenomenon that occurs when waterbody hypoxia or anoxia is induced from excessive nutrient inputs. In some waterbodies, particularly lakes, estuaries, or even low-flow streams, nutrients can stimulate algal blooms, which can lead to oxygen consumption when the dead plant material decomposes. The decomposing plant material is a source of Biochemical Oxygen Demand (BOD). As the decay sinks to the bottom of the waterbody, the sum of all biological and chemical processes can likewise further consume oxygen, and this process is known as Sediment Oxygen Demand (SOD).

Non-point sources of nutrients include urban and agricultural runoff. Point sources of nutrients are generally wastewater treatment facilities. All active NPDES point sources discharging within each impaired segment's watershed are described in Section 6.0. A general description of non-point sources is also provided in Section 6.0.

5.2.2 pH

Hidden Lake is targeted for a TMDL due to elevated pH. The WQS for pH is between 6.5 and 9.0 standard units (SU). pH measured in Hidden Lake in 2002, throughout the water column (down to 4' water depth), ranged from 7.7 to 9.1 SU. Values exceeding 9.0 SU were measured on September 4, 2002. These elevated pH values and low DO are likely the result of eutrophication and excessive algal densities. There are no chlorophyll *a* data to confirm this, but phosphorus concentrations are excessive in Hidden Lake (>0.18 mg/L). This waterbody is not targeted for a phosphorus TMDL, however, since the numerical WQS for phosphorus (≤ 0.05 mg/L) only applies to waterbodies with surface acreage greater than or equal to 20 acres. If it is later determined that phosphorus is responsible for the pH impairments then a phosphorus TMDL endpoint will be established.

Figure 5-1: Upper Fox River/Chain O' Lakes Water Quality Sample Locations

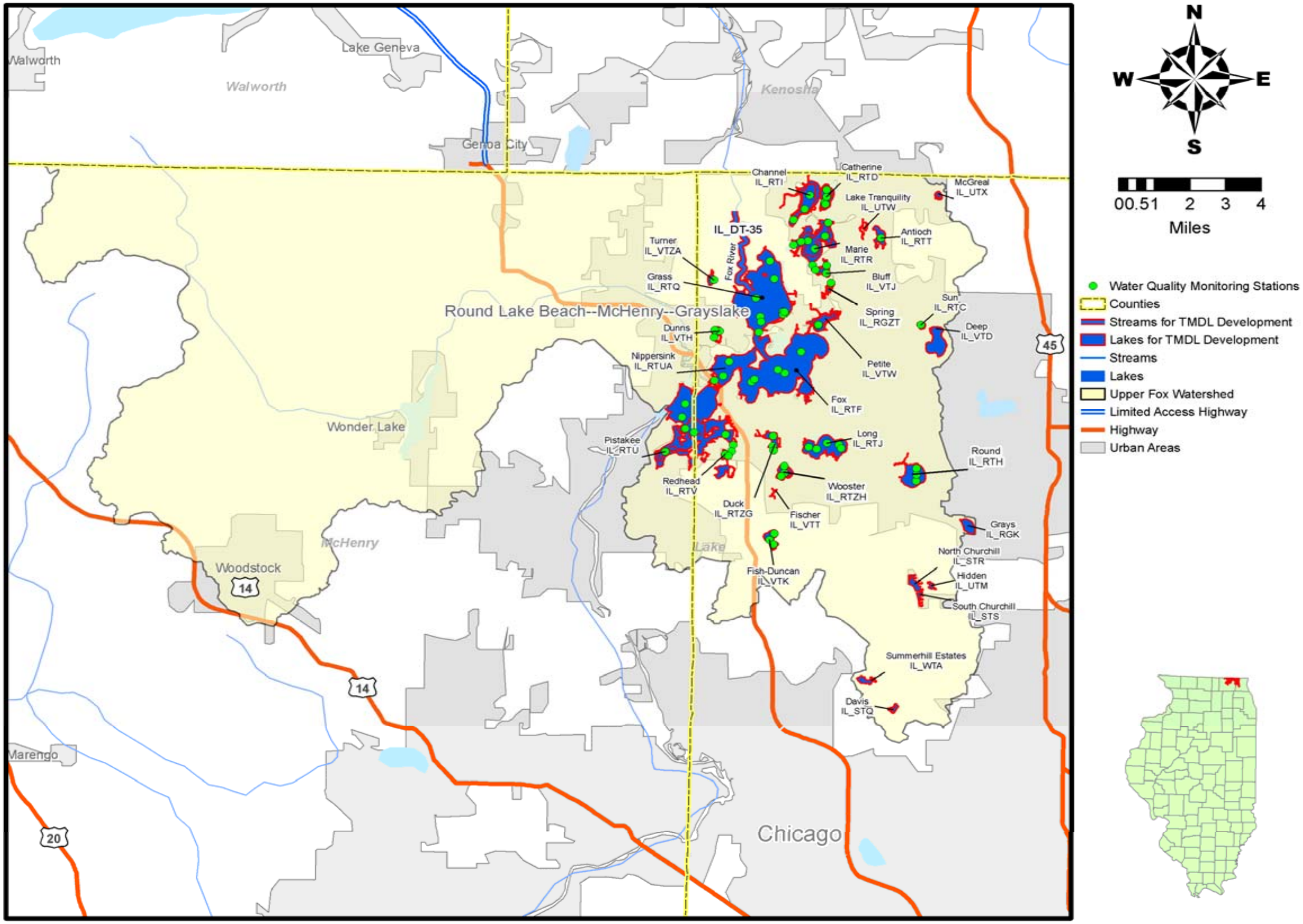
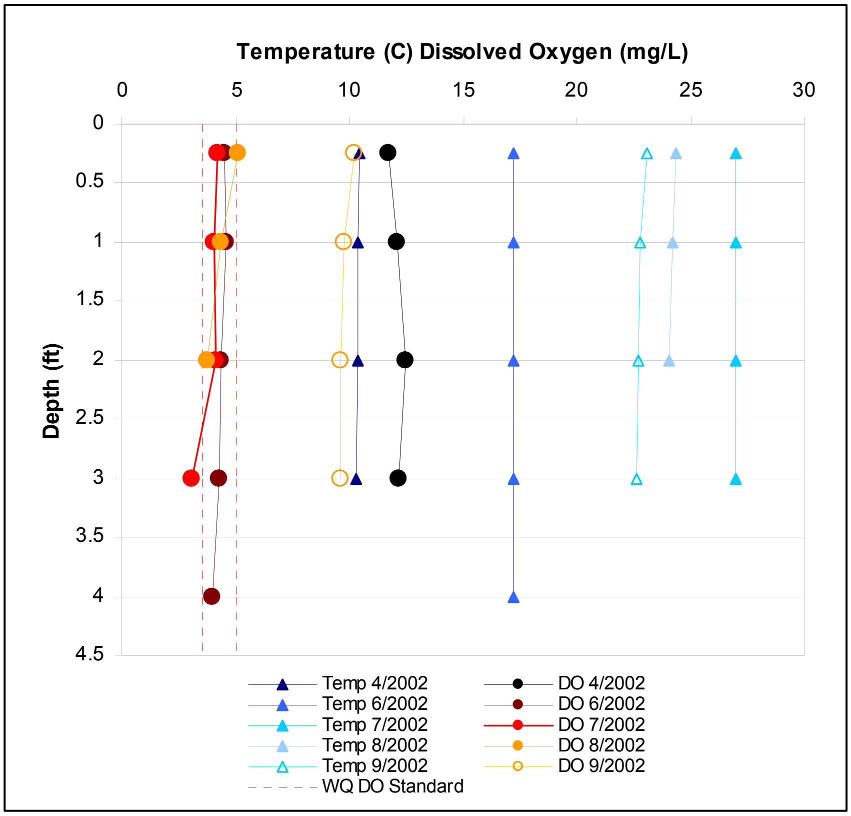


Figure 5-2: Hidden Lake Temperature and Dissolved Oxygen Profiles.



It is recommended that further sampling be conducted in Hidden Lake as part of Stage 2 to determine the cause of elevated pH and low DO. If these impairments are found to be related to TP concentrations than a TP TMDL should be prepared. Potential sources for elevated nutrients and therefore elevated pH, are the same as for low DO discussed above. All active NPDES point sources discharging within each impaired segment's watershed are described in Section 6.0. A general description of non-point sources is also provided in Section 6.0.

5.2.3 Fecal Coliform

The Fox River segment DT-35 and Deep Lake are targeted for TMDL development due to excessive fecal coliform numbers. The distribution of fecal coliform for each impaired segment in the Upper Fox River/Chain O' Lakes watershed is presented in Figure 5-3 and is compared to the WQS. The WQS for fecal coliform is a 200 cfu/100ml geometric mean based on a minimum of five samples collected over any 30 day period or a 400 cfu/100ml maximum not to be exceeded in more than 10% of samples collected during any 30 day period.

Data for Deep Lake includes samples from eight days in 2001. Sampling occurred twice on each day with the exception of the October sample when only one sample was collected. A total of 15 samples were analyzed for fecal coliform bacteria. Two samples, both collected on 7/10/2001, contained excessive bacteria concentrations well above the 200 cfu/ml WQS (2800 and 3700 cfu/ml).

Thirty one samples from the Fox River portion located in the Upper Fox River/Chain O' Lakes watershed were analyzed for fecal coliform from May 1999 through July 2008 (Figure 5-3). Twenty nine percent (9 samples) exceeded the 200 cfu/100 ml WQS.

Figure 5-3: Fox River and Deep Lake Fecal Coliform

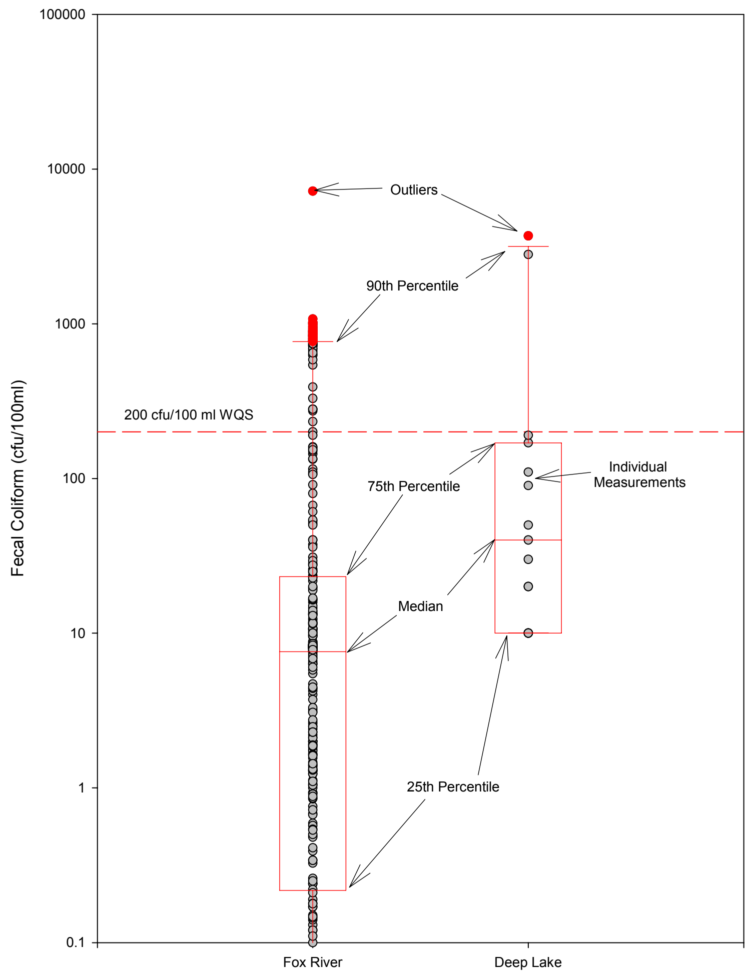
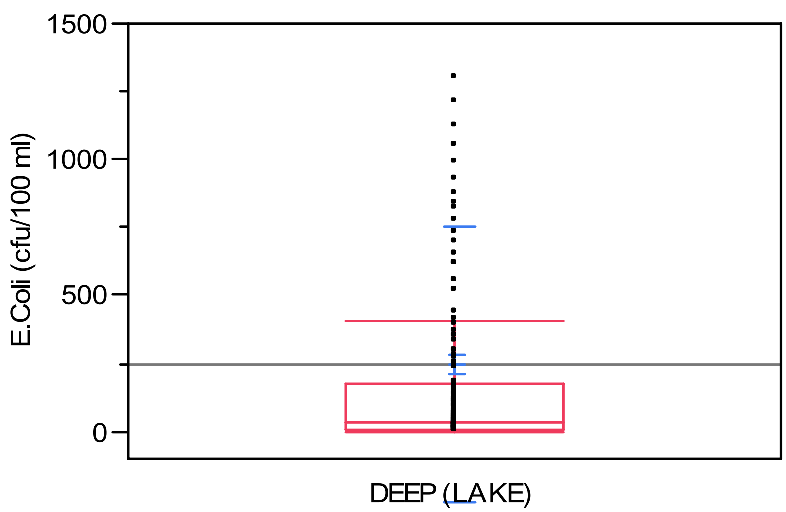


Figure 5-4: Deep Lake *E.Coli*



E. coli, another pathogen indicator species, was also sampled within Deep Lake. 246 *E. coli* samples were collected in Deep Lake at multiple locations and multiple times per day from May 2002 to August 2007. Although Illinois does not have a numerical standard for *E. coli*, the US EPA document "Ambient Water Quality Criteria for Bacteria – 1986" states a freshwater bathing criteria of a geometric mean from five samples within a 30 day period not exceed 126 cfu/100ml (US EPA 1986). Although geometric means were not calculated for each 30 day period for this analysis, 71 individual samples exceeded 126 cfu/100ml equating to 29% of the samples collected in Deep Lake.

Sources of bacteria in the Upper Fox River/Chain O' Lakes watershed are potentially storm water related. These potential sources may include failing systems, combined sewer overflows (CSO), sanitary sewer overflows (SSO), sewer pipes connected to storm drains, recreational activities, wildlife including birds along with domestic pets and animals and direct overland storm water runoff. Note that bacteria from wildlife is generally considered a natural condition unless some form of human inducement, such as feeding, is causing congregation of wild birds or animals. But this source is often difficult to separate from others. Further, some WWTPs within the Upper Fox River/Chain O' Lakes maintain disinfection exemptions and these facilities also serve as potential sources of bacteria. Such exemptions allow WWTPs to discharge without disinfection if they are able to prove that bacterial water quality standards can be met further downstream. Stage 3 of TMDL development will identify those WWTPs that have been assigned disinfection exemptions.

All active NPDES point sources discharging within each impaired segment's watershed are described in Section 6.0. A general description of non-point sources is also provided in Section 6.0.

5.2.4 Total Ammonia Nitrogen

Pistakee Lake was targeted for an ammonia nitrogen TMDL due to available data for ammonia (1987). More recent data (2008) have shown that both acute and chronic standard violations no longer exist, and as such, Illinois EPA expects to de-list Pistakee Lake for its ammonia impairment. Surface water (1.0 ft water depth) ammonia nitrogen concentrations ranged from 0.03 to 1.46 mg/L, with an average of 0.32 mg/L.

Table 5-1: Pistakee Lake 2008 Surface Ammonia-N Concentrations and Water Quality Standards

Date	Station	NH3 (mg/l)	temp ©	pH	Acute Standard	exceedance	Usability
7/7/2008	RTU-1	ND	24.5	8.38	4.03602655	no	usable
7/7/2008	RTU-3	ND	24.5	8.36	4.195718573	no	usable
8/6/2008	RTU-1	ND	27	8.36	4.195718573	no	usable
8/6/2008	RTU-3	0.0600	27	8.48	3.327964404	no	usable
9/3/2008	RTU-1	0.0700	25.1	8.24	5.298706304	no	usable
9/3/2008	RTU-3	0.0300	25.1	8.16	6.18881402	no	usable
10/22/2008	RTU-1	0.1750	13.1	7.61	16.76052785	no	usable
10/22/2008	RTU-3	0.0841	10.6	7.85	11.09847562	no	usable

Date	Station	NH3 (mg/l)	temp ©	pH	Chronic Standard	exceedance	Usability
7/7/2008	RTU-1	ND	24.5	8.38	1.162000184	no	usable
7/7/2008	RTU-3	ND	24.5	8.36	1.201587432	no	usable
8/6/2008	RTU-1	ND	27	8.36	1.127182088	no	usable
8/6/2008	RTU-3	0.0600	27	8.48	0.920813759	no	usable
9/3/2008	RTU-1	0.0700	25.1	8.24	1.441499912	no	usable
9/3/2008	RTU-3	0.0300	25.1	8.16	1.638201139	no	usable
10/22/2008	RTU-1	0.1750	13.1	7.61	3.936232762	no	usable
10/22/2008	RTU-3	0.0841	10.6	7.85	2.987931888	no	usable

Elevated ammonia concentrations are likely related to eutrophication which may be caused by point and non-point sources. Point sources of total ammonia nitrogen are generally waste water treatment facilities. All active NPDES point sources discharging within each impaired segment's watershed are described in Section 6.0. A general description of non-point sources is also provided in Section 6.0.

5.2.5 Total Phosphorus

Compliance with the TP WQS for this report is based on samples collected at three feet or less from the water surface. A three foot depth maximum was used due lack of data at the one foot depth for many of the impaired lake segments. The WQS for total phosphorus is a maximum concentration of 0.05 mg/L and is applicable only to lakes with a surface area of 20 acres or greater. Twenty eight lake segments in the Upper Fox River/Chain O' Lakes watershed are targeted for TP TMDL development.

A database was created for this TMDL analysis and includes 1,786 phosphorus samples collected between September 1972 and August 2007 from the 28 impaired segments. Many of the lakes contained data from multiple depths and multiple stations on any given day. To summarize in-lake TP concentrations for the 28 segments, surface water samples (samples collected at water depths less than or equal to three feet) were averaged by date across the lake; 996 individual samples collected at ≤ 3ft (Table 5-2) were averaged to yield 636 data points. A majority of the 996 samples were collected prior to 2005. A summary of the averaged data (636 points) are presented in Table 5-3 and graphically represented as box and whiskers plots in Figure 5-5. Overall 63% of the average TP concentrations were equal to or exceeded the 0.05 mg/L WQS. Individual box plots and time-series figures for each waterbody are included in Appendix E.

Elevated phosphorus concentrations are potentially the result of point and non-point sources. Non-point sources of nutrients within the Upper Fox River/Chain O' Lakes watershed may include urban and agricultural runoff. Point sources of nutrients are generally from waste water treatment facilities. All active NPDES point sources discharging within each impaired segment's watershed are described in Section 6.0. A general description of non-point sources is also provided in Section 6.0.

Table 5-2: Upper Fox River/Chain O' Lakes Surface Total Phosphorus Samples by Year

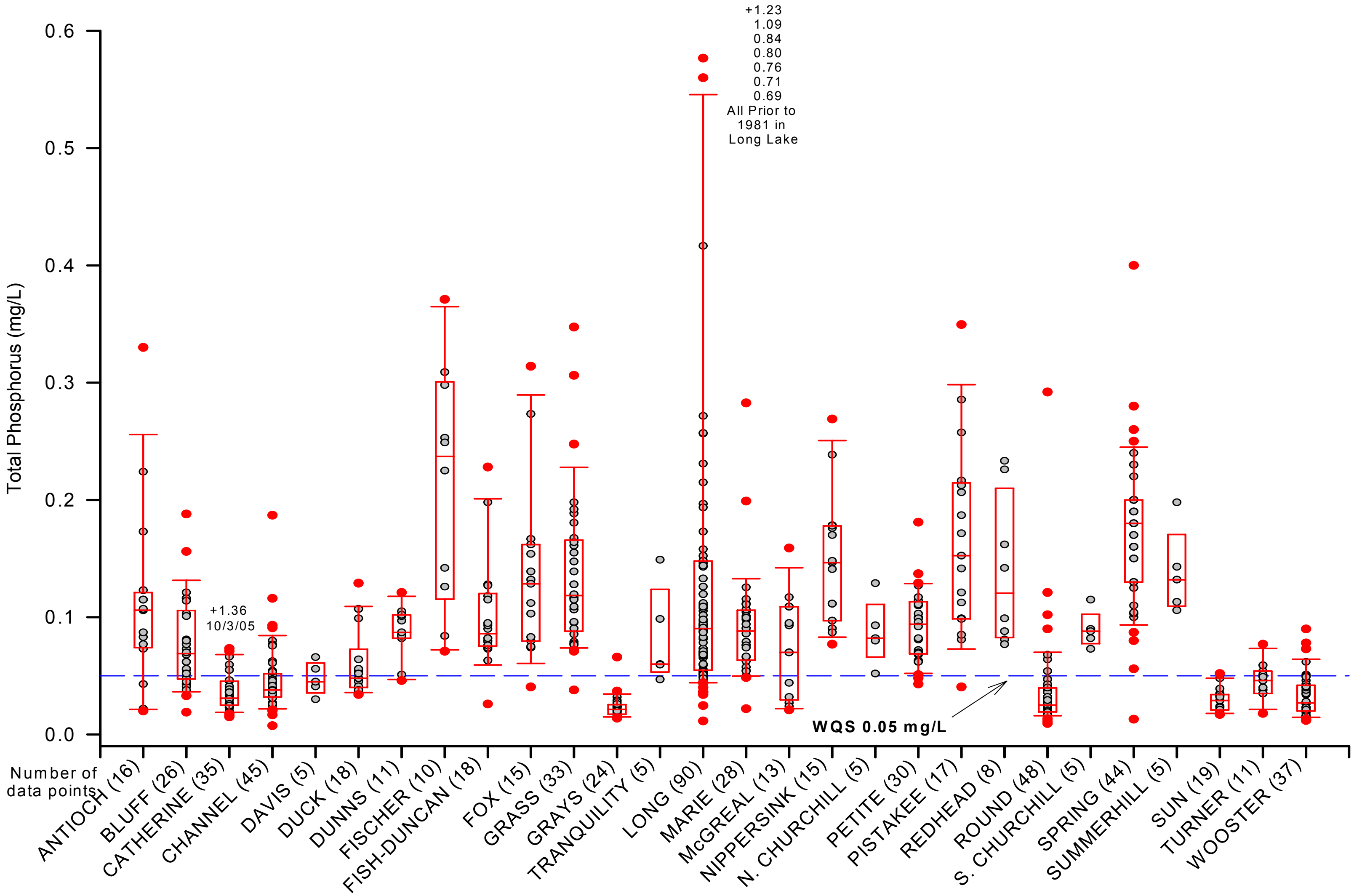
	Total Number of Samples	Number of Stations	Available Data
Antioch	16	1	1988-89,1992-93,2001
Bluff	26	1	1987-88, 1993, 1996, 1998-99, 2002, 2005
Catherine	73	8	1981, 1984, 1987, 1990, 1993, 1996, 1998-00, 2002, 2005
Channel	97	3	1979, 1981, 1984, 1987, 1990, 1993, 1996, 1998-99, 2002-03, 2005
Davis	5	1	2000
Duck	18	1	1988-89, 1995, 1997, 2001, 2006
Dunns	11	1	1989, 1997, 2002
Fischer	10	1	2001, 2006
Fish-Duncan	18	1	1988-89, 1997, 2002, 2006
Fox	32	5	1973, 1979, 1983, 1999, 2002, 2004-05
Grass	69	5	1973, 1983, 1987, 1990, 1993, 1996, 1999, 2002, 2005
Grays	30	3	1988, 1991, 1996, 1998, 2002
Tranquility	10	2	2002
Long	195	5	1973, 1977, 1979-86, 1988, 1991, 1996, 1999, 2000-03, 2005-07
Marie	57	5	1973, 1987, 1993, 1996, 1999, 2002, 2005
McGreal	13	1	1992-93, 2002
Nippersink	27	2	1996, 1999, 2002, 2005
N Churchill	5	1	2003
Petite	30	2	1987, 1989, 1990, 1993, 1996, 1998-99, 2002, 2005
Pistakee	35	5	1973, 1983, 1987, 1999, 2002, 2005
Redhead	12	3	1981, 1988, 2002
Round	84	3	1977, 1979-80, 1989, 1991, 1995-96, 1999, 2002-03, 2005
S Churchill	5	1	2003
Spring	44	1	1972-76, 1999, 2002
Summerhill	5	1	2004
Sun	19	1	1991-93, 2001
Turner	11	2	1989, 1997, 1999, 2002, 2006
Wooster	39	3	1983, 1989, 1992, 1995, 1999, 2003, 2005-07

Table 5-3: Upper Fox River/Chain O' Lakes Surface Total Phosphorus Concentration Summary (1998 – 2008)

	Number of Data Points after Averaging by Date	Minimum Conc. (mg/L)	Maximum Conc. (mg/L)	Average Conc. (mg/L)	Median Conc. (mg/L)	# ≥ WQS (0.05 mg/L)	% Exceed WQS (0.05 mg/L)
Antioch	5	0.08	0.33	0.14	0.12	5	100
Bluff	13	0.03	0.19	0.07	0.07	10	77
Catherine	22	0.02	1.36	0.09	0.03	2	9
Channel	28	0.02	0.19	0.04	0.04	5	18
Davis	5	0.03	0.07	0.05	0.05	2	40
Duck	10	0.03	0.13	0.07	0.05	6	60
Dunns	5	0.08	0.12	0.10	0.09	5	100
Fischer	10	0.07	0.37	0.21	0.24	10	100
Fish-Duncan	10	0.07	0.13	0.10	0.09	10	100
Fox	15	0.03	0.16	0.08	0.08	10	67
Grass	15	0.04	0.25	0.11	0.09	12	80
Grays	8	0.02	0.07	0.03	0.02	1	13
Tranquility	5	0.05	0.15	0.08	0.06	4	80
Long	35	0.02	0.15	0.08	0.06	25	71
Marie	13	0.03	0.12	0.07	0.07	10	77
Mcgreal	5	0.02	0.16	0.09	0.10	4	80
Nippersink	10	0.08	0.27	0.16	0.16	10	100
N Churchill	5	0.05	0.13	0.09	0.08	5	100
Petite	14	0.02	0.13	0.07	0.08	10	71
Pistakee	16	0.02	0.35	0.13	0.11	10	63
Redhead	5	0.08	0.23	0.14	0.14	5	100
Round	24	0.002	0.1	0.03	0.02	2	8
S Churchill	5	0.07	0.12	0.09	0.09	5	100
Spring	5	0.01	0.1	0.07	0.09	4	80
Summerhill	5	0.11	0.20	0.14	0.13	5	100
Sun	5	0.03	0.05	0.04	0.04	1	20
Turner	10	0.02	0.06	0.03	0.03	1	10
Wooster	28	0.01	0.09	0.04	0.03	4	14

Surface data include samples collected at or less than 3' from the surface. Data were averaged across the lake (i.e., includes multiple stations when available) by date including all depths at or below 3' from the surface.

Figure 5-5: Average Surface Phosphorus Concentrations by Date for Impaired Lakes (1972-2007)



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6.0 Impaired Segments and Potential Sources

This section provides a brief description of each impaired segment within the Upper Fox River/Chain O' Lakes watershed. Much of the information provided in this section was obtained from the Lake County Health Department (LCHD) Environmental Health Services Lakes Management Unit (LMU) and from the Fox Chain O' Lakes Investigation and Water Quality Management Plan (Kothandaraman et al., 1977). The LCHD has been collecting water quality data from lakes since the 1960's. Detailed lake reports have been developed for a number of lakes in the County. For those lakes not covered by LCHD reports, the 1977 study and information provided in the Illinois Integrated Water Quality Report and Section 303(D) List – 2008, were used to characterize the listed segments. Since most of these segments are hydraulically connected, they are discussed in an upstream to downstream order. The LCHD's detailed lake report can be found in the following website: http://www.lakecountyil.gov/Health/want/LakeReports.htm.

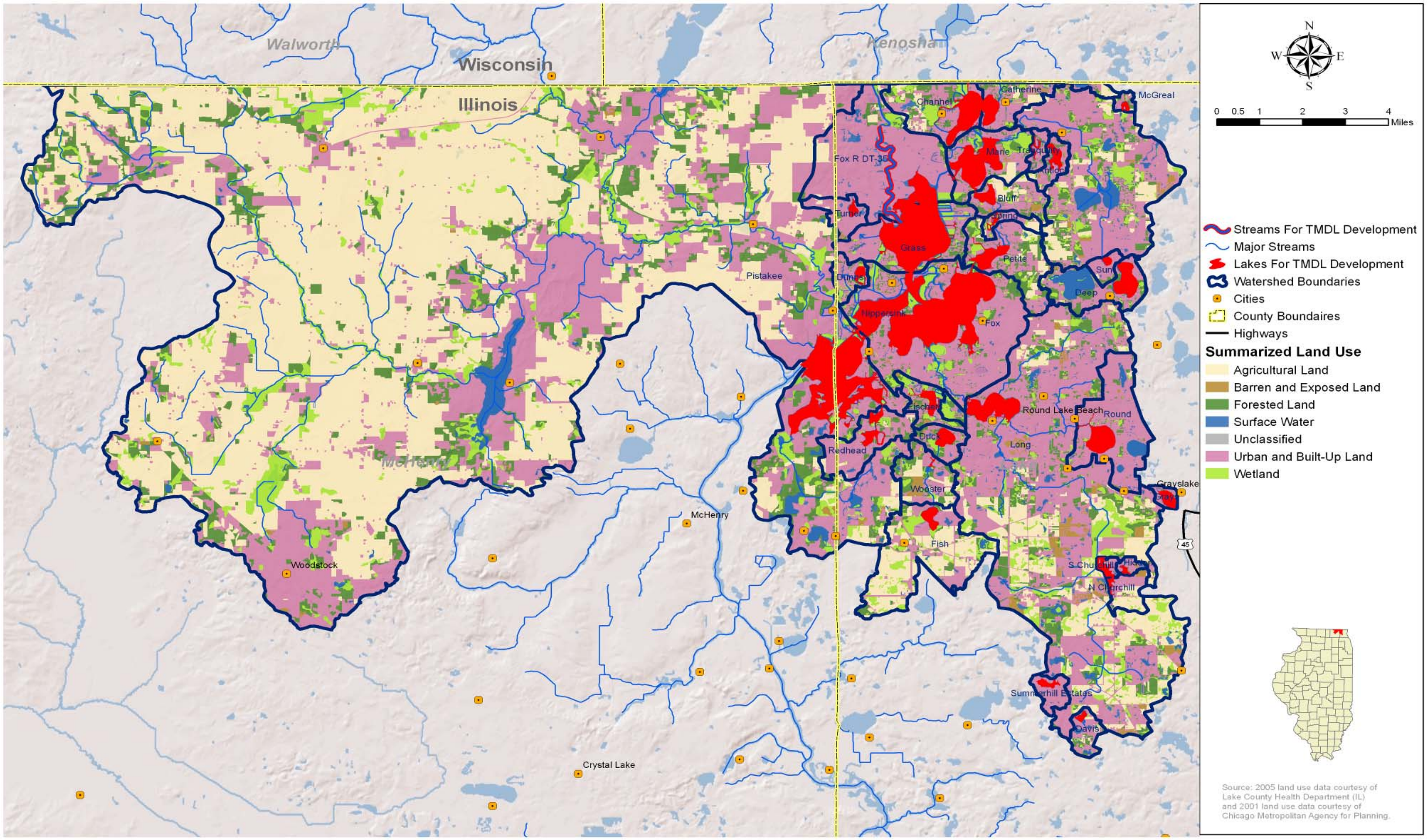
Segment subwatersheds were delineated using ArcMap software based on LCHD, Lake County Stormwater Management Commission (SMC) information and topographic maps (two foot surveys). Land use within each segment subwatershed is based on data provided by Lake County from 2005 land use where available. In areas where 2005 data were not available, 2001 data provided by the Chicago Metropolitan Agency for Plan were used. A majority of the segment watersheds were covered under the Lake County 2005 data. Small portions of watersheds for the following segments utilized 2001 data: Grass, Nippersink, Fox Lake, Turner, Dunns, Redhead and Louise. Figure 6-1 provides a land use map with each impaired segment's watershed boundary. The watershed areas described below do not include the area of the lake itself. Individual maps for each waterbody as well as a summary of land use data for all watersheds can be found in Appendix A and C respectively.

Lakes with high watershed-to-lake area ratios have a large portion of the hydrologic budget stemming from surface water flow. Water quality in these lakes is highly dependant on in-flow water quality. In-lake water quality typically declines with increasing watershed-to-lake ratios. Lakes with watershed-to-lake ratios <10:1 are less likely to have eutrophication problems. These ratios have been calculated for all the lake segments and are discussed below.

In addition, the water quality condition of a water body is related to the level of development or urbanization in its watershed. The more developed an area is, the higher the percentage of impervious surface. The Center of Watershed Protection published a document entitled "*Impacts of Impervious Cover on Aquatic Systems*" (2003) which summarizes two dozen studies documenting a strong relationship between impervious cover and stream water quality. They concluded that stream quality declines with increased impervious cover such that drainage areas containing >10% impervious cover were impacted and areas with >25% were impaired (CWP 2003).

Impervious cover (IC) was estimated for each watershed by using the land use data for each segment and multiplying this area by the estimated impervious percentage based on the land use category. The estimated IC percentage was derived from the Center of Watershed Protection's study of the Chesapeake Bay Watershed (CWP 2001). Similar to the Chesapeake Bay Study, the average of the low and high IC percentage for all residential land use was used to characterize imperviousness for the Fox River/Upper Chain O' Lakes due to insufficient residential use data (i.e., low and high).

Figure 6-1: Impaired Segment Watershed Land Use



6.1 Non-Point Sources and Subwatershed Characteristics

When discussing surface water total phosphorus concentrations in the paragraphs below, the average of surface concentration from all stations and at water depths ≤ 3 feet on a given sampling date were calculated before determining statistics unless otherwise noted. For example, the minimum value is the minimum average of all in-lake stations sampled on a given day at depths ≤ 3 feet. These data are presented in Section 5 in Table 5-3 and illustrated on Figure 5-5.

6.1.1 Fox River

The Fox River segment located in the northwest portion of the Upper Fox River/Chain O' Lakes watershed extends from the Wisconsin border to the Chain O' Lakes on the western portion of Grass Lake. This segment is 4.9 miles and is impaired for fecal coliform.

The Illinois portion of the watershed is approximately 3,911 acres. The majority of this area is classified as open space (60%). Industrial, warehousing, and wholesale trade make up the next largest area (10%). All other areas are less than 10% of the Illinois portion of this watershed. Impervious cover for the area accounts for approximately 12% of the total area.

Thirty one samples from the Fox River portion located in the Upper Fox River/Chain O' Lakes watershed were analyzed for fecal coliform from May 1999 through July 2008 (Figure 5-3). Twenty-nine percent (9 samples) exceeded the 200 cfu/100 ml WQS.

Sources of fecal coliform in this portion of the Fox River stemming from Wisconsin are unknown. Sources of bacteria in the Fox River in the Illinois portion of the watershed are potentially storm water related. Sources may include combined sewer overflows (CSO), sanitary sewer overflows (SSO), illicit connections (sewer pipes connected to storm drains), failing systems, recreational activities, wildlife including birds along with domestic pets and animals and direct overland storm water runoff. Note that bacteria from wildlife is generally considered a natural condition unless some form of human inducement, such as feeding, is causing congregation of wild birds or animals. But this source is often difficult to separate from others. There are no active NPDES dischargers in the Illinois portion of the Fox River segment DT-35. Dischargers upstream of this segment in Wisconsin have the potential to impact water quality within this segment. Additional investigations into the Wisconsin's impacts on the Fox River water quality will be conducted in Stage 3 of the TMDL.

6.1.2 Davis Lake

Davis Lake is located in the southern portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is a shallow impoundment with 33.1 surface acres created by flooding an existing wetland in 1940. Maximum and mean water depths are 18.0 and 9.0 feet respectively (LCHD 2001).

The watershed of Davis Lake is 441 acres. The watershed-to-lake area ratio is 13:1, slightly higher than the 10:1 threshold when one would expect to have water quality problems. The Davis Lake watershed is primarily open space (31%) and residential (22%) and contains approximately 12% impervious surface.

Although shallow, this impoundment does experience strong thermal stratification during the summer months. The LMU 2000 Summary Report of Davis Lake (LCHD 2001) notes that Davis Lake undergoes anoxia (DO < 1.0 mg/L) in water depths below 3.6 feet in July. Surface water DO concentrations are also lower than desirable with concentrations below 5.0 mg/L in July, August and September. Fish kills are not uncommon in Davis Lake due to oxygen depletion, but this condition is consistent with similar bog type lakes like Davis Lake.

Davis Lake is listed as impaired due to excessive phosphorus concentrations. Water quality data for Davis Lake is limited to the 2000 study conducted by the LMU. Concentrations of surface TP ranged from 0.03 to 0.07 mg/L, with an average of 0.05 mg/L (Table 5-3, Figure 5-5, Appendix E). The July and August samples contained concentrations above WQS (0.07 and 0.06 mg/L respectively). Hypolimnetic concentrations were much higher and ranged from 0.30 to 0.84 mg/L, with an average of 0.57 mg/L.

The lake does not experience algal blooms but contains extensive stands of submerged rooted aquatic plants, dominated by coontail (*Ceratophyllum demersum*). Coontail was observed at 91% of sampled sites in 2000 (LCHD 2001). Eutrophic lakes are typically algal or rooted plant dominated; rarely does co-dominance exist. It is believed that rooted plants are outcompeting algae for resources and therefore planktonic blooms are limited in Davis Lake and water clarity remains desirable; Secchi disk transparency (SDT) was 8.1 feet on average.

Potential sources of phosphorus entering Davis Lake, according to the LMU, includes Owens Lake and internal loading. Much of the watershed is undeveloped and therefore non-point sources are limited. Although not specifically discussed as internal loading in the 2000 Summary Report, the recycling of phosphorus from sediments is likely significant. The extensive stands of rooted plants decay and accumulate phosphorus in bottom sediments which can be released under anoxic conditions or resuspended due to turbulence. There are no active NPDES discharges in the Davis Lake watershed.

6.1.3 Summerhill Estates Lake

Summerhill Estates Lake is located in the southern portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is a small shallow glacial lake with 49.9 surface acres. Maximum and mean water depths are 6.3 and 3.2 feet respectively (LCHD 2005).

The watershed encompasses 395 acres resulting in a watershed-to-lake ratio of 8:1. The flushing rate of Summerhill Estates is 1.5 years (LCHD 2005). The southern portion of the watershed is used as residential (11%) while the remaining portion is primarily open space (69%). Summerhill Estates' watershed is 11% impervious. Use of this waterbody is limited to the lakeside residents (approximately 10 homes).

The LMU 2004 Summary Report of Summerhill Estates Lake (LCHD 2005) notes that Summerhill Estates Lake undergoes a sharp decline in surface water DO concentrations in June with low concentrations continuing through July with rebounding concentrations in August and September. The drop in DO is assumed to be the result of decomposition of an invasive species (curly leaf pondweed, *Potamogeton crispus*). This plant reaches excessive densities in the early summer and dies off mid-summer.

Summerhill Estates Lake is listed as impaired due to excessive phosphorus concentrations. Water quality data for Summerhill Estates Lake is limited to the 2004 study conducted by the LMU. Concentrations of surface TP ranged from 0.11 to 0.20 mg/L, with an average of 0.14 mg/L (Table 5-3, Figure 5-5, Appendix E). All five samples collected contained concentrations above WQS.

The lake experiences late summer algal blooms and contains extensive stands of submerged rooted aquatic plants, dominated by curly leaf pondweed (LCHD 2005). Eutrophic lakes are typically algal or rooted plant dominated; rarely does co-dominance exist due to competition for resources. Summerhill Estates Lake does experience both, however, not concurrently. Curly leaf pondweed is an early summer plant, dying off mid-summer. The desiccation of this plant reduces resource competition and releases phosphorus. These factors provide an ideal environment for planktonic blooms. Blue green algal blooms have been documented in Summerhill Estates Lake, but were not present during the 2004 study. It is suspected that blooms in Summerhill Estates Lake would be much worse if the rooted plants did not curtail bloom formation in early summer.

Potential sources of phosphorus entering Summerhill Estates Lake, according to the LMU, are limited due to the small watershed. Based on information provided in the LMU report, sources potentially include residential septic systems, internal loading (plant decomposition and sediment release and resuspension) and agricultural runoff. Lawn fertilizer runoff, while not listed by the LMU, is also a potential source of TP. There are no active NPDES discharges in the Summerhill Estates Lake watershed.

6.1.4 North and South Churchill Lake

North Churchill Lake and South Churchill Lake are located in Round Lake Park the southern portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2) and are owned by the Saddlebrook Farms Retirement Community. Both lakes were artificially created in the 1990's during the development for Saddlebrook Farms, a retirement community, and are shallow (LCHD 2003). North Churchill Lake is slightly larger and deeper than South Churchill Lake. North Churchill Lake is 62.1 acres with a maximum and mean depth of 11.0 and 5.5 feet respectively. South Churchill Lake is 24.8 acres with a maximum and mean depth of 9.0 and 4.5 feet respectively. The lakes are connected by a small channel and drain to Squaw Creek.

The watershed of South Churchill Lake is 504 acres with a watershed-to-lake area ratio of 20:1. The watershed is primarily used for row crop, grain or grazing (41%), residential (16%) and transportation, communication, and utilities (17%). Fifteen percent of the watershed is impervious. The North Churchill Lake watershed is 640 acres and includes South Churchill Lake and its watershed. The watershed-to-lake area ratio is 10:1, the threshold at which one would expect to have water quality problems. However, South Churchill Lake drains to North Churchill Lake and characteristics of the South Churchill Lake watershed are ones in which water quality problems are likely (high watershed-to-lake area ratio and high IC%). The North Churchill Lake watershed is 14% impervious surface.

The LMU 2003 Summary Report of North Churchill Lake and South Churchill Lake (LCHD 2003) notes that these lakes do not thermally stratify because of their shallow morphometry. Surface concentrations of DO remain above 5.0 mg/L throughout the summer, but concentration near the bottom in both lakes were below this threshold during the summer. Bottom waters in North Churchill Lake & South Churchill Lake did not go anoxic during 2003, but concentrations in North Churchill Lake were very low (<2.0 mg/L at and below 9' in August).

Both the North Churchill Lake and South Churchill Lake are impaired due to excessive phosphorus concentrations. These lakes also have poor water clarity and high suspended solid concentrations. Water quality data for the North Churchill Lake and South Churchill Lake are limited to the 2003 study conducted by the LMU. Concentrations of surface TP in North Churchill Lake ranged from 0.05 to 0.13 mg/L, with an average of 0.09 mg/L in North Churchill Lake (Table 5-3, Figure 5-5, Appendix E). South Churchill Lake had similar concentrations: range 0.07 – 0.12 mg/L and an average of 0.09 mg/L. Bottom TP concentrations in both lakes were similar to surface concentrations. All 10 surface samples in 2003 exceeded the WQS. Water clarity in both lakes is poor and averaged just above a half of foot (0.6 and 0.7 feet in North Churchill Lake and South Churchill Lake respectively). The poor clarity is related to high total suspended solids (TSS) concentrations. Average seasonal TSS for North Churchill Lake and South Churchill Lake are 77 and 44 mg/L respectively, 6-10 times the Lake County median.

Filamentous forms of algae were noted in South Churchill Lake but neither lake experienced an algal bloom during the 2003 study (LCHD 2003). TP concentrations are high enough to support frequent nuisance blooms, but high turbidity and low clarity appear to be limiting algal growth. Rooted plant growth is also limited in these lakes.

Potential sources of phosphorus and other nutrients entering North Churchill Lake and South Churchill Lake, according to the LMU, include stormwater which carries runoff containing fertilizers and eroding soils from the shoreline and construction sites. Significant erosion of the shoreline was documented by the LMU due to poorly constructed walls and buffers. High TSS can also be attributed to the excessive carp population in these lakes. Carp disturb bottom sediments during rooting and foraging which increases TSS and nutrients while decreasing water clarity. Stormwater from a local greenhouse was also noted as a significant source in the LMU 2003 Summary Report.

Effluent from a waste water treatment facility (WWTF) and excessive carp may also be substantial sources of nutrients within these lakes. There is a WWTF for Saddlebrook Farms within the watershed. This facility sprays treated effluent on fields for irrigation (LCHD 2003). It is likely that some of the nutrients are transported to these lakes during runoff events.

6.1.5 Hidden Lake

Hidden Lake is located in the Saddlebrook Farms retirement community in the southern portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2) and is owned by the Saddlebrook Farms Retirement Community. Hidden Lake is a small, shallow, artificially created waterbody. The lake is 19.1 acres with a maximum and mean depth of 6.0 and 3.0 feet respectively. The outlet structure was not operational at the time of the LMU study (2002) and the lake level was lower than normal. Under normal conditions, water would top the spillway and drain to Squaw Creek.

The watershed of Hidden Lake is 140 acres resulting in a watershed-to-lake area ratio of 7:1, below the 10:1 threshold when one would expect to have water quality problems. The Hidden Lake watershed is primarily residential (30%) and open space (22%). Nineteen percent of the watershed is impervious surface, a level where water quality issues are highly likely.

The LMU 2002 Summary Report of Hidden Lake (LCDH 2003) shoreline assessment revealed a high level of development. Ninety-six percent of the shoreline is developed of which 43% is manicured lawn. These land uses do not provide an ideal environment for pollutant mitigation. Also discouraging is the fact that 53% of the shoreline had some level of erosion. Historical use of the watershed was agricultural.

The LMU 2002 Summary Report of Hidden Lake (LCHD 2003) notes that this lake does not thermally stratify because of its shallow morphometry. Concentrations of DO were below 5.0 mg/L in June, July and August (Figure 5-2). Extensive algal blooms, which occurred concurrently with the low DO, consume oxygen during respiration and decomposition and is the presumed cause for the low DO.

Hidden Lake is impaired due to low DO and high pH. Both of these water quality variables can be attributable to excessive algal densities, which are linked with excessive phosphorus concentrations. During photosynthesis, algae remove carbon dioxide from the water increasing hydroxide concentration (increasing pH). During respiration, algae will consume oxygen reducing the amount available for other biota. Oxygen is also consumed during the decomposition process. The more organic material available for breakdown, the more oxygen is consumed. The extensive algal blooms observed in Hidden Lake explain the low DO and high pH values observed (>9.0 on September 4, 2002).

Hidden Lake is not listed as impaired for excessive TP concentrations since the standard is applicable only to lakes with surface acreage of ≥ 20. However, elevated TP concentrations fuel algal blooms which have resulted in the impairment conditions. TP concentrations in Hidden Lake are excessive with values ranging from 0.19 to 0.27 mg/L and an average of 0.22 mg/L, well above the 0.05 mg/L standard for larger lakes. Controlling phosphorus in Hidden Lake may result in increased DO and lower pH.

Hidden Lake also suffers from poor water clarity and high suspended solid concentrations. Like the Churchill Lakes, poor clarity and high TSS concentrations are likely due to an extensive carp population. Water clarity in Hidden Lake ranged from 0.4 to 0.8 feet (average 0.6 feet) and can be explained by high TSS concentrations and algal blooms (LCHD 2003). Average TSS for Hidden Lake was 74 mg/L respectively, 12 times the Lake County median. The low light and disruptive nature of carp has severely limited the aquatic vegetation in Hidden Lake, so much so that aquatic vegetation was listed as “nonexistent” in the LMU 2002 Summary Report of Hidden Lake (LCHD 2002).

Potential sources of phosphorus, and therefore indirect cause of low DO and high pH, include stormwater and internal recycling. There are two large stormwater drainage pipes that discharge directly to Hidden Lake. Discharge from these pipes is so severe that sediment deposition deltas have formed. The LMU noted that although there are significant stormwater related sources (including fertilizers and erosion) the majority of the input is suspected to be internal. Potential internal sources include waterfowl, sediment resuspension and flux of phosphorus from sediments accumulated during decomposition of organic matter. There are no active NPDES dischargers within the Hidden Lake watershed.

6.1.6 Grays Lake

Grays Lake is located in the southern portion of the Upper Fox River/Chain O’ Lakes watershed (Figure 2-2). It is a glacial lake with 80 surface acres. Maximum and mean water depths are 20 and 5.7 feet respectively.

The watershed of Grays Lake is small (176 acres) in proportion to the lake area (ratio 2:1). The low watershed-to-lake area ratio suggests that water quality is likely desirable. However, 36% of the watershed is residential with the majority of it concentrated along the shoreline. The shoreline of Grays Lake is highly developed (96%) and composed of rip rap (39%) and seawall (37%) (LCDH 2002). The impervious cover in Grays Lake watershed is relatively high at 15%.

The LMU 2002 Summary Report of Grays Lake (LCDH 2002) notes that the lake thermally stratifies during the summer months (June-Sept) and mixes in the fall. DO concentrations remain above 5.0 mg/L throughout the year except in July and August where less than 10% of the volume of the lake becomes anoxic.

Grays Lake is listed as impaired due to excessive TP concentrations. Water quality data for Grays Lake were collected in 1988, 1991, 1996, 1998 and 2002. Surface water TP concentrations for more recent data (i.e. after 1998) ranged from 0.02 to 0.07 mg/L, with an average of 0.03 mg/L (Table 5-3, Figure 5-5, Appendix E). Thirteen percent were above the 0.05 mg/L WQS. The highest TP concentration occurred in May 2002 before the lake underwent stratification (LCDH 2002). Bottom concentrations were only slightly higher (average = 0.04 mg/L).

Grays Lake is dominated by aquatic rooted vegetation. The most frequent species is *Chara sp.*(a macro alga) which occurred at 41% of sites sampled in 2002. The lake contains invasive aquatic plants, Eurasian watermilfoil (*Myriophyllum spicatum*) and curly leaf pondweed, which are controlled through the use of herbicides. Eutrophic lakes are typically algal or rooted plant dominated; rarely does co-dominance exist. It is believe that rooted plants are outcompeting algae for resources and therefore planktonic blooms are limited in Grays Lake. Water clarity is above average; Secchi disk transparency (SDT) was 8.46 feet on average.

The Grays Lake Park District has managed Grays Lake for the past 30 years conducting activities ranging from fish stocking to herbicides control of nuisance plant growth such as Eurasian watermilfoil and curly leaf pondweed. The reduction of these two plants may be the reason for the dominance of *Chara sp*. in Grays Lake. During sampling in 2002 milfoil was only found at four of the 153 sites.

Potential sources of phosphorus entering Grays Lake, according to the LMU 2002 study, include internal loading from nutrient rich sediment. External phosphorus inputs to the lake may consist of fertilizer runoff and erosion however rainfall data did not correspond with this assumption, pointing towards internal loading from bottom sediment being the dominate source of phosphorus into the lake. There are no active NPDES dischargers within the Grays Lake watershed.

6.1.7 Round Lake

Round Lake is located in the eastern mid section of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is a glacial lake with 228.6 surface acres. Maximum and mean water depths are 32 and 8.4 feet respectively (LCDH 2004).

The watershed encompasses 2,549 acres resulting in a watershed-to-lake area ratio of 11:1. The watersheds land use is mostly residential (37%), transportation, communication, and utilities (17%) and open space (16%). Impervious cover is high (23%) above the threshold where water quality issues are likely. Fish and wildlife are abundant throughout the Round Lake watershed and support recreational fishing and hunting.

The LMU 2003 Summary Report of Round Lake (LCDH 2004) notes that the lake thermally stratifies during the summer months, starting at 12 feet in June and dropping to a low 28 feet in September. DO concentrations remained above 5.0 mg/L throughout the year except during the summer months. Concentrations below 1.0 mg/L were recorded in August at 17' or deeper as recently as 2005.

Round Lake is listed as impaired due to excessive TP concentrations. Phosphorus data in 1977, 1979, 1980, 1989, 1991, 1996, 1999, 2002, 2003 and 2005 are available from Illinois EPA, Lake County and the Legacy STORET database (Appendix B). Recent surface water TP data (i.e. after 1998) ranged from 0.001 to 0.10 mg/L, with an average of 0.03 mg/L. 2005 surface TP concentrations ranged from 0.01 to 0.06 mg/L, with an average of 0.02 mg/L (three stations evaluated independently). One sample collected in August was above the WQS. 2005 bottom TP concentrations were higher than surface concentrations. Values ranged from 0.03 to 0.125, with an average of 0.06 mg/L.

Round lake is dominated by Eurasian watermilfoil found at 65% of all sample sites. Other species of aquatic vegetation such as coontail, Illinois pondweed (*Potamogeton illinoensis*) and *Chara sp.* are common in this lake as well. Eutrophic lakes are typically algal or rooted plant dominated; rarely does co-dominance exist. It is believed that aquatic vegetation is outcompeting algae for resources and therefore planktonic blooms are limited in Round Lake. Water clarity in Round Lake is above the Lake County mean and averaged 7.3' historically. There is also a concern that over management of aquatic vegetation will result in nuisance algal blooms.

Potential sources of phosphorus entering Round Lake, according to the LMU 2003 study, have been traced to stormwater runoff flushing a mixture of road salt and lawn fertilizer into the lake. It has been suggested that no-phosphorus lawn fertilizers be used within the watershed. Internal loading may also be a source in Round Lake given the higher concentrations at the bottom and low DO concentrations. There are no active NPDES dischargers within the Round Lake watershed.

6.1.8 Fish-Duncan Lake

Fish-Duncan Lake is located in the south-central portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). Fish-Duncan Lake (also known as Fish Lake) is 95.7 acres and was formed by glacial activity. The lake has a maximum and mean depth of 17.0 and 8.5 feet respectively. The Fish-Duncan Lake outlet is located on the northeast portion of the lake and flows north to Fisher Lake.

The Fish-Duncan Lake watershed is approximately 3,186 acres, resulting in a lake to watershed ratio of 33:1. This is a large watershed relative to lake area and therefore water quality of the watershed greatly impacts in-lake water quality. The flushing rate of Fish-Duncan is about 228 days (LCHD 2003), meaning that the entire lake volume is replaced 1.6 times per year. The majority of the watershed is agricultural land (row crop, grain, grazing - 46%) and wetland (14%). All other land uses comprise <10% of the total watershed area. IC is below the threshold (9%) where water quality impacts are likely.

Fish-Duncan Lake was thermally stratified from June through August in 2006. There was ample oxygen in the top layer (epilimnion) to support aquatic life. However, the bottom layer (hypolimnion) was anoxic.

Fish-Duncan Lake is impaired due to excessive phosphorus concentrations. This lake also experience blue-green algal blooms. Phosphorus data in 1988, 1997, 2002 and 2006 are available from Lake County and the Legacy STORET database. A summary of the recent surface TP from these years are provided in Table 5-3 Figure 5-5, and Appendix E. Surface TP ranged from 0.07 to 0.13 mg/L, with an average of 0.10 mg/L. All of the samples were above the 0.05 mg/L WQS including all surface TP concentrations in. Bottom TP concentrations in 2006 ranged from 0.08 to 0.28 mg/L.

Water clarity in Fish-Duncan has been linked to TSS concentrations (LMU 2006). Elevated TSS concentrations in 2006 (18 mg/L) occurred concurrently with a blue-green algal bloom. 2006 water clarity averaged 3.5 feet. Average TSS in 2006 was 11.0 mg/L.

Thirty four percent of Fish-Duncan's lake bottom is covered by rooted plants. Unfortunately, the rooted plant community is dominated by the invasive species Eurasian watermilfoil. Curly leaf pondweed, also invasive, was also identified in Fish-Duncan Lake.

Potential sources of phosphorus and other nutrients entering Fish-Duncan, according to the LMU, include stormwater and internal loading. Transportation land use was found to contribute the highest volume of runoff (24% of all runoff from the watershed). Agriculture land contributed the second most at 18%. Given the high TP concentrations in the hypolimnion and summertime anoxic conditions, internal loading may also be a substantial source of phosphorus in Fish-Duncan Lake. There are no active NPDES dischargers within the Fish-Duncan Lake watershed.

6.1.9 Wooster Lake

Wooster Lake is located in the middle portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is a glacial lake made up of 98.5 acres with a maximum and mean depth of 28.0 and 16.3 feet respectively.

The Wooster Lake watershed is large (4,806 acres) resulting in a watershed to lake ratio of 49:1. Wooster Lake receives water from Fish-Duncan and Fischer Lakes, their watersheds and lands surrounding Wooster Lake. Land use is primarily agricultural (row crop, grain, grazing 29%) with 12% classified as forested, grasslands, or vegetation and 12% wetlands. Twelve percent of the watershed is impervious.

The land use along the shoreline of Wooster Lake is predominately developed (70%). Shrubs, lawns, and wetlands largely make up the 2.0 mile shoreline creating buffers from erosion. When assessed, 31% of the shoreline was classified as slightly eroding and 4% was classified as moderately eroding. No points along the shoreline were flagged for severe erosion (LCHD 2006).

The LMU 2007 Summary Report of Wooster Lake (LCHD 2007) notes that the lake stratifies during the summer months. DO concentrations were above 5.0 mg/L in the epilimnion, but anoxic conditions exist in waters as shallow as 10 feet.

Wooster Lake is impaired due to high phosphorus concentrations. TP data are available from the Illinois EPA, Lake County and the Legacy STORET database for 1983, 1989, 1992, 1995, 1999, 2003 and 2005-2007. The recent average surface TP ranged from 0.01 to 0.09 mg/L, with an average of 0.04 mg/L (Appendix B). Fourteen percent were above the 0.05 mg/L. Average TP concentrations have more than doubled since 1995 (LCHD 2007). Surface TP concentrations in 2007 ranged from 0.03 to 0.08 mg/L, with an average of 0.05 mg/L (1995 average 0.02 mg/L). Bottom TP concentrations in 2007 were higher than surface water, ranging from 0.06 to 0.41 mg/L, with an average of 0.24 mg/L.

Other water quality variables have indicated a decline in water quality as well. TSS levels in Wooster Lake have been increasing since 1995, although on average they remain lower than the Lake County average (LCHD 2007). The higher values were recorded shortly after heavy rain events. Specific conductivity has increased by 43% since 1995. Blooms of bluegreen algae (*Aphanizomenon sp*.) are also on the rise.

The aquatic plant community in Wooster Lake covers approximately 45-49% in 2007. Eurasian watermilfoil dominated early while coontail dominated later in the growing season. Rooted plants were observed in water depths as great as 18 feet in May, but plant growth was limited to depths shallower than 11 feet. The LCHD postulates that if this healthy plant community were to be reduced, then algal growth would likely increase and water clarity would decrease (LCHD 2007).

Potential sources of phosphorus into Wooster Lake were not identified in the 2005-2007 summary reports. However, the large watershed and large percentage of agricultural and developed land suggest that runoff accounts for a large portion of the phosphorus load to Wooster Lake. In addition, the lack of oxygen in bottom waters coupled with high bottom TP concentrations, suggests that internal loading may be a substantial source. Camp Henry Horner is the only active NPDES discharger within the Wooster Lake watershed.

6.1.10 Duck Lake

Duck Lake is located in the Central portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2) and is managed by the Duck Lake Waterway Association. It is a natural slough pothole lake comprised of 110.4 surface acres. Maximum and mean water depths are 9.0 and 4.5 feet respectively. Duck Lake is located downstream of Fish-Duncan, Fischer and Wooster Lakes. Duck Lake discharges to the east into Squaw Creek to Fox Lake.

Duck Lake watershed is large (5,477 acres) and receives runoff from diverse sources. The primary use of the watershed is comprised of agricultural (row crop, grain, grazing 28%) with 13% classified as forested, grasslands, or vegetation and 13% wetlands. IC is also estimated at 12%. Shoreline erosion increased from the previous LMU 2001 study. Since that time rip rap and other restoration techniques were implemented along the banks to improve the condition (LCHD 2006).

The LMU 2006 Summary Report of Duck Lake (LCHD 2006) notes that this lake does not thermally stratify because of its shallow morphometry. Surface concentrations of DO remain above 5.0 mg/L throughout the summer, but concentration near the bottom were below this threshold during the summer. Bottom waters in Duck Lake did not go anoxic during 2006 (LCHD 2006).

Duck Lake is listed as impaired due to excessive phosphorus concentrations. Data are available for TP from Lake County and from the Legacy STORET database for 1988, 1989, 1995, 1997, 2001 and 2006. Recent surface water TP concentrations ranged from 0.03 to 0.13 mg/L with an average of 0.07 mg/L (only one station sampled; Table 5-3, Figure 5-5, Appendix E). The range of surface TP concentrations in 2006 was 0.03 - 0.052 mg/L, which was much lower than in 2001 (0.06 – 0.13 mg/L). Average bottom TP concentration in 2001 was similar to the surface average (0.10 mg/L). Bottom waters were not sampled for TP in 2006.

Rooted plant biomass is controlled in Duck Lake using herbicides. Prior to an herbicide treatment in 2001 submerged vegetation covered 61% of the lakes bottom, after the treatment vegetation decreased to 29%. The dominate species in Duck Lake is Eurasian watermilfoil followed by coontail and white water lily (*Nymphaea odorata*). The drop in rooted aquatic vegetation from the herbicide treatment resulted in an increase in algal blooms and TP (LCHD 2006).

Potential sources of phosphorus entering Duck Lake, according to the LMU 2001 Report, include runoff from surrounding agricultural farms, wetland runoff, and resuspension of sediments by stormwater, motor boats, wind, waves and carp. The Camp Henry Horner wastewater treatment facility is a potential source as it is located in the Wooster Lake watershed, a contributing watershed to Duck Lake.

6.1.11 Fischer Lake

Fischer Lake is located in the middle portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is a man made lake comprised of 98.5 acres with a maximum and mean depth of 11.0 and 5.5 feet respectively (LCHD 2002).

The watershed of Fischer Lake is 4,290 acres and encompasses Fish-Duncan Lake and its watershed. The watershed area to lake area ratio is very large (44:1) and suggests that water quality impacts are likely. The Fischer Lake watershed is primarily row crop, grain, or grazing lands (36%) and contains approximately 11% impervious surface. Residential areas comprise only 7%, but much of this development is concentrated along the shoreline. Sixty-three percent of the shoreline of Fischer Lake is developed (LCHD 2002). Riprap, lawn, seawall and beaches largely make up the 1.7 mile shoreline. Erosion occurs along 63% of the shoreline with 32% of the shoreline erosion categorized as severe (LCHD 2002).

The LMU 2001 Summary Report of Fischer Lake describes the lake as having polymictic characteristics, meaning the lake thermally stratifies and mixes several times throughout the year (LCHD 2002). Stratification occurred during the months of May-July although it is believed the lake mixed at various times between sample dates. During stratification bottom DO levels did reach anoxic levels. In August, mixing occurred throughout the lake and DO was sufficient enough to support aquatic life (LCDH2002).

Fischer Lake is impaired due to high phosphorus concentrations. TP data are limited to the 2001 and 2006 studies performed by Lake County. The average surface TP during the period of record ranged from 0.07 to 0.37 mg/L and averaged 0.21 mg/L (Table 5-3, Figure 5-5, Appendix E). Surface and bottom TP concentrations in 2006 each averaged 0.23 mg/L.

The LMU 2001 study found the aquatic plant community in Fischer Lake to be very minimal, about 5% of the lakes bottom area was covered with vegetation. Eurasian watermilfoil and pondweed (*Potamogeton sp*.) were the most commonly found species in the lake. The over abundance of algae and the high solids levels due resuspension of sediment limits light availability and therefore limits macrophyte growth in Fischer Lake. Water clarity in Fischer Lake is poor. The minimum Secchi disk transparency was 0.8 feet in August 2006. Average transparency in 2001 and 2006 was only 2.3 feet.

Phosphorus enters the lake from the surrounding watershed and from internal loading via resuspension and flux during periods of anoxia. Likely watershed sources consist of fertilizers and proximal agricultural fields. A large population of Canada geese also inhabits the lake adding feces which are highly concentrated with phosphorus (LCDH 2002). The Camp Henry Horner wastewater treatment facility is located in the Wooster Lake watershed and may be a substantial source of phosphorus for Fischer Lake depending on attenuation and uptake of phosphorus upstream.

6.1.12 Redhead Lake

Redhead Lake is located in the southeast portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). Redhead Lake is a shallow glacially formed lake that contains only portion of the open water it has today (51 surface acres). Redhead Lake's increased size was due to the impounding of water by the McHenry and Algonquin dams, erected in 1907 and 1946 respectively. The lake has a current maximum and mean depth of 4.5 and 2.3 feet respectively. Redhead Lake receives water from Lake of the Hollow and a small creek to the east. Redhead Lake drains to the southeast portion of Pistakee Lake.

Redhead Lake's watershed is large (1,326 acres) resulting in a large watershed-to-lake area ratio (26:1). The majority of the watershed is classified as open space (42%) with residential areas the next most abundant land use (19%). Much of Redhead Lake's shoreline remains undeveloped (68%). However, 20% of the developed area consisted of manicured lawns.

Water quality data collected in Redhead Lake is available from Lake County and Legacy STORET for 1981, 1988 and 2002 (Appendix B). DO concentrations in Redhead Lake remained above 5.0 mg/L during all investigations. The lake is very shallow and does not thermally stratify. Surface water TP concentrations, however, were above WQS (0.05 mg/L) for all dates. 2002 TP data ranged from 0.08 to 0.23 mg/L, with an average of 0.14 mg/L. Redhead Lake is listed as impaired due to excessive TP concentrations.

Redhead Lake also has poor water clarity and high TSS. Water clarity in 2002 averaged 1.3 feet, below the average water clarity of all Lake County lakes. TSS concentrations were high, with an average of 37 mg/L. LMU 2002 Summary Report of Redhead Lake (LCHD 2003) suggests that 33% of TSS was attributable to organic particles, like algae. Redhead Lake has thick growths of rooted plant and algae, both filamentous and planktonic.

The rooted plant community in Redhead Lake is dominated by Eurasian watermilfoil and coontail. Curly leaf pondweed was also noted in Redhead Lake. Plant growth covered 50-60% of the surface area of Redhead Lake and is considered undesirable.

Potential sources of phosphorus and other nutrients entering Redhead Lake, according to the LMU, include stormwater and internal loading. Stormwater runoff containing fertilizers and nutrients and solids from erosion may be substantial sources of pollutants to Redhead Lake. The 2002 Summary Report also notes failing septic systems, goose feces and internal sources (sediments and algae) as potential sources. There are no active NPDES dischargers located within this watershed.

6.1.13 Long Lake

Long Lake is located in the middle portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is glacial lake comprised of 392.6 acres with a maximum and mean depth of 30.0 and 13.1 feet respectively (LCHD 2007).

The watershed is large, encompassing 24,820 acres, resulting in a watershed-to-lake ratio of 63:1. Long Lake receives drainage from the Eagle and Squaw Creek watersheds from the north and south respectively. The Round Lake Drain also discharges to Long Lake from the southeast. The lake's outlet is located in the northwest portion and discharges to Squaw Creek to Fox Lake. Land use in the watershed is primarily residential (20%), open space (17%) row crop, grain or grazing (15%) and transportation, communication, and utilities (11%). Impervious cover is estimated at 16%.

The LMU 2007 Summary Report of Long Lake (LCHD 2007) documents week stratification from June through September 2007. DO concentrations below 5.0 mg/L were recorded in Long Lake and were believed to be the result of a planktonic algal bloom (LCHD 2007). Anoxic conditions were recorded during the summer at water depths as shallow as 10 feet.

Long Lake is listed as impaired due to excessive TP. Phosphorus data are available from Illinois EPA, Lake County and the Legacy STORET database for 1973, 1977, 1979-1986, 1988, 1991, 1996, 1999-2002 and 2005-2007 (Appendix B). Recent average surface TP concentrations ranged from 0.02 to 0.15 mg/L, with an average of 0.08 mg/L. Seventy-one percent were above the 0.05 mg/L WQS (Table 5-3, Figure 5-5, Appendix E). 2007 surface TP concentrations ranged from 0.04 to 0.14 mg/L, with an average of 0.09 mg/L; four of the five samples were equal to or exceeded the WQS. 2007 bottom TP concentrations were higher with a range of 0.04 to 1.33 mg/L and averaged 0.60 mg/L.

The LMU 2007 study found the aquatic plant community in Long Lake covers between 19 and 31% of the lake bottom. Rooted plants were limited to depths shallower than eight feet. The community is dominated by Eurasian watermilfoil with coontail the second most common species. Curly leaf pondweed also was considered dense in Long Lake. Some lake side residents have been treating spot areas with herbicides to control plant densities.

Runoff from roads and lawns from storm events has been identified as a major source of phosphorus in Long Lake. Sediment is also a potential source of phosphorus under anoxic conditions (LCHD2007). Long Lake receives water from Squaw Creek and its tributaries which receive treated sanitary wastewater from Freemont School District and Camp Hickory Ingleside. Baxter Healthcare discharges stormwater and treated process water to an unnamed ditch prior to entering Squaw Creek.

Deep LakeDeep Lake is located in the eastern mid section of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2) and is owned by Lake Villa as well as private residences. It is a glacial lake with 225.7 surface acres and maximum and mean water depths of 48.0 and 17.5 feet respectively (LCHD 2004). Recreational activities on the lake include swimming, boating, and fishing.

Deep Lake receives water from residential areas to the east, Cedar Lake to the west and its watershed and the downtown Lake Villa business district to the south. The watershed (1,401 acres) is small relative to lake area (ratio of 6:1). The watershed land use is predominantly lakes, reservoirs, or lagoons (37%), residential (17%), and forested, grasslands, or vegetation (17%). Impervious cover is estimated at 14%. Homes on the lake utilize septic systems or sewer systems.

The LMU 2003 Summary Report of Deep Lake (LCDH 2004) notes that the lake thermally stratified from May-September. DO concentrations remained above 5.0 mg/L in 69% of the lake volume. Ninety-four percent was > 1.0 mg/L, leaving only a small portion of the lake anoxic.

Many in-lake management techniques have been implemented to control rooted plant growth and algal blooms. Herbicides, harvesting and aeration have been employed at various times during the lakes history. Deep Lake is dominated by Eurasian watermilfoil. Algal blooms do not appear to be an issue for Deep Lake at this time, rather lake level, rooted plant growth, boat operations, runoff and failing septic systems are the largest management concerns (LCDH 2004).

Deep Lake is listed as impaired due to high levels of pathogen indicator species (fecal coliform and/or *E. coli*). Pathogen indicator data are available from 2001 through 2007. The LCHD routinely samples two locations in Deep Lake (Deep Lake Apartments Beach and Jack & Lidia's Resort). The Apartments Beach location was sampled for fecal coliform on eight days in 2001. A total of 15 samples were analyzed for fecal coliform bacteria. Two samples, both collected on 7/10/2001, contained excessive bacteria concentrations (fecal coliform and *E .coli*) above the 200 cfu/ml WQS (2800 and 3700 cfu/ml; Figures 5-3 and 5-4).

E. coli was also sampled 246 times from May 2002 to August 2007 at both locations (Appendix B). Although Illinois does not have a numerical standard for *E. coli*, the US EPA document “Ambient Water Quality Criteria for Bacteria – 1986” states a freshwater bathing criteria of a geometric mean from five samples within a 30 day period not exceed 126 cfu/100ml (US EPA 1986). Although geometric means were not calculated for each 30 day period for this analysis, 71 individual samples exceeded the 30 day geometric mean EPA freshwater bathing criteria of 126 cfu/100ml equating to 29% of the samples collected in Deep Lake.

Sources of pathogen indicators can be narrowed down to waterfowl (mainly Canada geese), runoff, and failing septic systems leaking into the watershed (LCDH 2004). Storm events wash waste from roads and failing septic systems into the lake, and high wind and wave action can stir up waste that is dormant in the sediment creating higher than normal bacteria levels. Historically untreated sewer that was discharged to the Lake Villa Creek during periods of overflow were the cause of high bacteria, but cross connections have been removed leaving stormwater as a primary source of poor water quality. There are no active NPDES dischargers in the Deep Lake watershed.

6.1.14 Sun Lake

Sun Lake is located in the eastern mid section of the Upper Fox River/Chain O’ Lakes watershed in the Forest Preserve property (Figure 2-2). The Lake is owned and managed by Lake County Forest Preserve District. It is a glacial pothole slough with characteristics similar to a bog system. It is comprised of 24.5 surface acres and maximum and mean water depths of 19.2 and 9.6 feet respectively (LCHD 2003).

The Sun Lake watershed is large (1,671 acres) and includes Cedar and Deep Lake and their watersheds. As a result, a large portion of the watershed land use is classified as lakes, reservoirs, or lagoons (32%). Seventeen percent is open space, 16% is forested, grasslands, or vegetation, and 15% is residential. The watershed-to-lake ratio is 68:1 and percent IC is 13%.

Sun Lake is used by the public for shoreline fishing. No boating of any kind is allowed on the lake. The shoreline (0.9 miles) consists of wetlands and woods. The lake and surrounding areas provides a favorable habitat for wildlife. The invasive species purple loosestrife (*Lythrum salicaria*) was located along the entire shoreline (LCDH 2003). The rooted aquatic plant community is also dominated by an invasive species, Eurasian watermilfoil.

The LMU 2001 Summary Report of Sun Lake (LCDH 2003) reported that the lake thermally stratified. DO concentrations remain above 5.0 mg/L in the epilimnion for the entirety of the summer study period. For the summer months anoxia did not occur until a depth of 10-14 feet was reached (LCDH 2003).

Sun Lake is impaired due to excessive phosphorous levels. TP data are available from the Legacy STORET database and Lake County from 1991 through 1993 and 2001. Epilimnetic TP levels have increased gradually since 1991 (LCDH 2003). Since 1998, surface TP levels ranged from 0.03 to 0.052 mg/L, with an average of 0.04 mg/L (Table 5-3, Figure 5-5, Appendix E). One sample exceeded the 0.05 mg/L WQS. Bottom concentrations, however, were higher.

There have been limited new residential/commercial developments in the watershed since the previous studies were conducted. The increase of phosphorus into Sun Lake is potentially caused by internal nutrient loading (plant decomposition and sediment release & resuspension). There are no active NPDES dischargers in the Sun Lake watershed.

6.1.15 McGreal Lake

McGreal Lake is located in the located in the northeast corner of the Upper Fox River/Chain O' Lakes watershed, which is privately owned by the Rettinger family (Figure 2-2). McGreal Lake is a relatively small and shallow waterbody created from a flooded wetland. This 24.5 acre lake has a maximum and mean depth of 9.2 and 4.6 feet respectively. The structure of McGreal Lake is separated into two lobes by a dam at the southern end of the lake. No lake management association is involved with McGreal Lake and all issues are addressed by property owners (LCHD 2003).

McGreal Lake receives water from a small creek, agricultural areas, and six residential properties around the lake. The McGreal watershed is small relative to lake area (6:1), but the majority of the watershed is residential (49%) with 15% IC. Fifty-four percent of the lakes shoreline is developed and consists almost completely of buffer (90.2%). As a result of the dominance of shrubs and buffer a large number of birds and waterfowl inhabit the shoreline.

The LMU 2002 Summary Report of McGreal Lake (LCHD 2003) notes that the lake thermally stratifies during the months of June-August. In July, McGreal Lake underwent a sharp decrease in surface water DO as a result of massive amounts of curly leaf pondweed decomposition, depleting the water of DO. Anoxia occurred between 5-7 feet.

McGreal Lake is impaired due to high concentrations of phosphorus. Phosphorus data are limited to the Lake County data collected in 1992, 1993 and 2002. Since 1998 the average surface TP levels ranged from 0.02 to 0.16 mg/L, with and average of 0.09 mg/L (Table 5-3, Figure 5-5, Appendix E). Four of the five surface samples exceeded the 0.05 mg/L WQS. Average bottom TP concentration in 2002 was 0.23 mg/L.

The dominant plant species in McGreal Lake is Eurasian watermilfoil. Twelve other plant species are present in the lake including curly leaf pondweed, and coontail. In the months of May and June curly leaf pondweed dominates the lake but naturally dies off and is replaced by a population of coontail. After the die off, water clarity drops and an algal bloom usually occurs. Unlike many other lakes rooted aquatic vegetation and algae are able to successfully compete for light resources because of their growth patterns in McGreal Lake (LCHD 2003).

McGreal Lake TP levels were directly correlated with rainfall amounts. This correlation suggests that elevated phosphorus may be influenced by non-point source runoff. A faulty septic system was also observed draining raw effluent into a tributary of McGreal Lake (LCHD 2003). There are no active NPDES dischargers in the of McGreal Lake watershed.

6.1.16 Antioch Lake

Antioch Lake is located in the northern portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is a shallow man made lake operated/owned by Osmond Enterprises and a private citizen. The lake is 89 surface acres created from the flooding of a natural slough in the 1930s. Maximum and mean water depths are 9.0 and 4.5 feet respectively. Antioch Lake discharges to the north into Lake Tranquility.

Antioch Lake receives water from a small creek and several swale/culverts draining the surrounding lands. The watershed area is approximately 442 acres and is small relative to lake size (5:1). Water quality impacts are not generally associated with such low ratios, but the majority of the land use is residential (40%) and transportation, communication, and utilities (11%), both of which have high IC. The IC for the Antioch watershed is estimated at 21%, a point where impaired conditions are common.

The LMU 2001 Summary Report of Antioch Lake (LCHD 2002) notes that the lake does not commonly stratify due to its shallow characteristics; this allows for wind and waves to effortlessly mix oxygen throughout the water column. During the 2001 LMU study DO concentrations remained above 5.0 mg/L at the surface. Concentrations below this threshold were at or below 5 feet in July. Anoxic conditions were present at 7 feet in July and August.

Antioch Lake is listed as impaired due to excessive phosphorus concentrations. Phosphorus data are available from the Legacy STORET database and Lake County for 1988, 1989, 1992, 1993 and 2001 (Appendix B). Recent TP ranged from 0.08 to 0.33 mg/L, with an average of 0.14 mg/L. All of the water quality data points exceeded the 0.05 mg/L WQS (Table 5-3, Figure 5-5, Appendix E). Concentrations of surface and bottom TP were the same. This is not surprising given the shallow morphometry of Antioch Lake.

In 2001, Antioch Lake was treated with herbicides significantly reducing the rooted plant biomass which previously covered 96% of the lakes bottom. Before the treatment the lake was populated with Eurasian watermilfoil, curly pondweed, and white water lily. With out the competition from rooted aquatic vegetation algal populations are able to thrive in Antioch Lake. Algal blooms are a common occurrence in Antioch Lake.

Potential sources of phosphorus entering Antioch Lake, according to the LMU 2001 Report, include inputs from the watershed and internal loading from the bottom sediment. Although not specifically discussed as internal loading in the 2001 Summary Report, the recycling of phosphorus from sediments is likely. There are no active NPDES dischargers in the of Antioch Lake watershed.

6.1.17 Lake Tranquility

Lake Tranquility is located in the northern portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is a 26.7 acre lake that was artificially created in 1940-1941 through dredging of an existing slough and is currently operated/owned by the Heron Harbor Homeowners Association. Maximum and mean water depths are 10.9 and 5.5 feet respectively. Lake Tranquility discharges through a wetland complex to Lake Marie.

Water enters Lake Tranquility on the northeast end as well as water from two detention basins located on the southern end. The watershed is approximately 249 acres (watershed-to-lake ratio 9:1). Much of this area is residential (35%) with 18% used for transportation, communication, and utilities. As a result the IC percentage is high 26% and water quality problems are expected.

The lake is used primarily for recreation by the public and residents around the lake (LCHD 2003). The shoreline is dominantly undeveloped (69%) and wetland and shrubs encompass most of the area. Some areas were noted in the 2002 LMU study as eroding including a 33 foot section that was classified as severely eroded (LCHD 2003).

The LMU 2002 Summary Report of Lake Tranquility (LCHD 2003) notes that the lake thermally stratifies during the summer months (Jun-Aug). Surface DO concentrations were above 5.0 mg/L during 2002. Anoxia was measured at depths at or greater than 7 feet in August. In the 2002 LMU report it is noted that in 1990 an aeration system was installed in the lake at the southern channel.

Lake Tranquility is listed as impaired due to excessive TP concentrations. Water quality data are limited to the 2002 LMU data (Appendix B). TP in Lake Tranquility varied at two different sites due to sediment resuspension by aerators. At site 1 located away from the aeration system, TP ranged from 0.04 mg/L to 0.07

mg/L. At site 2 located near the aeration system, TP increased to 0.10 mg/L. Overall, surface TP levels ranged from 0.05 to 0.15 mg/L, with an average of 0.08 mg/L (Table 5-3, Figure 5-5, Appendix E).

Annual herbicide and algaecides treatments are conducted in Lake Tranquility to control rooted aquatic vegetation and algae. Invasive species such as Eurasian watermilfoil, coontail, and curly leaf pondweed dominate the aquatic vegetation population. Several native species were found, but occurrence was rare. Lake Tranquility has a moderate algal population but blooms are controlled using algaecides. Lake Tranquility's water clarity was observed at two sites. Site 1 located away from aerators had an average Secchi disk transparency of 2.9 feet. Site 2 located near the aeration system obtained a transparency of 1.4 feet.

Potential sources of phosphorus entering Lake Tranquility, according to the LMU 2002 study, include runoff during storm events and internal loading from nutrient rich sediment. Internal loading from the aeration system creating constant sediment resuspension has resulted in higher levels of phosphorus in Lake Tranquility. There are no active NPDES dischargers in the of Lake Tranquility watershed.

6.1.18 Turner Lake

Turner Lake is located in the western portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is glacial slough comprised of 45.6 acres with a maximum and mean depth of 10.0 and 5.0 feet respectively. The Turner Lake watershed is 576 acres and is mostly open space (54%) and residential (22%). The watershed-to-lake area ratio is 13:1 and IC is estimated at 13%.

Due to the shallow morphology of Turner Lake polymictic mixing may occur. During a May 2002 sampling date the lake was weakly stratified, but in July a thermocline had established at 6 feet. The lake was mixed again in August (LCHD 2003). During months when Turner Lake was not stratified (May, August, and September) DO concentrations remained above 5.0 mg/L throughout the water column. In June and July DO concentrations in the hypolimnion were anoxic. An aeration system was installed in Turner Lake and runs during the winter to avoid fish kills.

Turner Lake is impaired due to high phosphorus concentrations. TP data are available from the Legacy STORET database, Illinois EPA and Lake County for 1989, 1997, 1999 and 2002 (Appendix B). Recent average surface TP concentrations ranged from 0.02 to 0.059 mg/L, with an average of 0.05 mg/L (Table 5-3, Figure 5-5, Appendix E). Thirty-six percent were above the 0.05 mg/L WQS. In 2002 the average concentration of TP was 0.05 mg/L; hypolimnion average concentration was also 0.05 mg/L.

The LMU 2002 study found the aquatic plant community in Turner Lake to be dominated by white water lily (60%), Eurasian watermilfoil (57%), *Chara spp*. (47%) and bladderwort (42%). Nine other aquatic macrophytes were also found at less than 20% of all sample sites. The occurrence of algal blooms was not mentioned in the 2002 Summary Report.

Potential sources of phosphorus entering Turner Lake are likely from resuspension of phosphorus rich sediment during mixing and stormwater runoff from near by farms and developments (LCHD 2003). There are no active NPDES dischargers in the of Turner Lake watershed.

6.1.19 Dunns Lake

Dunns Lake is located in the western portion of the Upper Fox River/Chain O' Lakes watershed (Figure 2-2). It is a 68 acre lake which receives water from surrounding lands and discharges to the south eventually draining to Nippersink Lake.

The Dunns Lake watershed is relatively small (455 acres) resulting in a low watershed to lake ratio (7:1). The most dominant land uses are open space (36%) and residential (26%). Transportation, communication, and utilities make up another 14% of the watershed. Impervious cover is higher than desirable (15%) and likely contributes to the water quality problems in Dunns Lake.

Dissolved oxygen levels in Dunns Lake were above 5.0 mg/L during 1989 and 2002 (available data) at the surface and for most of the water column. DO below 5.0 mg/ was limited to depths at or greater than 6 feet in July 2002 and 7 feet in September. Anoxic conditions were not encountered during either sampling year.

Dunns Lake is impaired due to high phosphorus concentrations. TP data are limited to 1989, 1997 and 2002 (Appendix B) from Lake County and the Legacy STORET database. Recent surface TP ranged from 0.08 to 0.12 mg/L, with an average of 0.10 mg/L (Table 5-3, Figure 5-5, Appendix E). All of the samples exceeded the 0.05 mg/L WQS. Surface TP concentrations in 2002 averaged 0.10 mg/L. Average bottom concentration was the same, which is not surprising given the shallow morphometry of Dunns Lake. An average Secchi Depth Transparency (SDT) of 1.62 feet was recorded for years 1989, 1997, and 2002.

A LCHD Summary Report was not available for Dunns Lake at the time this Stage 1 report was prepared because the LMU conducted monitoring in 2002 on behalf of Illinois EPA. Resuspension of sediment and stormwater runoff are expected to be potential sources of TP in Dunns Lake. Fox Lake Tall Oak sanitary wastewater is discharged to an unnamed tributary of Dunns Lake and may be a substantial source of phosphorus.

6.1.20 Chain O' Lakes

The Chain O' Lakes consists of ten glacially-formed, hydraulically connected lakes in a system. The system of lakes is publicly owned and managed by Fox Waterway Agency. In addition, the Agency collected water quality data in past to help assess, restore, and maintain the biological, chemical, and physical integrity of the waterway to ensure water quality, fish and wildlife populations, and ecosystem health. The data may be considered in Stage 3 TMDL development.

The following sections provide background information, including land use and potential pollution sources, regarding each sub-watershed. Appendix C provides an overall summary of land use within each sub-watershed as well as the total land use for the entire Chain O' Lakes.

6.1.20.1 Lake Catherine and Channel Lake

Lake Catherine and Channel lakes are two of the nine major hydraulically connected lakes in the Chain O' Lakes. These glacially formed lakes were expanded in size when the McHenry dam was erected in 1907. Lake Catherine (164.7 acres) and Channel Lake (337 acres) are connected via a sandy ridge about four to eight feet deep (Cochran & Wilken 2000). These lakes are the farthest upstream of all lakes in the chain and the deepest. Lake Catherine has a maximum depth of 39 feet and a mean depth of 16.7 feet. Channel Lake's maximum and mean depths are 35 and 14.5 feet respectively. Hydraulic detention time of Lake Catherine and Channel Lake is approximately 6 months.

The Lake Catherine and Channel Lake watershed is 12,384 acres and extends into Wisconsin (Cochran & Wilken 2000). These lakes receive water from Trevor Creek, the major tributary draining from the north, and several smaller tributaries and stormwater drainage outfalls. The watershed was primarily forested until the mid-1850 when the land was clear cut for row crop agriculture. Much of the agricultural area, especially along the shoreline, has been recently converted to industrial and residential use. The Illinois portion of Lake Catherine and Channel Lake's watershed is 32% residential, 17% forested, grasslands, or vegetation, 12% row crop, grain, or grazing and 11% wetland. Approximately 17% of the Illinois portion of the watershed is impervious surface.

Lake Catherine and Channel Lake stratify during the summer months. Surface DO concentrations were generally above 5.0 mg/L with the exception of three days in 1998 for Channel Lake. Anoxia was measured in Channel Lake at depths as shallow as eight feet (1993). Anoxia in Lake Catherine has been measured at a depth of seven feet in 2002. In 2005, anoxia at the deep water station within Channel Lake was encountered at 19 feet. In Lake Catherine during 2005 the anoxic boundary at the deep station was at 17 feet.

Both Lake Catherine and Channel Lake are impaired due to excessive phosphorus. TP data for Lake Catherine and Channel Lake are available from Lake County, Legacy STORET and Illinois EPA for 1979, 1981, 1984, 1987, 1990, 1993, 1996, 1998, 1999, 2002 and 2005. (Appendix B) Since 1998, average surface water TP concentrations in Lake Catherine and Channel Lake were 0.09 and 0.04 mg/L respectively. Between nine and seventeen percent of the averaged samples exceeded the 0.05 mg/L WQS. Average surface concentrations in 2005 for Lake Catherine and Channel Lake were 0.56 and 0.04 mg/L, respectively. The excessive average TP concentration in Lake Catherine during 2005 was due to exceptionally high TP concentrations in October (1.29 and 1.42 mg/L); all other surface values in 2005 were either 0.02 or 0.03 mg/L. Average bottom concentrations in 2005 were 0.64 and 0.53 mg/L for Lake Catherine and Channel Lake respectively (Table 5-3, Figure 5-5, Appendix E).

Both lakes experience intense algal blooms. The Illinois EPA Clean Lakes Program, Phase I Diagnostic Feasibility Study (2000) documented high chlorophyll *a* concentrations from July through October, with October experiencing the highest concentrations overall. Bluegreen algae dominate these lakes during intense blooms. This may explain the excessive TP concentration in October 2005. Lake Catherine may have been experiencing a bloom at the time of sampling.

The Clean Lakes study provided a nutrient budget for Channel Lake and Lake Catherine. Internal loading was found to be the dominant source of phosphorus (40%) and watershed surface water sources were the second highest contributor (31%). Storm drains accounted for 13% of the TP load to Lake Catherine and Channel Lake. There are no active NPDES dischargers located within the Illinois portion of the Lake Catherine and Channel Lake watersheds.

The rooted plant community in Channel Lake and Lake Catherine is dominated by the invasive species Eurasian watermilfoil (63-79% occurrence; Cochran & Wilken 2000). Coontail was the second most abundant species. The invasive species curly leaf pondweed is also found in these lakes.

Many in-lake management techniques have been employed to control both the rooted plant community and algal blooms. An aerator was installed in the late 70's to oxygenate bottom waters to prevent the release of phosphorus from sediments. Although DO levels in hypolimnetic waters following aeration were maintained above 2.0 mg/L, no measurable change was observed in nutrient levels. The system is not large enough to treat the entire anoxic zone and may be the reason for the lack of change in nutrient levels (Cochran & Wilken 2000). In addition, nutrient concentrations entering these lakes from the watershed remained high during the aerator operation and could be masking any impact the aerator may have had. Copper sulfate treatments have been employed to control algal blooms. Control was often achieve with measurable increased water clarity, but the lakes experience a DO sag due to algal decomposition and relief from blooms is temporary since phosphorus sources are not controlled. Herbicides have also been applied to control invasive rooted plant species. Recent information (i.e., > 2000) regarding the use of the aerator, algaecides or herbicides and their effectiveness was not readily available at the time this Stage 1 report was prepared.

6.1.20.2 Lake Marie

Lake Marie is one of the nine major hydraulically connected lakes in a system collectively known as the "Chain O' Lakes". Lake Marie is a 516 acre lake located south of Channel Lake and Lake Catherine and north of Bluff and Grass Lakes. Mean depth in Lake Marie is approximately 9.2 feet.

Lake Marie receives water from Channel Lake and Lake Catherine as well as the surrounding lands. The Illinois portion of Lake Marie watershed is 1,670 acres. Eighteen percent of this area is residential, 13% wetland and 10% forest, grasslands, and vegetation. Twelve percent is estimated to be IC.

Although it is not the predominant flow direction, Marie Lake receives water from Grass Lake depending on Fox River flow and wind direction and velocity. Typically, Marie Lake discharges to Bluff and Grass Lakes in a southern direction. Hydraulic detention time of Marie Lake at full capacity, as calculated in Fox Chain O' Lakes Investigation and Water Quality Management Plan (Kothandaraman et. al, 1977), is approximately 26 days.

Water quality data for Marie Lake are available from Lake County, Legacy STORET and from Illinois EPA from 1973, 1983, 1987, 1993, 1996, 1999, 2002 and 2005 (Appendix B). Surface water DO concentrations were above 5.0 mg/L. Bottom concentrations, however, were anoxic in water depth as shallow as 7' (August 2002) at the deep sample station. Anoxia was more common 13-15' below water surface during summer months.

The majority of recent surface water quality samples (77%) were above the WQS for TP. Averaged surface TP concentrations ranged from 0.03 to 0.12 mg/L with an average of 0.07 mg/L (Table 5-3, Figure 5-5, Appendix E). Surface TP from 2005 ranged from 0.05 to 0.12 mg/L and averaged 0.08 mg/L (two stations evaluated independently). Bottom TP concentrations in 2005 were higher and ranged from 0.09 to 1.28 mg/L, with an average of 0.79 mg/L (only one station sampled at the bottom).

Given the lack of oxygen and high TP concentrations in bottom waters, internal loading is a likely source of phosphorus in Marie Lake. Other potential sources include stormwater runoff and point sources. There are no active NPDES dischargers located in the immediate Marie Lake watershed. However, Marie Lake receives water from Sequiot Creek which eventually receives effluent from the Antioch WWTF, non-contact cooling water from the Antioch Packing House and quarry water from Dahl Enterprises. These sources will be confirmed in Stage 3.

There was no LMU Summary Report available for Marie Lake at the time of writing this Stage 1 summary because LMU conducted monitoring in 2002 on behalf of Illinois EPA. Therefore this segment's description is limited to water quality data associated with phosphorus impairment and information provided in the 1977 Fox Chain O' Lakes Investigation and Water Quality Management Plan. Specific information regarding potential sources, shoreline condition, and rooted plant community are not available.

6.1.20.3 Bluff Lake

Bluff Lake is one of the nine major hydraulically connected lakes in a system collectively known as the "Chain O' Lakes". Bluff Lake is an 86 acre lake and is located between Spring Lake to the south and Marie Lake to the north. Bluff Lake has a mean depth of 10.5 feet. Hydraulic detention time of Bluff Lake at full capacity, as calculated in Fox Chain O' Lakes Investigation and Water Quality Management Plan (Kothandaraman et. al, 1977), is approximately 4.9 days.

Bluff Lake receives water from Marie Lake, its watershed and drainage from surrounding lands. The Illinois portion of the watershed is approximately 943 acres and is primarily residential (30%), row crop, grain, or grazing (17%) and forested, grasslands, or vegetation (15%). This portion of the watershed is 18% impervious.

Water quality data for Bluff Lake are available from Lake County, Legacy STORET and from Illinois EPA from 1987, 1988, 1993, 1996, 1999, 2002 and 2005 (Appendix B). . Surface water dissolved oxygen concentrations were above 5.0 mg/L. Bottom concentrations, however, were generally below 1.0 mg/L during the late summer in water depth at or greater than 13'. Anoxia was observed in waters as shallow as 9' in August 1993, however.

The majority of recent surface water quality samples (77%) were above the WQS for TP. Surface TP concentrations ranged from 0.03 to 0.19 mg/L and averaged 0.07 mg/L (Table 5-3, Figure 5-5, Appendix E). Surface TP in 2005 ranged from 0.05 to 0.19 mg/L and averaged 0.10 mg/L (only one stations sampled). Bottom TP concentrations in 2005 were much higher and ranged from 0.20 to 1.17 mg/L, with an average of 0.68 mg/L (only one station sampled).

Given the lack of oxygen and high TP concentrations in bottom waters, internal loading is a likely source of phosphorus in Bluff Lake. Other potential sources include stormwater runoff and point sources. There are no active NPDES dischargers located in the immediate Bluff Lake watershed. However, Bluff Lake receives water from Marie Lake and its watershed. Point sources impacting Marie Lake have the potential to impact Bluff Lake as well.

There was no LMU Summary Report available for Bluff Lake at the time of writing this Stage 1 summary because LMU conducted monitoring in 2002 on behalf of Illinois EPA. Therefore this segment's description is limited to water quality data associated with phosphorus impairment and information provided in the 1977 Fox Chain O' Lakes Investigation and Water Quality Management Plan, Illinois Integrated Water Quality Report and Section 303(D) List - 2008 Specific information regarding potential sources, shoreline condition, and rooted plant community are not available.

6.1.20.4 Spring Lake

Spring Lake is part of the "Chain O' Lakes" waterway. However, given its small size (43 acres), it is not considered one of the nine major hydraulically connected lakes. Spring Lake is located between Bluff Lake to the north and Petite Lake to the south. Spring Lake discharges to the south to Petite Lake. Spring Lake is shallow with maximum depth less than 6 feet (based on Lake County water quality sample depths). Hydraulic detention time of Spring Lake is unknown as it was not specifically included in the Fox Chain O' Lakes Investigation and Water Quality Management Plan (Kothandaraman et. al, 1977).

Spring Lake receives water from Bluff Lake, its own watershed and drainage from surrounding land. The Illinois portion of the watershed is 298 acres. This watershed has a higher percentage of agriculture land use (row crop, grain, or grazing 22%) and less residential (19%) and forested, grasslands, or vegetation (8%) than the upstream watershed (Bluff Lake). As such the percent IC is lower, 13% versus 18%.

Water quality data for Spring Lake are available from Lake County, Legacy STORET and from Illinois EPA from 1972-1976 and 2002 (Appendix B) DO concentrations were below 5.0 mg/L at water depths at or less than 3.0' during July and August 2002.

The majority of recent surface TP concentrations were above the WQS (80%). TP ranged from 0.01 to 0.10 mg/L with an average of 0.07 mg/L (Table 5-3, Figure 5-5, Appendix E). Due to Spring Lake's shallow morphometry, bottom samples were not collected during these sampling programs.

Potential sources of phosphorus are likely to include stormwater runoff and resuspension of lake sediment. There are no active NPDES dischargers located in the immediate Spring Lake watershed. However, Spring Lake receives water from Bluff Lake and its watershed. Point sources impacting Bluff Lake have the potential to impact Spring Lake as well.

There was no LMU Summary Report available for Spring Lake at the time of writing this Stage 1 summary because LMU conducted monitoring in 2002 on behalf of Illinois EPA. Therefore this segment's description is limited to water quality data associated with phosphorus impairment and information provided in the Illinois Integrated Water Quality Report and Section 303(D) List - 2008. Specific information regarding potential sources, shoreline condition, and rooted plant community are not available.

6.1.20.5 Petite Lake

Petite Lake is one of the nine major hydraulically connected lakes in a system collectively known as the "Chain O' Lakes". Petite Lake is one of the smaller lakes in the chain, 165 acres, and is located north of Fox Lake. Mean depth in Petite Lake is approximately 7.7 feet. Petite Lake drains to the south into Fox Lake. Hydraulic detention time of Petite Lake at full capacity, as calculated in Fox Chain O' Lakes Investigation and Water Quality Management Plan (Kothandaraman et. al, 1977), is approximately 6.4 days.

Petite Lake receives water from Spring Lake and its watershed as well as the surrounding lands. The Illinois portion of the watershed is 1,790 acres. This watershed is predominately residential (24%) and forest, grasslands, or vegetation (23%). IC is estimated at 15%.

Water quality data for Petite Lake are available from Lake County, Legacy STORET and from Illinois EPA from 1987, 1989, 1990, 1993, 1996, 1998, 1999, 2002 and 2005 (Appendix B). Surface water DO concentrations were above 5.0 mg/L during the most recent sampling program (2005). Bottom concentrations, however, were below 5.0 mg/L in water depth at or greater than 13' during June, August and October 2005. DO concentrations below 1.0 mg/L were not observed, however.

Since 1998, the majority of the surface water quality samples (71%) were above the WQS for TP. Surface TP concentrations ranged from 0.02 to 0.13 mg/L and averaged 0.07 mg/L (Table 5-3, Figure 5-5, Appendix E). Surface TP from 2005 ranged from 0.04 to 0.13 mg/L and averaged 0.09 mg/L (only one station sampled). Bottom TP concentrations in 2005 were higher and ranged from 0.07 to 0.23, with an average of 0.13 mg/L, suggesting the potential for internal loading.

Although anoxic conditions were not observed in Petite Lake in 2005, older data 1987, 1993, 1996 and 2002 suggest that these conditions do exist on occasion. This is likely dependant on flow and circulation. Periodic lack of oxygen can cause the release of phosphorus from sediments.

Given the potential for anoxia and high TP concentrations in bottom waters, internal loading is a probable source of phosphorus in Petite Lake. Other potential sources include stormwater runoff and point sources. There are no active NPDES dischargers located in the immediate Petite Lake watershed. However, Petite Lake receives water from Spring Lake and its watershed. Point sources impacting Spring Lake have the potential to impact Petite Lake as well.

There was no LMU Summary Report available for Petite Lake because LMU conducted monitoring in 2002 on behalf of Illinois EPA. Therefore, this segment's description is limited to water quality data associated with phosphorus impairment and information provided in the 1977 Fox Chain O' Lakes Investigation and Water Quality Management Plan, Illinois Integrated Water Quality Report and Section 303(D) List - 2008. Specific information regarding potential sources, shoreline condition, and rooted plant community are not available.

6.1.20.6 Fox Lake

Fox Lake is one of the nine major hydraulically connected lakes in a system collectively known as the "Chain O' Lakes". Fox Lake is the largest lake within in the chain at 1881 surface acres. It is located east of Nippersink Lake. Like most of the lakes in the chain, it is shallow with a mean depth of 5.6 feet.

Fox Lake under normal flow conditions flows in a slight northwesterly direction to Nippersink then to Piskatee before reforming the Fox River. Fox Lake receives water from Petite Lake, immediately upstream of Fox Lake, and Duck and Long Lakes as well as many other upstream waterbodies via the Squaw River. Fox Lake is also the receiving water for the surrounding land. Flow may also enter Fox Lake from Nippersink and Grass Lake depending on water flow and wind direction and velocity. Hydraulic detention time of Fox Lake at full capacity, as calculated in Fox Chain O' Lakes Investigation and Water Quality Management Plan (Kothandaraman et. al, 1977), is approximately 48.5 days. A hydrodynamic model can be used to verify the residence time. The detention time is likely lower than predicted. As previously mentioned, water from Nippersink and Grass Lakes may flow into Fox Lake depending on wind velocity and direction, making accurate detention time calculations difficult.

The Fox Lake watershed is large with 22,950 acres in the Illinois portion alone. Twenty-two percent of this area is open space, 19% residential, 26% lakes, reservoirs, or lagoons and 9% forest, grasslands, or vegetation. The Illinois portion of the watershed is 13% impervious.

Water quality data for Fox Lake are available from Lake County, Legacy STORET and from Illinois EPA from 1973, 1979, 1983, 1999, 2002 and 2005 (Appendix B). Surface water DO concentrations were above 5.0 mg/L during the most recent samplings (2002 and 2005). DO concentrations near bottom also contained desirable concentrations (above 5.0 mg/L at 11 and 13').

Recent surface TP concentrations were undesirable and a majority of the averaged samples were above the WQS (67%). TP ranged from 0.03 to 0.16 mg/L, with an average of 0.08 mg/L (Table 5-3, Figure 5-5, Appendix E). 2005 surface TP concentrations ranged from 0.04 to 0.17 mg/L, with an average of 0.10 mg/L (two stations evaluated independently). Bottom concentrations were higher. The range was 0.09-0.23 mg/L and averaged 0.15 mg/L.

Potential sources of phosphorus likely include stormwater runoff and point sources. There are no active NPDES dischargers located in the immediate Fox Lake watershed. However, Fox Lake receives water from Petite Lake and its watershed. Point sources impacting Petite Lake have the potential to impact Fox Lake as well. Fox Lake also receives water from Squaw Creek and therefore may be impacted by discharges within the Squaw Creek watershed (see Long Lake and Fischer Lake description). In addition, Fox Lake periodically receives water from Nippersink and Grass Lakes. Dischargers located in these sub-watersheds have the potential to impact Fox Lake.

There was no LMU Summary Report available for Fox Lake at the time of writing this Stage 1 summary because LMU conducted monitoring in 2002 on behalf of Illinois EPA. Therefore this segment's description is limited to water quality data associated with phosphorus impairment and information provided in the 1977 Fox Chain O' Lakes Investigation and Water Quality Management Plan, Illinois Integrated Water Quality Report and Section 303(D) List - 2008. Specific information regarding potential sources, shoreline condition, and rooted plant community are not available.

6.1.20.7 Grass Lake

Grass Lake is one of the nine major hydraulically connected lakes in a system collectively known as the "Chain O' Lakes". Grass Lake is a 1,623 acre lake and is located just north of Nippersink and Fox Lake. Like most of the lakes in the chain, it is shallow with a mean depth of 2.7 feet. Grass Lake receives water from the Fox River and Marie Lake, their watersheds and drainage from the surrounding area. Interestingly, it is not uncommon for water within Grass Lake to move in an upstream direction to Marie Lake. In other instances, water in Grass Lake moves south into Nippersink Lake. The pattern depends on Fox River flows and wind velocity and direction. Hydraulic detention time of Grass Lake at full capacity, as calculated in Fox Chain O' Lakes Investigation and Water Quality Management Plan (Kothandaraman et. al, 1977), is approximately 4.3 days.

The Grass Lake watershed is also very large. The Illinois portion is 13,844 acres. Much of this area is classified as open space (28%). The two most prominent land uses after open space are residential (16%) and lakes, reservoirs, or lagoons (22%). The Grass Lake Illinois watershed IC is 12%.

Water quality data for Grass Lake are available from Lake County, Legacy STORET and from Illinois EPA from 1973, 1983, 1987, 1990, 1993, 1996, 1999, 2002 and 2005 (Appendix B). Surface water DO concentrations were above 5.0 mg/L. Bottom concentrations were also well oxygenated due to the lakes shallow morphometry.

Since 1999, the majority of the surface water quality samples (80%) were above the WQS for TP. Surface TP concentrations ranged from 0.04 to 0.25 mg/L and averaged 0.11 mg/L (Table 5-3, Figure 5-5, Appendix E). Surface TP in 2005 ranged from 0.04 to 0.27 mg/L and averaged 0.15 mg/L (all stations evaluated independently). Bottom samples were not collected in Grass Lake because it is so shallow.

Potential sources of phosphorus likely include stormwater runoff, resuspension of lake sediment and point sources. There are no active NPDES dischargers located within the immediate Grass Lake watershed. However, Grass Lake receives water from the Fox River, Marie Lake and periodically from Fox and Nippersink Lakes. Dischargers located in these sub-watersheds have the potential to impact Grass Lake.

There was no LMU Summary Report available for Grass Lake at the time of writing this Stage 1 summary because LMU conducted monitoring in 2002 on behalf of Illinois EPA. Therefore this segment's description is limited to water quality data associated with phosphorus impairment and information provided in the 1977 Fox Chain O' Lakes Investigation and Water Quality Management Plan, Illinois Integrated Water Quality Report and Section 303(D) List - 2008. Specific information regarding potential sources, shoreline condition, and rooted plant community are not available.

6.1.20.8 Nippersink Lake

Nippersink Lake is one of the nine major hydraulically connected lakes in a system collectively known as the "Chain O' Lakes". Nippersink is a 718 acre lake located immediately upstream of Piskatee Lake, which is the farthest downstream of all lakes in the chain before reforming the Fox River. Like most of the lakes in the chain, it is shallow with a mean depth of 3.0 feet. Hydraulic detention time of Nippersink Lake at full capacity, as calculated in Fox Chain O' Lakes Investigation and Water Quality Management Plan (Kothandaraman et. al, 1977), is approximately 1.5 days. Water within Nippersink Lake generally flows in a southwesterly direction, but under low flow conditions backflow can occur. Water from Piskatee Lake can flow into Nippersink Lake depending on wind velocity and direction, making accurate detention time calculations difficult.

Nippersink Lake receives water from two connected lakes, Fox and Grass Lake, their watersheds and drainage from surrounding land. The Illinois portion of the watershed is 23,405 acres and is 22% open space, 25% lakes, reservoirs, or lagoons, and 19% residential. Thirteen percent of the Illinois portion of the watershed is impervious.

Water quality data for Nippersink Lake are available from Lake County, Legacy STORET and from Illinois EPA from 1996, 1999, 2002 and 2005 (Appendix B). Surface water DO concentrations were above 5.0 mg/L during the most recent samplings (2002 and 2005). DO concentrations near bottom also contained desirable concentrations (9.3 and 10.8 mg/L at 4' in 2005).

Since 1999, most surface TP concentrations were above the WQS. TP ranged from 0.08 to 0.27 mg/L, with an average of 0.16 mg/L for the period of record (Table 5-3, Figure 5-5, Appendix E). Due to Nippersink's shallow morphometry, bottom samples were generally not collected during these sampling programs.

Potential sources of phosphorus likely include stormwater runoff, resuspension of lake sediment and point sources. The Spring Grove Sewer Treatment Plant and the Fox Lake School District 114 are located within the Nippersink Lake watershed and have the potential to impact Nippersink Lake. Dischargers located within the Fox Lake, Grass Lake, Dunns Lake and Pistakee Lake watersheds also have the potential to impact water quality within Nippersink Lake.

There was no LMU Summary Report available for Nippersink Lake at the time of writing this Stage 1 summary because LMU conducted monitoring in 2002 on behalf of Illinois EPA. Therefore this segment's description is limited to water quality data associated with phosphorus impairment and information provided in the 1977 Fox Chain O' Lakes Investigation and Water Quality Management Plan, Illinois Integrated Water Quality Report and Section 303(D) List - 2006. Specific information regarding potential sources, shoreline condition, and rooted plant community are not available.

6.1.20.9 Pistakee Lake

Pistakee Lake is one of the nine major hydraulically connected lakes in a system collectively known as the "Chain O' Lakes". Pistakee Lake is a 1,700 acre lake and is the farthest downstream of all lakes in the chain before reforming the Fox River. Like most of the lakes in the chain, it is shallow with a mean depth of 5.2 feet. Hydraulic detention time of Piskatee Lake at full capacity, as calculated in Fox Chain O' Lakes Investigation and Water Quality Management Plan (Kothandaraman et. al, 1977), is approximately 10.6 days.

Piskatee Lake receives water from Nippersink and Redhead Lakes, their watersheds, the Nippersink Creek watershed as well as the surrounding lands. As such it has the largest watershed of all lakes in the chain. The Illinois portion of the watershed is 170,857 acres and includes the Nippersink Creek watershed (Illinois portion). The majority of this land is row crop, grain, or grazing (37%), 16% residential and 11% open space. The IC is only 11% but the watershed-to-lake area ratio is huge (100:1)

Water quality data for Pistakee Lake are available from Lake County, Legacy STORET and from Illinois EPA from 1973, 1983, 1987, 1999, 2002 and 2005 (Appendix B). Surface water DO concentrations were above 5.0 mg/L during the most recent sampling program (2005). Bottom concentrations, however, were below 1.0 mg/L in water depth at or greater than 15' in 2005.

Pistakee Lake is listed as impaired due to excessive phosphorus concentrations. The majority of the surface water quality samples since 1999 were above the WQS for TP (63%). Surface TP concentrations ranged from 0.02 to 0.35 mg/L and averaged 0.13 mg/L (Table 5-3, Figure 5-5, Appendix E). Surface TP from 2005 ranged from 0.08 to 0.47 mg/L and averaged 0.23 mg/L (all stations evaluated independently), all of which above the WQS. Bottom TP concentrations in 2005 were much higher and ranged from 0.18 to 3.04, with an average of 1.07 mg/L (only one station sampled at the bottom).

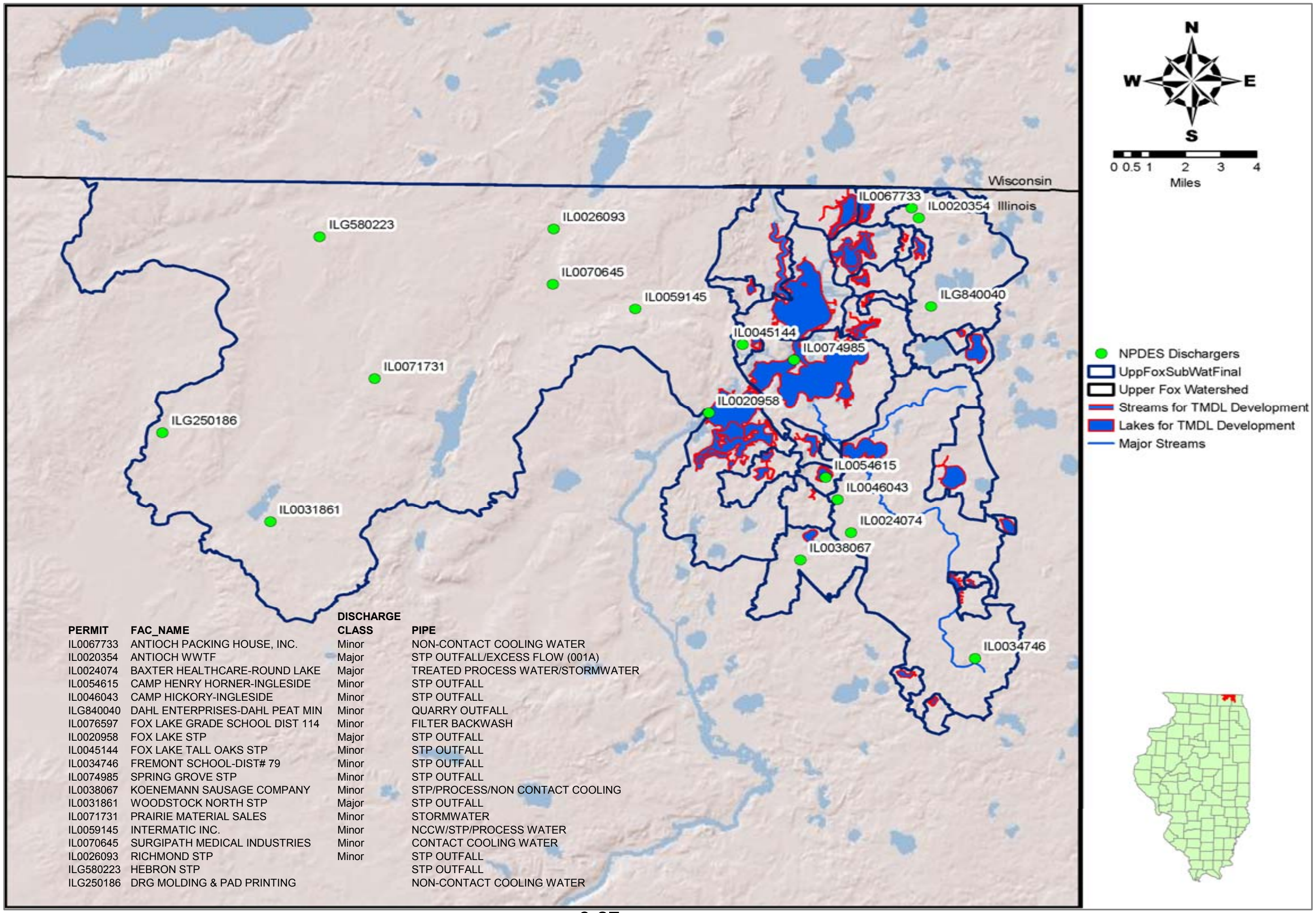
Pistakee Lake will be de-listed as part of the 2008 Integrated Report. Based on the most recent data for ammonia available (2008), Pistakee Lake surface water data no longer show impairment due to excessive ammonia nitrogen concentrations. Ammonia was sampled at two locations within Pistakee Lake in 2008 (RTU-1 and RTU-3) at surface and bottom locations. Usable surface water (1.0 ft water depth) ammonia nitrogen concentrations ranged from 0.03 to 0.18 mg/L. None of these values exceeded the 15 mg/L instantaneous standard. In addition, none of the individual surface water concentrations exceed either the Acute or Chronic WQS (Table 5-1).

There was no LMU Summary Report currently available for Piskatee Lake because LMU conducted monitoring in 2002 on behalf of Illinois EPA. Therefore, this segment's description is limited to water quality data associated with phosphorus impairment and information provided in the 1977 Fox Chain O' Lakes Investigation and Water Quality Management Plan, Illinois Integrated Water Quality Report and Section 303(D) List - 2008. Specific information regarding potential sources, shoreline condition, and rooted plant community are not available.

6.2 Potential Point Sources

Active NPDES point sources in the Fox River/Upper Chain O' Lakes watershed are listed and mapped on Figure 6-2 (dischargers for each individual waterbody can be found in Appendix A). These data were derived from both the publically available Better Assessment Science Integrating Point & Nonpoint Sources (BASINS) program and the inventory of active NPDES dischargers provided by IL EPA. If a point source is located within an impaired segments watershed, this point source is listed as a potential source within the segment description. Specific information regarding each discharger is provided in Appendix D. In addition to NPDES point sources, Stage 3 of the TMDL will also address municipal separate storm sewer systems (MS4s) and industrial and construction stormwater permits as they are also considered point source contributors. Because no GIS data layer currently exists that accurately displays the locations of relevant MS4s, the identification of these permittees will occur in the Stage 3 report.

Figure 6-2: Upper Fox River/Chain O'Lakes Active NPDES Dischargers



PERMIT	FAC_NAME	DISCHARGE CLASS	PIPE
IL0067733	ANTIOCH PACKING HOUSE, INC.	Minor	NON-CONTACT COOLING WATER
IL0020354	ANTIOCH WWTF	Major	STP OUTFALL/EXCESS FLOW (001A)
IL0024074	BAXTER HEALTHCARE-ROUND LAKE	Major	TREATED PROCESS WATER/STORMWATER
IL0054615	CAMP HENRY HORNER-INGLESIDE	Minor	STP OUTFALL
IL0046043	CAMP HICKORY-INGLESIDE	Minor	STP OUTFALL
ILG840040	DAHL ENTERPRISES-DAHL PEAT MIN	Minor	QUARRY OUTFALL
IL0076597	FOX LAKE GRADE SCHOOL DIST 114	Minor	FILTER BACKWASH
IL0020958	FOX LAKE STP	Major	STP OUTFALL
IL0045144	FOX LAKE TALL OAKS STP	Minor	STP OUTFALL
IL0034746	FREMONT SCHOOL-DIST# 79	Minor	STP OUTFALL
IL0074985	SPRING GROVE STP	Minor	STP OUTFALL
IL0038067	KOENEMANN SAUSAGE COMPANY	Minor	STP/PROCESS/NON CONTACT COOLING
IL0031861	WOODSTOCK NORTH STP	Major	STP OUTFALL
IL0071731	PRAIRIE MATERIAL SALES	Minor	STORMWATER
IL0059145	INTERMATIC INC.	Minor	NCCW/STP/PROCESS WATER
IL0070645	SURGIPATH MEDICAL INDUSTRIES	Minor	CONTACT COOLING WATER
IL0026093	RICHMOND STP	Minor	STP OUTFALL
ILG580223	HEBRON STP		STP OUTFALL
ILG250186	DRG MOLDING & PAD PRINTING		NON-CONTACT COOLING WATER

7.0 TMDL Approach and Next Stages

This chapter discusses the methodology that may be used for the development of TMDLs for the Upper Fox River/Chain O' Lakes watershed. While a detailed watershed modeling approach can be advantageous, a simpler approach is often able to efficiently meet the requirements of a TMDL and yet still support a TMDL-guided and site-specific implementation plan. IL EPA has used simplified approaches such as Load Duration Curve, BATHTUB, etc., for most TMDLs developed in the State of Illinois. The similar approaches were proposed in the procurement process for these watersheds. The final selection of a methodology will be determined with consultation with the IL EPA based on the following factors:

- Fundamental requirements of a defensible and approvable TMDL
- Data availability
- Fund availability
- Public acceptance
- Complexity of water body

A simpler approach shall be used as long as it adequately supports the development of a defensible TMDL. If it is deemed that this approach will not suffice, a more sophisticated modeling approach will be recommended for analysis to help better establish a scientific link between the potential pollutant sources and the water quality indicators for the attainment of designated uses. Methodology for estimating daily loads will depend on available data as well as the selected analysis.

7.1 Recommended Modeling Approach for Dissolved Oxygen and pH

Hidden Lake is the only segment within the Upper Fox River/Chain O' Lakes watershed targeted for DO and pH TMDL development. Based on preliminary evaluation of water quality data for Hidden Lake, DO and pH impairment are likely associated with excessive nutrient concentrations. Excessive nutrients often result in algal bloom and extensive rooted plant growths which can deplete oxygen and increase pH. The two main ways oxygen depletion occurs related to plant growth, both planktonic and rooted, include decomposition and respiration. Decomposition is the process of breaking down matter. During this process, aerobic bacteria utilize oxygen to convert organic matter into energy and release carbon dioxide. If the rate of decomposition is great enough, this process can result in deleterious oxygen depletion. Oxygen is also used during plant respiration for the conversion of stored sugars into energy. Excessive plant respiration can result in oxygen depletion. DO concentrations in lakes and ponds are typically at their lowest levels just before dawn after an evening of respiration without oxygen generation by photosynthesis.

Excessive plant densities can also impact pH. During the day plants utilize carbon dioxide for photosynthesis. The production of the hydroxyl ion and the consumption of hydrogen ions during photosynthesis results in an increase in water pH when excessive. pH is generally at its peak in the late afternoon.

These two processes are the likely cause of low DO and high pH in Hidden Lake. Hidden Lake contains excessive phosphorus levels, a nutrient required for algal growth and is typically the nutrient in shortest supply. Chlorophyll *a* concentrations (a measurement of algal biomass) are highly correlated with phosphorus concentrations. Waterbodies with high phosphorus levels generally contain excessive algal or rooted plant biomass. Given that Hidden Lake contain excessive TP concentrations which are likely related to the low DO and high pH, a phosphorus TMDL should be prepared using available data (see discussion on TP approach). Additional sampling is not required in order to proceed with this TMDL. The TMDL process for Hidden Lake will proceed to Stage 3.

7.2 Recommended Modeling Approach for Fecal Coliform

Many states currently use load duration curves for fecal coliform TMDLs for its simplicity and effectiveness. Load duration curves use water quality criteria, ambient concentrations, and observed flows to estimate loading capacities for streams under various flow conditions. The load duration methodology is recommended for the Fox River DT-35 TMDL. An alternative is discussed in the later part of this section. It should be noted that the majority of the bacteriological data available for Deep Lake is *E. coli* and therefore it may be more appropriate to develop an *E. coli* TMDL based on the "Ambient Water Quality Criteria for Bacteria – 1986" freshwater bathing criteria. TMDL development methodology for E. coli would be similar to that of fecal coliform.

The first step in load duration process is to obtain an appropriate stream flow record. This is often difficult for streams not monitored by the USGS. There are methods, however, for developing streamflow statistics on ungaged streams. Regional curve numbers and regression equations are typical used in such instances. Alternatively, a gaged reference watershed can be used to obtain a streamflow record.

Flow duration curves are developed from streamflow records spanning multiple decades. The flow duration curve is based on flow frequency which provides a probability of meeting or exceeding a given flow. The duration curve is broken into hydrologic categories where high flows represent a duration interval of 0-10%, moist conditions represent 10-40%, mid-range flows 40-60%, dry conditions 60-90% and low flows 90-100%.

Once the flow duration curve is established, a load duration curve can be generated by multiplying streamflow with the numerical water quality standard and a conversion factor to obtain the load per day for a given streamflow. Individual measurements can be plotted against the load duration curve to evaluate patterns of impairment. Values that fall above the load duration line indicate an exceedance of the daily load and hence, water quality standard. These data can aid in determining whether impairment occurs more frequently in one of the hydrologic categories (wet, moist, mid-range, dry or low).

The MOS for duration curves can be implicit or explicit. Implicit MOS are derived from the inherent assumptions in establishing the water quality target. Explicit MOS include setting the water quality target lower than the WQS or not allocating a portion of the allowable load. For the Fox River DT-35 and potentially Deep Lake TMDL, WLAs will be based on permit levels or percent reductions required to meet the target load. The MOS will be determined during modeling and will be further explained in the Stage 3 report. Design discharge flow, permit limits and TMDL targets will be used to calculate a daily load and serve as the WLA. WLAs for NPDES-permitted stormwater discharges, including current and future MS4s, "Urbanized" areas, construction and industrial discharges and SSOs that do not have numerical effluent limitations will be expressed as a percent reduction instead of a numerical target. The NPDES Phase II Stormwater Regulations require all areas defined as "Urbanized" by the US Census obtain a permit for the discharge of stormwater. A map of these MS4 dischargers will be provided in the Stage 3 report. Stormwater discharges are required to meet the percentage reduction or the existing instream standard for the pollutant of concern, whichever is less restrictive. The load allocation (LA) for all non-regulated sources, including non-point sources, will also be expressed as a reduction of the actual load. Sanitary Sewer Overflows (SSOs) will not receive an allocation as they are deemed illicit discharges.

The critical condition for fecal coliform load duration TMDLs is established by hydrologic category. It is defined as the greatest reduction needed to meet WQS among all hydrologic categories. Each hydrologic category will get its own stand-alone reduction.

Seasonality of loading will also be evaluated. Flow duration intervals will be plotted by month to determine if there is a strong seasonal component. Although this will not change allocations, this may assist in implementation planning.

Potential sources of bacteria in Deep Lake are waterfowl (mainly Canada geese), runoff, and failing septic systems (LCDH 2004). Historical loading of untreated sewer may also have contributed to water quality problems in Deep Lake. The Simple Method is the proposed for the development of a pathogen indicator (either fecal coliform or *E. coli*) TMDL. The Simple Method estimates loads based on runoff volume and pollutant concentrations on an areal basis. Impacts associated with direct loadings (failing septic systems and waterfowl) will be made in a similar way. Literature derived loadings per bird and/septic system will be used to generate direct loads. The MOS, WLA and LA will be determined in a similar manner as with the load duration curve (described above). The critical condition will be defined as the bathing season (May through October). Selection of this critical period will also address seasonality.

7.3 Recommended Modeling Approach for Total Ammonia Nitrogen

Piskatee Lake is listed as impaired due to elevated ammonia and phosphorus concentrations. Piskatee Lake surface water does not exceed the anytime, acute or chronic ammonia WQS. However, bottom ammonia concentrations do exceed the chronic standard during mid and late summer. This is not uncommon in highly eutrophic waters where anoxic conditions (lack of oxygen) exist due to decay processes (as discussed above in the DO Approach section). In oxygenated conditions ammonia is readily converted to nitrate by bacteria. Under anoxic conditions this process is inhibited and ammonia accumulates which can result in a toxic environment. Anoxic conditions exist in Piskatee Lake bottom waters (below 17') in June, July and August in 2005. Furthermore, elevated levels of TP and chlorophyll *a* have been consistently measured in Piskatee Lake (1983, 1987, 2002 and 2005) suggesting that eutrophication (elevated nutrients and high productivity levels) are the likely cause of the excessive ammonia concentrations.

An ammonia specific TMDL is not recommended at this time since surface levels of ammonia do not exceed the WQS. A phased implementation of a TP TMDL is recommended. See the recommended approach discussed below.

7.4 Recommended Modeling Approach for Total Phosphorus

For the majority of the 28 segments listed for TMDL development due to excessive phosphorus concentrations an export coefficient model linked to empirical in-lake response models will be used to determine existing loading and load reductions required to these segments into compliance with current WQS. In addition to these segments, a TP TMDL is also recommended for Hidden Lake and Pistakee Lake with the objective to bring DO, pH and ammonia variables into compliance with WQS.

A more comprehensive approach will be needed for phosphorus impaired lakes that are part of the "Chain O' Lakes". Fox River's Chain O' Lakes consists of nine major lakes that are hydraulically connected by a series of waterways, namely Fox, Marie, Catherine, Channel, Nippersink, Pistakee, Grass, Bluff and Petite Lakes; although not considered a major lake, Spring Lake is also part of the chain. Besides the direct loading from the banks, these lakes often have multiple tributaries feeding flows and pollutant loads. Unidirectional flow does not always occur within the main body of the chain because of flat topography and back water effect of a downstream dam. The hydrodynamics of the lakes should be taken into account in estimating nutrient loading to each lake. Therefore, it is recommended that a receiving water model is developed for the entire Chain O' Lakes, which includes a hydrodynamic model and a water quality model. The receiving water model is coupled with a watershed loading model. Specifically, the Hydrological Simulation Program--Fortran (HSPF) model is recommended for the watershed hydrology and pollutant loading. A hydrodynamic model, Environmental Fluid Dynamics Code (EFDC), is recommended to simulate water movement in the Chain O' Lakes, which is linked to Water Quality Analysis Simulation Program (WASP). Prior to TMDL Stage 3 work, a technical memo will be prepared to provide conceptual framework and details on how these models will be used to develop phosphorus TMDLs for Chain O' Lakes.

Table 7-1 provides a listing of phosphorus impaired lakes and the proposed modeling approach. For the lakes not associated with the chain, LLRM is proposed. The following section briefly describes the recommended models.

Table 7-1: Phosphorus TMDLs and Proposed Method

LLRM	HSPF/EFDC/WASP
Antioch	Bluff
Davis	Catherine
Duck	Channel
Dunns	Fox Lake
Fischer	Grass
Fish-Duncan	Marie
Grays	Nippersink
Hidden	Petite
Lake Tranquility	Pistakee
Long	Spring
Mcgreal	
North Churchill	
Redhead	
Round	
South Churchill	
Summerhill Estate	
Sun	
Turner	
Wooster	

7.4.1 LLRM

The suggested model, Lake Loading Response Model (LLRM), was developed by AECOM (formerly ENSR) and has been used for more than 35 lake TMDLs. LLRM uses export coefficients for runoff, groundwater and nutrients to estimate loading as a function of land use. Yields will be assigned to each defined parcel (sub-watershed) in the lake watershed. Loading estimates will be adjusted based on proximity to the lake, soils and major Best Management Practices (BMPs) in place. Model yields will be compared to measured data, where available. Export coefficients and attenuation factors will be adjusted such that model loading accurately reflects actual loading based on sample data and measured in-lake concentrations.

Watershed and sub-watershed boundaries have been delineated and watershed land use has been determined using publically available datalayers as part of this Stage 1 investigation. LLRM will be set-up on a sub-watershed level using available land use and average annual precipitation. The spreadsheet-based export coefficient model allows the user to select watershed yield coefficients and attenuation factors from a range appropriate for the region. The model also includes direct inputs for atmospheric deposition, septic systems, point sources, waterfowl and internal loading from lake sediments.

The generated load to the lake is processed through five empirical models: Kirchner & Dillon 1975, Vollenweider 1975, Larsen & Mercier 1976, Jones & Bachmann 1976 and Reckhow 1977. These empirical models predict in-lake phosphorus concentrations based on loading and lake characteristics such as mean water depth, volume, inflow, flushing and settling rates. Loads can be generated within the lake from direct release from the sediment (dissolved P, ammonium N), resuspension of sediment (particulate P or N) with possible dissociation from particles. Predicted in-lake phosphorus is compared to measured data. An acceptable agreement between measured and predicted concentrations indicates loading estimates are appropriate for use in the preparation of a TMDL. Adjustments to the loading portion of the model are made when necessary based on best professional judgment to ensure acceptable agreement between measured and predicted concentrations. These empirical models also predict chlorophyll concentrations and water clarity (Secchi disk transparency). LLRM also includes a statistical evaluation of algal bloom probability.

Once the model has been calibrated to existing conditions, adjustments to the model can be made to determine the load reductions necessary to meet WQS. Different scenarios can be modeled to determine the appropriate BMPs during the implementation plan stage. In some instances, waterbodies are naturally eutrophic and may not achieve numerical WQS LLRM is most effective when calibrated with water quality data for the target system, but can be used with limited data. While it is a spreadsheet model with inherent limitations on applied algorithms and resultant reliability of predictions, it provides a rational means to link actual water quality data and empirical models in an approach that addresses the whole watershed and lake. LLRM is an easy and efficient method of estimating current loads to lakes as well as providing predictions on lake response under countless loading scenarios.

LLRM, like most simplified lake models, predicts phosphorus concentrations and estimates loading on an average annual basis. As required by the EPA, the TMDL must be expressed on a daily basis. However, there is some flexibility in how the daily loads may be expressed (US EPA, 2006). Several of these options are presented in “Options for Expressing Daily Loads in TMDLs” (US EPA, 2007). For TMDLs based on watershed load and in-lake response models providing predictions on an annual basis, the EPA offers a method for calculating the maximum daily limit based on long-term average and variability. This statistical approach is preferred since long periods of continuous simulation data and extensive flow and loading data are not available. The following expression assumes that loading data are log-normal distributed and is based on a long term average load calculated by the empirical model and an estimation of the variability in loading.

$$MDL = LTA * e^{[z\sigma - 0.5\sigma^2]}$$

Where:
MDL = maximum daily limit
LTA = long-term average
Z = z-statistic of the probability of occurrence
$\sigma^2 = \ln(CV^2 + 1)$
CV= coefficient of variation

Data from similar lakes will be used in situations where there are not enough data to determine probability of occurrence or coefficient of variation for the impaired waterbody. The water quality data points from the entire watershed will be used in a statistic analysis to determine z-score and CV.

MOS for phosphorus using this method is implicit. There is substantial uncertainty when introducing concentration inputs to the models that results from the timing of sampling and analytical methods. Similarly, the empirical equations used to predict in-lake phosphorus concentrations, mean and maximum chlorophyll, Secchi disk transparency, and bloom probability also introduce variability into the predictions.

WLA will be determined based on NPDES permit effluent limitations and design flows. WLAs for NPDES-permitted stormwater discharges, including current and future MS4s, “Urbanized” areas, construction and industrial discharges that do not have numerical effluent limitations will be expressed as a reduction. Stormwater discharges are required to meet the existing instream standard for the pollutant of concern. LAs will also be expressed as a load reduction.

Critical conditions for lakes typically occur during the summertime, when the potential (both occurrence and frequency) for nuisance algal blooms are greatest. The loading capacity for total phosphorus is set to achieve desired water quality standards during this critical time period and also provide adequate protection for designated uses throughout the year. The target goal is based on average annual values, which is typically higher than summer time values. Therefore a load allocation based on average concentrations will be sufficiently low to protect designated uses in the critical summer period.

The LLRM derived TMDL takes into account seasonal variations because the allowable annual load is developed to be protective of the most sensitive (i.e., biologically responsive) time of year (summer), when conditions most favor the growth of algae. Maximum annual loads are calculated based on an overall annual average concentration. Summer epilimnetic concentrations are typically lower than the average annual concentration, so it is assumed that loads calculated in this manner will be protective of designated uses in the summer season. It is possible that concentrations of phosphorus will be higher than the annual average during other seasons, most notably in the spring, but higher phosphorus levels at that time does not compromise uses. The proposed TMDL is expected to protect all designated uses of the impaired waterbody.

7.4.2 Models for Chain O' Lakes

HSPF Watershed Loading Model

HSPF model is a US EPA program for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. The HSPF model uses information such as the time series of rainfall, temperature and solar radiation; land surface characteristics such as land-use patterns; and land management practices to simulate the processes that occur in a watershed. The result of this simulation is a time series of the quantity and quality of runoff from an urban or agricultural watershed. Flow rate, sediment load, and nutrient and pesticide concentrations are predicted. HSPF includes an internal database management system to process the large amounts of simulation input and output. The HSPF model incorporates the watershed-scale Agricultural Runoff Model (ARM) and Non-Point Source (NPS) models into a basin-scale analysis framework that includes pollutant transport and transformation in stream channels.

The benefit of using HSPF model is that it not only supports TMDL development but also can be used as a watershed management tool to assist with watershed planning and decision-making. The model provides the spatial and temporal resolution for load allocation. In addition, an HSPF model of the Upper Fox River/Chain O' Lakes will complement the existing HSPF model being developed by ISWS for the Lower Fox River watershed.

EFDC

The Environmental Fluid Dynamics Code (EFDC Hydro) is a state-of-the-art hydrodynamic model that can be used to simulate aquatic systems in one, two, and three dimensions. It has evolved over the past two decades to become one of the most widely used and technically defensible hydrodynamic models in the world. EFDC uses stretched or sigma vertical coordinates and Cartesian or curvilinear, orthogonal horizontal coordinates to represent the physical characteristics of a waterbody. It solves three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable-density fluid. Dynamically-coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity and temperature are also solved. The EFDC model allows for drying and wetting in shallow areas by a mass conservation scheme. The input of EPDC model includes inflows from watershed, boundary conditions, meteorological data, waterbody bathymetry. The outputs include water level profile, depth, and velocity fields, which are further used in WASP model to simulate the fate and transport of pollutant.

WASP

The Water Quality Analysis Simulation Program (WASP) is a water quality model developed for US EPA. This model helps users interpret and predict water quality responses to natural phenomena and manmade pollution for various pollution management decisions. WASP is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. WASP allows the user to investigate 1, 2, and 3 dimensional systems, and a variety of pollutant types. The state variables for the given modules are given in the table below. The time varying processes of advection, dispersion, point and diffuse mass loading and boundary exchange are represented in the model. WASP also can be linked with hydrodynamic and sediment transport models that can provide flows, depths, velocities, temperature, salinity and sediment fluxes. The model input includes the flow velocity field, depth, and pollutant loads. The output will be pollutant concentrations and mass in water body, which are compared against water quality standards.

7.5 Stages 2 & 3

Effective TMDL development heavily relies on site-specific data. Sufficient flow and water quality data are required for the evaluation of water conditions and for model calibration. In fact, data availability often dictates the modeling approach used for various watersheds. Five types of data are crucial for the Upper Fox River/Chain O' Lakes watershed TMDL development:

- Flow data
- Meteorological data
- Water quality data
- Watershed and water body physical parameters
- Source characteristics data

The Illinois EPA believes there are ample data to progress to Stage 3 for the following segments:

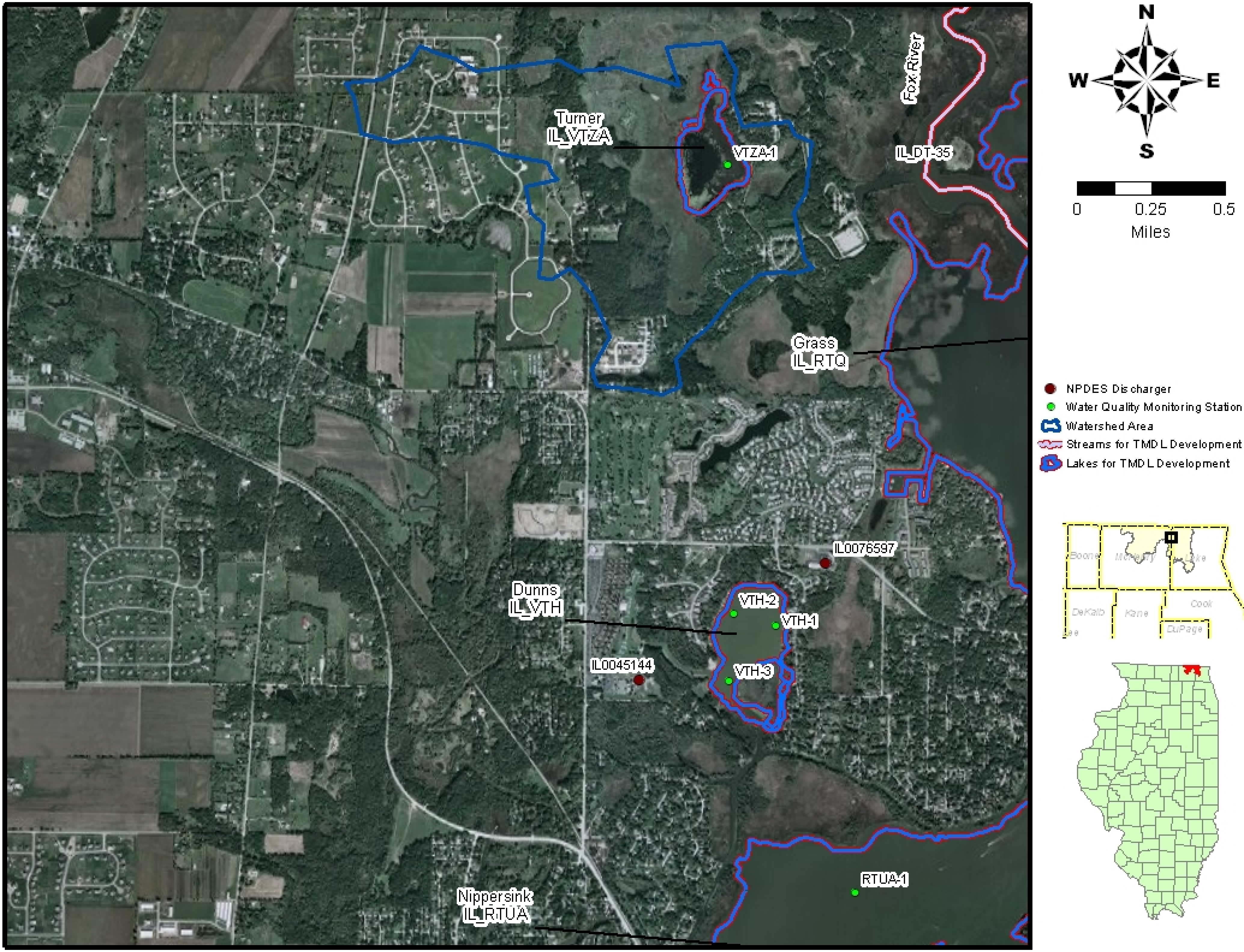
Catherine	Marie
Channel	McGreal
Davis	Nippersink
Deep	North Churchill
Duck	Petite
Fischer	Pistakee
Fish-Duncan	South Churchill
Fox River	Summerhill Estate
Grass	Sun
Hidden	Turner
Lake Tranquility	Wooster
Long	

Therefore the TMDL process for these segments will progress to Stage 3 - model calibration, TMDL scenarios, and implementation plans using the methods described in the previous sub-section.

IL EPA and Lake County sampled in twelve lakes in 2008, including Catherine, Channel, Bluff, Deep, Fox, Grass, Long, Nippersink, Petite, Pistakee, Sun, and Wooster Lakes. Six lakes are scheduled for additional sampling in 2009. These lakes include Anitoch, Dunns, Grays, Redhead, Round and Spring Lake. These collected data will be assessed to confirm if impairments still exist, and if so, the data will be used for Stage 3 analysis.

Appendix A

Waterbody Maps



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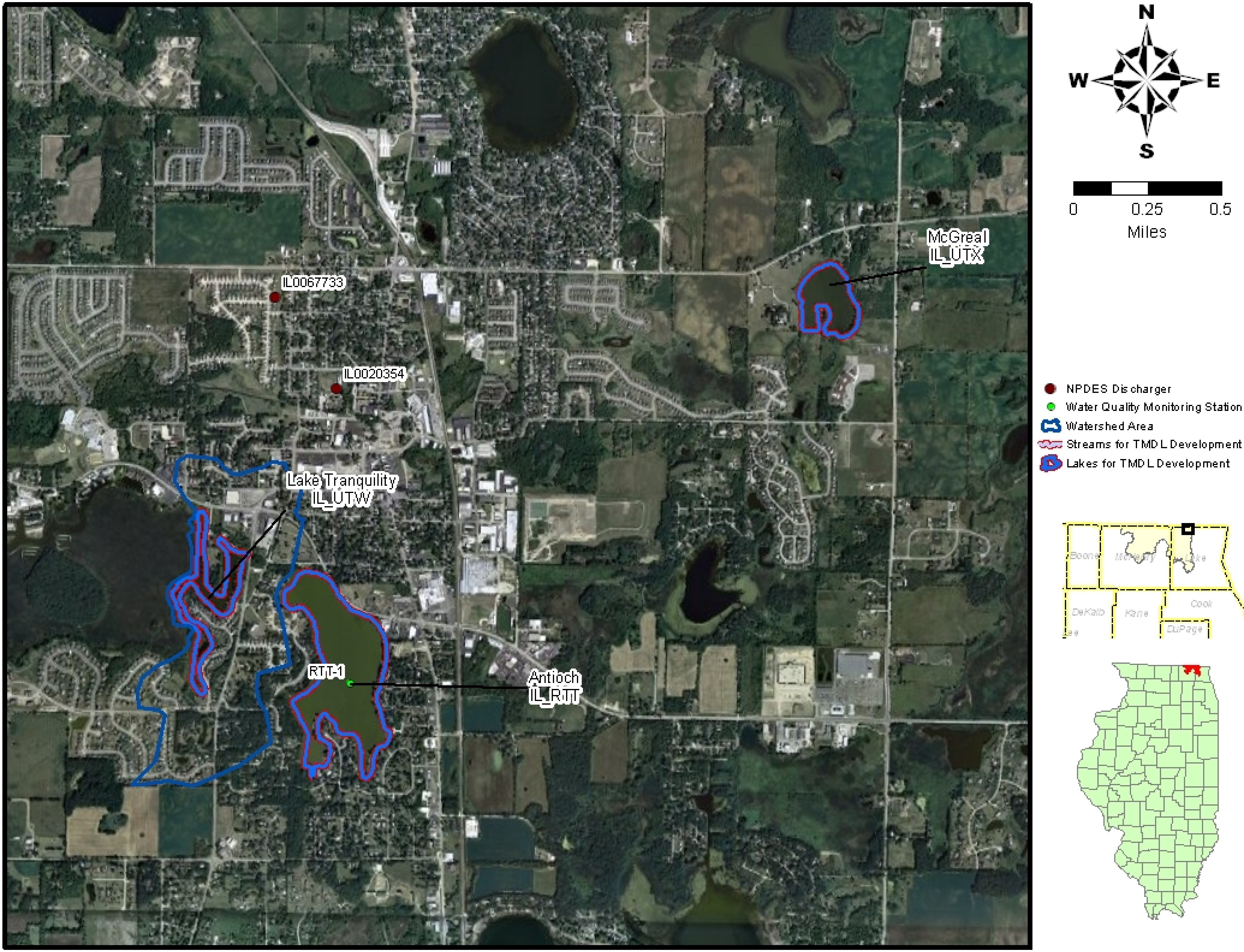
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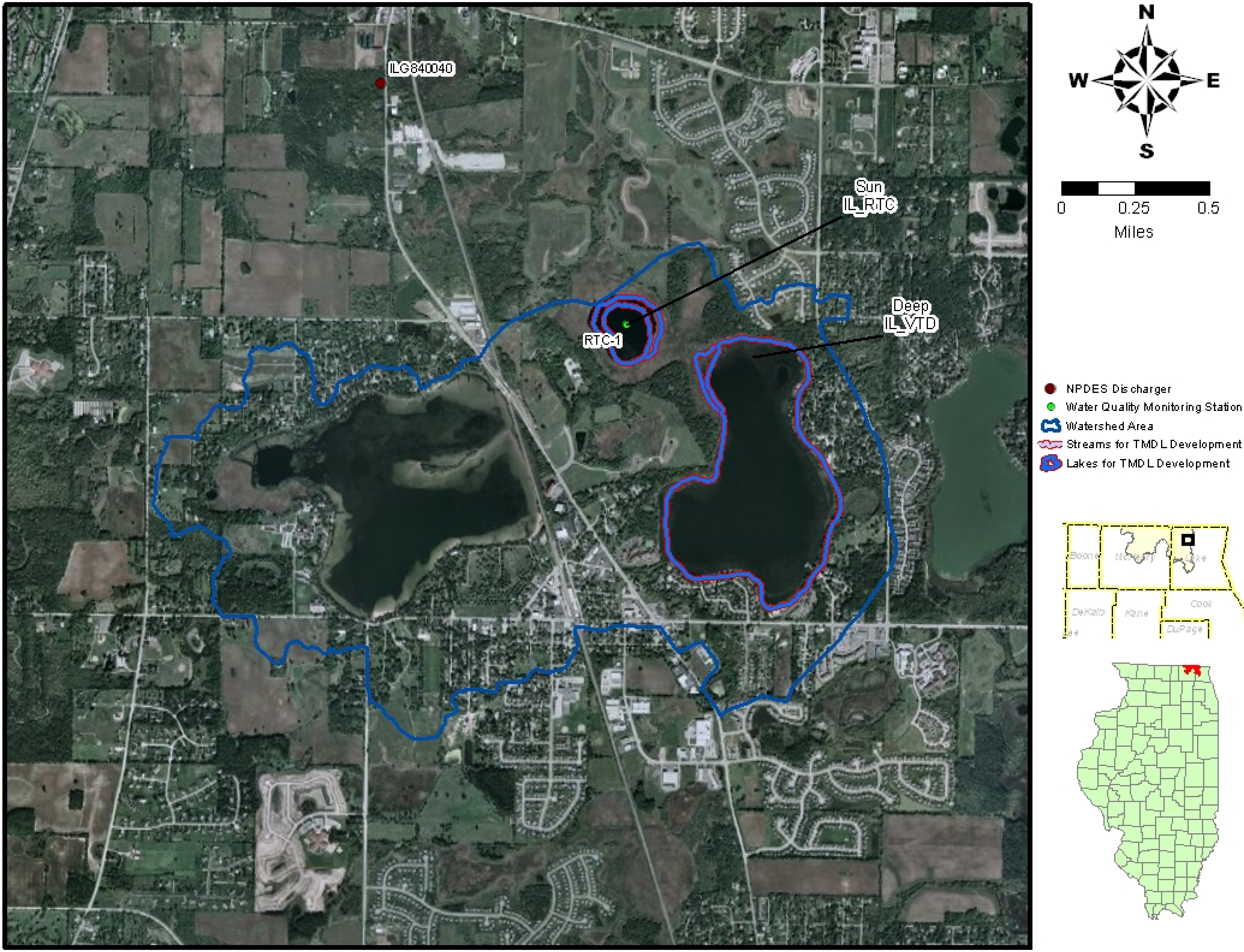
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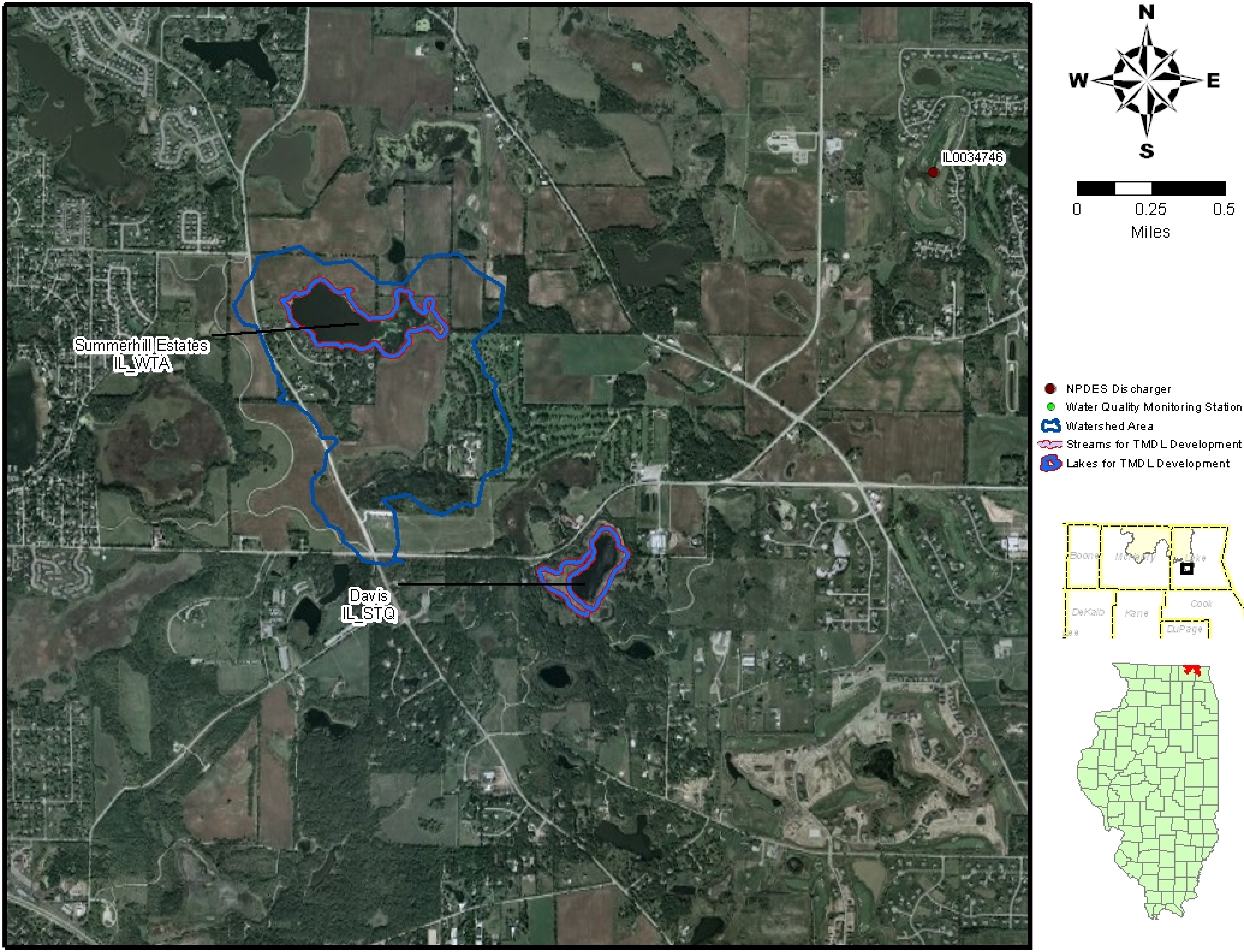

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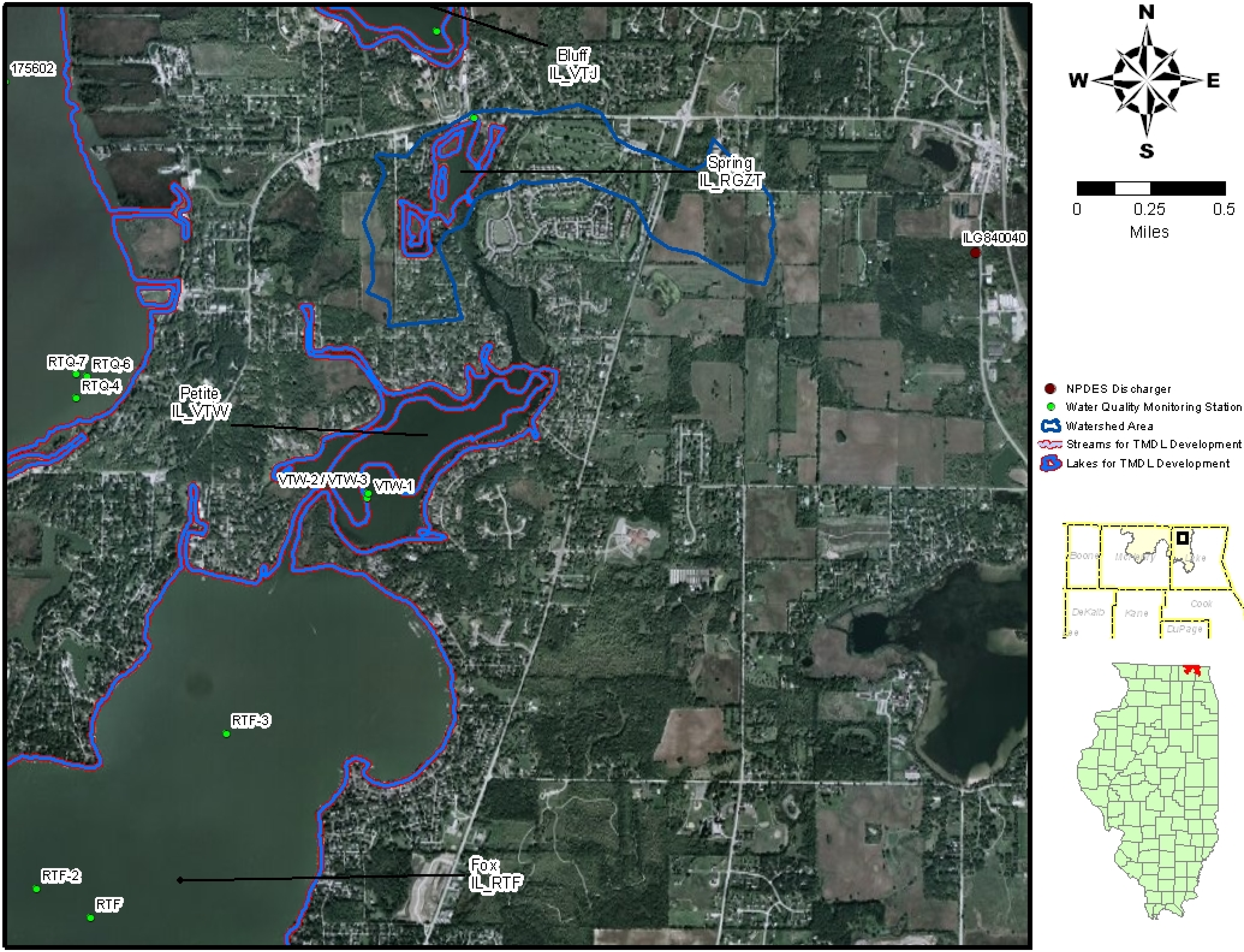
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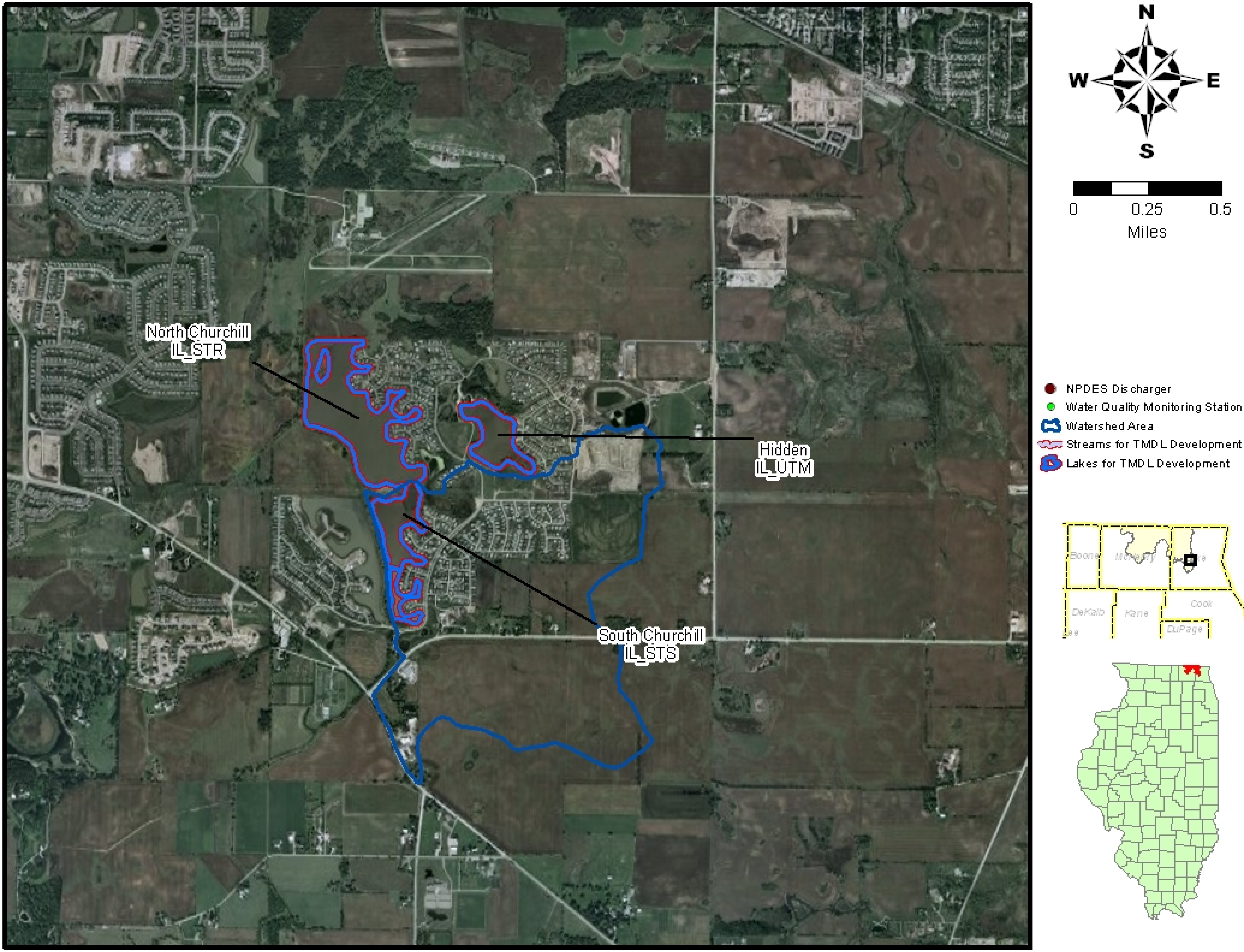
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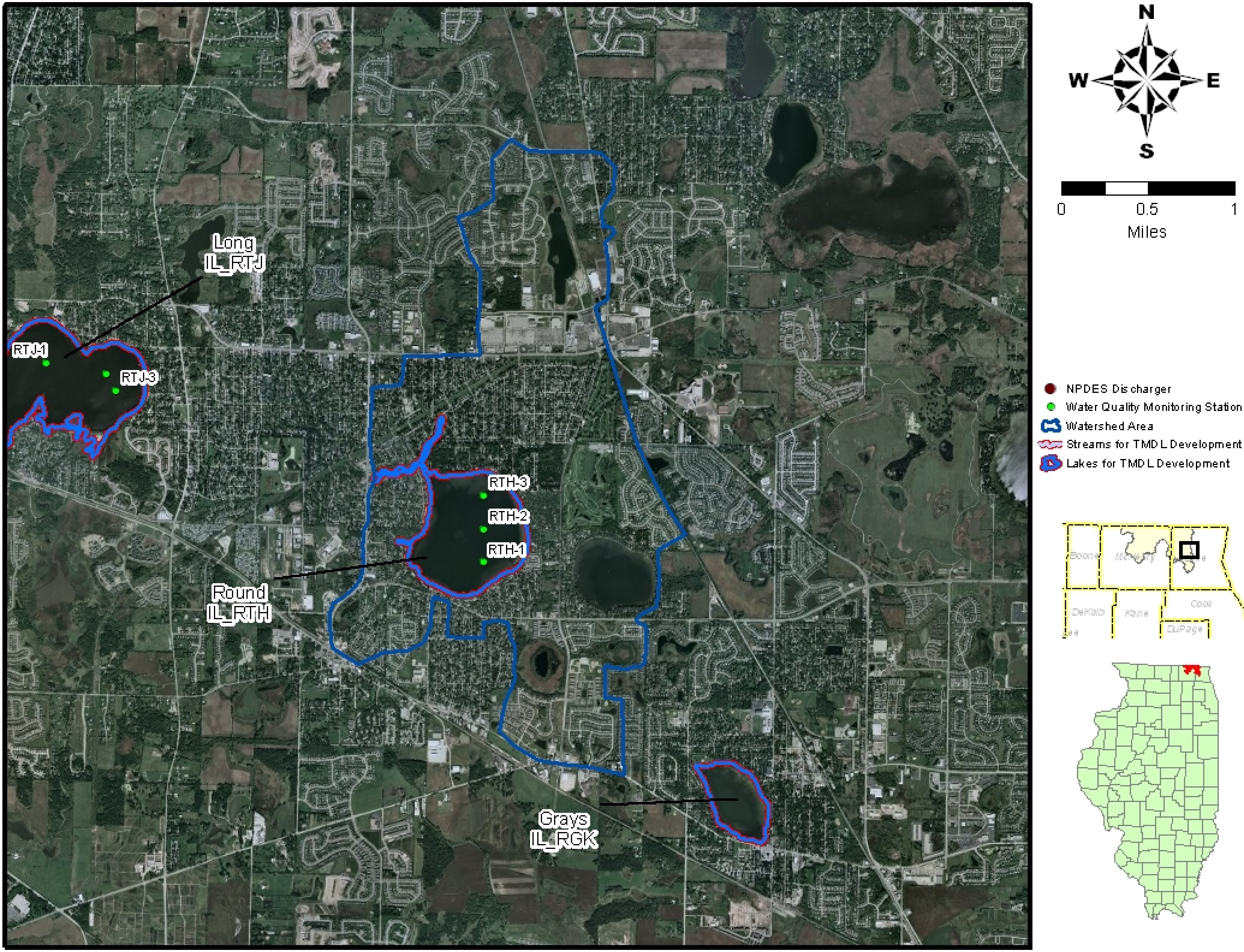
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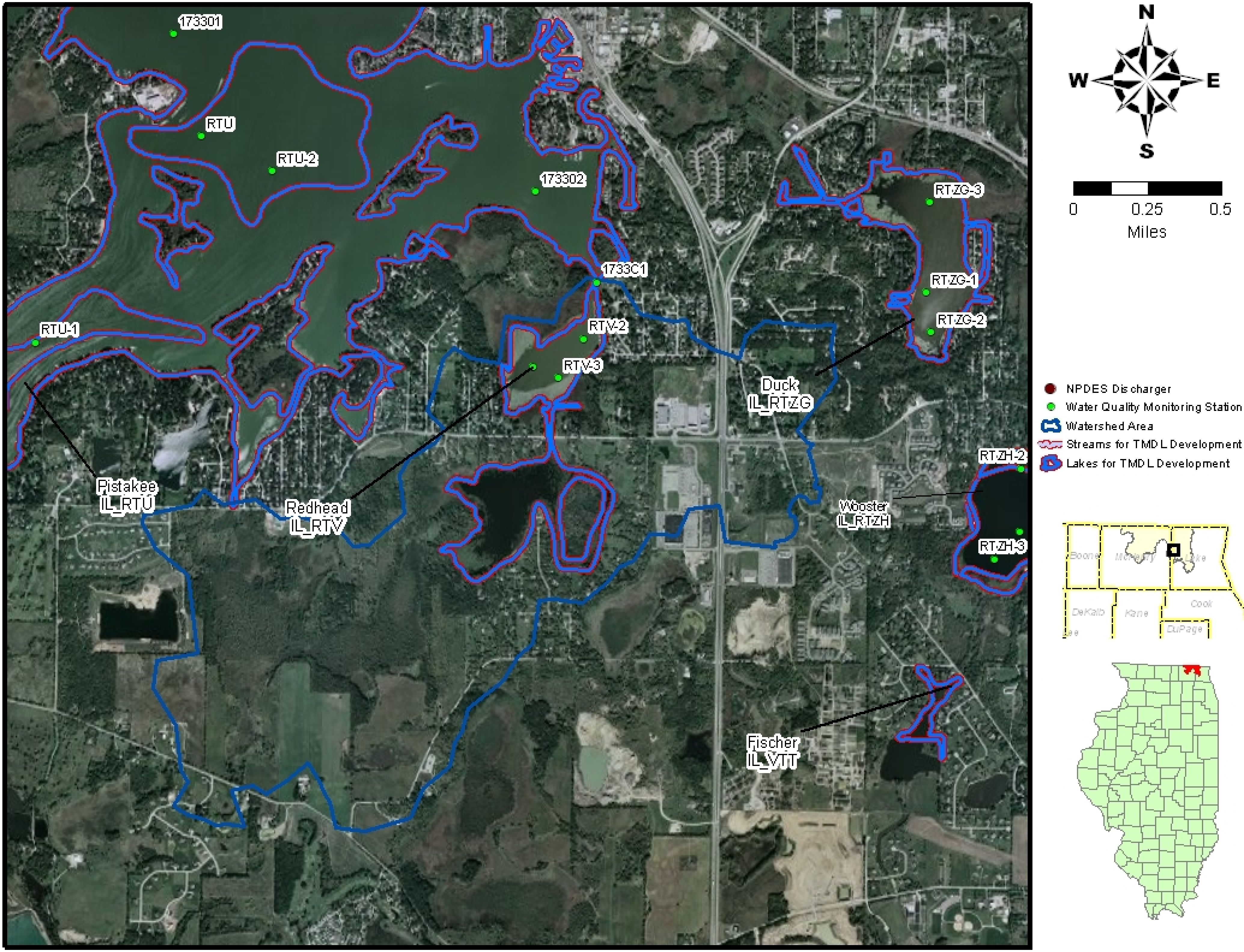
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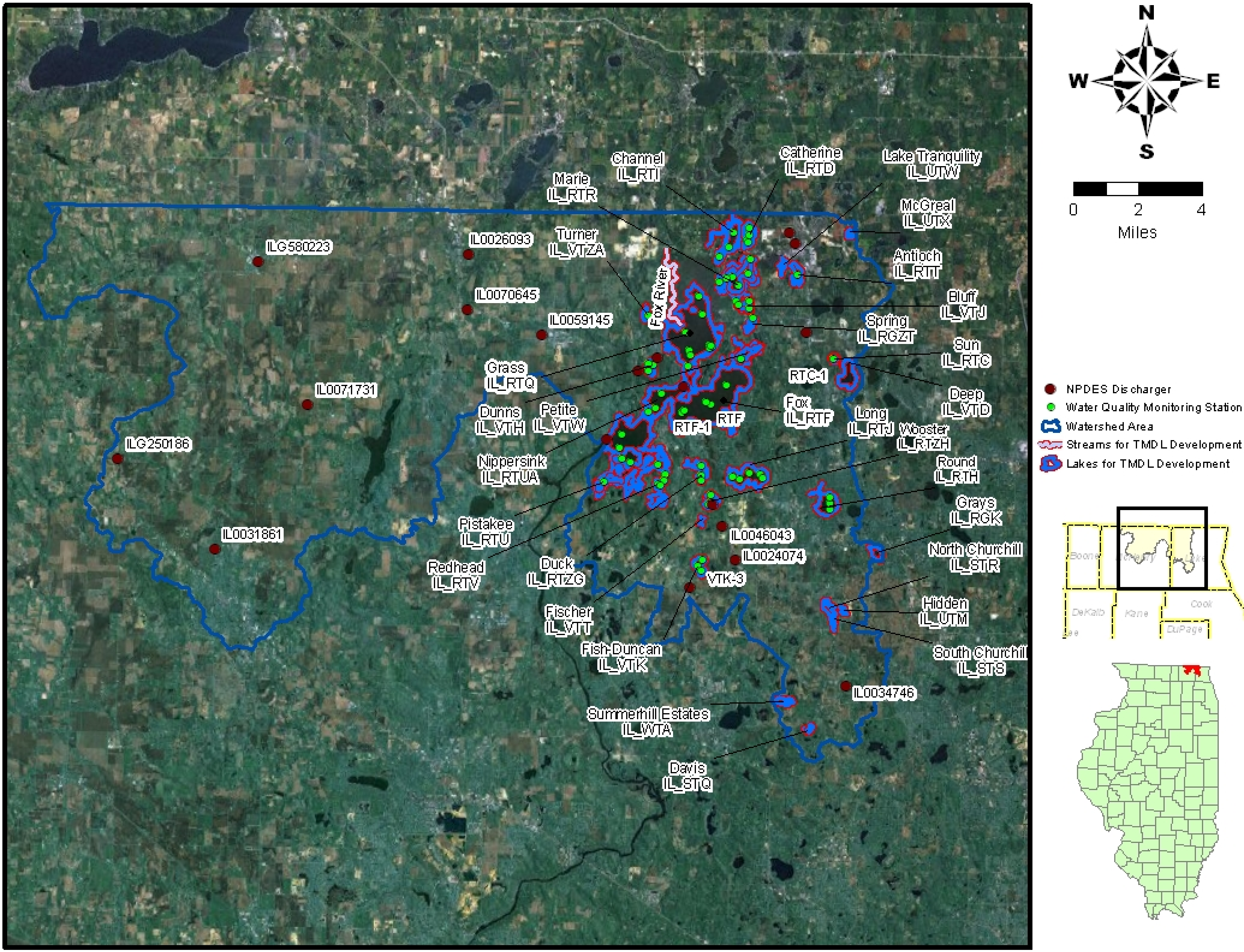

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Fox River
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Spring IL_RGZT
Sun IL_RTC
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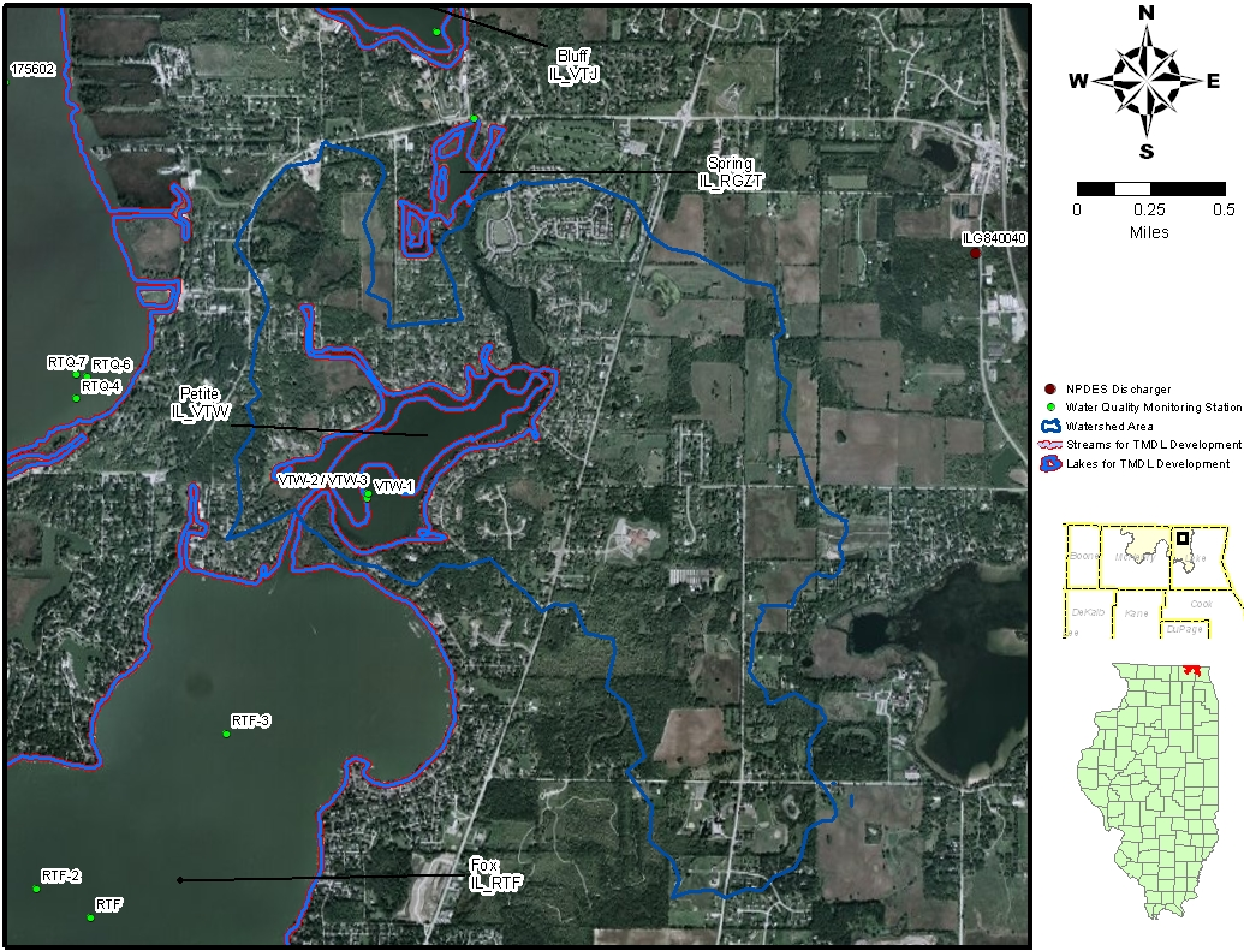

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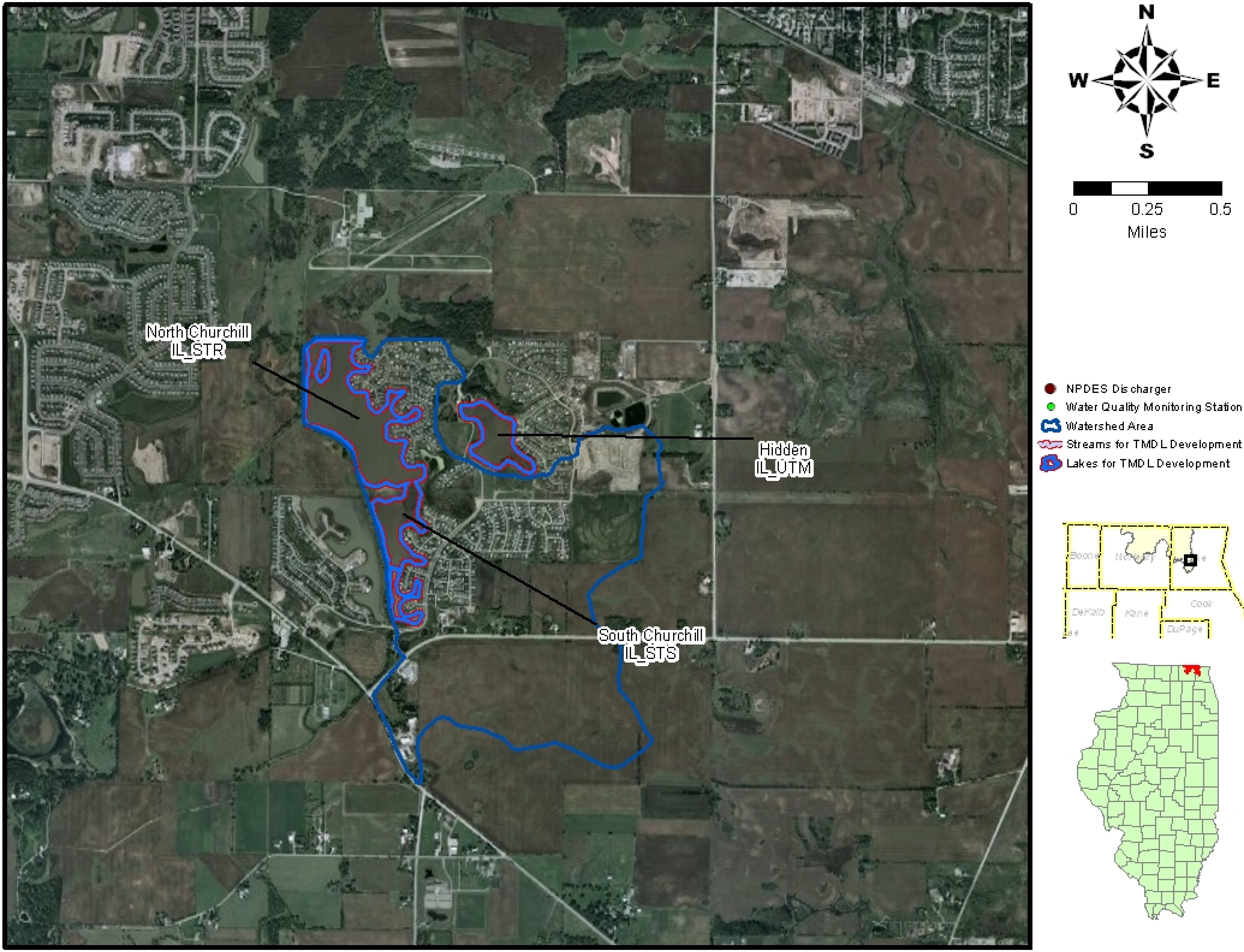
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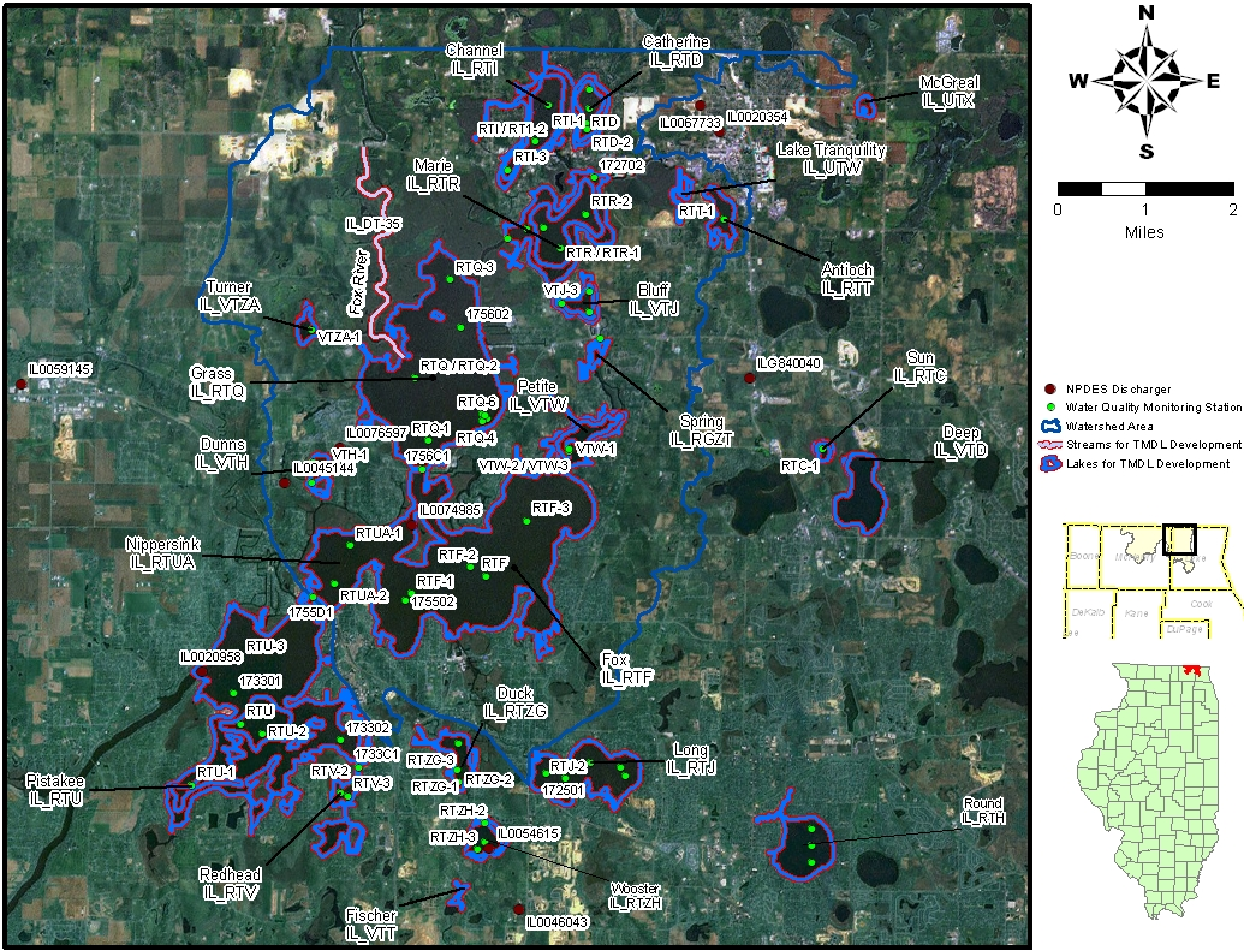

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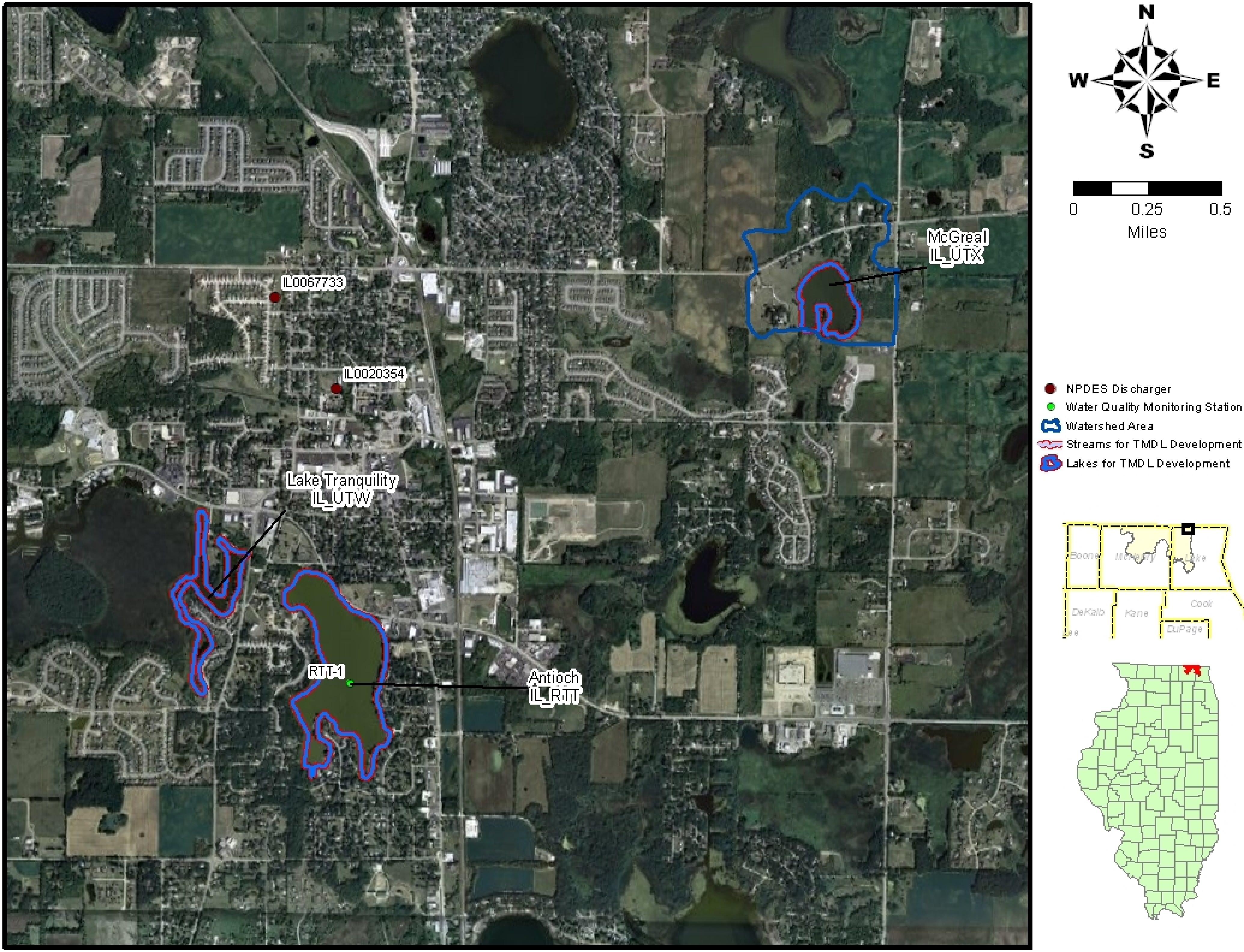

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Streams for TMDL Development
Lakes for TMDL Development
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McHenry
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DeKalb
Kane
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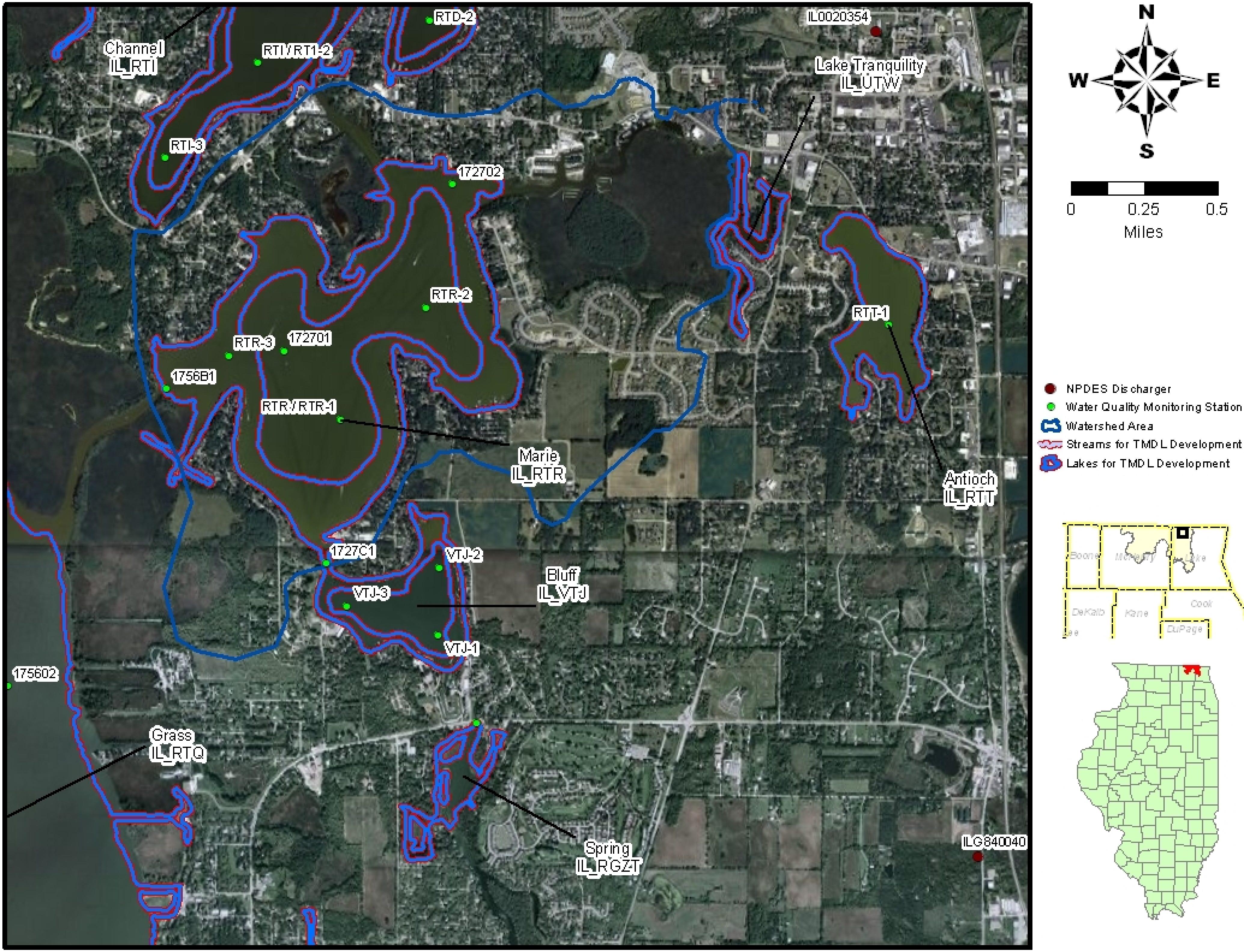

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IL_RTT
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Bluff
IL_VTJ
VTJ-3
VTJ-1
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Grass
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Spring
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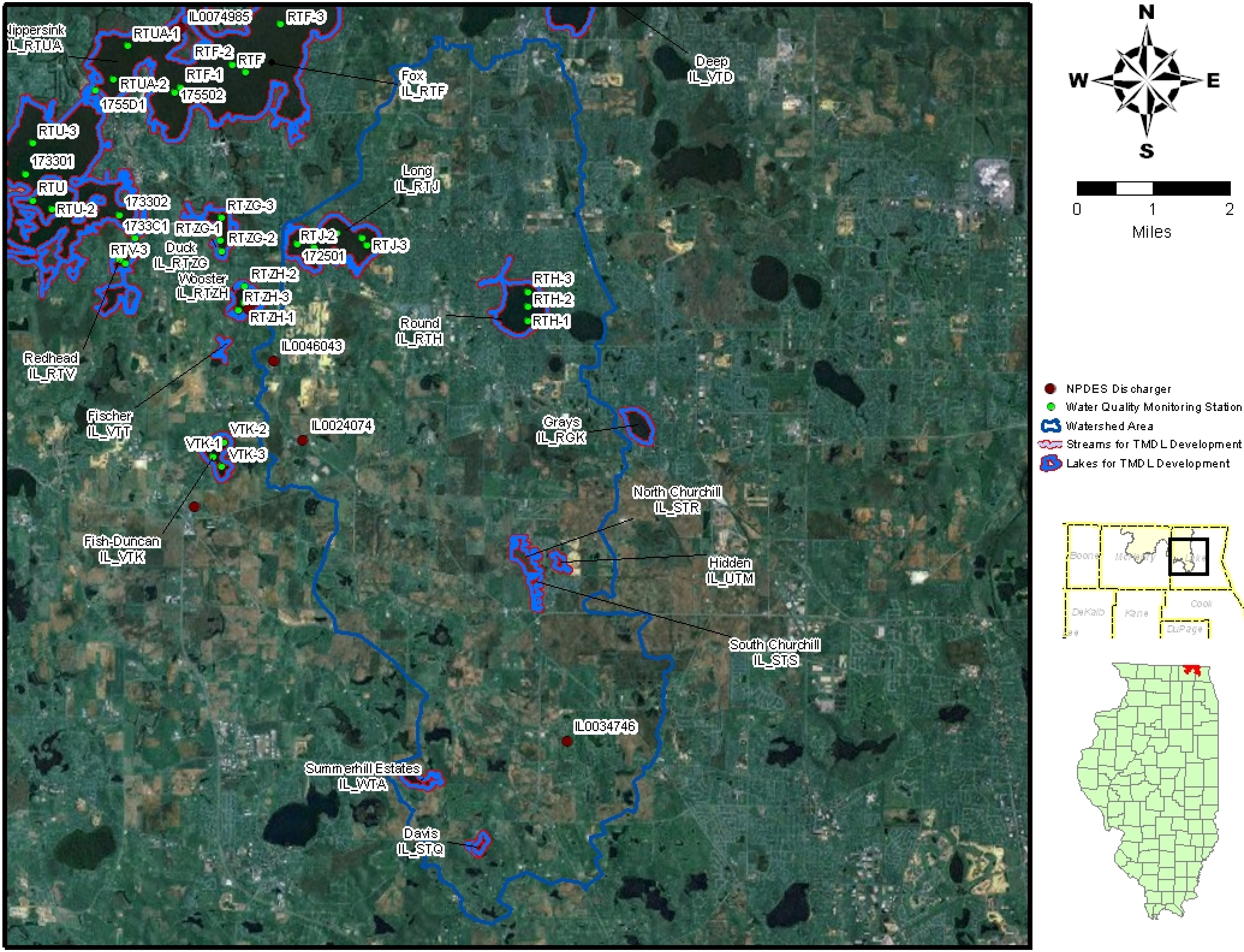
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Deep
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RTU-3
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RTU
RTU-2
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RTV-3
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South Churchill
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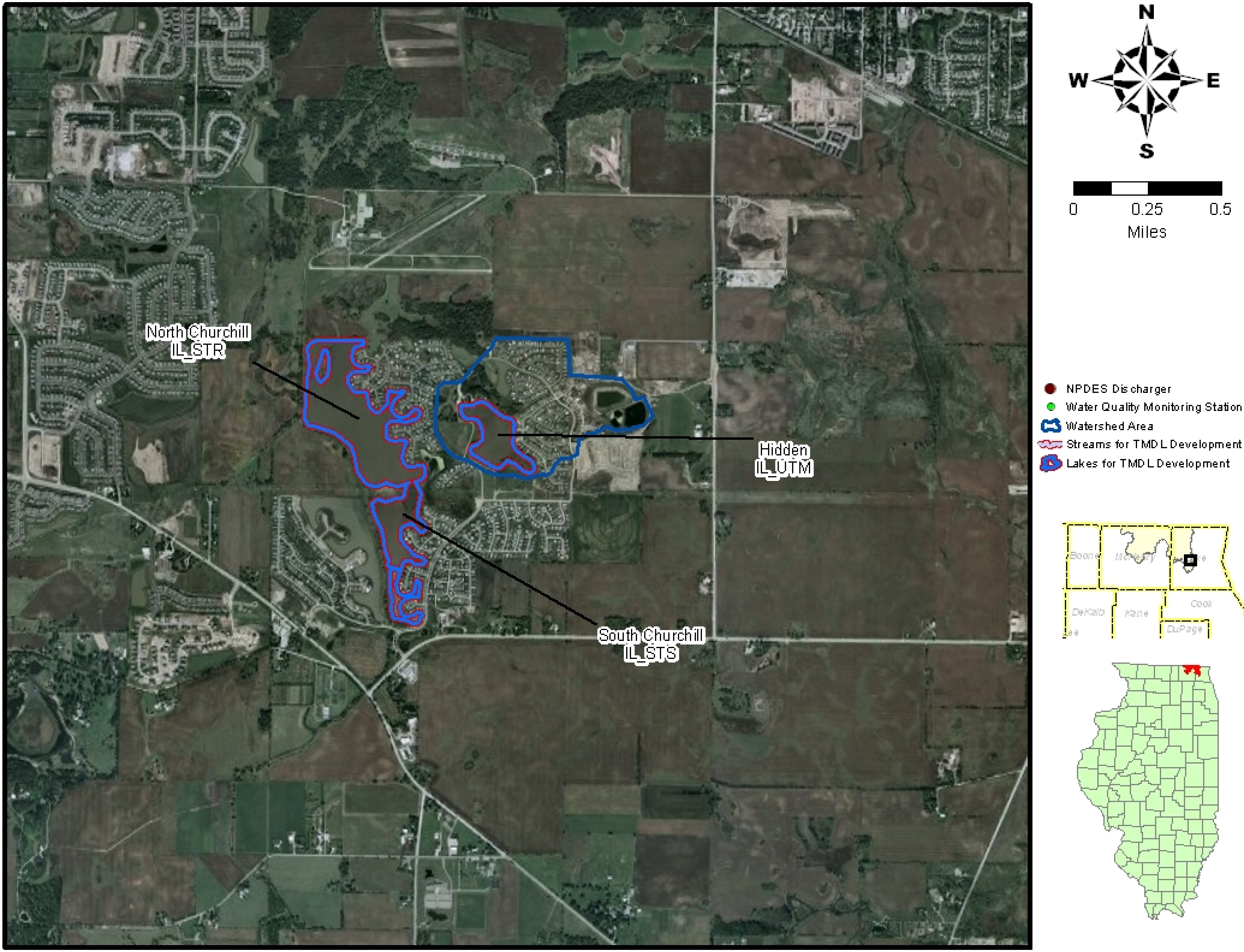
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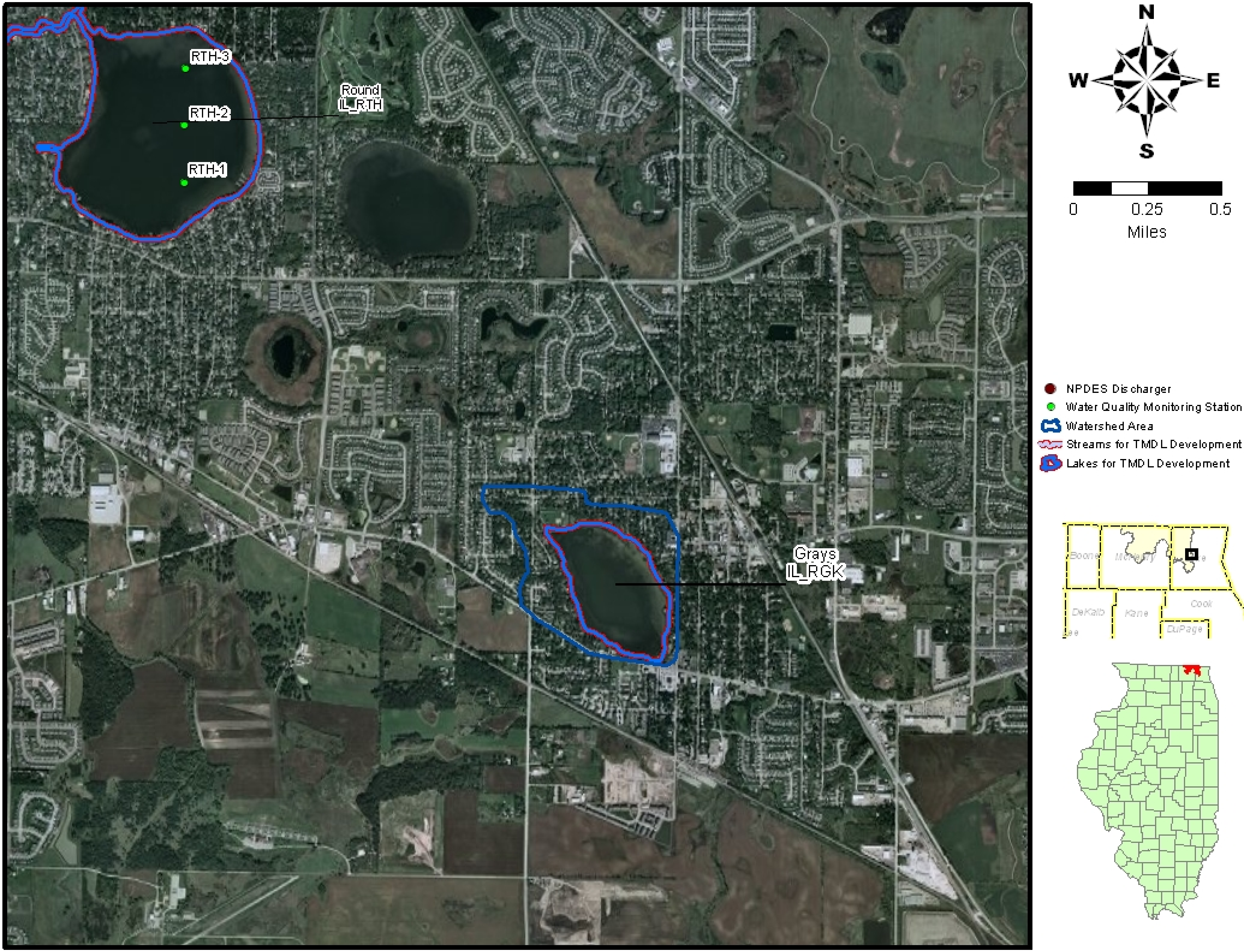

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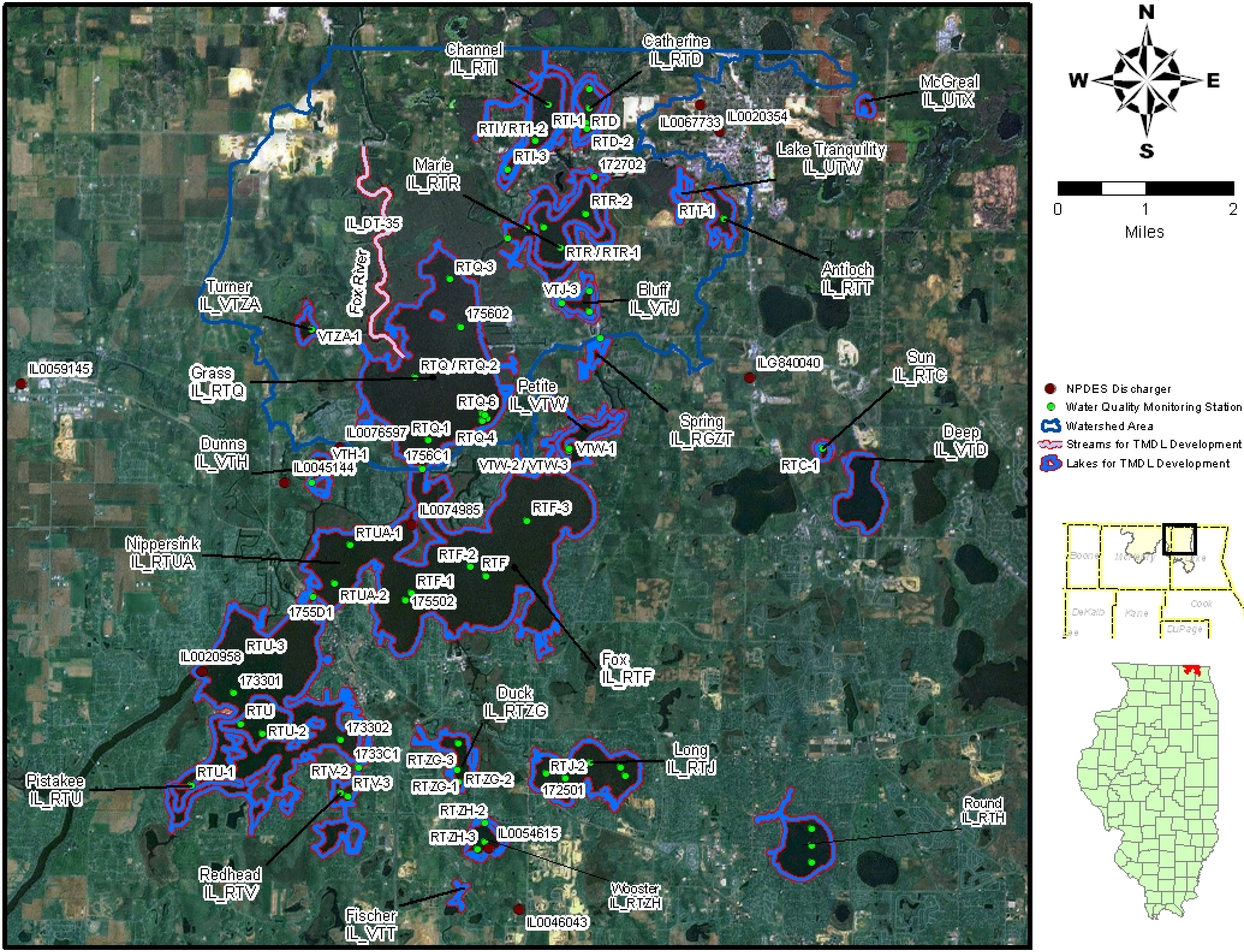
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RTR-2
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Fox River
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Antioch IL_RTT
RTQ-3
VTJ-3
Bluff IL_VTJ
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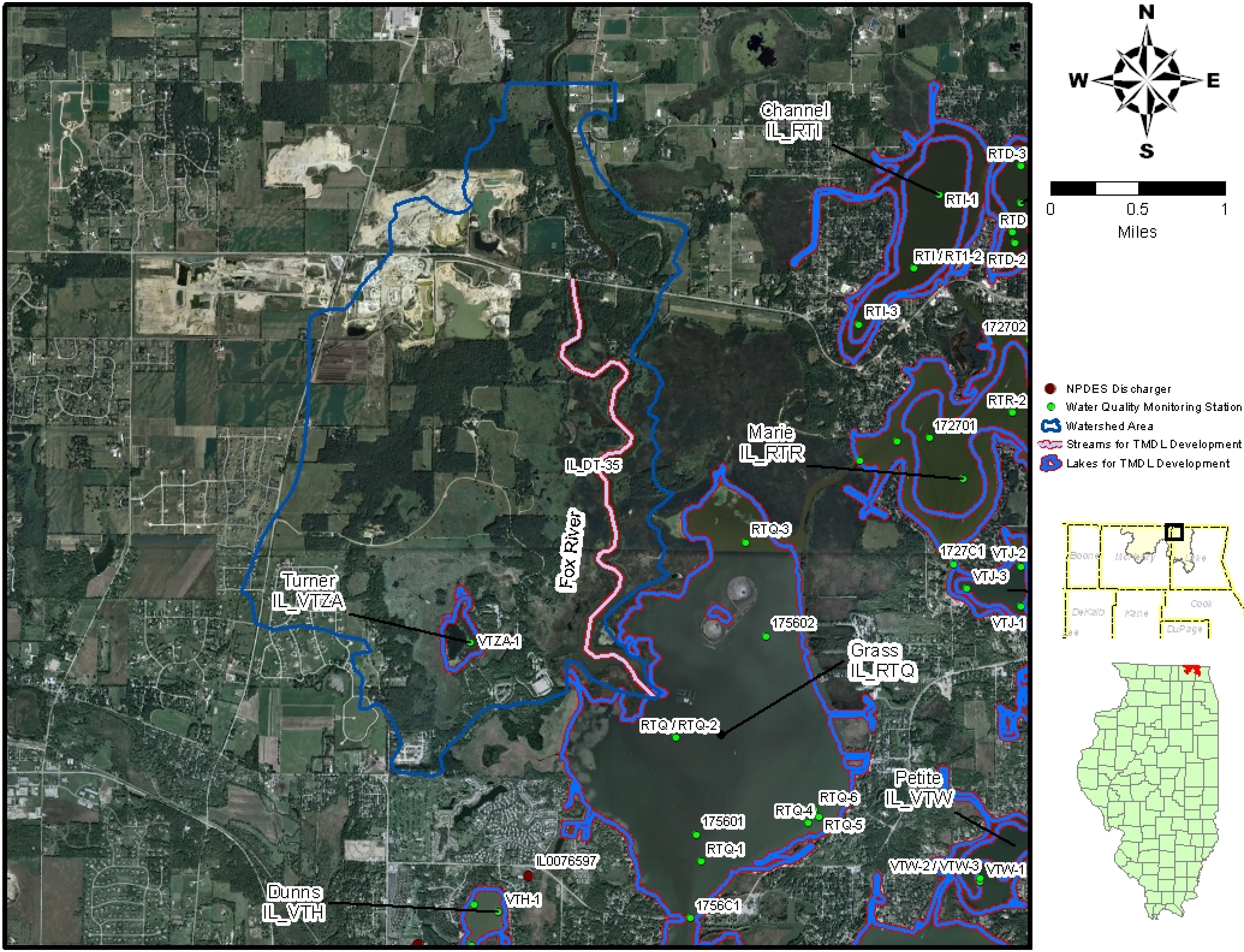

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Streams for TMDL Development
Lakes for TMDL Development
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Marie
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Fox River
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VTJ-3
VTJ-1
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IL_VTZA
VTZA-1
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Grass
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RTQ / RTQ-2
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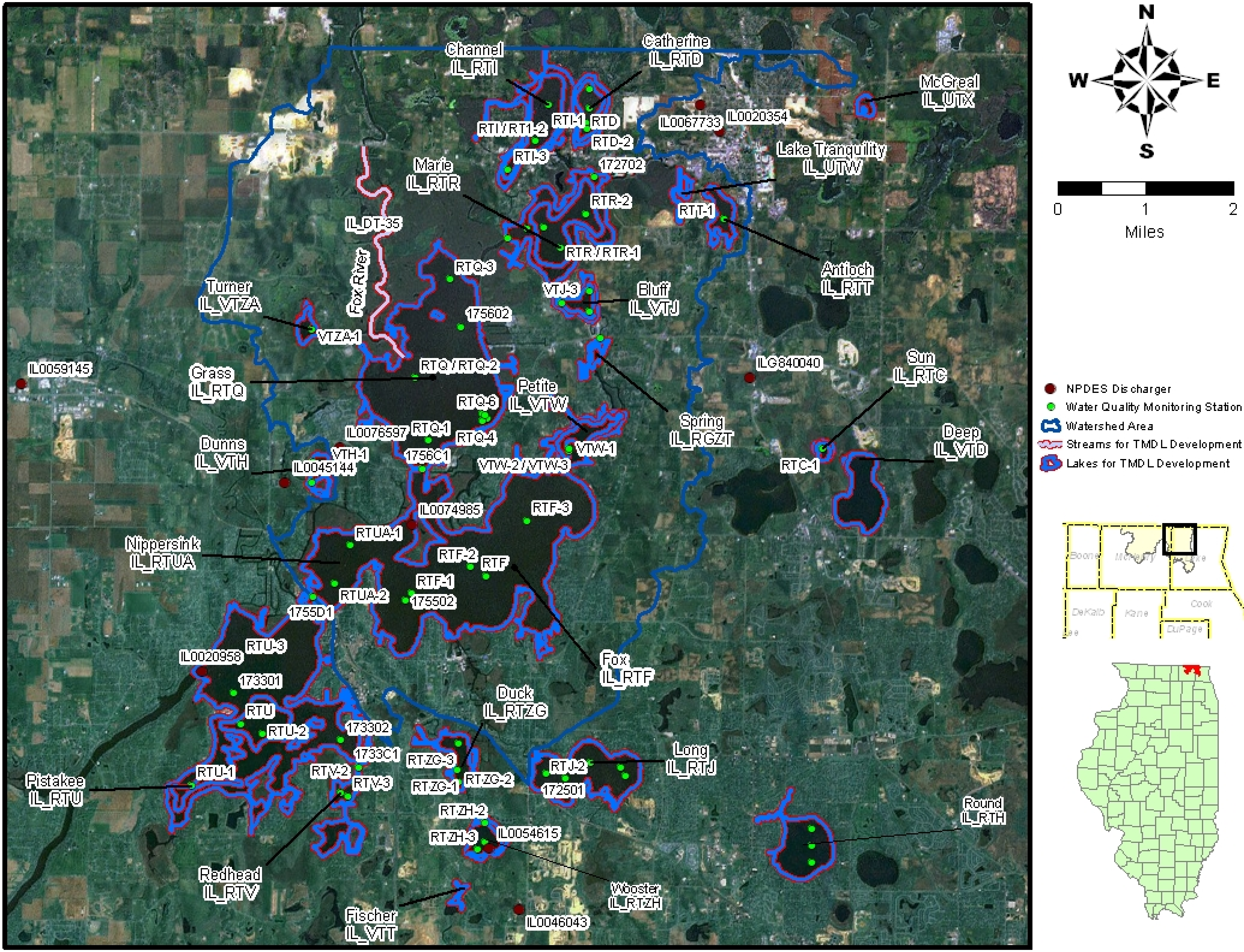
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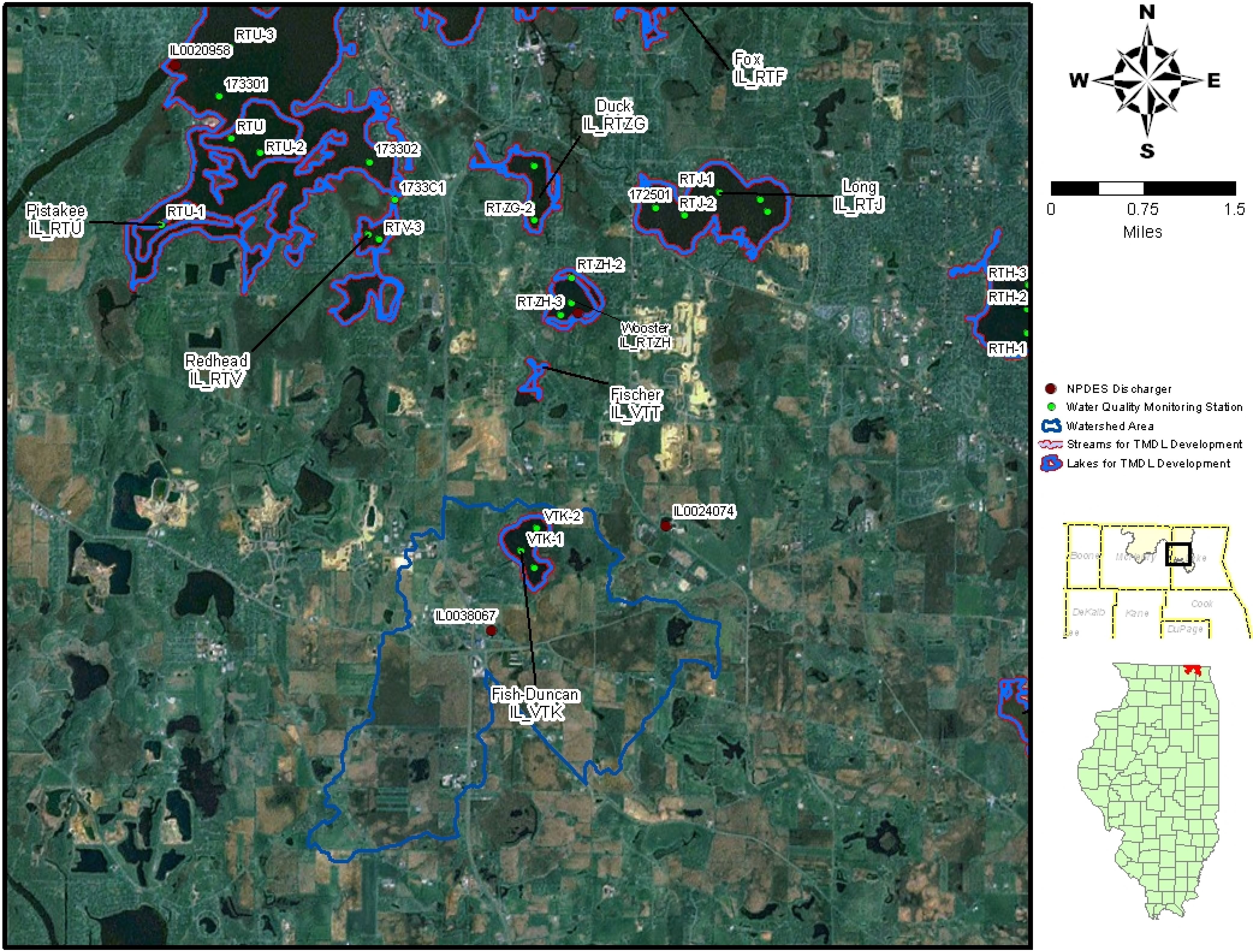
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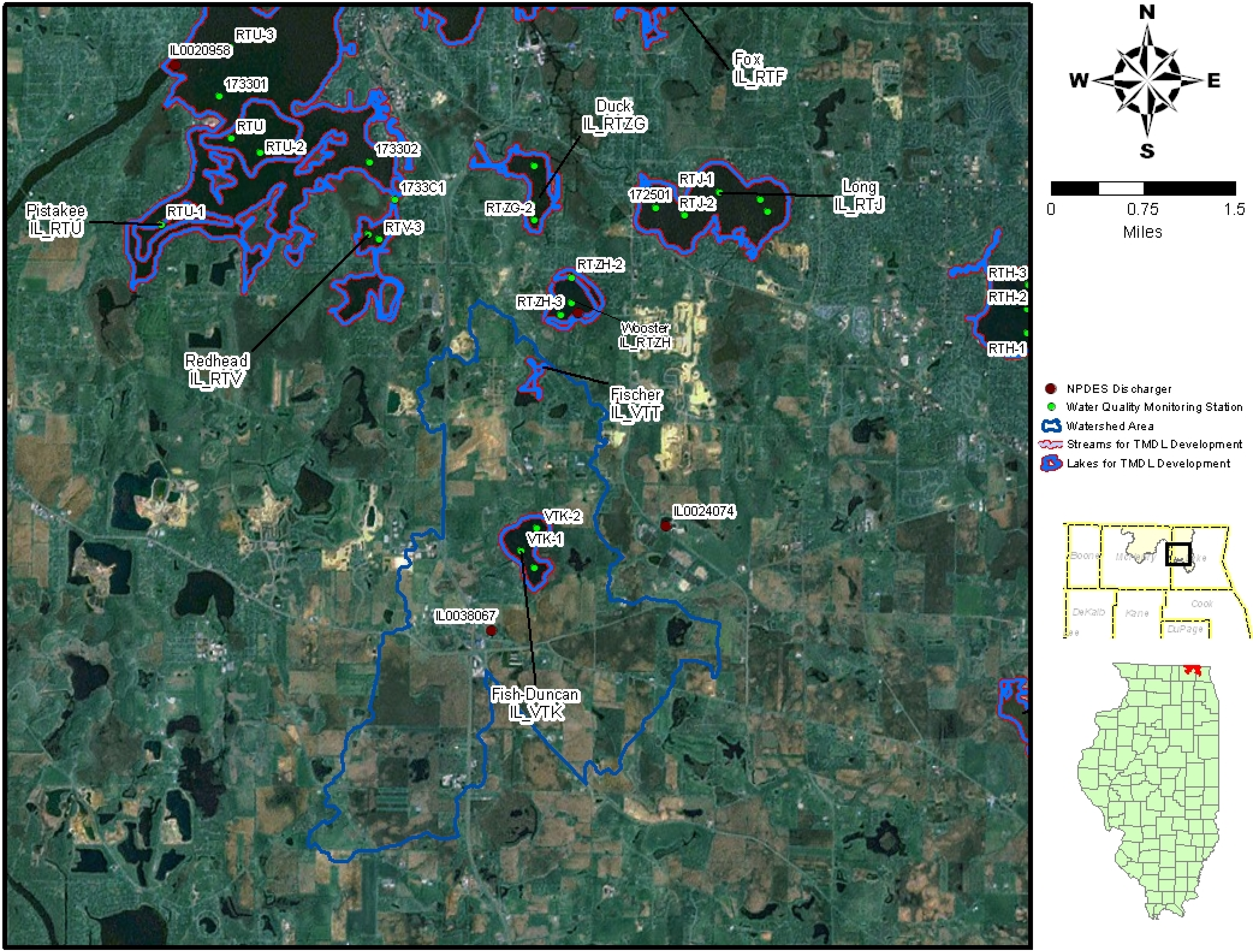
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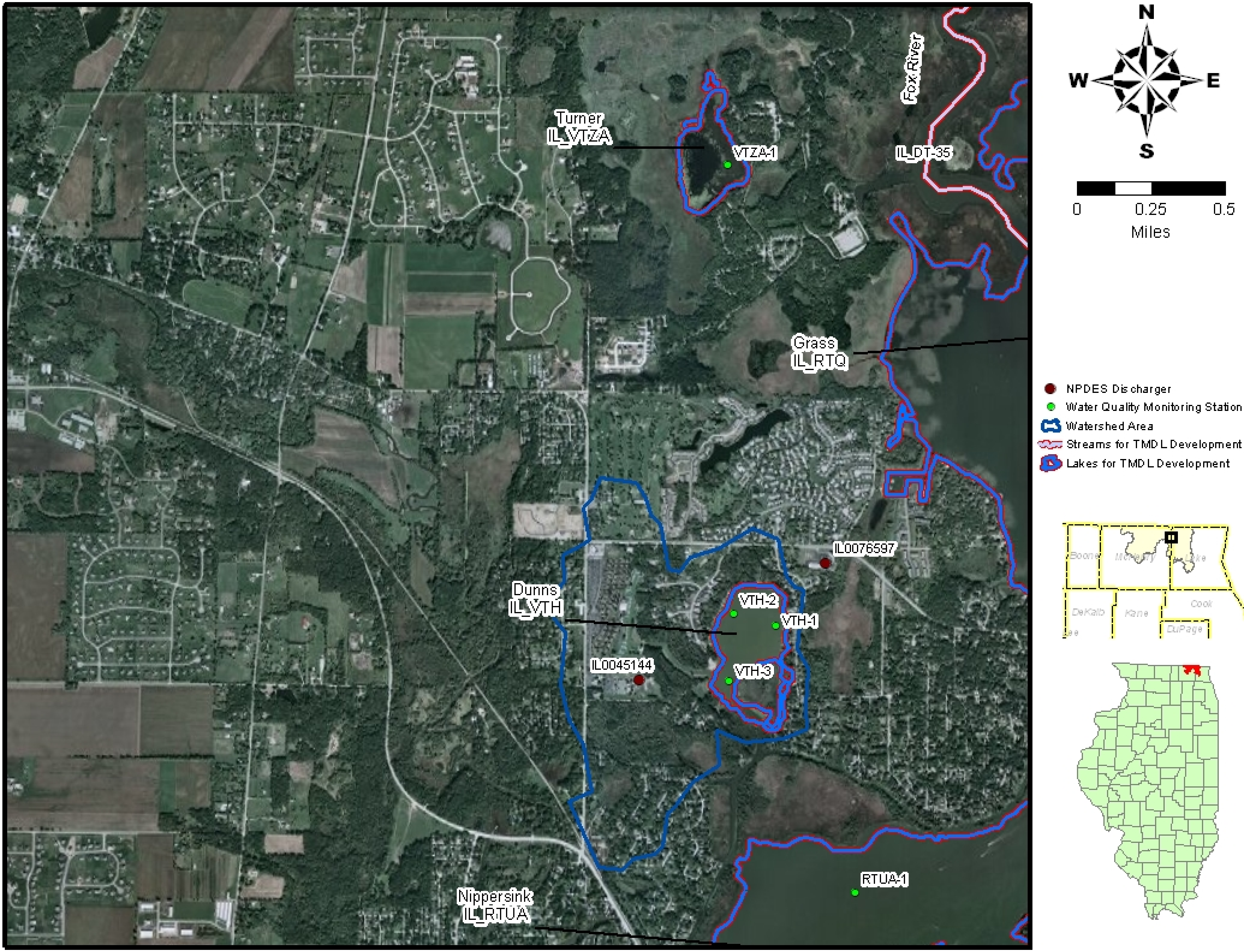
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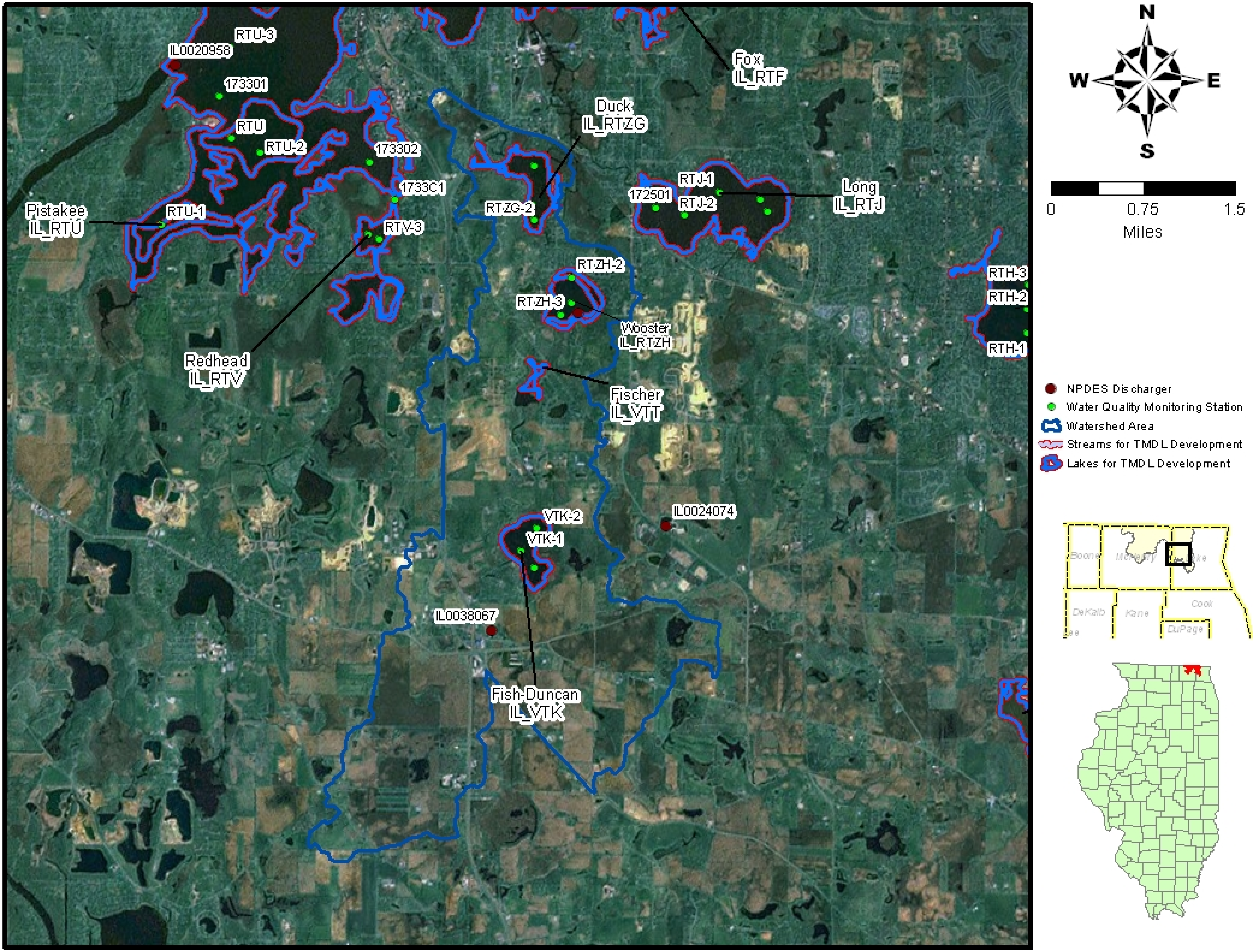
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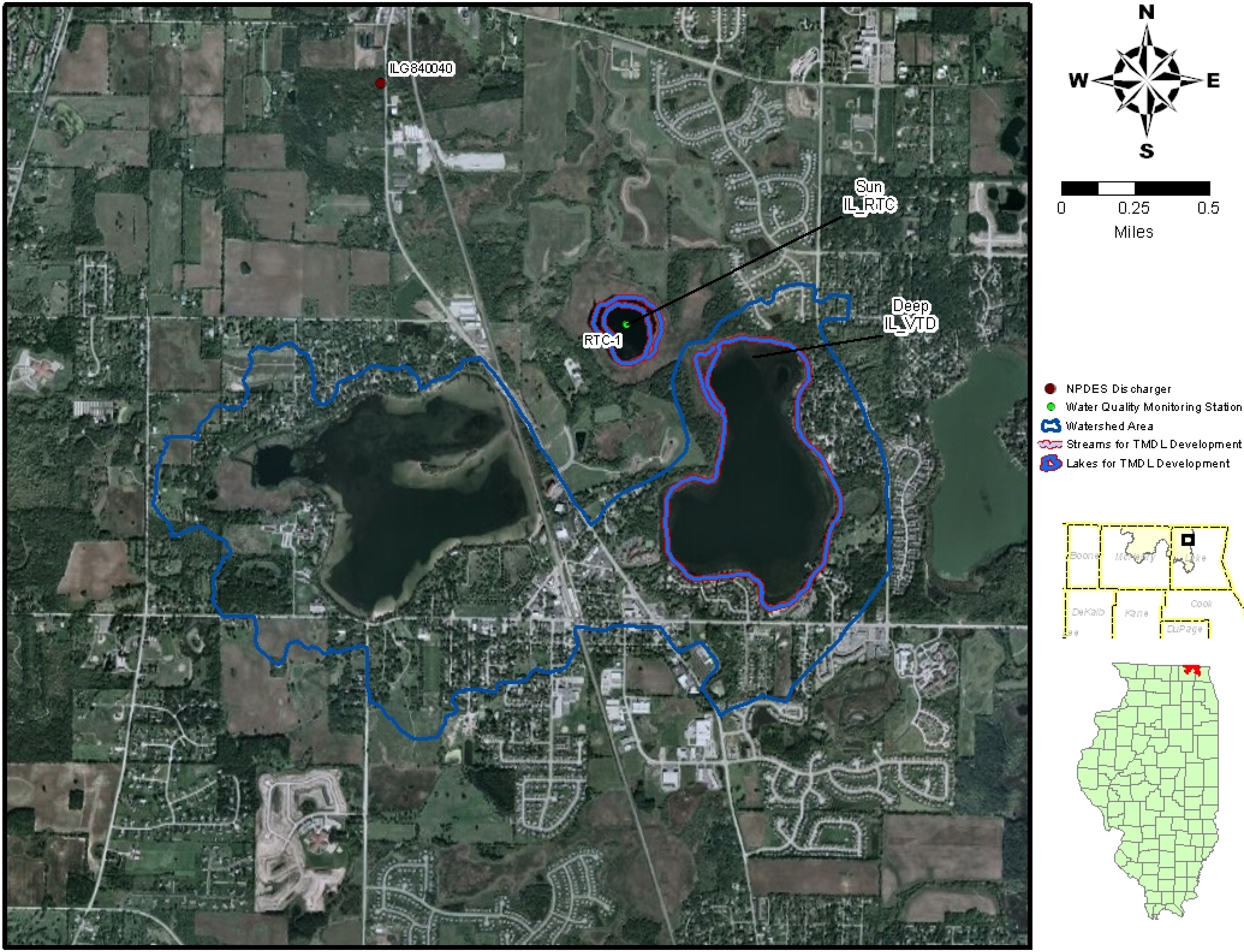
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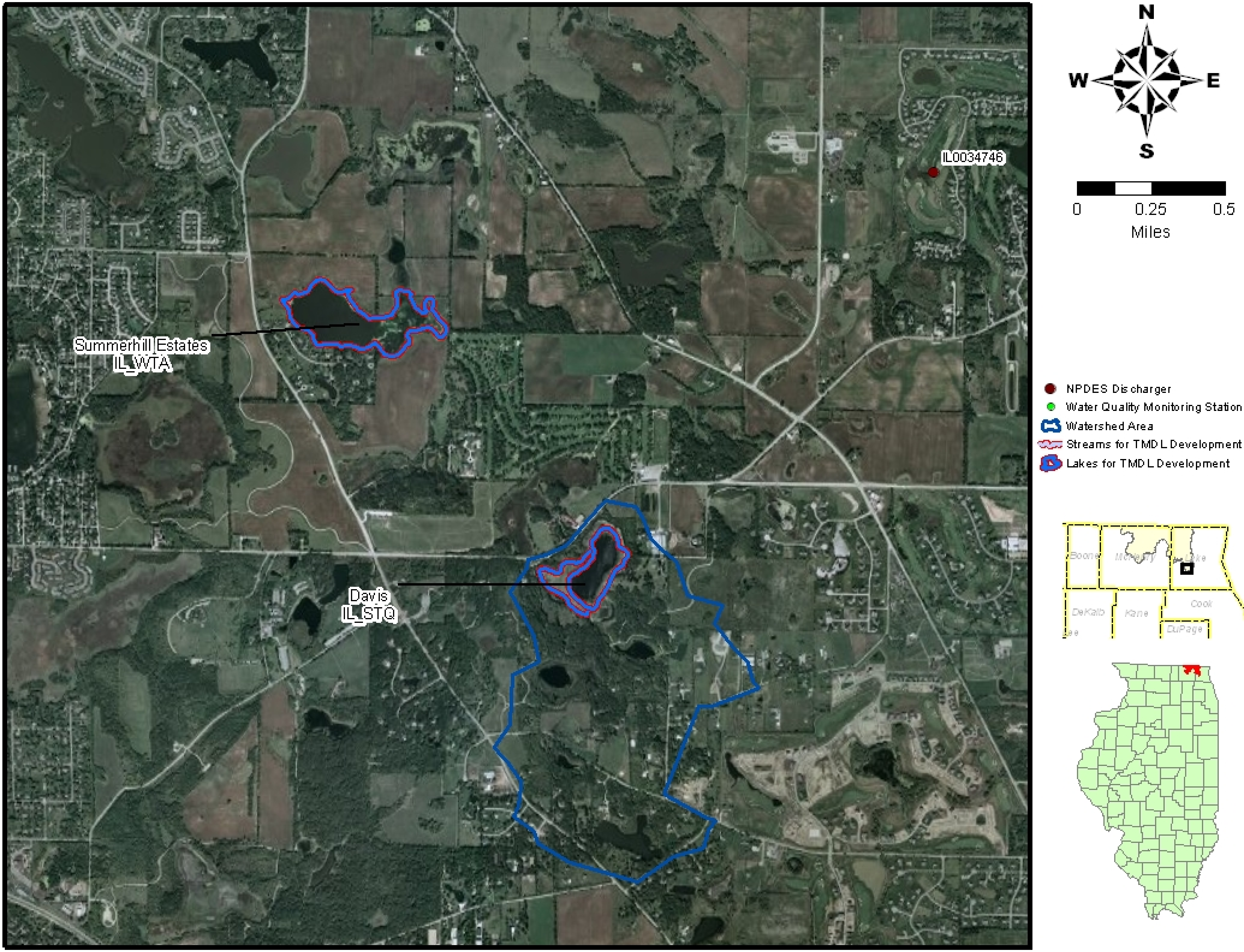
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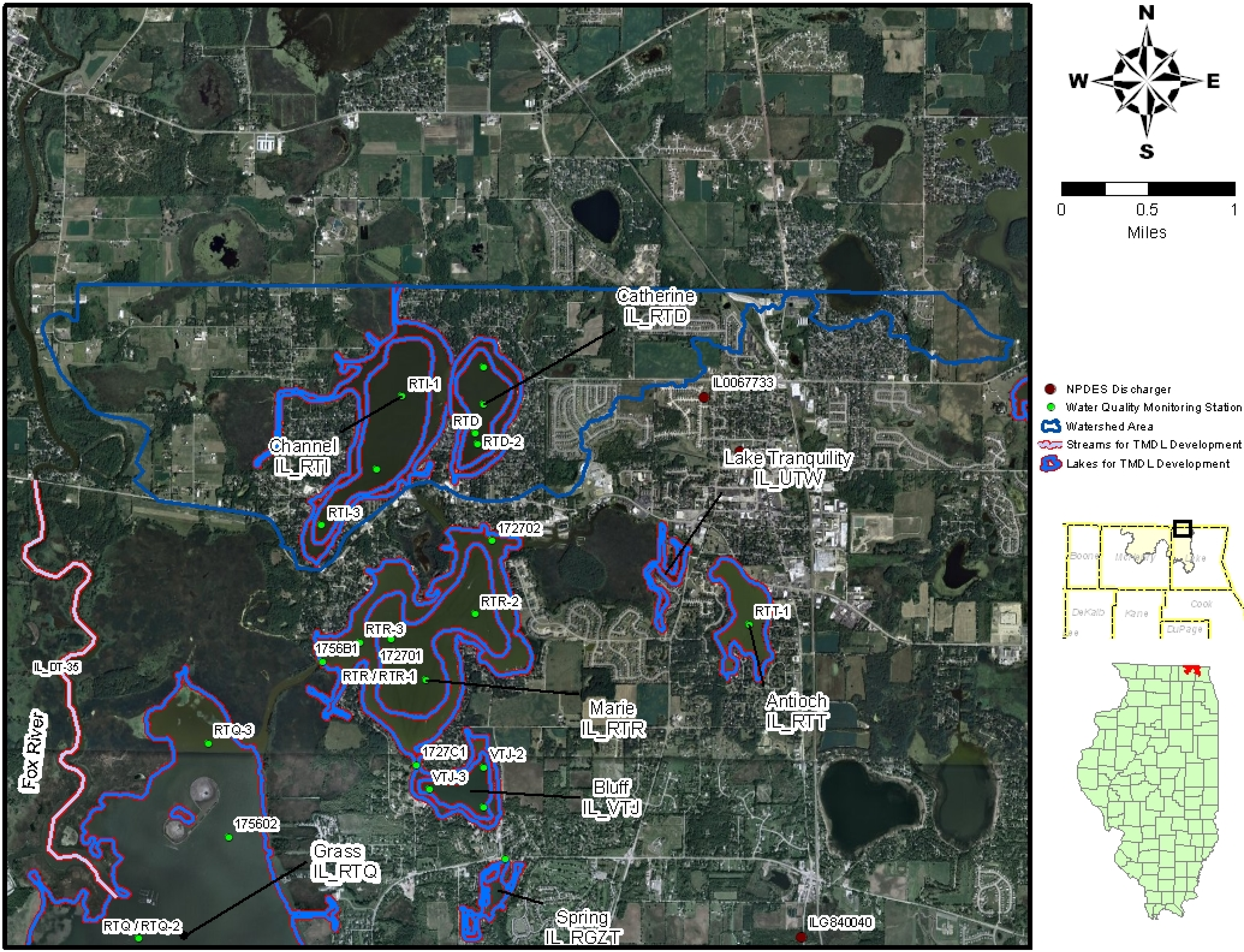

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Grass
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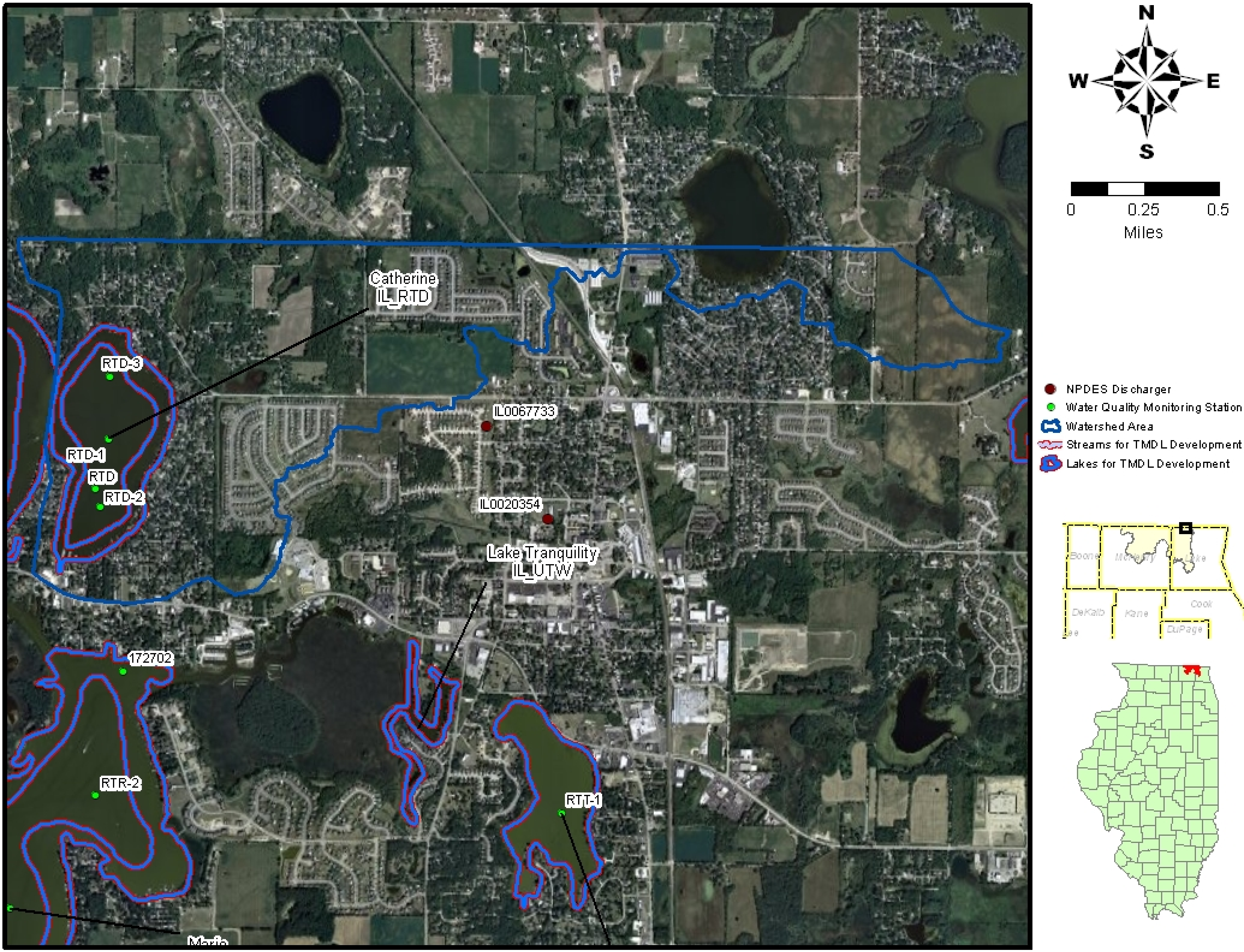
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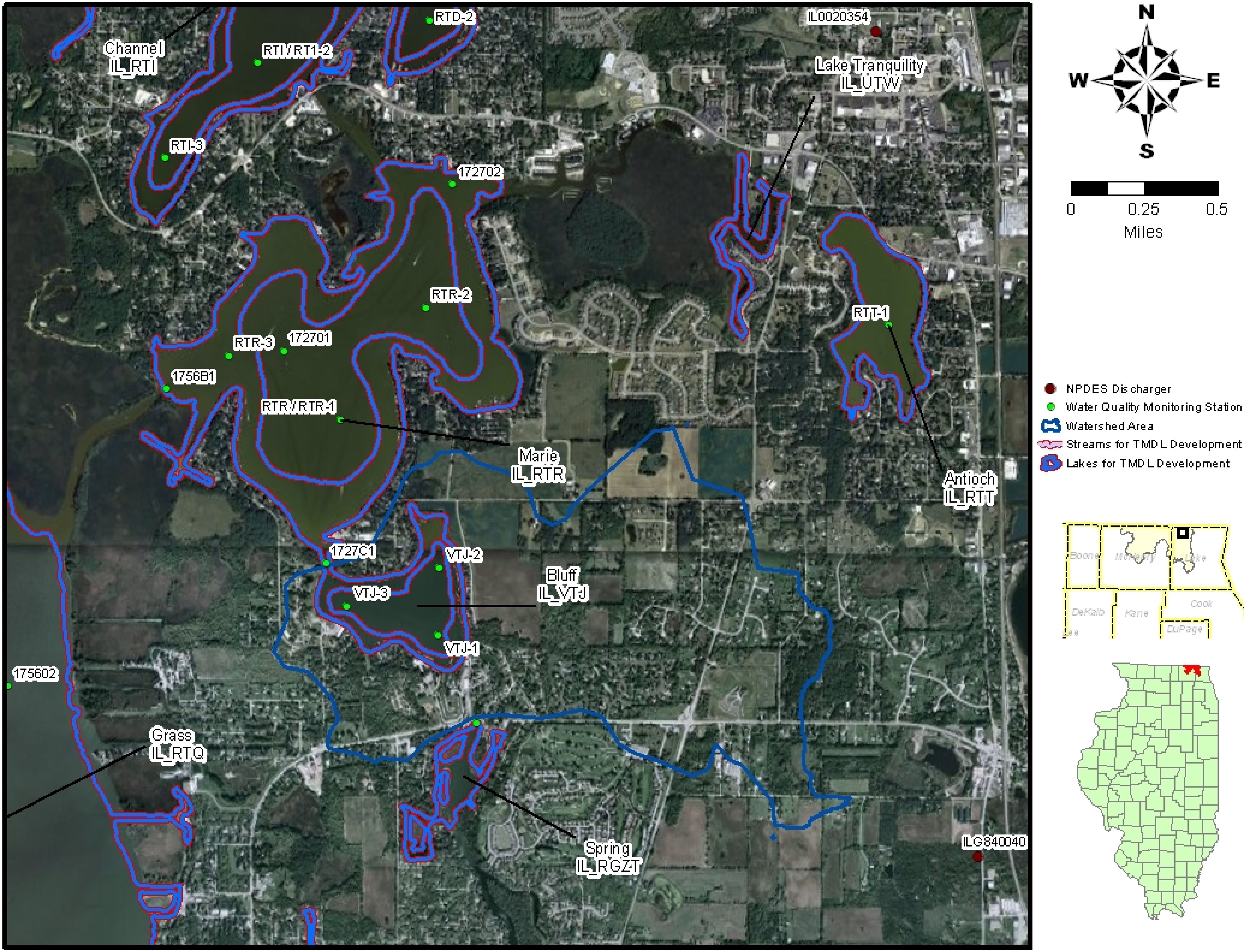

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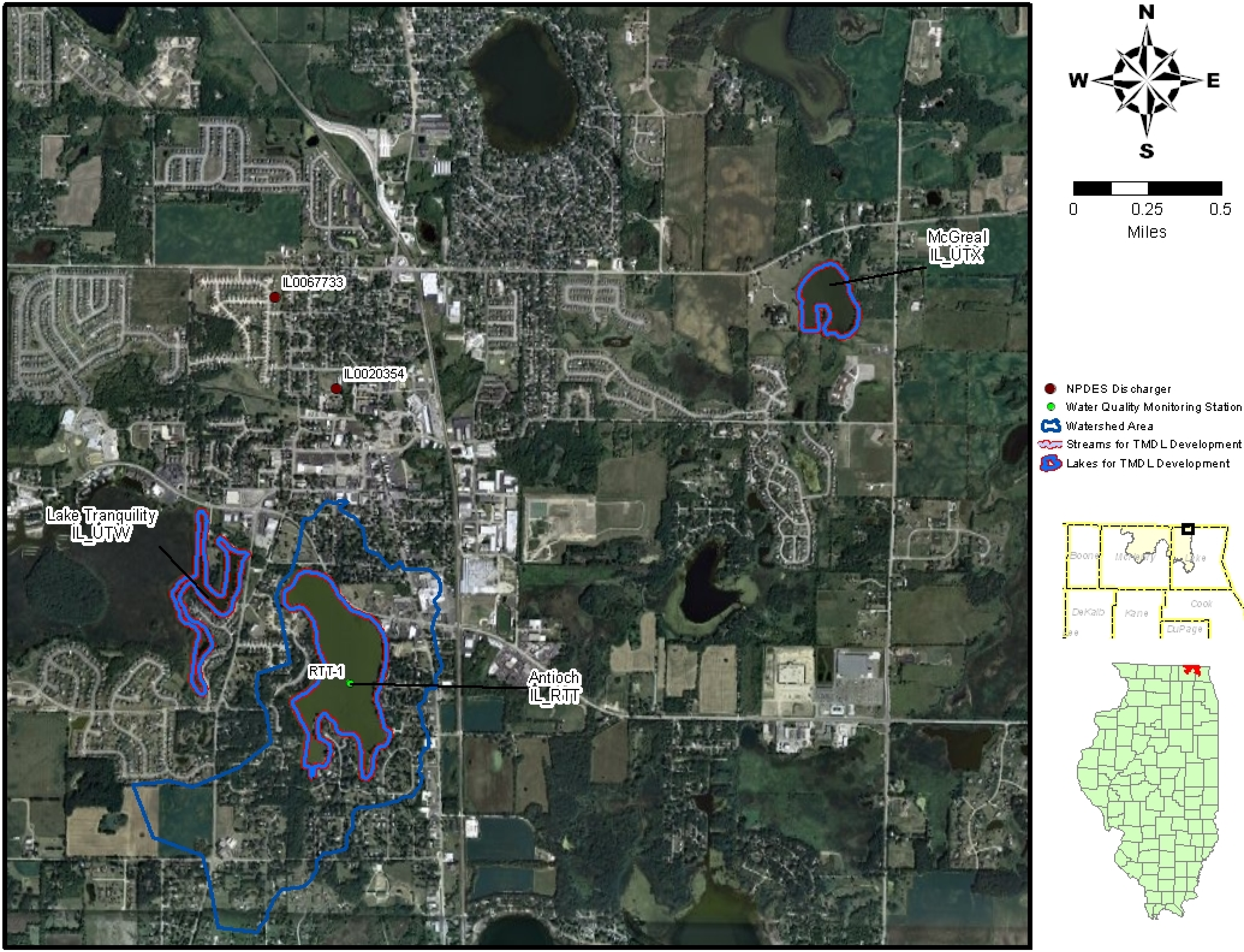
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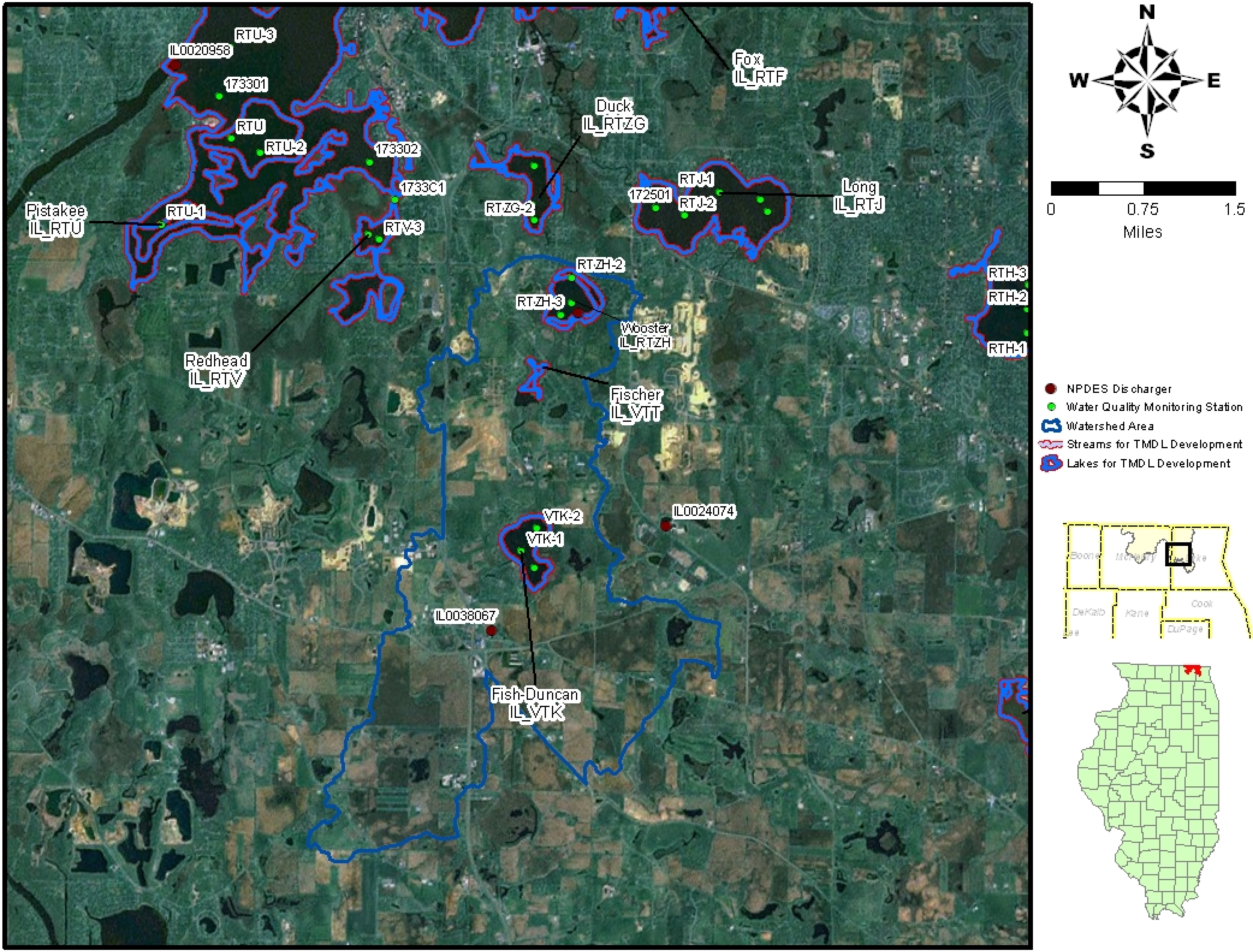

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DeKalb
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Cook
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Appendix B

Water Quality Data
(Available on a supplemental CD)

Appendix C

Land Use Tables for All Watersheds and the Chain O' Lakes

Land Use Summary for All Watersheds Within the Upper Fox River Watershed (Acres)

Name	Agriculture, Other	Commercial and Services	Forested, Grasslands, Vegetation	Industrial, Warehousing, Wholesale Trade	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses, Orchards, Tree Farms	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grain, Grazing	Transportation, Communication, and Utilities	Under Construction	Wetland	Grand Total
Sun	0.77	39.71	265.34	0.91	80.51	555.18		284.33			244.89	0.30	19.34	108.12	11.53	60.03	***1,670.96***
Antioch	1.65	16.93	44.88		14.60	90.32		4.63			175.26		22.12	51.41	7.02	12.88	***441.69***
Bluff	5.76	33.98	142.70	17.49	2.01	100.49	0.70	5.84	5.95	10.59	278.10	6.79	161.65	80.34	26.28	64.95	***943.63***
Catherine	0.02	13.38	148.20	3.61	4.66	192.53		26.73			341.23	9.43	151.77	116.13	23.24	73.66	***1,104.58***
Channel	26.40	23.66	442.00	3.61	4.66	567.90	7.66	103.07	0.62	51.41	758.61	40.27	248.00	202.99	23.24	306.87	***2,810.96***
Davis	13.38		47.23			75.69	3.97	136.68		22.07	98.18		5.51	20.83	1.23	16.69	***441.46***
Deep	0.77	38.76	240.09	0.91	68.69	528.82		97.50			244.72	0.30	12.71	98.02	11.53	58.65	***1,401.47***
Duck	52.80	66.32	713.60	74.06	228.82	409.00	169.72	376.09	12.06	4.02	606.92	5.44	1,544.53	394.64	125.86	693.46	***5,477.33***
Dunns		2.32	32.73		2.36	72.17		118.16			132.68	0.40	1.24	39.84	1.01	51.98	***454.90***
Fischer	52.80	58.03	492.36	73.18	171.69	193.33	168.42	320.42		4.02	317.30	0.43	1,544.52	272.88	94.75	525.63	***4,289.75***
Fish	39.10	51.52	232.46	53.18	76.75	146.01	59.88	282.29		4.02	140.01		1,460.53	196.48		444.21	***3,186.44***
Fox	50.85	369.14	2,099.58	493.49	221.78	5,812.50	45.49	5,003.74	15.13	76.51	4,284.72	518.52	1,001.88	1,351.59	108.71	1,496.73	***22,950.38***
Fox R DT-35	5.47	18.90	140.34	439.07		170.03	5.73	2,330.69		11.19	236.47	210.87	213.59	44.32	12.50	72.78	***3,911.95***
Grass	41.56	198.31	1,170.25	460.18	48.76	3,132.82	14.09	3,847.50	8.22	73.19	2,168.27	345.55	733.84	642.46	88.51	871.17	***13,844.70***
Grays		2.67	4.93			79.50		8.59			63.81			16.15			***175.65***
Hidden			2.79			31.65	0.38	31.15			41.49			19.59	12.94		***139.99***
Long	261.22	391.49	2,298.45	271.36	453.15	1,683.39	455.91	4,310.83	28.90	198.81	5,048.88	67.00	3,778.87	2,600.52	681.70	2,289.99	***24,820.47***
Marie	2.02	60.78	170.01		11.41	568.16		106.72	1.64		302.31	32.91	85.04	98.56	15.13	215.69	***1,670.39***
McGreal	2.71		26.51			24.64				0.67	54.16		15.73	6.18		4.97	***135.57***
N Churchill	7.37		9.40	6.77		92.02	4.58	37.39			124.84		209.64	100.42	27.23	20.34	***639.99***
Nippersink	50.85	371.46	2,132.37	493.49	224.14	5,884.67	45.49	5,121.90	15.13	76.51	4,417.55	518.93	1,003.12	1,391.64	109.71	1,548.74	***23,405.71***
Petite	8.38	20.92	411.77	0.52	38.91	192.04	27.43	139.12	1.25		436.96	29.84	199.96	117.96	11.98	153.83	***1,790.86***
Pistakee	650.59	1,962.94	16,446.27	2,884.27	1,859.68	12,565.41	3,194.74	18,936.40	90.35	342.73	27,648.89	631.75	64,068.90	5,733.37	1,228.09	12,586.00	***170,857.35***
Redhead	10.11	31.40	137.57		15.07	137.77	0.52	560.78		18.78	248.94	0.84	44.46	73.33	1.10	45.71	***1,326.38***
Round	2.28	139.33	103.89		46.20	410.00		407.15	3.89		947.85	10.63	8.24	435.71	2.63	31.57	***2,549.36***
S Churchill	7.37		8.47	6.77		27.14	4.58	23.47			81.95		209.50	87.61	27.23	19.89	***503.97***
Spring	0.53	4.29	23.06	2.37		0.80	3.97	51.75		3.32	56.03	29.28	66.53	30.17	0.02	26.46	***298.59***
Summerhill Estates			0.48		13.01	50.58		271.00			43.80		0.51	14.82		1.06	***395.26***
Tranquility		18.48	36.57		13.45	27.77		20.93			86.93		0.01	44.15		1.14	***249.43***
Turner			25.21			59.93		308.10		4.56	124.64		30.81	9.93	11.00	1.79	***575.97***
Wooster	52.80	60.61	592.20	73.18	228.82	297.80	169.68	353.17	2.64	4.02	443.13	1.35	1,544.52	311.93	108.32	562.24	***4,806.41***
Grand Total	***1,347.53***	***3,995.34***	***28,641.73***	***5,358.41***	***3,829.14***	***34,180.07***	***4,382.95***	***43,626.13***	***185.78***	***906.41***	***50,199.53***	***2,460.85***	***78,387.06***	***14,712.07***	***2,772.46***	***22,259.12***	***297,271.55***

Land Use Summary for All Watersheds Within the Upper Fox River Watershed (Percent)

Name	Agriculture, Other	Commercial and Services	Forested, Grasslands, Vegetation	Industrial, Warehousing, Wholesale Trade	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses, Orchards, Tree	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grain, Grazing	Transportation, Communication, and Utilities	Under Construction	Wetland
Sun	0.05 %	2.38 %	15.88 %	0.05 %	4.82 %	33.23 %	0.00 %	17.02 %	0.00	0.00 %	14.66 %	0.02 %	1.16 %	6.47 %	0.69 %	3.59 %
Antioch	0.37 %	3.83 %	10.16 %	0.00 %	3.31 %	20.45 %	0.00 %	1.05 %	0.00	0.00 %	39.68 %	0.00 %	5.01 %	11.64 %	1.59 %	2.92 %
Bluff	0.61 %	3.60 %	15.12 %	1.85 %	0.21 %	10.65 %	0.07 %	0.62 %	0.63	1.12 %	29.47 %	0.72 %	17.13 %	8.51 %	2.79 %	6.88 %
Catherine	0.00 %	1.21 %	13.42 %	0.33 %	0.42 %	17.43 %	0.00 %	2.42 %	0.00	0.00 %	30.89 %	0.85 %	13.74 %	10.51 %	2.10 %	6.67 %
Channel	0.94 %	0.84 %	15.72 %	0.13 %	0.17 %	20.20 %	0.27 %	3.67 %	0.02	1.83 %	26.99 %	1.43 %	8.82 %	7.22 %	0.83 %	10.92 %
Davis	3.03 %	0.00 %	10.70 %	0.00 %	0.00 %	17.15 %	0.90 %	30.96 %	0.00	5.00 %	22.24 %	0.00 %	1.25 %	4.72 %	0.28 %	3.78 %
Deep	0.05 %	2.77 %	17.13 %	0.06 %	4.90 %	37.73 %	0.00 %	6.96 %	0.00	0.00 %	17.46 %	0.02 %	0.91 %	6.99 %	0.82 %	4.18 %
Duck	0.96 %	1.21 %	13.03 %	1.35 %	4.18 %	7.47 %	3.10 %	6.87 %	0.22	0.07 %	11.08 %	0.10 %	28.20 %	7.20 %	2.30 %	12.66 %
Dunns	0.00 %	0.51 %	7.19 %	0.00 %	0.52 %	15.87 %	0.00 %	25.97 %	0.00	0.00 %	29.17 %	0.09 %	0.27 %	8.76 %	0.22 %	11.43 %
Fischer	1.23 %	1.35 %	11.48 %	1.71 %	4.00 %	4.51 %	3.93 %	7.47 %	0.00	0.09 %	7.40 %	0.01 %	36.00 %	6.36 %	2.21 %	12.25 %
Fish	1.23 %	1.62 %	7.30 %	1.67 %	2.41 %	4.58 %	1.88 %	8.86 %	0.00	0.13 %	4.39 %	0.00 %	45.84 %	6.17 %	0.00 %	13.94 %
Fox	0.22 %	1.61 %	9.15 %	2.15 %	0.97 %	25.33 %	0.20 %	21.80 %	0.07	0.33 %	18.67 %	2.26 %	4.37 %	5.89 %	0.47 %	6.52 %
Fox R DT-35	0.14 %	0.48 %	3.59 %	11.22 %	0.00 %	4.35 %	0.15 %	59.58 %	0.00	0.29 %	6.04 %	5.39 %	5.46 %	1.13 %	0.32 %	1.86 %
Grass	0.30 %	1.43 %	8.45 %	3.32 %	0.35 %	22.63 %	0.10 %	27.79 %	0.06	0.53 %	15.66 %	2.50 %	5.30 %	4.64 %	0.64 %	6.29 %
Grays	0.00 %	1.52 %	2.81 %	0.00 %	0.00 %	45.26 %	0.00 %	4.89 %	0.00	0.00 %	36.33 %	0.00 %	0.00 %	9.19 %	0.00 %	0.00 %
Hidden	0.00 %	0.00 %	1.99 %	0.00 %	0.00 %	22.61 %	0.27 %	22.25 %	0.00	0.00 %	29.64 %	0.00 %	0.00 %	13.99 %	9.24 %	0.00 %
Long	1.05 %	1.58 %	9.26 %	1.09 %	1.83 %	6.78 %	1.84 %	17.37 %	0.12	0.80 %	20.34 %	0.27 %	15.22 %	10.48 %	2.75 %	9.23 %
Marie	0.12 %	3.64 %	10.18 %	0.00 %	0.68 %	34.01 %	0.00 %	6.39 %	0.10	0.00 %	18.10 %	1.97 %	5.09 %	5.90 %	0.91 %	12.91 %
McGreal	2.00 %	0.00 %	19.56 %	0.00 %	0.00 %	18.17 %	0.00 %	0.00 %	0.00	0.49 %	39.95 %	0.00 %	11.60 %	4.56 %	0.00 %	3.67 %
N Churchill	1.15 %	0.00 %	1.47 %	1.06 %	0.00 %	14.38 %	0.72 %	5.84 %	0.00	0.00 %	19.51 %	0.00 %	32.76 %	15.69 %	4.25 %	3.18 %
Nippersink	0.22 %	1.59 %	9.11 %	2.11 %	0.96 %	25.14 %	0.19 %	21.88 %	0.06	0.33 %	18.87 %	2.22 %	4.29 %	5.95 %	0.47 %	6.62 %
Petite	0.47 %	1.17 %	22.99 %	0.03 %	2.17 %	10.72 %	1.53 %	7.77 %	0.07	0.00 %	24.40 %	1.67 %	11.17 %	6.59 %	0.67 %	8.59 %
Pistakee	0.38 %	1.15 %	9.63 %	1.69 %	1.09 %	7.35 %	1.87 %	11.08 %	0.05	0.20 %	16.18 %	0.37 %	37.50 %	3.36 %	0.72 %	7.37 %
Redhead	0.76 %	2.37 %	10.37 %	0.00 %	1.14 %	10.39 %	0.04 %	42.28 %	0.00	1.42 %	18.77 %	0.06 %	3.35 %	5.53 %	0.08 %	3.45 %
Round	0.09 %	5.47 %	4.08 %	0.00 %	1.81 %	16.08 %	0.00 %	15.97 %	0.15	0.00 %	37.18 %	0.42 %	0.32 %	17.09 %	0.10 %	1.24 %
S Churchill	1.46 %	0.00 %	1.68 %	1.34 %	0.00 %	5.38 %	0.91 %	4.66 %	0.00	0.00 %	16.26 %	0.00 %	41.57 %	17.38 %	5.40 %	3.95 %
Spring	0.18 %	1.44 %	7.72 %	0.79 %	0.00 %	0.27 %	1.33 %	17.33 %	0.00	1.11 %	18.77 %	9.81 %	22.28 %	10.10 %	0.01 %	8.86 %
Summerhill Estates	0.00 %	0.00 %	0.12 %	0.00 %	3.29 %	12.80 %	0.00 %	68.56 %	0.00	0.00 %	11.08 %	0.00 %	0.13 %	3.75 %	0.00 %	0.27 %
Tranquility	0.00 %	7.41 %	14.66 %	0.00 %	5.39 %	11.13 %	0.00 %	8.39 %	0.00	0.00 %	34.85 %	0.00 %	0.00 %	17.70 %	0.00 %	0.46 %
Turner	0.00 %	0.00 %	4.38 %	0.00 %	0.00 %	10.41 %	0.00 %	53.49 %	0.00	0.79 %	21.64 %	0.00 %	5.35 %	1.72 %	1.91 %	0.31 %
Wooster	1.10 %	1.26 %	12.32 %	1.52 %	4.76 %	6.20 %	3.53 %	7.35 %	0.05	0.08 %	9.22 %	0.03 %	32.13 %	6.49 %	2.25 %	11.70 %
Grand Total	***0.45 %***	***1.34 %***	***9.63 %***	***1.80 %***	***1.29 %***	***11.50 %***	***1.47 %***	***14.68 %***	***0.06***	***0.30 %***	***16.89 %***	***0.83 %***	***26.37 %***	***4.95 %***	***0.93 %***	***7.49 %***

Sub-Watershed and Total Watershed Land Use Areas (Acres) For Channel and Catherine Lakes

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands	Grand Total
Catherine	0.02	13.38	148.20	3.61	4.66	192.53		26.73			341.23	9.43	151.77	116.13	23.24	73.66	1104.58
Channel	26.40	23.66	442.00	3.61	4.66	567.90	7.66	103.07	0.62	51.41	758.61	40.27	248.00	202.99	23.24	306.87	2810.96
Total Watershed	26.42	37.04	590.20	7.23	9.33	760.43	7.66	129.80	0.62	51.41	1099.84	49.70	399.76	319.12	46.47	380.52	3915.54

Sub-Watershed and Total Watershed Land Use Areas (Acres) For Lake Marie

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands	Grand Total
Marie	2.02	60.78	170.01		11.41	568.16		106.72	1.64		302.31	32.91	85.04	98.56	15.13	215.69	1670.39
Contributing Watersheds (Channel, Catherine)	26.42	37.04	590.20	7.23	9.33	760.43	7.66	129.80	0.62	51.41	1099.84	49.70	399.76	319.12	46.47	380.52	3915.54
Total Watershed	28.43	97.82	760.21	7.23	20.74	1328.59	7.66	236.52	2.26	51.41	1402.15	82.61	484.80	417.68	61.60	596.21	5585.93

Sub-Watershed and Total Watershed Land Use Areas (Acres) For Bluff Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands	Grand Total
Bluff	5.76	33.98	142.70	17.49	2.01	100.49	0.70	5.84	5.95	10.59	278.10	6.79	161.65	80.34	26.28	64.95	943.63
Contributing Watershed (Marie, Channel, Catherine)	28.43	97.82	760.21	7.23	20.74	1328.59	7.66	236.52	2.26	51.41	1402.15	82.61	484.80	417.68	61.60	596.21	5585.92
Total Watershed	34.19	131.80	902.91	24.72	22.75	1429.08	8.36	242.36	8.21	62.00	1680.25	89.40	646.45	498.02	87.88	661.16	6529.55

Sub-Watershed and Total Watershed Land Use Areas (Acres) For Spring Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands	Grand Total
Spring	0.53	4.29	23.06	2.37		0.80	3.97	51.75		3.32	56.03	29.28	66.53	30.17	0.02	26.46	298.59
Contributing Watershed (Bluff, Marie, Channel, Catherine)	34.19	131.80	902.91	24.72	22.75	1429.08	8.36	242.36	8.21	62.00	1680.25	89.40	646.45	498.02	87.88	661.16	6529.54
Total Watershed	34.72	136.09	925.97	27.09	22.75	1429.88	12.33	294.11	8.21	65.32	1736.28	118.68	712.98	528.19	87.90	687.62	6828.13

Sub-Watershed and Total Watershed Land Use Areas (Acres) For Petite Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands	Grand Total
Petite	8.38	20.92	411.77	0.52	38.91	192.04	27.43	139.12	1.25		436.96	29.84	199.96	117.96	11.98	153.83	1790.86
Contributing Watershed (Spring, Bluff, Marie, Channel, Catherine)	34.72	136.09	925.97	27.09	22.75	1429.88	12.33	294.11	8.21	65.32	1736.28	118.68	712.98	528.19	87.90	687.62	6828.12
Total Watershed	43.10	157.02	1337.74	27.61	61.66	1621.92	39.76	433.23	9.46	65.32	2173.24	148.52	912.94	646.14	99.88	841.45	8618.99

Sub-Watershed and Total Watershed Land Use Areas (Acres) For Fox Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands	Grand Total
Fox	50.85	369.14	2,099.58	493.49	221.78	5812.50	45.49	5003.74	15.13	76.51	4,284.72	518.52	1,001.88	1351.59	108.71	1,496.73	22950.38
Contributing Watersheds (Nippersink, Pistakee)	701.44	2334.40	18578.65	3377.76	2083.82	18450.08	3240.23	24058.30	105.48	419.24	32066.44	1150.68	65072.02	7125.01	1337.80	14134.74	194236.09
Total Watershed	752.28	2703.54	20678.23	3871.25	2305.60	24262.58	3285.72	29062.04	120.61	495.75	36351.17	1669.21	66073.90	8476.60	1446.51	15631.47	217186.47

Sub-Watershed and Total Watershed Land Use Areas (Acres) For Grass Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands	Grand Total
Grass	41.56	198.31	1,170.25	460.18	48.76	3132.82	14.09	3847.50	8.22	73.19	2,168.27	345.55	733.84	642.46	88.51	871.17	13844.70
Contributing Watersheds (Fox, Nippersink, Pistakee, Marie, Channel, Catherine)	780.72	2801.36	21438.44	3878.48	2326.34	25591.17	3293.38	29298.57	122.87	547.16	37753.32	1751.82	66558.70	8894.28	1508.11	16227.69	222772.39
Total Watershed	822.28	2999.68	22608.69	4338.65	2375.10	28723.99	3307.47	33146.06	131.09	620.36	39921.59	2097.37	67292.54	9536.74	1596.61	17098.87	236617.10

Sub-Watershed and Total Watershed Land Use Areas (Acres) For Nippersink Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands	Grand Total
Nippersink	50.85	371.46	2,132.37	493.49	224.14	5884.67	45.49	5121.90	15.13	76.51	4,417.55	518.93	1,003.12	1391.64	109.71	1,548.74	23405.71
Contributing Watersheds (Fox, Pistakee, Grass, Marie, Channel, Catherine)	771.43	2628.22	20476.32	3845.17	2150.96	22839.32	3261.98	28024.16	115.96	543.85	35504.04	1578.44	66289.42	8145.10	1486.90	15550.13	213211.39
Total Watershed	822.28	2999.68	22608.69	4338.65	2375.10	28723.99	3307.47	33146.06	131.09	620.36	39921.59	2097.37	67292.54	9536.74	1596.61	17098.87	236617.10

Sub-Watershed and Total Watershed Land Use Areas (Acres) For Pistakee Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands	Grand Total
Pistakee	650.59	1962.94	16,446.27	2884.27	1,859.68	12565.41	3,194.74	18936.40	90.35	342.73	27,648.89	631.75	64,068.90	5733.37	1228.09	12,586.00	170830.38
Contributing Watersheds (Nippersink, Fox, Grass, Marie, Channel, Catherine, Redhead)	181.80	1068.14	6299.99	1454.38	530.50	16296.36	113.25	14770.45	40.74	296.41	12521.64	1466.46	3268.10	3876.69	369.63	4558.57	67113.11
Total Watershed	832.39	3031.08	22746.26	4338.65	2390.18	28861.77	3307.99	33706.85	131.09	639.14	40170.53	2098.21	67337.00	9610.06	1597.72	17144.57	237943.49

Sub-Watershed and Total Watershed Land Use Areas (Percent) For Channel and Catherine Lakes

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands
Catherine	0.00%	1.21%	13.42%	0.33%	0.42%	17.43%	0.00%	2.42%	0.00%	0.00%	30.89%	0.85%	13.74%	10.51%	2.10%	6.67%
Channel	0.94%	0.84%	15.72%	0.13%	0.17%	20.20%	0.27%	3.67%	0.02%	1.83%	26.99%	1.43%	8.82%	7.22%	0.83%	10.92%
Total Watershed	0.67%	0.95%	15.07%	0.18%	0.24%	19.42%	0.20%	3.31%	0.02%	1.31%	28.09%	1.27%	10.21%	8.15%	1.19%	9.72%

Sub-Watershed and Total Watershed Land Use Areas (Percent) For Lake Marie

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands
Marie	0.12%	3.64%	10.18%	0.00%	0.68%	34.01%	0.00%	6.39%	0.10%	0.00%	18.10%	1.97%	5.09%	5.90%	0.91%	12.91%
Contributing Watersheds (Channel, Catherine)	0.67%	0.95%	15.07%	0.18%	0.24%	19.42%	0.20%	3.31%	0.02%	1.31%	28.09%	1.27%	10.21%	8.15%	1.19%	9.72%
Total Watershed	0.51%	1.75%	13.61%	0.13%	0.37%	23.78%	0.14%	4.23%	0.04%	0.92%	25.10%	1.48%	8.68%	7.48%	1.10%	10.67%

Sub-Watershed and Total Watershed Land Use Areas (Percent) For Bluff Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands
Bluff	0.61%	3.60%	15.12%	1.85%	0.21%	10.65%	0.07%	0.62%	0.63%	1.12%	29.47%	0.72%	17.13%	8.51%	2.79%	6.88%
Contributing Watershed (Marie, Channel, Catherine)	0.51%	1.75%	13.61%	0.13%	0.37%	23.78%	0.14%	4.23%	0.04%	0.92%	25.10%	1.48%	8.68%	7.48%	1.10%	10.67%
Total Watershed	0.52%	2.02%	13.83%	0.38%	0.35%	21.89%	0.13%	3.71%	0.13%	0.95%	25.73%	1.37%	9.90%	7.63%	1.35%	10.13%

Sub-Watershed and Total Watershed Land Use Areas (Percent) For Spring Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands
Spring	0.18%	1.44%	7.72%	0.79%	0.00%	0.27%	1.33%	17.33%	0.00%	1.11%	18.77%	9.81%	22.28%	10.10%	0.01%	8.86%
Contributing Watershed (Bluff, Marie, Channel, Catherine)	0.52%	2.02%	13.83%	0.38%	0.35%	21.89%	0.13%	3.71%	0.13%	0.95%	25.73%	1.37%	9.90%	7.63%	1.35%	10.13%
Total Watershed	0.51%	1.99%	13.56%	0.40%	0.33%	20.94%	0.18%	4.31%	0.12%	0.96%	25.43%	1.74%	10.44%	7.74%	1.29%	10.07%

Sub-Watershed and Total Watershed Land Use Areas (Percent) For Petite Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands
Petite	0.47%	1.17%	22.99%	0.03%	2.17%	10.72%	1.53%	7.77%	0.07%	0.00%	24.40%	1.67%	11.17%	6.59%	0.67%	8.59%
Contributing Watershed (Spring, Bluff, Marie, Channel, Catherine)	0.51%	1.99%	13.56%	0.40%	0.33%	20.94%	0.18%	4.31%	0.12%	0.96%	25.43%	1.74%	10.44%	7.74%	1.29%	10.07%
Total Watershed	0.50%	1.82%	15.52%	0.32%	0.72%	18.82%	0.46%	5.03%	0.11%	0.76%	25.21%	1.72%	10.59%	7.50%	1.16%	9.76%

Sub-Watershed and Total Watershed Land Use Areas (Percent) For Fox Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands
Fox	0.22%	1.61%	9.15%	2.15%	0.97%	25.33%	0.20%	21.80%	0.07%	0.33%	18.67%	2.26%	4.37%	5.89%	0.47%	6.52%
Contributing Watersheds (Nippersink, Pistakee)	0.36%	1.20%	9.56%	1.74%	1.07%	9.50%	1.67%	12.39%	0.05%	0.22%	16.51%	0.59%	33.50%	3.67%	0.69%	7.28%
Total Watershed	0.35%	1.24%	9.52%	1.78%	1.06%	11.17%	1.51%	13.38%	0.06%	0.23%	16.74%	0.77%	30.42%	3.90%	0.67%	7.20%

Sub-Watershed and Total Watershed Land Use Areas (Percent) For Grass Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands
Grass	0.30%	1.43%	8.45%	3.32%	0.35%	22.63%	0.10%	27.79%	0.06%	0.53%	15.66%	2.50%	5.30%	4.64%	0.64%	6.29%
Contributing Watersheds (Fox, Nippersink, Pistakee, Marie, Channel, Catherine)	0.35%	1.26%	9.62%	1.74%	1.04%	11.49%	1.48%	13.15%	0.06%	0.25%	16.95%	0.79%	29.88%	3.99%	0.68%	7.28%
Total Watershed	0.35%	1.27%	9.55%	1.83%	1.00%	12.14%	1.40%	14.01%	0.06%	0.26%	16.87%	0.89%	28.44%	4.03%	0.67%	7.23%

Sub-Watershed and Total Watershed Land Use Areas (Percent) For Nippersink Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands
Nippersink	0.22%	1.59%	9.11%	2.11%	0.96%	25.14%	0.19%	21.88%	0.06%	0.33%	18.87%	2.22%	4.29%	5.95%	0.47%	6.62%
Contributing Watersheds (Fox, Pistakee, Grass, Marie, Channel, Catherine)	0.36%	1.23%	9.60%	1.80%	1.01%	10.71%	1.53%	13.14%	0.05%	0.26%	16.65%	0.74%	31.09%	3.82%	0.70%	7.29%
Total Watershed	0.35%	1.27%	9.55%	1.83%	1.00%	12.14%	1.40%	14.01%	0.06%	0.26%	16.87%	0.89%	28.44%	4.03%	0.67%	7.23%

Sub-Watershed and Total Watershed Land Use Areas (Percent) For Pistakee Lake

Name	Agriculture	Commercial	Forested, Grasslands	Industrial Warehousing	Institutional	Lakes, Reservoirs, Lagoons	Nurseries, Greenhouses	Open Space	Other Vacant Land	Pastureland	Residential	Rivers, Streams, Canals	Row Crop, Grazing, Grain	Transportation and Utilities	Under Construction	Wetlands
Pistakee	0.38%	1.15%	9.63%	1.69%	1.09%	7.36%	1.87%	11.08%	0.05%	0.20%	16.18%	0.37%	37.50%	3.36%	0.72%	7.37%
Contributing Watersheds (Nippersink, Fox, Grass, Marie, Channel, Catherine, Redhead)	0.27%	1.59%	9.39%	2.17%	0.79%	24.28%	0.17%	22.01%	0.06%	0.44%	18.66%	2.19%	4.87%	5.78%	0.55%	6.79%
Total Watershed	0.35%	1.27%	9.56%	1.82%	1.00%	12.13%	1.39%	14.17%	0.06%	0.27%	16.88%	0.88%	28.30%	4.04%	0.67%	7.21%

Appendix D

NPDES Information

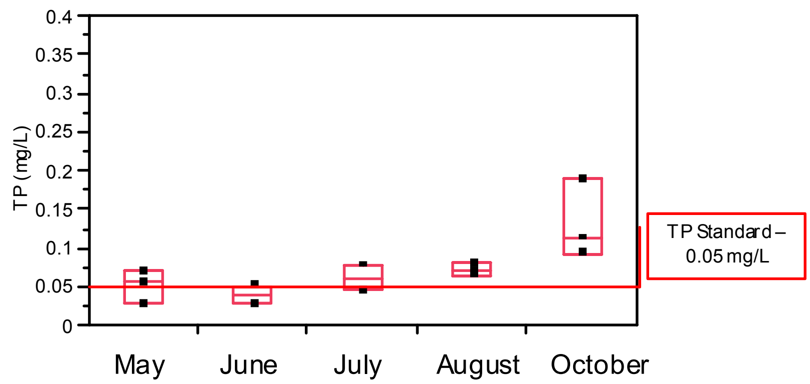
Permit Name	NPDES Number	Name of TMDL	Outfall	Outfall description	DAF (MGD)	DMF (MGD)	Receiving Water	TMDL Segment ID
ANTIOCH PACKING HOUSE INC.	IL0067733	Fox Chain O' Lakes	001	Non-contact cooling water	NA	NA	Sequoit Creek	Lake Tranquility UTW; Marie Lake RTR
VILLAGE OF ANTIOCH	IL0020354	Fox Chain O' Lakes	001	STP	1.6	3.0	Sequoit Creek	Lake Tranquility UTW; Marie Lake RTR
VILLAGE OF ANTIOCH	IL0020354	Fox Chain O' Lakes	A01	Excess Flow Outfall	NA	NA	Sequoit Creek	Lake Tranquility UTW; Marie Lake RTR
BAXTER HEALTHCARE CORPORATION	IL0024074	Fox Chain O' Lakes	001	Treated Industrial Wastewater	0.38	NA	Unnamed Ditch Tributary to Squaw Creek	Long Lake RTJ
BAXTER HEALTHCARE CORPORATION	IL0024074	Fox Chain O' Lakes	002	Stormwater Runoff	NA	NA	Unnamed Ditch Tributary to Squaw Creek	Long Lake RTJ
BAXTER HEALTHCARE CORPORATION	IL0024074	Fox Chain O' Lakes	003	Stormwater Runoff	NA	NA	Unnamed Ditch Tributary to Squaw Creek	Long Lake RTJ
BAXTER HEALTHCARE CORPORATION	IL0024074	Fox Chain O' Lakes	004	Stormwater Runoff	NA	NA	Unnamed Ditch Tributary to Squaw Creek	Long Lake RTJ
BAXTER HEALTHCARE CORPORATION	IL0024074	Fox Chain O' Lakes	005	Stormwater Runoff	NA	NA	Unnamed Ditch Tributary to Squaw Creek	Long Lake RTJ
CAMP HENRY HORNER-INGLESIDE	IL0054615	Fox Chain O' Lakes	001	STP	0.014	0.035	Wooster Lake	Wooster Lake RTZH
CAMP HICKORY-INGLESIDE	IL0046043	Fox Chain O' Lakes	001	STP	0.014	0.035	Sqaw Creek tributary to Fox River	Long Lake RTJ
DAHL ENTERPRISES INC	ILG840040	Fox Chain O' Lakes	001	Stormwater Runoff, groundwater seepage	0.45	NA	unnamed tributary to Loon Lake	Marie Lake RTR
FOX LAKE GRADE SCHOOL DIST 114	IL0076597	Fox Chain O' Lakes	001	Sand Filter Backwash	NA	NA	Wetlands Tributary to Nippersink Lake	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV
FOX LAKE GRADE SCHOOL DIST 114	IL0076597	Fox Chain O' Lakes	002	Carbon Filter Backwash	NA	NA	Wetlands Tributary to Nippersink Lake	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV
VILLAGE OF FOX LAKE-NW REGIONAL WRF	IL0020958	Fox Chain O' Lakes	001	STP	9.0	22.5	Fox River	Fox River DT-23

Permit Name	NPDES Number	Name of TMDL	Outfall	Outfall description	DAF (MGD)	DMF (MGD)	Receiving Water	TMDL Segment ID
VILLAGE OF FOX LAKE-TALL OAKS STP	IL0045144	Fox Chain O' Lakes	001	STP	0.50	1.25	Unnamed tributary to Dunns Lake	Dunns Lake VTH; Nippersink RTUA; Lake Pistakee RTU; Redhead Lake RTV
FREMONT SCHOOL-DISTRICT 79	IL0034746	Fox Chain O' Lakes	001	STP	0.01	0.04	Unnamed tributary to Sqaw Creek	Long Lake RTJ
VILLAGE OF HEBRON	IL0026433	Fox Chain O' Lakes	001	WWTP	0.158	0.288	Unnamed tributary of North Branch of Nippersink Creek	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV
INTERMATIC INC.	IL0059145	Fox Chain O' Lakes	001	Non-contact cooling water and Combined A01 and B01 Wastewater	0.478	NA	Nippersink Creek	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV
INTERMATIC INC.	IL0059145	Fox Chain O' Lakes	A01	Treated Phosphating Wastewater	0.0033	NA	Nippersink Creek	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV
INTERMATIC INC.	IL0059145	Fox Chain O' Lakes	B01	Treated Sanitary Wastewater	0.0076	NA	Nippersink Creek	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV
KOENEMANN SAUSAGE COMPANY	IL0038067	Fox Chain O' Lakes	001	Treated sanitary, process, non-contact cooling water and Stormwater	0.0054	NA	Unnamed tributary to Fish Lake	Unnamed tributary; Fish-Duncan Lake VTK
VILLAGE OF RICHMOND	IL0026093	Fox Chain O' Lakes	001	STP	0.50	1.625	North Branch of Nippersink Creek	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV
VILLAGE OF SPRING GROVE	IL0074985	Fox Chain O' Lakes	001	STP	0.075	0.1875	Nippersink Creek	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV
SURGIPATH MEDICAL INDUSTRIES, INC	IL0070645	Fox Chain O' Lakes	001	Contact Cooling Water	0.06	NA	Wetlands Tributary to North Branch of Nippersink Creek	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV
VILLAGE OF WOODSTOCK	IL0031861	Fox Chain O' Lakes	001	STP	3.5	10.5	Silver Creek	Nippersink Lake RTUA; Lake Pistakee RTU; Redhead Lake RTV

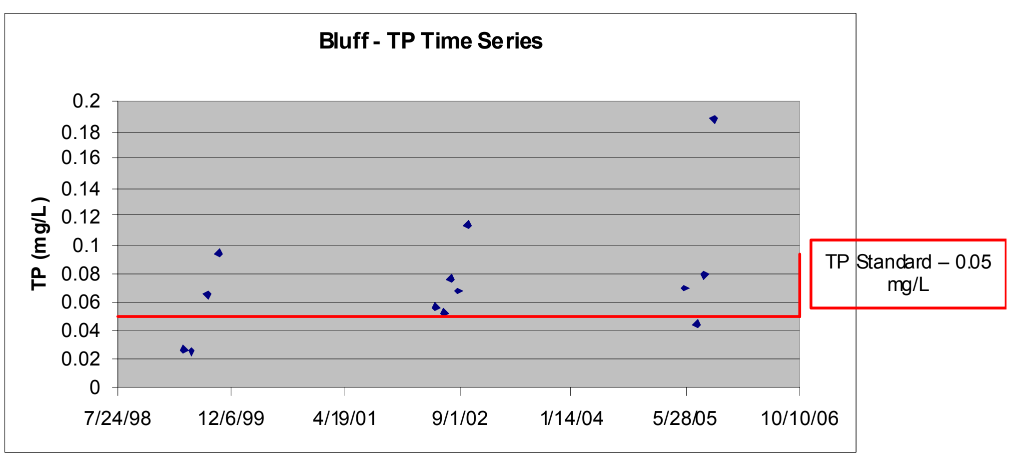
Appendix E

Total Phosphorus Box Plots and Time Series

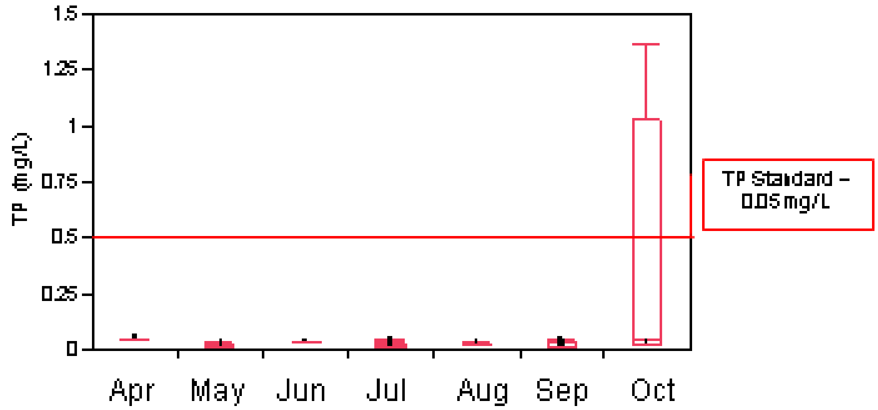
Bluff (All Stations) – Total Phosphorus 1998 - present



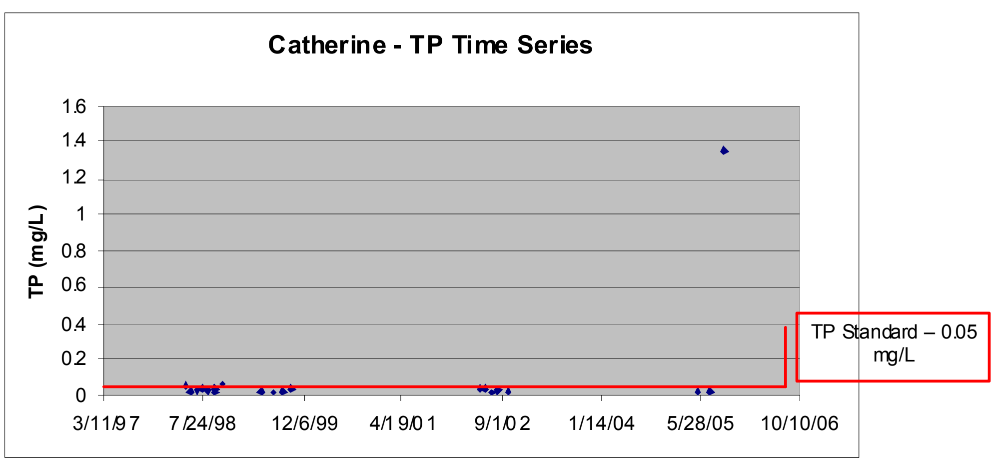
Bluff (All Stations) – Total Phosphorus Time Series 1998 - present



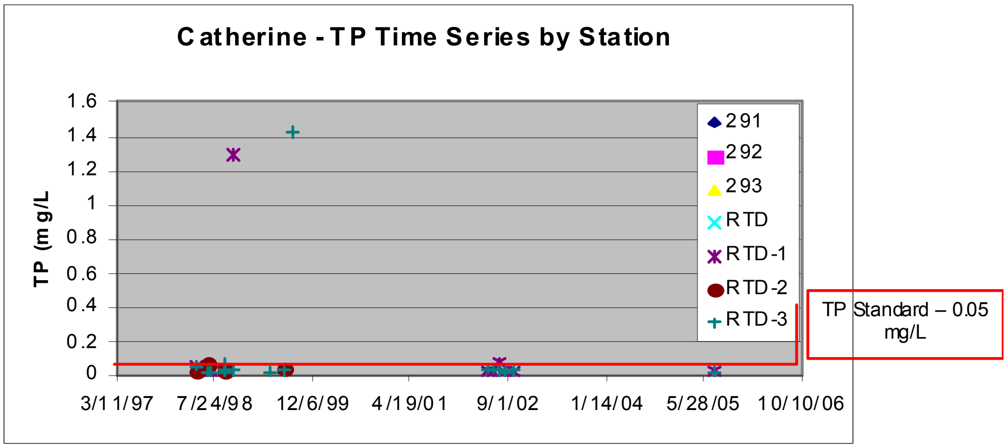
Catherine (All Stations) – Total Phosphorus
1998 - present



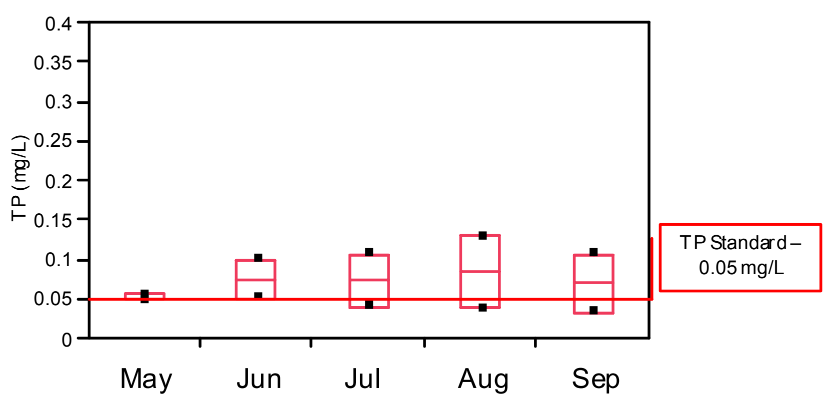
Catherine (All Stations) – Total Phosphorus Time Series
1998 - present



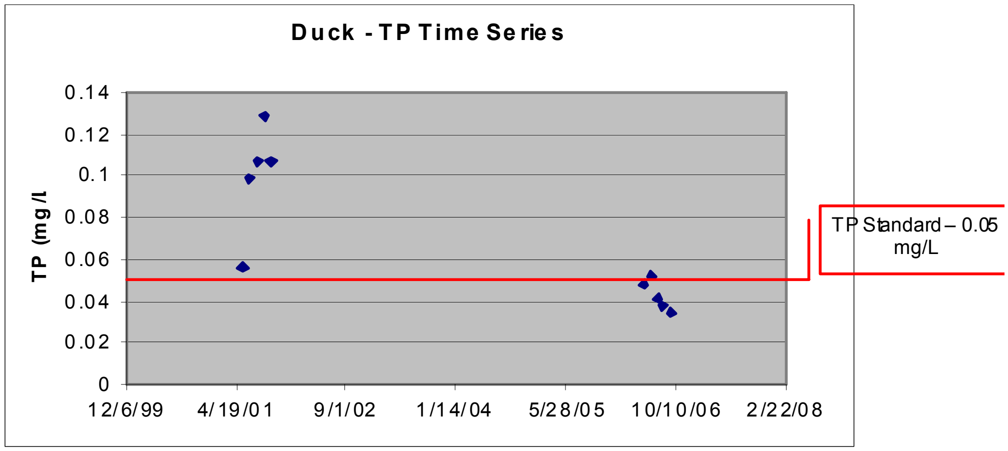
Catherine (By Station) – Total Phosphorus Time Series
1998 - present



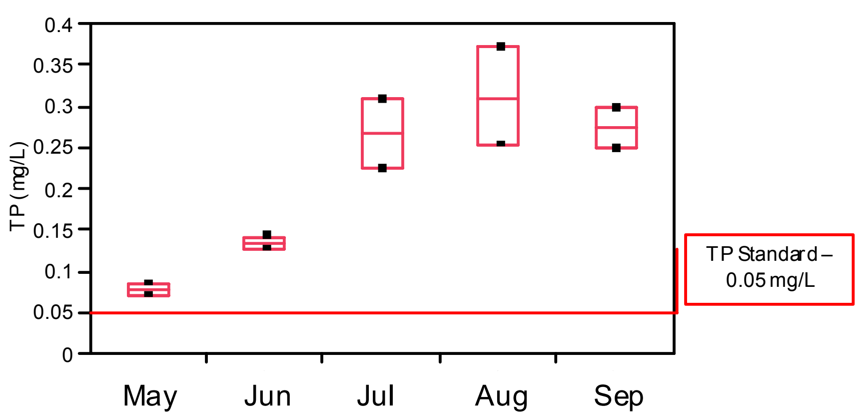
Duck (All Stations) – Total Phosphorus
1998 - present



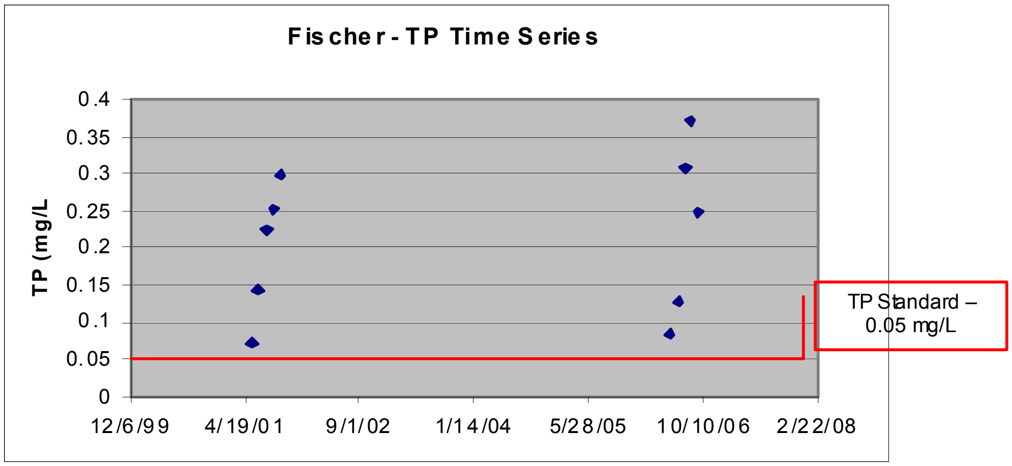
Duck (All Stations) – Total Phosphorus Time Series
1998 - present



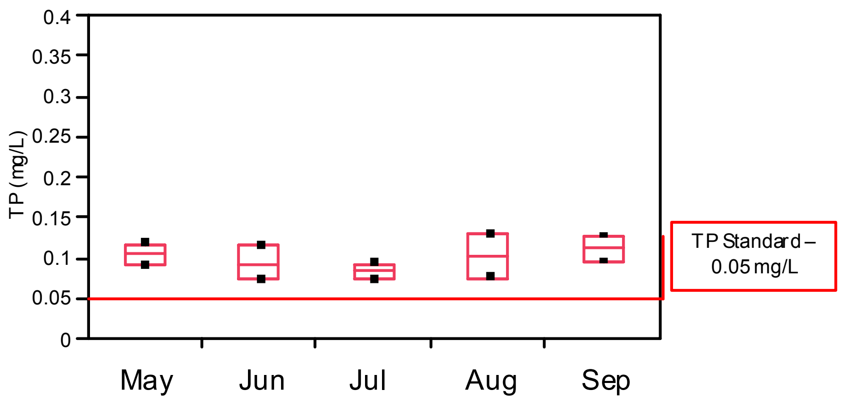
Fischer (All Stations) - Total Phosphorus
1998 - present



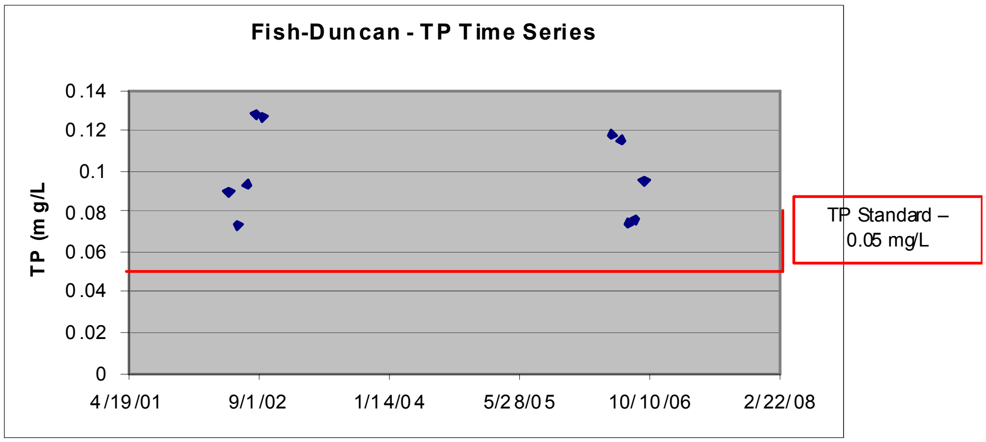
Fischer (All Stations) - Total Phosphorus Time Series 1998 - present



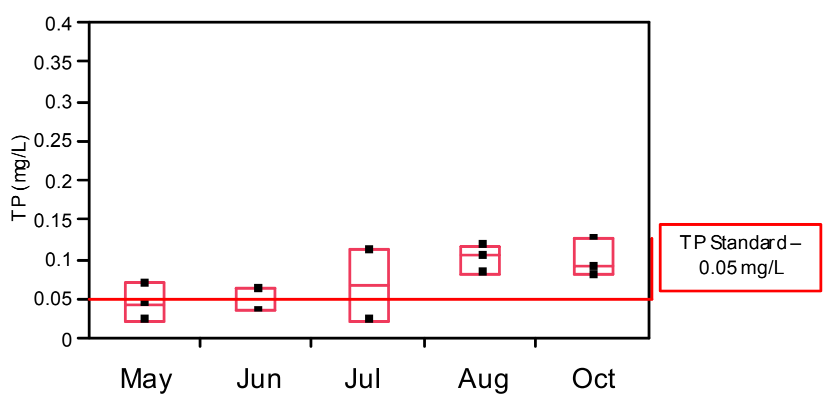
Fish-Duncan (All Stations) – Total Phosphorus 1998 - present



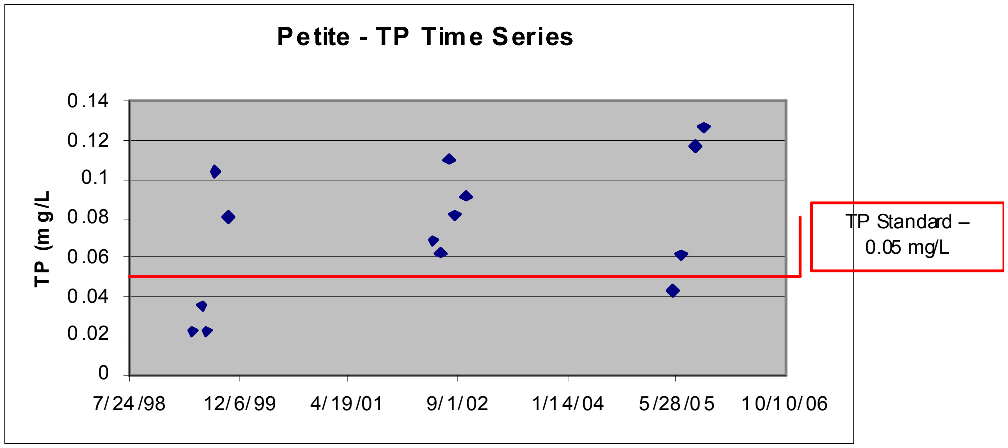
Fish-Duncan (All Stations) – Total Phosphorus Time Series 1998 - present



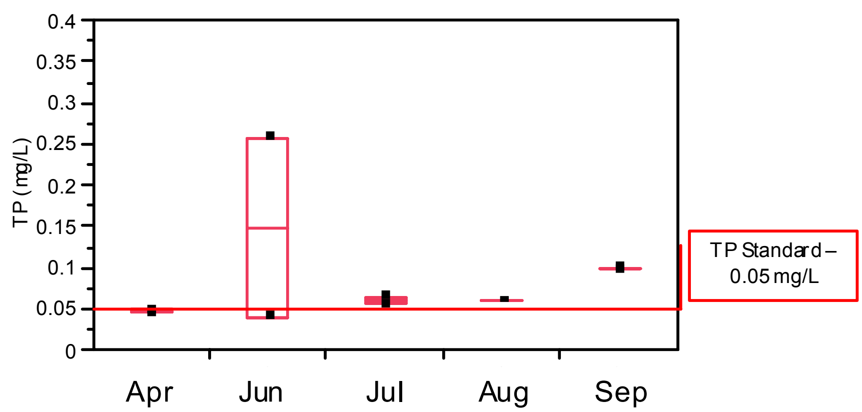
Petite (All Stations) – Total Phosphorus 1998 - present



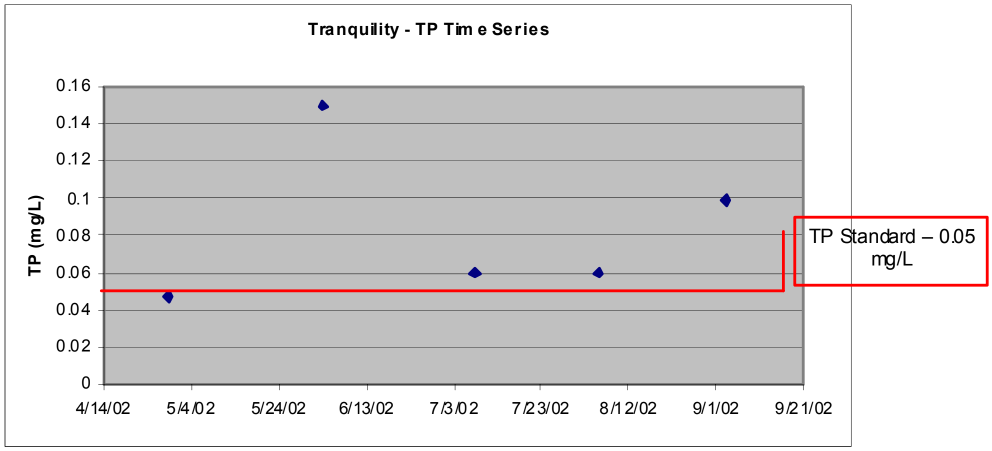
Petite (All Stations) – Total Phosphorus Time Series
1998 - present



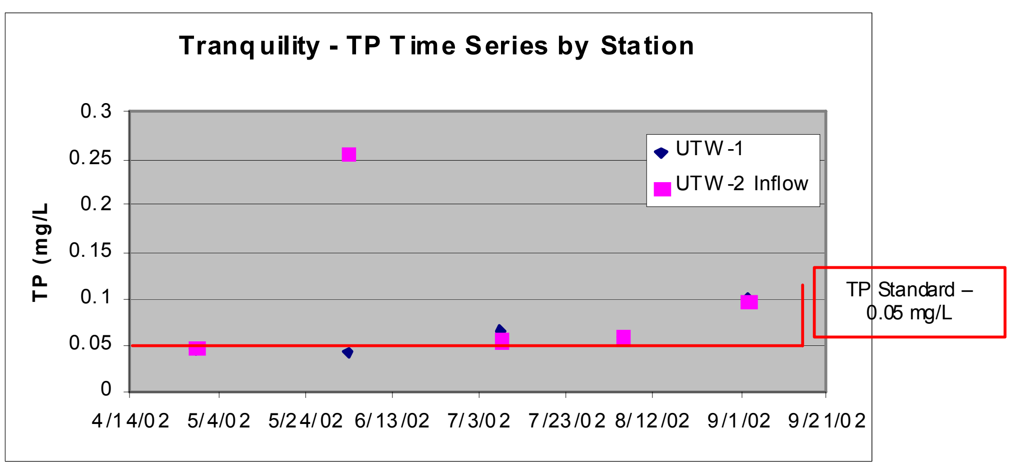
Tranquility (All Stations) – Total Phosphorus
1998 - present



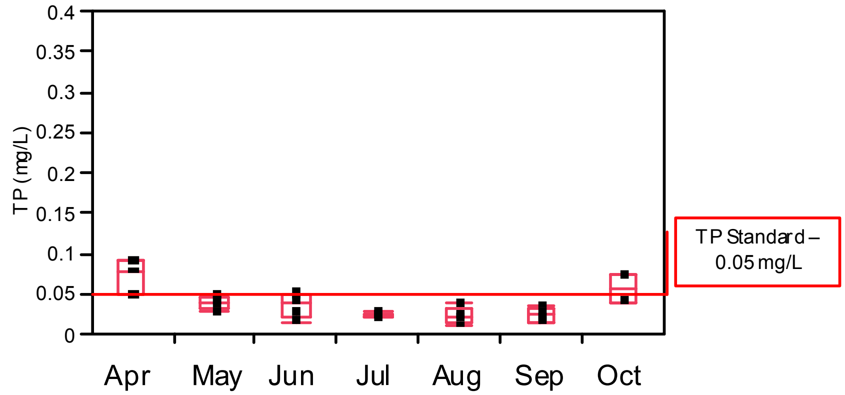
Tranquility (All Stations) – Total Phosphorus Time Series
1998 - present



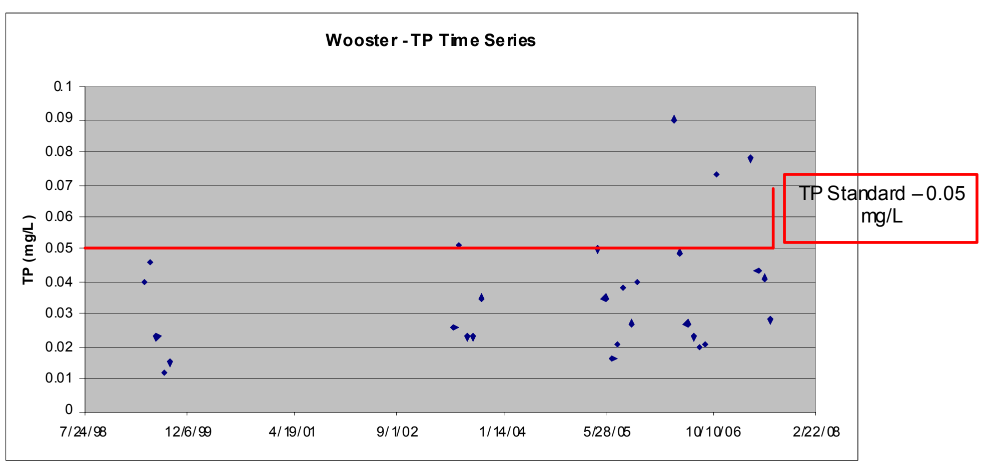
Tranquility (By Station) – Total Phosphorus Time Series
1998 - present



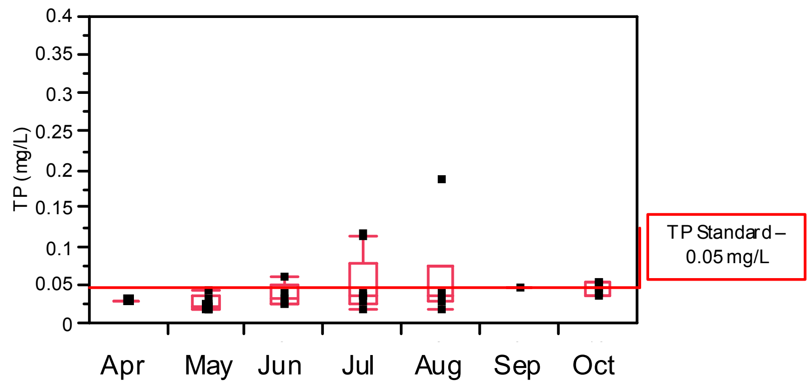
Wooster (All Stations) – Total Phosphorus
1998 - present



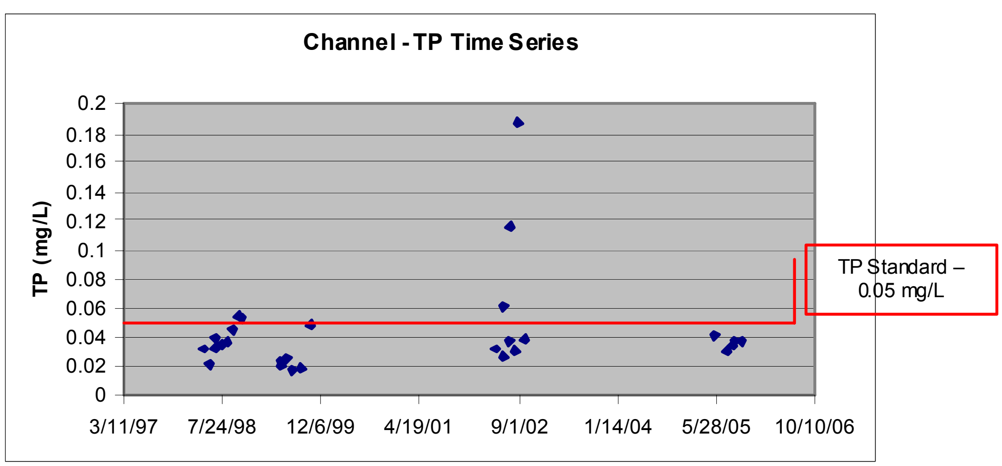
Wooster (All Stations) – Total Phosphorus Time Series
1998 - present



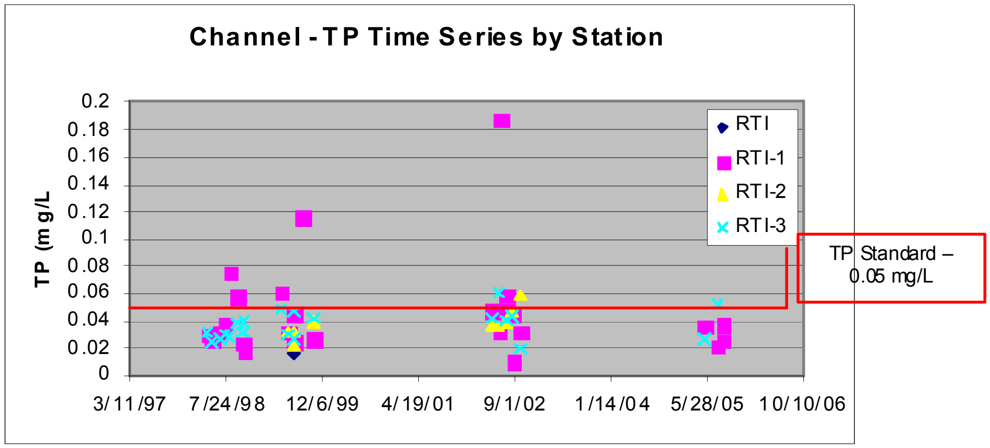
Channel (All Stations) – Total Phosphorus
1998 - present



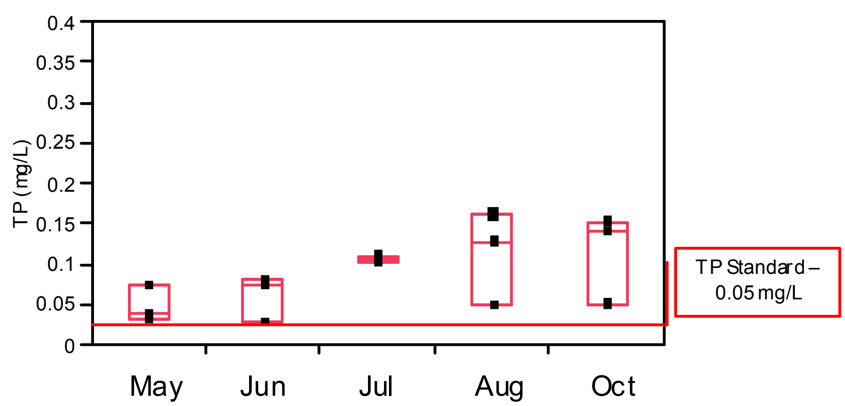
Channel (All Stations) – Total Phosphorus Time Series
1998 - present



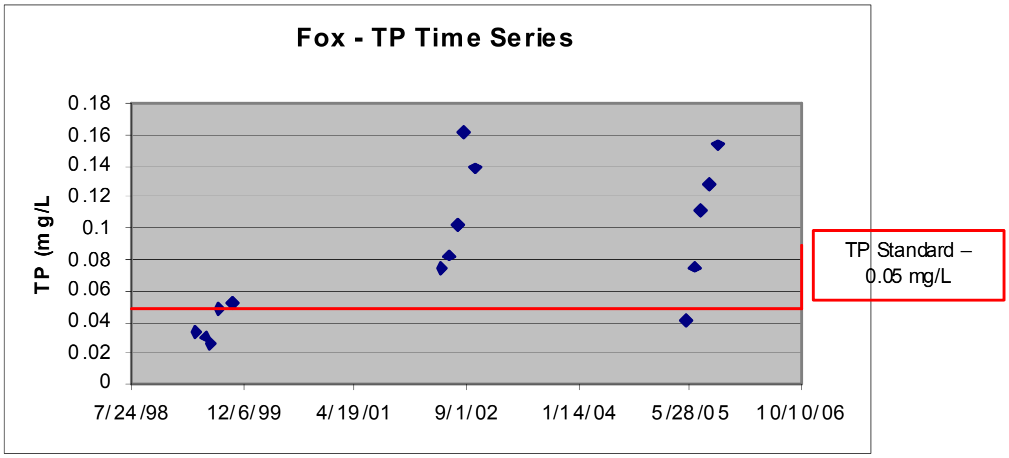
Channel (By Station) – Total Phosphorus Time Series
1998 - present



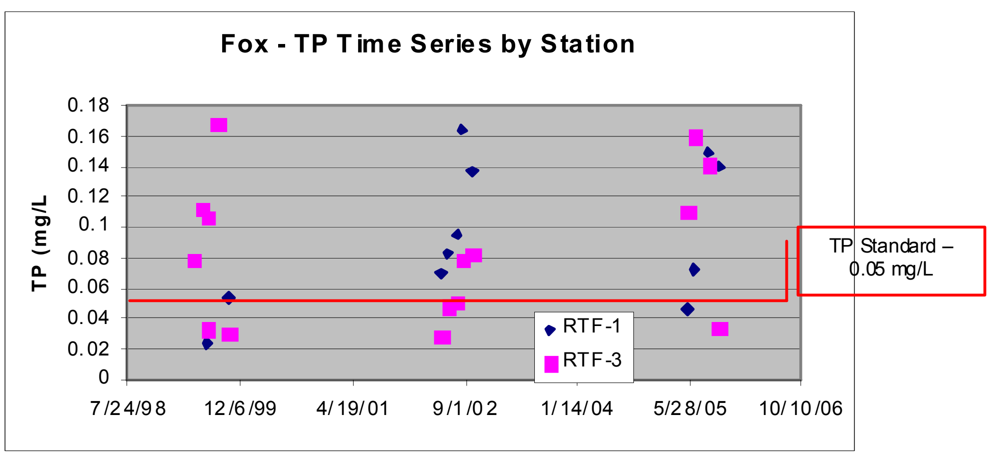
Fox (All Stations) – Total Phosphorus
1998 - present



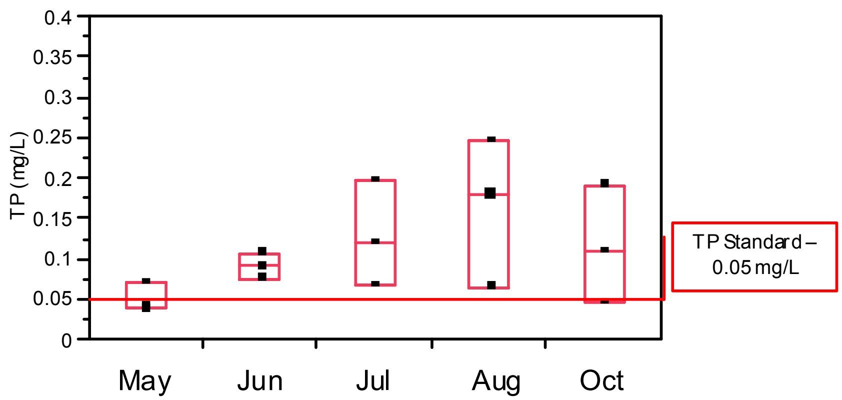
Fox (All Stations) – Total Phosphorus Time Series
1998 - present



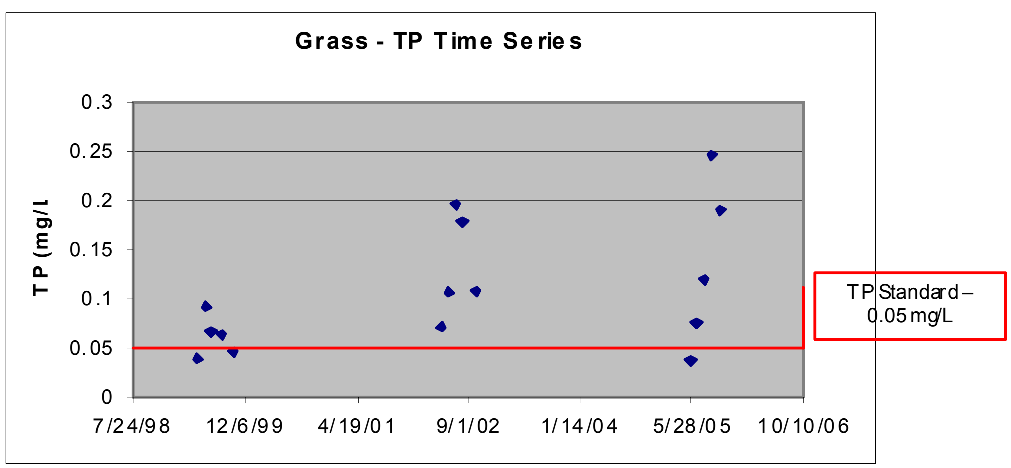
Fox (By Station) – Total Phosphorus Time Series
1998 - present



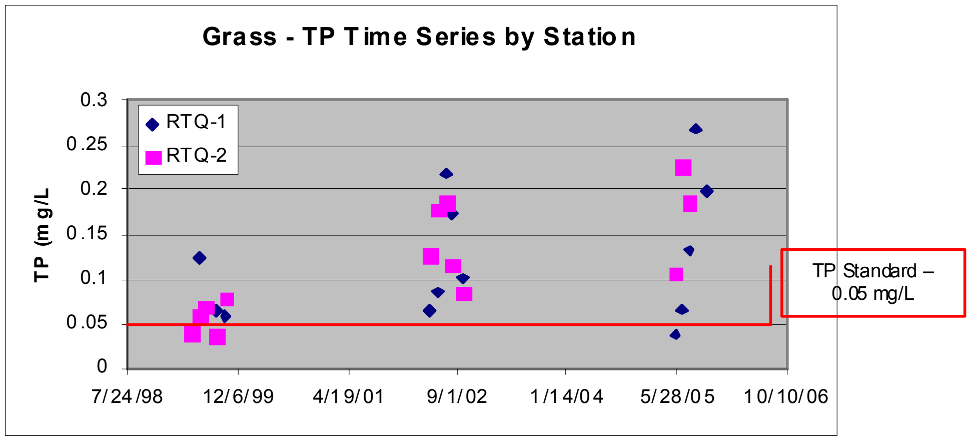
Grass (All Stations) – Total Phosphorus
1998 - present



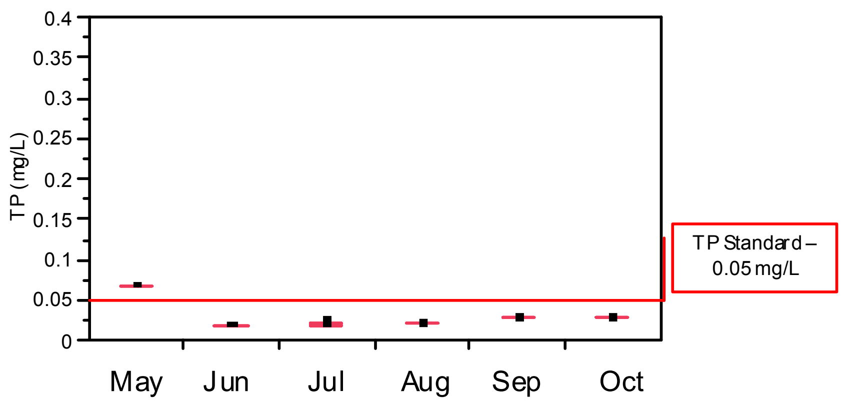
Grass (All Stations) – Total Phosphorus Time Series
1998 - present



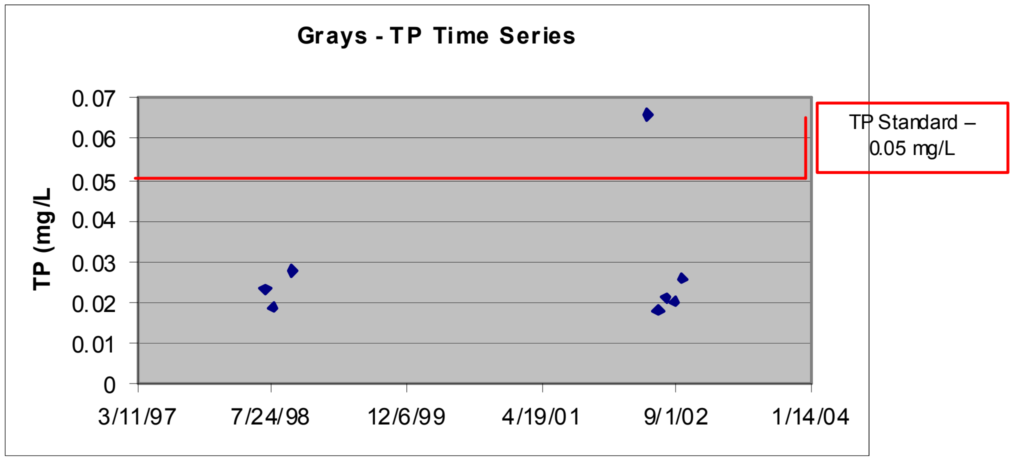
Grass (By Station) – Total Phosphorus Time Series
1998 - present



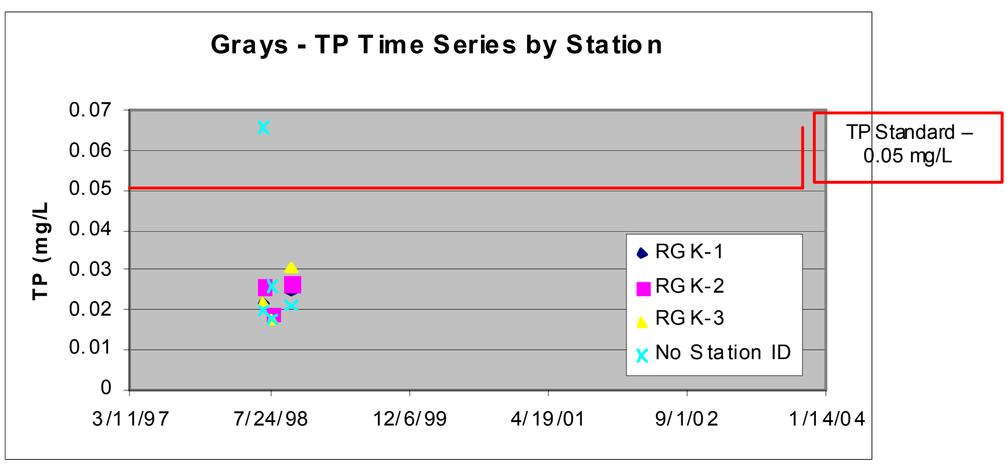
Grays (All Stations) – Total Phosphorus
1998 - present



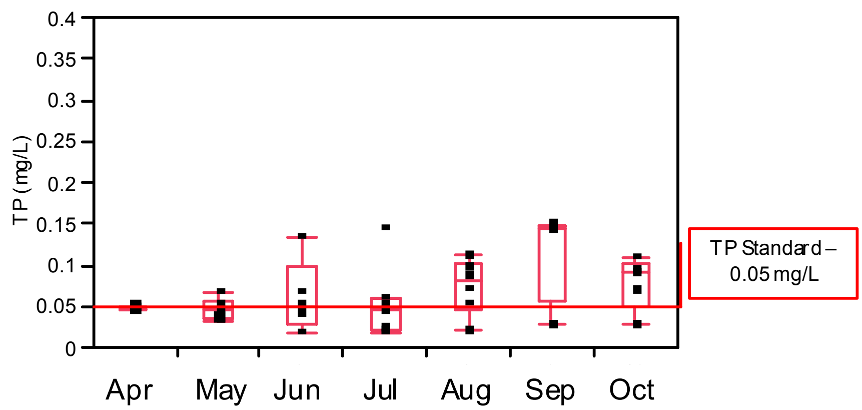
Grays (All Stations) – Total Phosphorus Time Series 1998 - present



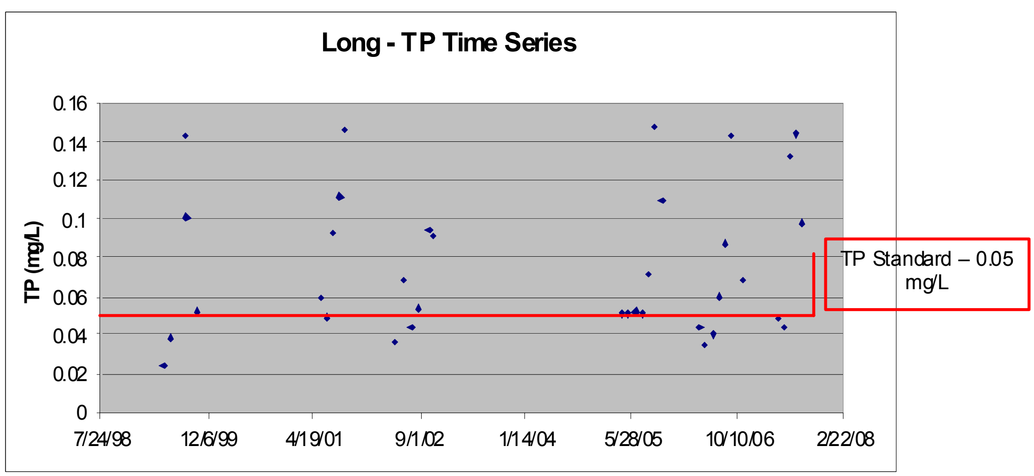
Grays (By Station) – Total Phosphorus Time Series 1998 - present



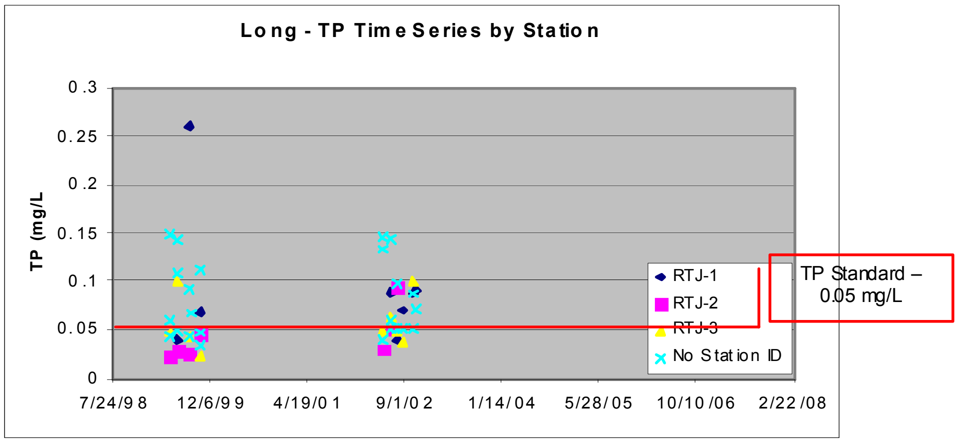
Long (All Stations) – Total Phosphorus
1998 - present



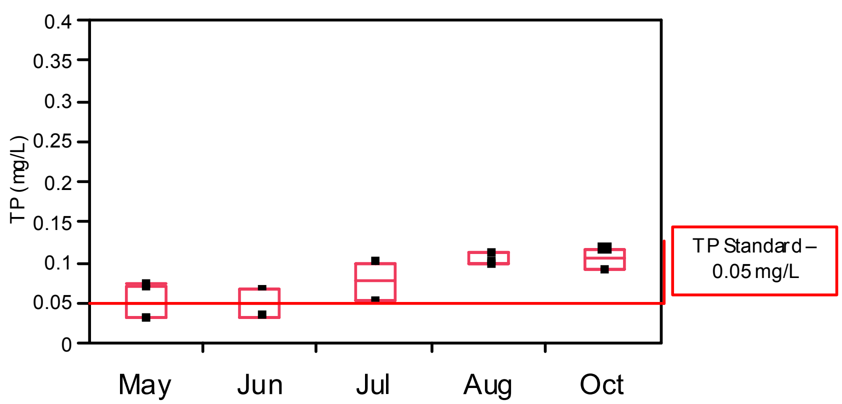
Long (All Stations) – Total Phosphorus Time Series
1998 - present



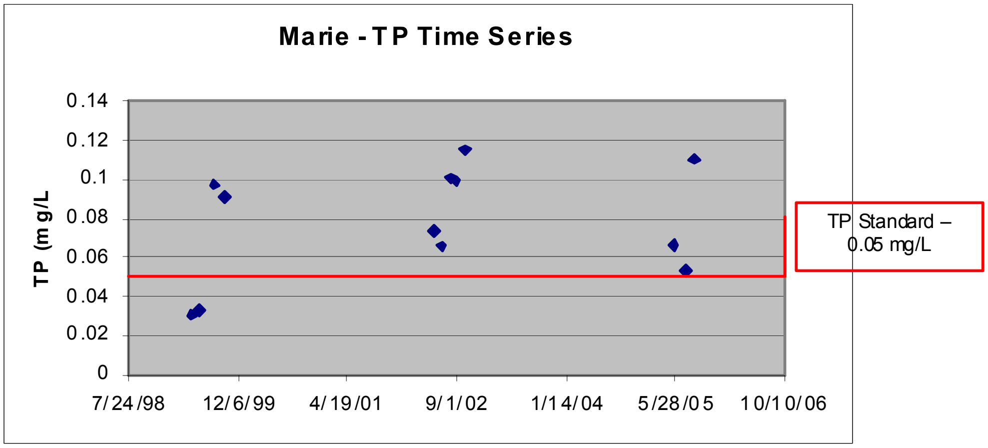
Long (By Station) – Total Phosphorus Time Series 1998 - present



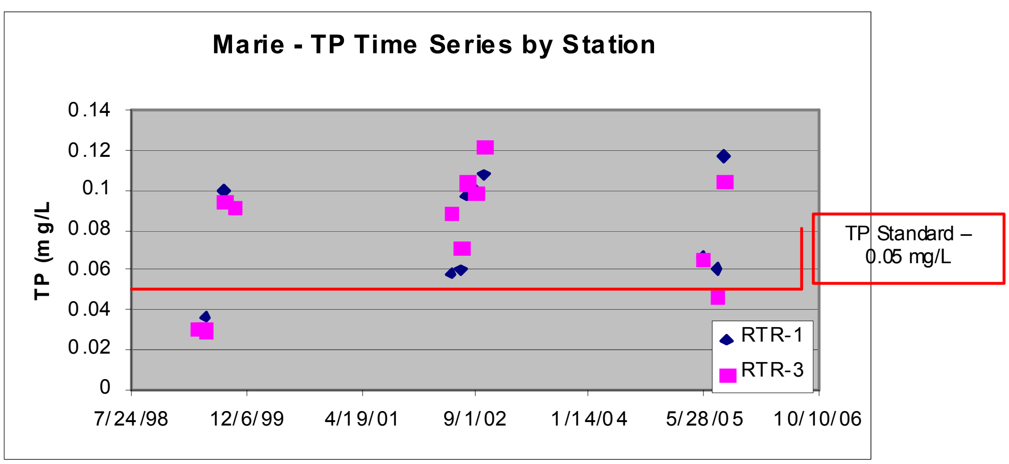
Marie (All Stations) – Total Phosphorus 1998 - present



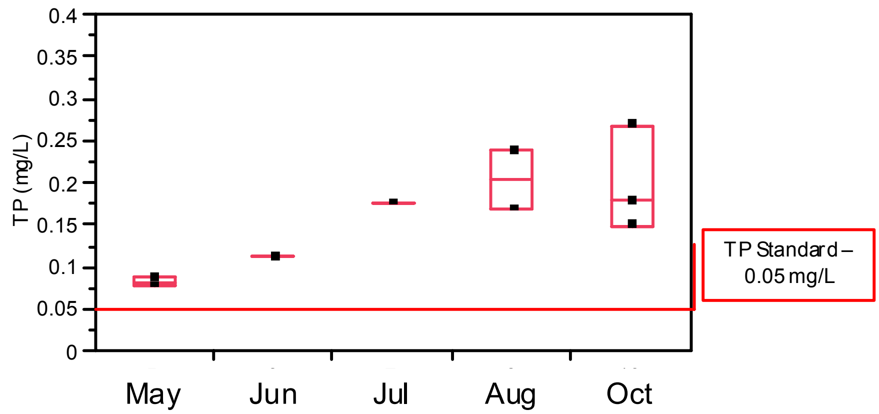
Marie (All Stations) – Total Phosphorus Time Series 1998 - present



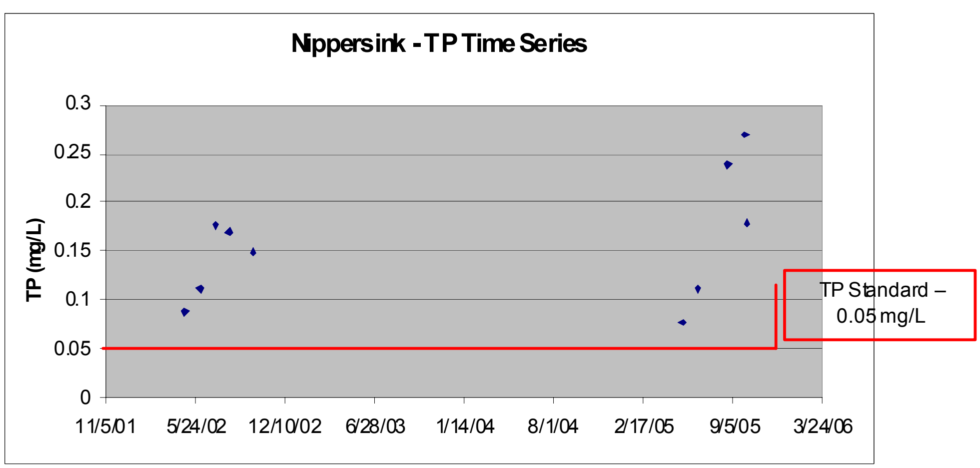
Marie (By Station) – Total Phosphorus Time Series 1998 - present



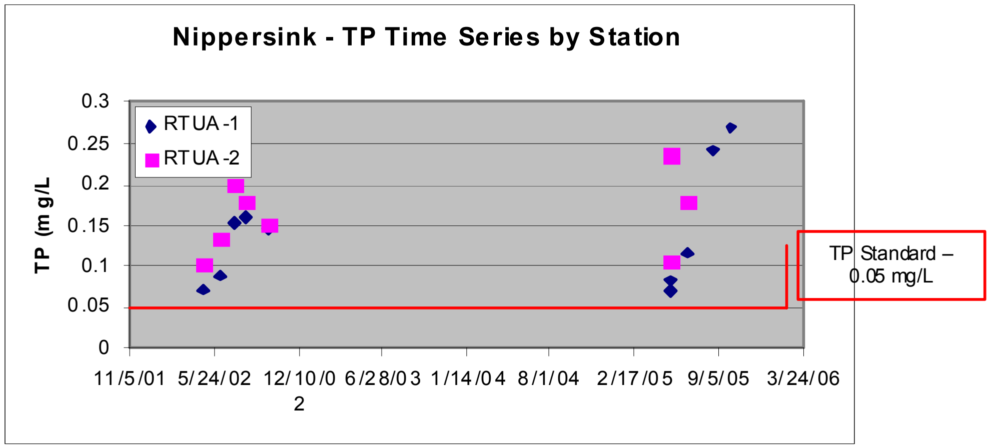
Nippersink (All Stations) – Total Phosphorus 1998 - present



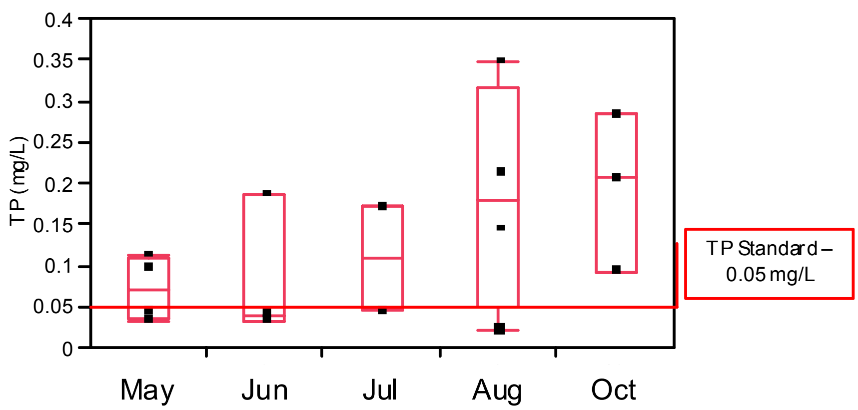
Nippersink (All Stations) – Total Phosphorus Time Series 1998 - present



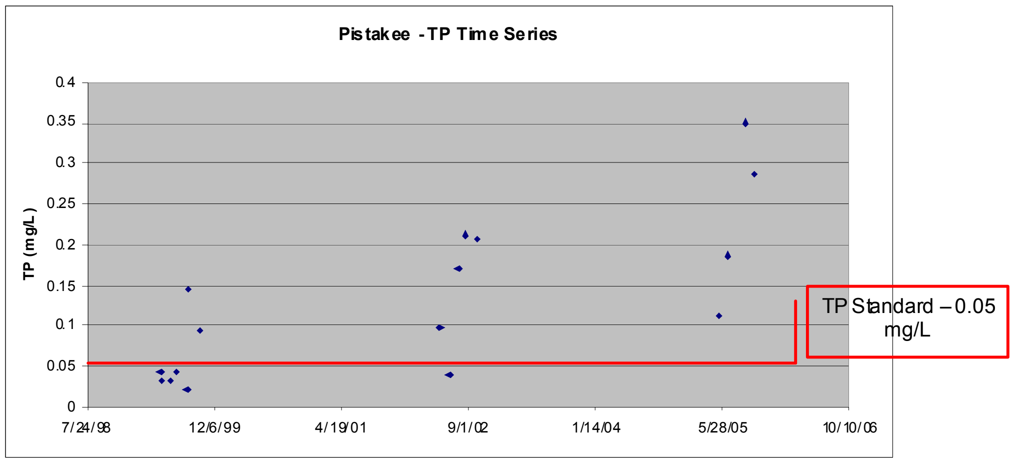
Nippersink (By Station) – Total Phosphorus Time Series 1998 - present



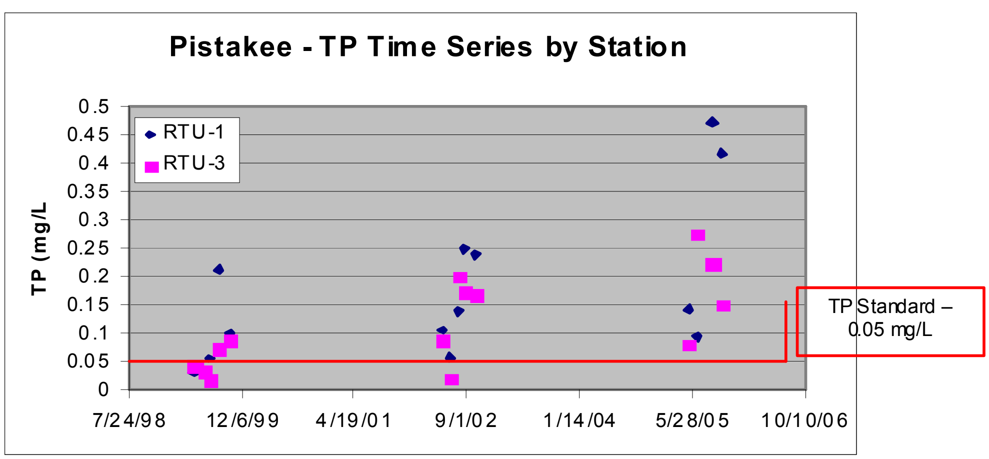
Pistakee (All Stations) – Total Phosphorus 1998 - present



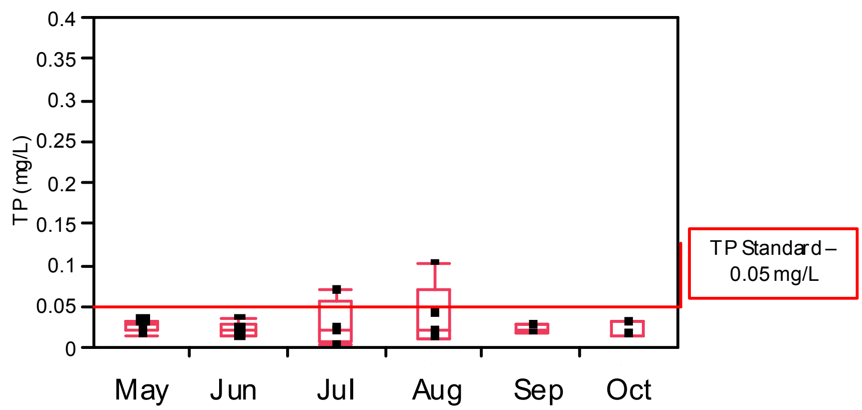
Pistakee (All Stations) – Total Phosphorus Time Series 1998 - present



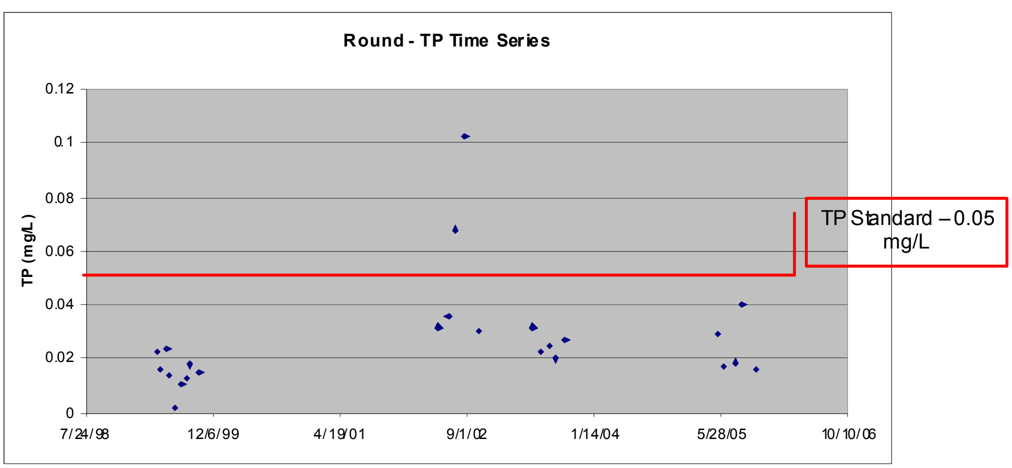
Pistakee (By Station) – Total Phosphorus Time Series 1998 - present



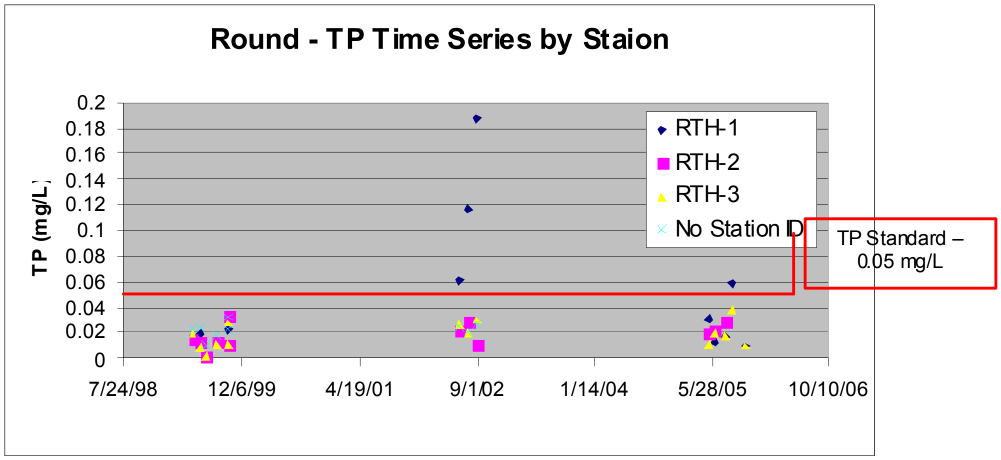
Round (All Stations) – Total Phosphorus
1998 - present



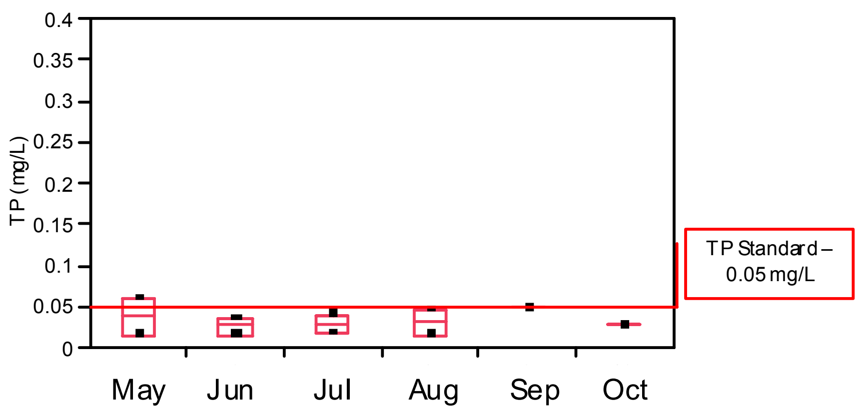
Round (All Stations) – Total Phosphorus Time Series
1998 - present



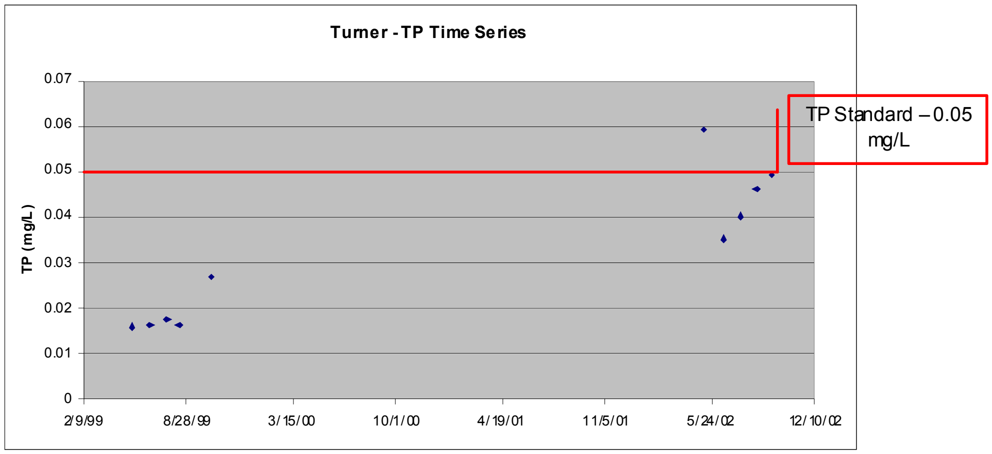
Round (By Station) – Total Phosphorus Time Series
1998 - present



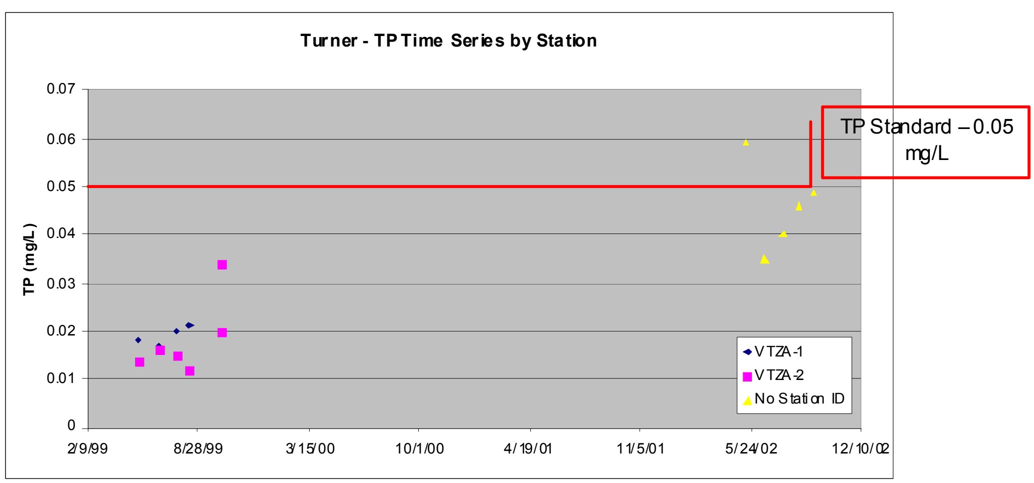
Turner (All Stations) – Total Phosphorus
1998 - present



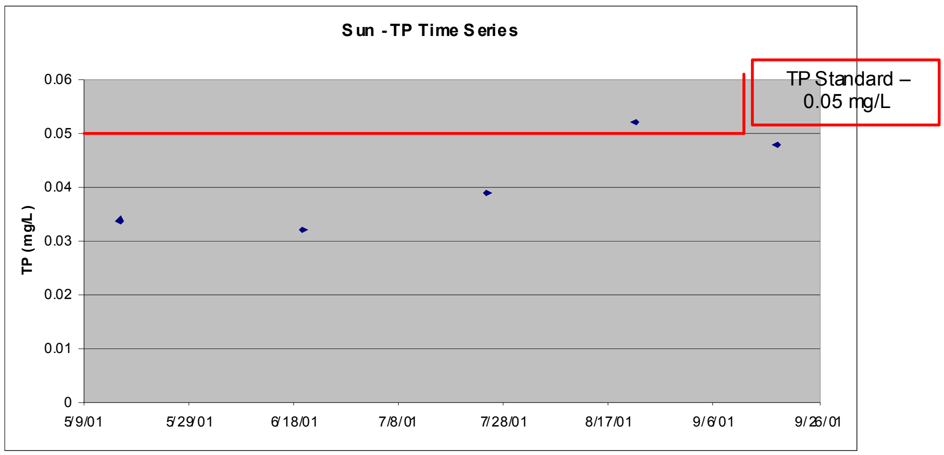
Turner (All Stations) – Total Phosphorus Time Series
1998 - present



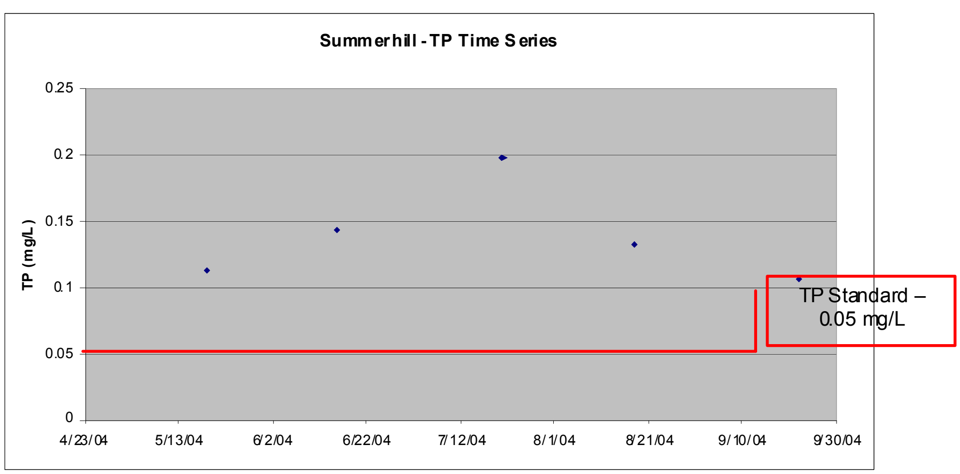
Turner (By Station) – Total Phosphorus Time Series
1998 - present



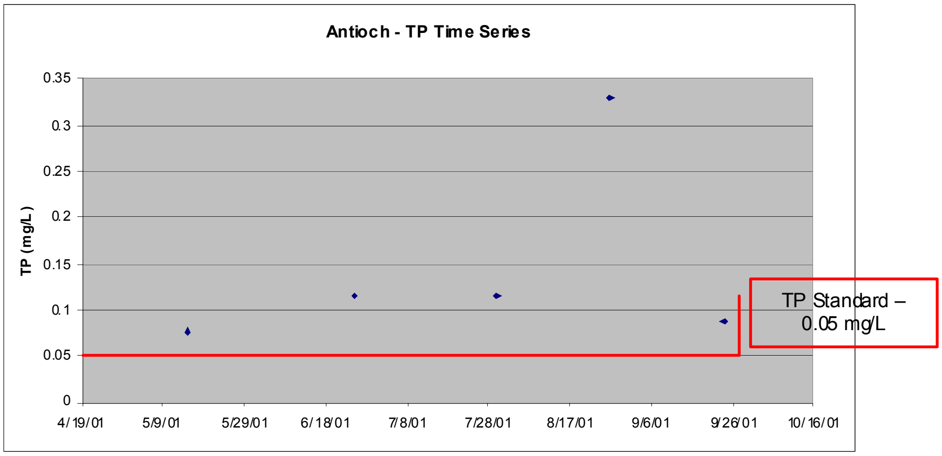
Sun (All Stations) – Total Phosphorus Time Series 1998 - present



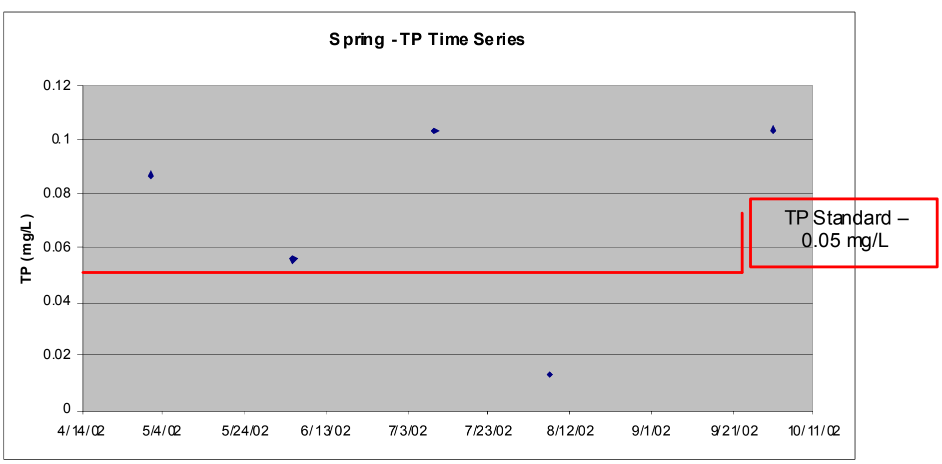
Summerhill (All Stations) – Total Phosphorus Time Series 1998 - present



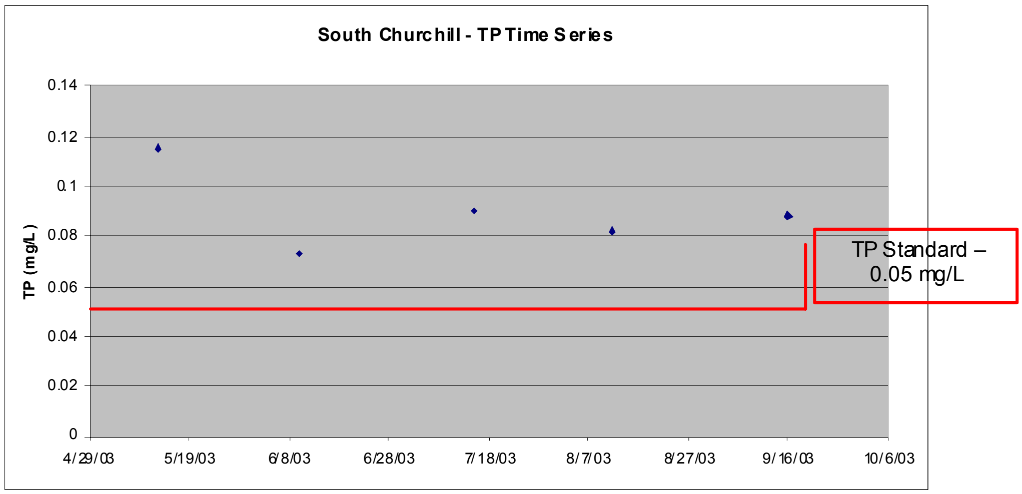
Antioch (All Stations) – Total Phosphorus Time Series 1998 - present



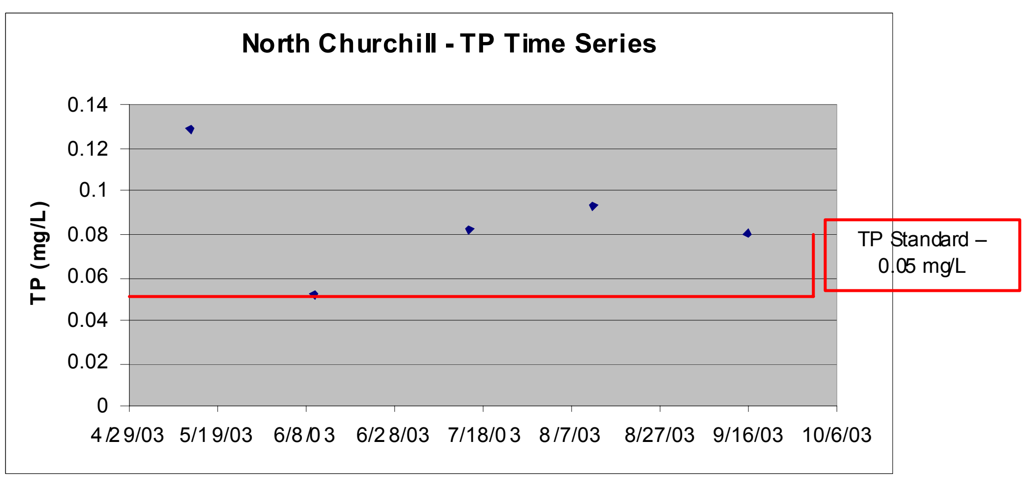
Spring (All Stations) – Total Phosphorus Time Series 1998 - present



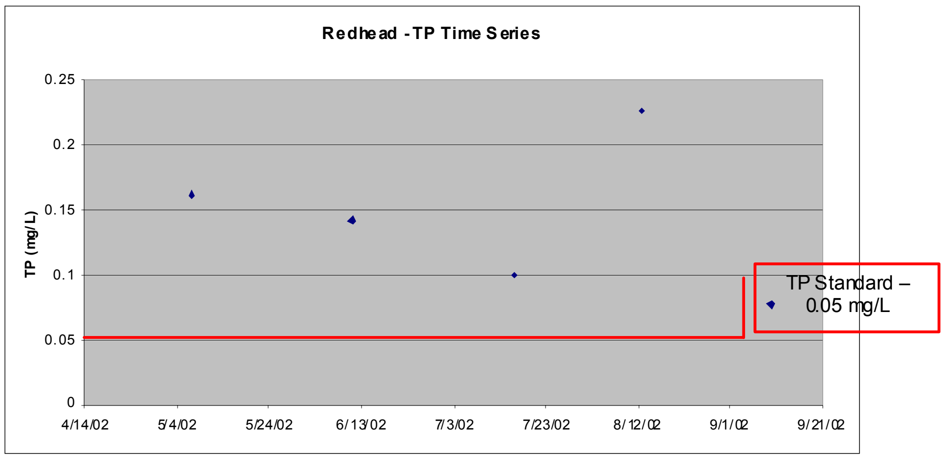
South Churchill (All Stations) – Total Phosphorus Time Series 1998 - present



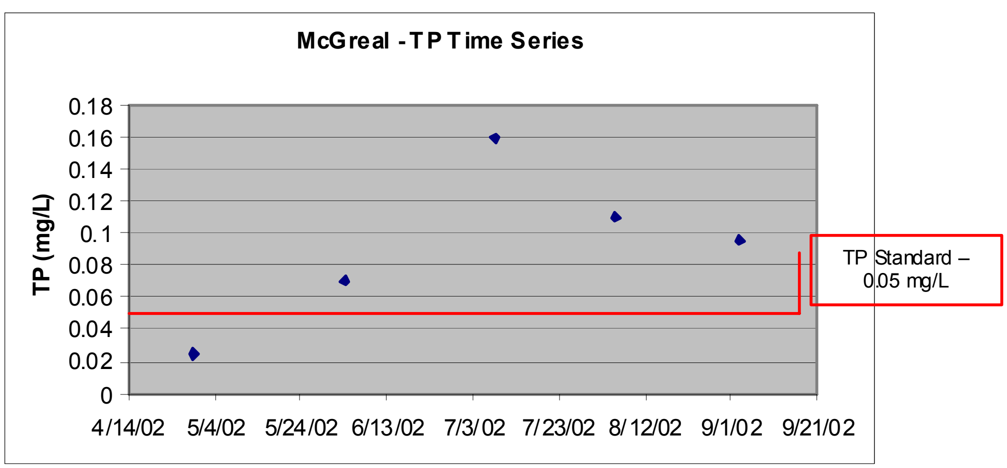
North Churchill (All Stations) – Total Phosphorus Time Series 1998 - present



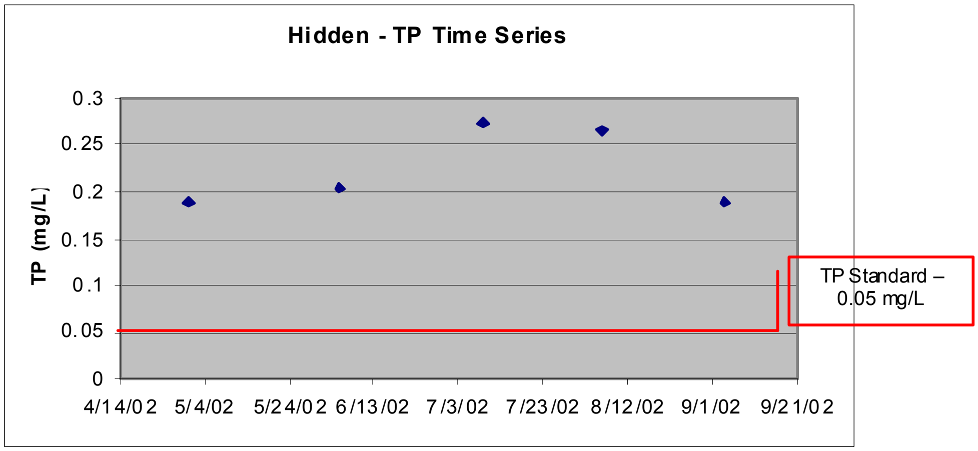
Redhead (All Stations) – Total Phosphorus Time Series 1998 - present



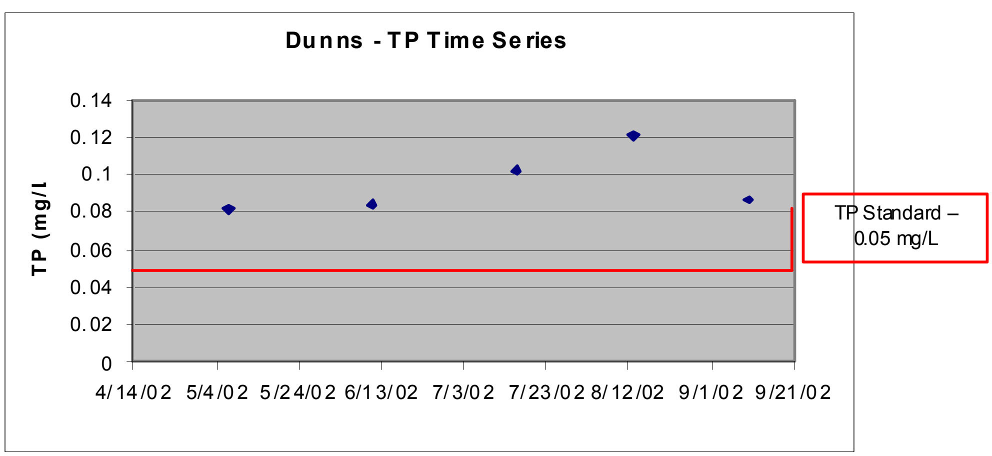
McGreal (All Stations) – Total Phosphorus Time Series 1998 - present



Hidden (All Stations) – Total Phosphorus Time Series 1998 - present



Dunns (All Stations) – Total Phosphorus Time Series 1998 - present



Davis (All Stations) – Total Phosphorus Time Series
1998 - present